SD1
Managing Northern Kentucky's
Wastewater and Storm Water

March 14, 2014

Director of the Division of Enforcement
Department for Environmental Protection
300 Fair Oaks Lane
Frankfort, KY 40601

Chief, Environmental Enforcement Section
Environmental and Natural Resources Division
U.S. Department of Justice
601 D Street NW
Washington, DC 20005
DOJ Case No. 90-5-1-1-08591

Chief, Water Program Enforcement Branch
Water Management Division
U.S. Environmental Protection Agency, Region 4
Atlanta Federal Center
61 Forsyth Street, S.W.
Atlanta, Georgia 30303

Re: Watershed Plans of Northern Kentucky
Consent Decree Case No. 2:05-cv-00199-WOB

To Whom It May Concern:

Enclosed, please find the final revision of the Watershed Plans for Northern Kentucky, as required by Paragraph 39(b) of the Consent Decree. Summarized below are the revisions, based upon recommendations given in the Watershed Plan Approval Letter from the Kentucky Department for Environmental Protection and United States Environmental Protection Agency, dated February 14, 2014.

a. References to Table 8.2 and Table 8.3 in Tables: 7.29, 7.30, 7.37, and 8.6 have been corrected. Additionally, incorrect references to Section 8.1.3 for the Richwood Pump Station have been removed from pages 8-14 and 8-31 of the Plan.

b. References to affordability and rate structure limitations in Section 4.2.3 (pg 4-16), Section 4.5.6 (pg 4-28), and Section 4.7 (pg 4-36) have been removed from the body of the Plan, and incorporated into the Executive Summary of the Plan.

c. Page header and Section cover sheet dates have been updated from October 1, 2013 to March 14, 2014.

If you have any questions or concerns, do not hesitate to contact me at 859-578-6762 or by e-mail at drager@sd1.org.

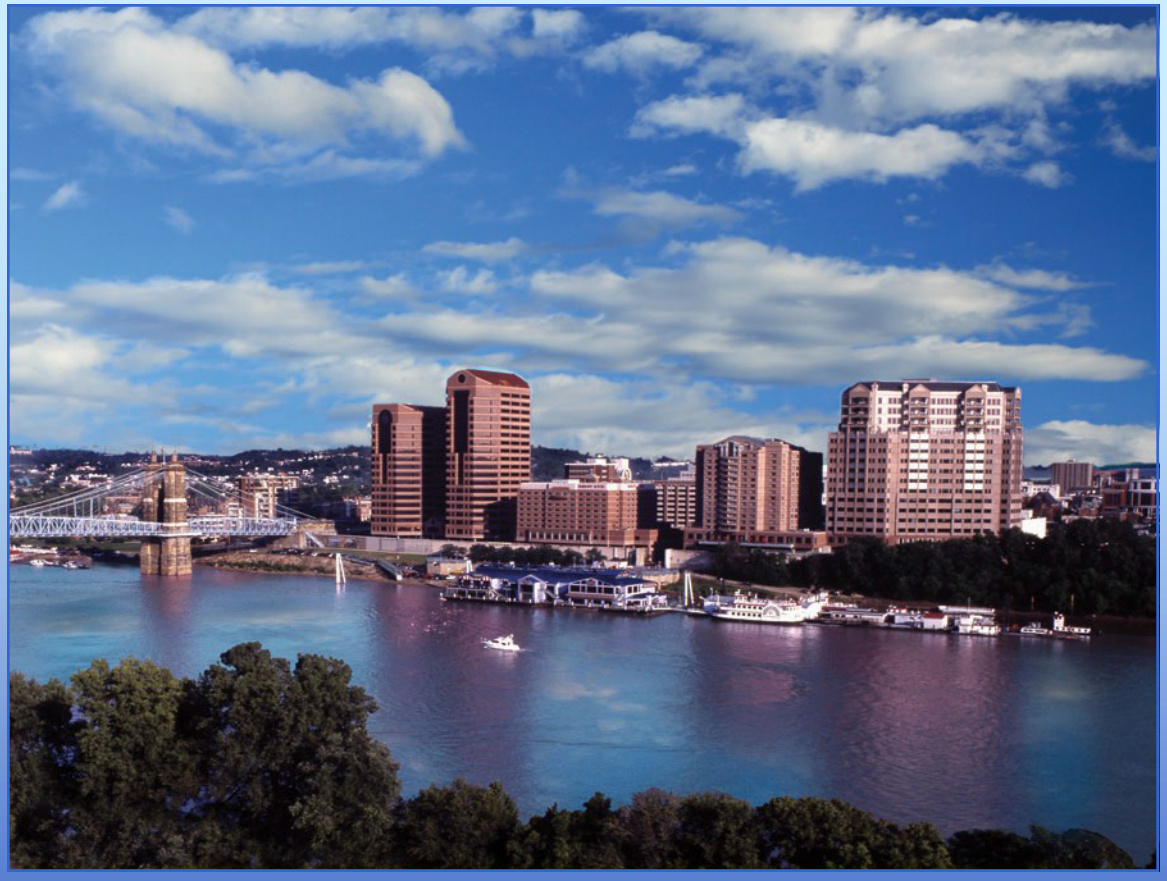
Best regards,

David E. Rager
Executive Director

DER/wck
Enclosures

Watershed Plans for Northern Kentucky

Sanitation District No. 1
March 14, 2014



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WATERSHED PLANS FOR NORTHERN KENTUCKY

March 14, 2014

Sanitation District No. 1
1045 Eaton Drive
Ft. Wright, KY 41017

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LIST OF ACRONYMS AND ABBREVIATIONS

Cabinet	Kentucky Energy and Environment Cabinet
CCI	Current Conditions Index
CCTV	Closed Circuit Television
CFS	Cubic Feet per Second
CFU	Colony-forming Unit
CIP	Capital Improvement Program
CPI	Consumer Price Index
CMOM	Capacity, Management, Operations, and Maintenance
CSAP	Continuous Sewer Assessment Program
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
CWP	Center for Watershed Protection
DRIP	Disconnection – Redirection – Infiltration Program
EFDC	Environmental Fluid Dynamics Code
EMC	Event Mean Concentration
EPA	United States Environmental Protection Agency
ESRI	Earth Sciences Research Institute
FY	Fiscal Year
gbaMS	GBA Master Services (asset management database)
GIS	Geographic Information System
GPCD	Gallons per Capita per Day
GPM	Gallons per Minute
GrIPP	Green Infrastructure Project Partnership
HAC	Housing Authority of Covington
HCF	Hundred Cubic Feet
HRT	High-rate Treatment
HSPF	Hydrologic Simulation Program in Fortran
I/I	Inflow and Infiltration
KPDES	Kentucky Pollutant Discharge Elimination System
KDOW	Kentucky Division of Water

KYTC	Kentucky Transportation Cabinet
LOC	Level of Control
LOS	Level of Service
LTCP	Long-term Control Plan
MG	Million Gallons
MGD	Million Gallons Per Day
MHI	Median Household Income
NKHD	Northern Kentucky Health Department
NKY	Northern Kentucky
NMC	Nine Minimum Controls
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
ODOT	Ohio Department of Transportation
OF	Overflow
ORSANCO	Ohio River Valley Water Sanitation Commission
Plans	Watershed Plans
PS	Pump Station
RDII	Rainfall-Derived Inflow/Infiltration
RM	River Mile
RWI	River Water Intrusion
SCI	Stream Condition Index
SD1	Sanitation District No. 1
SIP	Source Identification Program
SORP	Sewer Overflow Response Plan
SSO	Sanitary Sewer Overflow
SSES	Sanitary Sewer Evaluation Survey
SSOP	Sanitary Sewer Overflow Plan
SSS	Sanitary Sewer System
SWMM	Storm Water Management Model
TMDL	Total Maximum Daily Load
USGS	United States Geological Survey

WAT!	Watershed Assessment Tool
WCR	Watershed Characterization Report
WMP	Watershed Monitoring Program
WRF	Water Reclamation Facility
WWTP	Wastewater Treatment Plant
USACE	United States Army Corps of Engineers

LIST OF DEFINITIONS

Basins: The four watershed study basins (Central, East, North and West) defined as watersheds in the Consent Decree.

Basin Projects: Projects that were selected for the first set of Watershed Plans to address overflows in Priority Areas within each of the four basins identified in the Consent Decree. Projects include integrated solutions and demonstration projects.

Combined Sewer System: The portion of SD1's wastewater sewer system that is designed to collect and convey municipal sewage (domestic, commercial, and industrial wastewater) and storm water runoff through a single pipe to a wastewater treatment plant or combined sewer overflow.

Combined Sewer Overflow: Wet weather-related discharges from the combined sewer system.

Committed Projects: Projects that are focused on the rehabilitation and maintenance of assets SD1 currently owns. Investment in these assets is critical to fix failing pipes, maximize existing dry and wet weather capacity, prevent loss of service and basement backups, and minimize wet weather overflows. These projects include high priority sewer repairs and replacements, a number of Consent Decree required programs, improvements at pump stations and treatment facilities, and capital purchases.

Consent Decree: The April 18, 2007 agreement among Sanitation District No. 1, U.S. Environmental Protection Agency, and the Kentucky Energy and Environment Cabinet to address sanitary sewer overflows in the sanitary sewer system and combined sewer overflows in the combined sewer system to improve water quality. The Consent Decree required Watershed Plans, that include elements of the CSO Long Term Control Plan and Sanitary Sewer Overflow Plan, to accomplish specific goals no later than December 31, 2025.

Five-year Improvement Program: The detailed plan consisting of the recommended integrated projects, benefits and schedule of the proposed projects, and other potential watershed improvement recommendations. The Five-year Improvement Program is based on the results of the Integrated Plan for 2025 and takes into account the phasing of controls based on the prioritization process, cost-benefit analyses, watershed benefits, and financial capability considerations.

Full Program Costs: The total costs that SD1 will incur from FY-2010 through the end of the Consent Decree for CSO and SSO control as described in the Integrated Plan for 2025, as well as the costs for the committed obligations of asset management for infrastructure and Initial Watershed Projects, and the anticipated obligations of potential future effluent limits for nutrients (i.e., nitrogen and

phosphorus) at the treatment plants. The Full Program Costs were used in the Financial Capability Analysis for the 2025 Program.

Full System Bounding Analysis: The analysis of solutions for the 2025 planning horizon to assess the relative benefits of different levels of control and different combinations of control types (i.e. gray vs. gray, green and/or watershed controls). The Full System Bounding Analysis is comprised of solution concepts that include both gray infrastructure solution concepts and integrated solution concepts.

Future Conditions: Forecasts of future land use and population changes were developed to estimate runoff and sanitary sewer flows for the 2030 future conditions. The 2030 future condition was developed for assessing the controls needed for the Integrated Plan for 2025. The 2030 condition was selected since 1) very little growth is expected to occur in the combined sewer system beyond 2030; 2) it coincides with the Consent Decree deadline of 2025; and 3) little information about development beyond 2030 is available.

Gray infrastructure controls: Approaches such as pipes, pumps, storage tanks, tunnels, rehabilitation and other projects relating to the "hard infrastructure" that is traditionally used to store and treat sewage and storm water.

Green infrastructure controls: "Systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse storm water on the site where it is generated" (Grumbles, 2007). Examples of traditional green infrastructure include green roofs, rain gardens, vegetated swales, tree boxes, permeable pavements, rain water harvesting systems and other measures to prevent runoff from entering the sewer system. SD1's green infrastructure program focuses on: a) Strategic separation projects in the combined sewer system that route the separated storm water runoff through green infrastructure before the storm water is discharged to local waterways; b) Green street partnerships with local government entities to incorporate green infrastructure into new road construction and street reconstruction projects; and, c) Roof top disconnection of residential and commercial properties.

Initial Watershed Projects: Projects required as outlined in Exhibit D of the Consent Decree.

Integrated Plan for 2025: SD1's system-wide plan for addressing CSOs and SSOs by the 2025 deadlines stipulated in the Consent Decree. The Integrated Plan includes a mix of gray, green and/or watershed controls to address overflows and to optimize water quality improvements.

Integrated solutions: Solutions that include a mix of control types including gray, green and/or watershed controls.

Level of control: A metric for determining CSO control that is based on an end-of-pipe measure, such as the average number of overflows per year, as described in the CSO Control Policy. For the purpose of SD1's Watershed Plans, level of control is defined as the number of model-predicted activations during SD1's selected typical year.

Level of service: A metric for characterizing SSO abatement that is based on selecting facilities sufficient to control overflows during a particular storm or during a typical period of rainfall.

Policies, Regulations and Partnering Opportunities: Programmatic-type opportunities to supplement SD1's initiatives with: a) Newly developed policies and regulations that mitigate storm water runoff; b) Public and private partnerships to implement green infrastructure practices; and, c) Partnerships with entities such as watershed groups to provide technical support for reforestation, riparian buffer and stream restoration initiatives.

Priority Area: A watershed, sewershed, or specific overflow location where an improvement project will be considered for implementation in the next five years. The project may comprise any combination of gray, green, and watershed controls to achieve pollution reduction goals. The projects proposed for priority areas do not include the Initial Watershed Projects listed in Exhibit D of the Consent Decree.

ProForma: SD1's financial model for projecting capital and O&M expenses and the revenue needed to meet those expenses. The model evaluates SD1's user fees and capacity to borrow and meet required coverage rates.

Runoff: Storm water runoff is generated when precipitation from rainfall or snowmelt events flow over the land, transporting pollutants untreated into water bodies instead of infiltrating into the ground. As the runoff flows over agriculture lands, residential and commercial lawns, construction sites or impervious surfaces (roads, driveways, parking lots, and building rooftops), it accumulates chemicals, bacteria, sediment or other pollutants that can adversely affect water quality.

Sanitary Sewer System: The portions of SD1's wastewater sewer system that is designed to collect and convey only sanitary wastewater (domestic, commercial, and industrial wastewater). In such systems, storm water is conveyed through a separate set of pipes.

Sanitary Sewer Overflows: Recurring overflows from SD1's sanitary sewer system, typically during wet weather. Overflows are determined to be "recurring" if they have been observed to overflow twice in a 12-month period. This category includes wet weather-related discharges at pump stations that may or may not have a constructed bypass.

Study Area: The area encompassing SD1's jurisdictional area (Boone, Kenton, and Campbell Counties), which includes the four Consent Decree study basins and sixteen watersheds.

System-wide Projects: Regional projects that are programmatic in nature and intended to improve system operation and performance

Traditional Plan: A gray-only solution concept that would provide a two-year level of service for SSOs and a level of control for CSOs that resulted in four overflows per typical year; the Traditional Plan is used as a reference point for comparison with the Integrated Plan.

Watershed controls: Systems and practices that will reduce pollution from sources other than sewer overflows, such as runoff (point and nonpoint sources) before it is discharged to the local waterways. The emphasis on pollutant reduction differentiates these controls from green infrastructure, which is primarily focused on mitigating hydrologic impacts. SD1's watershed control program addresses instream water quality by focusing on a) Regional controls such as retention basins and constructed wetlands that address subwatershed areas greater than one square mile; and, b) Decentralized controls such as storm water wetlands, bioretention/biofiltration basins, and enhanced retention basins that address storm water catchment areas greater than five acres, but less than one square mile.

Watersheds: The sixteen watersheds encompassing SD1's jurisdictional area, which lie within the four Consent Decree study basins.

Executive Summary

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EXECUTIVE SUMMARY

Purpose

On April 18, 2007, the Consent Decree negotiated between Sanitation District No. 1 (SD1), the U.S. Environmental Protection Agency, and the Kentucky Energy and Environment Cabinet became effective. The purpose of the Consent Decree was to establish a structure for developing and implementing plans to address SD1's combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs). Such overflows can degrade the quality of streams and rivers and are regulated through the federal Clean Water Act. SD1's Consent Decree is unique because it incorporates a watershed-based approach in the planning process that allows for the consideration of pollution sources beyond sewer overflows.

As required in the Consent Decree, SD1 has prepared Watershed Plans describing projects for addressing overflows and other water quality issues to be implemented over the next five years as well as an Integrated Plan for 2025. The Integrated Plan is adaptive in nature and will be used to guide the future five-year updates of the Watershed Plans. The deadline for full implementation of these Plans is December 31, 2025. Through this decree, SD1 will be managing the largest program of water quality improvement in Northern Kentucky's history.

Background

Like many urban regions of the United States, the wastewater collection system of Northern Kentucky is comprised of both combined sewers and separate sanitary sewers. Combined sewers carry sewage and storm water runoff and are typically found in the older areas of cities such as Covington, Newport, and Bellevue. During dry weather conditions, flow in SD1's combined sewer system is mostly comprised of sewage from homes and businesses and is conveyed to the Dry Creek Wastewater Treatment Plant. At the plant, wastewater is treated to remove pollutants before being discharged to the Ohio River. During wet weather conditions, the capacity of the combined sewer system can be exceeded due to storm water runoff. As a result, excess flow is discharged from the system at CSO outfalls. The SD1 combined sewer system has 97 of these outfalls, the majority of which are located along the Ohio River and Licking River.

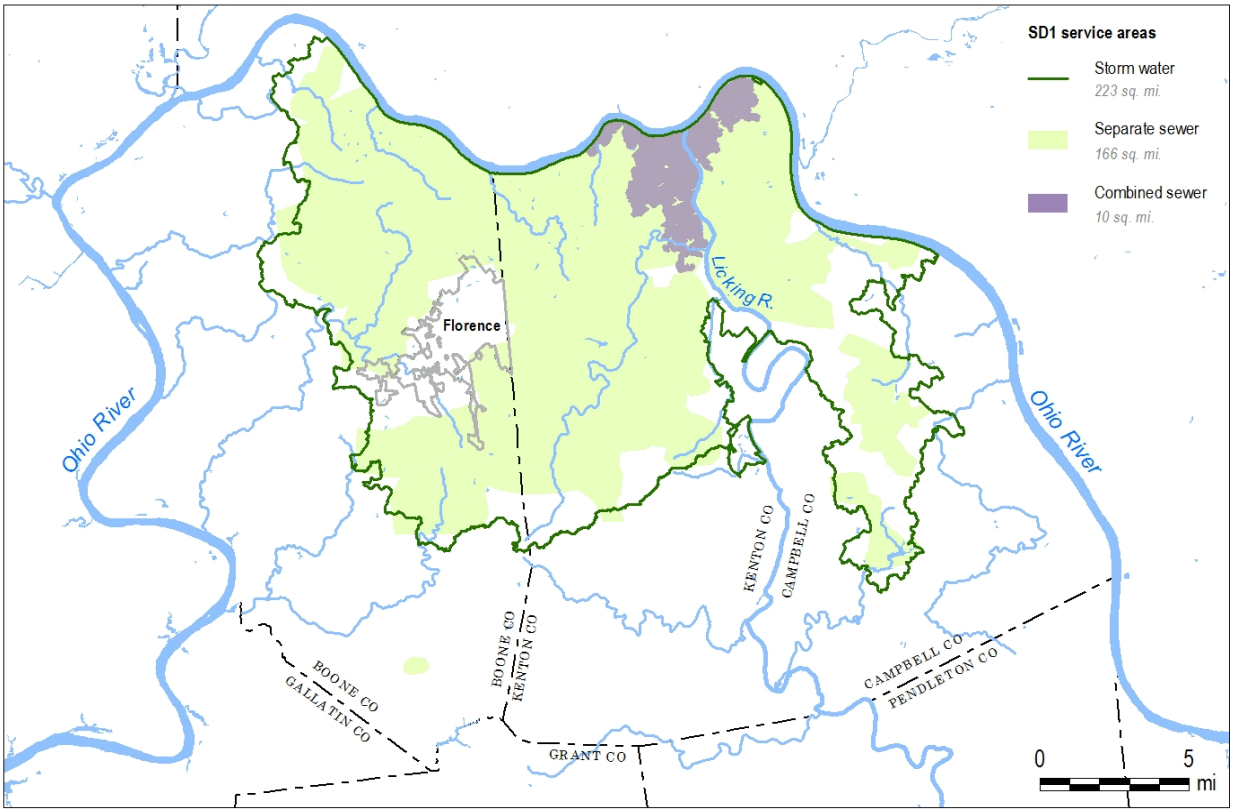
In more recently developed areas, a separate sanitary sewer system has been constructed to carry sanitary sewage and a separate storm sewer network has been constructed to carry storm water runoff. In properly functioning sanitary sewers, there is sufficient flow capacity in the system to convey all sewage to a treatment facility. In practice, separate sanitary sewers can be subject to additional flow during wet weather conditions. Increased wet weather flow in sanitary sewers can be caused by:

- Rain water inflow to the system from improper connections such as roof downspouts, driveway drains, etc.; and
- Rain water and ground water infiltration into aging manholes, pipes, and private laterals.

This increased wet weather flow has the potential to create SSOs. SSOs may also result from the loss of flow capacity in the system (pipe blockages or collapse) or malfunctions at pump stations. There are 126[1] confirmed recurring SSO points in the SD1 sanitary sewer system.

SD1's sanitary sewer service area encompasses 176 square miles of Campbell, Kenton and Boone Counties. The majority of this area is served by separate sanitary sewers as shown on Figure ES.1.

Figure ES.1 SD1 Service Area Overview (2009)



In addition to CSOs and SSOs, there are other pollution sources that can impact the quality of Northern Kentucky's waterways. These sources include polluted runoff (urban and agricultural land use), failing septic systems, and industrial point sources. The overall health of a waterway can also be affected by factors such as increased flows and erosion from the conversion of natural conditions to developed uses, the loss of riparian buffers along stream corridors, and the loss of wetlands.

[1] The number of confirmed SSO points is subject to change based on ongoing field investigations and hydraulic modeling of the collection system. The number quoted above was current as of the writing of the original Watershed Plans submitted June 30, 2009. This number is updated annually in the April Quarterly Report to the Kentucky Division of Water and the U.S. Environmental Protection Agency.

History of SD1

SD1 was established in 1946 by the Division of Sanitary Engineering of the Kentucky Department of Health pursuant to an amendment of Chapter 220 of the Kentucky Revised Statutes. This amendment gave SD1 the authority for the management, collection, transmission and treatment of wastewater. In 1954, SD1 completed the construction of Northern Kentucky's first wastewater treatment plant in the City of Bromley. In 1979, SD1 completed the construction of new interceptor sewers, associated pump stations, and the Dry Creek Wastewater Treatment Plant. To meet the needs of an expanding population, SD1 completed a major expansion of the Dry Creek plant in 1993.

Until 1995, a vast majority of the wastewater collection system of the Northern Kentucky region was owned, operated, and maintained by the different political jurisdictions of the region. In 1995, SD1 assumed ownership of this infrastructure for 28 municipalities and portions of three counties. By 1999, two more cities, Independence and Alexandria, had transferred their sewer system ownership and maintenance to SD1. At present, the Cities of Florence and Walton are the only jurisdictions in the region to retain ownership of their sewer systems. This consolidation process significantly increased the amount of infrastructure owned and maintained by SD1, as shown in Table ES.1.

Table ES.1 SD1 Infrastructure Inventory

	Before 1995	As of June 2009
Miles of sewer lines	128	1,600
Sanitary Pump Stations	16	129[1]
Catch Basins in Combined Sewer Area	0	3,302
Flood Pump Stations	0	15

Note:
[1] An additional thirteen (13) sanitary pump stations are operated by SD1 under contract.

At the time of this consolidation, it was recognized that there were a significant number of sewer overflows and other problems in the system. For example, the area served by the City of Alexandria's sewer system had been placed under a building moratorium in 1996 because of overflows at the Alexandria Wastewater Treatment Plant. The consolidation of the system represented an opportunity to address long-standing problems and improve sanitary sewer service for Northern Kentucky. Because the system is a complex network of pipes, pump stations, and treatment facilities, the previous structure of local control often hindered attempts to address sewer overflows. For example, excessive wet weather inflow into the sanitary sewer system of one jurisdiction could often lead to overflows in a downstream community.

As a regional utility, SD1 was able to direct resources to areas with the most pressing needs. For example, the Eastern Regional Water Reclamation Facility was constructed under SD1 management and replaced the failing Alexandria Wastewater Treatment Plant in 2007. The benefits of this project were the elimination of approximately eight

million gallons of sewer overflow volume in a typical year and a lifting of the building moratorium. SD1's long-range planning abilities have also helped to anticipate and respond to ongoing development in Northern Kentucky. This was particularly important in high-growth areas such as Boone County, which doubled in population between 1990 (57,589 people) and 2008 (115,231 people).

In 2003, SD1 became the regional authority, as a co-permittee with local jurisdictions, for the Phase II storm water regulations promulgated by the U.S. Environmental Protection Agency. This was another step forward in improved water quality management for the region; consolidation provided many of the same benefits as the sanitary sewer consolidation, since streams and rivers typically flow across jurisdictional boundaries, and polluted runoff originating in one city may impact downstream areas. Over the past few years, SD1 has taken over ownership and responsibility from the local cities for much of Northern Kentucky's public storm sewer infrastructure. Currently, SD1 is responsible for approximately 400 miles of storm sewers and associated structures.

Watershed-based Approach

SD1's Consent Decree is the country's first enforcement action that allows a community to use the watershed management approach to more efficiently and cost-effectively meet federal Clean Water Act requirements for addressing CSOs and SSOs. This approach is based on the fact that sewer overflows are not the sole source of impairment for Northern Kentucky's streams and rivers. Traditionally, most Consent Decrees focus solely on CSOs and SSOs, with an emphasis on gray infrastructure solutions. SD1's watershed approach identifies the characteristics of individual watersheds and considers CSOs and SSOs along with other sources impacting the waterways (such as runoff and dry weather sources). Additionally, the iterative structure allows time to investigate new technologies and update the Integrated Plan for 2025 using information gained from the implementation of projects during each five-year cycle. In addition to providing the backbone for the Integrated Plan, SD1's watershed approach:

- Characterizes water quality impacts, sources and sensitive areas;
- Prioritizes overflows based on public health and sensitive areas;
- Recognizes other pollutant sources and their relative impacts and puts CSOs and SSOs into context with those sources;
- Provides a process to address and control highest regional priorities first to offset controls on CSOs, with a focus on implementation of green infrastructure;
- Uses an integrated approach of controls that will address both wet and dry weather sources of pollution, eliminate SSOs, comply with the CSO Control Policy and lead to a greater improvement in water quality and public health;
- Provides additional benefits to the community such as air quality, wildlife habitat, urban beautification, and economic development; and
- Directs funds to projects that provide the greatest benefits.

SD1 has studied what other utilities across the country have implemented and spent to comply with their CSO and SSO Consent Decrees, which have often not achieved significant improvements in the attainment of water quality standards. These utilities have, at times, been forced to continue to spend money beyond a cost-effective level of control that did not result in additional water quality improvement because the other sources of pollution were left unaddressed. This type of silo approach to water quality improvement is neither efficient nor cost-effective, particularly in today's challenging economic climate.

Many sewer overflow programs have been developed that relied exclusively on gray infrastructure such as storage tanks, conveyance pipes, and high-rate treatment facilities. While gray infrastructure has its place in any sewer improvement program, there are situations where alternative strategies are the more cost-effective and beneficial solution. SD1 believes that the best approach is to implement an integrated watershed-based approach in a way that conforms with the CSO Control Policy and the Consent Decree mandate to eliminate SSOs, but is more cost-effective and more effective in reducing pollutant levels (and runoff) than traditional approaches.

The watershed-based approach in SD1's Consent Decree allows for the consideration of alternative control strategies such as green infrastructure and watershed controls. These techniques, as described below, can be used to offset or delay traditional overflow controls:

- **Green infrastructure** are systems and practices that mimic the natural process to infiltrate, evapotranspirate, or reuse storm water. When trees and vegetation are replaced with impervious surfaces, natural processes are impacted by: 1) a reduction in infiltration and evapotranspiration; and 2) an increase in runoff. Examples of traditional green infrastructure include green roofs, rain gardens, vegetated swales, tree boxes, permeable pavements, rain water harvesting systems and other measures to prevent runoff from entering the sewer system.
- **Watershed controls** are systems and practices that can reduce pollution from sources other than sewer overflows, such as runoff (point and non-point sources) before it is discharged to the local waterways. The emphasis on pollutant reduction differentiates these controls from green infrastructure, which is primarily focused on mitigating hydrologic impacts. Examples of watershed controls include wetlands and retention/detention basins enhanced with bioretention or biofiltration systems. These controls could be either large regional facilities or smaller decentralized storm water catchment controls.

Watershed and green controls also provide additional community benefits, such as improved air quality, wildlife habitat, urban beautification, and economic development. The inclusion of these benefits into a comprehensive, capital-intensive, water quality improvement program represents a new approach for public utilities and regulators. There is a growing expectation among the public that these techniques for water quality management should be included in the planning process.

SD1 is responsible for managing most of the capital funding to be used towards water quality improvements in Northern Kentucky. Past experience has shown that wastewater and storm water systems can be managed more efficiently when a single

organization has the ability to consider the overall system. A watershed-based approach is a logical extension of the sanitary and storm sewer system consolidation. While SD1 does not have authority to regulate all pollutant sources in Northern Kentucky, the role as a regional utility does provide the best opportunity for the development of plans that will focus resources towards the most critical areas of need, including helping to identify new policies and regulations, as well as partnerships that can be created for implementation of green infrastructure and watershed controls. Through the development of the Watershed Plans, SD1 will seek mechanisms to implement controls that extend beyond current authorities.

Characterization

To support the Watershed Plans and conform to the CSO Control Policy, it was necessary for SD1 to accurately characterize the combined and sanitary sewer systems, the watersheds and waterways of Northern Kentucky, and opportunities for alternative controls.

Sewer Systems

The sewer system characterization involved a combination of system mapping, rainfall monitoring, water quality sampling of CSO, SSO, and storm water outfalls, and hydraulic modeling of the combined and sanitary sewer systems. The hydraulic modeling task involved the development of a detailed computer model of the sewer systems. This model was used to calculate overflow characteristics (volume, duration, and activation frequency) and provide input to the water quality models. The hydraulic model was calibrated and validated using a combination of historical data and 12 months of data collected from approximately 250 flow monitors and 45 rain gauges in 2007 and 2008. The results were further validated by comparing model calculated overflow points to field investigations. The result was a state of the art hydraulic model that provides the best available representation of how SD1's sewer system operates during dry and wet weather conditions. This tool allows SD1 to have confidence in the calculated overflow volumes from the sewer system.

In accordance with standard guidelines, the hydraulic model was used to simulate "typical year" conditions. The rainfall record from 1970 was selected as the most representative of typical rainfall conditions for Northern Kentucky based on review of 50 years of rainfall data from the Cincinnati-Northern Kentucky International Airport. In the process of evaluating potential gray infrastructure projects, other rainfall conditions such as the one-year and five-year design storms and other extended typical periods of rainfall were also used in certain analyses. The calculated overflow volumes for current conditions using the typical year rainfall record are shown in Table ES.2.

Table ES.2 CSOs and SSOs for Current Conditions by Basin for a Typical Year (1970)

Basin	Number of CSOs	Total CSO Volume (Million Gallons) [1]	Number of Confirmed SSOs	Total SSO Volume (Million Gallons) [1 2]
North	26	796.2	45	7.5
Central	39	790.2	51	158.6
East	32	286.4	21	73.4
West	0	0	9	2.6
Total	97	1,872.8	126[3]	242.1

Note:

[1] Model calculations are current as of June 2009.

[2] Includes the model-calculated volume from model-predicted overflow locations, as well as the volume prior to the Eastern Regional sewer system improvements.

3 The number of confirmed SSO points is subject to change based on ongoing field investigations and hydraulic modeling of the collection system. The number quoted above was current as of the writing of the original Watershed Plans submitted June 30, 2009. This number is updated annually in the April Quarterly Report to Kentucky Division of Water and the U.S. Environmental Protection Agency.

Watersheds and Waterways

SD1's planning process involved a more thorough characterization of watersheds than is normally conducted in traditional sewer overflow control programs in order to identify opportunities for alternative controls beyond sewer overflow controls that could provide more public and water quality benefit for the dollar spent. This characterization involved both field data collection and water quality model development for Northern Kentucky's waterways to assess their current condition and response to overflows and other sources of pollution. Watershed characterization is particularly important in Northern Kentucky because of the wide variability in the size and characteristics of its watersheds. For example, the total watershed area of the Ohio River at its confluence with the Licking River is approximately 71,250 square miles, as compared to Taylor Creek which has a total watershed area of 4.2 square miles. Percent imperviousness ranges from three percent to 25 percent (2007 land cover) in the study area watersheds. These watersheds also contain exceptional waters and reference reach streams, an Outstanding State Resource Water, as well as numerous impaired waterways and threatened and endangered species.

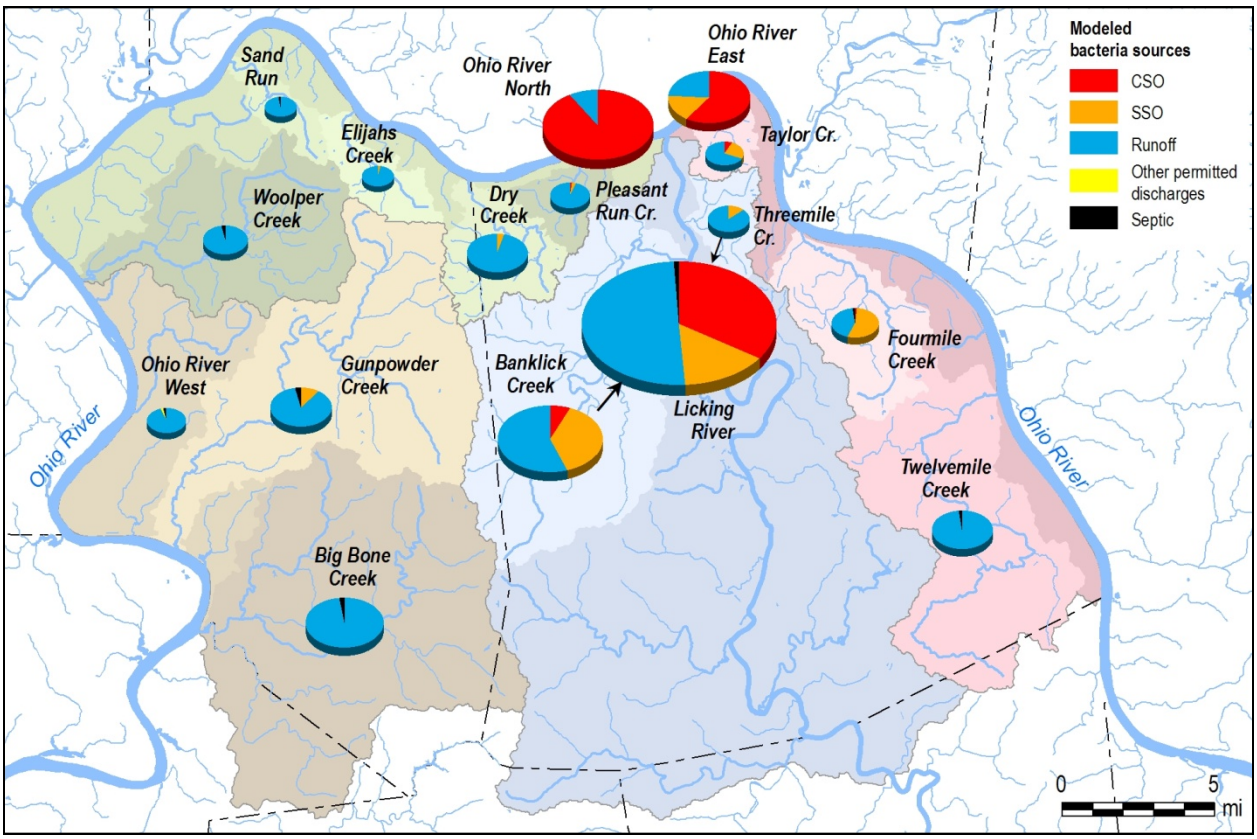
SD1's watershed characterization effort was based on a division of the entire three-county Northern Kentucky region into sixteen watersheds. SD1 compiled a variety of data from different sources, including current land use, zoning, and identified pollution sources other than sewer overflows. This effort was initiated in 2006 and SD1 continues to collect instream data from all sixteen watersheds, including water quality, flow, biologic and habitat data. While a variety of water quality data were collected, fecal coliform bacteria was the focus of the watershed characterization efforts. The selection of fecal coliform as the primary indicator of water quality in the Watershed

Plans is based on several factors. First, fecal coliform bacteria represent a public health risk because they are an indicator of pathogenic substances. Second, SSOs and CSOs are known sources of fecal coliform bacteria pollution to waterways. Third, earlier studies have also indicated elevated fecal coliform densities throughout Northern Kentucky watersheds. Most importantly, water quality standards for fecal coliform bacteria established by the Kentucky Division of Water and the Ohio River Valley Water Sanitation Commission were in place at the beginning of the watershed characterization work.

The most relevant fecal coliform water quality criteria with respect to the Watershed Plans are the 30-day maximum and the 30-day geometric mean, during the recreational season (May 1 to October 31). For the Ohio River, the 30-day maximum level is 400 colony forming units per 100 milliliters for 90 percent of the days within a 30-day period. The same level applies to all other waterways, but must be met for 80 percent of days. The 30-day geometric mean for all waterways is 200 colony forming units per 100 milliliters. In general, the 30-day maximum criterion is more stringent than the geometric mean for Northern Kentucky waterways.

SD1 developed a Watershed Assessment Tool to compile the results of the watershed and sewer characterization work. The Watershed Assessment Tool was developed for the entire three-county area and is used to calculate annual loads of fecal coliform, nitrogen, and phosphorus. The bacteria results were used to guide the development of detailed water quality models, evaluate watershed control opportunities, and provide a relative assessment of the effectiveness of different controls. Figure ES.2 provides a summary of the bacteria load results from the Watershed Assessment Tool for each of the sixteen modeled watersheds; the size of each pie chart in the figure is relative to the total bacteria load from its corresponding watershed (i.e., the Licking River watershed has a greater total load than Taylor Creek).

Figure ES.2 Watershed Assessment Tool Results for Current Conditions: Fecal Coliform Loading (June 2009)



More detailed water quality models were developed for the Banklick Creek, Taylor Creek, Licking River, and a combined section of the Ohio River / lower Licking River / lower Banklick Creek system. Two models were also developed for the watersheds in the three-county area that drain directly to the Ohio River. The models were developed using the instream water quality data (dry and wet weather conditions), sewer system hydraulic modeling results, storm water outfall sampling data, and other data. The detailed models calculate instream, hourly bacteria densities along the length of the modeled stream. These results were used to estimate the impact of different pollution sources, forecast the effect of different land development and pollutant control scenarios, and identify data gaps.

Opportunities for Alternative Controls

The characterization of alternative control opportunities (green infrastructure, watershed controls, and policies/regulations and partnership opportunities) covered a majority of the SD1 service area, with a particular emphasis in the combined sewer system. The focus on the combined sewer system was due to the potential benefits of green infrastructure in reducing CSO volumes, prior to the sizing and selection of gray infrastructure.

The green opportunities analysis included an inventory of natural features (including stream mapping, geology, soils, and tree canopy) and built systems (including

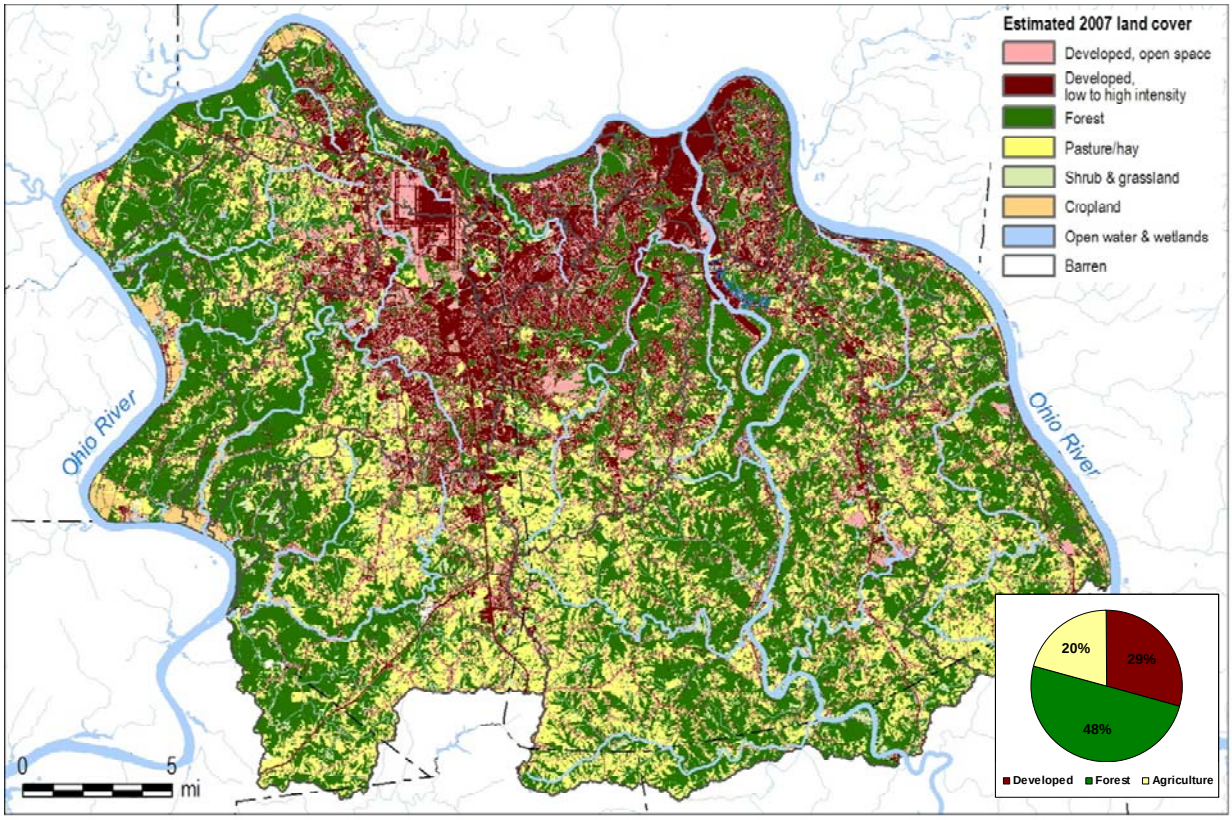
impervious surface mapping, transportation corridors, sewer system mapping, and current/projected land use). As shown in Table ES.3, the characterization of the combined sewer area indicated that approximately 38 percent of the total combined sewer service area (ten square miles) is covered with impervious surface. This type of characterization is useful because storm water runoff volume is closely linked to the amount of impervious surface. The detailed analysis of green infrastructure opportunities in the combined sewer area focused on reducing this imperviousness or capturing and treating runoff to reduce combined sewer overflow volume.

Table ES.3 Impervious Surface in Combined Sewer System (2007)

Surface Type	Amount of Impervious Area (square feet)	Percentage of Total Impervious Area
Rooftops	44,000,000	46%
Roadways	33,000,000	36%
Parking, driveways and sidewalks	17,000,000	18%
Total	94,000,000	38%

The watershed control opportunities analysis utilized current (2007) land cover data (Figure ES.3), because there is often a correlation between land use and the selection of an appropriate watershed control (i.e., stream corridors in agricultural areas may be good candidates for the restoration of riparian buffers). This analysis focused on the watersheds with combined or sanitary sewer systems, and initially assessed the bacteria reduction benefits resulting from regional projects such as regional retention basins, constructed wetlands, and riparian buffers. Subsequent assessments included a more detailed assessment of potential benefits from decentralized controls, such as storm water wetlands and retention/detention basins enhanced with bioretention or biofiltration systems.

Figure ES.3 Estimated 2007 Land Cover



Integrated Plan for 2025

SD1's June 2009 Watershed Plans included an analysis of a suite of full system gray and/or integrated solution concepts that addressed all sewer overflows, as required under the Consent Decree. This 'bounding' analysis identified several types of solution 'concepts' and considered combinations of gray, green and watershed controls at varying levels of control. Overall, the bounding analysis showed that the various solution concepts exceeded U.S Environmental Protection Agency's affordability standards and fell short of fully achieving water quality standards due to the presence of pollution sources (some unknown) other than CSOs and SSOs.

Based on the conclusions of the bounding analysis, SD1 developed a detailed Five-year Improvement Program, but did not recommend a preferred Integrated Plan for 2025. The U.S. Environmental Protection Agency's feedback on the June 2009 document indicated a need for SD1 to identify a preferred system-wide solution set to address all overflows, regardless of affordability or effectiveness in achieving water quality standards.

SD1 conducted further analysis and identified a preferred Integrated Plan for 2025. The Integrated Plan includes the results of more detailed analyses of potential gray infrastructure, green infrastructure, and watershed controls. The analysis also compared

the Integrated Plan with a Traditional Plan[1] using a suite of metrics to assess project benefits (both water quality and other associated benefits). The Integrated Plan for 2025:

- Provides a plan that eliminates SSOs (defined using a two-year level of service which is a calculated SSO discharge that occurs, on average, only once every two years);
- Provides a CSO level of control that meets the Presumption Approach under the CSO Policy (greater than 85 percent capture). Water quality modeling shows that if all other sources were controlled, this level of control would also meet water quality-based requirements for fecal coliform bacteria;
- Results in greater water quality benefit than a traditional plan (as measured by bacteria levels, days of water quality attainment, stream miles improved, and other additional benefits); and
- Prevents additional degradation of waterways in the future by requiring pollutant control with policies and regulations.

The Integrated Plan for 2025 does not, however, meet the U.S. Environmental Protection Agency's standards for affordability. SD1 has determined that the Plan is unaffordable and relief from the December 31, 2025 Consent Decree deadline (and/or other performance criteria) is therefore necessary through a material modification of the Consent Decree. Relief from the December 31, 2025 deadline (and/or other performance criteria) could be afforded through a number of mechanisms recognized by the CSO Control Policy and KRS 224.16-040, including extensions of deadlines, affordability reviews in conjunction with five-year Watershed Plan updates, Use Attainability Analyses, or combinations thereof. Consistent with the parties' agreement[2], the form and extent of the relief is not being addressed in this Integrated Plan. Rather, the purpose of the Integrated Plan for 2025 is to determine the most cost-effective approach to eliminate SSOs and address CSOs by December 31, 2025 consistent with the Consent Decree.

The following two sub-sections describe the bounding analysis and the analyses conducted to select the Integrated Plan for 2025. Both analyses used a 2025 future conditions baseline (no controls), as a standard reference point for comparison of potential 2025 solutions and their associated water quality improvements. When compared to current conditions, this future scenario indicated significant deterioration of water quality in Northern Kentucky's watersheds.

[1] The traditional plan is a reference point for comparison with the Integrated Plan. SD1 defined the traditional plan as a gray-only solution concept that would result, on average, a calculated SSO discharge only once every two years and a CSO discharge only four times a year.

[2] The parties' agreement regarding resubmittal of the Watershed Plan to include an integrated approach to achieve the goals of the Consent Decree by December 31, 2025 was set out in a letter dated August 23, 2010.

Bounding Analysis

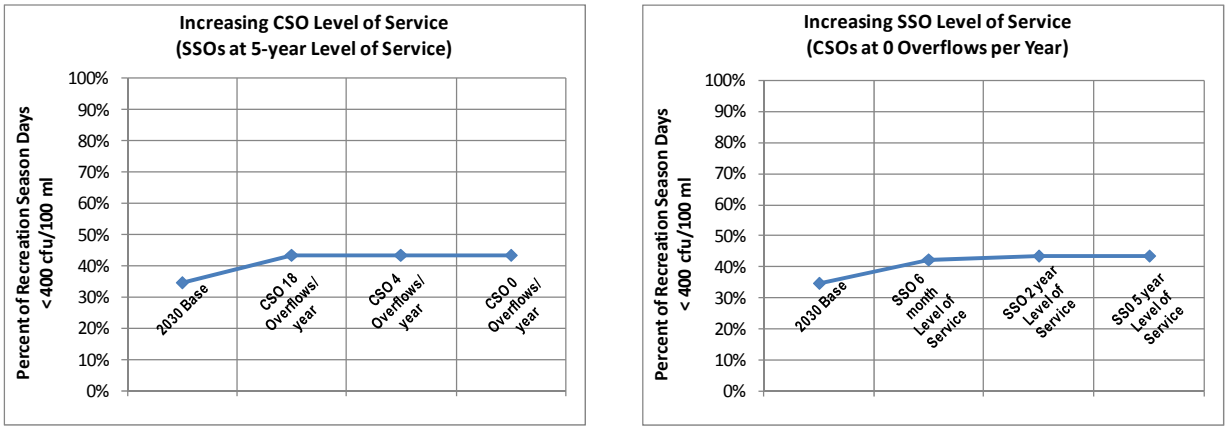
The bounding analysis presented in the June 2009 Watershed Plans compared a gray-only solution concept, at varying levels of control to various integrated solution concepts. The gray-only solution concept included the following technologies:

- Primary and secondary treatment expansion,
- High-rate treatment,
- Deep tunnel for storage and/or conveyance,
- Storage tanks, and
- Conveyance improvements (pump stations and piping).

This set of controls was then evaluated at a level of service for SSOs ranging from six months to five years and a level of control for CSOs ranging from 18 to zero overflows per typical year. The cost of the gray-only solution concept varied from $1.9 Billion to $3.2 Billion in 2009 dollars, depending on the level of overflow reduction.

Despite this massive investment in gray infrastructure and the corresponding reductions in overflow volume, SD1's water quality models often indicated minimal improvements in water quality standards compliance. For Banklick Creek, the elimination of all CSO volume increases compliance with the bacteria water quality standard by only seven percent (from 35 percent with no overflow control to 42 percent with the elimination of CSOs) (Figure ES.4). The elimination of SSOs (five-year level of service) on Banklick Creek similarly increases compliance by just six percent (from 35 percent with no control to 41 percent with elimination of SSOs). The Taylor Creek model also indicated minimal improvement in water quality standards compliance at similar levels of CSO and SSO control.

Figure ES.4 Water Quality Benefits of Increasing the Level of CSO and SSO Control in Banklick Creek



Note: cfu/100 ml stands for colony forming units per 100 milliliters.

For Banklick and Taylor Creeks, the limited value of sewer overflow control can be attributed to: (1) the overflow volume entering these streams is relatively small compared to other sources of pollution, and (2) the stream monitoring and models

indicate that the water quality of both streams is severely impacted by dry weather and non-overflow wet weather sources of bacteria pollution.

The calculated water quality improvements in the Ohio River resulting from the control of SD1 overflows were also marginal, but for different reasons. While a majority of the total SD1 overflow volume flows directly into the Ohio River, SD1 overflows comprise only approximately six percent of the total annual bacteria load to the 13-mile reach of the river adjacent to Northern Kentucky. The Ohio River is subject to significant wet weather input of bacteria from sources other than SD1 overflows. These sources include CSOs and SSOs from other urban sewer utilities, as well as urban and agricultural runoff, both locally and upstream. While loads from SD1 overflows can result in elevated bacteria levels in the river, the duration of these levels is short enough that water quality standards are still met more than 90 percent of the time along the Kentucky shore, if other sources are controlled. These results show that controlling SD1 overflow sources that discharge to the Ohio River would result in little increase in compliance with water quality standards.

SD1's analysis indicates that the Licking River is affected by both SD1 overflows and other upstream sources, depending on the stretch of river examined. This highlights the need for a watershed-based approach that addresses the multiple sources of pollution contributing to the water quality impairment of this river.

The final assessment in the bounding analysis was a preliminary evaluation of integrated solution concepts consisting of a combination of gray infrastructure, green infrastructure, and watershed controls. The purpose of this evaluation was to determine whether a more cost-effective solution with increased improvement to water quality could be achieved using an integrated approach as compared to sewer overflow control only. This was a particularly important question to address given the extremely high-cost of a traditional gray-only solution and its limited benefits in water quality improvement.

The watershed and green controls used in this analysis represented assumptions regarding the implementation of controls for new development, the retrofit of runoff controls into existing development, the protection and re-establishment of riparian buffers where feasible, and control of dry weather-related bacteria sources. The analysis of the integrated solution concepts provided encouraging results - that a program based on lower levels of gray CSO and SSO controls with a moderate implementation of green and watershed controls yields greater water quality improvement than higher levels of overflow control utilizing gray-only solutions. The value of this assessment is its prediction that green and watershed controls can provide substantial improvements in water quality relative to their cost.

The most important conclusions resulting from the bounding analysis were as follows:

- A traditional gray-only program to eliminate SSOs and reduce CSOs varied from $1.9 to $3.2 Billion (2009 dollars). The economic analysis, conducted in June 2009, indicated that SD1 ratepayers do not have the ability to support this expensive of a program within the timing of the Consent Decree. For a $3.2

Billion full program expenditure[3], the residential indicator was calculated to be 3.6 percent of median household income, which is well above the U.S. Environmental Protection Agency's threshold of two percent.

- Increasing levels of sewer overflow control provide diminishing returns in water quality and public health improvement. Even at high levels of overflow control, improvements in water quality from a traditional gray-only solution concept were limited.
- The impact of overflow control was not consistent across all watersheds, depending on watershed characteristics and the other sources of pollution. High levels of overflow control, however, provide diminishing instream water quality standards compliance returns in all watersheds.
- Decisions on overflow control should first target protection of human health, rather than compliance with water quality standards.
- Targeting dry weather and runoff sources can provide cost-effective improvements for complying with water quality standards.
- Green and watershed controls can be a more cost-effective approach for improving water quality and public health than gray-only controls.

The results of this work provided critical input into shaping the Integrated Plan for 2025, the updated economic analysis, and the selection of projects for the Five-year Improvement Program.

Additional Analyses to Develop the Integrated Plan

In reviewing the June 2009 Watershed Plans, the U.S. Environmental Protection Agency indicated that it generally supported SD1's Five-year Improvement Program, which was based on the findings from the bounding analysis. The agency requested, however, that SD1 conduct additional analyses of gray and integrated solutions to identify a single preferred solution set for 2025. This section summarizes those additional analyses, which are described in detail in Section 3.

SSO Elimination Evaluation

For the SSO elimination analysis, SD1 first prioritized the SSOs based on an evaluation of a series of factors, including annual activation frequency, public health risk, Consent Decree Appendix D listed overflows, and proximity to integrated solutions or early action projects. SD1 then used the hydraulic model to identify areas in the separate sewer system where more than two percent of annual rainfall was estimated to result in inflow and infiltration to the sanitary sewer system. Portions of the separate sewer service area were identified for Sanitary Sewer Evaluation Surveys, which will be used to develop projects to remove inflow and infiltration, construct storm water controls, and implement green infrastructure. Prioritization of these survey activities was based on SSO volume, public health impact, and coordination with other local projects.

SD1 then incorporated assumptions about the collective effectiveness of the inflow and infiltration removal projects into the hydraulic model. The model was run with the two-

[3] The $3.2 Billion Full Program Cost of the Traditional Plan includes Committed Projects for Asset Management; Initial Watershed Projects; traditional, gray-only controls for CSOs and SSOs (four CSO events per year and a two-year level of service for SSOs); and anticipated future effluent limits projects.

year, six-hour design storm under saturated antecedent conditions to simulate post-inflow and infiltration removal conditions and post Five-year Improvement Program using the 2030 future build-out condition. The model results were then used to size and cost the gray infrastructure improvements needed to achieve a two-year level of service for the remaining SSOs.

SD1 intends to continue the overall strategy for eliminating the remaining SSOs identified in the Five-year Improvement Program by first maximizing public and private inflow and infiltration reduction to reduce and, in some areas, eliminate overflows, renew crumbling infrastructure, and reduce public health risk. This approach is fundamental to SD1's asset management approach to renewing both the sanitary and storm sewer infrastructure on a neighborhood-by-neighborhood level. By also addressing the storm water runoff, SD1 will reduce storm water runoff peak flows and improve runoff quality through the implementation of green infrastructure.

CSO Long-term Control Plan Evaluation

This section summarizes the process SD1 used to develop the CSO long-term control plan. SD1 first conducted a detailed analysis of green infrastructure opportunities, both within the combined sewer system and SD1's entire service area. SD1 then used a "knee-of-the-curve" analysis to determine target levels of control for CSOs that would remain after full implementation of the green infrastructure programs. These targets were then used to evaluate costs and effectiveness of different gray infrastructure solutions for each CSO sub-basin. At the same time, SD1 evaluated the potential for watershed controls, such as storm water controls associated with inflow and infiltration projects (described above), regional watershed control measures[4] (retention basins, constructed wetlands), decentralized watershed controls (smaller-scale storm water wetlands, bioretention / bioinfiltration basins, enhanced retention basins), and stream restoration (in-channel practices, riparian buffer restoration, and livestock exclusion).

Green Infrastructure Opportunities Assessment

Subsequent to the June 2009 Watershed Plans, SD1 conducted a more detailed investigation of opportunities to reduce overflows through the use of green infrastructure, after accounting for the benefit of the Five-year Improvement Program. This analysis showed that green infrastructure projects can remove and treat storm water from approximately one-third of the combined sewer system area (2,349 of the 6,931 acres), reducing annual CSO volume by a total of 506 million gallons. Green infrastructure can also treat 562 million gallons per year of storm water within the remaining combined sewer system area.

SD1 also conducted an analysis of system-wide green infrastructure opportunities to identify high level, long term strategies to help improve the water quality in Northern Kentucky. These strategies did not result in specific projects, but will be used to guide project selection in future plans and identify potential demonstration projects during the

[4] Two major forms of regional watershed controls were considered: instream and side-stream. Instream regional controls were temporarily suspended as an option following feedback from the Agencies on the June 2009 Watershed Plans.

five-year planning periods. This evaluation also resulted in the identification of system-wide green programs that are part of the Integrated Plan. These programs include the Disconnection – Redirection – Infiltration Program (DRIP), the Green Infrastructure Project Partnership Program (GrIPP), and technical support for urban reforestation and riparian buffers. Through these programs, SD1 intends to demonstrate a cost-effective and sustainable approach to storm water management while working to reduce overflow volume and improve water quality, as well as to provide additional benefits to the communities.

In addition to these programs, SD1 recognizes the value of community partnerships for the success of implementing green infrastructure. To begin forming these partnerships, SD1 met with many communities and other stakeholders in Northern Kentucky to discuss potential opportunities for partnering on green infrastructure projects. Since implementation rates of these programs and partnerships depend on local priorities and are difficult to forecast, SD1 will monitor, evaluate and update the green infrastructure projects and programs every five years.

Gray Infrastructure Opportunities Assessment for Remaining CSOs

SD1 used the water quality models to evaluate whether increasing levels of CSO control would continue to provide additional water quality benefit after implementation of the Five-year Improvement Program and the Green Infrastructure Programs. This analysis, called the "knee-of-the-curve" in the CSO Control Policy, determines the point where the water quality benefit from additional levels of control diminishes compared to the increase in costs. SD1 used the "knee" to help develop a targeted level of CSO control to guide analysis of additional gray infrastructure opportunities. This analysis revealed that, with implementation of the Five-year Improvement Program and the Green Infrastructure Program, discharges from 20 CSOs could be eliminated and that many of the remaining CSOs would already meet or exceed the targeted level of control.

SD1 then built upon the Bounding Analysis (described previously) by evaluating various control strategies including regional storage (equalization), regional high-rate treatment, deep tunnel storage, and combinations of these technologies (as described in Section 3). Initial sizing was based on meeting the targeted levels of control identified from the knee-of-the-curve analysis. The analysis showed that the deep tunnel solution (selected as the Traditional Plan under the Bounding Analysis) was the most expensive. A combination of regional storage and high-rate treatment was determined to be the most cost-effective and was selected as the preferred solution. This option reduced untreated overflows by another 726 million gallons in a typical rainfall year (1970).

This preferred solution also is calculated to achieve a minimum of 85 percent and up to 94 percent system-wide capture[5] which meets the Presumption Approach in the CSO Control Policy. A further analysis was conducted with the water quality models to assure the plan would reasonably be expected to not cause or contribute to a water quality (in terms of bacteria) violation. That modeling analysis shows that, assuming other non-

[5] As stated in the CSO Control Policy in Section II.C.4.a.ii, percent capture is the "elimination or the capture for treatment … by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual basis."

CSO sources are controlled within the implementation period, remaining CSOs would not cause or contribute to a water quality violation.

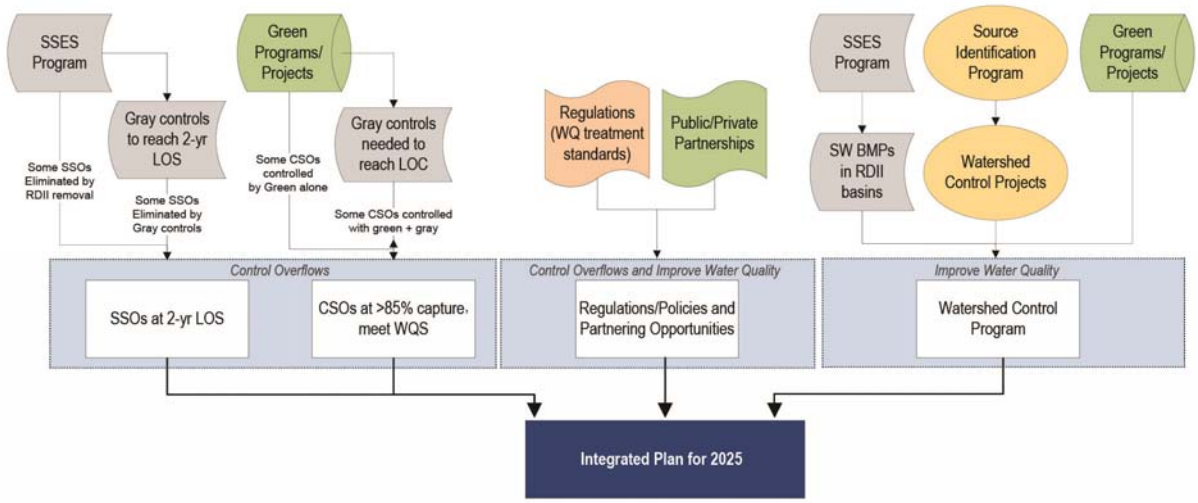
Other Opportunities Assessment

SD1 also expanded the 2009 watershed control analysis to determine if watershed controls could be used to cost-effectively enhance the level of CSO control and achieve greater water quality benefit. The analysis looked at controls such as storm water policies and regulations, a Source Identification Program, and storm water control measures that could be used to treat the storm water in areas associated with inflow and infiltration reduction projects.

Costs and Benefits of the Integrated Plan

The Integrated Plan for 2025 (Figure ES.5) incorporates these additional analyses. It has four components: SSO Elimination Program, CSO Long-term Control Plan, Watershed Control Program, and Policy/Regulations and Partnership Opportunities, as described above and in detail in Section 3. The Plan (beyond the Five-year Improvement Program), however, remains preliminary. This is because there is still significant uncertainty in the control design and modeling assumptions for the 2025 planning horizon. Consequently, the Plan will be refined and updated (in each five-year planning cycle) as more information and data become available.

Figure ES.5 Schematic of SD1's Integrated Plan for 2025.



Note: SSES = Sanitary Sewer Evaluation Survey; SSO = sanitary sewer overflow; RDII = rainfall derived inflow and infiltration; LOS = level of service; LOC = level of control; WQS = water quality standards; SW BMPs = storm water best management practices.

Table ES.4 summarizes the categories of projects and costs of the Integrated Plan for 2025. The cost of the Integrated Plan is $1.26 Billion in 2009 dollars and includes $103 Million for the System-wide and Basin Projects included in the Five-year Improvement Program; $463 Million in SSO control; $489 Million in CSO control; and $201 Million in

watershed controls (including the storm water controls associated with SSO control). The $489 Million in CSO control includes an estimated $145 Million of SD1 funding for green infrastructure projects and green programs in the combined area; it is estimated that this will leverage an additional $13 Million investment in green infrastructure from the Kentucky Transportation Cabinet.

Table ES.4 Cost of Integrated Plan for 2025

Categories of Projects	Capital Cost (Current 2009 $ M)
System-wide and Basin Projects in Five-year Improvement Program (including River Water Intrusion)	$103
SSO Control – Source Reduction Projects	$248
SSO Control – Gray SSO Projects to meet 2-year level of service	$215
SUBTOTAL – SSO Control	$463
CSO Control – Green Tier 1 Projects in Combined Sewer System Area	$136
CSO Control – Green Programs in Combined Sewer System Area	$9.2
CSO Control – Gray CSO Projects to meet targeted Level of Control	$344
SUBTOTAL – CSO Control	$489
Watershed – Source Identification Program Decentralized Projects	$12
Watershed – Stormwater Best Management Practices in RDII Basins	$187
Watershed – Green Programs outside Combined Sewer System	$1.8
SUBTOTAL – Watershed and Programmatic Projects	$201
TOTAL Consent Decree Costs	*$1,260*
Committed Projects for Asset Management	$252
Public Structural Rehabilitation	$197
Facility Planning Projects	$254
Initial Watershed Projects	$241
Anticipated Future Effluent Limits Projects	$229
TOTAL Full Program Costs	*$2,430*

Table ES.5 presents the model-calculated CSO and SSO volumes for the current conditions (based on 2007 land use) and future conditions (using 2030 land use). Current conditions include the baseline condition (pre-implementation of the Watershed Plans) and full implementation of the Five-year Improvement Program. Future conditions include full implementation of the Five-year Improvement and Green Infrastructure Programs, and full implementation of both programs with additional regional storage and high rate treatment for the remaining CSOs. Results are shown for the typical rainfall year (1970) and the typical water quality evaluation period (1992 to 1996). This shows that substantial reductions in CSO (26 to 31 percent) and SSO (45 to 43 percent) volume could be achieved with the Five-year Improvement Program over existing conditions. Full implementation of the green infrastructure is estimated to provide an additional 23 to 24 percent of CSO reduction (over existing conditions). Full implementation of the Integrated Plan for 2025 is estimated to provide an 88 to 91 percent reduction in CSO volumes and eliminate SSOs.

Table ES.5 CSO and SSO Modeled Volumes

Scenario	Typical Year (1970)		Five-Year Period for Water Quality Evaluation (Annual Average of 1992-1996)	
	CSO Volume (Million Gallons)	SSO Volume (Million Gallons)[1]	CSO Volume (Million Gallons)	SSO Volume (Million Gallons)[1]
Existing Conditions (2007 land use)				
Current Conditions	1,873	242	2,073	247
After Five-Year Improvement Program	1,376	134	1,422	140
Future Conditions (2025, using 2030 land use)				
With Green Infrastructure Added	952	134	945	140
Integrated Plan for 2025 (With Additional Gray Infrastructure Added)	226	0	178	0

Notes:

Two planning horizons are provided, the 1970 "typical year" period and the five-year typical period (1992-1996) used for the water quality evaluations. The 1970 period, while typical from a rainfall perspective, had unusually low flow conditions in Banklick Creek and the Licking River, making it unsuitable for evaluating the water quality impacts of CSOs. The five-year period was typical from a combination of rainfall and instream flow conditions.

Model calculations are current as of February 2011.

[1] Includes the model-calculated volume from model-predicted overflow locations, as well as the volume prior to the Eastern Regional sewer system improvements.

An added benefit of SD1's Watershed Plans is that pollutant loads (other than bacteria) can be considered in selection of controls. Table ES.6 compares the estimated percent reduction in bacteria, nitrogen, and phosphorus loads from all sources in the Northern Kentucky watersheds from current conditions under the Traditional Plan and the Integrated Plan for 2025. The Integrated Plan provides significantly greater percent reduction than the Traditional Plan for many of the watersheds.

Table ES.6 Percent Reduction from Current Condition in Bacteria, Nitrogen, and Phosphorus Loads for the Traditional and Integrated Plans

	Bacteria Loads		Total Nitrogen Loads		Total Phosphorus Loads	
Watershed	Traditional Plan	Integrated Plan	Traditional Plan	Integrated Plan	Traditional Plan	Integrated Plan
Banklick Creek	40%	53%	1%	20%	1%	19%
Licking River	53%	53%	3%	6%	3%	6%
Taylor Creek	32%	46%	3%	25%	3%	24%
Fourmile Creek	56%	60%	1%	10%	1%	10%
Pleasant Run	6%	38%	0%	31%	0%	31%
Ohio River	75%	73%	4%	5%	3%	5%
Twelvemile Creek	0%	2%	0%	2%	0%	2%
Threemile Creek	16%	36%	0%	21%	1%	18%
Dry Creek	42%	52%	2%	18%	3%	19%
Elijahs Creek	0%	13%	1%	10%	0%	8%
Sand Run	0%	8%	0%	8%	0%	9%
Woolper Creek	59%	62%	0%	11%	1%	11%
Gunpowder Creek	1%	9%	0%	9%	0%	9%
Big Bone Creek	4%	9%	0%	8%	0%	8%
Total	**47%**	**51%**	**2%**	**9%**	**1%**	**8%**

SD1's Integrated Plan for 2025, as currently envisioned, achieves the following as compared to the future baseline and traditional plans:

- Elimination of SSOs at a two-year level of service;
- Elimination of 20 CSOs;
- Treatment of 562 million gallons per year of storm water through green infrastructure and reduction in storm water runoff quantity;
- Elimination of 1,287 million gallons per year of CSO volume from the completion of the Five-year Improvement Program and additional green infrastructure projects identified in the Integrated Plan for 2025;
- Treatment of 767 million gallons per year of CSO volume through high-rate treatment; and
- Minimum of 85 up to 94 percent capture and treatment of the volume of CSO.

The Traditional Plan that was evaluated under the Bounding Analysis used a level of control for CSOs at four overflows per year. SD1's analysis showed that, although the traditional plan results in less annual average volume of CSO over the five-year typical period (124 million gallons per year) versus the Integrated Plan for 2025 (178 million gallons per year as shown in Table ES.5), the water quality and other benefits of the

Traditional Plan are far less. Table ES.7 provides a comparison of some of the benefits under the traditional plan and the Integrated Plan for 2025 conditions.

As discussed in Section 3, the benefits of the Integrated Plan as compared to the traditional plan include:

- A greater reduction in bacteria levels (during both dry and wet weather conditions) and total bacteria loads from the watersheds.
- More water quality benefit using number of days where fecal coliform bacteria levels are less than 400 colony forming units during the recreation season (a common benchmark for safe recreating conditions). For example, the Traditional Plan results in 18 additional days of recreation in Banklick Creek (as compared to the baseline condition) whereas the Integrated Plan results in an additional 42 days of recreation.
- More water quality benefit using the average (geometric mean) of bacteria levels across the recreation season.
- Improved water quality in 148 miles of streams. These streams will also benefit from water quantity improvements from the integrated controls (gray, green, watershed, and policy/regulation).
- Greater reductions in total nitrogen and phosphorus loads from the three-county area.

Table ES.7 Additional Benefits of a Traditional Plan and the Integrated Plan (2025 Baseline)

Watershed	Additional Days of attainment (< 400 colony forming units per 100 milliliters)		Recreation Season geometric mean concentration (colony forming units per 100 milliliters)			Stream length with improved water quality (Miles)	
	Traditional Plan	Integrated Plan	Base-line	Traditional Plan	Integrated Plan	Traditional Plan	Integrated Plan
Banklick	+17	+41	1,080	586	310	1	19.1
Licking	+10	+11	136	105	96	4.8	9.2
Taylor	0	+1	2,628	2,572	2,204	0.2	2.5
Fourmile	+7	+8	446	323	305	2.1	9.5
Pleasant Run	0	+2	387	385	364	0.7	3.4
Ohio River	+7	+6	14	6	7	55.4	73.0
Twelvemile	0	+1	329	329	315	0	10.4
Threemile	+2	+4	517	492	464	0	4.3
Dry	+5	+7	514	426	402	0	7
Elijahs	0	+1	250	250	245	0	4
Sand	0	+1	488	484	467	0	5.8
Total	+63	+96				64.2	148.2

Notes:
Gunpowder, Big Bone, and Woolper were not assessed because the models have not been calibrated.
For modeling water quality benefit, the Pleasant Run Creek and Fourmile Creek CSOs were input directly to the Ohio River because of their proximity to the mouths of their respective creeks.
Ohio River model water quality results are presented at River Mile 471.32, just downstream of the Willow Run CSO. The reported numbers of stream miles improved for the Ohio River were calculated as the streamwise distance between the downstream extent of the study area (river mile 516.6 at the Boone County line) and the upstream most control for each scenario.

As compared to a traditional (gray-only) plan, the Integrated Plan, through its focus on multiple pollutant sources, is also anticipated to provide additional qualitative benefits for ecological and human health. Additional benefits include reduced public health risk, reduced flooding, improved aquatic habitat and biology, streambank stabilization and reduced erosion, preservation of green space and provision of opportunities to connect public lands and greenways, and support for community involvement and partnering.

Economic Analysis

Financing a long-term, capital intensive program without placing an unreasonable burden on ratepayers is one of SD1's biggest challenges. The timing of the Watershed Plans submission is unique, in that it is occurring in the midst of the most severe national economic crisis in generations. As a result, the financial affordability precedents from other utilities' sewer overflow control programs established in consent decree negotiations over the past ten years may no longer be valid.

SD1 is funded through a combination of sanitary and storm water utility rates and fees; no income is available from property, sales or other taxes. Sanitary sewer rates currently represent more than 70 percent of this revenue stream. The current economic situation has the potential to significantly impact SD1's financial position. For example, the recession will clearly affect the ability of some ratepayers to pay increased sewer rates. As unemployment and foreclosures increase, and credit markets tighten, some ratepayers will soon be unable to afford their sewer bills.

More critical, however, is state legislation that has limited SD1's Board of Directors' ability to approve rate increases. On March 17, 2011, House Bill 26 was signed into law (Kentucky Revised Statutes Section 220.542(3), effective June 8, 2011). This law requires SD1 to submit all proposed rate increases of greater than five percent to the three county fiscal courts. On March 22, 2011, SD1's Board of Directors approved 15 percent rate increases for fiscal years 2012 and 2013. For fiscal year 2014, SD1 submitted a rate increase of greater than five percent to the fiscal courts and the fiscal courts did not approve it, resulting in no rate increase for the fiscal year. SD1 is facing the same process every year going forward, with no guarantee that adequate funding will be available for compliance with the existing implementation schedule.

This situation will directly impact the ability of SD1 to maintain adequate revenue, meet its bond coverage requirements, and keep a high credit rating. SD1 is required to maintain fiscally conservative accounting by the Board of Directors. The recent history of sanitary sewer rate adjustments (average annual increases over 14 percent for the last ten years) have supported a bond rating of AA or better. The minimum debt service coverage required by SD1's bond indenture is 125 percent; however, the Board of Directors has set a goal of 150 percent. With the current and projected impact of the economic crisis, and KRS 220.542(3), there will be increased pressure for, and scrutiny of, future rate adjustments.

In addition to funding projects associated with the Consent Decree, SD1 has an obligation to operate and maintain current assets. These "Committed Projects" are asset management costs that are not discretionary, as they reflect the cost of doing business for a sewer and storm water utility. This would include projects to fix failing pipes, prevent loss of service and building backups, and minimize wet weather overflows.

Funding scenarios and affordability implications were developed for two time frames, the full Consent Decree implementation period ending in 2025 and the watershed planning cycle for the next five years. As a result, the Agencies have recognized the high burden that this Plan places on Northern Kentucky ratepayers. Additional

discussions with the Agencies regarding affordability and schedule extension have been initiated.

Integrated Plan for 2025

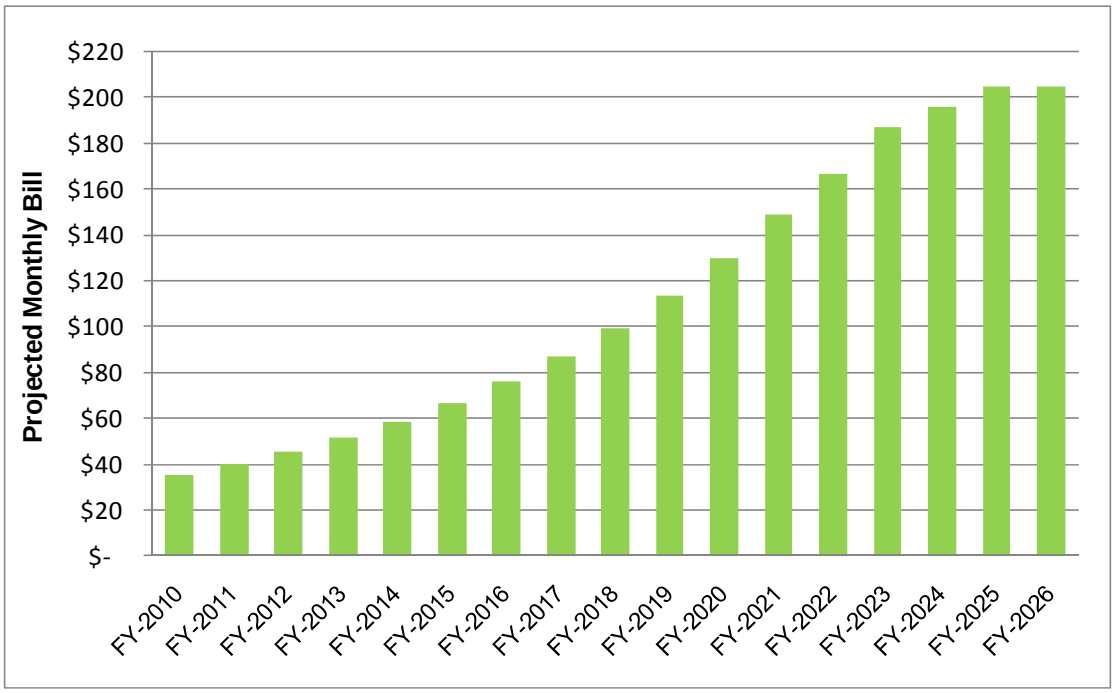
In accordance with the Consent Decree, SD1 used the Financial Capability Assessment approach that is typically included in long-term control plans for CSO control to assess the Integrated Plan for 2025 (Section 3). This Plan achieves a high level of SSO control (two-year level of service) and meets the Presumption Approach (e.g., minimum of 85 percent capture and treatment of wet weather flow) in the CSO Control Policy. The Full Program Costs for the Integrated Plan for 2025 (Table ES-4 above) were the basis for the formal U.S. Environmental Protection Agency's financial capability assessment analysis.

The Full Program Costs consist of the projected costs of the Integrated Plan for 2025 as well as the costs for the committed obligations of asset management for infrastructure and Initial Watershed Projects, and the obligations of anticipated future effluent limits for nutrients (i.e., nitrogen and phosphorus) at the treatment plants. The cost for SD1 to implement this full program is $2.4 Billion, in 2009 dollars (See Table ES.4).

Per the Financial Capability Assessment, this program equates to an annual cost per household of $1,680. The corresponding Residential Indicator is 3.0 percent, based on a median household income of $55,840 (overall SD1 service area). This analysis indicates that SD1's program is clearly in the "High Financial Impact" category. When assessed in terms of Northern Kentucky's lower-income communities, the financial impact is even greater. The seven lowest income communities (representing approximately 40 percent of the households in SD1's service area) have a median household income of $38,000. For these households, the Residential Indicator is 4.4 percent.

In addition to the Residential Indicator analysis, SD1 estimated the future rate increases that would be needed to support the Full Program Cost of the Integrated Plan for 2025. To assess the year-by-year impacts of the program, an initial schedule was developed to represent a construction sequence with final completion by 2025. This capital spending schedule was then incorporated into SD1's financial tools to estimate future rate requirements, as shown in Figure ES.6.

Figure ES.6 Residential Sewer Rates for the Full System Solution Concept – Future Projections (Future Dollars)



An average residential monthly sewer bill over $200 in 2025 represents an increase of 500 percent over 2010 rates ($35 per month). Even when allowing for future income growth, which is particularly difficult to predict in today's economic climate, these rate projections represent staggering increases that are unaffordable for SD1's ratepayers. The need for developing a watershed-based program that is cost effective, maximizes improvements to water quality and public health, and is supported by the public is clear.

Five-year Watershed Plan Horizon

The five-year cycle of the Watershed Plans also requires its own economic analysis. Because this analysis is not based on the full duration of the Consent Decree, the traditional affordability metrics such as the Residential Indicator are not directly applicable. Rather, SD1 used the estimated rate increase scenarios as the controlling indicator for determining an affordable five-year program.

As noted previously, SD1 has obligations both to the Committed Projects (asset management efforts) as well as the completion of the Initial Watershed Projects. These combined programs represent approximately $396 Million in capital spending over the five-year period of fiscal years 2010 to 2014. It should be noted that the two approved 15 percent rate increases in 2010 and 2011 were approved at the beginning of Northern Kentucky feeling the full brunt of the national economic crisis. This positioned SD1 with the funding to at least initiate significant improvements over the first five-year implementation cycle. Further, the two additional 15 percent rate increases for 2012 and 2013 were approved by the Board of Directors and Judges Executive in March 2011, immediately prior to this 2011 submittal. These increases for fiscal years 2010, 2011, 2012, and 2013 demonstrate the commitment by SD1, in particular its Board of

Directors and Judges Executive, to fund SD1 initiatives upon demonstration of return on investment in terms of protecting public health and improving water quality. Future increases, however, will inevitably be linked to regional economic conditions in Northern Kentucky and restricted by affordability limitations and House Bill 26.

SD1's objective for the next five years is to complete the Initial Watershed Projects, continue working on the Committed Projects, and implement the System-wide and Basin Projects that have been identified through the watershed planning process. All of these projects will provide significant improvements in CSO reduction, SSO elimination, public health, and result in water quality benefits for Northern Kentucky's waterways. The Five-year Improvement Program requires an additional rate increase in fiscal year 2014, beyond the currently-approved increases (through fiscal year 2013 inclusive). In order to configure the Five-year Improvement Program, SD1 has assumed an additional 15 percent rate increase in fiscal year 2014. Under this scenario, the average residential customer using seven hundred cubic feet per month would be paying $35 per month in fiscal year 2010 and projected payment of $59 per month in fiscal year 2014.

Five-Year Improvement Program

Improvements to be made over the next five years include the completion of the Initial Watershed Projects, continued work on asset management in order to renew existing assets and reduce inflow and infiltration, and the implementation of System-wide and Basin Projects that have been identified through the watershed planning process. In addition, SD1 will evaluate, pursue, and seek commitments to ensure the successful implementation of green infrastructure in the Integrated Plan for 2025. These commitments will be included in updates to the five-year Watershed Plans and will serve as a model for future green infrastructure projects and programs.

Initial Watershed Projects

A total of 52 different Initial Watershed Projects are listed in Exhibit D of the Consent Decree. These projects can be broadly categorized into three groups, as shown in Table ES.8. The benefits associated with these projects include SSO elimination, CSO elimination, overflow volume reduction, increased treatment capacity, and increased conveyance capacity.

Table ES.8 Five-year Improvement Program: Initial Watershed Projects

Project Name	Benefit	Spending through 2009 ($ Millions)	Fiscal Year 2010-2014 Budget ($ Millions)
Western Regional (11 projects)	New water reclamation facility, conveyance improvements, SSO elimination	$46	$258
Eastern Regional (10 projects)	New water reclamation facility, conveyance improvements, SSO elimination	$75	$3
Pump Station and Sewer Improvements, Sewer Separation, and Overflow Studies (31 projects)	SSO elimination, CSO elimination, overflow volume reduction, increased conveyance capacity	$37	$0 (all projects completed)
Total		$158	$261

The Eastern Regional and Western Regional project groups represent the largest portion of the Initial Watershed Project set. The Eastern Regional projects were needed to eliminate the sewer overflows and resolve the 1996 sanction that led to a building moratorium in the Alexandria area; those projects are complete at this time. The Western Regional projects include the construction of the new Western Regional Water Reclamation Facility and significant sewer construction throughout the area tributary to that facility. The largest of these sewer projects is the $141 Million conveyance tunnel project. The Western Regional projects will serve as a cornerstone in the ultimate solution to SD1's sewer overflow problems. These projects allow for the diversion of wastewater flow away from stressed areas of the SD1 system such as the Dry Creek Wastewater Treatment Plant and Lakeview Pump Station, thereby eliminating sewer overflows and providing additional capacity to accommodate future growth.

Committed Projects

In addition to funding projects associated with the first Watershed Plans, SD1 has an obligation to operate and maintain current assets and to meet other obligations. These Committed Projects represent a total of approximately $144 Million in spending over the period of fiscal year 2010 through 2014. As shown in Table ES.9, these projects include high priority sewer repairs and replacements, a number of Consent Decree required programs, sewer asset renewal and inflow and infiltration reduction, improvements at pump stations and treatment facilities, and capital purchases.

Table ES.9 Five-year Improvement Program: Committed Projects

Project Name	Benefit	Fiscal Year 2010-2014 Budget ($ Million)
High-priority Sewer Projects	Critical sewer rehabilitation / replacement; Projects include Van Deren, Highland Pike, Wayman's Branch	$10.1
Nine Minimum Control Program	Element of Nine Minimum Controls Program, Consent Decree requirement	$2.1
River's Edge Inline Storage and Solids & Floatables Project	CSO volume reduction, Solids and Floatables Controls at 2 CSO outfalls	$5.2
Capacity, Management, Operations, and Maintenance Program	Consent Decree requirement; Projects include Pump Station Back-up Power, South Park Industrial Pump Station Overflow Elimination	$11.0
Consent Decree Planning, Implementation, Management	Necessary to ensure effective implementation of overall Consent Decree program	$12.2
Improvements at Dry Creek Wastewater Treatment Plant	System maintenance, increased treatment capacity	$28.8
Pump Station Projects	Pump station asset management and elimination	$14.9
Ongoing Sewer Rehabilitation / Repair Projects	Rehabilitation / replacement based on Continuous Sewer Assessment Program and Cities' opportunities; SSO elimination	$42.0
Storm Sewer Rehabilitation / Repair Projects	Storm water asset management	$11.0
Capital Purchases (vehicles, construction equipment, etc.)	Equipment	$6.6
	Total	$143.8

System-wide Projects and Basin-Specific Projects

As required in the Consent Decree, SD1 has developed a Five-year Improvement Program describing improvement projects to be implemented over the next five years. Information that was needed for the development of this program included the results of the system characterization, the bounding analysis, and the economic analysis. In addition, public participation was a critical component in the watershed planning process.

SD1 solicited public input through a variety of channels. Those included a widely-publicized and well-attended Watershed Summit meeting in 2007, the formation of a 53-member Watershed Community Council that met regularly over an 18-month period, and the development and distribution of a survey to assess the community's support of the Consent Decree program. Through that process, a set of criteria were established that guided the selection of projects for the Watershed Plans. Those criteria included:

- Reduction of sanitary sewage entering waterways,
- Reduction of polluted runoff,
- Public health benefits,
- Maintenance of critical, aging infrastructure, and
- Cost.

The selected projects for the Five-year Improvement Program includes both System-wide and Basin Projects. As shown in Table ES.10, these projects also include a combination of gray infrastructure, green infrastructure, and watershed control approaches.

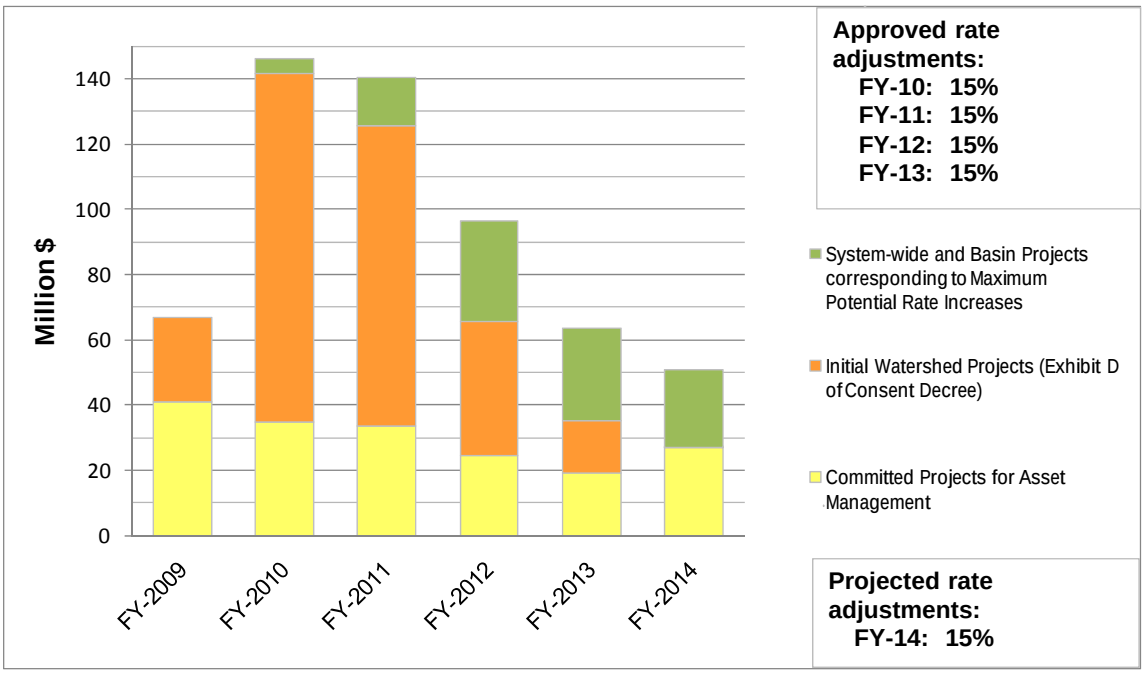
Table ES.10 Five-year Improvement Program: System-wide and Basin Projects

Project Name	Benefit	Fiscal Year 2010-2014 Budget ($ Millions)[1]
System-wide		
River Water Intrusion Mitigation	CSO reduction	$5.0
Priority Inflow and Infiltration Source Identification and Removal	SSO reduction/elimination	$6.0
Green Programs (DRIP, GrIPP)	Source runoff control, CSO reduction, and pollutant load reduction from both CSO control and runoff	$2.0
Demonstration Projects (pilot projects, innovative technology testing)	Source runoff control, CSO reduction, and pollutant load reduction from both CSO control and runoff. Performance data to inform future Watershed Plans	$4.6
Dry Creek WTP Headworks Project	Increases the primary and disinfection capacity to 93 million gallons per day	$19.1
	System-wide Project Total	$36.7
Central Basin		
Lakeview Pump Station Pumps Replacement	Increase pump station capacity and reliability	$5.4
Church Street (Gray, Green, and Watershed controls)	CSO reduction, storm water runoff, green space	$3.8
Vernon Lane –Public & Private Source Inflow and Infiltration Removal	SSO elimination	$3.8
Watershed Controls Pilot Projects - Regional and decentralized controls	Improve dry and wet weather water quality and stream conditions; Reduce public health risk; Pilot projects that will provide performance data to inform future plans	$3.6
Ripple Creek Pump Station Removal	SSO elimination	$0.9
	Central Basin Project Total	$17.5
East Basin		
Ash Street Pump Station and Forcemain	CSO elimination (Sensitive area); SSO reduction	$19.7
	East Basin Project Total	$19.7
North Basin		
Allen Fork Pump Station Overflow Elimination	SSO elimination	$8.3
Lakeside Park – Public Sewer Rehabilitation and Private Source Removal	SSO elimination	$5.8
Willow Run Dynamic Control	CSO reduction	$1.3
Willow Run Direct Entry Point Bar Racks	Reduce debris entry and reduce blockages	$0.06
Kentucky Transportation Cabinet Basin – Green Infrastructure Retrofit	CSO reduction, inform future green infrastructure	$1.5
	North Basin Project Total	$17.0
West Basin		
Highland Acres Pump Station Removal	SSO elimination	$1.65
Kentucky Aire Pump Station Removal	SSO elimination	$4.0
	West Basin Project Total	$5.7
	System-wide and Basin Projects Total	$96.5

Note: [1]The System-wide and Basin Projects budget total from Table 8.1 Components and Cost of the Integrated Plan for 2025 of $103 Million differs from the budget total in Table 8.6 of $96.5 Million. The $103 Million includes the full river water intrusion (RWI) costs outside the five-year window, and is based on the current costs to date (fiscal year 2010 audited actual and fiscal years 2011 to 2014 budget with a 3% deflation rate to 2009 dollars) used in the Financial Capacity Assessment.

The total capital spending associated with all project work over the next five years is approximately $497 Million. The distribution of spending over that period is weighted towards Initial Watershed Projects in the first few years with a transition to the System-wide and Basin Projects towards the end, as shown in Figure ES.7.

Figure ES.7 Capital Spending and Rate Adjustment Schedule



Overflow Reduction Benefits

The overflow reduction benefit resulting from the projects described in the Five-year Improvement Program is substantial, with an overall 28 percent reduction in typical year sewer overflow volume. Based on hydraulic model results, the CSO volume for a typical year will be reduced by 493 million gallons, representing a 26 percent decrease from current conditions. The annual SSO volume, calculated for both confirmed and model-predicted overflow locations, for a typical year is reduced by 108 million gallons, representing a 44 percent decrease. The overflow reduction is associated with the projects presented in Table ES.11.

Table ES.11 Five-year Program: Overflow Reduction for Selected Projects

Project	Overflow Reduction in the Typical Year (millions of gallons)	
	CSO	SSO
Western Regional	-	59.7
Eastern Regional	-	8.0
River Water Intrusion Mitigation	281	7.5
Church Street	35	-
Ash Street Pump Station	2.4	21.6
Vernon Lane Infiltration/Inflow Reduction	-	3.8
Ripple Creek Pump Station Removal	-	0.3
Lakeside Park Improvements o Van Deren Sanitary Sewer Improvements o Avon Drive Sanitary Sewer Improvements o Public Sewer Rehabilitation and Private Source Removal	-	0.4
Additional System Improvements o Static Inline Storage o Bromley Wet Well Modifications o Willow Run Dynamic Control o Kentucky Transportation Cabinet Basin Retrofits o Taylor Creek Improvements	166.8	6.5
Disconnection – Redirection – Infiltration Program (DRIP) Green Infrastructure Project Partnership Program (GrIPP)	1	
Green Demonstration Projects o Kentucky Transportation Cabinet Bioretention Facility o Terraced Reforestation o St. Elizabeth's Rain Garden o 12th Street Rain Garden	11.2	
Selected Project Totals	497.4	107.8

Lakeview Pump Station- Example of Benefits of the Watershed Approach

The Lakeview Pump Station, located on Banklick Creek, was once SD1's largest SSO. Since SD1 entered into the Consent Decree, significant improvements have been completed at the Lakeview Pump Station and additional improvements will be completed within the next five years. As a result of those projects, the annual overflow volume from the Lakeview bypass will be reduced by more than 90 percent in a typical year. Water quality sampling shows that this reduction in overflow results in approximately ten additional days of achievement of instream water quality standards, annually. As SD1 evaluated control alternatives for the remaining overflow at the bypass, it was estimated that higher levels of control to eliminate the one million gallons of remaining annual overflow volume will produce no additional days of achievement of instream water quality standards for Banklick Creek.

The cost to construct a storage tank or install interim high rate treatment that would eliminate or treat the remaining overflow volume ranged between $15 Million to $27 Million. In addition, this investment would only address the overflow at the pump station and would do nothing to improve the condition of the water quality in the upper two-thirds of the watershed. Model results have shown that far greater water quality, community, and public health benefits can be achieved by directing resources toward the reduction of dry weather sources to Banklick Creek. Further, SD1's characterization efforts revealed that there were CSOs and SSOs contributing more than 38 million gallons of overflow volume in the Silver Grove area that were of greater public health risk than the remaining discharge from the Lakeview Pump Station. Because of these higher public health risk overflows, SD1 committed to addressing these problems in the Five-year Improvement Program.

SD1 is therefore proposing that the solution to address the remaining discharge at Lakeview be focused on the overall water quality issues within the Banklick Creek watershed, and that SD1 be allowed to delay eliminating this SSO. The proposed solution includes five components:

- Replace existing pumps at the Lakeview Pump Station to maximize and provide reliable peak pumping capacity;
- Redirect a portion of the Lakeview tributary area to the new Western Regional Water Reclamation Facility and reduce the annual calculated overflow from 10.6 to one million gallons (under construction);
- Conduct investigations and target cost-effective inflow and infiltration removal in the area remaining tributary to Lakeview to reduce wet weather flows and target upstream SSOs at locations with a higher risk for public exposure;
- Implement a Source Identification Program to detect sources of pollution (dry and wet weather-related) determined to exist through monitoring and modeling efforts; and
- Construct a wetland system along Banklick Creek to reduce dry weather bacteria levels and improve overall water quality in the downstream system.

This combination of controls represents a cost-effective solution that provides greater water quality, public health, and community benefits than a more costly investment to contain or treat the remaining one million gallons of overflow from the Lakeview Pump Station. In addition, by delaying action at Lakeview with respect to the remaining overflow volume, SD1 will be able to reallocate $20 Million over the next five years to the Ash Street Pump Station project in Silver Grove, which will provide approximately 38 million gallons of annual overflow reduction in a part of the system where the overflow has greater potential for public health impacts.

SD1 strongly believes that elimination of the remaining one million gallons of overflow for the typical year at the Lakeview Pump Station will be achieved through aggressive inflow and infiltration removal which will take some time to implement. Additional improvements needed to eliminate all remaining overflows in the Lakeview Pump Station service area will be implemented in subsequent Watershed Plan implementation phases.

This approach represents a change from the language of Exhibit E in the Consent Decree which specifies a completion date of December 31, 2013 for the construction of remedial measures at the Lakeview Pump Station to eliminate the bypass. However, the proposed solution described above supports the position that this modified approach will provide substantially greater improvements to water quality and public health. Therefore, the Watershed Plan provides for a delay in the December 31, 2013 Consent Decree deadline to eliminate the bypass at the Lakeview Pump Station.

Implementation Plan

SD1 has developed an implementation plan for the Five-year Improvement Program and the Integrated Plan for 2025, as described in Section 8. SD1 has budgeted for a substantial commitment in system-wide and basin projects in the first five years, as discussed above. These projects were selected based on criteria important to both SD1 and local stakeholders:

- Reduction of sanitary sewage entering waterways,
- Public health benefit,
- Reduction of storm water runoff pollutants,
- Cost effectiveness,
- Eco-friendliness, and
- Criticality of aging infrastructure.

Reduction of sanitary sewage entering waterways and public health benefit led SD1 to target SSOs that discharge in areas with a high potential for public contact; while many of these are small volume overflows, their public health risk made them a priority. Reduction in storm water runoff pollutants, cost effectiveness, and eco-friendliness led SD1 to include a range of green and watershed controls. These innovative techniques have the potential to provide cost-effective control of many different source types. Finally, criticality of aging infrastructure supported inclusion of system-wide controls such as infiltration and inflow source detection; these programs are directly aligned with SD1's institutional goal of maintaining existing infrastructure assets. These guiding principles were also used to establish priorities for selection and implementation of controls for the Integrated Plan for 2025.

Several of the five-year projects will be used to evaluate the benefit of integrated green, gray, and watershed solutions that are necessary components of the Integrated Plan for 2025. Many of these projects will include a performance monitoring program to allow SD1 to determine general effectiveness of different approaches and technologies, and to inform the prioritization of projects for subsequent Watershed Plans.

The Five-year Improvement Program projects and their timing for completion are ultimately linked to SD1's ability to obtain rate increases. The implementation schedule for the Five-year Program (presented in Section 8) balances the following key factors:

- **Financial Capability and Cash Flow:** Sequencing of work to fit within SD1's affordable capital budget;
- **Consent Decree Deadlines:** Impacts the timing of several Pump Station Overflow Elimination projects. Several stations with 2010 and 2013 deadlines

needed to be started earlier in the schedule so the overflows associated with those pump stations will be eliminated by their scheduled deadline;

- **Demonstration Projects:** Design and construct green and watershed demonstration projects or integrated control projects so that sufficient time was left to collect meaningful post-construction monitoring data to inform and support future plans; and,
- **Public Health Priorities:** Attempt to prioritize projects that will have the greatest public health benefits.

Through the characterization and planning work, SD1 identified three Initial Watershed Projects or Pump Station Overflow Elimination Projects that will not meet the dates stipulated in the appendices of the Consent Decree, or the subsequent approved Pump Station Overflow Elimination Plan. These projects are the Lakeview Pump Station, the Richwood Pump Station, and the Sunset Pump Station (details are provided in Section 8.3). Justification for the modifications is as follows:

- **Lakeview Pump Station:** SD1 is proposing to replace existing pumps at the Lakeview Pump Station to maximize and provide reliable peak pumping capacity; redirect a portion of the Lakeview tributary area to the new Western Regional Water Reclamation Facility and reduce the annual calculated overflow from 10.6 to one million gallons (under construction); conduct Sanitary Sewer Evaluation Studies to remove public and private inflow and infiltration; conduct a Source Identification Program in the Banklick Creek watershed; construct an innovative wetland system and other decentralized watershed controls; and spend $20 Million over the next five years to construct the Ash Street Pump Station project in Silver Grove. The Ash Street project will provide approximately 38 million gallons of annual overflow reduction in a part of the system where the overflow has greater potential for public health impacts.

- **Richwood Pump Station:** The upgrade of Richwood Pump Station and the construction of a new forcemain to redirect flows to the Western Regional System were originally included in the Initial Watershed Projects due to the pump station's potential lack of dry and wet weather capacity and its perceived reduction in overflow volume in the Lakeview system. Based on flow monitoring conducted in 2007 and 2008 as part of the hydraulic model calibration and validation and subsequent hydraulic modeling, SD1 has found that the Richwood Pump Station does not bypass during wet weather and has sufficient capacity to convey all dry and wet weather flows. In addition, redirecting the flows from the Richwood Pump Station to the Western Regional system did not significantly reduce overflows downstream in the Lakeview system. The potential future need to construct this project will be based on monitoring the existing upstream and downstream sewer system after the Western Regional Water Reclamation Facility is in operation. The timing of the upgrade and redirection of the Richwood Pump Station to the Western Regional System will be evaluated based on monitoring the available capacity of the pump station and the downstream Lakeview sewer system. Richwood Pump Station will receive a backup power solution as well to eliminate any overflows due to power outages.

- **Sunset Pump Station:** The original plan in the Pump Station Overflow Elimination Plan was for a private developer to partner with SD1 to construct a new pump station farther north to serve a new development as well as the existing Sunset Pump Station area. This new pump station (Arcadia Pump Station) would have eliminated the Sunset Pump Station and overflow and would have a firm capacity of 1.3 million gallons per day to provide capacity to convey peak dry and wet weather flows for current and future conditions. The original schedule provided in the Pump Station Overflow Elimination Plan stated construction would be complete by spring of 2009. Due to the significant economic downturn and the slow-down in the housing and lending markets, SD1's partnership with the developer to construct the new pump station was delayed. At this point in time, it is optimistic that SD1's partnership will be restored at some point in the future in order to complete the new pump station construction. SD1 has implemented an interim solution that provided the required capacity in the near term to eliminate the overflow. The solution constructed a new eight-inch force main and installed new discharge piping in the existing pump station to allow the existing pumps to provide the necessary capacity in order to eliminate overflows. A new back-up diesel-driven pump was also provided to be used during power outages. This project was completed ahead of the Consent Decree deadline of December 31, 2010.

As part of the implementation plan, SD1 has developed a post-construction monitoring plan in accordance with the U.S. Environmental Protection Agency's guidance and information needed to support continued implementation of the Watershed Plans. The post-construction monitoring plan includes monitoring programs specific to project performance monitoring (with an emphasis on green infrastructure projects), the sanitary sewer collection system and watershed monitoring.

Performance monitoring plans will be included in the detailed design for projects in the Five-year Improvement Program, as appropriate, and will continue through the full implementation of the Watershed Plans. Performance monitoring is necessary to evaluate specific watershed, green and integrated infrastructure control projects, test the effectiveness of phased controls (and aid in decisions about additional levels of control), and inform decisions about cost-effective projects in future control planning cycles. Because site-specific and cost data on these controls are needed for Northern Kentucky, performance monitoring may also be necessary to test the effectiveness of green infrastructure or watershed controls before decisions are made about implementation at other sites, or to inform the overall potential of these controls to improve water quality.

The green infrastructure performance monitoring will be a critical element in the early stages of SD1's overflow control strategy, and will ultimately shape the level and extent of specific strategies, as well as the overall role that green infrastructure will play in achieving SD1's water quality improvement goals for Northern Kentucky. The primary objectives of this monitoring are to measure and document specific project and/or storm water control measures performance and to compare this data to modeled projections. These data may also prove useful in identifying the key design parameters that impact

overall performance which will then allow for better and more cost-effective designs moving forward.

The sanitary sewer collection system monitoring will provide information to continue to characterize the collection system and update the collection system models as projects are completed, generate quarterly and annual reporting of wet weather CSO and SSO activations, and monitor performance of constructed controls. As part of this ongoing characterization effort, SD1 will periodically update the model with new information from field inspections and, when necessary, verify that the model is still calibrated for its intended use.

Because SD1 is pursuing an Integrated Plan that includes green infrastructure and watershed controls in addition to traditional gray infrastructure controls, monitoring is needed throughout the 16 watersheds to measure the success of the Watershed Plans. The Watershed Monitoring Program consists of three phases that include collecting data to initially characterize the waterways, capture changes in the waterway conditions, and post-construction monitoring to assess improvements in overall water quality, biology and habitat after the Watershed Plans are implemented. The phases of the Watershed Monitoring Program are:

- Baseline Monitoring Characterization and Model Development (2006-2011),
- Baseline Trend Monitoring (2012-2026), and
- Post-Construction Monitoring (2026-2028).

These phases reflect the expected timing of activities needed to implement the Watershed Plans, to inform the five-year planning cycles of the Consent Decree, and to conform to the post-construction monitoring requirements of the CSO Control Policy. The Program includes monitoring to be conducted by SD1, continued cost-share funding for monitoring conducted by the United States Geological Survey, and collaboration with other parties that are conducting monitoring in Northern Kentucky, such as the Kentucky Division of Water, local universities, and non-governmental organizations.

Conclusion

SD1's Consent Decree is unique in that it incorporates a watershed-based approach that allows SD1 to put CSO and SSO controls into context with other sources of pollution, reflecting watershed-specific characteristics. This approach provides an alternative to traditional regulatory practices which target specific sources through individual pollution control programs. By taking a watershed-based approach, SD1 will make use of a wider variety of data to assess the relative impact of different pollutant sources on the receiving waterways.

This approach also prevents the pitfall of directing funds towards increasingly higher levels of CSO and SSO control when those improvements do not provide corresponding improvements in water quality. Traditionally, most consent decrees focus solely on CSOs and SSOs, with an emphasis on gray infrastructure solutions. SD1's watershed approach identifies the characteristics of individual watersheds and considers CSOs and SSOs along with other pollution sources impacting the waterways (such as runoff and dry weather sources). The iterative structure of SD1's Watershed Plans allows time

to investigate new technologies and adjust the approach so that solutions for updated Plans will be developed using information gained from the implementation of projects during the first five years. This includes the pursuit of green infrastructure approaches that are more cost effective than traditional gray infrastructure, including mechanisms to ensure the implementation of such controls.

The U.S. Environmental Protection Agency acknowledges that "[for] some receiving water reaches within a watershed, CSOs could well be less significant contributors to nonattainment than storm water or upstream sources. In such cases, a large expenditure on CSO control could result in negligible improvement in water quality" (EPA, 1995b). Much of the work performed by SD1 thus far supports this statement. The proposed Integrated Plan for 2025, with gray and green infrastructure along with watershed controls is shown to be more cost effective at meeting the long-term goals of the Consent Decree. However, the Integrated Plan with a completion date of December 21, 2025, has also been shown to be unaffordable and, as stated previously, relief from the deadline (and/or other performance criteria) is therefore required.

The SD1 Consent Decree, developed in partnership with state and federal regulatory agencies, represents a paradigm shift in wet weather control programs. The watershed approach is one of the U.S. Environmental Protection Agency's "Four Pillars" for sustaining water infrastructure (EPA, 2006). Under the watershed approach, priorities and solutions that provide the largest overall environmental impact are developed based on current information considering watershed-based, cost-effective alternatives as well as traditional gray-only infrastructure solutions. This process recognizes the need to consider environmental progress, make wise use of public resources, and direct funds towards the most significant problems first.

SD1's Watershed Plans are focused on prioritizing those projects that maximize the return on investment, protect public health, and improve water quality. This approach also allows SD1 to compare gray-only controls against integrated sets of gray, green, and watershed solutions and calculate the estimated cost savings and greater net environmental benefit of the integrated solutions. The watershed approach provides SD1 with the opportunity to learn from experience and allows the information gained on project effectiveness to be factored into the next round of decision-making and project selection. The overall effectiveness of this new approach will require additional work for post-construction monitoring and results confirmation, which is why the Consent Decree requires the development and submittal of updated Watershed Plans every five years. This iterative cycle provides all stakeholders with an opportunity to review performance and benefits and make appropriate adjustments to program goals moving forward. The 28 percent reduction in overflow volume associated with this first Watershed Plan is indicative of the fact that substantial progress is being made towards the ultimate goals of the Consent Decree.

As a pioneer in this approach, SD1 will need to work closely with the regulatory agencies and local stakeholders to coordinate and maintain considerable flexibility throughout the duration of the Consent Decree. For example, this could mean that, in certain situations, it is sensible to accept a lower level of overflow control than traditional programs, in exchange for greater improvement in water quality through investments in a combination of controls that address other dry weather and wet weather-related

sources. Likewise, directing resources toward other sources of pollution may provide a more substantial improvement in water quality. The planning of such projects will require assurances by SD1 that they can be implemented as well as the willingness of regulators to accept offsets or delays in typical overflow controls.

Given the adaptive nature of this approach and of the Integrated Plan for 2025, the total cost of the SD1 program and a comprehensive schedule, with which controls are implemented over the full duration of the Consent Decree, cannot be precisely defined at this time. However, through these five-year cycles, SD1 will measure progress and ensure that funds are directed into control programs that meet regulatory mandates, maximize improvements in water quality and public health, and meet the expectations of the public.

Section 1
Introduction

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SECTION 1. INTRODUCTION

On April 18, 2007, the Consent Decree among Sanitation District No. 1 (SD1), U.S. Environmental Protection Agency (EPA), and the Kentucky Energy and Environment Cabinet (Cabinet) became effective. The purpose of the Consent Decree is the reduction and control of discharges from combined sewer overflows (CSO) consistent with the CSO Control Policy, the elimination of sanitary sewer overflows (SSOs) and Unpermitted Discharges in the Sewer System, and the improvement of water quality in the receiving waters (Consent Decree, 2007).

The SD1 Consent Decree is unique in that it incorporates a watershed-based approach into traditional wet weather improvement programs. This Consent Decree was specifically crafted by the EPA, the Cabinet, and SD1 to allow for a program that evaluates water pollution control needs using a holistic, watershed-based approach. SD1 is required to develop, submit, and implement Watershed Plans (Plans), with subsequent five-year updates, to accomplish specific Consent Decree goals by no later than December 31, 2025. These Watershed Plans are to be developed for four basins (Central, East, North, and West) and address components of both a CSO Long-term Control Plan (LTCP) and Sanitary Sewer Overflow Plan (SSOP).

1.1 Plan Structure

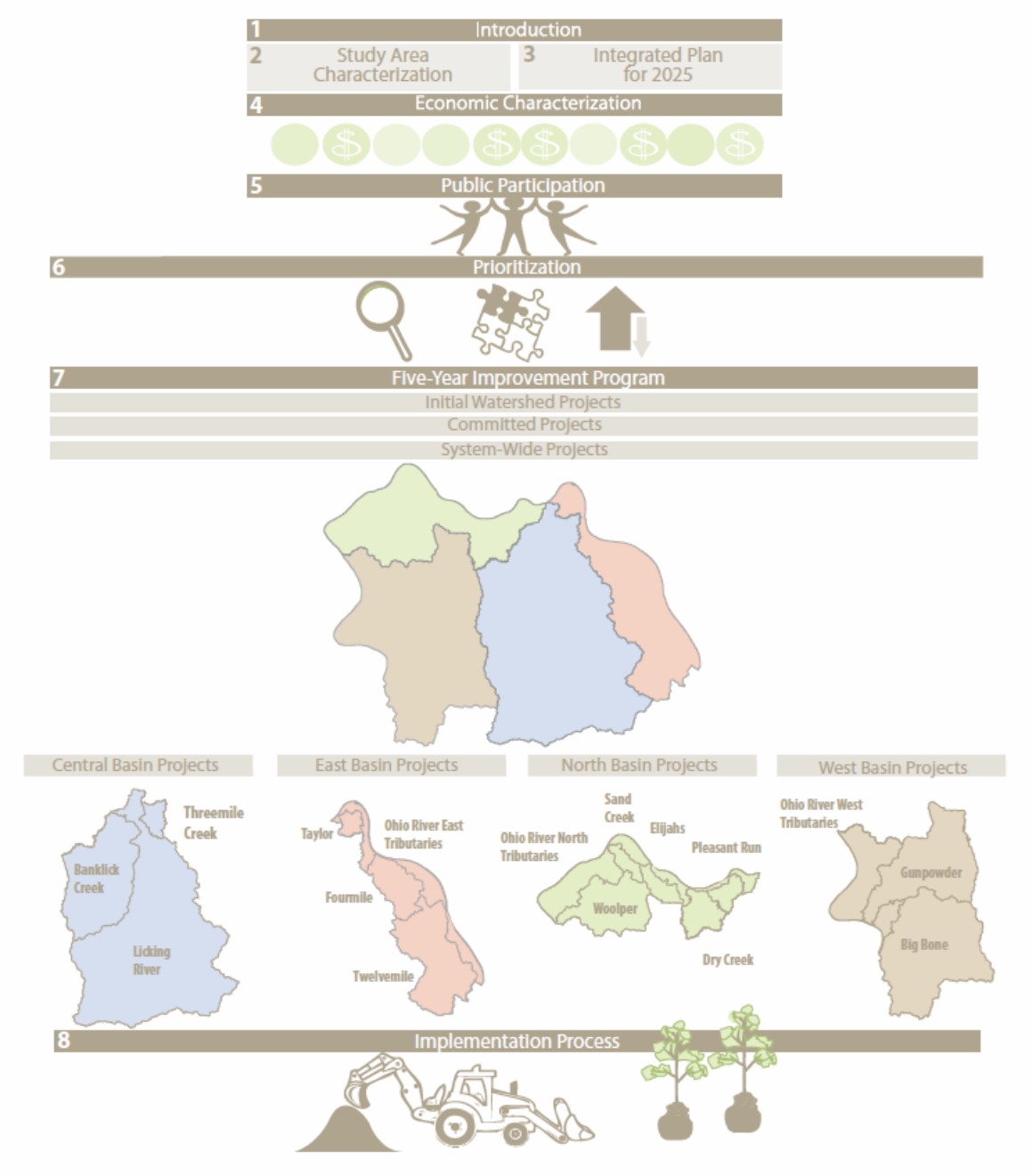
The Watershed Plans present solutions for two planning horizons: 2025 and the first five years (2009-2013). The Integrated Plan for 2025 addresses all overflows in SD1's system under 2030 build-out conditions. The Five-year Improvement Program describes the specific projects proposed for this first set of Watershed Plans for each of the four Consent Decree basins. SD1 is already implementing the first Five-year Improvement Program, which was originally submitted to the EPA and the Cabinet in June 2009.

The Watershed Plans (Figure 1.1) contain a discussion of SD1's extensive characterization efforts (Section 2); an Integrated Plan for 2025 (Section 3); an economic characterization of the financial impacts of the Integrated Plan (Section 4); the public participation process (Section 5); the prioritization process (Section 6); the Five-year Improvement Program (Section 7); and the planned implementation process (Section 8).

The study area characterization (Section 2) describes SD1's efforts to develop a better understanding of the conditions of Northern Kentucky's streams and the sources impacting them, for both current conditions and predicted future conditions. SD1's stream and watershed characterization exceeds the levels typically found in LTCPs, and was used to support better water quality-based decisions and develop a more cost-effective program for Northern Kentucky with greater overall benefits. SD1 is also one of the first communities to conduct a comprehensive, region-wide green infrastructure and large-scale watershed opportunities analysis to help elevate the role of green solutions in mitigating the impacts of sewer overflows.

Section 3, the Integrated Plan for 2025, was added for the updated (March 2011) version of the Watershed Plans[1]. This section describes the Consent Decree required solution set that address all overflows by 2025. SD1's approach to developing the Integrated Plan is different than traditional approaches, as it includes a comprehensive evaluation of gray, green, and watershed controls.

Figure 1.1 Watershed Plan Structure



[1] The previous Section 3 is now included in Appendix 3-A as the Full System Bounding Analysis. The Bounding Analysis was an integral first step to understand the relative benefits of different levels of control and different combinations of control types (i.e. gray-only vs. an integration of gray, green and/or watershed solutions)..

The economic characterization (Section 4) presents two different analyses that were conducted to estimate the financial impacts of the Watershed Plans on Northern Kentucky ratepayers. The first looks at the overall affordability of the Integrated Plan for 2025 according to EPA's financial capability guidance. The second examines the impacts of potential rate increases needed to fund the Five-year Improvement Program. The factors discussed in the economic characterization section include the ongoing and serious challenges to both the national economy and the economy of Northern Kentucky. The ultimate impact of these challenges is unknown, but the economic circumstances are the most difficult in decades. It is worth noting that these circumstances may have substantial impacts on SD1's ability to raise the necessary funds to fully implement the proposed program.

Section 5 (public participation) and Section 6 (prioritization) provide the background on SD1's decision making process, selection of projects within the Five-year Improvement Program, and prioritization of the overflows remaining after the Five-year Improvement Program.

The Five-year Improvement Program (Section 7) sets forth SD1's planned activities for this first five-year cycle. The program identifies the following categories of projects:

> **Initial Watershed Projects** are required by the Consent Decree and identified in Exhibit D.
>
> **Committed Projects** are focused on the rehabilitation and maintenance of assets SD1 currently owns. Investment in these assets is critical to fix failing pipes, maximize existing dry and wet weather capacity, prevent loss of service and basement backups, and minimize wet weather overflows. These projects include high priority sewer repairs and replacements, a number of Consent Decree required programs, improvements at pump stations and treatment facilities, and capital purchases.
>
> **System-wide Projects** are programmatic in nature and intended to improve system operation and performance.
>
> **Basin Projects** are the projects selected for the first set of Watershed Plans to address overflows in Priority Areas, including integrated solutions (a mix of gray, green and watershed controls) and demonstration projects.

Solutions for future plans will be developed using information gained from the implementation of projects during the first Five-year Improvement Program.

The implementation process (Section 8) details the anticipated benefits of the proposed projects and the associated schedules. It also provides SD1's approach for monitoring progress and for future watershed planning cycles.

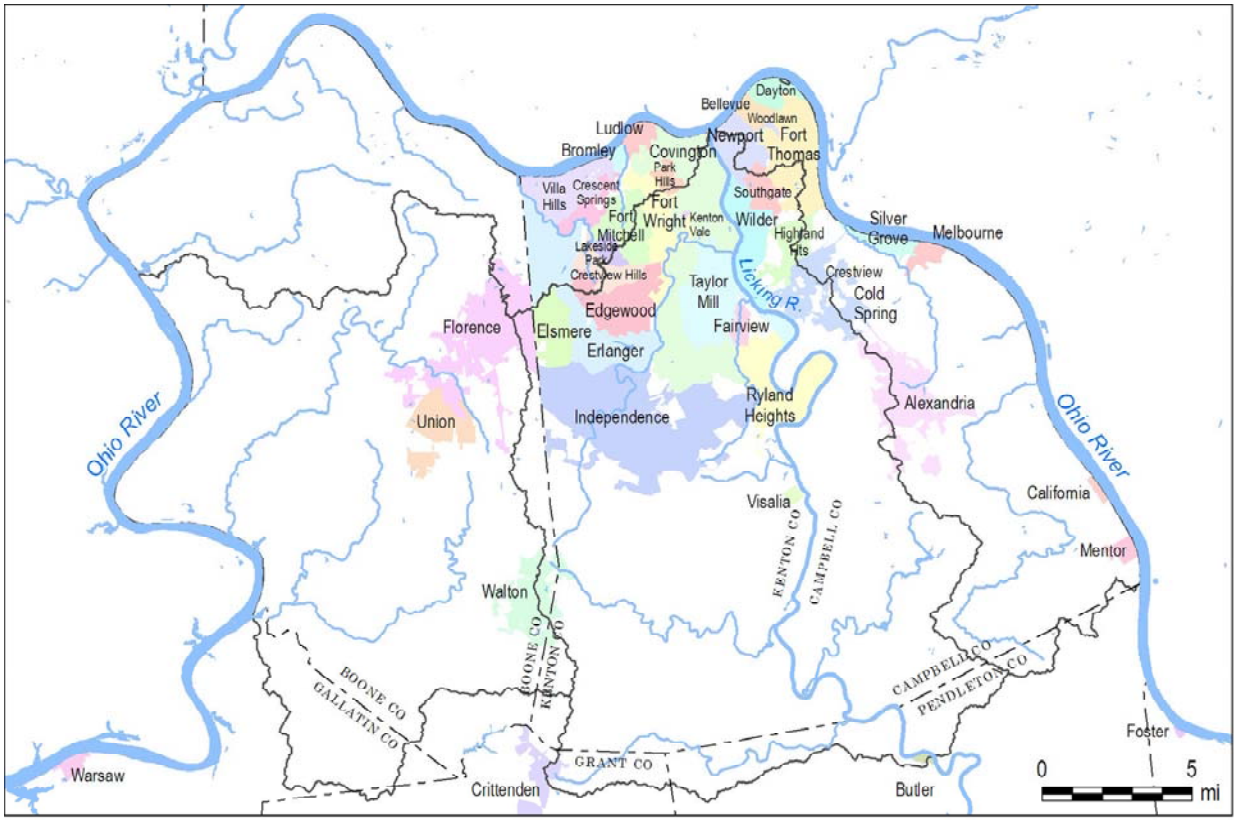
The required elements of the CSO LTCP and the SSOP are addressed throughout the Watershed Plans. Several appendices are provided to further demonstrate that SD1's approach fulfills the regulatory requirements in Paragraphs 39 and 40 of the Consent

Decree. Appendix 1-A contains the Consent Decree paragraphs relating to the development of the Watershed Plans. Appendix 1-B provides a summary of the Consent Decree requirements, how they are met, and maps them to their location within the Plans. Other appendices support the various other requirements of the Consent Decree or provide additional details on the analyses and information provided in the Watershed Plans.

1.2 Historical Background

SD1's sanitary sewer service area encompasses 176 square miles in Boone, Campbell, and Kenton Counties in Northern Kentucky. Prior to 1995, the numerous municipalities within SD1's service area owned, operated and maintained their own sanitary and storm water sewer systems (Figure 1.2). With more than 30 independent municipalities responsible for the infrastructure, the system suffered from lack of capacity, exhibited various states of disrepair, and lacked consistent standards. At that time, SD1 was only responsible for the wastewater treatment plants and the main interceptors conveying flow to those facilities. In 1994, a change in legislation allowed SD1 to assume ownership, operation and maintenance of the sanitary and combined sewers within the service area.

Figure 1.2 Northern Kentucky Municipalities



1.2.1 Infrastructure Consolidation

In 1995, SD1 consolidated the ownership, and operation and maintenance of the sewer infrastructure for 28 municipalities and portions of three counties. By 1999, two more cities, Independence and Alexandria, had consolidated their sewer system ownership and maintenance with SD1. The Cities of Florence and Walton are the only municipalities to retain ownership of their sanitary sewers, though Walton now contracts with SD1 for the operation and maintenance of their system.

The consolidation was a result of the local communities realizing that a single regional entity would be more effective in the management of the sewer infrastructure. Because this system is a highly-interconnected network of pipes, pump stations (PS), and treatment facilities, the previous structure of local control often hindered attempts to address sewer overflows and other problems. By transferring the infrastructure to a single, regional entity, many of the inter-jurisdictional issues between the cities could be addressed.

For SD1, assuming responsibility for Northern Kentucky's sewer systems significantly increased the amount of infrastructure it owned and maintained (Table 1.1).

Table 1.1 SD1 Infrastructure Asset Comparison

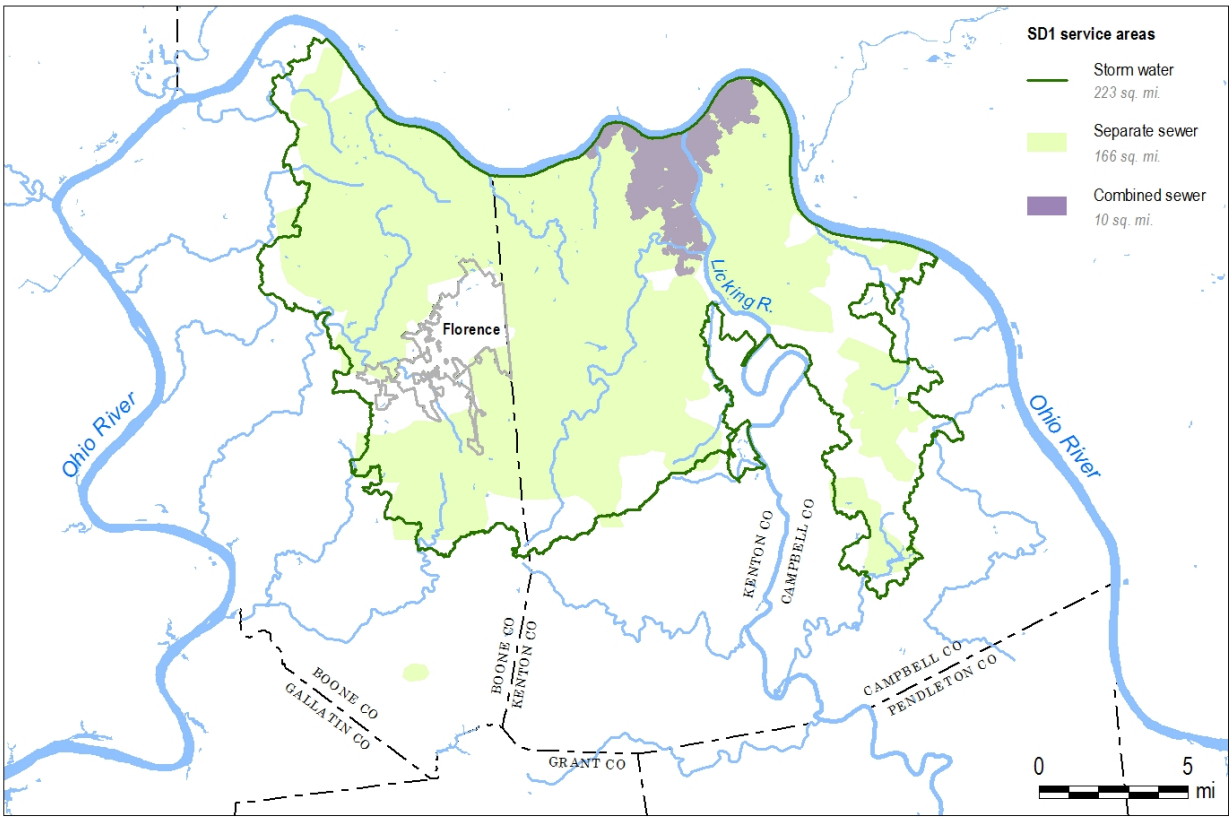
	Before 1995	As of June 2009
Miles of sewer lines	128	1,600[1]
Sanitary Pump Stations	16	129[2]
Catch Basins in Combined Sewer Areas	0	3,302
Flood Pump Stations	0	15
Sanitary Sewer Overflows	7	126[3]
Combined Sewer Overflows	0	97
Advanced Treatment Capacity (MGD)[4]	46.5	50.5

Notes:
1. Includes forcemains
2. An additional 13 sanitary pump stations operated by SD1 under contract are not included in the reported figure of 129.
3. Includes pump stations
4. MGD = Million Gallons per Day. Provided by the Dry Creek Wastewater Treatment Plant and the Eastern Regional Water Reclamation Facility

In 2003, SD1's responsibilities expanded further when it assumed responsibility for the regional storm water management programs associated with the municipal separate storm sewer system (EPA's Stormwater Phase II program). Again, local communities realized the value of having a single regional entity administering the new regulations, and petitioned SD1 to again expand its role in regional water resource management. As of June 2009, SD1 conducts permit compliance activities for 34 Northern Kentucky co-permittees, which include the three counties and Kentucky Transportation Cabinet (KYTC). The City of Florence conducts its own program and as of February 26th, 2009,

the Kentucky Division of Water (KDOW) removed the compliance obligation for the Cities of Fairview and Ryland Heights (Figure 1.3).

Figure 1.3 SD1 Service Area Overview (2009)



Since consolidation, SD1 has worked to improve the condition of the sewers and address both wet and dry weather capacity issues. As of June 2009, SD1 had invested more than $140 Million in addressing the needs of Northern Kentucky's sewer infrastructure. This included sewer cleaning programs to increase their capacity, preventive maintenance programs, pump station upgrades, and treatment plant upgrades. With these extensive upgrades and rehabilitation, SD1 has reduced basement backups, eliminated wet weather overflows and dry weather capacity issues, and recovered capacity at the treatment plants.

In 2007, SD1 completed construction of the 4 million gallons per day (MGD) Eastern Regional Water Reclamation Facility (WRF) which replaced the Alexandria Wastewater Treatment Plant (WWTP) in Campbell County. The new treatment facility addresses a long-standing lack of capacity in southern Campbell County that had resulted in a moratorium on new development for over a decade. In Boone County, SD1 is currently constructing the 20 MGD Western Regional WRF, which is scheduled to open in 2013.

While dramatically improving the system, these investments in Northern Kentucky's infrastructure have not eliminated the problems; wet weather issues, such as CSOs and SSOs, still remain.

1.2.2 Early Characterization Efforts

Shortly after the consolidation of the sewer infrastructure, SD1 initiated studies to increase its understanding of the sewer systems and their impacts to local waterways. The first study was conducted to understand the impacts of CSOs on Banklick Creek and the lower Licking River (LTI, 1998). SD1 then participated in the Ohio River Valley Water Sanitation Commission's (ORSANCO) wet weather demonstration program to evaluate CSO impacts on the Ohio River (ORSANCO, 2002). Both these studies determined that CSOs were contributing to exceedances of recreational use criteria, but were not impacting aquatic life.

In 2004, SD1 obtained a federal grant to assess the feasibility of a watershed approach for reducing impacts of pollutants on Banklick Creek. The study identified that sources such as runoff, failing septic tanks, straight pipe discharges, streambank erosion, and livestock were contributing to water quality problems (LTI, 2004). This study justified SD1's incorporation of watershed monitoring and modeling into its budget so that resources could be used to gather information and develop tools to better evaluate sources of pollutants.

In 2006, SD1 increased its data collection efforts to further characterize the sewer systems and the area's streams and rivers, to better understand the relationship between the two systems in preparation for the Watershed Plans. Watershed characterization included dry and wet weather-related stream monitoring and watershed model development and analysis. The results of this characterization effort are documented in sixteen individual Watershed Characterization Reports which are available at www.sd1.org. An overview of all sixteen watersheds can be found in Appendix 2-A, Watershed Characterization Summary Report.

Characterization of the infrastructure was also essential to better understand the CSOs and SSOs, and their potential impacts on public health and is a required element of a LTCP. Early efforts to characterize CSOs included development and refinement of a model of the major trunk sewers. In 2001, SD1 initiated development of a comprehensive infrastructure model framework for both the combined and separate sewer systems.

SD1 identified key overflow areas that needed further data collection, using an extensive flow monitoring network and field inspections. This information was used to update and refine the infrastructure model, making it a more effective and accurate tool in preparation for the development of the Watershed Plans (Section 2.1.2).

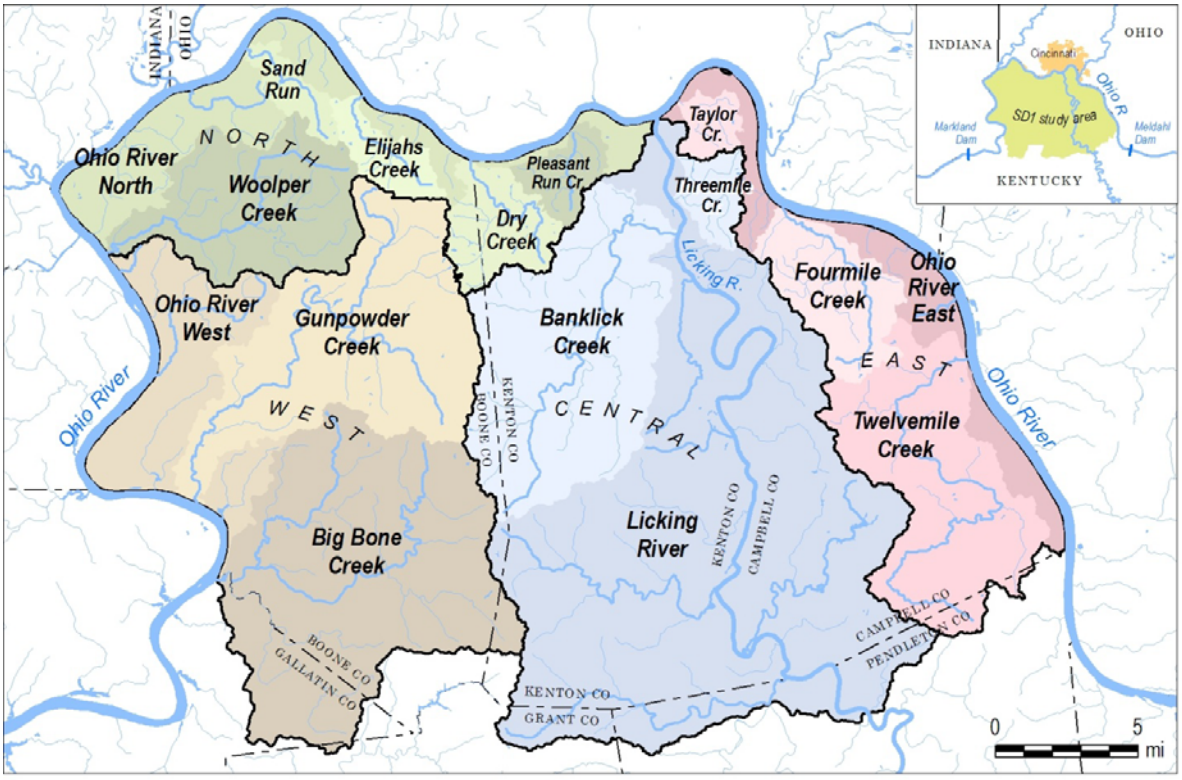
1.3 Study Area and Challenges

The Consent Decree describes four study basins (Central, East, North, and West) that span 580[2] square miles in three counties. SD1 divided this area (Figure 1.4) into

[2] Figure 1.4 shows the full extent of the watersheds, which includes 12 square miles that extends southward into Gallatin, Grant and Pendleton Counties.

sixteen watersheds to better correlate stream water quality with the potential pollution sources in the watersheds.

Figure 1.4 Study Basins and Watersheds



As of June 2009, SD1 has approximately 100,000 customer accounts (this includes City of Florence accounts) and provides sanitary sewer service for a 176[3] square mile area and storm sewer service for a 223 square mile area (Figure 1.3). There are approximately 219 miles of sewer in the combined area, which is 6.6% of the sanitary sewer service area. The combined area includes the river cities of Dayton, Bellevue, Newport, Covington, Ludlow and Bromley. Some of the combined sewers date back to the mid-1800s.

The separate sanitary sewer area includes 1,382 miles of sewers and 129 pump stations. The combined area also includes all 15 Flood Pumping Stations, as well as 5 sanitary wastewater pump stations that lift flow along the main interceptors.

As of June 2009, the storm water area includes over 500 miles of municipal separate storm sewers[4].

SD1's service area, which encompasses 30 municipalities and unincorporated portions of three counties, is part of the greater Cincinnati metropolitan area and has

[3] This includes SD1's separate (166 square mile) and combined (10 square mile) sewer systems. The Florence (12 square mile) and Walton (6 square mile) systems are not included, but make the total area in Northern Kentucky served by sewer systems approximately 194 square miles.
[4] SD1 is in the planning process for assuming responsibility for components of the region's storm water infrastructure.

experienced rapid growth and development since 1990 (Table 1.2). In Boone County alone, the estimated population doubled between 1990 and 2008.

Table 1.2 Northern Kentucky Population Growth

	1990	2008 Estimates	% Change
Boone	57,589	115,231	100.1%
Campbell	83,866	87,038	3.8%
Kenton	142,031	157,629	11.0%
Total	*283,486*	*359,898*	*27.0%*

Development is concentrated along the north-central portion of the study area and extends southward along the Licking River and various transportation corridors (Section 2.2). The land cover in outlying areas remains predominately agricultural or forested.

As part of the watershed planning process, SD1 developed land cover data that reflects the forecasted 2030 future conditions in the study area (Section 2.3). Development in Northern Kentucky will continue to increase in the future, resulting in additional impervious surfaces which contribute to increased runoff and stream impairments and place further stress on the aging sewer system.

1.3.1 Stream Conditions

The majority of the streams traverse rolling to hilly areas that are predominantly underlain by highly erodible limestone and shale. Flatter areas are found closer to the Licking and Ohio River valleys. The hilly topography and erodibility of the landscape has resulted in highly entrenched stream systems with steep gradients. Soils in the area are typically rated as having slow or very restricted infiltration rates, which restricts their ability to absorb storm water runoff or support septic systems.

Figure 1.5 shows some of the challenging stream conditions found in the study area, including stream channelization, streambank erosion and hydromodification, flooding and the elimination of riparian buffers. These conditions are found throughout the study area, but are more frequently found in developed areas where they not only impact water quality, but can also severely impact adjacent infrastructure, such as roads and sewers.

The combined effect of loss of riparian buffers and increased and sustained runoff flows, can severely impact the ability of the stream to support aquatic life or recreational uses. These conditions also exacerbate the amount and duration of downstream flooding, while also increasing channel erosion and pollutant loads.

Typical water quality impairments within the study area include elevated instream densities of bacteria, low dissolved oxygen concentrations, and some exceedances of the criteria for pH and metals. Recent habitat and biological (fish and macroinvertebrate) data and observations of excess algae growth and high turbidity, demonstrate that many streams are impaired due to problems other than sewer overflows.

Figure 1.5 Stream Conditions

Top: Stream erosion along Banklick Creek; Middle: Loss of riparian corridor and channelization along Covert Run; Bottom: Flooding along Banklick Creek at Pioneer Park.

1.3.2 Sewer Conditions

As described in Section 1.2.1, the sewer system, while significantly improved since SD1 assumed ownership in 1995, still faces ongoing problems. These problems are associated with aging sewer lines, manholes, and pump stations; CSOs – relics of a century old sewer system in the river cities; SSOs; and the pressure of ongoing growth and development. Figure 1.6 shows some of the challenges that complicate the continued remediation of these sewer infrastructure problems.

In some areas, aging sewer pipes have begun to fail or fill with debris and sediment. These conditions limit the capacity of the sewers, which contributes to CSOs and SSOs. The older portions of the sewer system are generally in urban, highly developed areas complicating repair and replacement.

Since sewer lines generally follow the topography of the terrain, along the lowest elevation in the watershed, they are susceptible to impacts from hydromodification of the stream channel. Northern Kentucky streams, like Banklick Creek, have been observed to move laterally up to 75 feet and over 5 feet vertically over the past 15 years. This migration threatens the stability of the sewer system and increases the amount of storm water entering the sewer system through inflow and infiltration (I/I), which worsens SSOs.

Many of the older separate sewers were built in areas with insufficient storm water conveyance. This means that in many neighborhoods, runoff from residential, commercial, and public properties is directed into the sanitary sewers. Because the sanitary sewers are not designed to accept runoff, SSOs in these areas can occur even with relatively small rainfall events. These problems will worsen with any additional impervious area or runoff from these areas.

Figure 1.6 Sewer Conditions in the Study Area

Top: Aging sewers show partial collapse and decreased capacity due to debris; Middle: Manhole with anchoring now located in Banklick Creek due to channel widening and migration; Bottom: Manhole submerged in Gunpowder Creek.

1.3.3 Characterization Challenges

SD1 conducted extensive characterization of both the sewer systems and watersheds (examples shown in Figure 1.7) in preparation for the Watershed Plans. Because of the large size of the study area, complexity of the sewer system and consolidation of infrastructure for more than 30 communities, the effort to compile the information to characterize the infrastructure and watersheds was significant.

Figure 1.7 Characterization Activities

Top: Closed-circuit television; Middle: SD1 staff with vactor; Bottom: Biological monitoring along Brush Creek.

The hydraulic model of the sewer system required extensive data collection (such as continuous field inspection, Closed Circuit Television or CCTV, sonar inspections, and smoke and dye testing) to assess areas with reduced capacity or excessive I/I. Extensive rainfall and flow monitoring was necessary due to the size of the service area and multiple urban cores. SD1 also had to realign the data collection and inspection programs to meet specific Consent Decree requirements, reporting needs, and tracking of system performance. SD1's computerized maintenance management system, GBA Master Series (gbaMS), required modifications to the data input and output processes to generate more precise reports and link the information to SD1's sewer system model.

Watershed characterization required an extensive effort to compile existing data and information from numerous agencies[4]. SD1 implemented monitoring programs for all sixteen watersheds, as well as outfall sampling to characterize pollutant concentrations in SSO, CSO, and storm sewer system discharges. Models were developed that required geospatial data for the entire study area, much of which did not previously exist and had to be generated (such as land cover and possible septic system locations).

[4]Data were collected from KDOW (including data from routine monitoring programs and many published reports), ORSANCO (data from eight routine sampling programs), counties, the National Weather Service, USACE, EPA STORET, KY State Nature Preserves Commission, Northern Kentucky Health Department, (NKHD), Northern Kentucky Area Planning Commission, KYTC, Natural Resources, Conservation Service, USGS, Licking River Watershed Watch, Northern Kentucky University, the Cincinnati Northern Kentucky Airport, National Climatic Data Center, KY Geographic Network, and many others.

These characterization efforts revealed several inconsistencies and issues to address. The sewer system model identified areas with excess wet weather flows, prompting Sewer System Evaluation Surveys (SSES) to identify the sources of I/I. Similarly, the water quality monitoring and modeling identified areas of unexpected bacteria levels during dry weather conditions, and has prompted the development of a Source Identification Program.

1.3.4 Water Quality Standards Challenges

In 1972, the Clean Water Act was amended to include the goal that all navigable United States waters be "fishable" and "swimmable" by 1983 and that all pollutant releases into these waters be eliminated by 1985. To achieve this goal, the Act required states to establish water quality standards that include designated uses for streams and criteria to protect those uses. All of the streams in Northern Kentucky are designated for warm water aquatic habitat, primary contact recreation (e.g. swimming), secondary contact recreation (e.g. wading), and domestic water supply (see Appendix 2-E). Although these standards recognize that aquatic life uses might not be attainable at all times (such as drought conditions), there is no distinction that recreational uses might not be attainable at all times (such as during storm events).

SD1's watershed characterization showed that water quality in Northern Kentucky streams is highly variable, and the potential pollution sources vary greatly between dry and wet weather conditions. For example, Figure 1.8 illustrates stream conditions along Banklick Creek during both conditions.

Figure 1.8 Stream Conditions during Dry and Wet Weather

Top: Banklick Creek during Dry Conditions shows stairs leading to trail along the creek; Bottom: Banklick Creek during Wet Weather from the base of stairs with trail covered.

Typical water quality problems include elevated bacteria (fecal coliform and/or *E. coli*) densities, low dissolved oxygen, and some violations of pH and metals. These problems are not always related to CSOs and SSOs, and current data suggests that eliminating overflows would not result in recreational uses being met in all waterways. Additionally, CSOs and SSOs are wet weather sources, and as Figure 1.8 shows, stream conditions during dry and wet weather can vary dramatically. This variation can become important when making decisions about public health and spending money to control pollution sources. For example, if bacteria densities are already exceeding water quality criteria during dry weather, when people are more likely to recreate in the stream, then spending money to eliminate CSO and SSO discharges during large rainfall events may not result in the desired public health benefit or any additional attainment of current water quality standards.

SD1's approach focuses on addressing CSOs and SSOs, as well as other sources of pollution. The evaluation of control alternatives will include an assessment of the attainability of water quality standards in Northern Kentucky streams, even assuming unrealistic and unattainable level of controls.

1.4 Goals

Consistent with EPA guidance, goals were established and refined early in SD1's watershed planning process. Metrics were established, such as the number of overflow events, volume of overflows, percent capture, reduction of instream bacteria densities, and percent bacteria load reduction to help evaluate controls and SD1's progress in attaining these goals.

SD1's goals for the Watershed Plans include achieving regulatory compliance (such as eliminating recurring SSOs, complying with the CSO Control Policy no later than December 31, 2025 and improving water quality), additional proposed goals (such as maximizing improvement to public health and promoting the use of green infrastructure when appropriate), and more watershed-specific goals (such as developing regional wetlands or retention basins). These goals are based on SD1's core mission to provide affordable, effective service to our rate payers and align with the community values provided through the public input process.

Basis for Identifying Goals

SD1's strategic plan outlines the organization's mission, which is to provide affordable, sustainable protection of water resources and to enhance economic opportunities by serving the three counties through regional collaboration, education of the public, and unparalleled customer service. SD1's vision is to be a nationally recognized steward of the environment, enhancing the quality of life in Northern Kentucky. SD1's mission and vision were also recently updated to reflect EPA's recommended attributes of effective utility management (Effective Utility Management Steering Committee, 2007). These attributes have been adopted as themes in SD1's strategic planning program and consequently help guide SD1's watershed approach.

SD1's public participation process began early and included a Watershed Summit, a community council, and numerous presentations to local stakeholders (Section 5). This, along with a community values survey, was used to understand and assess local environmental values, the importance of specific project criteria, and the willingness of the public to pay for the proposed program.

Integrated Plan for 2025 Goals

The Integrated Plan for 2025 (Section 3) provides the analysis required by the CSO Control Policy to consider a range of alternatives to make a reasonable assessment of cost and performance. The Integrated Plan identifies projects that would address all overflows in SD1's system under 2030 build-out conditions. To assess the effectiveness of the Integrated Plan, SD1 first developed a 2025 baseline model without any improvement projects to document the future water quality conditions. This "no control" scenario provides the basis of comparison to document the potential water quality improvement of the Integrated Plan for 2025.

Five-year Improvement Program Goals

The goal of the Five-year Improvement Program is to achieve the greatest water quality and public health improvement, through a cost-effective, integrated approach that considers both dry and wet weather-related sources of pollution. This approach utilizes SD1's extensive characterization to identify the most effective ways to maximize improvements to water quality, and unlike traditional approaches, considers pollution sources other than just CSOs and SSOs. By identifying green and watershed goals, SD1 hopes to realize more sustainable approaches that complement the gray infrastructure and provide additional aesthetic and environmental benefit. This first Five-year Improvement Program identifies the most promising gray, green and watershed controls, tracks improvements in water quality, and reevaluates priorities to maximize water quality improvement in updated Plans, consistent with a watershed-based approach.

1.5 Watershed Approach

In developing the Watershed Plans, SD1 made significant investments to determine the cause of the overflows, understand their impacts, and develop proposed solutions. While the discharge of sewage from CSOs and SSOs can pose a threat to human health and water quality of the creeks and rivers in Northern Kentucky, there are other pollutant sources (such as urban and agricultural runoff, residential and industrial point sources, private package wastewater treatment plants, animal feeding operations, failing septic systems, and straight pipe discharges) that are also contributing to water quality problems.

To address these sources holistically and more effectively improve water quality than traditional approaches, EPA advocates a watershed-based approach. The watershed approach uses "a series of cooperative, iterative steps to characterize existing conditions, identify and prioritize problems, define management objectives, develop

protection or remediation strategies, and implement and adapt selected actions as necessary" (EPA, 2008). SD1 sees the watershed-based approach as a preferred methodology, since it will:

- Recognize other pollutant sources and their relative impacts and puts CSOs and SSOs into context with those sources;
- Provide a process to address and control highest regional priorities first to offset controls on CSOs;
- Use an integrated approach of controls that will address both wet and dry weather sources of pollution and lead to a greater improvement in water quality and public health;
- Provide additional benefits to the community such as air quality, wildlife habitat, urban beautification, and economic development; and
- Direct funds to projects that provide the greatest benefits.

SD1's Watershed Plans contain a combination of gray, green, and watershed controls, as well as policies, regulations and partnering opportunities, all aimed at improving water quality and protecting public health in a fiscally responsible manner. These controls are defined as:

Gray Infrastructure: which are pipes, pumps, storage tanks and other 'hard infrastructure' that is traditionally used to store and treat sewage and runoff.

Green Infrastructure: includes "Systems and practices that use or mimic natural processes to infiltrate, evapotranspirate (the return of water to the atmosphere either through evaporation or by plants), or reuse storm water on the site where it is generated" (Grumbles, 2007). Examples of traditional green infrastructure include green roofs, rain gardens, vegetated swales, tree boxes, permeable pavements, rain water harvesting systems and other measures to prevent runoff from entering the sewer system. SD1's green infrastructure program focuses on the following:

- Strategic separation projects in the combined sewer system that route the separated storm water runoff through green infrastructure before the storm water is discharged to local waterways;
- Green street partnerships with local government entities to incorporate green infrastructure into new road construction and street reconstruction projects; and,
- Roof top disconnection of residential and commercial properties.

Watershed Controls: Include systems and practices that will reduce pollution from sources other than sewer overflows, such as runoff (point and nonpoint sources) before it is discharged to the local waterways. The emphasis on pollutant reduction differentiates these controls from green infrastructure, which is primarily focused on mitigating hydrologic impacts. SD1's watershed control program addresses instream water quality by focusing on:

- Regional controls such as retention basins and constructed wetlands that address subwatershed areas greater than one square mile; and,

- Decentralized controls such as storm water wetlands, bioretention/biofiltration basins, and enhanced retention basins that address storm water catchment areas greater than 5 acres, but less than one square mile.

Policies, Regulations and Partnering Opportunities: includes opportunities to supplement SD1's initiatives with:

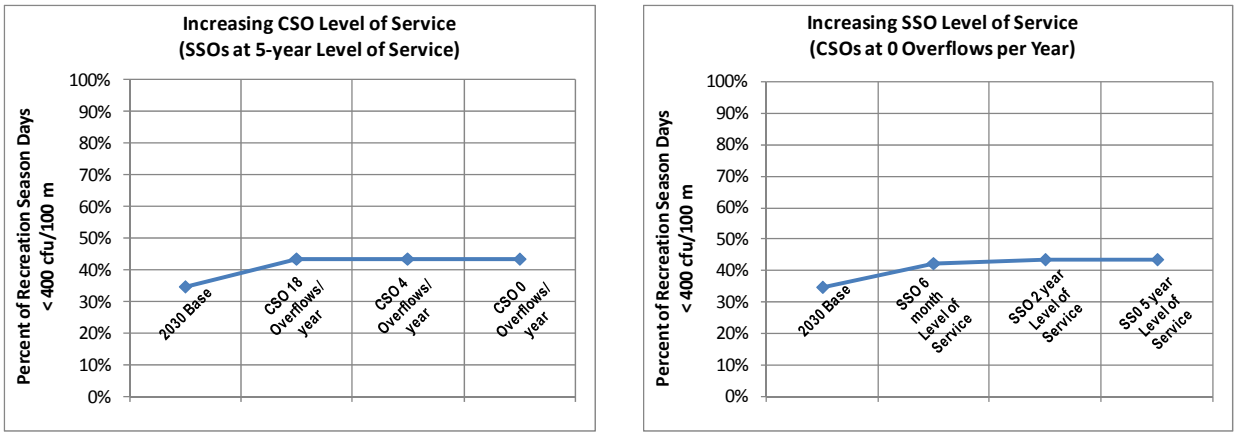
- Newly developed policies and regulations that mitigate storm water runoff;
- Public and private partnerships to implement green infrastructure practices; and,
- Partnerships with entities such as watershed groups to provide technical support for reforestation, riparian buffer and stream restoration initiatives.

A combination of these control options are used in the Full System Bounding Analysis to better understand the potential benefits of the Integrated Plan in comparison to that of a traditional gray-only approach (Appendix 3-A). This comparison demonstrates that greater water quality improvements can be achieved using the watershed-based approach than provided in a more costly traditional gray-only solution set.

1.5.1 Watershed Approach is Better than Traditional Approaches

Traditionally, most consent decrees focus solely on CSOs and SSOs, with an emphasis on gray infrastructure solutions. SD1's watershed-based approach identifies the characteristics of individual watersheds and considers CSOs and SSOs in conjunction with other sources impacting the streams and rivers (such as runoff and dry weather sources). Runoff alone has been ranked by EPA as one of the leading sources of water quality impairments to rivers and streams, behind only agriculture, hydrologic modifications, and habitat modifications (EPA, 2002). At the same time, some areas of Northern Kentucky, such as Banklick Creek, have such elevated dry weather bacteria densities, that the slightest input from wet weather sources causes exceedances of the bacteria criteria. Increasing the controls on overflows in these types of areas will do little to increase attainment of water quality standards (Figure 1.9), whereas an investigation and identification of dry weather sources or regional runoff controls (such as large-scale retention basins or wetlands) could yield significant results.

Figure 1.9 Banklick Creek Bacteria Findings



Note: Results summarized at the mouth of Banklick Creek (downstream of all SD1 CSOs and SSOs)

Table 1.3 emphasizes why consideration of sources other than CSOs and SSOs is important in improving water quality. It illustrates that CSOs and SSOs are only a small portion of the overall issue when it comes to addressing wet weather water quality. Runoff, which can carry pollution from urban, rural, and suburban areas, can contribute to a comparable, if not greater, impairment of water quality. In more traditional consent decrees, utilities can spend billions on wet weather programs that only address a portion of the problem.

Table 1.3 CSO, SSO, and Runoff Volume Comparison

	Million Gallons (MG) Annually
Combined Sewer Overflows (CSOs)	1,873
Sanitary Sewer Overflows (SSOs)	242
Runoff	70,000

SD1's watershed approach identifies the relative sources impairing water quality and proposes controls, which will be much more effective in lowering bacteria levels and achieving more days of compliance than the traditional approach. By utilizing a watershed-based approach and putting CSOs and SSOs into context, SD1's program will identify the most affordable controls for addressing both dry and wet weather-related sources of pollution, leading to greater improvement in water quality and public health for the money spent.

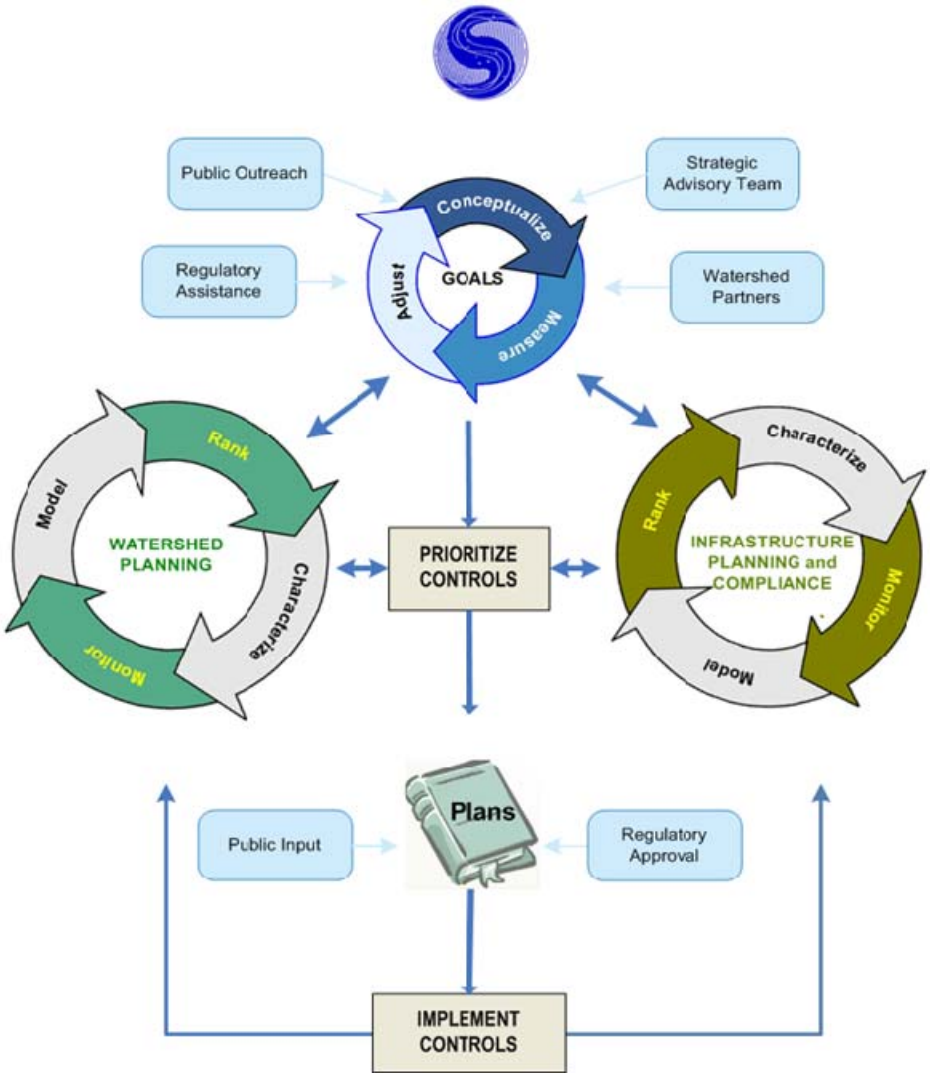
1.5.2 SD1 Watershed Approach

SD1's watershed-based approach is based on EPA's guidance for developing watershed plans (EPA, 2008) and the requirements contained in the Consent Decree. Figure 1.10 provides an overview of SD1's watershed approach, which coordinated goal-setting, watershed planning, and infrastructure planning into the development of the Watershed Plans.

SD1's Consent Decree is the country's first enforcement action that allows a community to use the watershed-based approach to more efficiently and cost-effectively meet federal Clean Water Act requirements for controlling CSOs and SSOs. This approach is based on the fact that sewer overflows are not the sole source of impairment for Northern Kentucky's streams and rivers. Traditionally, most consent decrees focus solely on CSOs and SSOs, with an emphasis on gray infrastructure solutions. SD1's watershed approach identifies the characteristics of individual watersheds and considers CSOs and SSOs along with other sources impacting the waterways (such as runoff and dry weather sources). The iterative structure allows time to investigate new technologies and make adjustments in five-year increments using information gained from the implementation of projects during the first five years.

SD1 has studied what other utilities across the country have implemented and spent to comply with their CSO and SSO consent decrees, which have often not achieved significant improvements in the attainment of water quality standards. These utilities have, at times, been forced to continue to spend money beyond a cost-effective level of control that did not result in additional water quality improvement because the other sources of pollution were left unaddressed. This type of silo approach to water quality improvement is neither efficient nor cost-effective, particularly in today's challenging economic climate.

Figure 1.10 SD1 Watershed-based Approach



Many sewer overflow programs have been developed that relied exclusively on gray infrastructure such as storage tanks, conveyance pipes, and high-rate treatment facilities. While gray infrastructure has its place in any sewer improvement program, there are situations where alternative strategies are the more cost-effective and beneficial solution. SD1 believes that an integrated watershed-based approach is more effective in reducing pollutant levels, and is consistent with the CSO Control Policy and the Consent Decree goal of eliminating SSOs.

SD1 will be responsible for managing most of the capital funding to be used towards water quality improvements in Northern Kentucky for the foreseeable future. Past experience has shown that wastewater and storm water systems can be managed more efficiently when a single organization has the ability to consider the overall system. A watershed-based approach is a logical extension of the sanitary and storm sewer system consolidation. While SD1 does not have authority to regulate all pollutant sources in Northern Kentucky, their role as a regional utility does provide the best

opportunity for the development of plans that can focus resources towards the most critical areas of need. Through the development of the Watershed Plans, SD1 will seek mechanisms to implement controls that extend beyond current authorities.

SD1 used extensive data and public input to focus this first Five-year Improvement Program on the most cost-effective controls. As discussed in Section 1.2.2, early characterization identified that sewer overflows are a contributor to elevated levels of bacteria in the streams. The first Five-year Improvement Program, therefore, focuses on bacteria as a primary pollutant of concern, recognizing that secondary pollutants will also be addressed. Once these controls are implemented, their performance will be assessed, lessons will be learned, and the planning cycle will begin again for further reduction of bacteria (and increasingly other pollutants) in the subsequent five-year programs.

Alternative Controls

One of the more unique elements of SD1's Watershed Plans is the emphasis on green infrastructure to help reduce overflow volumes and the analysis of large-scale regional watershed controls to reduce pollutants in other Priority Areas.

In 2007, EPA released a memorandum stating that "Green infrastructure can be both a cost effective and environmentally preferable approach to reduce storm water and other excess flows entering combined or separate sewer systems in combination with, or in lieu of, centralized hard infrastructure solutions" (EPA, 2007). Consistent with this, SD1 identified green infrastructure controls as a promising alternative technology, and focused the analysis on the combined sewer areas (Appendix 3-B). This analysis included a comprehensive assessment of regional green opportunities as well as site specific opportunities, where reduction in runoff directly reduces the CSO overflow volume.

SD1 also conducted detailed assessments of regional and decentralized watershed controls (Appendix 3-C). These assessments included an analysis of the bacteria reduction benefits resulting from large-scale regional projects (such as basins, wetlands, and riparian buffers), to smaller scale decentralized projects and stream restoration, and provided a basis of comparison for traditional gray-only projects.

Green and watershed controls also provide the community with supplemental benefits such as improved air quality, enhanced wildlife habitat, urban beautification, and/or economic development opportunities. The inclusion of these benefits in a comprehensive, capital-intensive, water quality improvement program represents a new approach for public utilities and reflects a growing expectation among the public that these techniques for water quality management should be included in the planning process.

Overall, the watershed-based approach provides the opportunity to maximize the role of green and watershed controls, provides a potentially more cost-effective approach to

water quality improvement, and provides ancillary benefits unavailable through gray-only approaches.

1.6 Public Participation

SD1's watershed planning process began long before entry into the Consent Decree to collect the data and establish the tools necessary to develop the unique watershed-based approach. One element key to the success of the Watershed Plans is the involvement and acceptance of the Plans from the local community. Their involvement helps ensure, at a minimum, that the public feels that funding is well spent and should continue throughout the 20-year timeframe. SD1's public outreach program (Section 5) has worked to educate stakeholders on the issues facing Northern Kentucky, ensure that the Watershed Plans reflect the goals and concerns of the community, obtain input and feedback on key milestones and establish ongoing communication.

The public input and outreach activities, which have helped to guide the development of the first set of Watershed Plans, will continue throughout the implementation of this, and future Watershed Plans. SD1 is committed to keeping stakeholders and area residents informed of upcoming projects and successes achieved as the five-year program is implemented. Additionally, SD1 will look to involve the public and other stakeholders as active participants in the watershed-based approach, through community partnerships and decentralized approaches like green infrastructure.

1.7 Early Compliance Activities

The Consent Decree's overall objectives include compliance with the CSO Control Policy (EPA, 1994), and elimination of SSOs, which encompass numerous specific programmatic requirements related to overflow control or reduction. SD1 has met all the early requirements contained in the Consent Decree according to schedule, and all the following documents have been submitted, reviewed, and approved by the EPA and the Cabinet:

> **Capacity, Management, Operation, and Maintenance (CMOM) Program** that outlines SD1's efforts to manage the sewer systems' assets and operations to help reduce the number, frequency, and volume of SSOs and CSOs (SD1, 2007c, 2008b, and 2008m). One major component is the Continuous Sewer Assessment Program, which is anticipated to inspect the equivalent length of the entire SD1 sewer system in the first five years of program implementation (2008-2013), clean sewers based on need, and rehabilitate or repair sewers in a systematic manner based on watershed priorities. SD1 has also developed and submitted a Sewer Overflow Response Plan (SD1, 2008d) and a phased Grease Control Program (SD1, 2007a). The Pump Station Operation Plan for Backup Power is another CMOM requirement that evaluated SD1's pump stations and included schedules for providing backup power or other appropriate measures for addressing power outages at the stations by December 31, 2015 (SD1, 2007b).

Pump Station Overflow Elimination Plan that identified watershed projects to eliminate overflows and included expeditious schedules for implementing remedial measures for SSOs at the pump stations listed in Exhibit E of the Consent Decree (SD1, 2008c).

Initial Watershed Projects includes 52 ongoing projects that are at various levels of completion, with status updates provided in quarterly reports (SD1, 2008a, 2008f, 2008h, 2008j, 2008k, 2009a, 2009b (as of June 2009)). Projects include the Eastern Regional WRF, Eastern Regional Conveyance System, Western Regional WRF, and the Western Regional Conveyance System. Cumulatively, it is projected that SD1's Initial Watershed Projects will total more than $415 Million in capital spending.

Framework for Developing Watershed Plans that described how SD1 would meet the Long-term Control Plan, Sanitary Sewer Overflow Plan, and identify and incorporate controls on other pollution sources in the Watershed Plans (SD1, 2008g).

Nine Minimum Controls Documentation of Compliance Report describes the status of SD1's compliance with the Nine Minimum Controls (NMC) as set forth in the CSO Control Policy, as well as proposed projects for ensuring compliance is achieved no later than April 18, 2009 (SD1, 2008e).

In addition to the elements presented above, the Consent Decree requires other key elements of the CSO Control Policy to be addressed, and other evaluations which are necessary to comply with SSO control.

1.7.1 Compliance with the CSO Control Policy

SD1's significant progress on the Consent Decree requirements has resulted in compliance with key regulatory benchmarks identified in the CSO Control Policy (EPA, 1994). These objectives stipulate that communities ensure CSOs occur only as a result of wet weather (while accounting for the flood protection system) and implement technology-based CSO controls to minimize the impacts of CSOs. Communities must also develop and implement water quality-based CSO controls through development of a long-term control plan using either the demonstration or presumption approach (EPA, 1995b). These were all considerations and defined components of SD1's Consent Decree.

Technology-based CSO Controls: These are "technology-based actions or measures designed to reduce CSOs and their effects" that "do not require significant engineering studies or major construction, and can be implemented in a relatively short period" (EPA, 1995a). SD1 complied with the technology-based control requirement through its NMC program. The Nine Minimum Controls Compliance Report was submitted on March 12, 2008 and approved by the EPA and the Cabinet on July 6, 2008 (SD1, 2008e). This report documented SD1's

implementation of these controls. SD1 will also continue to evaluate the performance of the NMC program to enhance these controls when appropriate.

CSOs Occur Only as a Result of Wet Weather: This is another requirement of the CSO Control Policy which is addressed through SD1's NMC program. The NMC program includes several strategies to identify, address, and prevent dry weather CSOs. This includes the Continuous Sewer Assessment Program which focuses on high Priority Areas; identification of areas where the existing configuration or structural condition indicated a potential for dry weather overflows; and assessment of pump station power outages. To further eliminate the risk of dry weather overflows, SD1 has also taken remedial measures including catch basin modification to reduce the introduction of solids, modification of diversion structures, targeted cleaning, and more frequent inspections.

Wet Weather Discharges Consider Flood Protection System: The Consent Decree also requires that SD1 "include addressing those discharges resulting from SD1's compliance with the requirements of the United States Army Corps of Engineers' (USACE) Ohio River Flood Protection System Pumping Operations Manual" to meet the goal of no dry weather CSOs. SD1 has conducted a detailed River Water Intrusion Mitigation Feasibility analysis as described in (Section 7.3.1). This analysis was conducted to understand the effects of USACE's Flood Protection System on the combined sewer system and to identify alternatives to mitigate river water intrusion into elements of the sewer system that are located below the normal and elevated river levels.

Water Quality-Based Requirements: These are utilized by the CSO Control Policy in conjunction with the technology-based controls, to mitigate the impacts of CSOs. The water quality based requirements are founded on a longer-term plan for ensuring remaining CSOs do not cause instream excursions of water quality standards either by demonstrating compliance with standards or by presuming compliance through a specified level of treatment. The water quality-based requirement aligns with SD1's watershed-based approach outlined in the Consent Decree. Ultimately, the water quality-based CSO controls will be addressed through the implementation of the improvement programs included in the Watershed Plans.

1.7.2 Compliance with Requirements to Control SSOs

The Consent Decree requires that SD1 eliminate SSOs by December 31, 2025. This requirement means that SD1 must establish a metric to measure when an SSO is considered eliminated. Typically, states and federal EPA establish policies that require or recommend that the sewer systems be designed to transport wastewater to the treatment plants for storm events up to a specific size. This approach establishes a "design storm" that is used to evaluate the controls needed to achieve a desired level of service for the sewer system (such as 6-month, 2-year, 5-year storms). SD1 developed a continuous model of the separate sewer system that incorporates antecedent

groundwater conditions. This model was calibrated to flows measured during a year-long monitoring program. The model was applied to run long-term continuous simulations for the typical year and to develop appropriate antecedent conditions for design storms. Discussion of SSO activation frequency and magnitude in this document is based on the typical year simulation. In establishing cost-effective improvements to improve the level of control for SSOs, infrastructure was sized based on a two-year design storm event under a conservative saturated condition, confirmed with the typical year. As presented in Section 2.1.2, the typical year rainfall record included at least one storm event with a recurrence interval of two years or longer.

By using the design storm approach for a range of levels of service, SD1 was able to calculate the costs for various levels of service throughout the region for the first set of Plans. The results of this analysis were used to inform the selection of the SSO level of service included in the Integrated Plan for 2025. SD1's efforts focused on estimating the costs associated with providing a system-wide level of service and identifying the cost-effective controls that should be implemented first to reduce priority SSOs. The effectiveness of these controls, such as reduction of rainfall derived inflow/infiltration (RDII), need to be evaluated so that the preferred level of service and the associated costs can be determined and refined for future watershed planning cycles.

1.8 Consistency with Watershed Framework

The Framework for Developing Watershed Plans for Northern Kentucky (Watershed Framework) described SD1's rationale and approach for structuring and developing the Watershed Plans. The Framework was submitted on April 17, 2008 and approved by the EPA and the Cabinet on July 24, 2008 (SD1, 2008g). The Framework set forth an anticipated process for producing the Watershed Plans, and the actual implementation of the process closely followed what was outlined in the Framework:

- Four basin plans were developed with detailed projects identified for the first five-year period;
- An Integrated Plan for 2025 was developed to provide context for the Five-year Improvement Program and to establish controls that would meet the requirements of the Consent Decree;
- The Watershed Plans were based on extensive characterization of the sixteen watersheds and a detailed understanding of the sewer infrastructure;
- The public was educated and provided input on priorities and concerns;
- Goals were developed to provide the foundation for the prioritization and identification of Priority Area locations for possible controls; and
- The Plans fulfill the necessary elements of the LTCP and SSOP in an innovative way that identifies the characteristics of individual watersheds and considers CSOs and SSOs along with other sources impacting the waterways (such as runoff and dry weather sources).

As with any planning process, minor adaptations were necessary to adjust to the realities of implementation of the process. The following list addresses the minor

'course-corrections' SD1 had to make to account for lessons learned during the watershed planning process.

Public Comment Period: The original proposed date for public review of the draft Plans was April 19, 2009. This was modified to May 7, 2009 as SD1 worked through a number of unanticipated issues associated with analyzing alternatives and financial considerations.

System-wide Solution vs. Full System Bounding Analysis vs. Integrated Plan for 2025: The Framework originally described a system-wide solution to provide the foundation for the Five-year Improvement Program. SD1 conducted multiple system-wide analyses as part of the planning process.

The first was a Full System Bounding Analysis which was a set of solution concepts (gray and integrated gray/green/watershed) for the 2025 planning horizon (Appendix 3-A). The purpose of the analysis was to assess the relative benefits of different levels of control and different control types. This was submitted as part of the original Watershed Plans and provided a set of gray infrastructure solution concepts and integrated solution concepts and did not commit to a particular CSO level of control or SSO level of service due to affordability and only achieving limited improvements to water quality.

Subsequently, SD1 developed and is resubmitting a system-wide solution called the Integrated Plan for 2025 (Section 3). This provides analysis of the preferred solution set for addressing all overflows by 2025 using gray, green, and watershed controls, as mandated by the Consent Decree.

A financial analysis was conducted for the Full System Bounding Analysis in the June 2009 Watershed Plan. The March 2011 Watershed Plan updates the original submittal by incorporating the financial analysis for the Integrated Plan for 2025 (Section 4). As required by USEPA guidance, the financial analyses included the full cost of SD1's program, made up of the costs for CSO,SSO, and watershed control as well as the costs for the committed obligations of asset management for infrastructure and Initial Watershed Projects, and the anticipated obligations of facility planning projects, structural rehabilitation, and anticipated future effluent limits for nutrients (i.e., nitrogen and phosphorus) at the treatment plants. These full program costs are estimated to be $2.4 Billion (in 2009 dollars) through 2025 and would equate to an annual cost per household of $1,660 or a Residential Indicator of 3.0% of median household income on a service-area wide basis. This is well beyond EPA affordability standards. Based on these findings, SD1 placed more emphasis on evaluating the impact, performance, applicability, and benefit of green, watershed and integrated solutions in the first five years, while implementing a control set that will be an essential component of the remedy for the full Integrated Plan for 2025.

Accordingly, the Integrated Plan was found herein to be the most cost-effective and environmentally sound plan for eliminating SSO and controlling CSOs to

meet water quality based requirements by 2025, but it cannot be completed by 2025 due to its costs. As set forth in Section 3, the parties will need to determine the best approach for addressing the affordability constraint through deadline extensions or other CSO policy options.

Report Structure: The Framework described three sections (Regional, Basin, and Watershed) which would be stand-alone and geared toward the needs of different stakeholders. The realities of the stand-alone sections were found to be challenging and repetitive, so the structure was modified into a single, comprehensive document. As a result, the original regional section was split into study area characterization (Section 2), Integrated Plan for 2025 (Section 3), economic characterization (Section 4), public participation (Section 5), and prioritization (Section 6). The four basin sections now comprise the Five-year Improvement Program (Section 7). The watershed sections identified in the Framework are now incorporated into Section 2 and Section 7.

Evaluating Combinations of Controls: The Framework proposed a detailed schematic of the process for identifying, prioritizing and selecting controls. In actuality, once the preferred solution for addressing all overflows by 2025 (Integrated Plan for 2025) was developed and evaluated, the constraints from the economic affordability and subsequent public input resulted in a prioritization process based on: 1) Completion of Initial Watershed Projects; 2) Address known, significant public health concerns; and 3) Ability to assess the performance of green and watershed controls. These constraints supplanted the need for comparison of each watershed solutions set in this first set of Watershed Plans, as originally proposed in the Framework. Although SD1 modified the approach for this first set of Plans, the rationale behind the approach remains the same, and may be engaged in updated Watershed Plans as needed.

Water Quality Standards Change/Variance: The Framework recognized the option for SD1 to pursue a change in designated use consistent with the LTCP guidance or exceptions to water quality criteria provided under Kentucky Administrative Regulations (401 KAR 10:031). In this submittal, SD1 is not requesting any changes to designated uses or exceptions to water quality criteria. Even though the Full System Bounding Analysis (Appendix 3-A) shows that these standards are probably both unaffordable and unattainable, SD1 understands the options for addressing the affordability of completing the Integrated Plan by 2025 will be addressed through other mechanisms while SD1 implements the first Five-year Improvement Program.

These changes represent minor modifications to the Framework's proposed process, and the watershed-based approach presented in the Framework remains largely unchanged and appropriate for the development of the first set of Watershed Plans.

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Section 2
Study Area Characterization

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SECTION 2. STUDY AREA CHARACTERIZATION

Characterization of the watersheds and infrastructure is required by the Consent Decree and was necessary to provide the information and tools for decision-making for both the five-year and 2025 planning horizons. SD1's objectives for characterization were:

- establish current conditions for measuring progress towards achieving watershed goals;
- understand the relative impacts that sewer overflows and other pollutant sources have on water quality and public health; and
- understand the water quality and public health benefits that can be achieved under current and future planning horizons.

This section describes SD1's efforts to monitor, inspect, and model the sewer system and the watersheds in order to understand current conditions, and identify problems and sources. SD1 has gone beyond characterization that is typically performed for CSO and SSO control plans, and has characterized the entire study area in order to develop more cost-effective and higher benefit solutions for the ratepayers of Northern Kentucky as compared to overflow control only. The resulting data and their application in calibrated infrastructure, watershed, and water quality models have enabled SD1 to understand current conditions and watershed-specific stressors. This understanding also enables SD1 to anticipate water quality improvement benefits resulting from different control scenarios.

As a result of substantial characterization activities (some preceding the Consent Decree, as described in Section 1.2.2), SD1 now serves as a clearinghouse of data and tools for Northern Kentucky watersheds. These data, which include instream monitoring and outfall sampling data, as well as infrastructure and water quality models, have been compiled in a single location, and provide easy access to the best available information for watershed characterization and development of the Watershed Plans.

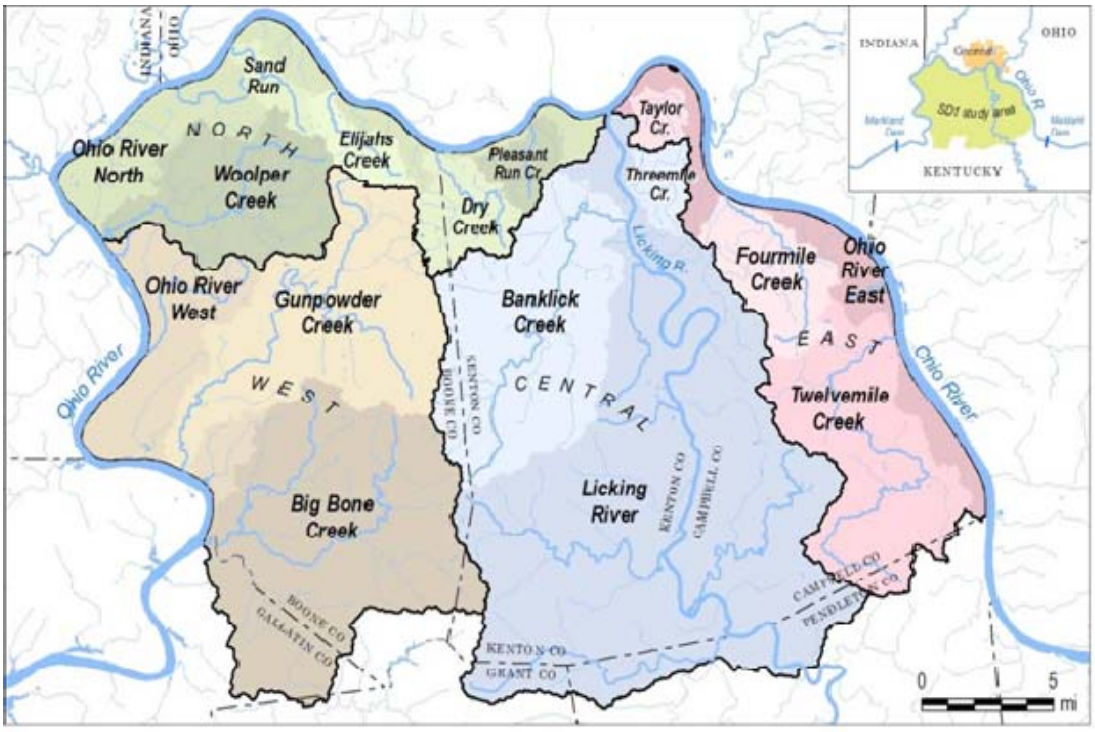
2.1 Characterization Activities

SD1 has undertaken a substantial multi-year effort to obtain and verify existing data, collect and generate additional information, and compile data that describe the study area watersheds and infrastructure. This effort includes instream monitoring, water quality modeling, outfall sampling, flow monitoring, sewer system modeling, and green infrastructure characterization. The details related to these characterization activities are presented in this section.

2.1.1 Watershed Characterization

Watershed characterization was completed for the entire study area. This information was compiled at the basin scale defined in the Consent Decree and at a watershed scale to relate instream conditions to watershed characteristics. Figure 2.1 shows the location of the sixteen watersheds and the four study basins that were the focus of these activities.

Figure 2.1 Study Basins and Watersheds



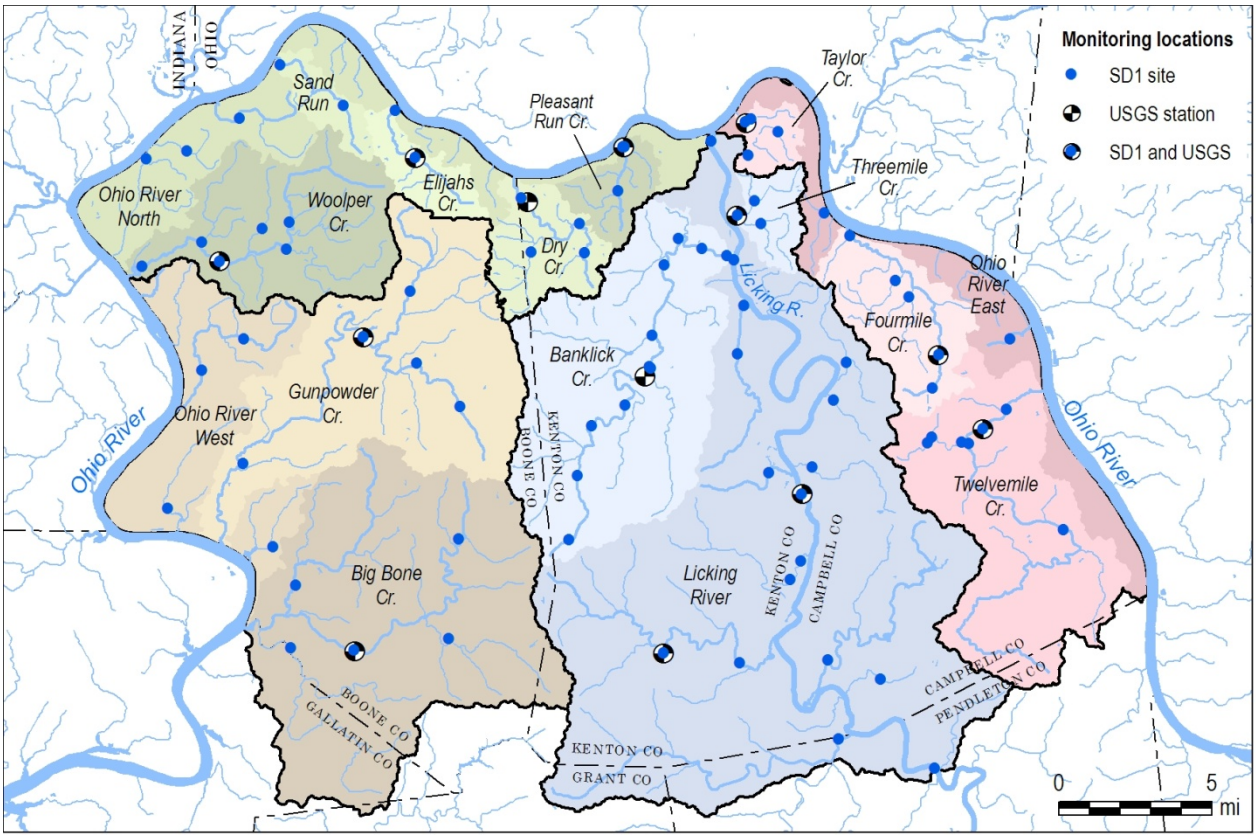
A comprehensive set of data are available for Northern Kentucky in SD1's geographic information system (GIS) or MicroSoft Access databases. These data have been obtained or generated, checked for accuracy, and standardized. The data include information describing streams, watersheds, monitoring locations, soils, topography, precipitation, hydrology, current and predicted future land cover, impervious cover, sanitary and storm water infrastructure, permitted dischargers (residences and industries), private package wastewater treatment plants, septic and livestock locations, and ongoing and planned improvement projects. Water quality, aquatic habitat, biological, flow, climate, and source concentration data have been obtained, reviewed and compiled in a database, which SD1 updates annually with new information. SD1 databases contain data collected from the 1980's through present time from all identified Northern Kentucky sampling programs, including SD1, ORSANCO, KDOW, Licking River Watershed Watch, Northern Kentucky University (NKU), and United States Geological Survey (USGS). Currently, the databases contain millions of discrete and continuous data points. Stream names and monitoring location identifiers have been standardized for all historical and newly collected data to facilitate analysis.

These data have been used to describe land cover, physical and infrastructure features, current conditions, and sensitive areas within each of the sixteen watersheds. Additional data obtained from published reports, site visits and interviews supported characterization of current uses, public interest and watershed group activities. Sources have been identified and quantified through model application. The results of this characterization effort are documented in sixteen individual Watershed Characterization Reports which are available at www.sd1.org. An overview of all sixteen watersheds can be found in Appendix 2-A, Watershed Characterization Summary Report.

Monitoring

SD1 initiated a comprehensive monitoring program in 2006 to collect instream water quality, aquatic habitat, fish, and macroinvertebrate data to establish current conditions and datasets for model development. This program, summarized in Table 2.1, is being implemented in a phased approach. In addition to these locations, SD1 also funds thirteen continuous monitoring stations in cooperation with the USGS to collect 15-minute stage, flow and water quality measurements. Monitoring locations are shown in Figure 2.2 and additional detail on the monitoring program is provided below.

Figure 2.2 Stream Monitoring Locations



In 2006, base flow monitoring was initiated in all sixteen watersheds; approximately 75 locations were monitored per year through 2010. Base flow monitoring is defined as occurring during dry weather periods when there is little to no runoff. In addition, event-based monitoring (where teams monitor a location multiple times during a rainfall event) was conducted within primary watersheds[1] on a scheduled basis through 2010. Event-based monitoring is defined as occurring during and immediately following rainfall events that produce runoff. In some cases, event-based monitoring may also capture dry weather conditions occurring immediately before or some period after a rainfall event. The following instream water quality parameters are collected: fecal coliform, *E.*

[1] Primary watersheds are shown in bold in Table 2.1.

coli, total suspended solids, carbonaceous biochemical oxygen demand, total phosphorus, orthophosphate, nitrate-nitrite, total Kjeldahl nitrogen and ammonia. In selected watersheds (Threemile Creek, Taylor Creek, Dry Creek, Pleasant Run, Gunpowder Creek and the four most downstream sites in Banklick Creek), metals and hardness are also collected. In addition, flow measurements are recorded at sites within the primary watersheds during base flow monitoring.

Biological monitoring was conducted on a scheduled basis through 2010 similar to the water quality monitoring. Sites located in watersheds greater than five square miles are assessed for habitat quality, along with fish and macroinvertebrate communities, while only habitat and macroinvertebrates are assessed in those less than five square miles. In 2008, four least impacted monitoring sites (Double Lick Creek, Middle Creek, Garrison Creek, and Second Creek) were added to the monitoring program to establish "best attainable" conditions for Northern Kentucky streams. These data will serve as a benchmark for biological communities and a point of comparison for other streams.

As of June 2009, event-based monitoring has been completed for forty-four locations in eight watersheds, along with three separate rounds of base flow monitoring and two rounds of biological assessments. All monitoring data have been reviewed prior to inclusion in the project database, and have been analyzed to characterize current stream conditions and identify potential pollutant sources. These data have also been used to calibrate the water quality models described later in this section.

Table 2.1 shows the planned monitoring program, which is adapted as needed to respond to unanticipated conditions. For example, 2008 event-based monitoring planned for the Licking River watershed was re-scheduled to 2009, due to the lack of sufficient rainfall. Additionally, some sites have been relocated due to access issues. 2011 is being used as a catch-up year, to complete the planned sampling.

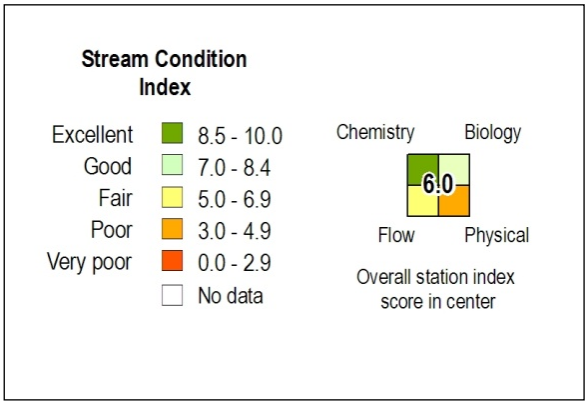
The Ohio River continues to be monitored through various programs conducted by ORSANCO, such as Contact Recreation Season Program, Longitudinal Bacteria Surveys and biological programs. SD1 plans to supplement ORSANCO's data by collecting additional data along the mainstem of the Ohio River as needed.

As discussed in Section 8, SD1 intends to continue the monitoring program as part of the ongoing characterization effort. The resulting data will be used to update the existing water quality models, identify trends in water quality, and provide feedback on the effectiveness of pollutant controls and other actions to improve water quality. These data will also be used to support development of additional tools, such as the Stream Condition Index (SCI). The SCI was originally designed to facilitate public understanding of the results generated by SD1's monitoring program and serve as a potential "measuring stick" to graphically display overall stream improvements as projects are implemented during the Consent Decree period.

Currently SD1 is developing the SCI to score stream sites based on flow, water chemistry, physical habitat and biological characteristics. Results for each category are

displayed at the stream site (Figure 2.3), and can also be aggregated for all sites, providing the potential to assign a given watershed an overall condition score.

Figure 2.3 Example of Stream Condition Index



SD1 understands that caution is needed with these types of indexes, as resolution is lost with data combination and heterogeneity within a watershed can introduce bias when applying an "overall" watershed score. However, SD1 intends to evaluate the capability of the tool to assess overall stream conditions.

Table 2.1 SD1 Monitoring Program to Establish Current Conditions - 2006 to 2010

Study Basin	Watershed[1]	Water Quality Monitoring[2]										Biological Monitoring[2]				
		Base Flow[3] (1 round/year)					Event-based[4] (3 rounds/year)					Habitat / Fish & Macroinvertebrates (1 round/year)				
		2006	2007	2008	2009	2010	2006	2007	2008	2009	2010	2006	2007	2008	2009	2010
Central	**Licking**	4	4	4	4	4				4				4		
Central	**Banklick**	0	8	8	8	8				4				4		
Central	**Threemile**	3	3	3	3	3				3				3		
Central	Licking River Tribs	10	11	11	12	12				2				7		
	Subtotal	17	26	26	27	27										
East	**Fourmile**	5	5	5	5	5		5					5			
East	**Twelvemile**	0	6	6	6	6	7						6			
East	**Taylor**	4	4	4	4	4		4					4			
East	Ohio River East Tribs	1	1	1	2	2										
	Subtotal	10	16	16	17	17										
North	**Woolper**	5	5	5	5	5				5					5	
North	**Elijahs**	2	2	2	2	2				2					2	
North	**Dry Creek**	4	4	4	4	4			4					4		
North	**Pleasant Run**	2	3	3	3	3			3					3		
North	**Sand Run**	1	2	2	2	2				2					2	
North	Ohio River North Tribs	3	3	3	3	3										
	Subtotal	17	19	19	19	19										
West	**Gunpowder**	4	5	5	5	5					5					5
West	**Big Bone**	3	5	5	5	5					5					5
West	Ohio River West Tribs	4	4	4	4	4										
	Subtotal	11	14	14	14	14										
	Total	55	75	75	77	77	7	9	7	22	10		15	25	9	10

[1]Bold = Primary watersheds;

[2] Digits = Number of monitoring sites

[3] Base flow monitoring is defined as occurring during dry weather periods when there is little to no runoff, and no rain in the previous 72 hours.

[4] Event-based monitoring is defined as occurring during and immediately following rainfall events that produce runoff.

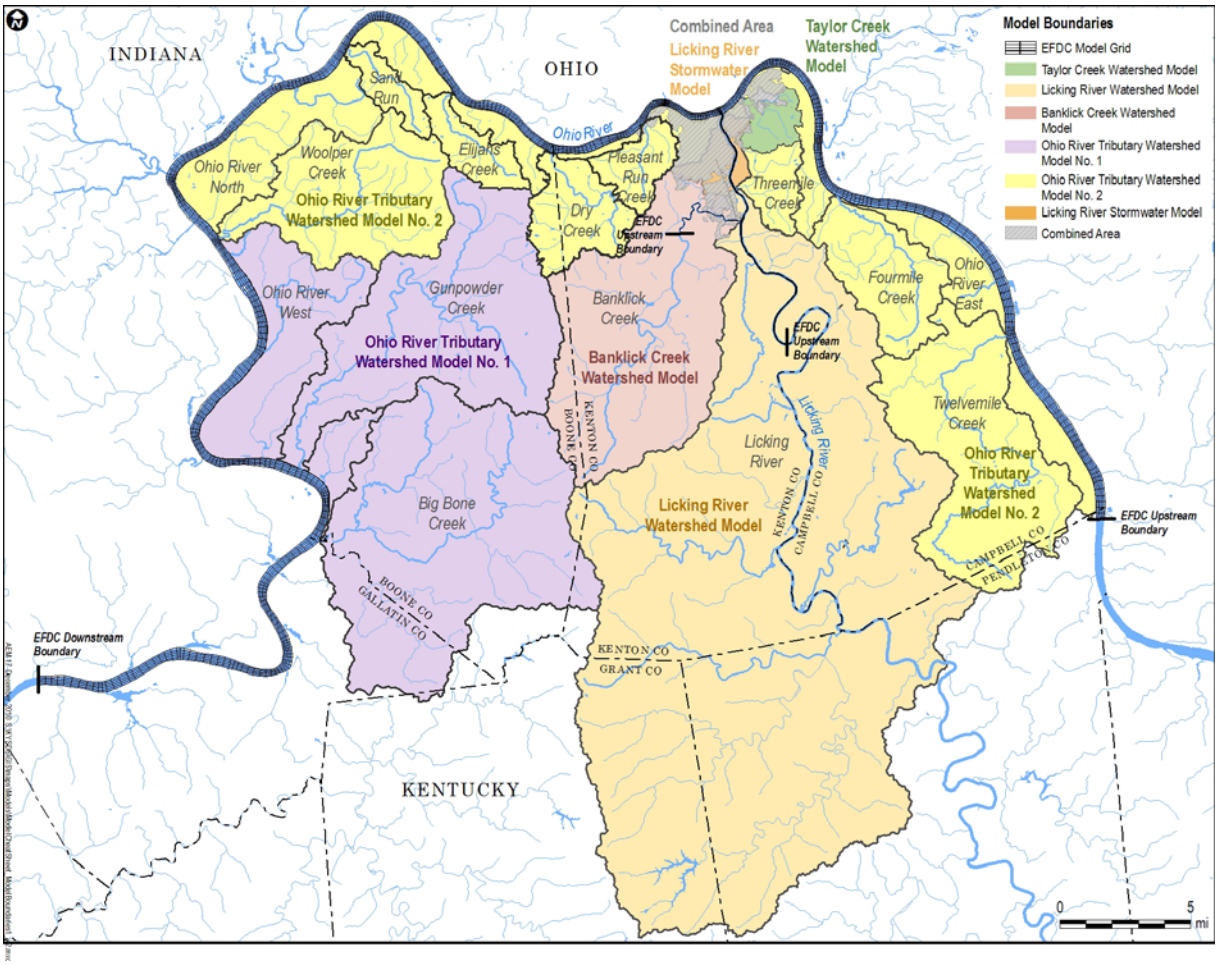
Data Gaps

Through the characterization effort, it was determined that sufficient data and information are currently available to support a good understanding of current waterway conditions in the study area. Data are insufficient, however, to identify specific sources contributing to elevated levels of bacteria during dry weather. Potential dry weather sources include septic systems, livestock and Kentucky Pollutant Discharge Elimination System (KPDES)-permitted facilities not meeting permit limits.

Modeling

SD1 has developed two types of tools to assess current water quality conditions and calculate water quality response to different controls alternatives. These models include the Watershed Assessment Tool (WAT!), which estimates the annual bacteria loading potential of different sources throughout the study area, along with detailed watershed and water quality models. The spatial extent of the detailed models is shown in Figure 2.4.

Figure 2.4 Extent of Detailed Watershed and Water Quality Models



These tools were developed to assess impacts of fecal coliform bacteria (since substantially more fecal coliform data exist than for *E. coli* bacteria). SD1 can expand these tools, as necessary, to address other pollutants such as total suspended sediment and nutrients for use in subsequent Watershed Plans. Bacteria was selected as the pollutant of most interest due to the public health risks associated with sewer overflows and because historical characterization activities (described in Section 1.2.2) indicated that CSOs were contributing to exceedances of bacteria criteria in the streams and rivers, but were not causing exceedances of aquatic life criteria in the large rivers (e.g. Licking and Ohio Rivers).

The watershed and water quality models were developed in conjunction with the infrastructure models (Section 2.1.2). The models were applied for a typical period of rainfall to:

- define the impact of current stressors on instream water quality;
- identify important sources under different environmental conditions;
- forecast the impacts and benefits of different land development and pollutant control scenarios; and
- identify data gaps.

These computer models integrate watershed and water quality data and define the link between sources of bacteria and water quality impacts. The models calculate instream bacteria densities for each hour of the simulation along the length of tributaries and mainstem streams. The models were developed (or updated) using:

- instream base flow and event-based monitoring;
- infrastructure model calculations of sewer overflows;
- CSO, SSO, and storm water outfall sampling data;
- updated land use/land cover data; and
- other information such as soils, topography/elevation, meteorological, stream bathymetric and hydraulic, and KPDES-permitted facilities' data.

Different detailed model frameworks were selected for different watersheds based on multiple objectives as discussed below. It is important to note that the results from both the water quality models and the infrastructure models are based on SD1's current understanding of the watersheds and the sewer system infrastructure. These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the watersheds and sewer system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the study area, improvements that occur within the study area, and changes in land use and development.

The WAT! has been developed for the entire study area and its estimates represent annual loads of fecal coliform bacteria and nutrients based on source characteristics, including loading potential, slope, and proximity to streams. This information enables SD1 to evaluate relative impacts of pollutants on water quality and to examine relative contributions of different sources at the subwatershed, watershed, and regional scales. The WAT! has been used to prioritize watersheds for development of detailed models,

to evaluate watershed control opportunities, and to provide a relative assessment of the benefits of the Five-year Improvement Program across all watersheds. The WAT! will continue to be further refined and developed to reflect updated monitoring data and to evaluate solids. Details on WAT! development and implementation are provided in Appendix 2-B.

The Banklick Creek watershed model was developed using Hydrologic Simulation Program in Fortran (HSPF), an EPA supported watershed model. The model was originally developed in 2004 as part of a federal grant to develop and apply a Watershed Assessment Protocol to understand water quality problems on a watershed basis (LTI, 2004). The model was updated to incorporate a more detailed land cover analysis and to link dry weather and wet weather loads to instream densities of fecal coliform. The model was calibrated in a step-wise fashion. First, the hydrology was calibrated to two years of data (2002 and 2003); then a dry weather load was calibrated to five years of fecal coliform data (2002 to 2007); third, the wet weather calibration and corroboration was conducted using wet weather data from four storms (one in 2008 and three in 2002 to 2003). Finally, a second model corroboration test was conducted using 2009 wet weather data from three storm events. Runoff characteristics from each land cover were constrained to values within the ranges of runoff concentrations found in the literature or measured by SD1. Details on the model development and calibration are provided in Appendix 2-B.

The Taylor Creek watershed model was developed using the runoff and transport features in EPA's Storm Water Management Model (SWMM). An existing PC-SWMM (SWMM 4.4) model for the Taylor Creek watershed, which was developed for flooding analysis, was converted and adapted into the recent version of EPA-SWMM 5 using recent GIS data sets. A water quality component (fecal coliform) was also added to the model for long-term simulation of dry and wet weather instream densities of fecal coliform. The model was calibrated in a step-wise fashion. First, the hydrology was calibrated to approximately one year of continuous stage and flow data from a recently installed USGS station (2007). Then, a dry weather load was calibrated to the three years of dry weather fecal coliform data collected by SD1 (2006 to 2008). Finally, the wet weather calibration and corroboration was conducted using wet weather data from three storms in 2007. Runoff characteristics from each land cover were constrained to values within the ranges of runoff densities found in the literature or measured by SD1. The runoff characteristics from each land cover were also compared to the calibrated runoff characteristics within the Banklick Creek watershed to ensure that the models were consistent. Details on the model development and calibration are provided in Appendix 2-B.

The Lower Licking River watershed model was developed using HSPF, an EPA supported watershed model. The model covers most of the Licking River watershed within the SD1 service area. However, the model excludes the Banklick Creek and Threemile Creek watersheds, and drainage near the Licking River mouth within sewered areas because these areas are represented in other models. The model was developed to simulate runoff of water and washoff of bacteria from the land surface, flow and bacteria routing through streams and instream losses of bacteria. The model

was calibrated in a step-wise fashion. First, the hydrology was calibrated for a five-year period (2000-2005) and evaluated in terms of total annual flow, monthly flow, daily flow and timing of monthly and daily flows. Next, a dry weather load was calibrated to fecal coliform data collected in the mainstem and ten tributaries between 2002 and 2009. The wet weather calibration and corroboration were conducted using 2009 wet weather data from three storm events. Runoff characteristics from each land cover were constrained to values within the ranges of runoff concentrations found in the literature or measured by SD1. Details on the model development and calibration are provided in Appendix 2-B.

Ohio River tributary watershed model was developed using HSPF, for a 355-square mile area encompassing Big Bone Creek, Dry Creek, Elijahs Creek, Fourmile Creek, Gunpowder Creek, Pleasant Run Creek, Sand Run, Threemile Creek, Twelvemile Creek, Woolper Creek and several areas with direct drainage to the Ohio River. This area was modeled as two separate sets of watersheds, numbered 1 and 2, as shown on Figure 2.4. The model was developed to simulate runoff of water and washoff of bacteria from the land surface, flow and bacteria routing through streams and instream losses of bacteria. The model was calibrated in a step-wise fashion. First, the hydrology was calibrated to flow data for a five-year period (2001-2006) for the gaged streams, and evaluated in terms of total annual flow, monthly flow, daily flow and timing of monthly and daily flows. Next, a dry weather load was calibrated to fecal coliform data collected between 2002 and 2009 within all ten watersheds and three direct drainage areas. The wet weather calibration and corroboration were conducted to wet weather events in 2006, 2007, 2008 and 2009 that were sampled by SD1. Currently, no wet weather data are available in Big Bone or Gunpowder Creeks (sampling is scheduled to be completed during 2011), so the wet weather calibration was only performed for watershed model number 2. Runoff characteristics from each land cover were constrained to values within the ranges of runoff concentrations found in the literature or measured by SD1. Details on the model development and calibration are provided in Appendix 2-B.

The Ohio/Licking/Banklick Creek water quality model was developed in collaboration with the Metropolitan Sewer District of Greater Cincinnati using EPA's Environmental Fluid Dynamics Code (EFDC). EFDC was applied in a two-dimensional mode to represent differences in bacteria in segments across the river (the model calculates vertically-averaged densities in each segment). Important processes in the model include hydrodynamic transport, lateral mixing, and the loss rate of bacteria. The hydrodynamic portion of the model includes 90 miles of the Ohio River from upstream river mile (RM) 443.4 (Campbell/Pendleton County Line seven miles downstream of the Meldahl Dam) to downstream RM 532.7 (Markland Dam near Warsaw, KY). Approximately 5.5 miles of the lower Licking River and 4.0 miles of lower Banklick Creek are also included in the model. Both of these tributaries are modeled from their mouths up to their respective intersection with I-275 highway bridges (refer to Figure 2.4).

The water quality portion of the model includes the Ohio River from RM 443.4 to RM 490 (upstream of the confluence of the Great Miami River) and the lower portions of the

Licking River and Banklick Creek. The model was calibrated in a step-wise fashion. First, the river hydraulics were calibrated to two USGS intensive velocity surveys and to stage data measured at the USGS station in Cincinnati. Then, the lateral mixing rate was calibrated to two dye surveys conducted by the USGS in the Ohio River. Finally, water quality in the Licking River and Banklick Creek was calibrated to wet weather data collected in May 2008 by SD1 and then validated to event data from seven storms in 1995 and 1996. A second water quality corroboration for the Licking River and Banklick Creek was conducted using three 2009 wet weather data sets.

Because a complete set of loads could not be obtained from all sources to the Ohio River, water quality was calibrated only in the upper portion of the river (RM 443.4 - RM 462) where there are fewer sources. The model was calibrated to fecal coliform data from three dry weather and two wet weather events collected by SD1 in 2007 and 2008 in the upper portion of the Ohio River. SD1 intends to collect additional bacteria data for the middle portion of the Ohio River (RM 462 – RM 490) to complete the calibration of the water quality portion of the model in the next five-year cycle. Details on the model development and calibration are provided in Appendix 2-B.

Because the model is not fully calibrated and validated in all reaches of the Ohio River for bacteria, the Ohio River portion of the model was applied to assess the impact of fecal coliform loads from sources upstream and adjacent to the river. Currently, the Ohio River portion of the model is configured to assess the impact of bacteria from SD1 sewer overflows, and watershed sources from Banklick Creek and Taylor Creek. This configuration allows the model to be used to evaluate the relative benefit of different control strategies for SD1 overflows and storm water sources from the Kentucky side of the Ohio River. SD1 is planning to extend the model calibration, which will require additional data collection, through the rest of the water quality portion of the Ohio River (RM 462 – RM 490) for the next set of Watershed Plans. The calibration of the most downstream portion of the Ohio River model from RM 490 – RM 517 (Boone/Gallatin county line sixteen miles upstream of the Markland Dam) will be addressed in collaboration with the Metropolitan Sewer District of Greater Cincinnati and other local entities so that estimates of bacteria loads for the non-SD1 portions of the Ohio River watershed can be developed cost-effectively and with mutual consensus among the stakeholders in the region. This collaboration will also allow the model to be used in a regional planning capacity.

Typical Period

The CSO Control Policy (EPA, 1994) indicates that CSO controls be evaluated to determine the average number of overflows per year that can be achieved with controls. EPA (1999) prefers that continuous simulations (rather than design storms) of the combined sewer system be used to evaluate the performance of CSO controls and their benefits. As discussed in Section 2.1.2, 1970 has been selected as the most typical year for sizing infrastructure controls.

Typical conditions are also needed for stream conditions to drive the fate and transport in the water quality models and quantify improvement in water quality based on implemented controls. Stream flow in 1970 was evaluated to determine if this period would also qualify as a typical period for instream conditions. However, stream flow in the recreation season in 1970 tended to be lower than historical averages in Banklick Creek and the Licking River. Furthermore, no other single year provided a representative period of both rainfall and stream conditions. Therefore, a typical period of rainfall and stream conditions was identified by comparing longer periods (e.g. three years, five years) of rainfall and stream flow characteristics to historical annual and recreation season averages.

Ultimately, a five-year period, 1992-1996, was identified and used to evaluate the instream benefits of the different control alternatives. Table 2.2 provides a comparison of the annual average characteristics of this five-year period to historical annual and recreation season averages. Most of the criteria calculated for the five-year period are within 10% of the corresponding historical average value.

Table 2.2 Comparison of 1992-1996 Period to Typical Statistics

Criterion	Annual Historical Average (1951-2005)	1992-1996 Annual Average	Recreation Season Historical Average (1951-2005)	1992-1996 Recreation Season Average
Number of Rainfall Events > 0.10"	74	71	38	36
Rainfall Volume (inches)	41	41.27	21.3	21.24
Number of back-to-back storms	5	5	3	3
Maximum Hourly Rainfall Intensity (inches/hour)	1.11	1.10	1.10	1.10
No. of Months with at least two storms > 1.5"	3	2	2	1
Largest Storm (inches)	3.94	4.41	3.87	4.41
Ohio River 25th Percentile Flow (cfs)	45,600	49,800	34,200	39,375
Ohio River 50th Percentile Flow (cfs)	82,480	81,820	54,371	55,265
Ohio River 75th Percentile Flow (cfs)	153,000	158,800	89,888	86,000
Licking River 25th Percentile Flow (cfs)	645	693	387	372
Licking River 50th Percentile Flow (cfs)	2,185	2,637	907	863
Licking River 75th Percentile Flow (cfs)	6,160	6,685	2,973	3,008
Banklick Creek 25th Percentile Flow (cfs)	17.6	17.3	11.72	12.74
Banklick Creek 50th Percentile Flow (cfs)	33.2	32.8	20.97	18.98
Banklick Creek 75th Percentile Flow (cfs)	62.82	56.2	40.30	36.36
Number of Days Ohio River Stage < 30 feet	246	243	158	159
No. of Days Ohio River Stage $\geq$ 30 and < 40 feet	89	88	21	18
Number of Days Ohio River Stage $\geq$ 40 feet	30	35	5	7

cfs = cubic feet per second

Note that while the five-year period has annual average statistics that are more typical than any single year, it also includes extreme events, such as a ten-year storm in 1995. Therefore, it is not unusual for a source control that is sized to overflow four times in a typical year (using 1970 rainfall) to overflow more than four times per year on average in the five-year period.

2.1.2 Gray Infrastructure Characterization

Similar to the watershed characterization efforts, infrastructure characterization activities were conducted across the entire sewer system (Figure 1.3 shows the sanitary sewer system), but data were compiled and analyzed on the basin level as the basins provided a way to easily subdivide the sewer system into manageable pieces for analysis.

Characterization efforts were focused on collecting data to update the sewer system model, but also structured to provide SD1 and the project team with a current awareness of sewer system operation and operational problems. This awareness was critical in identifying priorities and projects for the initial Watershed Plans.

SD1 conducted flow and rainfall monitoring, water quality sampling of CSO, SSO, and storm water outfalls, and hydraulic modeling to characterize and document the

performance of the SD1 infrastructure. To maximize the quantity and quality of data collected, SD1 developed a coordinated and prioritized approach for data collection across the four basins, which is described below, followed by a description of the hydraulic modeling.

Overflow Prioritization

Performing detailed monitoring and sampling at all of the SD1 overflow locations and across the entire system is not cost-effective and EPA recommends that monitoring be targeted at outfalls that are representative of the system (EPA, 1999). Therefore, SD1 prioritized characterization efforts to focus on the most critical locations within the service area that would provide the greatest benefit in long-term planning. Overflows were ranked to develop a list of potential monitoring and sampling locations.

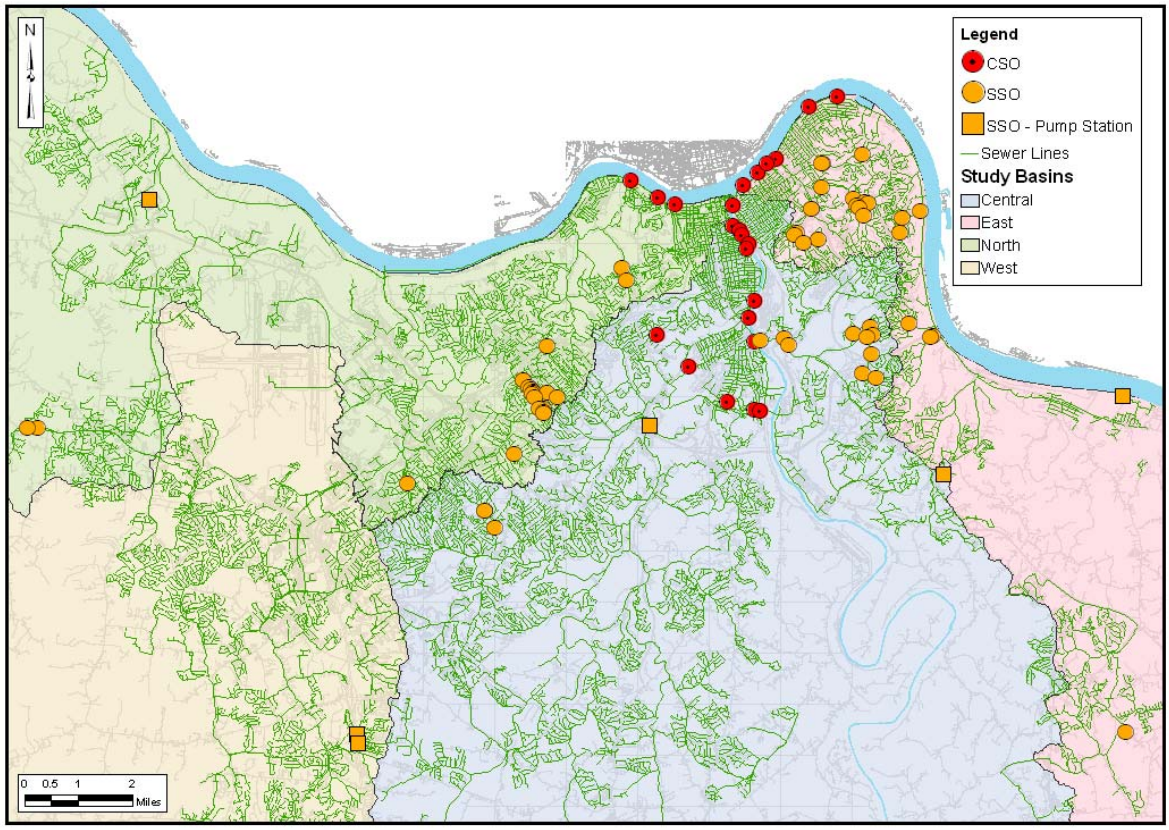
To develop the overflow ranking, a base list of all SSOs and CSOs was developed from the overflows listed in the Consent Decree. The list of SSOs included all the recurring SSOs listed in Exhibit A of the Consent Decree, known pump stations with bypasses, and pump stations with specific deadlines outlined in Exhibit E. The CSO list included all permitted CSOs within the SD1 service area and overflows that SD1 identified during characterization that should be permitted as CSOs.

The individual CSOs and SSOs on the two lists were then prioritized using quantitative and qualitative metrics to develop a scoring for individual overflows. The quantitative metrics were developed based on the Consent Decree and EPA guidance (EPA, 1999) including frequency of overflow; volume of overflow; public health impacts; and water quality impacts. Detail of the quantitative and qualitative metrics can be found in Appendix 2-C.

The qualitative and quantitative metrics were gathered and compiled into two separate spreadsheets for the purpose of developing the final prioritization for both SSOs and CSOs. Based on individual criteria and an overall score, the final prioritization was determined to guide the infrastructure characterization efforts. These priority overflow locations are generally described below and shown in Figure 2.5. A more detailed map of these locations is found in Appendix 2-C.

As described below, 23 CSO and 63 SSO locations were selected for monitoring, accounting for over 80% of the modeled CSO and SSO volume of the entire system. By monitoring these locations to provide data to update, calibrate and validate the existing hydraulic model, SD1 was confident that the combined and separate sewer systems would be accurately represented and characterized for development of the Watershed Plans.

Figure 2.5 Priority CSOs and SSOs for Monitoring



CSOs

Based on the qualitative and quantitative metrics, the five CSOs that discharge into Banklick Creek were identified as a high priority for monitoring and sampling. In addition, eighteen other CSO locations throughout the study area that had the potential for inline storage or had a significant volume also ranked high on the priority list. These locations represented early action opportunities to reduce overflow frequency and volume without significant capital cost as well as being the largest overflows within the SD1 system. The remaining CSOs were ranked according to their overall score. Lower priority overflows were sometimes bracketed or clustered nearby higher priority overflows, and therefore monitored and characterized at the same time as the higher priority overflows.

Based on model simulations, the 23 highest priority CSOs accounted for approximately 80% of the calculated CSO volume occurring within the SD1 system during a typical year.

SSOs

The final SSO prioritization list was developed using a combination of the quantitative and qualitative measures that were included in the prioritization spreadsheet and included 63 SSOs. SD1 decided that any pump station included in Consent Decree

Exhibit E with a deadline of December 31, 2010, was, by previous determination, a priority and should therefore be assigned highest priority. The pump stations that are currently being addressed through planned capital improvements were not included. Beyond the Exhibit E pump stations, the prioritization list was based on the overall score developed for each overflow. As with the CSO listing, a cluster of lower priority overflows associated with a high priority overflow were also monitored and characterized at the same time.

Based on model simulations, the 63 SSO locations accounted for approximately 80% of the calculated SSO volume within the SD1 system during a typical year.

Infrastructure and Overflow Monitoring

Once the priority overflows were identified, a monitoring program could be developed around these locations. The monitoring program to characterize the system included flow monitoring, rainfall monitoring, and water quality and outfall sampling

Flow Monitoring and Rainfall Monitoring

Based on the final prioritization lists, a monitoring plan was developed to gather sufficient rainfall and flow data to characterize the system and to calibrate and verify the hydraulic model. These data were organized to improve the quality of the hydraulic model and served to increase the system understanding prior to the development, sizing and evaluation of control alternatives. Flow and rainfall monitoring was conducted throughout the SD1 system from June 2007 through June 2008. A total of approximately 250 flow monitors and 45 rain gauges were used during this monitoring period, as shown in Figure 2.6 and Figure 2.7.

Figure 2.6 Flow Monitor Locations

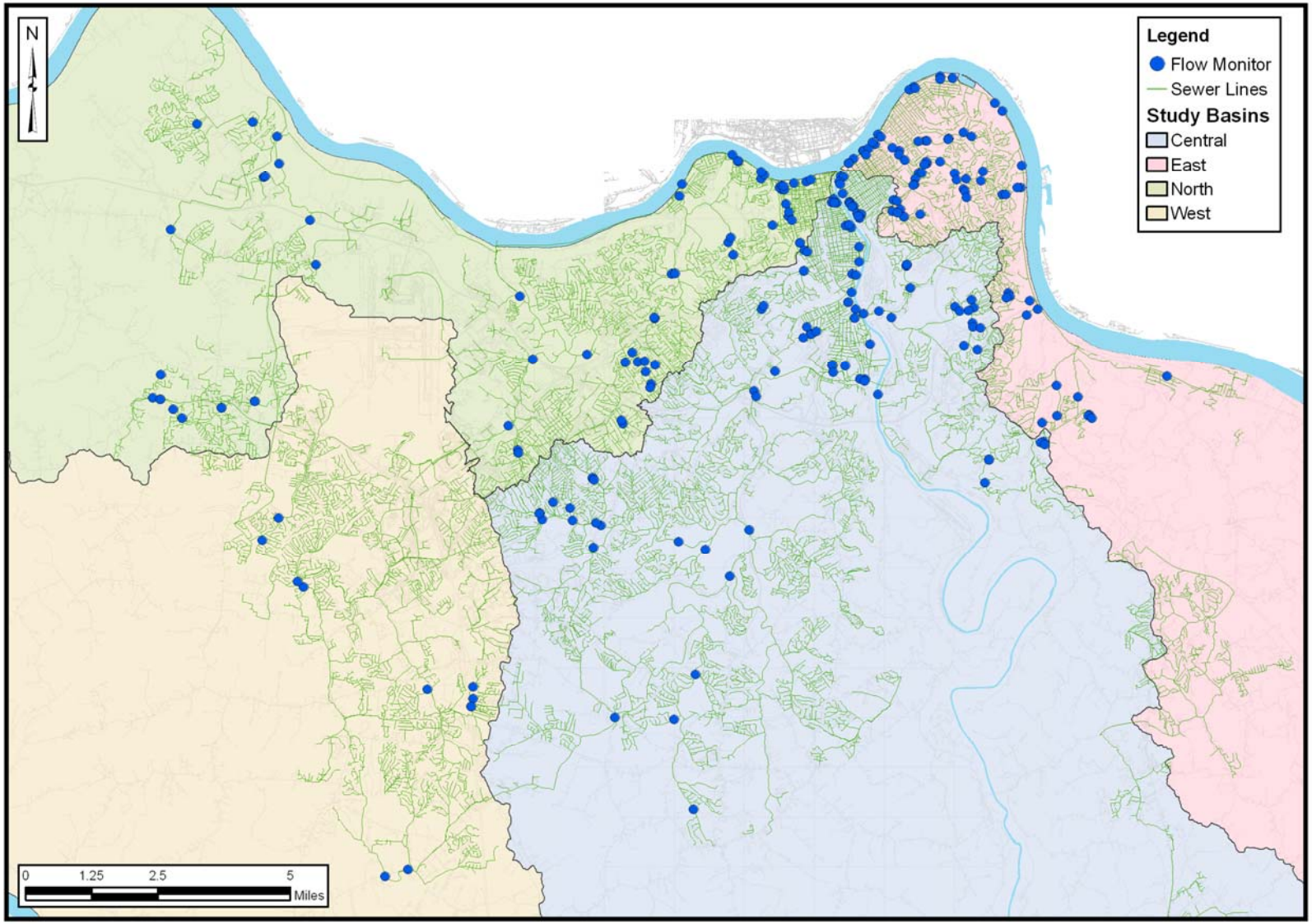
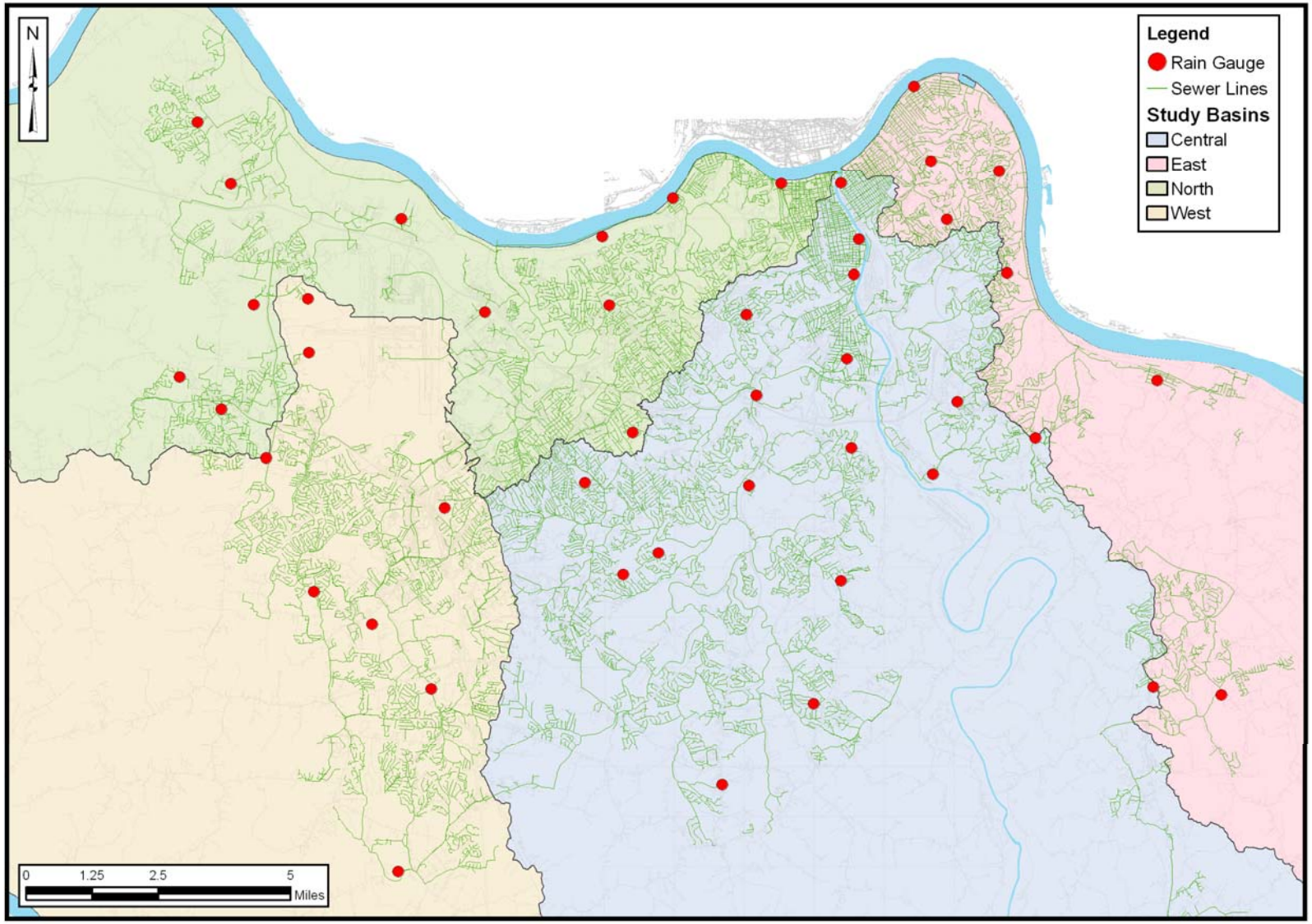


Figure 2.7 Rain Gauge Locations



As part of the flow and rainfall monitoring program, SD1 and their infrastructure consultants reviewed and provided ongoing data analysis to ensure that the collected flow monitoring and rain gauge data were suitable for use in model calibration and validation. The location of these monitors and a discussion of quality assurance / quality control (QA/QC) efforts are described in Appendix 2-C.

In addition to characterizing the hydraulic conditions in trunk sewers and pipe networks upstream of priority overflow locations, flow monitors were also placed in several strategic locations within the system that enabled SD1 to better understand the operation of their system and the contributions from different sources. Two examples include monitors downstream of new development to characterize the dry and wet weather contribution from new construction in separate areas and flow monitors downstream of SD1's connection with Florence to quantify the wet weather flows contributed by this independent municipality.

Water Quality and Outfall Sampling

SD1's 2007-2008 outfall sampling program was designed to support multiple project objectives. The primary purpose was to support the system characterization phase of the Watershed Planning effort by sampling multiple discharge types (SSO, CSO, and storm water discharges). This was necessary so that a pollutant load could be calculated for each source type using the measured bacteria densities and the model-calculated outfall volumes. These loads could then be entered into the watershed and water quality tools so that the impact of SSO, CSO activations, along with storm water discharges, could be assessed on the waterways. Certain sampling locations were also selected to assess potential Significant Industrial User impacts as part of SD1's Nine Minimum Controls program.

Approximately 20 outfall locations were sampled for 12 wet weather events. Given the extended duration of the program (approximately 15 months), the number of locations was not static; as data were collected and specific analysis needs identified, the program allowed for locations to be added, dropped, or relocated to maximize the value of collected data. In selecting the sampling locations, SD1 took into account the prioritization process as well as access, tributary area land use, and likelihood of activation. The program's goal was to capture water quality data from a variety of source types and land uses. Locations were selected that had the highest potential to provide quality data for a large number of storm events and would be safe to access at all times of day. Automatic samplers and corresponding flow monitors were used, and the sampling protocol was to collect multiple samples during each event to define the time variation in concentrations and loadings.

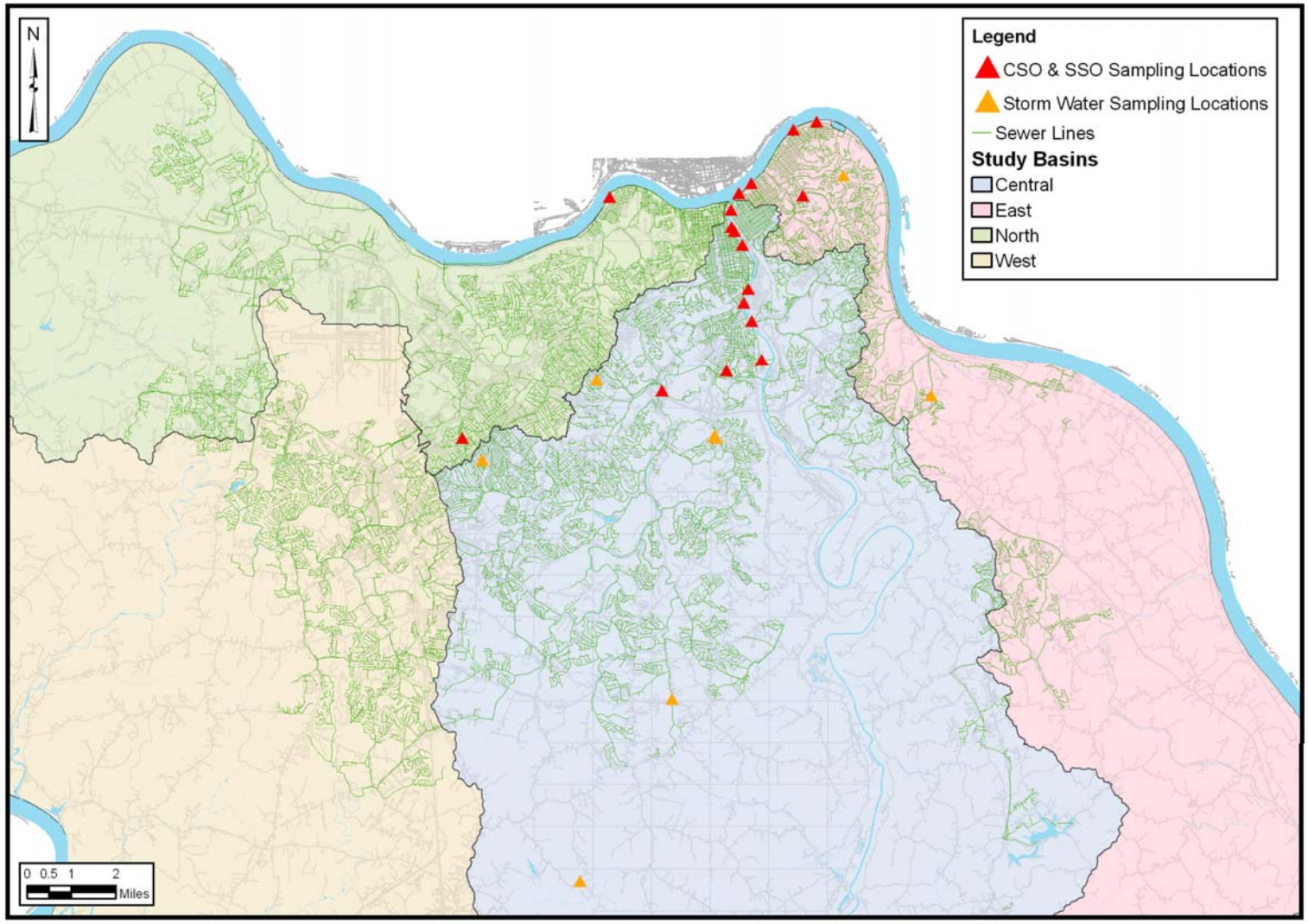
Figure 2.8 shows the location of the CSO, SSO and storm water sites selected for sampling. A description of the locations and the number of events in which they were sampled is shown in Table 2.3. Twelve storm events were sampled between June 2007 and December 2008.

Table 2.3 Summary of Outfall Sampling Locations

	Location	Event 0	Event 1	Event 2	Event 3	Event 4	Event 5	Event 5A	Event 6/6A	Event 7/7A	Event 8	Event 9/9A	Event 10/10A
CSO Sites	4th Street	N	N	N	S	S	S	N	S	S	N	S	S
	8th Street	N	S	N	S	S	S	N	S	S	N	S	S
	10th Street									N	N	S	N
	44th Street						S	S	S	S			
	Adela Street				S	S	S	S	S				
	Church Street	S	N	S	S	S	S	S	S	S	S	S	S
	Columbia Street									S	S	S	S
	Eastern Avenue	N	N	S	S	S	S	N	S	S	N	S	S
	James Avenue	S	S	S	S	S	S	N	S	S	S	N	S
	Main Street	N	S	S	S	S	S	N	S	S	S	S	S
	McKinney Street	N	S	N	S	S	S	N	S	S	S	S	S
	Pleasant Street FS	N	N	N	S	N	S	N	S				
	Riverboat Row	N	S	S	S	S	S	N	S	S	N	S	S
SSO Sites	Lakeview PS Bypass	N	N	N	S	S	N	N	S	S	N	N	S
	Lafayette	N	N	N	S	S	S	N	S	S	S	N	N
	Licking River Siphon	N	N	N	N	N	N	N	S	N	N	N	N
	Waterworks Road	N	N	N	S	S	N	N	S	S	N	N	N
Storm Sites	Caldwell	N	S	S	S	S	S	N	S	S	N	S	S
	Dodsworth	N	N	S	N	S	S	N	S	S			
	Green Road										N	N	S
	Gunpowder Court	N	S	S	N	S	N	N	S	S	S	S	S
	Harris Road										N	S	S
	Huckleberry Hill (Orphanage Rd)	N	S	S	S	S	S	N	S	S	N	S	S
	Old Taylor Mill Storm (Upstream)	S	S	S	S	S							
	Old Taylor Mill Storm (Downstream)	S	S	S	S	S	S	N	S	S	S	S	S
SIU Sites (NMC Program)	Imperial Sugar						N	S	S				
	Newport Aquarium									S	N	S	S
	NKWD						N	S	N				
	Norfolk Southern						S	S	S				
	Trauth Dairy									S	N	S	S

S=Site sampled; N=Site not sampled; Blank cell =Site not active in program

Figure 2.8 Outfall Sampling Locations



Samples were analyzed for several constituents; however, bacteria densities were of most interest for sewer system and water quality characterization efforts. Event mean concentrations (EMCs) were developed for both fecal coliform and *E. coli* bacteria for seven of the sampling events; evaluation and analysis of data from the final three sampling events is ongoing.

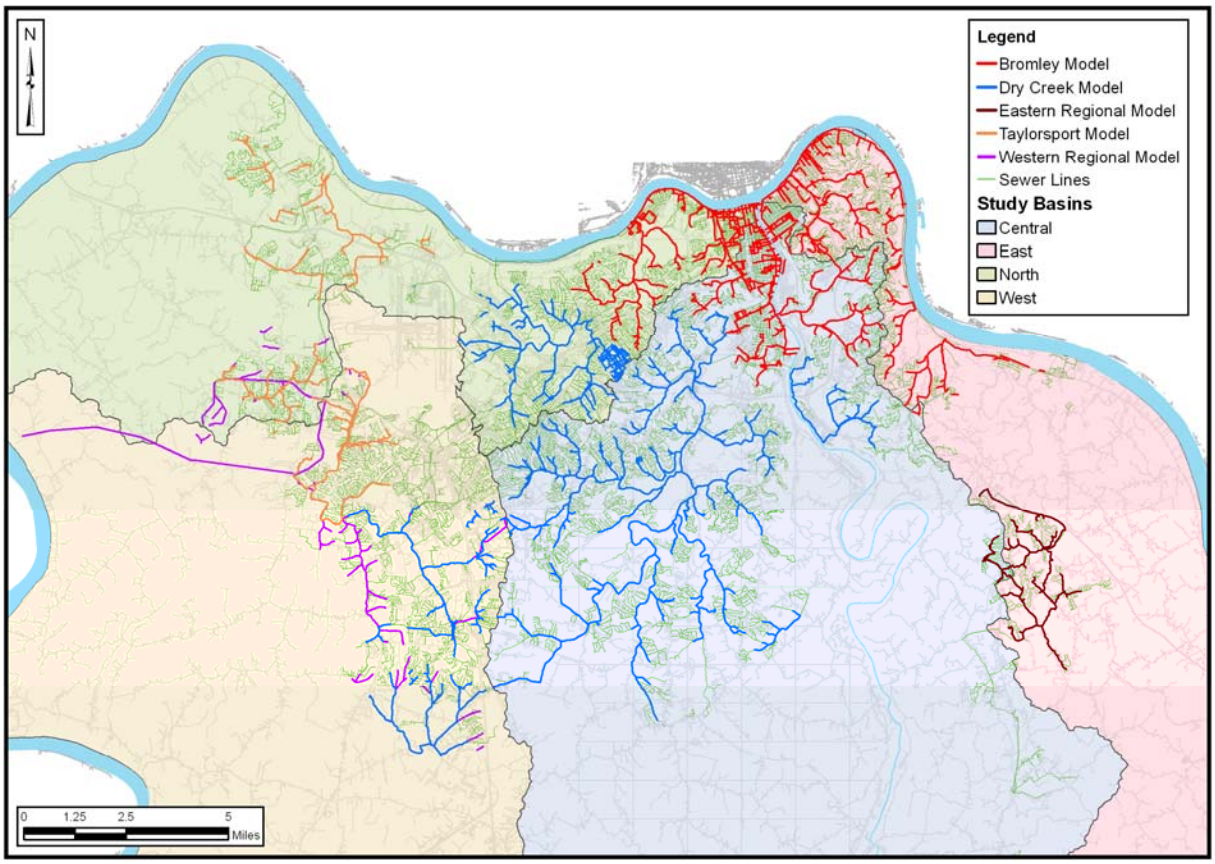
Hydraulic Model Update and Calibration

SD1's existing sanitary sewer system is represented in five distinct model networks all modeled using Wallingford Software's InfoWorks CS (collection (i.e. sewer) systems) model, as shown in Figure 2.9. These include:

- **Bromley model:** represents the total area that is tributary to the Bromley pump station and contains the entire SD1 combined sewer network.
- **Dry Creek model**: represents the total area that is tributary to the Lakeview pump station and tributary to the Dry Creek WWTP by gravity (including pumped flows from Florence).
- **Taylorsport model:** represents the total area that is tributary to the Taylorsport pump station.
- **Eastern Regional model:** represents the total area that is tributary to the Eastern Regional WRF.
- **Western Regional model:** represents SD1's system tributary to the planned Western Regional WRF following construction of the treatment plant and the tributary gravity sewers and tunnel.

The hydraulic model was originally developed as part of other projects previously undertaken by SD1 and updated as part of the characterization effort. This was necessary so that the most recent changes within the SD1 sewer system, including updated sewer connectivity and pump station capacities, could be reflected in the model.

Figure 2.9 Extent and Location of SD1's Hydraulic Model



Model Calibration

Model calibration is the process of adjusting estimated model parameters to match observed flows and water depths in the system. This step is essential to create a predictive model that accurately represents the response of a sewer system to both dry and wet weather conditions. In general, there are few parameters that can and should be adjusted, and the final value should always fall within the range of reasonable values for that parameter.

The goal of the model calibration process was to adjust the parameters in the hydraulic model so that model calculations of flow, velocity, and depth would match monitoring data from multiple storm events. SD1's model was calibrated using a continuous simulation that covered a range of seasonal conditions.

Different monitored rainfall periods were utilized for the calibration to ensure the model could represent a range of varying rainfall conditions. In addition, the model was run continuously over the calibration period and compared against the collected flow monitoring data. This cutting edge calibration methodology was devised to provide a hydraulic model that could be accurate in long-term continuous simulations for watershed planning. Because most of the sewers in SD1's sanitary service area are over 50 to 75 years old and the majority are clay pipe, the sewers are subject to varying

levels of I/I based on ground water and seasonal conditions. These conditions produce different responses to rain events and varying overflow volumes in SD1's sewer system throughout the year. To accurately characterize and simulate sewer system response for long-term continuous simulations, it was critical to incorporate the impacts of the changing ground water conditions and antecedent moisture conditions to provide the most representative model of the conditions within the SD1 service area.

Data from June 25, 2007 through March 31, 2008 were used as the 9-month period simulated for the model calibration process. Within that timeframe, SD1 and the infrastructure consultants identified seven distinct periods to use as the comparison for calibration purposes. These seven periods represent the full range of seasons and the varying ground water and antecedent moisture conditions that occur in the SD1 service area. The seven periods and a brief description of each are shown in Table 2.4.

Table 2.4 Calibration Period Descriptions

Storm Period	Average Rainfall	General Description
July 4 – 7, 2007	0.9 inches	Mostly < 2 months for most durations but had some high intensity local bursts– contains some 5-minute, 1-year peak return intervals
September 27-29, 2007	1.2 inches	Low peak intensity event but had some 2- to 4-month return intervals for 1- to 6-hour durations
October 16-27, 2007	7.0 inches	Series of several smaller 0.5-inch storm events culminating in large storm event that was a 5- or 10-year, 24-hour event (~5 inches)
November 11-30, 2007	2.5 inches	Two smaller storms (< 0.3 inches) between November 11 and 15, a 0.75-inch storm on November 21-22 and a larger storm (~ 1.5 inches) on November 25-26
		No high intensities – approx 2 to 3 month 6- to 12-hour durations at some locations
January 8-13, 2008	1.3 inches	Two smaller storms (0.5 to 0.75 inches) with low return intervals < 2 month
January 29-February 11, 2008	3.0 inches	Smaller storm in late January (0.5 inches) and larger storm (2.5 to 3 inches) in February; 4- to 6-month, 6- to 24-hour durations storms
March 18- 25, 2008	5.0 inches	Large storm event that was 5 to 10+ year, 12- to 24-hour storm

By selecting these seven storm periods, the model calibration sufficiently covered dry and wet periods of varying duration, different types of storm events, and varying seasonal conditions. Within the InfoWorks CS software, there are a number of different methods that can be used to represent the different sources of water that enter a sewer. By using these methods together, the model could accurately simulate the performance of SD1's system under long-term simulations, including back-to-back storm events and storm events that occur under different antecedent conditions or at different times of the year. This state-of-the-art approach to hydraulic modeling provided SD1 with an accurate understanding of the sewer system and its performance during a variety of wet and dry weather conditions. The output from the model also provided SD1 with an understanding of the magnitude of overflows so they can be put into context with other sources of pollution.

Calibration Goals

The degree of model calibration is evaluated by quantitative comparison of model calculations with the flow monitoring measurements, expressed in terms of percent deviation. The calibration standards are shown in Table 2.5 for the selected wet weather periods that were described above. The calibration was simulated as a continuous period, but the assessment as to whether the model complied with the calibration standards was based on individual storm periods.

Table 2.5 Wet Weather Calibration Criteria (for Seven Selected Periods)

Criteria	Calibration Standard
Peak Flow Rate:	-15% to + 25% of measured, or ±0.1 million gallons per day (MGD)
Flow Volume:	-10% to +20 % of measured, or ±0.1 million gallons
Maximum, Average, and Minimum Depth:	-0.33 feet to +1.67 feet at surcharged locations ± 0.33 feet at non-surcharged locations
Shape:	The shape of modeled and monitored curves should be similar for flow and depth.
Timing:	The timing of the peaks, troughs and recessions of modeled and monitored curves should be similar for flow and depth.

The comparison against the criteria shown in Table 2.5 was focused on flow monitors located within the pipe network upstream of the priority overflows. The monitors used in calibration were in place within the system for the entire 12 months. Additional flow monitors were also placed on certain overflows to monitor volume and frequency of activation. The model output was also compared against data from these monitors as a means of assessing overall calibration and to determine if any significant adjustments should be made to the model. In summary, the flow monitoring breakdown for calibration was as follows:

- 180 flow monitors located within the pipe network that were in place for a year and judged against the criteria in Table 2.5.
- 38 flow monitors located in CSO and SSO locations to monitor overflow magnitude and activation frequency.
- 32 flow monitors located across the system at different points and for different durations to assess specific modeling questions such as: new development impact, pump station performance, and potential SSES locations. These monitors were not used in the full system calibration due to limited data but were instead used to inform specific modeling decisions.

Of the 180 flow monitor locations that were examined for calibration standards, a monitor was considered calibrated for peak flow, volume, or peak depth if it met the accepted standards in at least 50% of the calibration periods. These goals could not be met for all cases for a variety of reasons, including flow monitor malfunction, system repairs and system blockage. When the calibration goals could not be met with reasonable parameter adjustments, the reason for the discrepancy was checked to

ensure it was a plausible explanation and then a determination on impact to calibration was made. Often, when a monitor did not meet the calibration standards, upon close examination, it may have been close to the standards. In many cases, it was not possible to meet a majority of calibration periods due to difficulty in replicating field conditions; SD1 worked to resolve those issues to ensure that the model was calibrated well overall.

SD1 developed a system to summarize the calibration results in a ranking system. For peak flow, volume, and peak depth, each monitor was judged to determine in how many of the seven periods (or fewer if the monitor failed during one of the selected periods) it met the required calibration goals. For summary, each monitor was placed in a range to signify the level of the calibration. The results of the calibration for the 180 flow monitor locations in the pipe network are shown in Table 2.6.

Table 2.6 Model Calibration Results for Flow Monitor Data Collected from June 25, 2007 to March 31, 2008

	Peak Flow	Volume	Peak Depth
(1) % FM met > 50% of the periods in that category	86%	85%	81%
(2) % FM met < 50% and > 15% of the periods in that category	13%	14%	16%
(3) % FM met15% periods in that category	1%	1%	3%
% of Monitors in Category 1 and 2	99%	99%	97%

FM = flow monitor

The in-system monitors represent individual locations across the entire system and a large percentage of those monitors were found to be calibrated well against observed data. In more than 80% of the locations, the model met the calibration goals in a majority of the examined periods; the remaining 15-20% of the locations were examined on an individual basis and determined that they represented all of the observed conditions at a sufficient level for planning purposes. Though individual locations or events may not have met the set standards, the sum total of all of the locations and events were determined to produce a highly calibrated model of the SD1 system.

Since this model was to be used for long-term planning of overflow reduction, an important metric was how the model matched observed data at a significant number of the overflow locations. Table 2.7 shows the total SSO and CSO volumes observed at the flow monitors when compared with the model calculations. In both cases, the agreement between the modeled and monitored volume was extremely good, providing SD1 with another measure of confidence that the hydraulic model were accurately representing the existing system and its performance. Given that these locations represented approximately 80% of the CSO and known SSO volume, the close match in terms of calculated volume was critical in determining that the model was calibrated well and could be used for planning purposes with a high degree of confidence. It is important to note that the values presented in Table 2.7 do not include the impacts of elevated river stage which occurred in 2007 and 2008. During the elevated river stage, several monitors were influenced by river water and could not be used as reasonable

points to calibrate the model against. A discussion of the impacts of the Ohio and Licking Rivers on the SD1 system operation is presented in Section 7.3.1.

Table 2.7 Model Calculated Overflow Volume – June 25, 2007 to March 31, 2008

Overflow Category	Total Observed Volume (MG)	Total Model Calculated Volume (MG)	% Deviation
10 SSO Locations	115	112.6	- 2%
28 CSO Locations	731	790	+8%

Model Verification

SD1 used rainfall and flow data from April 1, 2008 to June 30, 2008 in a continuous simulation to independently verify the accuracy of the model's calibration. Table 2.8 shows the rainfall periods that were used as part of the model verification. Results showing the comparison for the in-system monitor locations based on the SD1 criteria (from Table 2.5) are shown in Table 2.9. The volumes in Table 2.10 include a comparison of the calculated model volumes for both the SSO and CSO locations that were monitored during the verification period (again excluding the elevated river stage which occurred in 2008 because of this influence on monitor operation).

Table 2.8 Verification Period Descriptions

Storm Period	Average Rainfall	General Description
April 3 -7 2008	2.0 inches	Generally, a 2 inch low-intensity storm that was around a 3-4 month, 12-24 hour event in most cases. No high intensity periods; ground was extremely saturated from wet March
May 13 - 23 2008	4.0 inches	3 total events, a 0.5 inch rain on May 14, a 2 inch rain on May 16, and a 1.5 inch rain on May 19. All storms were low-intensity, with the highest return interval being the 2 inch storm, which was about a 6 month, 12 hour event
June 3- 7 2008	3.0 inches	Back-to-back storms, the first 1.75 inches was a 6 month, 12 hour storm while the next storm started 12 hours later and was about 1.25 inches and only about a 2 month storm

Table 2.9 Model Verification Results for Flow Monitor Data Collected from April 1, 2008 to June 30, 2008

	Peak Flow	Volume	Peak Depth
(1) % FM met > 50% of the periods in that category	59%	53%	49%
(2) % FM met < 50% and > 15% of the periods in that category	25%	30%	25%
(3) % FM met < 15 % periods in that category	16%	17%	26%
% of Monitors in Category 1 and 2	84%	83%	74%

FM = flow monitor

Table 2.10 Model Calculated Overflow Volume – April, 1 2008 to June 30, 2008

Overflow Category	Total Observed Volume (MG)	Total Model Calculated Volume (MG)	% Deviation
10 SSO Locations	29.8	33.5	+ 12%
28 CSO Locations	345	352	+ 2%

In addition to the above verification process, SD1 had collected flow and rain monitoring data in 2005 and 2006 in several key areas within the sewer system for past studies. Rainfall collected during these periods in areas where the sewer system had not significantly changed was also run through the model and the collected flow monitoring data were compared against the model results. The comparisons of the collected data to the model results showed similar verification results as those presented in Tables 2.9 and 2.10 and provided an additional level of confidence in the accuracy of SD1's hydraulic model.

As part of the ongoing characterization work and model updates, SD1 has developed a prioritized field inspection program by watershed for field inspection staff to visit model-predicted and recurring overflow locations in the sewer system during and after rain events to compare against the model results. This program is in addition to the ongoing SORP (Sewer Overflow Response Plan) that SD1 currently employs. Inspections completed in the Banklick Creek watershed show good correlation between model calculations and field observations. Validation of the hydraulic model continues through ongoing field inspections of model-predicted overflow points where previous field inspections had not been conducted. SD1 will continue to refine the hydraulic model as needed based on this ongoing watershed prioritized overflow field inspection program for use in updating recurring SSOs and CSOs, SD1's SORP, and for future Watershed Plans.

Model Calibration & Verification Summary

As noted above, the most critical aspect of judging the model performance was in examining how the model calculated overflows at several critical locations within the system. SD1 monitored the 38 priority and major overflow locations in its sewer system over a full year and compared those results against the model calculations for the total volume that was spilled to provide evidence that the model was accurately representing overflow locations and was sufficient for use in the Watershed Planning process. The totals for the entire monitoring period are shown in Table 2.11.

Table 2.11 Model Calculated Overflow Volume – June 25, 2007 to June 30, 2008

Overflow Category	Total Observed Volume (MG)	Total Model Calculated Volume (MG)	% Deviation
10 SSO Locations	145	146	+ 1%
28 CSO Locations	1,076	1,142	+ 6%

Based on the results of the model calibration and verification, SD1 has developed a highly calibrated hydraulic model that provides an accurate representation of the sewer system. This tool allows SD1 to have confidence in the results of the overflow volumes from the sewer system and their context with other pollution sources for use in making informed and accurate decisions for the Watershed Plans.

Model Application

Once the hydraulic model was updated and calibrated, it was applied to quantify the current performance of the system during a typical year rainfall event and used to size and evaluate the impact of different solutions designed to eliminate SSOs and control CSOs. The development of these conditions is described below.

It is important to note that the results from both the water quality tools and the infrastructure model are based on SD1's current understanding of the sewer system infrastructure and sources of pollutants in the watersheds. These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the sewer system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development.

Typical Year Development

As discussed previously, the CSO Control Policy (EPA, 1994) indicates that CSO controls should be evaluated to determine the average number of overflows per year that can be achieved with controls. EPA prefers that continuous simulations (rather than design storms) of the combined sewer system be used to evaluate the performance of CSO controls and their benefits (EPA, 1999). Typical conditions are needed for rainfall, which drive the infrastructure hydraulic model and overflow calculations.

SD1 analyzed available historical rainfall data from the Cincinnati/Northern Kentucky International Airport (1949-2005) and selected the 1951-2005 period for rainfall analysis, to consider only those years with complete rainfall records. These rainfall data were analyzed to identify a year-long period that was similar to historical averages of total rainfall, number of events, peak intensity and other rainfall characteristics.

Including these factors in the selection of a typical period helps to ensure that the overall rainfall depth is similar to the average and the distribution of specific storms over that period is also close to the average storm distribution. These factors also help ensure that a representative activation frequency will result and that back-to-back storm events are considered. Consideration of longer-term rainfall averages also is important for evaluation of storage facilities (tanks, tunnels), to ensure there is appropriate time for fill/drain cycles under all conditions.

To better understand improvements to water quality based on evaluation of controls, the typical period analysis was expanded to consider rainfall statistics during the recreation season (May 1 – October 31) and non-recreation season, to ensure that the distribution

of the storm events was not only typical among different rainfall categories but also typical among the seasonal distribution of events.

The analysis was conducted for different categories of rainfall depths and a score was assigned to the recreation and non-recreation season periods. The score for each category was based on how close that category matched the full period average. This computation was done for each category in the recreation and non-recreation seasons. For each typical period, there were 16 scores generated for the recreation season and 16 scores generated for the non-recreation season. The scores for all of the categories were then summed together to provide the most typical total rainfall period for the typical year.

The year 1970 was identified as the most typical and was used to size the infrastructure controls and verify their performance. The comparison of 1970 rainfall to averages for the 1951-2005 period is presented in Table 2.12. It should be noted that in the typical year, there is at least one event with a recurrence interval of two years (July 8, 1970, 2.2 inches in 4 hrs, results in a storm recurrence of greater than a 2yr/4hr storm (Huff and Angel, 1992)). In addition, as discussed in Section 2.1.1, a five-year period (1992 – 1996) was also used for evaluating the performance of the infrastructure controls for water quality purposes.

Table 2.12 Comparison of Rainfall in 1970 to Typical Statistics

Category – Typical Year		Recreation Season Average (1951-2005)	1970 Recreation Season	Non Recreation Season Average (1951-2005)	1970 Non Recreation Season
Annual Statistics	Total Depth (in)	21.3	20.35	19.7	20.46
Count of storms with depths (in)	< 0.25	32.1	31	40.7	43
	0.25 to 0.5	10.1	12	9.7	9
	0.5 to 1	8.8	10	8.8	15
	1 to 2	4.3	3	3.9	1
	2 to 3	0.9	1	0.6	1
	> 3	0.3	0	0.1	0
Count of storms with peak hourly intensities (in/hr)	< 0.1	27.1	25	42.4	44
	0.1 to 0.25	14.7	14	15.3	17
	0.25 to 0.5	9.1	10	5.1	6
	0.5 to 0.75	3.6	5	0.8	2
	> 0.75	2.1	3	0.2	0
# of Days - Weekly Rainfall Depth (in)	1 to 2	38.3	42	37.8	40
	2 to 3	12.9	14	10.5	11
	> 3.0	6.0	5	2.7	3
Weekly Maximum (in)		3.9	3.64	3.3	3.56

2.1.3 Green Infrastructure Characterization

SD1 characterized green infrastructure features to identify opportunities to maximize the storm water management capacity of the built and natural environment. SD1's evaluation of green infrastructure features has focused on the portion of the service area that is served by combined sewers. However, an inventory of physical characteristics pertinent to green infrastructure controls, namely an evaluation of natural and built systems, was compiled and reviewed across the entire service area. This inventory supports the selection of controls for the Five-year Improvement Program (Section 7). Sources of data for the natural and built systems evaluation, inventory results, and the evaluation of green infrastructure features in the combined sewer service area are discussed below.

Natural and Built Systems Evaluation

The natural and built systems inventory consisted of comprehensive evaluations of local conditions. GIS was used to combine multiple data sources and assess current conditions in regard to natural and built systems. Natural systems include hydrology (*e.g.*, rivers and streams, lakes, wetlands, watersheds, and flood information), geology, soils, and tree canopy cover; while built systems include impervious surfaces, transportation corridors, infrastructure (*e.g.*, utility structures, pipes, pump stations, locations of CSOs and sewersheds), land use information, and land cover information. GIS data were obtained from over twenty federal, state, and local-level sources.

GIS data are essential for regional and local level planning and design efforts. GIS data can be points (*e.g.*, locations of CSOs); lines (*e.g.*, roadways); or polygons (*e.g.*, parcels). These features contain geographic coordinates that indicate location and a variety of other attributes. ArcGIS software, developed by the Earth Sciences Research Institute (ESRI), was used to show the location and extent of existing landscape features (GIS inventory), and to identify opportunities and constraints for green infrastructure (GIS analysis). For example, data for hydrology were displayed to show the region's streams, rivers, wetlands and lakes.

Detailed maps were developed to create an inventory of the current conditions within the three counties, with a higher level of detail generated for the combined sewer service area. These inventory maps were then evaluated to analyze and identify potential opportunities for green infrastructure in Northern Kentucky.

During the analysis phase, GIS data were used to measure features within a specified distance from a boundary, and to integrate different layers into one composite data set. For example, ArcGIS software was used to determine the length of existing sewer and storm water infrastructure that was within 100 feet of a stream, and to combine separate data for buildings, roadways, parking lots, and driveways into one layer representing impervious surfaces.

Appendix 2-D contains a complete list of data sources and the results of the GIS inventory and analysis that were completed for the Northern Kentucky region and the combined sewer system.

2.2 Current Conditions

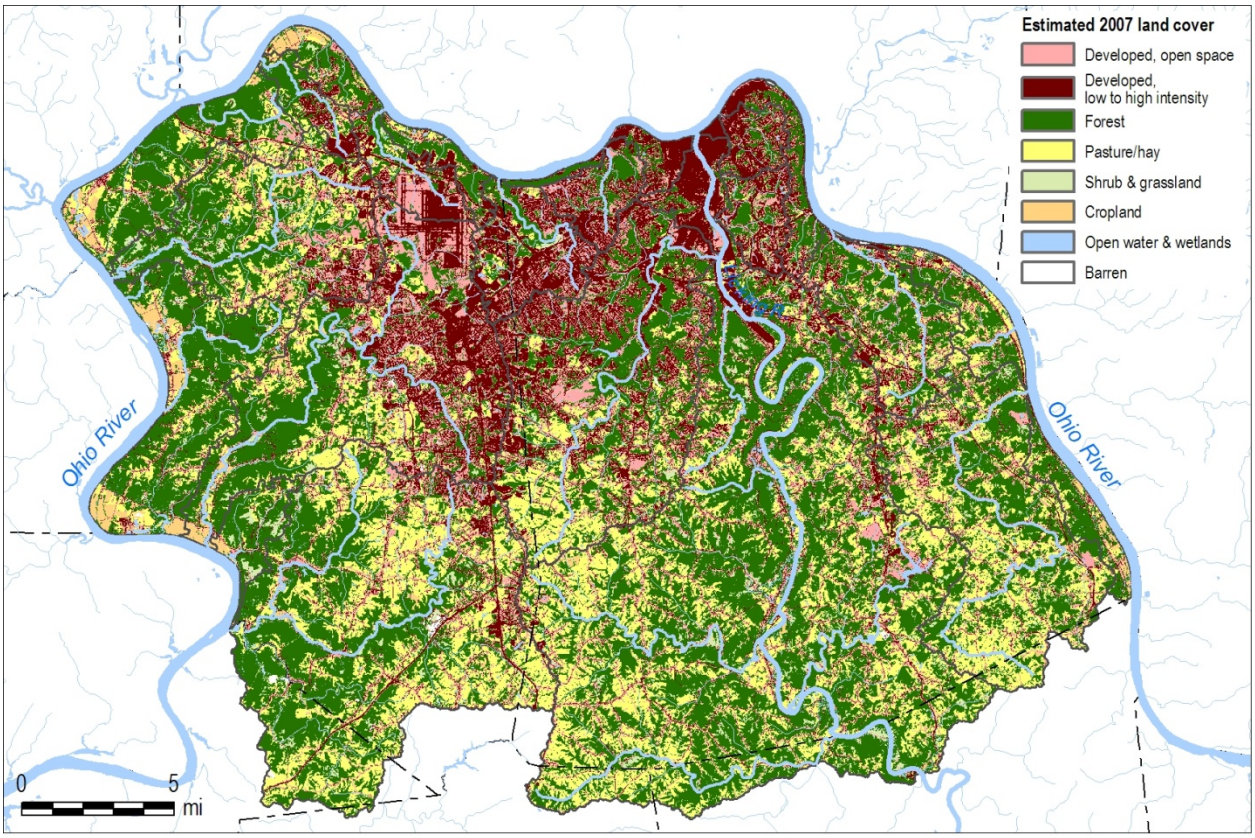
2.2.1 Overview

This section generally describes watershed, infrastructure, and green features and summarizes current conditions across the study area. Features that span watersheds are described more generally below, and characteristics and conditions that are watershed-specific are described later in this section for each of the four basins. This information is condensed and slightly updated from work presented in the individual Watershed Characterization Reports (WCRs) which are available at www.sd1.org and the WCR Summary Report (Appendix 2-A).

The 592-square mile study area contains sixteen watersheds, which are contained within four study basins. The study area watersheds range in size from 4.2 to 170 square miles and contain approximately 500 miles of named streams and several thousand miles of unnamed tributaries. The watersheds are characterized as having rolling hills as well as some areas with steep slopes. The underlying geology is primarily limestone and shale, with some areas underlain by glacial deposits and alluvium. The majority of the soils are classified as highly erodible and as having slow infiltration rates.

Development is currently concentrated in the north and central portion of the study area, and comprises 10% to 75% of the individual watersheds. Eight of the watersheds currently have imperviousness in excess of 10%; stream conditions in watersheds with 10% or higher imperviousness will generally be impaired (Booth and Jackson, 1997; May, 1997). The land cover in outlying areas remains predominately agricultural or forested (Figure 2.10). Development in Northern Kentucky is expected to continue to increase, and future conditions are discussed in Section 2.3.

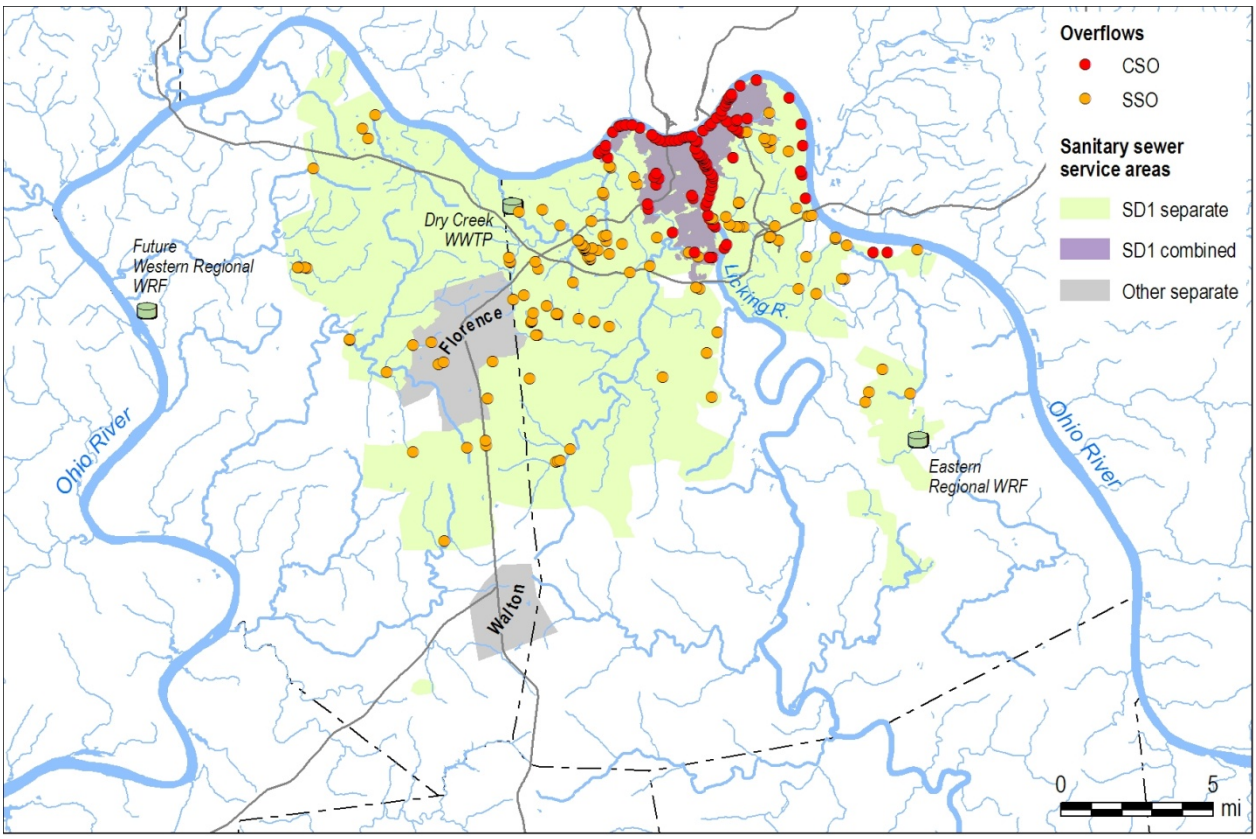
Figure 2.10 Estimated 2007 Land Cover



Gray Infrastructure Features

SD1's sewer system includes both a combined sewer system (CSS) and separate sanitary sewer system (SSS). A combined sewer system is designed to collect and convey sanitary wastewater and storm water through a single pipe. This type of system exists in several of the older communities in the study area, mainly in the river communities within the Central, North, and East Basins. Newer development in the southern and western parts of SD1's service area is more commonly serviced by separate sanitary and storm water sewers. In these systems, the storm water is discharged directly to local waterways. The extent of SD1's sewer system is shown in Figure 2.11 and a larger map can be found in Appendix 2-C.

Figure 2.11 Sewer Overflows and Sanitary Service Area



The sanitary service area in Northern Kentucky is approximately 194 square miles which includes the service areas for SD1 and the cities of Walton and Florence. Excluding the pipes and manholes maintained by Florence and Walton, SD1 is responsible for over 1,600 miles of pipe, 129 pump stations and over 45,000 manholes. SD1 is continually working to improve the capacity of the sewer system, as well as upgrade aging infrastructure.

Adjacent to SD1's service area, the City of Florence continues to own and maintain their sanitary sewer system. Flow is transferred to SD1's system through three main connection points. SD1 is working with Florence to implement controls to reduce the excessive I/I that is sent to SD1's system.

Flow collected in the sewer system is currently conveyed to one of two major treatment facilities. More than 90% of the wastewater generated in the SD1 service area is conveyed to the Dry Creek WWTP, located in the northern end of the service area. The Dry Creek plant has an average treatment capacity of 46.5 MGD and a peak sustained capacity of 75 MGD. The Eastern Regional WRF, completed in 2007, provides service to the eastern portion of the service area. This facility has an average treatment capacity of 4 MGD and a peak capacity of 12 MGD.

A third major treatment facility is currently under construction to provide sewer capacity to the western parts of SD1's service area. The Western Regional WRF will have an

average capacity of 20 MGD. Construction of this facility will provide hydraulic relief to the existing Dry Creek plant and the associated sewer system network, reducing and eliminating SSOs.

In the Consent Decree, 106 recurring SSOs are listed. Through infrastructure characterization and ongoing construction activities, SD1 has identified that many of the Consent Decree-listed SSOs are no longer active. However, through the update and recalibration of the model and through ongoing field work, SD1 has identified additional overflow locations within the separate system that have been confirmed to be recurring SSOs. In addition to the confirmed SSOs that have been identified, SD1 has also identified model-predicted overflow locations in the separate system that have not yet been confirmed. SD1 is currently conducting a comprehensive field investigation program to confirm that the overflow locations calculated by the model are actually occurring in the field. For the purpose of the Watershed Plans, all confirmed recurring SSO locations are being referred to as SSOs (a total of 126 locations including pump stations) and all additional model-calculated overflows that have not yet been confirmed will be referred to separately as model-predicted overflow locations..

Table 2.13 summarizes the CSO and confirmed recurring SSO locations by basin as well as the model-calculated volume for the typical year simulation.

Table 2.13 CSOs and SSOs by Basin for a Typical Year (1970)

Basin	Number of CSOs	Volume (MG)	Number of Confirmed SSOs	Total SSO Volume (MG) [1]
North	26	796.2	45	7.5
Central	39	790.2	51	158.6
East	32	286.4	21	73.4
West	0	0	9	2.6
Total	97	1,872.8	126	242.1

Note:
1. Includes the model-calculated volume from model-predicted overflow locations, as well as the volume prior to the Eastern Regional sewer system improvements

Many projects are well underway to reduce or eliminate known sewer overflows as well as to eliminate smaller treatment plants and failing septic systems. Many Initial Watershed Projects have been completed or are currently under construction to reduce or eliminate known sewer overflows as well as to eliminate smaller treatment plants and failing septic systems. Additional details on the existing infrastructure improvement projects are provided in Section 7 and Section 8.

SD1 will continue to monitor suspected overflow points that have been identified through modeling to determine if they are recurring SSOs. These efforts also help SD1 determine if an overflow was attributed to blockages or other easily fixed operations and maintenance issues, or if the overflow is capacity-related. Through the annual reporting

program, SD1 will continue to update the number of overflow locations and corresponding activation statistics.

Samples were analyzed for several constituents at different outfall types; however bacteria densities were of most interest for sewer system and water quality characterization efforts. Event mean concentrations (EMCs) were developed for both fecal coliform and *E. coli* bacteria for seven of the sampling events. Table 2.14 presents a summary of the EMC values calculated for each of the source types, based on the collected sample data.

Table 2.14 Bacteria EMC Values by Source Type

Source Type	No. of Calculated EMCs	Geometric Mean of EMCs (cfu/100 ml)	
		Fecal Coliform	*E. coli*
CSO	45	682,000	210,000
SSO	10	1,870,000	704,000
Older Urban Storm Water	22	86,500	17,300
Newer Urban Storm Water	8	14,200	6,840

Since SD1's system varies in age and land use, storm water samples were collected at different locations in the system in an attempt to determine if storm water quality from older urban areas differs from storm water from newer urban areas. Results show that there is a difference between the two sources. The higher values seen with the older urban sources are likely attributed to illicit cross connections that have been made into the expansive older urban storm water network over time. The lower densities observed in the newer urban storm water could be attributed to better design practices and oversight by utility inspectors who are checking for illicit cross connections during development of subdivisions.

The EMC values were used in the watershed and water quality models as the models were calibrated to instream fecal coliform data. The detailed water quality models were calibrated using the fecal coliform EMC values of 682,000 colony forming units per 100 milliliters (cfu per 100 ml) for CSOs and 1,870,000 cfu per 100 ml for SSOs. The models were also applied using *E. coli* and compared to data during the calibration process.

The bacteria EMCs characterizing storm water runoff from older and newer developed areas were also used in the detailed models to constrain the modeled fecal coliform bacteria runoff density from developed areas. During model calibration, parameters affecting bacteria densities in runoff were adjusted to approximate the monitored bacteria EMCs from the older and newer developed areas. The geometric mean fecal coliform density from outfalls in older areas was 86,500 cfu per 100 ml, while in the newer areas, the geometric mean density was 14,200 cfu per 100 ml. Using the Banklick model as an example, this division in the storm water data was consistent with the instream monitoring data for Banklick Creek, which showed an increase in fecal coliform densities in the vicinity of the older developed areas not fully accounted for by other watershed and infrastructure sources.

Designated Uses, Stream Condition and Sensitive Areas

Designated uses and applicable water quality criteria, state-impaired waterways, ongoing or planned total maximum daily load (TMDL) studies and sensitive areas are all described in this section. Stream conditions are also generally described, with additional waterway-specific conditions described in subsequent sections.

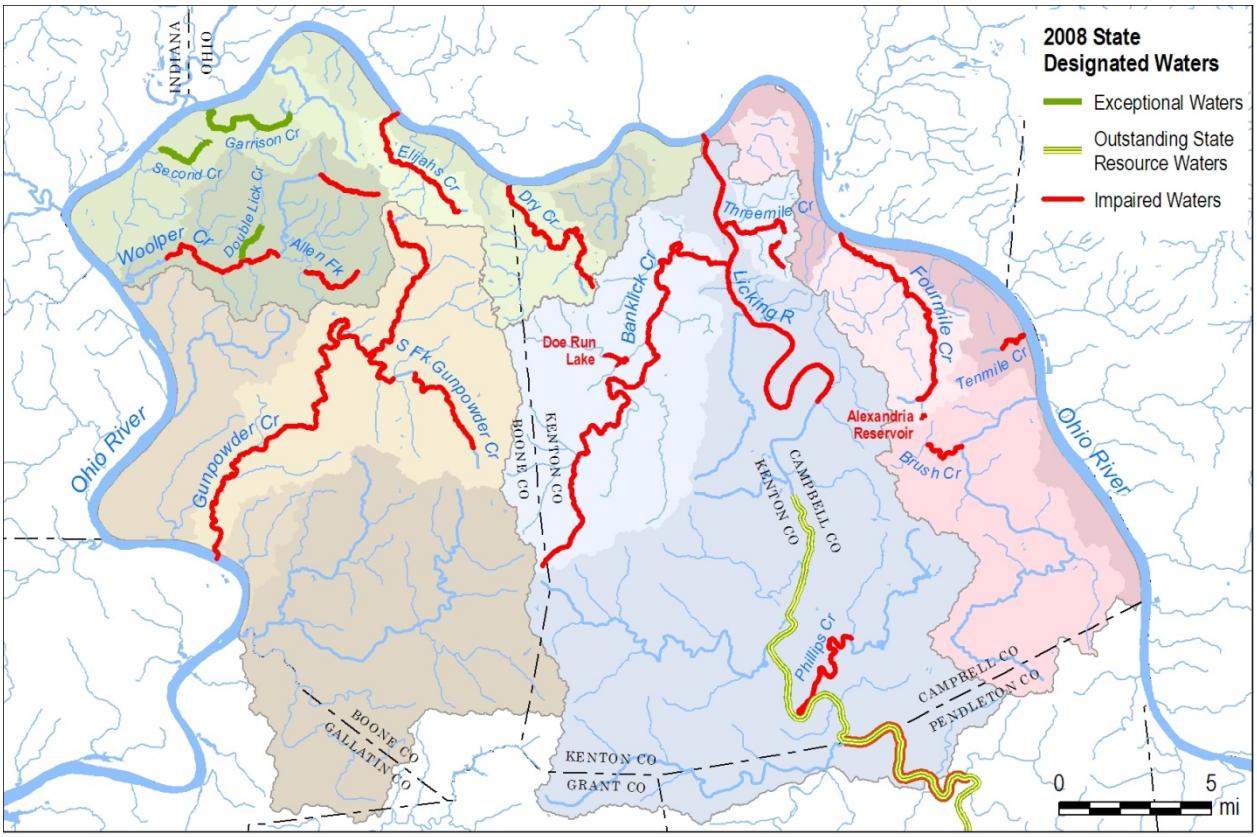
KDOW promulgates water quality standards that designate each waterway with a particular use. All waterways in the study area are designated by the State for warm water aquatic habitat, primary contact recreation, secondary contact recreation and domestic water supply, applicable at existing points of public water supply withdrawal[2] (401 KAR 10:026). Water quality criteria associated with the designated uses are presented in Appendix 2-E, for parameters that have been measured. Information discussed below and included in Appendix 2-E is current as of June 2009.

KDOW has designated a portion of the Licking River as an Outstanding State Resource Water, and portions of Double Lick Creek, Second Creek and Garrison Creek as exceptional waters and reference reach streams (Figure 2.12; KAR, 2008). KDOW identifies waterways that do not support their designated uses on the 303(d) list of impaired waterways. Ten watersheds contain at least one waterway that appears on the 2008 303(d) list, due to partial or non-support of the primary contact recreation (swimming) or warm water aquatic habitat use (Figure 2.12). Roughly 105 unique miles of study area streams and 57 acres of lakes have been identified as impaired (KDOW, 2008). The most commonly identified pollutants include fecal coliform, sediment, nutrients, and organic enrichment. In some cases, such as locations where the fish or macroinvertebrate populations are impaired, the pollutants are unknown. In other cases, habitat impairments are likely caused by excessive stream flow, which is not considered a pollutant. Instream data collected by SD1 and other agencies generally support the KDOW assessments of impairment, or provide information for segments not assessed by KDOW.

KDOW has approved two TMDLs (Elijahs and Gunpowder glycol TMDLs) to address impacts from deicing fluid runoff from the Cincinnati/Northern Kentucky International Airport (KDOW, 1998). There are no CSOs in either of those two watersheds. TMDLs are currently planned for Banklick Creek, Threemile Creek, Woolper Creek and Gunpowder Creek for a variety of pollutants including nutrients, organic enrichment, total suspended solids, sedimentation/siltation and fecal coliform (KDOW, 2008).

[2] There are three public water supply intakes in the study area. Two intakes are in the Licking River and one is in Big Bone Lick State Park Lake. There are three additional public water supply intakes in the Ohio River.

Figure 2.12 Impaired or Special Waters (2008)



Current stream conditions have been assessed through analysis of recent water quality, habitat, and biological data, supplemented by information obtained through site visits, interviews with local agencies, and published reports. Typical water quality problems in the study area include elevated levels of bacteria (fecal coliform and/or *E. coli*) during wet and dry weather conditions, low dissolved oxygen, and some exceedances of pH and metals criteria. Aquatic habitat and biological conditions range from very poor to excellent, both within and between the watersheds. Streambank erosion is severe in places, and has been identified as a problem in portions of all sixteen watersheds. Flooding occurs within eleven watersheds, and is a recurring problem in some areas, especially in the Taylor and Banklick Creek watersheds.

SD1 conducted a comprehensive assessment of sensitive areas, as defined by the CSO Control Policy, and identified sensitive areas in all sixteen watersheds. Even though CSOs are not present in all watersheds, SD1 chose to assess sensitive areas throughout the study area for watershed planning purposes.

Sensitive areas in the study area include waters with threatened or endangered species and their habitat, public drinking water intakes and their designated protected areas, and waters with primary contact recreation. Under the CSO Control Policy, if sensitive areas are present and are impacted by CSOs, eliminating or relocating CSOs that impact the areas should be given priority if this is feasible (EPA, 1995b). A summary of

sensitive areas in relation to watersheds with CSOs is presented in Table 2.15, along with clarification as to whether the sensitive area is located upstream or downstream of CSOs. The consideration of sensitive areas in relation to CSO control prioritization is discussed in Section 6.

Table 2.15 Sensitive Area Summary for Watersheds with CSOs

Sensitive Area	Banklick Creek	Fourmile Creek	Licking River	Ohio East	Ohio North	Pleasant Run Creek	Taylor Creek	Notes
Primary contact recreation use designation	Y	Y	Y	Y	Y	Y	Y	--
Threatened and/or endangered species that depend on aquatic habitats	Y	NA	Y	Y	Y	Y	NA	All are located upstream of CSOs
Public drinking water intakes from surface sources	NA	Y (Watershed is upstream of Ohio R. intake)	Y	Y (Watershed is upstream of Ohio R. intake)	NA	NA	NA	Licking River intakes are located upstream of CSOs.
Source water protection area	Y	Y	Y	Y	NA	NA	NA	Y means a portion of the watershed is within source water assessment and protection zone 1.
Outstanding National Resource Waters	NA	NA	NA	NA	NA	NA	NA	--
National Marine Sanctuaries	NA	NA	NA	NA	NA	NA	NA	--
Shellfish beds	NA	NA	NA	NA	NA	NA	NA	--

NA = Not applicable

Sensitive areas were also identified in the nine non-CSO watersheds. All waterways in the study area are designated for primary contact recreation; however, it is not clear whether swimming occurs in these waterways, as public surveys regarding this information are unavailable. Furthermore, threatened and endangered species dependent on aquatic habitat were identified in the Woolper Creek and Big Bone Creek

watersheds, and a public drinking water intake was identified in the Big Bone Creek watershed.

Current Uses

In addition to the drinking water uses noted above within the Central and West Basins, fishing and boating are also identified uses, occurring within all four basins. The use of Northern Kentucky waterways for swimming is generally not known. The exception is that swimming and wading are reported uses in the Gunpowder Creek watershed, and wading has been observed in Banklick Creek.

Summary of Potential Sources

Potential pollutant sources in the study area include 97 CSOs[3], 131 SSOs[4], point and nonpoint sources of runoff, 355 other KPDES[5]-permitted discharges, and failing septic systems (roughly 12% of all property parcels are not served by a public sewer system)[6]. The distribution of these sources in the study area is shown on Figure 2.13 and previously on Figure 2.11, along with the boundaries for the sanitary (wastewater) and storm water service area. The City of Florence is shown separately, because this community is responsible for its own wastewater and storm water. Florence does not have its own wastewater treatment facility. Wastewater from Florence is discharged to and treated by the SD1 system.

The potential for pollutant sources to generate fecal coliform bacteria loads has been assessed using the WAT!. Pollutant sources represented in WAT! include sewer overflows, other permitted point sources, failing septic systems, straight pipe discharges, animal feeding operations, and runoff from different land uses. Results are presented for a five-year typical period (1992-1996) and incorporate calculated sewer overflow volumes from the infrastructure hydraulic model simulations for the same period.

[3] 97 CSOs had been identified as of Nov. 21, 2008. Subsequent work has identified two that have been eliminated, and three determined not to be CSOs. These changes will be included in subsequent Watershed Plan updates.

[4] This includes 96 SSOs and 30 pump stations identified as SD1 SSOs either in the Consent Decree or in the April – June, 2008 Quarterly Report, and 5 Florence SSOs identified in the Florence Sanitary Sewer Overflow Plan (City of Florence, 2007).

[5] KPDES stands for Kentucky Pollutant Discharge Elimination System. Any point source that discharges to a Kentucky stream must have a permit from the State to ensure that the discharge will not adversely impact stream water quality.

[6] Septic information is not available for the southern-most extent of the watersheds, which extend approximately 12 square miles beyond the SD1 jurisdictional area and into Pendleton, Grant and Gallatin Counties.

Figure 2.13 Other Permitted Discharges, Properties Potentially Served by Septic, and Storm Water Service Area

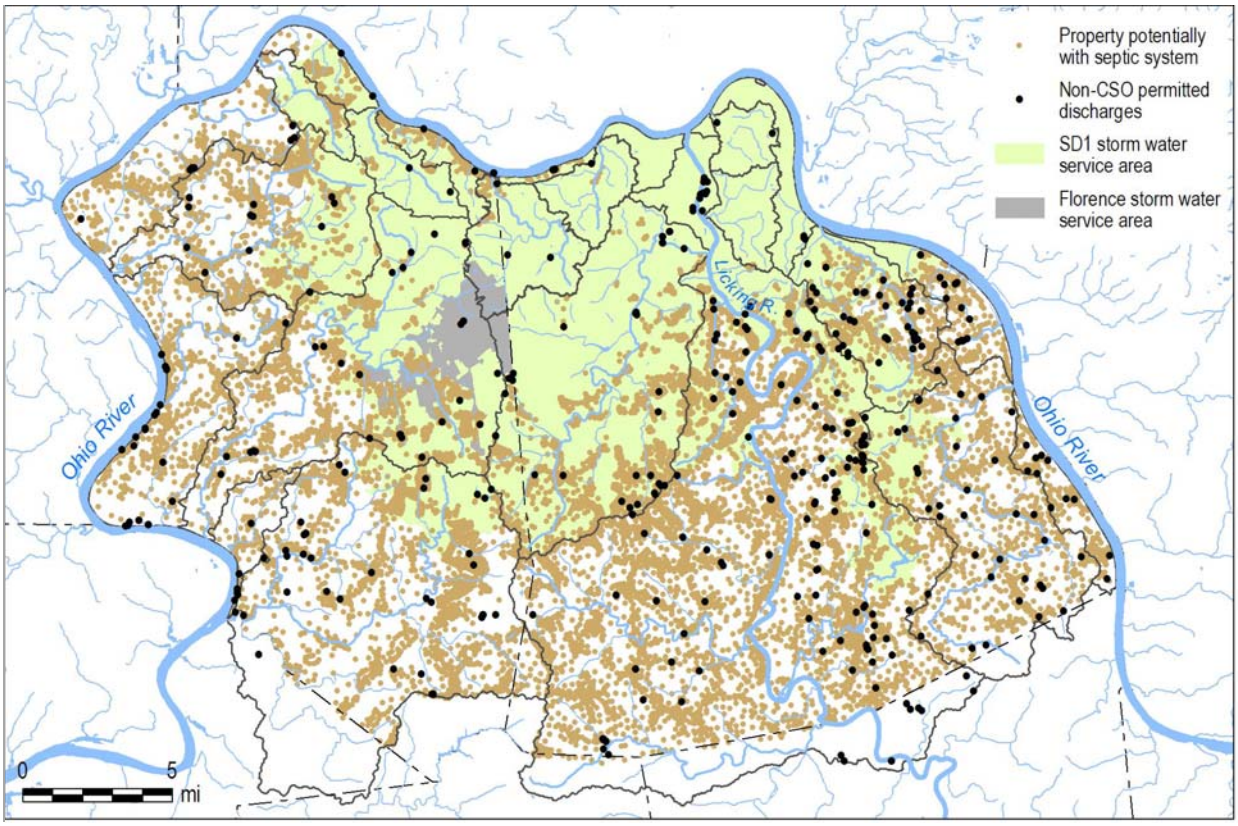
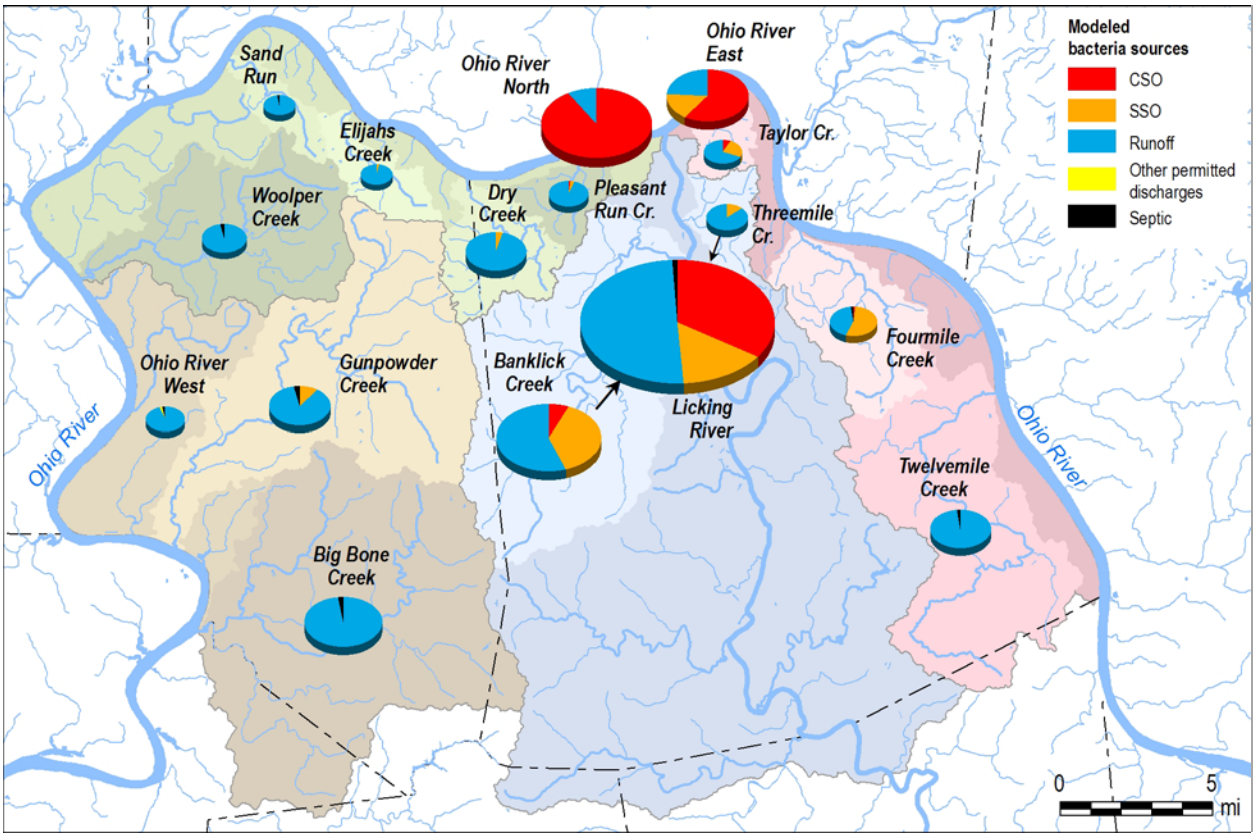


Figure 2.14 summarizes the results of the WAT! analysis. The loadings within each watershed were estimated, and the pie charts reflect the calculated bacteria contribution from CSOs, SSOs, runoff, KPDES discharges, and septic sources within the watershed. The pie charts are sized to reflect potential for each watershed (within the study area) to generate fecal coliform bacteria for year-round conditions, relative to the other study area watersheds. The relative size of each pie chart reflects the modeled bacteria load for that watershed. In most watersheds, runoff (e.g., runoff from agricultural, developed and forested lands) is the source with the highest potential to generate bacteria. The pie chart shown for the Licking River includes the contributions from sources in the Banklick and Threemile Creek watersheds, which are tributaries to the Licking River[7].

[7] Less than 5% of the 3,600 square mile Licking River watershed lies within the study area. The pie chart for the Licking River represents the load generated within the study area.

Figure 2.14 WAT! Loading Potential Results for Fecal Coliform



The pie chart shown for the Licking River includes the contributions from sources in Banklick and Threemile Creeks, which are tributaries to the Licking River. The pie chart does not incorporate contributions from the Licking River watershed upstream of the study area.

Green Features

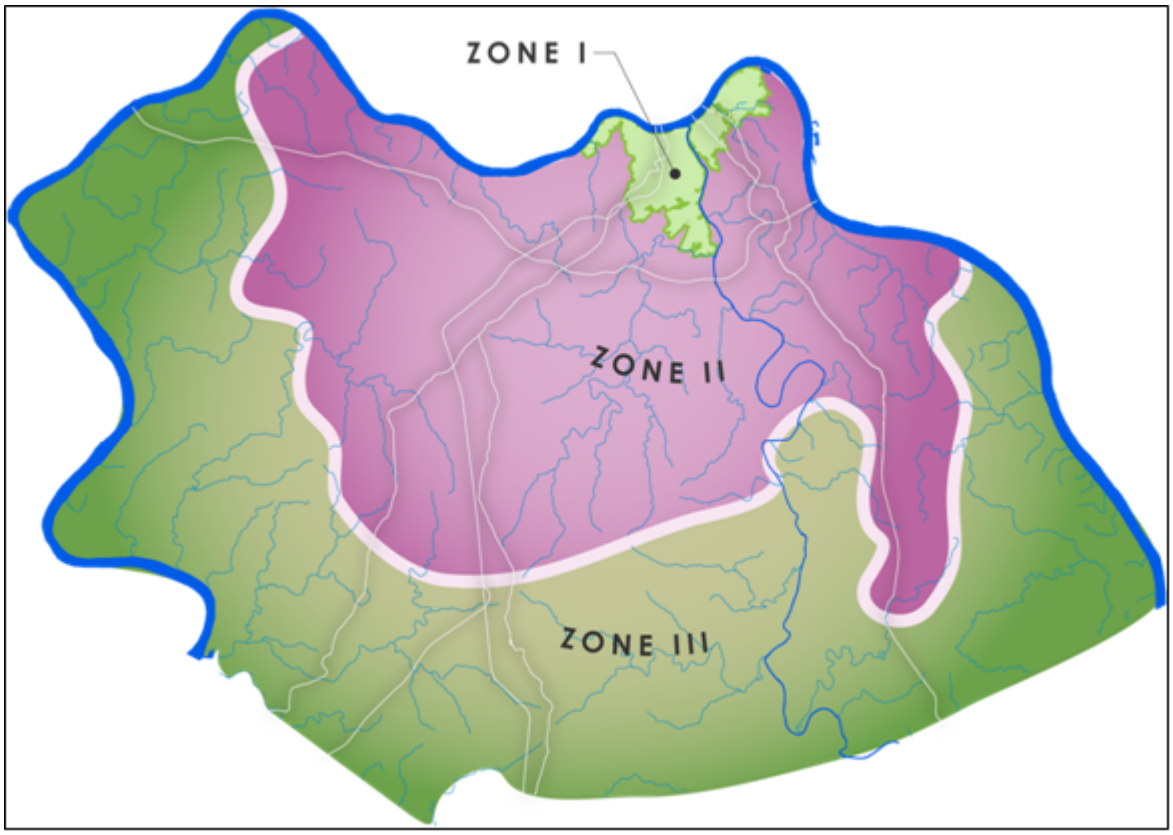
The urbanization of cities has involved the systematic replacement of streams and wetlands with hard surfaces and piping networks. The result has been a lower ground water table, lower base flows in streams, higher peak flows in the streams during wet weather and an overall change in the natural hydrologic and hydraulic cycle. Green infrastructure can be used to restore some of the natural hydrologic balance and maximize the functional capacity of natural systems to convey and infiltrate storm water. In the combined sewer system, the objective is to restore some of the natural hydrologic balance. For less developed and undeveloped areas further away from the urban core, the objective transitions from restoration to protection.

Natural and Built Systems Regional Inventory Results

To support the evaluation of green infrastructure opportunities, SD1 delineated the three-county area into three zones: Zone I, Zone II, and Zone III. Each zone is characterized by different physical conditions (i.e., varying land use, varying infrastructure, natural systems, and built systems); therefore, each zone has a unique set of existing infrastructure-related challenges and constraints.

As shown in Figure 2.15, Zone I covers the 10-square mile combined sewer system. This urban core includes the older, highly developed river cities. Zone II covers 235 square miles and includes the remainder of SD1's sanitary sewer and storm sewer service areas. This zone is characterized by suburban development. Zone III covers 335 square miles and includes areas of Boone, Kenton and Campbell counties that lie outside the SD1 service area.

Figure 2.15 Zone Delineations for the Green Infrastructure Evaluation



The root cause of excessive runoff is impervious surfaces. There are approximately 37.3 square miles of impervious surfaces in the three-county area, representing 7% of the total land area. As landscapes are developed, natural vegetation is replaced with pavement and rooftops, wetlands are destroyed, and riparian buffers are lost to development or agriculture. As a result the rate and volume of runoff that occurs during precipitation events dramatically increases.

A detailed evaluation was performed on the three-county region to identify opportunities for preserving, enhancing, and restoring the region's natural systems. These opportunities are aimed at reducing runoff by increasing infiltration and evapotranspiration. In addition to quantifying the amount of impervious surface throughout the study area, it is important to understand the primary land uses. Table 2.16 provides the distribution of different land uses within Northern Kentucky and information on the percent of each zone covered by impervious surfaces.

Table 2.16 Land Use and Impervious Surface Distribution in Northern Kentucky

Land Use Description	Zone I	Zone II	Zone III	Total
Agricultural	0%	16%	33%	28%
Residential	49%	34%	14%	24%
Woodlands	0%	10%	23%	19%
Undeveloped	0%	10%	17%	15%
Transportation (includes airport)	19%	9%	1%	5%
Industrial	2%	4%	1%	2%
Commercial	10%	4%	0%	2%
Other (public, institutional, office, etc.)	20%	13%	11%	5%
Impervious Surfaces	38%	12%	2%	6%

Natural systems such as stream networks (existing and historical), soils, geology and wetlands were evaluated and considered in the identification of opportunities to implement green infrastructure. With the goal of promoting controls that closely mimic the natural hydrologic cycle, an important first step in the green evaluation process was to develop an understanding of natural systems in terms of their location, capacity and suitability to accommodate additional runoff. For example, within the three-county area there are 460 miles of major streams and 5.3 square miles of lakes. There are approximately 223 square miles of tree canopy cover, representing approximately 38% of the land area.

Many green infrastructure controls rely on infiltration as the primary mechanism to achieve runoff volume reductions. Slopes, soils, and geology are important components in determining if and where runoff can be infiltrated into the subsurface. There are approximately 58 square miles of land with slopes over 20%. These areas are more landslide-prone, susceptible to erosion and can exacerbate flooding.

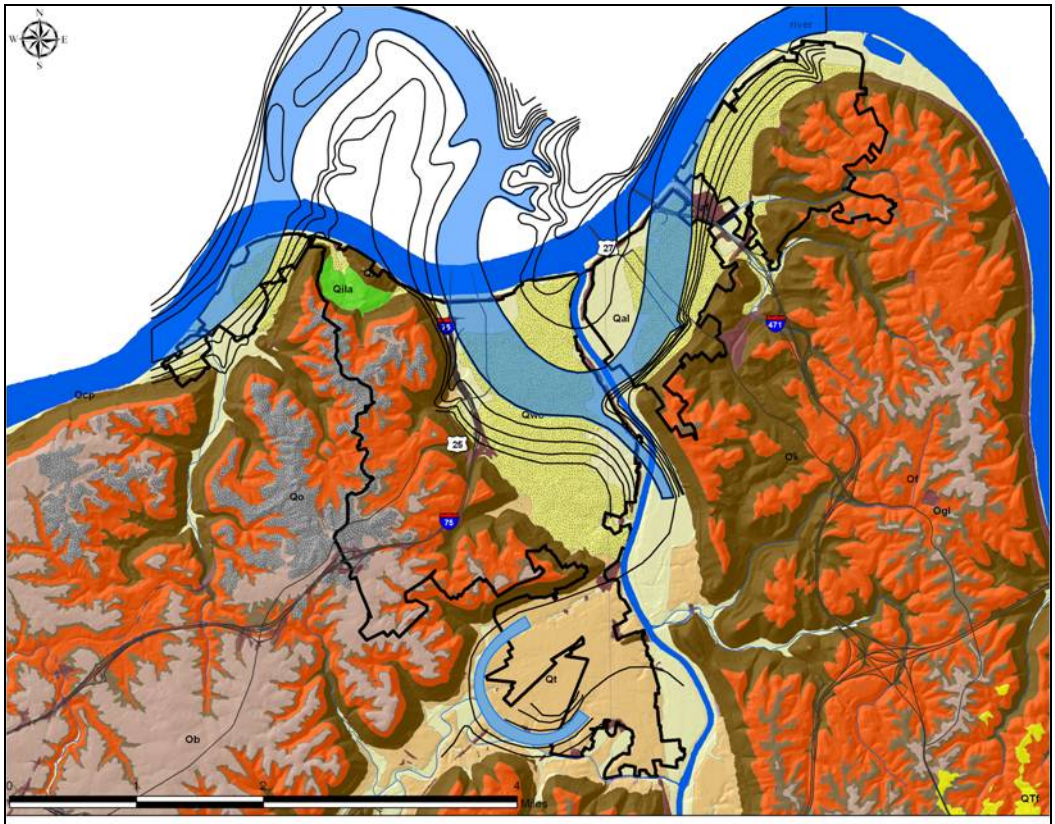
Soil permeability plays a major role in the design configuration and the functionality of certain green controls. High permeability rates can reduce the required footprint and/or depth profile of a proposed green control resulting in very cost effective designs. SD1 worked with a local geotechnical engineer with years of experience in the Northern Kentucky area to evaluate the soils and geology in this region. A generalized understanding of soil and rock conditions was generated using a combination of published subsurface data, engineering experience, and local records of excavations and soil test borings within the study area. The evaluation showed limited opportunities for shallow infiltration and highlighted unstable geologic layers along steep hillsides. In addition, areas of alluvium deposits were identified along existing stream beds as well as some glacial outwash along portions of the Ohio and Licking Rivers. These deposits help identify the ancestral river beds of the Ohio and Licking Rivers shown in Figure 2.16.

Reforestation can be an effective tool at reducing the quantity of storm water runoff and improving the quality of runoff. A CITYgreen™ evaluation was performed for the

Northern Kentucky region. CITYgreen is a GIS-based tool, included in EPA's recommended tools for green infrastructure[8] which analyzes the ecological and economic benefits of tree canopy cover (American Forests, 2006). CITYgreen was developed by American Forests, Inc., a pioneer in the science and practice of urban forestry. In addition to computing air pollution removal and carbon storage, this tool calculates storm water runoff using the Natural Resource Conservation Service (NRCS) model. Several major cities have used the CITYgreen tool to guide implementation of green infrastructure programs. For Northern Kentucky, CITYgreen calculated that the existing tree canopy provides 579 million gallons of storage based on a 2-year, 24-hour rainfall design storm, CITYgreen's programmed design storm. Maintaining or increasing this coverage will provide SD1 with additional storm water benefits.

[8] CITYgreen™ is one of the tools included on EPA's website for green infrastructure (www.epa.gov/greenkit/toollan.htm).

Figure 2.16 Deposits of Glacial Outwash and Alluvium Form Ancestral River Beds



KGS Detailed Geology

- Qaf - Alluvial Fan Deposits
- Qal - Alluvium
- Qam - Alluvium of valley sides, etc.
- af - Artificial fill
- Ob - Bull Fork Formation
- Qe - Eolian sand, dune sand
- Of - Fairview Formation
- Qid - Glacial drift (Illinoian)
- Qd - Glacial drift (pre-Illinoian)
- Qio - Glacial outwash (Illinoian)
- Qwo - Glacial outwash (Wisconsinan)
- Qgl - Grant Lake Limestone
- QTf - High-level fluvial deposits
- Ok - Kope Formation
- QTlf - Lacustrine and fluvial deposits (pre-Illinoian)
- Qila - Lacustrine deposits (Illinoian)
- Qwla - Lacustrine deposits (Wisconsinan)
- Lake - Lake area
- Qld - Landslide and alluvial fan deposits
- Ql - Loess
- Qo - Outwash deposits (pre-Illinoian)
- Ocp - Point Pleasant Tongue of Clays Ferry Formation
- River - River area
- Qt - Terrace deposits

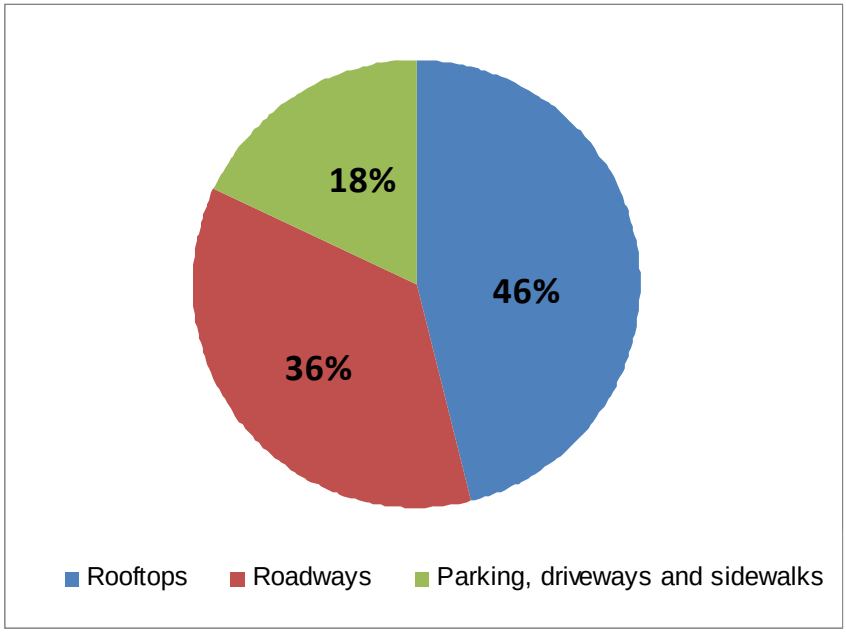
Green Infrastructure Features within the Combined Sewer System

The regional evaluation of green infrastructure features defined the unique characteristics of the study area (including geology, soils, stream networks, canopy cover and topography) that supported the evaluation of how green infrastructure could best be incorporated into the Watershed Plans. Because the Consent Decree requires SD1 to develop a plan to address its CSOs, the combined sewer area has been identified as the primary focus for green infrastructure techniques within the first five years.

A detailed impervious area evaluation was performed for Zone I, to determine the distribution of impervious surfaces and their relative significance throughout the approximately 10-square mile combined sewer service area. Major categories of impervious surfaces were identified to aid in selecting appropriate green techniques to reduce runoff from these surfaces.

A total of 3.4 square miles (38%) of the combined sewer service area is covered by impervious surfaces. This impervious area is comprised of rooftops (44 million square feet), roadways (33 million square feet), and parking lots, sidewalks and driveways (17 million square feet), as shown in Figure 2.17.

Figure 2.17 Impervious Surfaces by Category in Zone I



An evaluation of impervious surfaces by land use type showed that 43% of the impervious surfaces in the combined sewer system are located on publicly owned property, including roadways. However, SD1-owned property includes only 9,000 square feet, or 0.01%, of hard surface. This underscores the importance of partnerships in promoting the use of green infrastructure to reduce overflows.

A breakdown of the primary land use types that account for the majority of impervious surfaces in the combined sewer system is provided in Table 2.17.

Table 2.17 Impervious Surface by Land Use Type Evaluation in Zone I

Land Use Classification	% of CSS	% Impervious
Residential Property	44%	24%
Public Property (including roadways)	24%	69%
Commercial Property	18%	48%
Right of Way Property (excluding pavement)	12%	0%
Industrial Property	1%	65%
Unknown Property	1%	99%

For the green infrastructure program to have a major impact on CSO reduction in Northern Kentucky, the program will need to target roads, residential properties and some percentage of commercial land uses. These three land use types represent approximately 87% of the total impervious area in the combined sewer system.

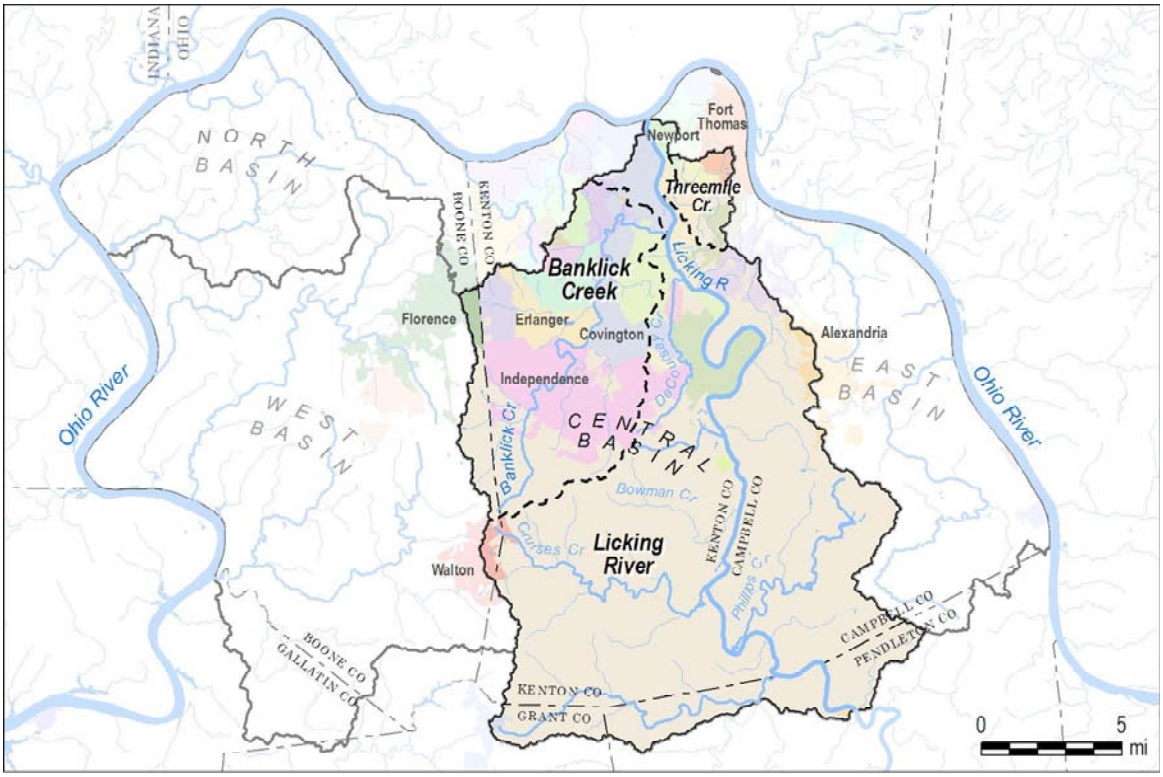
Teaming Partners

SD1 has identified many potential teaming partners that are actively conducting monitoring, investigating greenways and implementing stream or wetland restoration projects within the study area. Organizations actively conducting stream monitoring include KDOW, ORSANCO and the Licking River Watershed Watch. Organizations investigating greenways include the Boone County Planning Commission (Boone County greenways), Riverfront Commons (Ohio River greenway) and Vision 2015 (Licking River greenway). Additionally, the Banklick Creek Watershed Council has obtained funding to implement controls within that watershed. The Boone County Conservation District has received 319 funding for developing a watershed-based plan to address nonpoint source pollution and related issues in the Gunpowder Creek watershed. The Woolper Creek watershed group has also been notified that they will receive 319 funding, pending revisions to their application. Finally, Northern Kentucky University's Center for Applied Ecology has plans to conduct stream and wetland restoration at several sites in the study area. Additional detail related to teaming partners programs and projects can be found in the Watershed Characterization Reports (www.sd1.org).

2.2.2 Central Basin Characteristics

Bisected by the Licking River mainstem, the Central Basin extends from the Licking/Ohio River confluence southward into Pendleton and Grant counties, just beyond the Kenton and Campbell County boundaries (Figure 2.18). The basin is 234 square miles in size, 77 of which are within the SD1 sewer service area. SD1 has delineated this basin into three major watersheds: 1) the Licking River mainstem and its minor tributaries (those primarily in the rural, southern portion), 2) Banklick Creek, and 3) Threemile Creek. Although the Threemile Creek watershed is small, it was denoted as a primary watershed because it lies entirely within the SD1 service area and has been subjected to fairly intense development, both historical and new. The portion of the Licking River outside this basin (approx. 95% occurs beyond the study area boundaries) is not included in this characterization. Watershed and infrastructure features are summarized in SD1's Watershed Summary Report (Appendix 2-A), and in the individual Watershed Characterization Reports which are available at www.sd1.org.

Figure 2.18 Central Basin and Watersheds

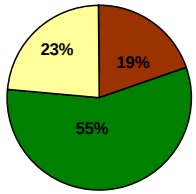
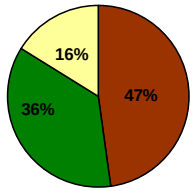
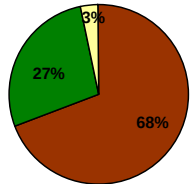
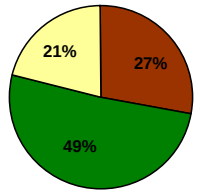


Watershed Features

The Central Basin contains the highest elevations in the study area (966 feet) and soils are predominantly characterized as having slow infiltration rates and as being fairly to highly erodible. Important features of the three Central Basin watersheds are presented in Table 2.18. The Licking River tributaries drain rolling hills and narrow valleys, which widen as they approach their confluence with the mainstem, which itself is quite wide, ranging in widths form 100 to 300 feet. The elevation of the mainstem varies little

between the mouth and RM 4.8, and is impacted significantly by backwater from the Ohio River. Backwater effects have also been observed in Banklick Creek from the Licking confluence upstream to RM 3.8 and in Threemile Creek, less than one mile upstream from the Licking.

Table 2.18 Watershed Characteristics for the Central Basin

Feature	Licking River	Banklick Creek	Threemile Creek	Central Basin
Drainage Area (square miles)	170.0 [1]	58.2	5.9	234
USGS station and location	03254520, Licking R. RM 19.3 [2] 03254480, Cruises Cr. RM 8.0	03254550, Banklick Cr. RM 8.1	03254695, Threemile Cr. RM 0.3 [2]	NA
2006 Average Annual Flow (cfs)	-- (Licking) 24 (Cruises)	43.3	--	NA
Mainstem length (miles)	35.6	19.2	4.8	59.6
2007 Land Cover Developed Forest/shrub Agriculture				
Current (2007) imperviousness (percent)	3%	11%	17%	5.6%
Future (2030) imperviousness (percent)	4%	17%	19%	7.9%

Notes:

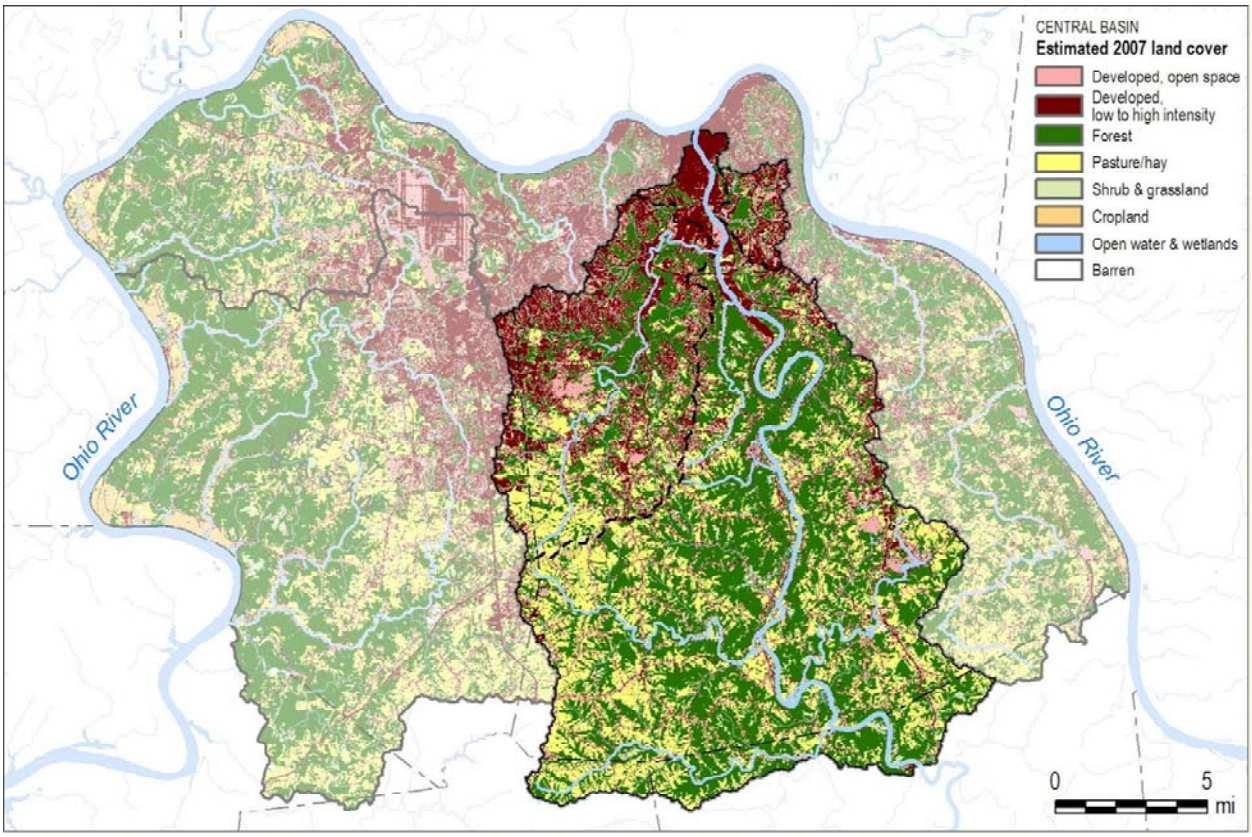
1. The Licking River extends 300 river miles to Magoffin County, KY, with only the last 35.6 miles lying within the Central Basin. The Licking River drainage area is 3,600 square miles, with less than 5% lying within the Central Basin study area.
2. These stations began operating in 2007 and flow data were not available as of June 2009.

NA = Not applicable

-- indicates data were not available as of June 2009

Current land cover in the Central Basin is shown in Figure 2.19. Development is primarily concentrated in the north, giving way to a predominantly rural landscape to the south. Within this basin, portions of the Banklick Creek watershed are currently experiencing rapid development.

Figure 2.19 Current (2007) Land Cover in the Central Basin



The more highly developed areas in this basin are predominantly served by SD1's sanitary sewer system, with a small portion served by the City of Florence's sanitary sewer system. Properties located outside the sanitary sewer service area primarily use septic systems and small wastewater treatment plants (less than 1,000 gallons per day). Roughly 70% of the sanitary wastewater outfalls are covered by residential general permits for individual family residential package wastewater treatment plants.

Agriculture uses within this basin include cropland and pastureland, which are more predominant in the southern portions. Cattle, horses, sheep, swine and some poultry are common (and include permitted animal feeding operations), and in several instances, these livestock have stream access.

Green Infrastructure Features

Specific features within this basin are relevant to the identification of green infrastructure opportunities in this area. These include:

- 187 miles of rivers and streams (excluding the Ohio River)
- 1,270 acres of lakes
- 8,990 acres of impervious surfaces (roughly 6% of the land area)
- 58,220 acres with slopes over 20% (39% of the land area)
- 8,370 acres of right-of-way (6% of land area)
- 57,210 acres of tree canopy coverage (38% of the land area)

The amount of impervious surface in combination with major land uses within the basin will guide SD1 to the best green techniques for this region. Table 2.19 provides the distribution of different land uses within the Central Basin.

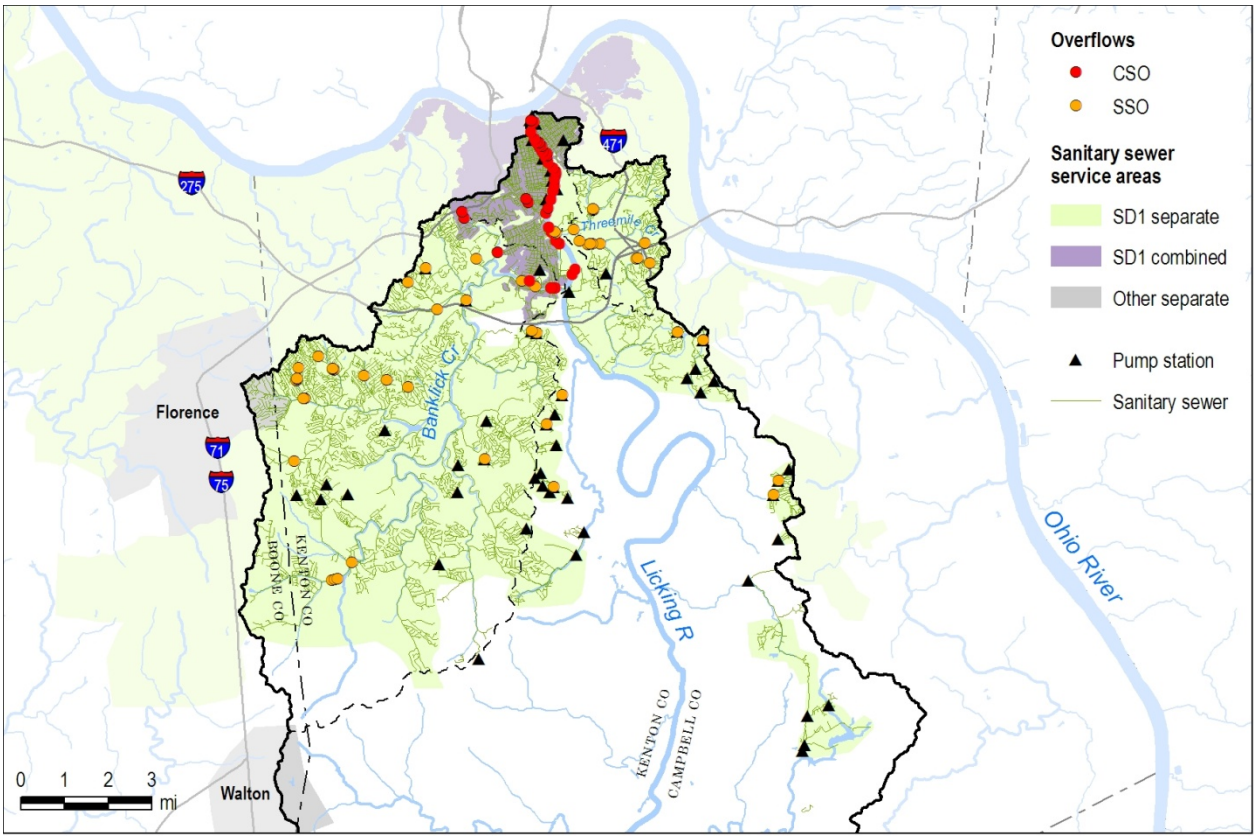
Table 2.19 Central Basin Land Use Distribution

Land Use Type	% of Area
Agricultural	28%
Residential	28%
Woodlands	2%
Undeveloped	24%
Transportation (includes airport)	4%
Industrial	2%
Commercial	2%
Other	10%

Gray Infrastructure Features

The Central Basin includes portions of SD1's separate and combined sanitary sewer systems. The Central Basin combined sewer service area, shown in Figure 2.20, generally runs along the Licking River and flows are ultimately routed to the Dry Creek WWTP. The separate sanitary sewer service area generally runs along Banklick Creek with flows routed to the Dry Creek WWTP.

Figure 2.20 Central Basin Service Area



A detailed map of the gray infrastructure is provided in Appendix 2-C. Southern portions of the basin will eventually be redirected to flow toward the West Basin once the Western Regional Conveyance System and WRF are in operation. The planned Western Regional improvements are discussed in further detail in Section 7 of this report.

Combined Sewer System

The combined sewer system is located at the north end of the Central Basin. A large portion of the combined system is served by regional pump stations that pump flow to the Licking River Interceptor. Table 2.20 provides a summary of combined sewer system characteristics for the Central Basin by watershed.

Table 2.20 Central Basin Combined Sewer System Summary

Parameter	Banklick Creek	Licking River	Threemile	Central Basin
Combined Sewer (miles)[1]	18.2	95.6	0	113.8
Diameter Range (inches)	8 - 60	6 - 100	N / A	6 - 100
Number of Manholes[1]	672	5,299	0	5,971
Number of Pump Stations[1]	1	1	0	1
Number of Treatment Plants[1]	0	0	0	0
Forcemain (miles)[1]	1.5	< 0.1	0	1.6
Current Service Area (square miles)[2]	1.2	3.6	0	4.8
Number of Overflow Points[3]				
CSOs	5	34	0	39

Notes:

1. Combined sewer designation for sewers, manholes, pump stations, treatment plants, and forcemains were based on SD1's infrastructure geodatabase.
2. Current service area estimates are for SD1's combined sewer service area within the Central Basin.
3. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections. This list is current based on data as of November 21, 2008.

Table 2.20 also includes the number of CSOs within the Central Basin. Developed based on infrastructure characterization activities, including flow monitoring, modeling, and ongoing field inspections, the list of overflow points is continuously updated to track the magnitude and location of overflows due to sewer system changes. Sewer system changes may be a result of improvements, new development, or infiltration/inflow reduction efforts. The data presented above are current as of November 21, 2008. Appendix 2-C provides additional detail on the overflows predicted by the model as well as a description of how the listing was updated for the December 2008 quarterly report and how SD1 will update the overall listing of CSOs and SSOs annually based on the findings of their ongoing field verification program.

Separate Sanitary Sewer System

The Central Basin contains many separate sanitary sewer systems. The Lakeview system, which serves the southern portion of the Central Basin, lies within the Banklick Creek watershed. Flows are conveyed to the Lakeview Pump Station and then pumped to the Dry Creek Interceptor for eventual treatment at the Dry Creek WWTP. Some portions of SD1's separate sanitary sewer system are tributary to the combined system along the Licking River. These sections discharge to the Bromley combined system and are conveyed through the Licking River Interceptor to the Bromley PS and then to the Dry Creek WWTP. Table 2.21 presents a summary of separate sanitary sewer system characteristics for the Central Basin, excluding those assets owned and operated by the City of Florence.

Table 2.21 Central Basin Separate Sewer System Summary

Parameter	Banklick Creek	Licking River	Threemile	Central Basin
Separated Sanitary Sewer (miles)[1]	383.1	83.7	60.4	527.2
Diameter Range (inches)	4 - 48	6 - 30	6 - 27	4 - 48
Number of Manholes[1]	10,888	2,497	1,740	15,125
Number of Pump Stations[1]	14	31	1	46
Number of Treatment Plants[1]	0	0	0	0
Forcemain (miles)[1]	10.4	16.9	0.5	27.8
Current Service Area (square miles)[2]	48.1	16.6	5.9	70.6
Number of Overflow Points[3]				
SSOs – Pump Stations	2	8	0	10
SSOs	25	3	13	41

Notes:
1. Separate sewer designation for sewers, manholes, pump stations, treatment plants, and forcemains were based on SD1's infrastructure geodatabase.
2. Current service area estimates are for SD1's separate sewer service area within the Central Basin.
3. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections. This list is current based on data as of November 21, 2008.

Table 2.21 also includes the number of overflow points in the separate sanitary sewer system within the Central Basin. "SSOs – Pump Stations" identify locations where wet weather overflows occur at SD1 pump stations, while "SSOs" are recurring overflows that occur at sewer system manholes. Developed based on infrastructure characterization activities, including flow monitoring, modeling, and ongoing field inspections, this list of overflow points is continuously updated to track the magnitude and location of overflows due to sewer system changes, including improvements, new development, and I/I reduction (as examples). The data presented above are current as of November 21, 2008. Appendix 2-C provides additional detail on the overflows predicted by the model as well as a description of how the listing was updated for the December 2008 quarterly report and how SD1 will update the overall listing of CSOs and SSOs annually based on the findings of their ongoing field verification program.

Modeled Sewer System Overflow Volumes

Table 2.22 summarizes Central Basin overflow volumes by watershed, based on model results from SD1's 2008 sewer system hydraulic model. As shown, CSOs account for most of the overflow volume in the Central Basin, with the largest contributor being CSOs along the Licking River. The annual simulations used SD1's selected typical year of 1970 and include system impacts from restricting the Bromley Pump Station to one small pump under high river conditions (Ohio River stage 41 feet and above). See Section 7.3.1 for a discussion on river water intrusion and SD1's compliance with the USACE Flood Protection system.

Appendix 2-C contains an individual listing of annual overflow statistics for these locations.

Table 2.22 Central Basin Model-Calculated Typical Year Overflow Volume Summary

Watershed	Model-Calculated Overflow Volume (MG)[1,2]		Central Basin Overflow Volume (MG)
	CSOs	SSOs[3]	
Banklick Creek	58.8	97.5	156.3
Licking River	731.4	54.0	785.4
Threemile	0	7.1	7.1
Total	790.2	158.6	948.8

Notes:

1. Annual simulations of SD1's 2008 calibrated system-wide model use SD1's selected typical year of 1970 and include river water intrusion effects.
2. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing coordinated field inspections. This list is current based on data as of November 21, 2008.
3. SSO model-calculated overflow volume consists of confirmed SSOs, SSOs at pump stations, and locations predicted to overflow in the model in the typical year but which have not yet been field verified as recurring SSOs. See Appendix 2-C for further details.

Waterway Conditions

Current waterway conditions are assessed through a review of recent (2006-2008) water quality, habitat and biological data, supplemented by site visits, reports and interviews. Current conditions are summarized in Table 2.23 and described below by watershed.

Table 2.23 Current Conditions for Central Basin Waterways

Watershed	Bacteria Wet Weather	Bacteria Dry Weather	Dissolved Oxygen (discrete measurements)	WY 2000-05 USGS continuous monitoring station	Aquatic habitat	Aquatic biology	Flooding	Streambank erosion
Licking River	●	●	○	◐ DO, pH	●	◐	○	●
Banklick Creek	●	●	○	◐ DO, Temp., pH	●	●	●	●
Threemile Creek	◐	●	○	NA	●	●	○	●

○ Not identified as a problem

◐ Potential problem

● Identified problem

NA No data available as of June 2009

Banklick Creek

Recent water quality data are available for six mainstem sites and two tributaries (Bullock Pen and Fowler Creek). Elevated levels of bacteria are observed at all eight locations during both dry and wet weather conditions. Additionally, a review of the 15-minute data (Water Year 2000-2005) collected at Banklick Creek RM 8.1 reveals recurring, infrequent dissolved oxygen, temperature and pH violations.

Flooding is a recurring problem in the Banklick Creek watershed, especially in the Pioneer Park area. Streambank erosion has been observed along the mainstem of Banklick Creek and its tributaries. Erosion is severe in places, causing damage to sewer and transportation infrastructure.

2008 aquatic habitat surveys indicate a majority of sampling locations only partially support a diverse aquatic habitat, with some sites rated as non-supporting. 2008 macroinvertebrate surveys indicate primarily poor conditions throughout the entire length of the creek.

Threemile Creek

Recent water quality data are available for four locations along the mainstem of Threemile Creek and for one location on North Branch Threemile Creek. Elevated bacteria levels are observed at all locations during dry weather and at the single mainstem location sampled during wet weather.

Streambank erosion has been observed at multiple locations along Threemile Creek, and its primary tributary, North Branch Threemile Creek.

Aquatic habitat and biological assessments in this watershed were conducted in 2008 Aquatic habitat at two mainstem sites and two tributary sites were rated as not supporting and the biological conditions were rated poor at all sites.

Licking River (RM 35.6 to RM 0.0, excluding Banklick and Threemile Creeks)

Recent water quality data are available for nine mainstem and twelve tributary locations. Elevated bacteria levels were observed at thirteen of the twenty-one locations sampled, including locations along both the mainstem and tributaries. During dry weather, elevated bacteria levels were observed in the mainstem at several upstream and downstream locations, and in eight of the tributaries. During wet weather, elevated bacteria levels were observed at two downstream mainstem locations. Recent wet weather data were not available for the tributaries or upstream mainstem locations as of June 2009.

A review of the 15-minute data collected at the USGS monitoring station on Cruises Creek (Water Year 2000-2005) revealed recurring dissolved oxygen violations, primarily during periods of low flow. Infrequent pH violations were also observed, due to pH changes greater than 1 s.u. in a 24-hour period. Data were not available as of June 2009 for the USGS station on the Licking River at RM 19.3, which began operation in 2007. Streambank erosion is frequently observed in this portion of the Licking River watershed along the mainstem and many tributaries.

Macroinvertebrates were sampled in 2008 at one mainstem location and in seven tributaries. The mainstem site was sampled twice, receiving a good and excellent rating. The tributary results were highly variable and ranged from very poor to fair. Aquatic habitat assessments at the same tributary locations indicated non-supporting to partially supporting conditions. Habitat assessed at the Licking River mainstem site indicates non-supporting conditions.

Impact of Pollution Sources

Potential pollution sources in this basin include sewer overflows, other KPDES-permitted dischargers, septic systems, storm water runoff, and unknown dry weather sources. Potential pollution sources are presented in Table 2.24 and are shown on Figure 2.21.

Sewer overflow locations and model-calculated volumes are described previously in this section. Septic systems are generally located outside of the SD1 sanitary sewer area.

The NKHD estimates that 10% or more of septic systems in Northern Kentucky may be operating improperly and those in Campbell County are prone to more frequent failures than those located in Boone or Kenton Counties (NKHD, 2008a). Three septic areas were identified in this basin as having problems (NKHD, 2008b). The majority of the permitted KPDES sanitary outfalls in this basin which are located in the Licking River and Banklick Creek watersheds, are covered by residential general permits, and the required twice-annual data were not available for 65% of these locations for the January 2007-June 2008 period. The failure rate for these residential dischargers may be higher than 10% (KDOW, 2007).

The bacteria loading potential for each watershed has been calculated using WAT!. Bacteria loading potential by watershed and source is shown in Table 2.24.

Figure 2.21 Potential Sources in the Central Basin

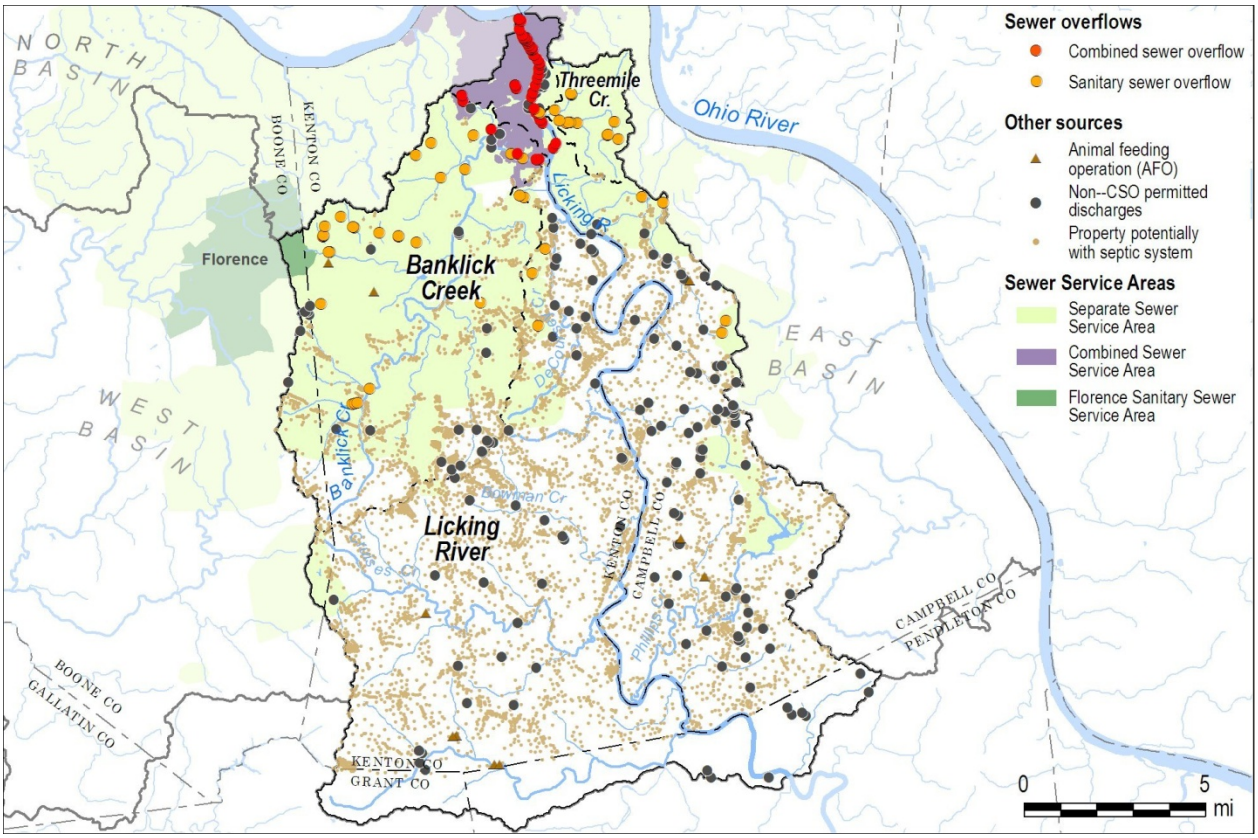
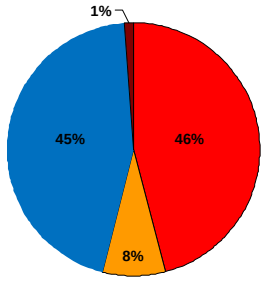
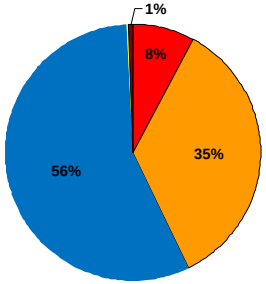
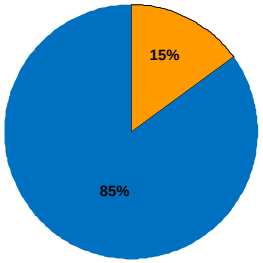
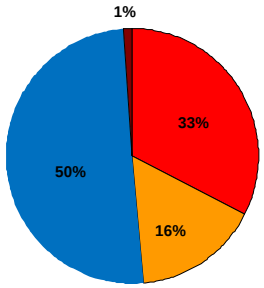


Table 2.24 Potential Pollution Sources in the Central Basin

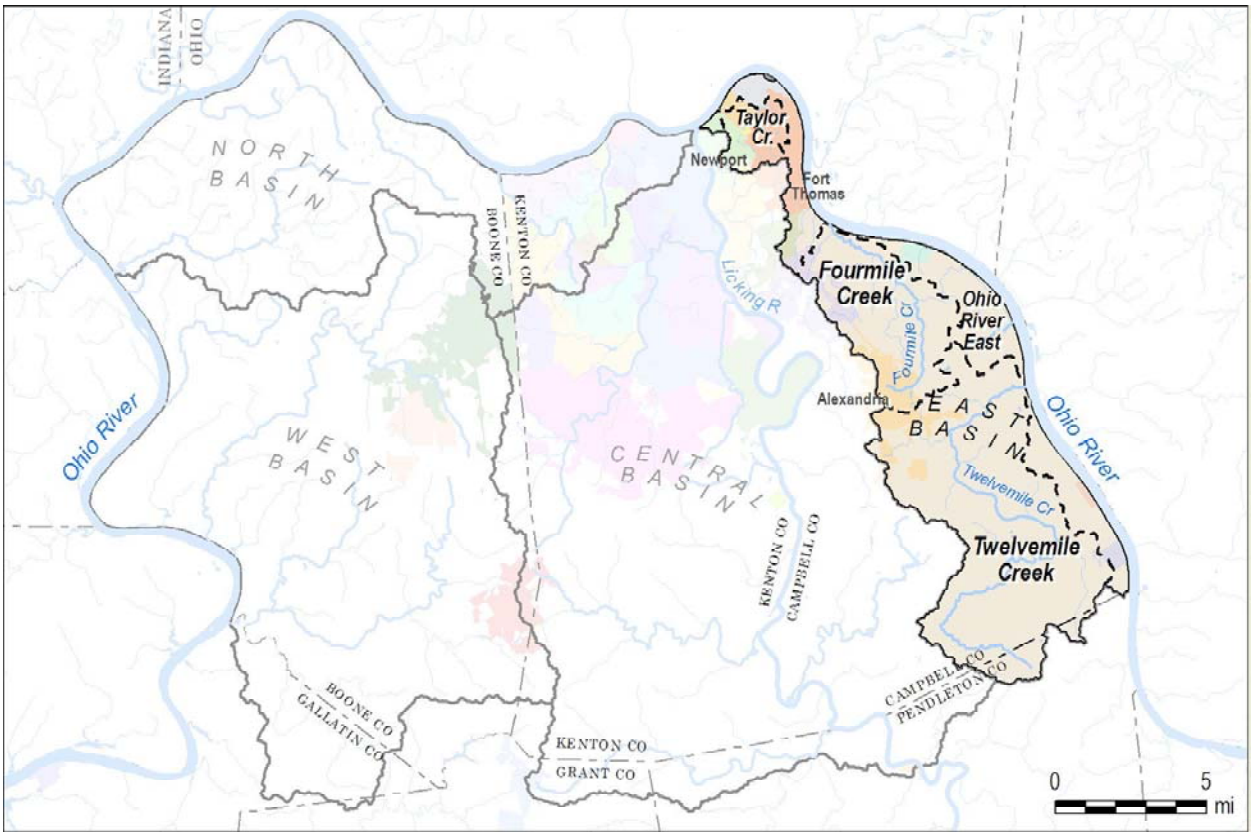
Source	Licking River	Banklick Creek	Threemile Creek	Central Basin
CSOs	34	5	0	39
SSOs	11	27	13	51
Septic systems	Many upstream of RM 4.8, two known problem areas	Many upstream of RM 8.2; few downstream	Very few	Many
KPDES-sanitary outfalls	125	15	0	140
Storm water runoff	Urban and rural. Rural runoff includes areas with cattle, horses and poultry	Urban and rural, small portion of watershed is in Florence	Urban	Urban and rural. Small portion in Florence
Livestock	Cattle, horses, poultry; 8 AFOs	Cattle, horses, 2 AFOs	None identified	Cattle, horses, poultry, 10 AFOs
WAT! bacteria loading potential CSO SSO Runoff Septic *KPDES are negligible (<1%)				

AFO = Animal feeding operation

2.2.3 East Basin Characteristics

The East Basin is approximately 88 square miles in size, and primarily lies within Campbell County, with a small portion extending into Pendleton County, as shown in Figure 2.22. This basin consists of the Twelvemile Creek, Fourmile Creek, Taylor Creek and Ohio River East Tributaries watersheds. Watershed and infrastructure features are summarized in SD1's Watershed Summary Report (Appendix 2-A) and in the individual Watershed Characterization Reports which are available at www.sd1.org.

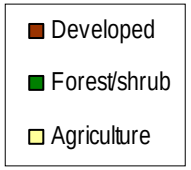
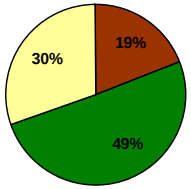
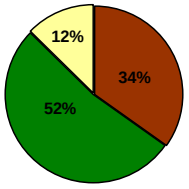
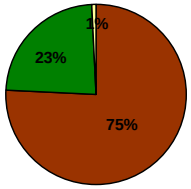
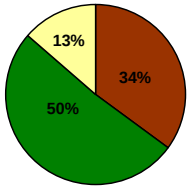
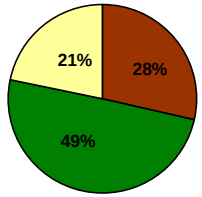
Figure 2.22 East Basin and Watersheds



Watershed Features

Table 2.25 summarizes important watershed characteristics of the four East Basin watersheds. These watersheds all flow into the Ohio River between the Pendleton/Campbell county line and the Licking River confluence. The majority of streams drain rolling hills with tight valleys, that give way to gentle slopes and wide flat valleys near the Ohio River. Soils in this basin are predominantly characterized as having slow infiltration rates and as being fairly to highly erodible.

Table 2.25 Watershed Characteristics for the East Basin

Feature	Twelvemile Creek	Fourmile Creek	Taylor Creek	Ohio River East Tributaries	East Basin
Drainage Area (square miles)	46.1	17.8	4.2	20	88.1
USGS station and location	03238745, Twelvemile Creek RM 3.0	03238772, Fourmile Creek RM 6.9	03238140, Taylor Creek RM 0.6 [1]	NA	NA
Average Annual Flow (cfs)	44.1 cfs	3.5 cfs	--	NA	NA
Mainstem length (miles)	22	9.4	4.4	0.8 – 2.6	NA
Land Cover 					
Current (2007) imperviousness (percent)	3%	6%	23%	8%	6%
Future (2030) imperviousness (percent)	4%	9%	25%	10%	8%

Notes:

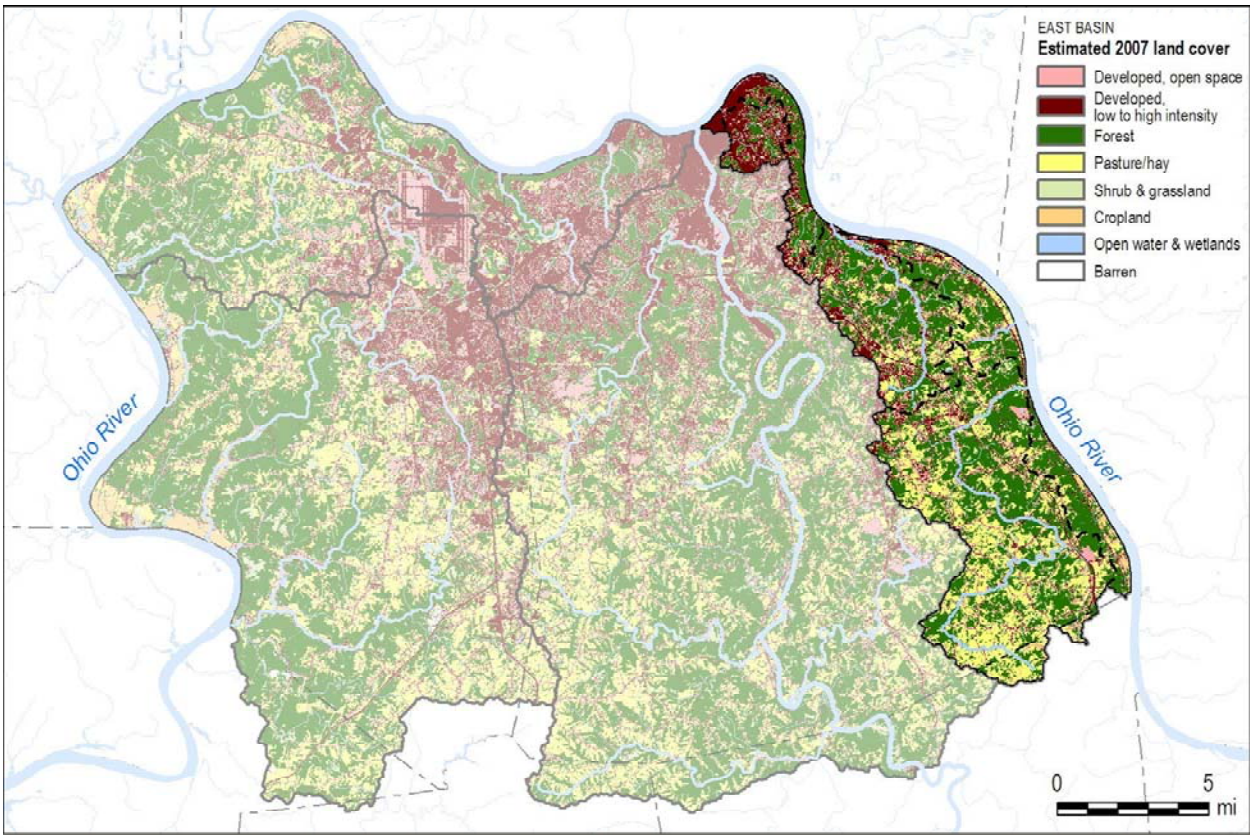
1. This station began operating in 2007 and flow data were not available as of June 2009.

NA = Not applicable

-- indicates data were not available as of June 2009.

Current land cover in the East Basin is shown in Figure 2.23. Development is concentrated in the north and along Alexandria Pike, near the western edge of this basin. Currently, the Taylor Creek watershed ranks as having some of the highest imperviousness within the study area, which has been shown to significantly contribute to water quality impairments. Some of these watersheds are also experiencing development pressures, and in the future, development is predicted to increase in all four watersheds.

Figure 2.23 Current (2007) Land Cover in the East Basin



The more highly developed areas in this basin are predominantly served by SD1's sanitary sewer system. Properties located outside the sanitary sewer service area primarily use septic systems and small wastewater treatment plants (less than 1,000 gallons per day). Roughly 73% of the sanitary wastewater outfalls are covered by residential general permits for individual family residential package wastewater treatment plants.

Agricultural areas in this basin include cropland and pastureland. Cattle, horses and swine are present in this basin, and cattle are more common in the Twelvemile Creek watershed than elsewhere in the study area. Permitted animal feeding operations (beef cattle and swine) also exist in this basin.

Green Infrastructure Features

Specific features within this basin are relevant to the identification of green infrastructure opportunities in this area. These include:

- 78 miles of rivers and streams (excluding the Ohio River)
- 310 acres of lakes
- 3,200 acres of impervious surfaces (6% of the land area)
- 3,370 acres with slopes over 20% (6% of the land area)
- 2,860 acres of right-of-way (5% of land area)
- 22,310 acres of tree canopy coverage (40% of the land area)

The amount of impervious surface in combination with major land uses within the basin will guide SD1 to the best green techniques for this region. Table 2.26 provides the distribution of different land uses within the East Basin.

Table 2.26 East Basin Land Use Distribution

Land Use Type	% of Area
Agricultural	16%
Residential	26%
Woodlands	8%
Undeveloped	35%
Transportation (includes airport)[1]	0.02%
Industrial	0%
Commercial	3%
Other	12%

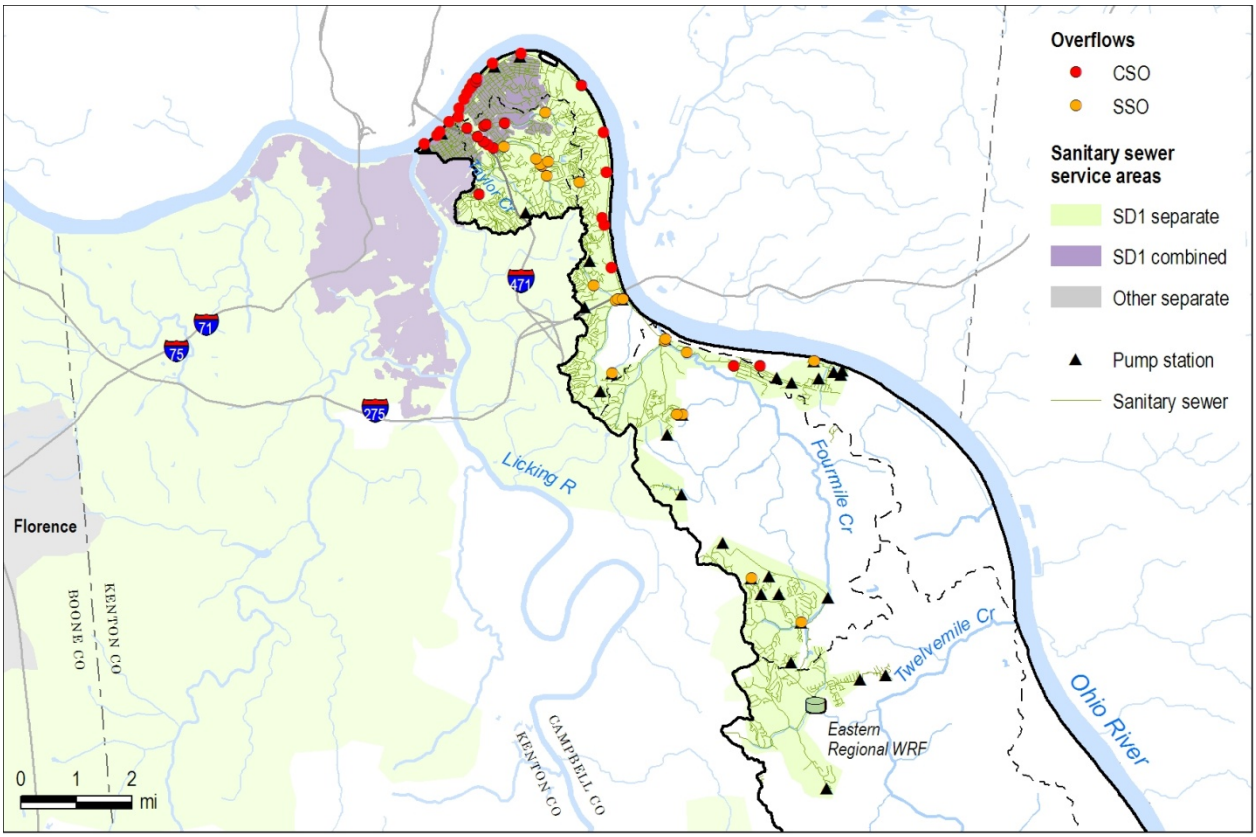
Note:

1. Transportation data were based on the Property Valuation Administration land use information.

Gray Infrastructure Features

The East Basin contains both combined and separate sewer service areas, and some portions of the East Basin are a hybrid of both combined and separate sewers. Figure 2.24 shows the overall East Basin service area. A more detailed map of the service area can be found in Appendix 2-C. These areas represent the most upstream portions of the Dry Creek WWTP service area. All flows from the East Basin are tributary to the Bromley pump station, which discharges directly to the Dry Creek WWTP.

Figure 2.24 East Basin Service Area



Combined System (and Hybrid)

The combined portion of the East Basin generally begins at the Highland Heights forcemain and then follows along the Ohio River Interceptor. Downtown Silver Grove and the Taylor Creek area are the exceptions and are considered a hybrid of both combined and separate sewers. Most of the combined system is in the Ohio River East Tributaries watershed, which includes the Ohio River cities of Dayton, Bellevue, and Newport. Table 2.27 provides a summary of combined sewer system characteristics for the East Basin by watershed.

Table 2.27 East Basin Combined Sewer System Summary

Parameter	Fourmile Creek	Taylor Creek	Ohio River East Tributaries	East Basin
Combined Sewers (miles)[1]	1	15	44	60
Diameter Range (inches)	8 - 24	6 - 60	6 - 110	6 – 110
Number of Manholes[1]	22	649	2,877	3,548
Number of Pump Stations[1]	0	0	8	8
Number of Treatment Plants[1]	0	0	0	0
Forcemains (miles)[1]	0	0	5	5
Current Service Area (square miles)[2]	0	0.7	1.3	2.0
Number of Overflow Points[3]				
CSOs	1	9	22	32

Notes:
1. Combined sewer designation for sewers, manholes, pump stations, treatment plants, and forcemains were based on SD1's infrastructure geodatabase.
2. Current service area estimates are for SD1's combined sewer service area within the East Basin.
3. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections. This list is current based on data as of November 21, 2008.

Table 2.27 also includes the number of CSOs within the East Basin. Developed based on infrastructure characterization activities, including flow monitoring, modeling, and ongoing field inspections, the list of overflow points is continuously updated to track the magnitude and location of overflows due to sewer system changes. Sewer system changes may be a result of improvements, new development, or infiltration/inflow reduction efforts. The data presented above are current as of November 21, 2008. Appendix 2-C provides additional detail on the overflows predicted by the model as well as a description of how the listing was updated for the December 2008 quarterly report and how SD1 will update the overall listing of CSOs and SSOs annually based on the findings of their ongoing field verification program.

Separate System

The separate sewer system comprises the entire area tributary to the Highland Heights Pump Station and the Cold Springs area that drains to the Silver Grove Pump Station. Although a portion of the Taylor Creek watershed is combined, the majority is separated prior to entering the Ohio River Interceptor. Table 2.28 provides a summary of separate sewer system characteristics for the East Basin by watershed.

Table 2.28 East Basin Separate Sanitary Sewer System Summary

Watershed	Twelvemile Creek	Fourmile Creek	Taylor Creek	Ohio River East Tributaries	East Basin
Separate Sanitary Sewers (miles)[1]	27	52	55	58	192
Diameter Range (inches)	6 - 42	4 - 15	6 - 60	6 - 36	4 - 60
Number of Manholes[1]	590	1129	1845	885	4,449
Number of Pump Stations[1]	3	12	1	5	21
Number of Treatment Plants[1]	1	0	0	0	1
Forcemains (miles)[1]	3	9	0	1	13
Current Service Area (square miles)[2]	3.0	5.9	3.5	5.1	17.5
Number of Overflow Points[3]					
SSOs	0	3	7	4	14
SSOs – Pump Stations	0	4	0	3	7

Notes:
1. Separate sewer designation for sewers, manholes, pump stations, treatment plants, and forcemains were based on SD1 infrastructure geodatabase.
2. Current service area acreage estimates are for SD1's separate sewer service area within the East Basin.
3. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections. This list is current based on data as of November 21, 2008.

Table 2.28 also includes the number of overflow points in the separate sanitary sewer system within the East Basin. "SSOs – Pump Stations" identify locations where wet weather overflows occur at SD1 pump stations, while "SSOs" are recurring overflows that occur at sewer system manholes. Developed based on infrastructure characterization activities, including flow monitoring, modeling, and ongoing field inspections, this list of overflow points is continuously updated to track the magnitude and location of overflows due to sewer system changes, including improvements, new development, infiltration/inflow reduction, etc. The data presented above are current as of November 21, 2008. Appendix 2-C provides additional detail on the overflows predicted by the model as well as a description of how the listing was updated for the December 2008 quarterly report and how SD1 will update the overall listing of CSOs and SSOs annually based on the findings of their ongoing field verification program.

Modeled Sewer System Overflow Volume

Table 2.29 summarizes East Basin overflow volumes by watershed based on model results from SD1's 2008 sewer system hydraulic model. The annual simulations used SD1's selected typical year of 1970 and include system impacts from restricting the Bromley Pump Station to one small pump under high river conditions (Ohio River stage 41 feet and above). See Section 7.3.1 for a discussion on river water intrusion and SD1's compliance with the USACE Flood Protection system.

Appendix 2-C contains an individual listing of annual overflow statistics for these locations.

Table 2.29 East Basin Model-Calculated Typical Year Overflow Volume Summary

Watershed	Model-Calculated Overflow Volume (MG)[1,2]		East Basin Overflow Volume (MG)
	CSOs	SSOs[3]	
Twelvemile Creek	0	8.0	8.0
Fourmile Creek	2.4	23.9	26.3
Taylor Creek	8.4	14.2	22.6
Ohio River East	275.6	27.3	302.9
Total	286.4	73.4	359.8

Notes:

1. Annual simulations of SD1's 2008 calibrated system-wide model use SD1's selected typical year of 1970 and include river water intrusion effects. Volume in Twelvemile Creek is attributed to the Eastern Regional Sewer System.
2. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing coordinated field inspections. This list is current based on data as of November 21, 2008.
3. SSO model-calculated overflow volume consists of confirmed SSOs, SSOs at pump stations, and locations predicted to overflow in the model in the typical year but which have not yet been field verified as recurring SSOs. See Appendix 2-C for further details.

Waterway Conditions

Current waterway conditions are assessed through a review of recent (2006-2008) water quality data, the most recent habitat and biological data, supplemented by site visits, reports and interviews. Current conditions are summarized in Table 2.30 and described below by watershed.

Table 2.30 Current Conditions for East Basin Waterways

Watershed	Bacteria – Wet Weather	Bacteria – Dry Weather	Dissolved oxygen (discrete measurements)	WY 2000-05 USGS continuous monitoring station	Aquatic habitat	Aquatic biology	Flooding	Streambank erosion
Twelvemile Creek	●	●	○	● Temp, DO, pH	●	●	●	◐
Fourmile Creek	●	●	●	● DO	●	◐	○	●
Taylor Creek	●	●	●	NA	●	●	●	●
Ohio River East Tributaries	NA	○	○	NA	●	◐	○	◐

○ Not identified as a problem

◐ Potential problem

● Identified problem

NA No data available as of June 2009

Twelvemile Creek

Recent water quality data are available for five mainstem sites and two tributary sites on Brush Creek. Elevated levels of bacteria are observed at all seven locations during wet weather and at one mainstem and two tributary sites during dry weather. Additionally, a review of the 15-minute data (Water Year 2000-2005) collected at Twelvemile Creek RM 3.0 reveals recurring dissolved oxygen, temperature and pH violations.

Flooding is a problem in some areas of this watershed, occurring near the mouth, and less frequently along Route 10/Flagg Springs Pike. Streambank erosion has been observed at locations along Brush Creek and the mainstem.

In 2007, aquatic habitat was rated as partially supporting of a diverse aquatic habitat at four mainstem sites, and not supporting of a diverse aquatic habitat at two Brush Creek sites. Biological conditions were assessed at the same time, and ranged from poor to good at the same site assessed in spring and fall. In general, biological conditions at

the mainstem sites were rated poor between RM 3.0 and the mouth, and farther upstream, biological scores ranged between fair and good.

Fourmile Creek

Recent water quality data are available for four mainstem sites and two tributaries. Elevated levels of bacteria are observed at all of the sites sampled during wet weather (three mainstem and two tributary sites), and at three mainstem sites during dry weather. Recent dissolved oxygen violations were also observed at two of the mainstem locations. A review of 15-minute data (Water Year 2000-2005) collected at Fourmile Creek RM 6.9 reveals more dissolved oxygen violations at this site than the other Northern Kentucky USGS stations that had data for this time period.

No recurring flooding issues were identified in this watershed; however there are persistent drainage issues at the culverts under Route 8 near the mouth. Streambank erosion in this watershed is severe in some locations.

In 2007, aquatic habitat was assessed as not supporting of a diverse aquatic habitat at four mainstem and two tributary sites. Biological conditions at the same sites were highly variable, ranging from poor to good.

Taylor Creek

Recent water quality data are available for two mainstem locations and three tributaries during dry weather and for one mainstem location and three tributaries during wet weather. Elevated levels of bacteria were observed at all five locations sampled during dry weather and all four locations sampled during wet weather. Dissolved oxygen, copper and zinc violations were observed at four locations during wet weather. pH violations were observed at two locations during wet and dry weather. Cadmium and unionized ammonia violations were observed at one location during wet weather. Data were not available as of June 2009 for the USGS station on Taylor Creek at RM 0.7, which began operation in 2007.

Flooding is identified as a recurring problem in the Taylor Creek watershed, particularly in the lower third of the watershed (XCG Consultants, Inc., 2006). Streams in this watershed are frequently channelized and streambank erosion is observed.

In 2007, aquatic habitat was assessed as not supporting of a diverse aquatic habitat at all three sites assessed, and biological conditions ranged from very poor to fair.

Ohio East Tributaries

Streambank erosion has been observed in Tenmile Creek, the only waterway assessed in this watershed to date (starting in 2009, an additional site was added to monitor Threemile Creek)[9]. Recent water quality data reveal one pH violation during dry

[9] This Threemile Creek drains directly to the Ohio River and is different from the Threemile Creek discussed elsewhere in this section, which is a tributary of the Licking River.

weather. A 2003 assessment of this creek found that aquatic habitat is not supporting of a diverse aquatic habitat and biological conditions were rated fair.

Impact of Pollution Sources

Potential pollution sources in this basin include sewer overflows, other KPDES-permitted dischargers, septic systems and storm water runoff. Potential pollution sources are presented in Table 2.31 and shown on Figure 2.25.

Sewer overflow locations and model-calculated volumes are described previously in this section. Septic systems are generally located outside of the SD1 sanitary sewer area. The NKHD estimates that 10% or more of septic systems in Northern Kentucky may be operating improperly and those in Campbell County are prone to more frequent failures than those located in Boone or Kenton Counties (NKHD, 2008a). Furthermore, three septic areas in the Fourmile Creek watershed were identified as having problems (NKHD, 2008b). The majority of the permitted sanitary wastewater outfalls in this basin which are located in the Twelvemile Creek, Fourmile Creek and Ohio River East tributaries watersheds are covered by residential general permits, and the required twice-annual data were not available for 57% of these locations for the January 2007-June 2008 period. The failure rate for these residential dischargers may be higher than 10% (KDOW, 2007).

The bacteria loading potential for each watershed has been calculated using the WAT!. Bacteria loading potential by watershed and source is shown in Table 2.31.

Figure 2.25 Potential Sources in the East Basin

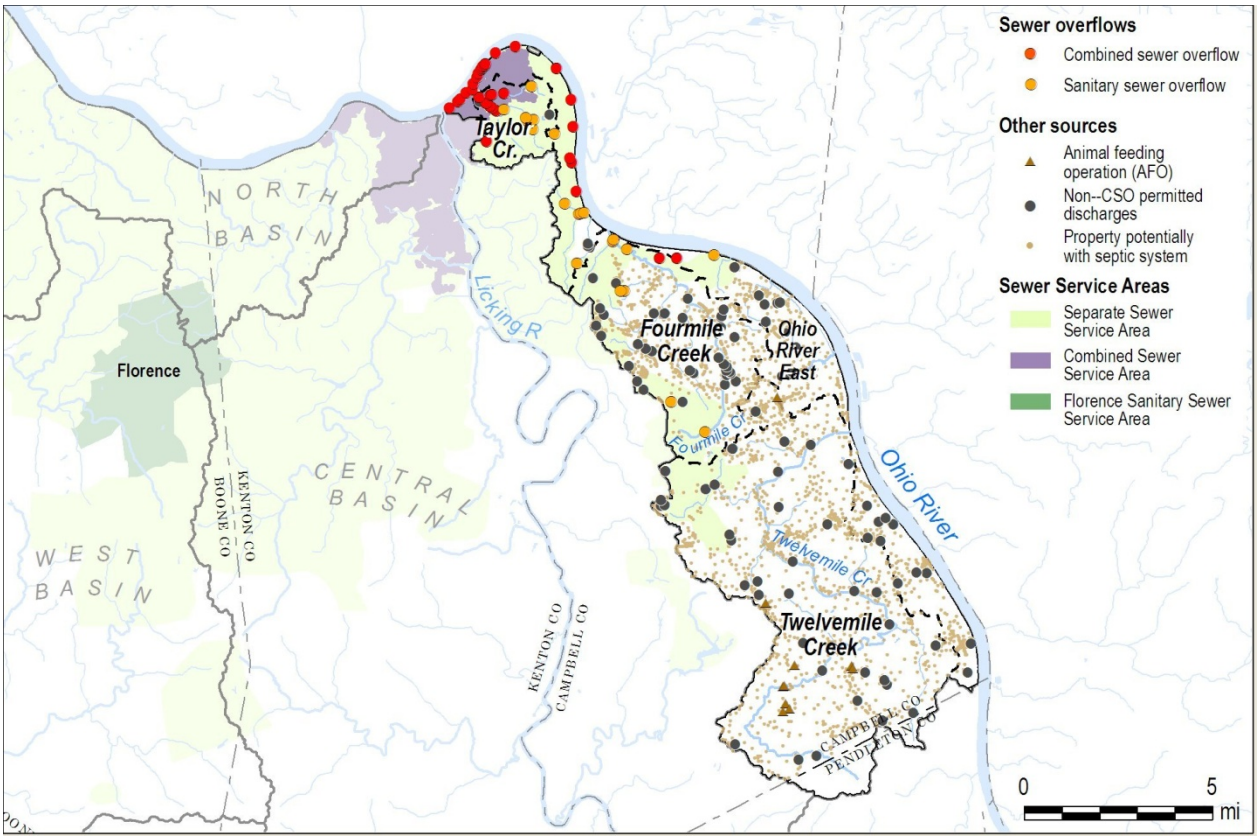
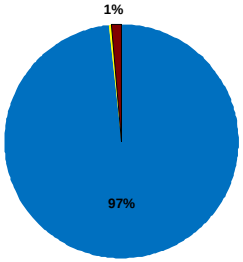
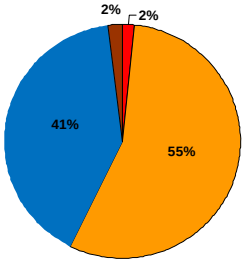
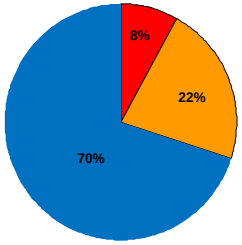
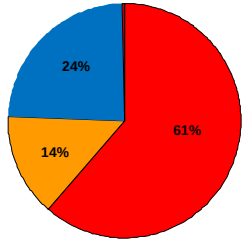
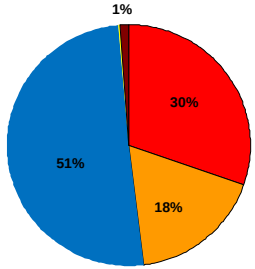


Table 2.31 Potential Pollution Sources in the East Basin

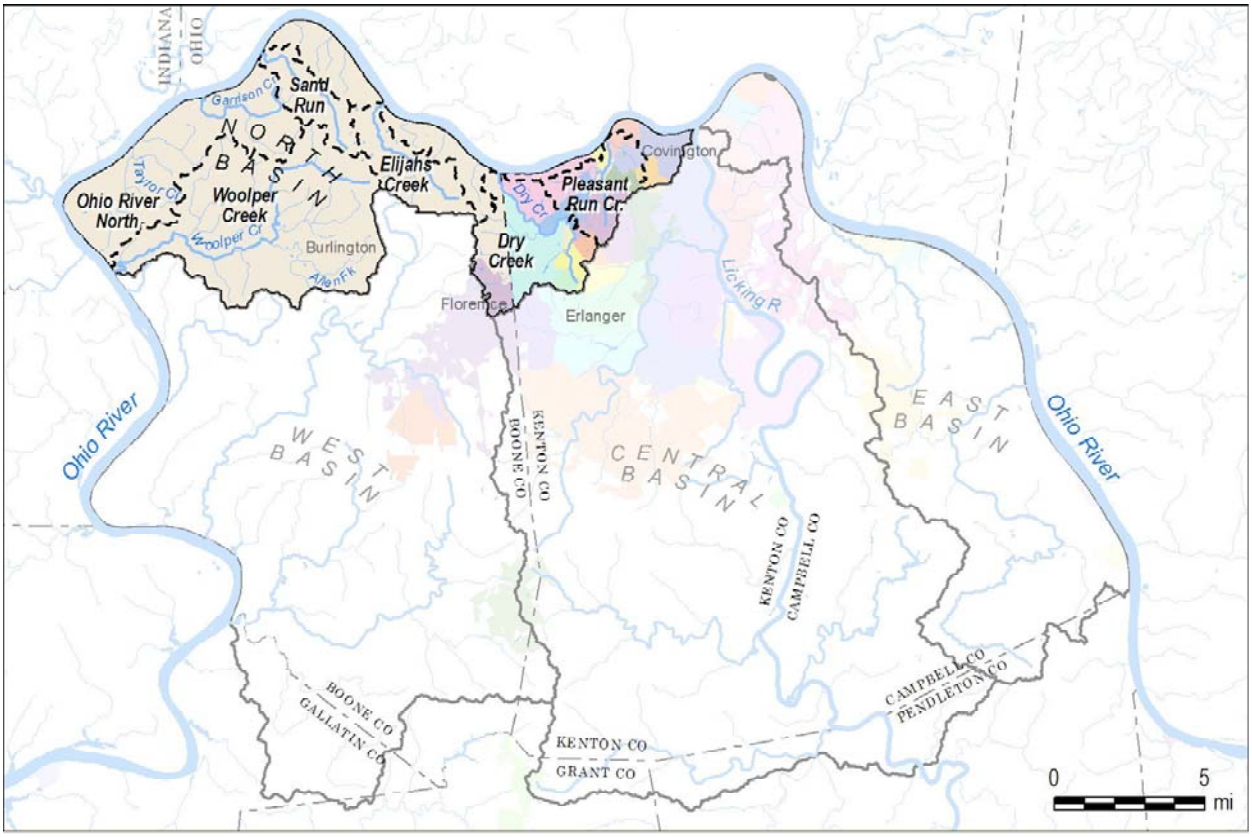
Feature	Twelvemile Creek	Fourmile Creek	Taylor Creek	Ohio River East Tributaries	East Basin
CSOs	0	1	9	22	32
SSOs(1)	0	7	7	7	21
Septic systems	Many	Many, 3 known problem areas	Few	Many	Many
KPDES-sanitary outfalls	38	37	0	26	101
Storm water runoff	Urban and rural	Urban and rural	Urban	Urban and rural	Urban and rural
Livestock	Numerous cattle, 9 AFOs	Cattle, swine, horses	None identified	1 AFO	Cattle, swine, horses, 10 AFOs
WAT! bacteria loading potential CSO SSO Runoff Septic *KPDES are negligible (<1%)					

Note:
1. All SSOs were eliminated in the Twelvemile Creek watershed with the Initial Watershed Projects for the Eastern Regional Sewer System and WRF.
2. AFO = Animal Feeding Operation

2.2.4 North Basin Characteristics

Shown in Figure 2.26, the North Basin is approximately 95 square miles in size and lies within Kenton and Boone Counties. This basin consists of the Pleasant Run Creek, Dry Creek, Elijahs Creek, Sand Run, Woolper Creek and Ohio River North Tributaries watersheds. Watershed and infrastructure features are summarized in SD1's Watershed Summary Report (Appendix 2-A) and in the individual Watershed Characterization Reports which are available at www.sd1.org.

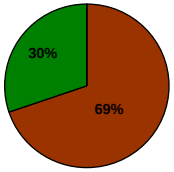
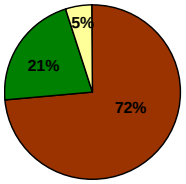
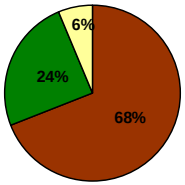
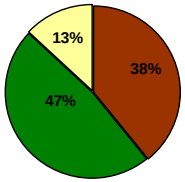
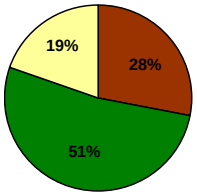
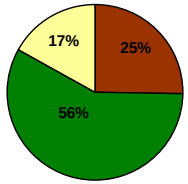
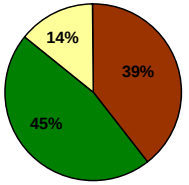
Figure 2.26 North Basin and Watersheds



Watershed Features

Table 2.32 summarizes important watershed characteristics of the North Basin watersheds, which flow into the Ohio River between the Licking River confluence and the Woolper Creek confluence. The majority of these streams drain rolling hills with steep valleys; however slopes near the Ohio River shore can be quite flat. Stream channels tend to be narrow near the headwaters and widen as they approach the Ohio River. Soils in this basin are predominantly characterized as having slow infiltration rates and are highly erodible.

Table 2.32 Watershed Characteristics for the North Basin

Feature	Pleasant Run Creek	Dry Creek	Elijahs Creek	Sand Run	Woolper Creek	Ohio River North Tributaries	North Basin
Drainage Area (square miles)	6.5	12.4	6.7	5.0	33.0	31.8	95.4
USGS station and location	03260015 [1], Pleasant Run Cr. RM 0.3	03260050 [1], Dry Cr. RM 1.3	03260100, Elijahs Cr RM 2.8	NA	03262001, Woolper Cr. RM 5.0	NA	NA
2006 Average Annual Flow (cfs)	--	--	9.6 cfs	NA	29 cfs	NA	NA
Mainstem length (miles)	3.3	6.9	5.1	5.7	13.9	0.4 – 4.9	NA
2007 Land Cover							
Current (2007) Imperviousness (percent)	18%	24%	25%	12%	5%	7%	11%
Future (2030) imperviousness (percent)	19%	28%	31%	16%	9%	10%	14%

Notes:

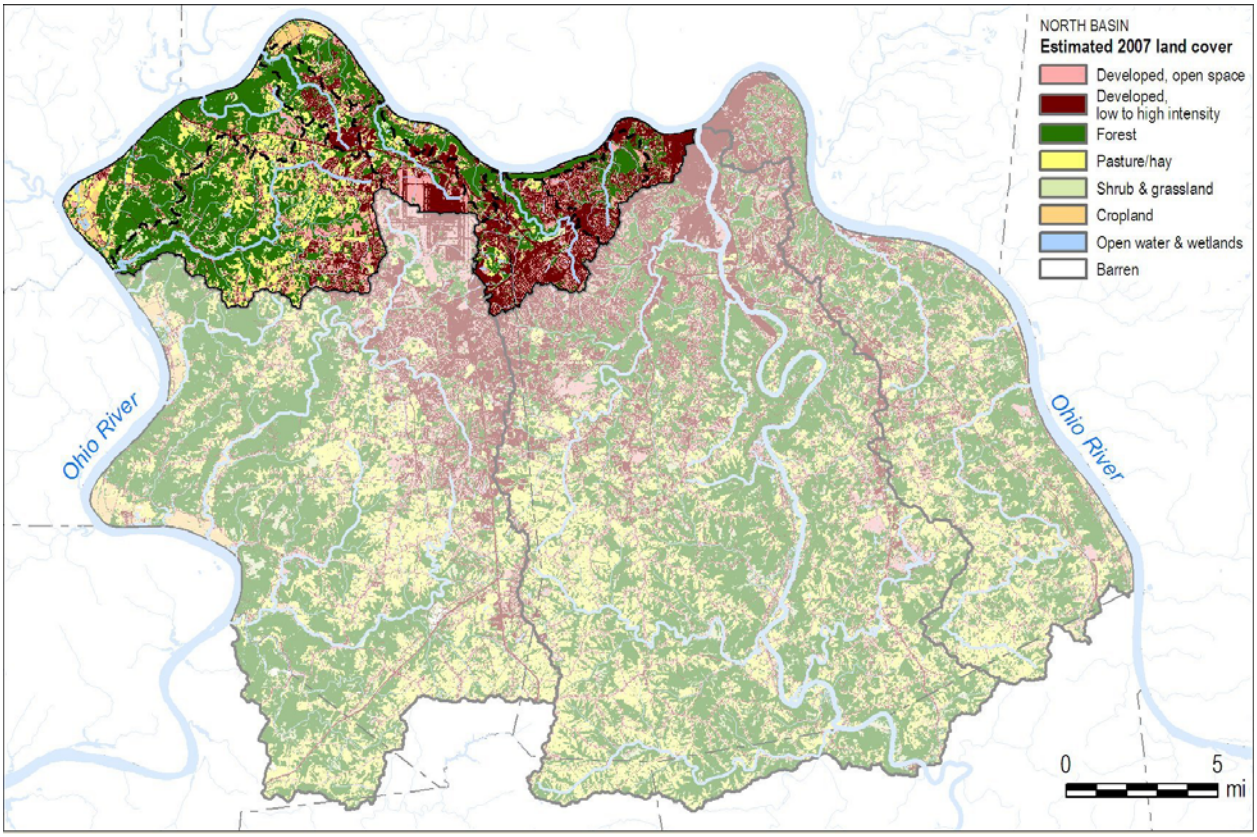
1. These stations began operating in 2007 and flow data were not available as of June 2009..

NA = Not applicable

-- indicates data were not available as of June 2009

Current land cover in this basin is shown in Figure 2.27. This basin contains some highly developed areas and some watersheds have been experiencing rapid growth as development extends to the west and north. A portion of the Cincinnati Northern Kentucky Airport is located in this basin, and Interstate-275 passes through five of the six North Basin watersheds. Currently, the Elijahs Creek and Dry Creek watersheds have, on average, some of the highest impervious cover in the study area, which has been shown to significantly contribute to water quality impairments. These watersheds, as well as the Sand Run watershed are also experiencing development pressures. In contrast, Woolper Creek and the Ohio River North Tributary watersheds have the lowest percent impervious cover in this basin, and KDOW has identified three streams in these watersheds as exceptional waters.

Figure 2.27 Current (2007) Land Cover in the North Basin



The more highly developed areas in this basin are predominantly served by SD1's sanitary sewer system, with a small portion served by the City of Florence's sanitary sewer system. Properties located outside the sanitary sewer service area primarily use septic systems and small wastewater treatment plants (less than 1,000 gallons per day). Roughly 74% of the sanitary wastewater outfalls are covered by residential general permits for individual family residential package wastewater treatment plants.

Agricultural areas such as cropland and pastureland are generally located to the west. Cattle and horses have been observed in the more rural areas, although some family farms and horses are also found in more developed watersheds.

Green Infrastructure Features

Specific features within this basin are relevant to the identification of green infrastructure opportunities in this area. These include:

- 70 miles of rivers and streams (excluding the Ohio River)
- 620 acres of lakes
- 7,000 acres of impervious surfaces (11% of the land area)
- 16,430 acres with slopes over 20% (27% of the land area)
- 4,730 acres of right-of-way (8% of land area)
- 23,240 acres of tree canopy coverage (38% of the land area)

The amount of impervious surface in combination with major land uses within the basin will guide SD1 to the best green techniques for this region. Table 2.33 provides the distribution of different land uses within the North Basin.

Table 2.33 North Basin Land Use Distribution

Land Use Type	% of Area
Agricultural	23%
Residential	21%
Woodlands	32%
Undeveloped	2%
Transportation (includes airport)	8%
Industrial	4%
Commercial	2%
Other	8%

Gray Infrastructure Features

The North Basin includes the downstream sections for SD1's three major sewer systems, which discharge to the Dry Creek WWTP.

- The Ohio River Interceptor and the Bromley Pump Station convey flows from SD1's entire combined sewer system, including portions in the North Basin.
- The Dry Creek Interceptor collects separate flows discharged from the Lakeview Pump Station and Lakeside Park.
- The Taylorsport Pump Station serves currently developed sections of SD1's western separate service area in Boone County.

Appendix 2-C contains a detailed sewer system map for the North Basin. Table 2.34 summarizes model-calculated peak wet weather and average dry weather flows for these three systems under current conditions for SD1's selected typical year.

Table 2.34 Model-Calculated Existing System Discharges to Dry Creek WWTP Under the Typical Year (1970)

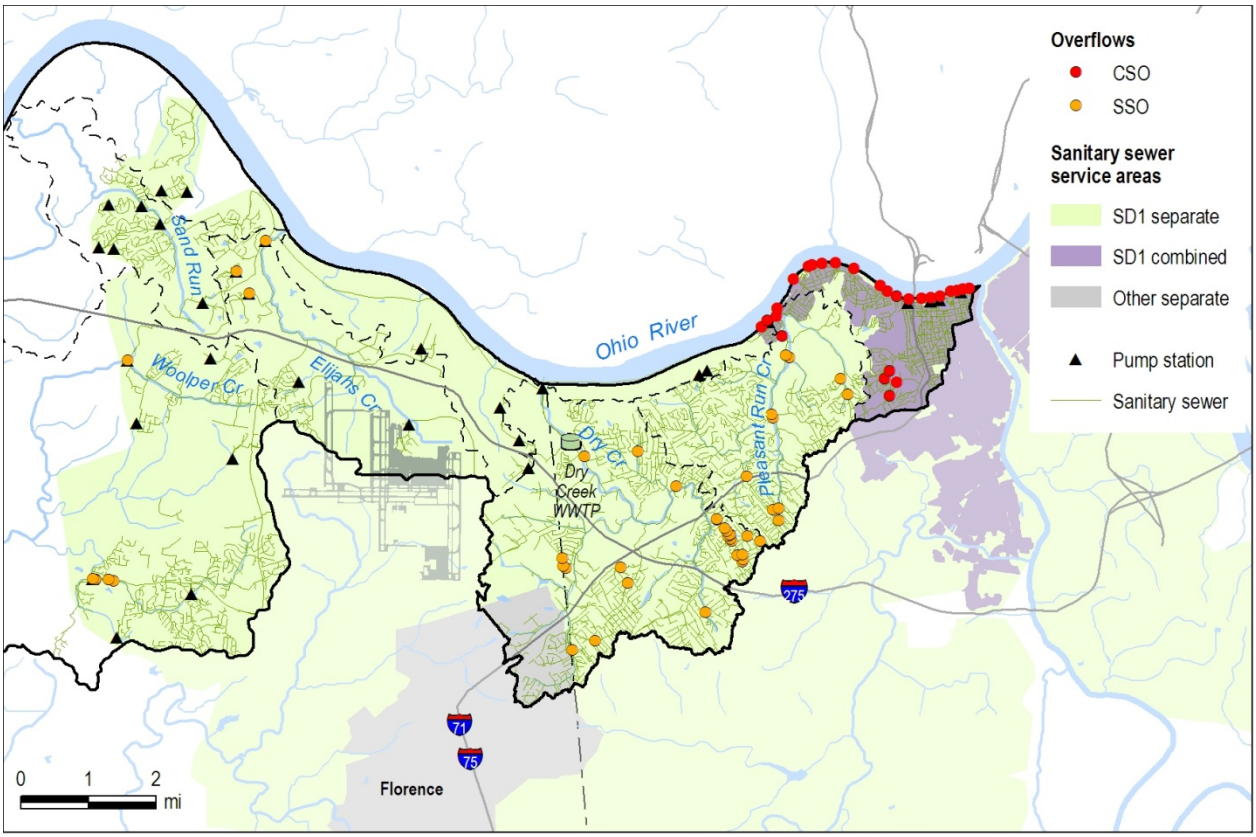
Sewer System	Peak Wet Weather Flow (MGD)[1]	Average Dry Weather Flow (MGD)[1]
Ohio River Interceptor/ Bromley PS	37.1	14.5
Dry Creek Interceptor	46.9	15.6
Taylorsport PS	9.8	2.8

Notes:

1. Results from annual simulations with SD1's 2008 refined calibrated system-wide model using SD1's selected typical year of 1970, and including river influence.

Currently, the Taylorsport Pump Station receives flows discharged from the manifolded Burlington and Gunpowder Pump Station forcemains. Once the Western Regional WRF goes online, flows from these areas will be disconnected from the Taylorsport Pump Station and discharge to the Western Regional Tunnel. The Gunpowder Pump Station will be eliminated and its flows will be conveyed by gravity to the tunnel. The Burlington forcemain will discharge to a new forcemain and gravity sewer and connect to the tunnel. Flows upstream of Florence's Fowler Creek Pump Station and Rosetta Pump Station will also be redirected from the Dry Creek Interceptor to the Western Regional sewer system. Figure 2.28 shows the overall North Basin service area.

Figure 2.28 North Basin Service Area



Combined Sewer System

The combined sewer system is located at the east end of the North Basin. Within this basin, the combined sewer system comprises approximately 8% of the total basin sewer system by length; it also accounts for approximately 28% of SD1's total combined sewer system by length. Table 2.35 provides a summary of combined sewer system characteristics for the North Basin by watershed.

Table 2.35 North Basin Combined Sewer System Summary

Parameter	Pleasant Run Creek	Ohio River North	North Basin
Combined Sewers (miles)[1]	6	33	39
Diameter Range (inches)	8 - 36	6 - 144	6 - 144
Number of Manholes[1]	130	751	881
Number of Pump Stations[1]	0	1	1
Number of Treatment Plants[1]	0	0	0
Forcemains (miles)[1]	0	0	0
Current Service Area (square miles)[2]	0.2	2.5	2.7
Number of Overflow Points[3]			
CSOs	2	24	26

Notes:
1. Separate sewer designation for sewers, manholes, pump stations, treatment plants, and forcemains were based on SD1's infrastructure geodatabase.
2. Current service area acreage estimates are for SD1's combined sewer service area within the North Basin.
3. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections. This list is current based on data as of November 21, 2008.

Table 2.35 also summarizes the number of CSOs (already permitted or to-be-permitted) within the North Basin. Developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections, this list of overflow points is continuously updated to track the magnitude and location of overflows due to sewer system changes, including improvements, new development, inflow and infiltration reduction, etc. The data presented above are current as of November 21, 2008. Appendix 2-C provides additional detail on the overflows predicted by the model as well as a description of how the listing was updated for the December 2008 quarterly report and how SD1 will update the overall listing of CSOs and SSOs annually based on the findings of their ongoing field verification program.

Separate Sanitary Sewer System

Separate sanitary sewers account for approximately 92% of the total sewer system by length in the North Basin. The Bromley-Crescent Springs service area, which discharges to the Ohio River Interceptor and Bromley Pump Station, is also separate sanitary area. Table 2.36 presents a summary of separate sanitary sewer system characteristics for the North Basin, excluding those assets owned and operated by the City of Florence.

Table 2.36 North Basin Separate Sanitary Sewer System Summary

Parameter	Dry Creek	Elijahs Creek	Ohio River North	Pleasant Run Creek	Sand Run	Woolper Creek	North Basin
Separate Sanitary Sewers (miles)[1]	126	25	42	75	23	68	359
Diameter Range (inches)	2 - 42	8 - 30	6 -60	4 - 24	8 - 24	6 - 30	2 - 60
Number of Manholes[1]	3,104	618	1,415	2,074	661	1,806	9,678
Number of Pump Stations[1]	0	5	8	0	6	7	26
Number of Treatment Plants[1]	1	0	1	0	0	3	5
Forcemains (miles)[1]	3	2	10	2	5	9	31
Current Service Area (square miles)[2]	10.9	6.7	7.2	6.4	2.8	12.6	46.6
Number of Overflow Points[3]							
SSOs	25	0	0	11	0	4	40
SSOs – Pump Stations	0	3	0	0	0	2	5

Notes:

1. Separate sewer designation for sewers, manholes, pump stations, treatment plants, and forcemains were based on SD1's infrastructure geodatabase.
2. Current service area acreage estimates are for SD1's separate sewer service area within the North Basin.
3. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections. This list is current based on data as of November 21, 2008.

Table 2.36 also summarizes the overflow points in the separate sanitary sewer system within the North Basin "SSOs – Pump Stations" identify locations where wet weather overflows occur at SD1 pump stations, while "SSOs" are recurring overflows that occur at sewer system manholes. Developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections, this list of overflow points is continuously updated to track the magnitude and location of overflows due to sewer system changes, including improvements, new development, inflow and infiltration reduction, etc. The data presented above are current as of November 21, 2008. Appendix 2-C provides additional detail on the overflows predicted by the model as well as a description of how the listing was updated for the December 2008 quarterly report and how SD1 will update the overall listing of CSOs and SSOs annually based on the findings of their ongoing field verification program.

Modeled Sewer System Overflow Volume

Table 2.37 summarizes North Basin overflow volumes by watershed based on model results from SD1's 2008 sewer system hydraulic model. The annual simulations used SD1's selected typical year of 1970 and include system impacts from restricting the

Bromley Pump Station to one small pump under high river conditions (Ohio River stage 41 feet and above). See Section 7.3.1 for a discussion on river water intrusion and SD1's compliance with the USACE Flood Protection system.

Appendix 2-C contains an individual listing of annual overflow statistics for these locations.

Table 2.37 North Basin Model-Calculated Typical Year Overflow Volume Summary

Watershed	Model-Calculated Overflow Volume (MG)[1,2]		North Basin Overflow Volume (MG)
	CSOs	SSOs[3]	
Dry Creek	0	4.0	4.0
Elijahs Creek	0	0.7	0.7
Ohio River North	793.6	0.9	794.5
Pleasant Run Creek	2.7	1.6	4.3
Sand Run	0	0	0
Woolper Creek	0	0.3	0.3
Total	796.3	7.5	803.8

Notes:

1. Annual simulations of SD1's 2008 calibrated system-wide model use SD1's selected typical year of 1970 and include river water intrusion effects.
2. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing coordinated field inspections. This list is current based on data as of November 21, 2008.
3. SSO model-calculated overflow volume consists of confirmed SSOs, SSOs at pump stations, and locations predicted to overflow in the model in the typical year but which have not yet been field verified as recurring SSOs. See Appendix 2-C for further details.

Waterway Conditions

Current waterway conditions are assessed through a review of recent (2006-2008) water quality, habitat and biological data, supplemented by site visits, reports and interviews. Current conditions are summarized in Table 2.38 and described below by watershed.

Table 2.38 Current Conditions for North Basin Waterways

Watershed	Bacteria – Wet Weather	Bacteria – Dry Weather	Dissolved oxygen (discrete measurements)	WY 2000-05 USGS continuous monitoring station	Aquatic habitat	Aquatic biology	Flooding	Streambank erosion
Pleasant Run Creek	NA	●	○	NA	●	●	●	◐
Dry Creek	NA	●	○	NA	●	●	○	●
Elijahs Creek	NA	○	○	● DO, pH	●	●	◐	●
Sand Run	NA	●	◐	NA	NA	NA	●	●
Woolper Creek	NA	○	○	◐ DO, pH, temp	●	●	●	●
Ohio River North Tributaries	NA	○	◐	NA	●	○	○	◐

○ Not identified as a problem

◐ Potential problem

● Identified problem

NA No data available as of June 2009

Pleasant Run Creek

Recent water quality data collected during dry weather at two mainstem locations reveal elevated levels of bacteria at both locations. Periodic flooding has been documented as a problem in Bromley (KCPC et al., 2006), and erosion has been observed at one location. Macroinvertebrate sampling at two locations in 2008 indicates poor conditions. Aquatic habitat at the same locations was assessed as non-supporting.

Dry Creek

Recent water quality data collected during dry weather at three mainstem and one tributary location (West Fork Dry Creek) reveal elevated levels of bacteria in the tributary and two of the mainstem sites. Macroinvertebrate sampling at four locations in 2008 indicates poor to very poor conditions. Aquatic habitat at the same locations was assessed as non-supporting. Erosion has been observed at several locations.

Elijahs Creek

Recent water quality data collected during dry weather at two mainstem locations reveal elevated bacteria in a single sample. A review of the 15-minute data (Water Year 2000-2005) collected at Elijahs Creek RM 2.8 reveals recurring dissolved oxygen and pH violations.

The Comprehensive Plan (BCPC, 2005) indicates portions of this watershed experience frequent flooding. Stream bank erosion has been observed in several locations and is sometimes severe. Aquatic habitat and biology were assessed at two locations in 2004. Aquatic habitat was rated not supporting and biological conditions were assessed as poor to very poor.

Sand Run

Recent water quality data collected during dry weather at two mainstem locations reveal elevated levels of bacteria at both locations, and dissolved oxygen violations at one location. According to the Comprehensive Plan, flooding has recently become a problem due to urban and suburban development (BCPC, 2005). Areas with severe streambank erosion have also been observed in this watershed. No aquatic habitat or biological data were available for this creek as of June 2009.

Woolper Creek

Recent water quality data collected during dry weather at three mainstem sites, and two tributaries (Allen Fork and Ashbys Fork) reveal a single dissolved oxygen violation in Ashbys Fork. A review of the 15-minute data (Water Year 2000-2005) collected at Woolper Creek RM 5.0 reveals infrequent dissolved oxygen, water temperature and pH violations during periods of low flow

Aquatic habitat and biology were assessed in 2004 at two Woolper Creek sites and eight tributary sites. Aquatic habitat was predominantly assessed as not supporting, with only one tributary site rated supporting, but threatened. All sites assessed for aquatic biology were rated poor for at least one metric (macroinvertebrates, fish and diatoms).

According to the Comprehensive Plan, portions of Woolper Creek experience frequent flooding (BCPC, 2005). Flooding was also identified as a concern in the Allen Fork watershed (Lighthiser et al., 2005). Erosion is a documented problem near the Woolper Creek mouth, due to significant channel modification that occurred during construction of a marina in the early 1990s. This project failed; however, modifications that remain

include straightening of the natural creek meander, dredging of seven acres of ponds and wetlands and placement of dredge material near the creek.

Ohio River North Tributaries

Recent water quality data were collected during dry weather in Garrison Creek, Second Creek and Taylor Creek. Elevated levels of bacteria were observed in one Garrison Creek sample. Dissolved oxygen violations were observed in one Garrison Creek measurement and one Taylor Creek measurement.

In 2008, aquatic habitat was assessed in Garrison Creek and Second Creek and both sites were rated as partially supporting. Macroinvertebrate samples collected at the same locations indicate excellent conditions in Garrison Creek and fair conditions in Second Creek. Stream bank erosion has been observed in Garrison Creek and Second Creek.

Impact of Pollution Sources

Potential pollution sources in this basin include sewer overflows, other KPDES-permitted dischargers, septic systems and storm water runoff. Potential pollution sources are presented in Table 2.39 and are shown on Figure 2.29.

Sewer overflow locations and model-calculated volumes are described previously in this section. Septic systems are generally located outside of the SD1 sanitary sewer area. The NKHD estimates that 10% or more of septic systems in Northern Kentucky may be operating improperly (NKHD, 2008a). The majority of the permitted sanitary outfalls in this basin which are located in Woolper Creek, Ohio River North Tributaries, and Dry Creek watersheds are covered by residential general permits, and the required twice-annual data were not available for 53% of these locations for the January 2007-June 2008 period. The failure rate for these residential dischargers may be higher than 10% (KDOW, 2007).

The bacteria loading potential for each watershed has been calculated using WAT!. Bacteria loading potential by watershed and source is shown in Table 2.39.

Figure 2.29 Potential Sources in the North Basin

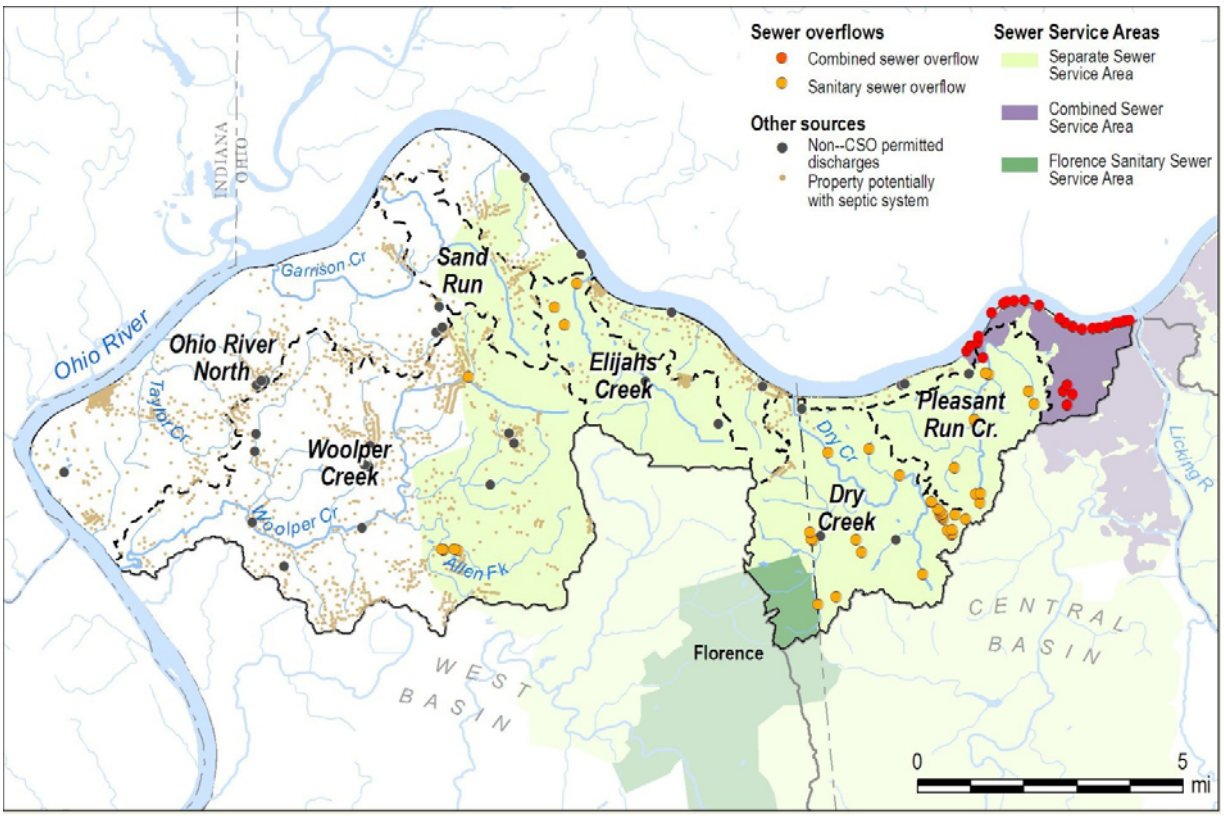
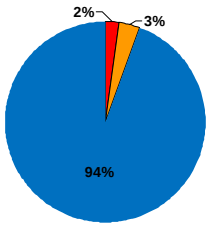
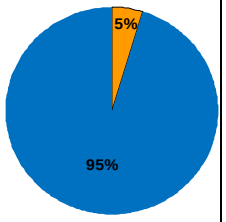
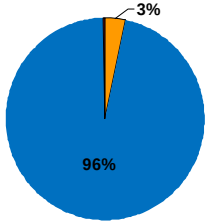
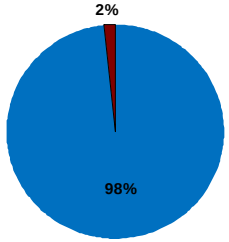
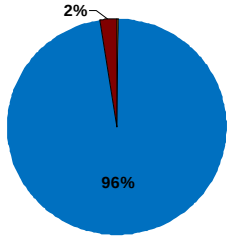
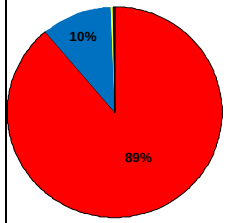
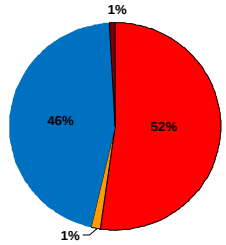


Table 2.39 Potential Pollution Sources in the North Basin

Source	Pleasant Run Creek	Dry Creek	Elijahs Creek	Sand Run	Woolper Creek	Ohio River North Tributaries	North Basin
CSOs	2	0	0	0	0	24	26
SSOs	11	25	3	0	6	0	45
Septic systems	Very few	Few	Few	Few	Many	Many	Very few in some areas, many in others
KPDES-sanitary outfalls	0	2	0	0	11	10	23
Storm water runoff	Urban	Urban; small portion of watershed is in Florence	Urban	Urban and rural	Urban and rural	Urban and rural	Urban and rural, portions in Florence storm water service area
Livestock	None identified	Small family farms present	None identified	None identified	Cattle, horses	Cattle, horses	Cattle, horses, small family farms
WAT! bacteria loading potential CSO SSO Runoff Septic *KPDES are negligible (<1%)							

2.2.5 West Basin Characteristics

The West Basin is approximately 174 square miles in size, and primarily lies within Boone County, with a small portion extending into Kenton, Gallatin and Grant Counties, as shown in Figure 2.30. This basin consists of the Gunpowder Creek, Big Bone Creek and Ohio River West Tributaries watersheds. Watershed and infrastructure features are summarized in SD1's Watershed Summary Report (Appendix 2-A) and in the individual Watershed Characterization Reports which are available at www.sd1.org.

Figure 2.30 West Basin and Watersheds

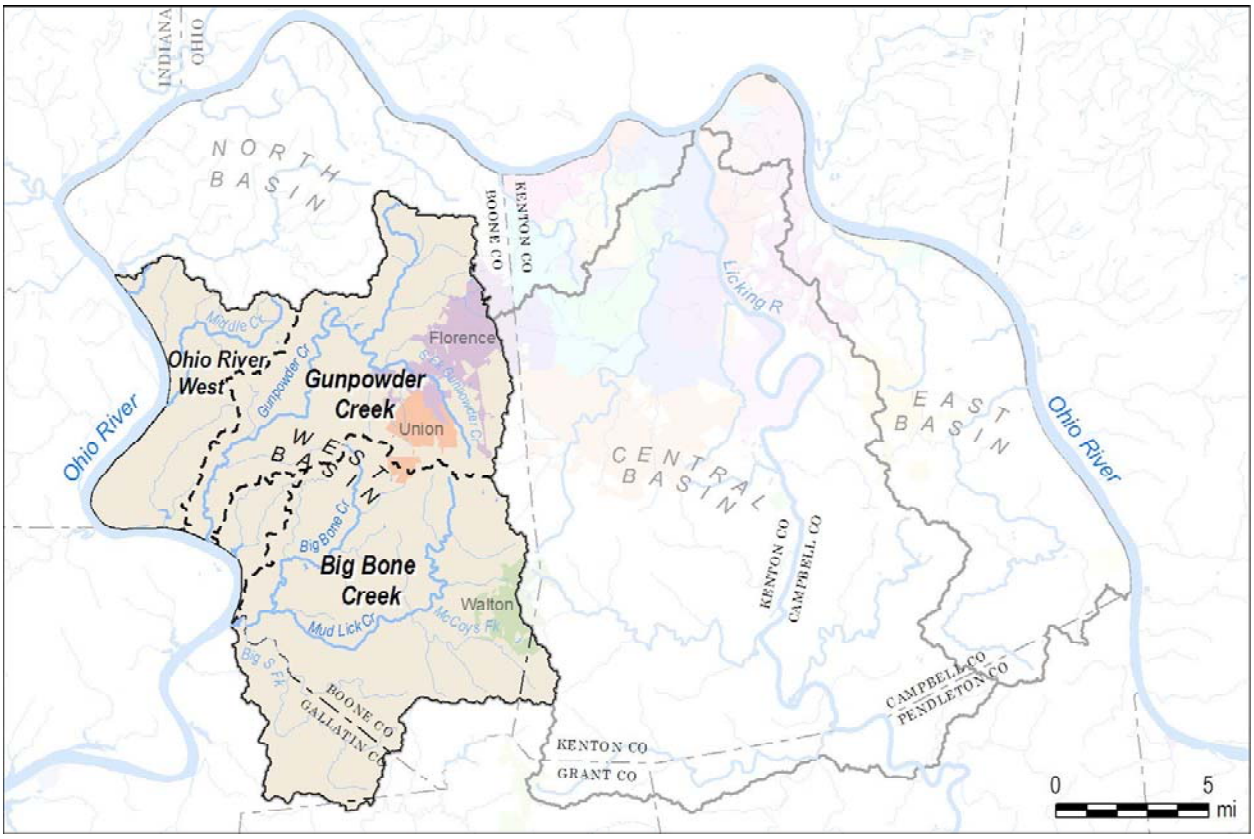
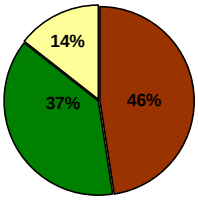
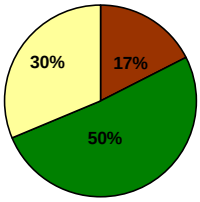
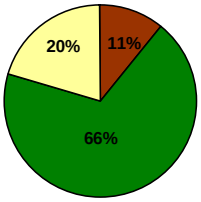
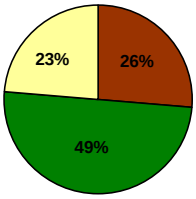


Table 2.40 summarizes important characteristics of the West Basin watersheds, which flow into the Ohio River between the Woolper Creek confluence and the Boone/Gallatin county line. Higher relief is generally found in the east portion of this basin, and the majority of streams drain rolling hills with broad valleys. Soils in this basin are predominantly characterized as having slow infiltration rates and as being highly erodible.

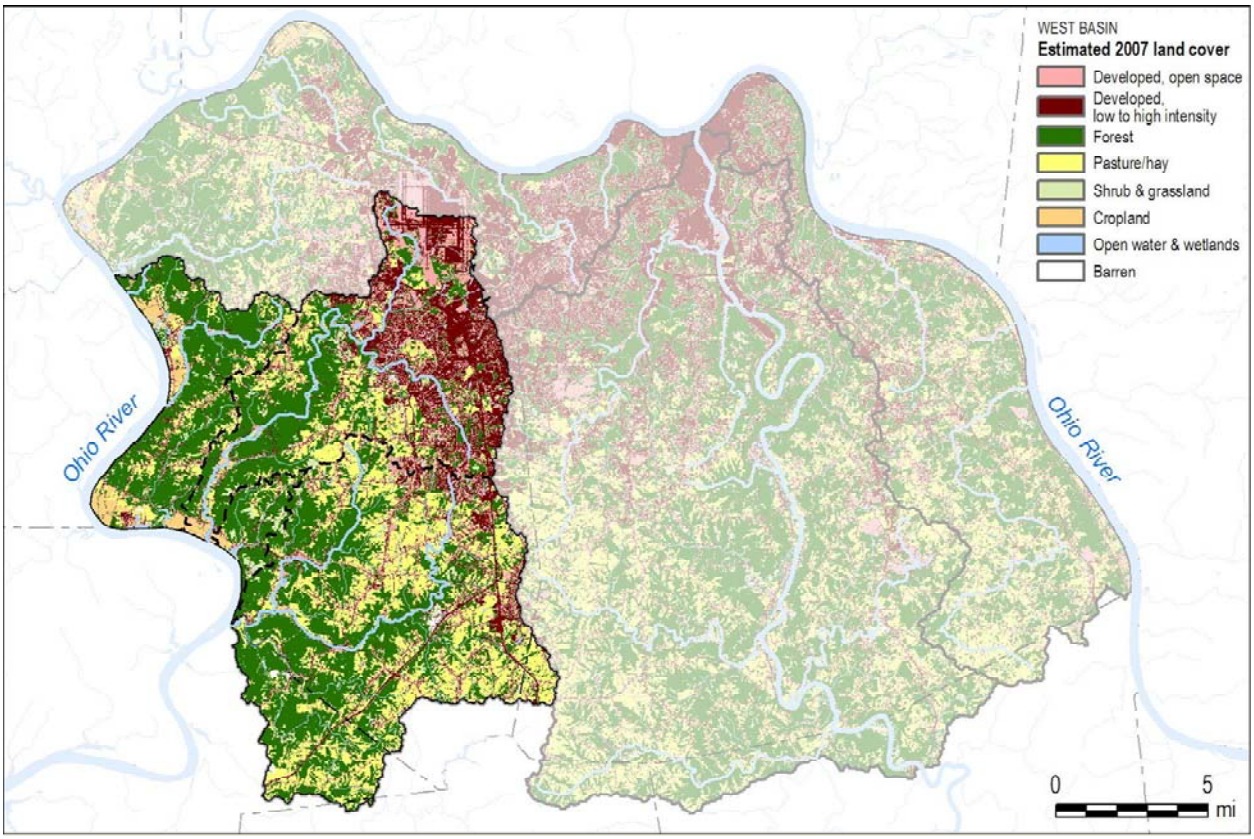
Table 2.40 Watershed Characteristics for the West Basin

Feature	Gunpowder Creek	Big Bone Creek	Ohio River West Tributaries	West Basin
Drainage Area (square miles)	58.2	82.6	33	173.8
USGS station and location	03277075, Gunpowder Cr. RM 14.7	03277130, Mud Lick Cr. RM 3.0	NA	NA
Average Annual Flow (cfs)	62.3	46.6	NA	NA
Mainstem length (miles)	21.9	11.8	1.1 – 8.6	NA
Land Cover				
Current (2007) imperviousness (percent)	12%	3%	2%	6%
Future (2030) imperviousness	16%	6%	4%	9%

NA = Not applicable

Current land cover in this basin is shown in Figure 2.31. Development is primarily concentrated in the northeast portion of this basin, near the headwaters of the Gunpowder Creek and Big Bone Creek watersheds, and is forecast to increase in these areas in the future.

Figure 2.31 Current (2007) Land Cover in the West Basin



The more highly developed areas in this basin are predominantly served by SD1's sanitary sewer system or the sanitary sewer systems owned by Walton and the City of Florence. Properties located outside the sanitary sewer service area primarily use septic systems and small wastewater treatment plants (less than 1,000 gallons per day). Roughly 77% of the sanitary wastewater outfalls are covered by residential general permits for individual family residential package wastewater treatment plants.

Agricultural areas in this basin include cropland and pastureland. Beef cattle, dairy cows and horses are present in this basin. Permitted animal feeding operations (beef and dairy) also exist in this basin.

Green Infrastructure Features

Specific features within this basin are relevant to the identification of green infrastructure opportunities in this area. These include:

- 126 miles of rivers and streams (excluding the Ohio River)
- 1,100 acres of lakes
- 6,500 acres of impervious surfaces (6% of the land area)
- 31,260 acres with slopes over 20% (28% of the land area)
- 4,550 acres of right-of-way (4% of land area)
- 38,640 acres of tree canopy coverage (35% of the land area)

The amount of impervious surface in combination with major land uses within the basin will guide SD1 to the best green techniques for this region. Table 2.41 provides the distribution of different land uses within the West Basin.

Table 2.41 West Basin Land Use Distribution

Land Use Type	% of Area
Agricultural	32%
Residential	18%
Woodlands	36%
Undeveloped	0%
Transportation (includes airport)	5%
Industrial	3%
Commercial	1%
Other	5%

Gray Infrastructure Features

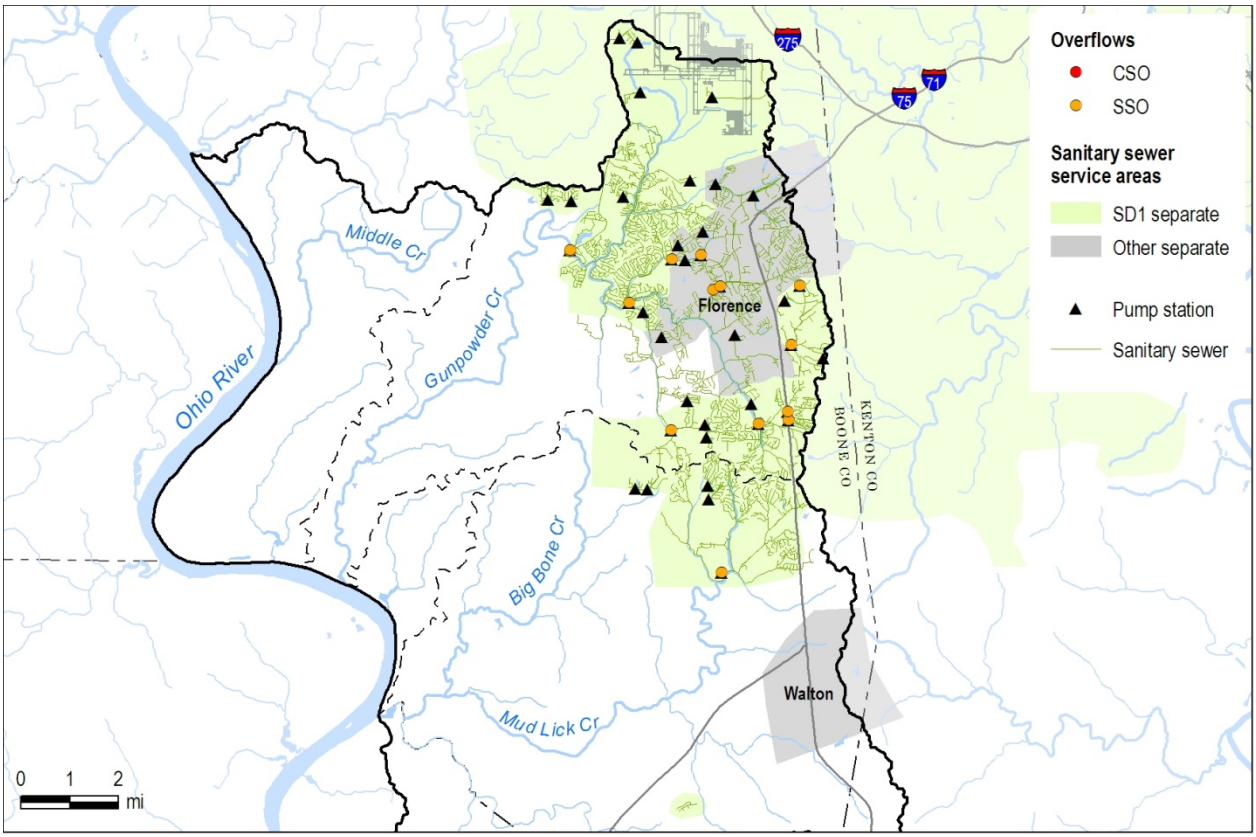
The West Basin includes portions of the SD1 separate sanitary service area as well as additional tributary portions of the City of Florence (Figure 2.32). The small portion of SD1's system that is tributary to the Florence system is not included in service area boundary.

The West Basin does not contain any combined sewers and does not have any tributary areas which are combined. Currently, all flow from the West Basin is conveyed to the Dry Creek WWTP through several different paths:

- Gunpowder Pump Station pumps to Taylorsport Pump Station which is then pumped to Dry Creek WWTP.
- Several pump stations (Richwood, Kentucky Aire, Gammon Calmet, Levi, American Sign) collect flows to pump to Lakeview Pump Station which then pumps to the Dry Creek Interceptor and the Dry Creek WWTP.
- A small portion of the SD1 system is tributary to the City of Florence, where flows are pumped through the Rosetta Pump Station (owned by the City of Florence) back into the SD1 system and to the Dry Creek WWTP through the Dry Creek Interceptor.

Construction of the Western Regional Conveyance System and WRF will greatly change the infrastructure within the West Basin. The majority of collected flows will be redirected to the new reclamation facility through the new infrastructure following the completion of these projects.

Figure 2.32 West Basin Service Area



Separate Sanitary Sewer System

The West Basin is composed entirely of separate sewers in all of its tributary areas. Table 2.42 provides a summary of the West Basin separate sanitary sewer system by watershed, excluding those assets owned and operated by the City of Florence and five SSOs identified in the City of Florence Annual Sanitary Sewer Overflow Plan (City of Florence, 2007).

Table 2.42 West Basin Separate Sanitary Sewer System Summary

Parameter	Gunpowder Creek	Big Bone Lick	West Basin
Separate Sanitary Sewers (miles)[1]	171	47	218
Diameter Range (inches)	8-36	8-18	8-36
Number of Manholes[1]	4,417	1,163	5,580
Number of Pump Stations[1]	21	5	26
Number of Treatment Plants[1]	0	1	1
Forcemains (miles)[1]	10	3.5	13.5
Current Service Area (square miles)[2]	22.5	8.9	31.4
Number of Overflow Points[3]			
SSOs	1	0	1
SSOs – Pump Stations	7	1	8

Notes:
1. Separate sewer designation for sewers, manholes, pump stations, treatment plants, and forcemains were based on SD1's infrastructure geodatabase.
2. Current service area acreage estimates are for SD1's separate sewer service area within the West Basin.
3. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections. This list is current based on data as of November 21, 2008.

Table 2.42 also summarizes the overflow points in the separate sanitary sewer system within the West Basin. "SSOs – Pump Stations" identify locations where wet weather overflows occur at SD1 pump stations, while "SSOs" are recurring overflows that occur at sewer system manholes. Developed based on infrastructure characterization activities, including flow monitoring and ongoing field inspections, this list of overflow points is continuously updated to track the magnitude and location of overflows due to sewer system changes, including improvements, new development, inflow and infiltration reduction, etc. The data presented above are current as of November 21, 2008. Appendix 2-C provides additional detail on the overflows predicted by the model as well as a description of how the listing was updated for the December 2008 quarterly report and how SD1 will update the overall listing of CSOs and SSOs annually based on the findings of their ongoing field verification program.

Modeled Sewer System Overflow Volume

Table 2.43 summarizes the overflow locations for the West Basin. Estimated overflow volumes are based on the 2008 calibrated model and the use of the 1970 typical year rainfall. Typical year volumes are only available for those overflows which are modeled in the SD1 model; overflows within the City of Florence are not represented within the

SD1 model. In addition, only those locations which activate during the typical year simulation are included.

Table 2.43 West Basin Model-Calculated Typical Year Overflow Volume Summary

Watershed	Model-Calculated Overflow Volume (MG)[1,2]		West Basin Overflow Volume (MG)
	CSOs	SSOs[3]	
Big Bone Lick	0	0	0
Gunpowder Creek	0	2.6	2.6
Total	0	2.6	2.6

Notes:

1. Annual simulations of SD1's 2008 calibrated system-wide model use SD1's selected typical year of 1970 and include river water intrusion effects.
2. The list of overflow points by type was developed based on infrastructure characterization activities, including flow monitoring and ongoing coordinated field inspections. This list is current based on data as of November 21, 2008.
3. SSO model-calculated overflow volume consists of confirmed SSOs, SSOs at pump stations, and locations predicted to overflow in the model in the typical year but which have not yet been field verified as recurring SSOs. See Appendix 2-C for further details.

Waterway Conditions

Current waterway conditions are also assessed through a review of recent (2006-2007) water quality data, the most recent habitat and biological data, supplemented by site visits, reports and interviews. Current conditions are summarized in Table 2.44 and described below by watershed.

Table 2.44 Current Conditions for West Basin Waterways

Watershed	Bacteria – Wet Weather	Bacteria – Dry Weather	Dissolved oxygen (discrete measurements)	WY 2000-05 USGS continuous monitoring station	Aquatic habitat	Aquatic biology	Flooding	Streambank erosion
Gunpowder Creek	●	●	○	◐ DO, Temp, pH	●	●	●	●
Big Bone Creek	NA	◐	○	● DO, Temp, pH	◐	○	●	●
Ohio River West Tributaries	NA	◐	○	NA	◐	○	○	◐

○ Not identified as a problem

◐ Potential problem

● Identified problem

NA No data available as of June 2009

Gunpowder Creek

Recent water quality data are available for seven mainstem sites and fifteen tributary sites, six of which are on South Fork Gunpowder Creek. Elevated levels of bacteria were observed at six of the ten locations sampled during dry weather, and at all four locations sampled during wet weather. All locations with elevated bacteria levels are all within the South Fork Gunpowder Creek watershed. Additionally, a review of the 15-minute data (Water Year 2000-2005) collected at Gunpowder Creek RM 14.7 reveals recurring dissolved oxygen and pH violations and infrequent temperature violations. Within the recent data, one pH violation was observed.

Flooding has occurred in this watershed since the early 1990s. Upstream areas frequently experience flooding, and more recently smaller tributaries have been affected. The most extensive flood zone area identified is near the mouth of Gunpowder creek (BCPC, 2005). Streambank erosion and stream channel widening has been identified along the mainstem and in tributaries.

In 2004, aquatic habitat was rated as partially supporting to fully supporting at two mainstem and two tributary locations. Biological conditions at a subset of these sites ranged from very poor to excellent.

Big Bone Creek

Recent water quality data are available for one mainstem and four tributary locations, for dry weather conditions. Elevated levels of bacteria are observed at one mainstem and one Mud Lick Creek location, and one dissolved oxygen violation was observed in the mainstem. A review of 15-minute data (Water Year 2000-2005) collected at Mud Lick Creek RM 3.0 reveals recurring dissolved oxygen, pH and temperature violations, with this location having significantly more temperature violations than the other Northern Kentucky USGS stations.

Portions of the Mud Lick Creek watershed experience frequent flooding (BCPC, 2005), and areas with significant stream bank erosion have been observed along the mainstem.

In 2004, stream habitat was assessed as partially to fully supporting in the mainstem and two tributaries. Biological conditions at the same sites ranged from good to excellent.

Ohio West Tributaries

Recent water quality data collected during dry weather are available for two locations in Middle Creek and one location in Lick Creek and Landing Creek. Recent data reveal elevated levels of bacteria in at least one sample in all three creeks. One dissolved oxygen violation has also been observed in Lick Creek.

Streambank erosion is evident in some of the streams in this watershed, although other streams appear to be in very good condition. A 1999 assessment of Middle Creek found that aquatic habitat is partially supporting. A 2008 biological assessment (macroinvertebrates) at a different Middle Creek location reflected excellent conditions.

Impact of Pollution Sources

Potential pollution sources in this basin include sewer overflows, other KPDES-permitted dischargers, septic systems and storm water runoff. Potential pollution sources are presented in Table 2.45 and shown on Figure 2.33.

Sewer overflow locations and model-calculated volumes are described previously in this section. Septic systems are generally located outside of the SD1 sanitary sewer area. The NKHD estimates that 10% or more of septic systems in Northern Kentucky may be operating improperly (NKHD, 2008a). Two septic areas were identified in this basin as having problems (NKHD, 2008b). All three watersheds in this basin have a high potential for failing septic systems to contribute bacteria during dry weather. Permitted sanitary wastewater outfalls in this basin are covered by residential general permits, and the required twice-annual data were not available for 56% of these locations for the

January 2007 to June 2008 period. The failure rate for these residential dischargers may be higher than 10% (KDOW, 2007).

The bacteria loading potential for each watershed has been calculated using SD1's Watershed Assessment Tool (WAT!). Bacteria loading potential by watershed and source is shown in Table 2.45.

Figure 2.33 Potential Sources in the West Basin

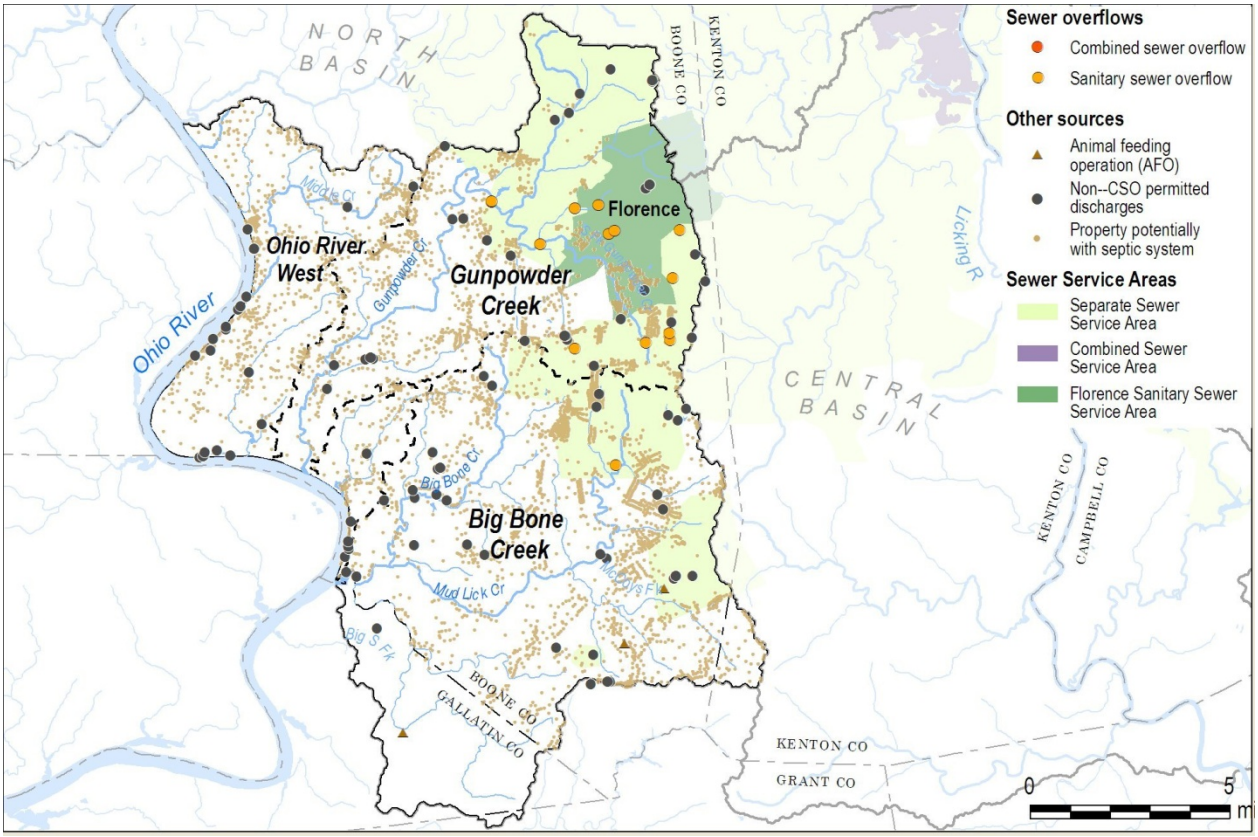
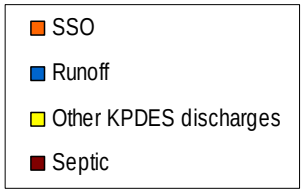
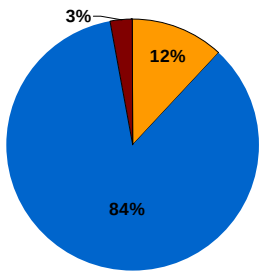
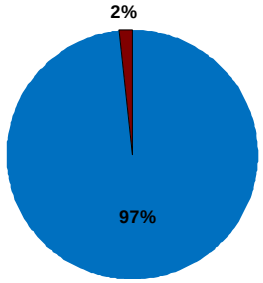
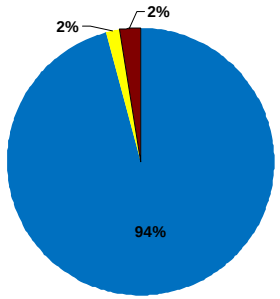
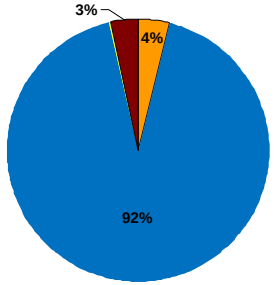


Table 2.45 Potential Pollution Sources in the West Basin

Feature	Gunpowder Creek	Big Bone Creek	Ohio River West Tributaries	West Basin
SSOs	13 [1]	1	0	14
Septic systems	Many downstream 1 known problem area	Many 1 known problem area	Many	Many 2 known problem areas
KPDES-sanitary outfalls	18	23	24	65
Storm water runoff	Urban and rural	Rural, with some urban	Rural	Predominantly rural, with some urban
Livestock[2]	Beef cattle and horses	Beef cattle, dairy cows, 3 AFOs	Beef cattle and horses	Beef cattle, dairy cows, horses, 3 AFOs
WAT! bacteria loading potential 				

Note:
1. Five of these are Florence SSOs
2. AFO = Animal Feeding Operation

2.2.6 Summary of Current Water Quality Impacts

The WAT! and the detailed watershed and water quality models of Banklick Creek, the Lower Licking River, Taylor Creek, and the Ohio River have been applied to assess water quality impacts. The application of WAT! to assess the potential of different sources to generate fecal coliform bacteria has been previously discussed in Section 2.2.1. WAT! has also been applied to assess the potential that each watershed has to impact water quality. This potential impact can be calculated in WAT! by normalizing the bacteria loading potential of each watershed by the watershed's drainage area. The area-normalized results for each watershed can be ranked for year-round or dry weather conditions to inform prioritization of pollutant source investigations and controls.

Figure 2.34 shows the area-normalized results for each watershed, where the size of each pie chart reflects what can be viewed as loading potential per acre. For example, both the rural Ohio River West watershed (with a 33.0 square mile drainage area) and much smaller, urban Pleasant Run Creek watershed (with a 6.5 square mile drainage area) have similar bacteria loading potentials (Figure 2.14). However, when these results are normalized by watershed area, as shown in Figure 2.34, it can be seen that, on average, land in the Pleasant Run Creek watershed has a higher bacteria loading potential than land in the Ohio River West watershed.

Figure 2.34 WAT! Area-Normalized Results Indicating Fecal Coliform Impact

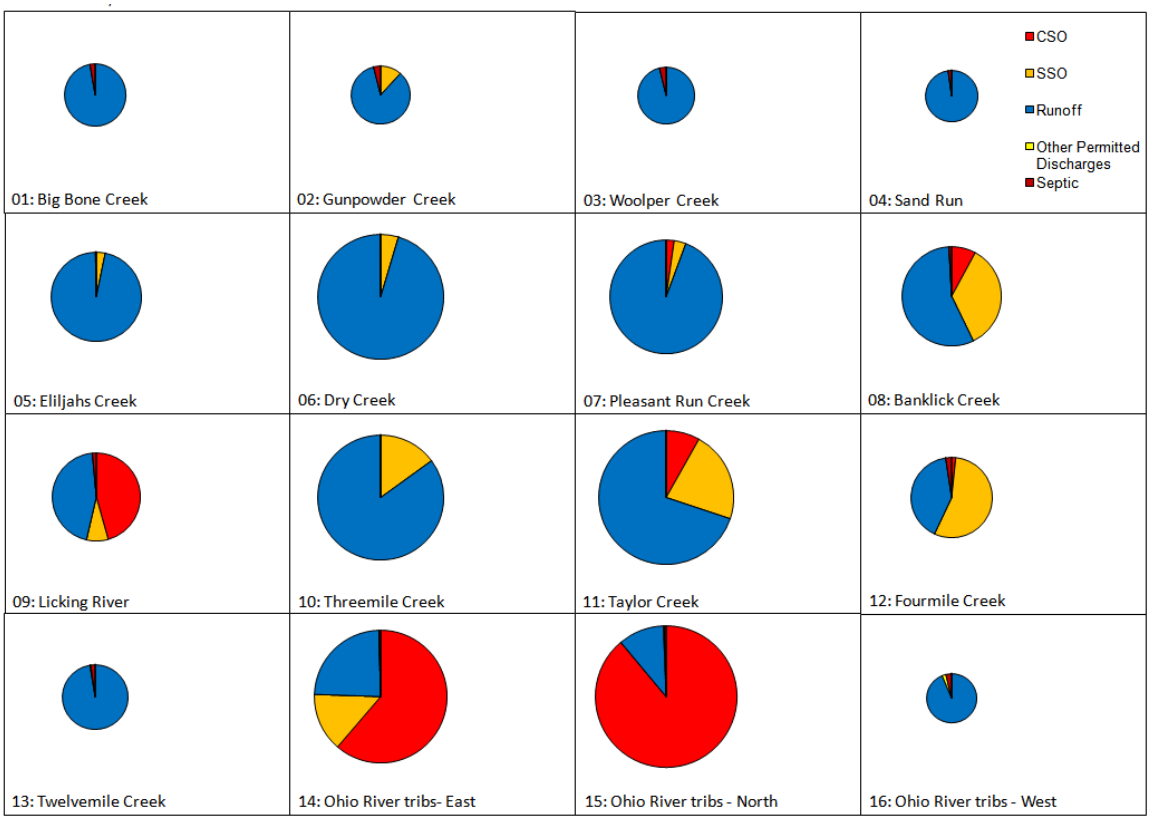


Table 2.46 shows the rankings for the sixteen watersheds based on their respective area-normalized results for year-round conditions.

A ranking of 1 reflects a larger potential to impact instream water quality and a ranking of 16 reflects a lower potential to impact water quality. As discussed previously, even though the Ohio River West and Pleasant Run Creek watersheds have similar bacteria loading potentials, their watershed rankings based on potential impact (area-normalized results) are quite different.

Table 2.46 WAT! Watershed Rankings Based on Area-Normalized Results for Bacteria

Watershed	Rank, year-round fecal coliform results
Banklick Creek	7
Big Bone Creek	12
Dry Creek	5
Elijahs Creek	8
Fourmile Creek	10
Gunpowder Creek	13
Licking River	9
Ohio River East	3
Ohio River North	1
Ohio River West	16
Pleasant Run Creek	6
Sand Run	15
Taylor Creek	2
Threemile Creek	4
Twelvemile Creek	11
Woolper Creek	14

In addition to the WAT!, SD1 conducted a more detailed analysis of CSO-impacted waterways, using a range of watershed and water quality models that are supported by EPA, including HSPF, SWMM and EFDC as described in Section 2.1.1. These computer models calculate bacteria densities, in cfu per 100 ml, along the entire length of the waterway for each hour of the simulation. This provides a more refined temporal and spatial analysis of compliance with water quality standards than use of data alone.

The Banklick Creek, Taylor Creek and Licking River models were applied over a five-year typical period (1992-1996) of rainfall and stream conditions to evaluate current bacteria conditions in these streams. All known sources of pollutants were represented in these models. The Ohio River model was also applied over the five-year period. The Ohio River model includes all SD1 source loads and the watershed sources in Banklick

Creek, the Licking River and Taylor Creek. Current conditions were evaluated by comparing model results during the recreation season (May 1 to October 31) to current KDOW water quality standards (note: Ohio River model results were compared to ORSANCO water quality standards):

- "**30-day Max**": The tributary models were evaluated with respect to compliance with the State's 30-day maximum fecal coliform criterion (at least 80% of days within a 30-day period have densities less than 400 cfu per 100 ml) while the Ohio River model results were evaluated with respect to ORSANCO's 30-day maximum fecal coliform criterion (at least 90% of days within a 30-day period have densities less than 400 cfu per 100 ml);
- "**30-day GM**": Compliance with the State's and ORSANCO's 30-day geometric mean[10] fecal coliform criterion (200 cfu per 100 ml);

The first measure tends to be the most difficult to meet in water bodies impacted by wet weather sources because the frequency of storm events often causes instream densities to exceed 400 cfu per 100 ml more than six days (20%) in a 30-day period. Current conditions for each model were characterized on the basis of compliance with this criterion (number of 30-day periods where at least 80% of the days were less than 400 cfu per 100 ml) so that conclusions regarding each watershed were based on a consistent evaluation metric. The model results were compared to both standards but results are discussed in detail for the 30-day maximum criterion since this criterion is more restrictive and better illustrates the impact from pollutant loads. Table 2.47 presents a summary of each modeled stream's compliance with current water quality standards under current conditions.

[10] The geometric mean is typically used to represent the true "average" of bacteria densities, because there is a tendency for the range of counts to include several very high values that are not representative of the majority of the densities and skew the value of the arithmetic average density.

Table 2.47 Compliance with Current Water Quality Standards Criteria Based on Detailed Model Results

Stream/Watershed	Pollutant Sources Included in Simulation	Length of Stream Modeled	Range of compliance with 30-day GM WQS[1],[2]	Range of compliance with 30-day Max WQS[1],[3]
Banklick Creek	All[4]	All	4.5% - 23%	2.0% - 15%
Taylor Creek	All[4]	All	0% (all locations)	0% (all locations)
Licking River	All[4]	Lower 5.5 miles	25.3% - 95.6%	27.5% - 99.7%
Ohio River	SD1 overflows Banklick, Taylor, Licking watershed[5]	RM 443.4 – RM 490[6]	100% (all locations)[5]	90.0% - 100%[5]

Notes:

1. The output at each model node/grid cell was evaluated and the minimum and maximum compliance rates are shown in this table. Additional discussion about the locations corresponding to high and low rates of compliance is presented in the text below.
2. 30-day GM WQS = KDOW and ORSANCO Water Quality Standard: Percent of rolling 30-day periods where the geometric mean density is less than 200 cfu per 100 ml.
3. 30-day Max WQS = KDOW Water Quality Standard: Percent of rolling 30-day periods where at least 80% of days within a 30-day period have densities less than 400 cfu per 100 ml. ORSANCO Water Quality Standard: Percent of rolling 30-day periods where at least 90% of days within a 30-day period have densities less than 400 cfu per 100 ml. The KDOW criterion was used for Banklick, Taylor and Licking Rivers. The ORSANCO criterion was used for the Ohio River.
4. Sources include dry weather sources (such as KPDES discharges, failing septics, wildlife, livestock), runoff and SD1 overflows (CSOs, SSOs).
5. The Ohio River simulation includes SD1 overflows (CSOs, SSOs) discharging directly to the Ohio River and the results at the mouth from the detailed Licking River (which includes Banklick Creek) and Taylor Creek models (which include all sources in their watersheds). This simulation does NOT include sources originating on the Ohio side of the river because they were not available. Upstream loads were also not included so that the simulation results would primarily reflect the impact of SD1 overflows on Ohio River water quality.
6. River mile 443.4 corresponds to the Campbell/Pendleton County line. River mile 490 corresponds to the confluence of the Great Miami River. This length comprises all of the area of the Ohio River potentially affected by SD1 overflows

Compliance with 30-day water quality criteria (e.g. 30-day maximum and 30-day geometric mean) is driven by both dry and wet weather source loads. Because dry weather conditions occur more frequently over a 30-day period, low compliance is an indication that dry weather-related sources are important. Low compliance rates during dry weather conditions have been calculated in both Banklick Creek and Taylor Creek using available dry weather monitoring data. The detailed model results are consistent with the data. The importance of wet weather-related sources can be identified in areas where the overall compliance rate simulated with the detailed models is lower than the data-derived dry weather compliance rate.

Compliance can also be evaluated for specific reaches to assess the importance of SD1 overflows relative to other watershed sources. Low compliance rates calculated in portions of streams that do not receive any SD1 overflows are an indicator that other,

non-SD1 wet weather sources are also important. Water quality standards compliance in the upper portions of Banklick Creek and Taylor Creek is driven by other wet weather sources; there are no SD1 overflows contributing to these headwater reaches. In the lower Licking River, where dry weather loads are not apparently significant, compliance with water quality standards as calculated by the model is better. The detailed water quality model results are consistent with the instream water quality data (see WCRs) and with the WAT! conclusions.

Banklick Creek

The Banklick model calculates fecal coliform densities for 14 subwatersheds along the mainstem creek and 14 subwatersheds representing the 8 tributaries. Under current conditions, annual average loads to this creek are largely from runoff sources (Figure 2.35). The majority of the volume from SD1 CSOs and SSOs occurs primarily in the lower 4 miles of the creek. It is important to note that loads from wet weather sources such as runoff, CSO and SSO are periodically input to the stream; however, loads from dry weather sources are always present in the stream. Therefore, even though dry weather loads comprise a small overload fraction of the total load, because they are always present, these sources can have a larger influence on compliance with water quality standards.

Figure 2.35 Annual Average Fecal Coliform Loads to Banklick Creek (Five-year Typical Period) for Current Conditions

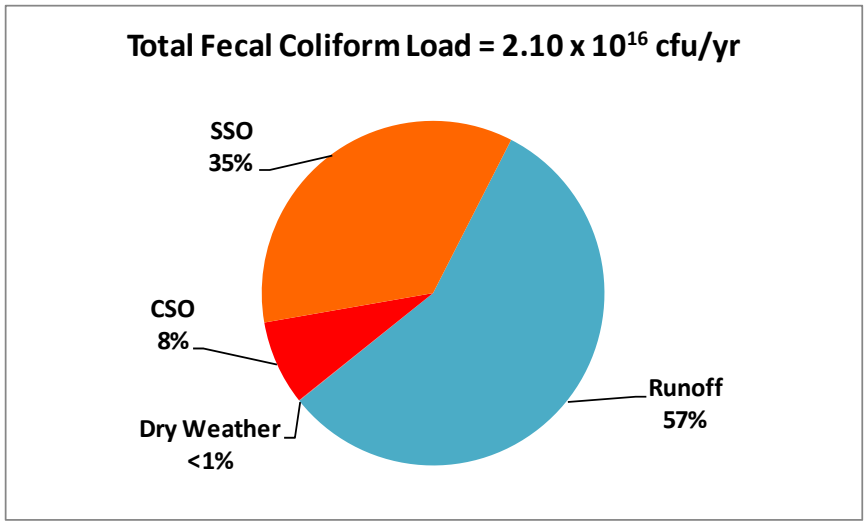
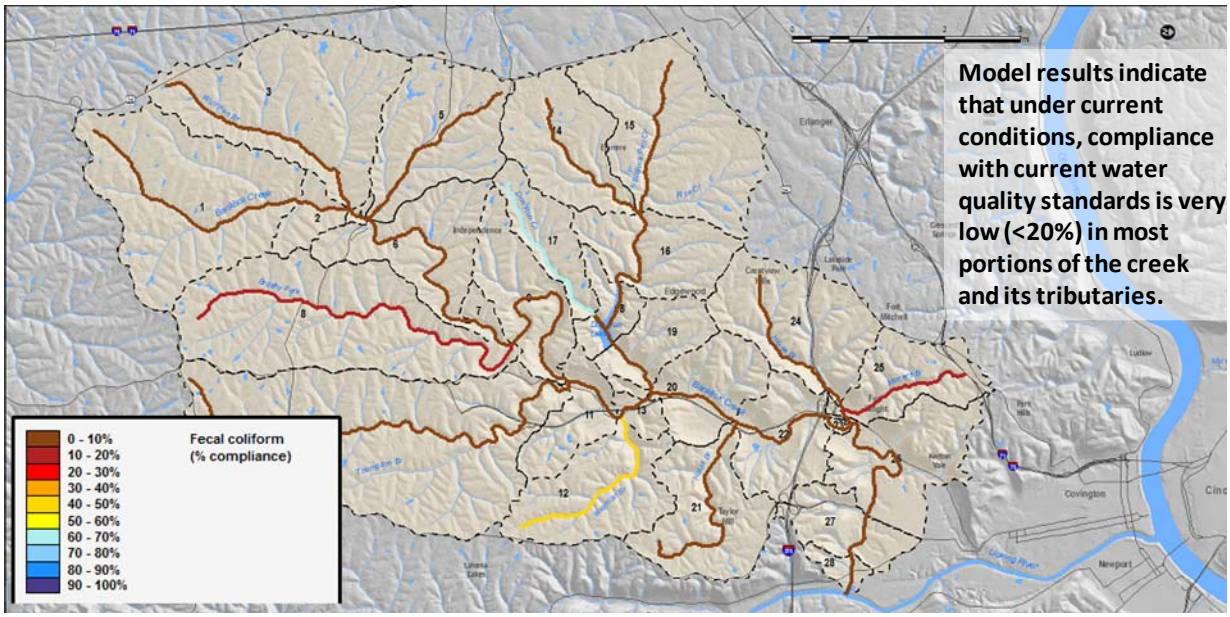


Figure 2.36 below shows that the model calculates relatively low compliance (<20%) with current water quality criteria throughout the length of the creek. The figure also shows that water quality in the Banklick Creek tributaries is slightly better, but compliance never exceeds 50% in the major tributaries. Results like those found in Figures 2.36 and 2.37 show that an approach that only addresses CSOs and SSOs would fall well short of improving water quality in the Banklick Creek and reinforces the value of SD1's watershed approach that addresses multiple sources of pollution.

Figure 2.36 Banklick Creek Current Conditions-Compliance with Fecal Coliform 30-day Maximum Water Quality Criterion (% of 30-day periods where at least 80% of values < 400 cfu/100 ml)

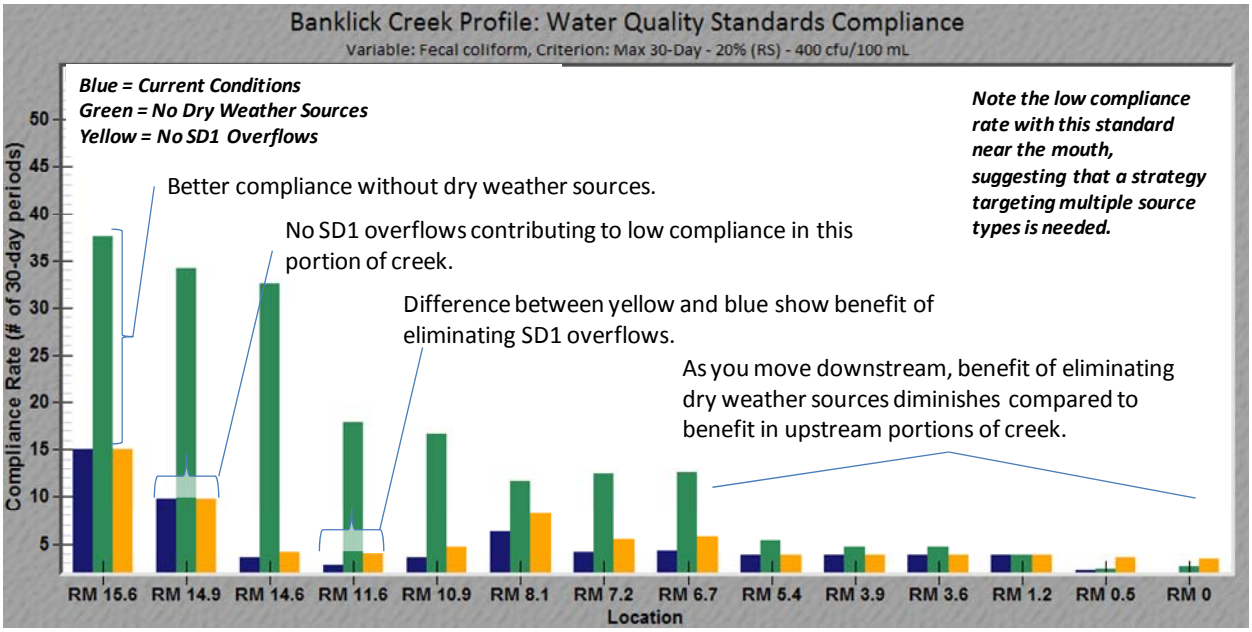


Because SD1 sewer overflows are primarily found near the mouth of Banklick Creek, the low compliance rate with water quality criteria along the length of Banklick Creek suggests that other significant sources of fecal coliform present. An analysis of the frequency of rainfall events from the Greater Cincinnati airport data indicates that an event occurs approximately every 3-4 days. This suggests that the majority of a given week, month, year is comprised of dry weather conditions. Because the creek exceeds water quality standards more than half the time, some of these exceedances occur during dry weather conditions. Therefore, this low compliance rate indicates dry weather sources are also important in this watershed.

Two sensitivity simulations were done with the model to evaluate the importance of non-sewer overflow sources: 1) current conditions without overflow sources, and 2) current conditions without dry weather sources. Figure 2.37 shows that similar compliance rates are calculated for the “current conditions” (blue bar) and “no SD1 overflows” (yellow bar) model runs. This is expected because SD1 overflows are primarily found in the downstream portion of the watershed.

Figure 2.37 shows that compliance increases more noticeably in response to the theoretical elimination of dry weather sources (green bar). Although it’s not practical to completely eliminate dry weather sources (for example, there are KPDES-permitted dischargers in the watershed), the results from this sensitivity analysis suggest that spending resources on reducing dry weather sources would improve water quality. Controls that address other wet weather sources may also yield more improvement in water quality than SD1 overflow control alone.

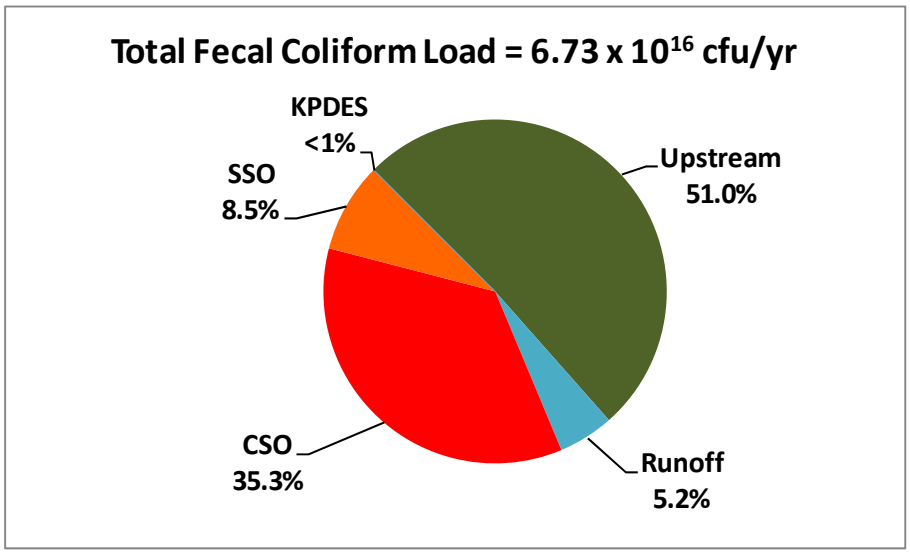
Figure 2.37 Comparison of Banklick Creek Model Sensitivity Simulations-Compliance with Fecal Coliform 30-day Maximum Water Quality Criterion (% of 30-day periods where at least 80% of values < 400 cfu/100 ml)



Licking River

The Licking River model calculates fecal coliform densities for 210 segments in the lower Licking River, with three segments across the river and 70 segments in a longitudinal direction along the mainstem. The model also includes the lower 4 miles of Banklick Creek, which are represented with 42 segments. In contrast to Banklick Creek, SD1 sewer overflows are located along the lower five miles of the Licking River and are significant sources of bacteria (Figure 2.38), comprising approximately 45% of the total fecal coliform load.

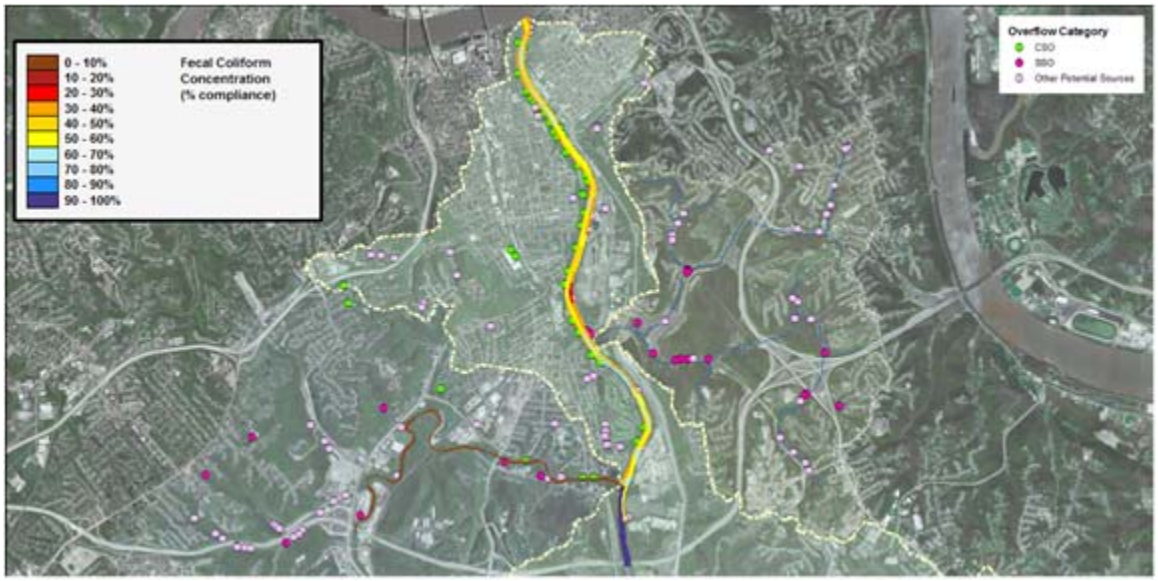
Figure 2.38 Annual Average Fecal Coliform Loads to Lower Licking River (Five-year Typical Period) for Current Conditions



Note: CSO and SSO percentages include fecal coliform load from CSOs and SSOs directly to the Licking River, CSOs and SSOs in lower four miles of Banklick Creek and from SSOs in Threemile Creek. Upstream loads include loads from all sources (runoff, KPDES, etc.) upstream of river mile 4.0 in Banklick Creek (including loads from SSOs in that portion of Banklick Creek) and loads from all sources (e.g. runoff, KPDES, etc.) upstream of river mile 5.5 in the Licking River (including loads from SSOs in that portion of the Licking River).

Figure 2.39 shows good water quality (>80% compliance) is calculated in the Licking River upstream of Banklick Creek. Below the Banklick Creek confluence, compliance in most of the model cells is only 30 to 55% during the recreation season, although some locations have higher or lower compliance. Exceedances of this criterion, particularly for the segments near the east or west banks of the Licking River, are largely driven by wet weather loads.

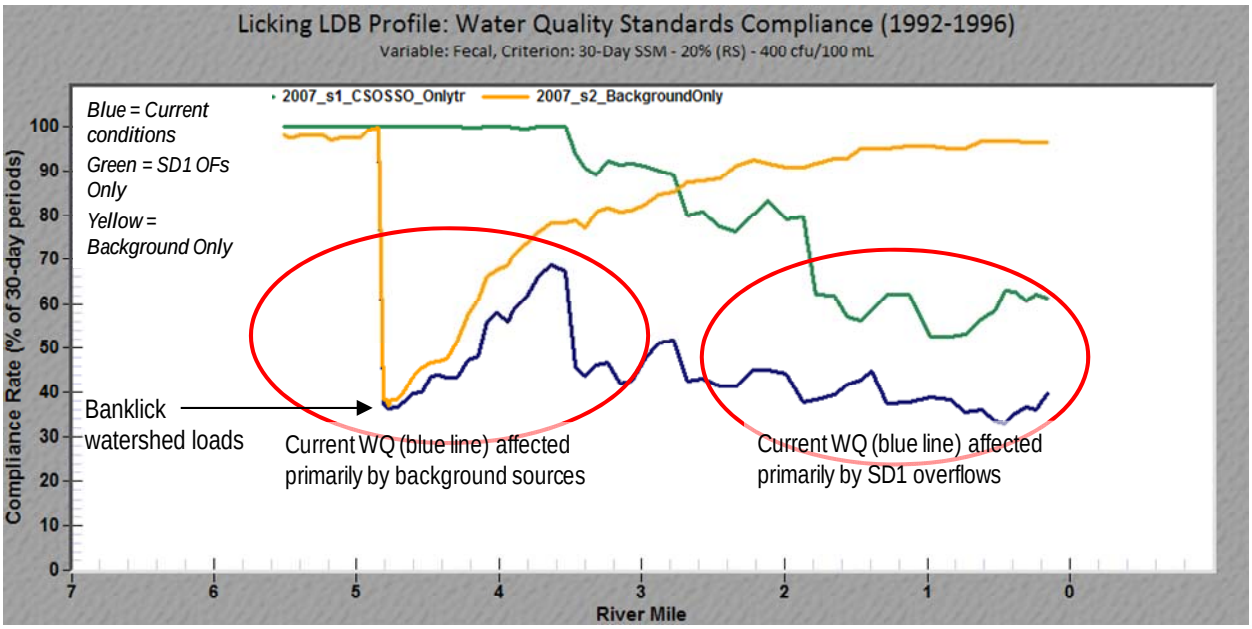
Figure 2.39 Licking River Current Conditions-Compliance with Fecal Coliform 30-day Maximum Water Quality Criterion (% of 30-day periods where at least 80% of values < 400 cfu/100 ml)



To better understand the relative importance of SD1 CSOs and SSOs on Licking River water quality, two sensitivity simulations were conducted: 1) current conditions without background sources ("SD1 only"), and 2) current conditions without SD1 overflows ("background only"). In the first sensitivity, only the loads from SD1 CSOs and SSOs within the model domain were input to the model for the typical period. In the second sensitivity, the SD1 overflow loads within the model domain were zeroed out, so the only model inputs included upstream, other KPDES, and runoff loads.

The effects of the Ohio River stage on Licking River hydraulic characteristics can be seen in compliance rates for the "SD1 only" (green line in Figure 2.40), which range between 52% and 63% near the mouth while compliance is higher further upstream (>80%). The Ohio River tends to slow down the flow in the Licking River so loads that are discharged near the mouth, such as SD1 CSOs, are not quickly transported downstream into the Ohio River. Instead, these loads linger near the mouth and so, exert more impact on water quality near their outfalls than in a freely-flowing stream system. A similar situation is observed in the "background only" simulation (yellow line in Figure 2.40). The river hydraulics slow down the transport of the background source loads, which tend to be input further upstream, so more impact (lower compliance rate) is calculated near the upstream portion of the model. However, loads further upstream benefit from the slow velocity conditions in the Licking River because the lengthy transport time allows more bacteria to die-off, lowering densities and increasing compliance near the mouth. Taken together, current conditions in the river are affected by both SD1 overflows and background sources which points to the need for a watershed based approach that addresses the multiple sources of pollution contributing to water quality impairment.

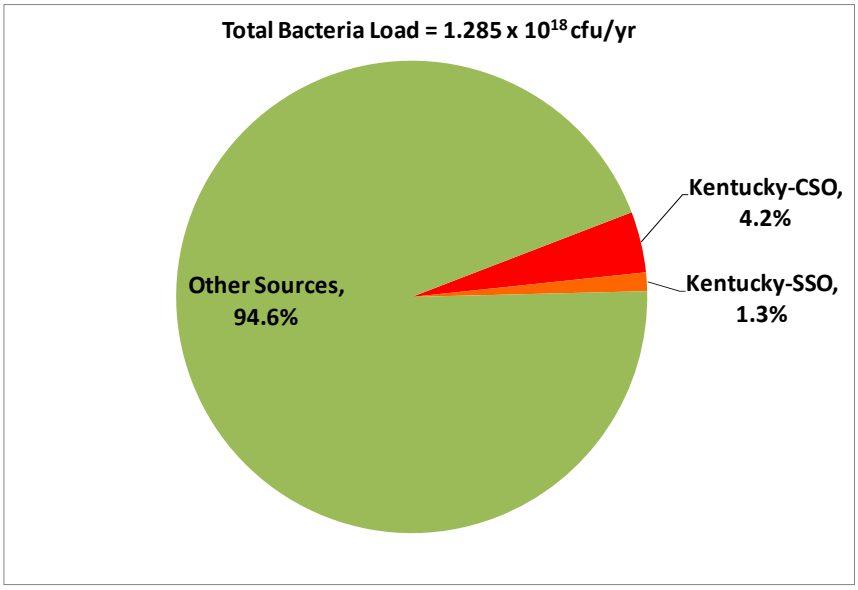
Figure 2.40 Comparison of Licking River Model Sensitivity Simulations-Compliance with Fecal Coliform 30-day Maximum Water Quality Criterion (% of 30-day periods where at least 80% of values < 400 cfu/100 ml) Along Left Descending Bank



Ohio River

The water quality component of the Ohio River model extends between the Campbell/Pendleton County line (RM 443.4) downstream to the confluence of the Great Miami River (RM 490), for a total length of 46.6 miles. This model calculates fecal coliform densities in five segments across the Ohio River and 283 segments along the longitudinal direction. Annual average bacteria loads to this reach of the river in a typical year were estimated using available data and published information. This analysis (Figure 2.41) indicates that SD1 overflows comprise approximately 6% of the total annual bacteria load to the river in a typical year.

Figure 2.41 Annual Average Bacteria Loads to Ohio River (RM 443.6 – RM 490)



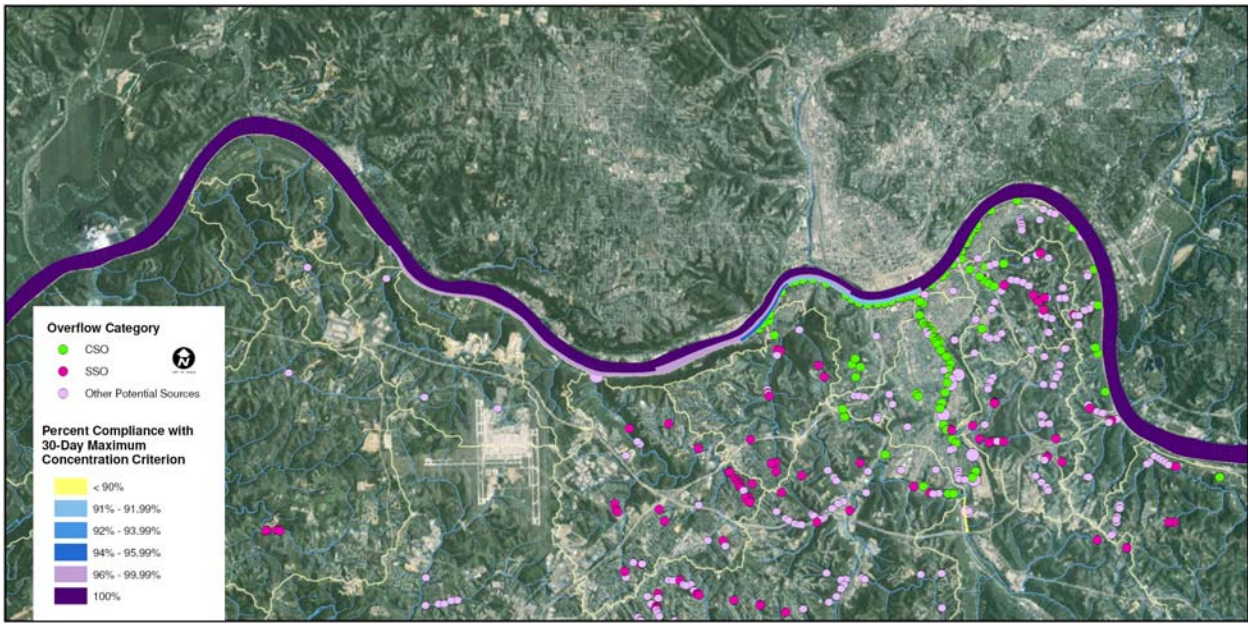
The bacteria load for the CSO and SSO slices shown in Figure 2.41 includes all SD1 CSOs and SSOs, both tributary to and directly discharging to the Ohio River. Cumulatively, the SD1 CSO and SSO load accounts for 5.5% of the total annual load to the Ohio River. The watershed loads from the detailed models for the Licking River, Banklick Creek and Taylor Creek correspond to 2.9% of the total load. The watershed loads from these detailed models are included in the "Other Sources" slice of the pie chart in Figure 2.41. Therefore a total of 8.4% of the total annual load to the Ohio River is represented by SD1's hydraulic model and detailed water quality models.

The loading sources input to the Ohio River model include all SD1 overflows and the watershed loads simulated by the Banklick, Licking and Taylor detailed models. This approach was chosen for several reasons: 1) although fate and transport mechanisms are calibrated in the model, fecal coliform in the middle portion of the Ohio River model is not as rigorously calibrated as the rest of the model domain so simulations of water quality with loads from all sources (including Ohio-side and upstream) may not reasonably represent actual conditions, and 2) inputs for all sources were not available at the temporal frequency needed for the model (e.g. hourly flows and densities). Nevertheless, this approach permits SD1 to evaluate relative benefits from different control scenarios because it isolates the impact of SD1 overflows on instream water quality from other sources.

Loads to the model are input to the near shore (Kentucky bank) segments and are transported downstream and across the river within the model. Modeled instream densities along the Kentucky bank receiving SD1 overflows (RM 461 – RM 474) show that this portion of the river is the most impacted portion of the river, yet the number of 30-day periods meeting the maximum criterion (at least 90% of the fecal coliform densities in the 30-day period are less than 400 cfu per 100 ml) is greater than 90% in

all segments, even in the immediate vicinity of SD1 overflows, as shown in light purple in Figure 2.42.

Figure 2.42 Ohio River Current Conditions-Compliance with Fecal Coliform 30-day Maximum Water Quality Criterion (% of 30-day periods where at least 90% of values < 400 cfu/100 ml)



Note: SD1 overflows only are shown in this figure. Point sources north of the Ohio River are not mapped. Other potential sources include model-calculated overflows at manholes that have not been field verified.

Maximum densities in the Kentucky bank segments can exceed 50,000 cfu per 100 ml. This suggests that while loads from SD1 overflows can result in elevated densities in the river, the duration of these high densities is short enough that water quality standards are still met more than 90% of the time along the Kentucky shore. The Ohio River provides significant dilution as the maximum densities in the segments along the Ohio bank are over an order of magnitude smaller (e.g. less than 5,000 cfu per 100 ml) and SD1 overflows alone do not cause exceedances of fecal coliform water quality standards along the Ohio side of the Ohio River in a typical year for any 30-day period in the recreation season. These results show that controlling SD1 sources that discharge to the Ohio River would result in little increase in improvement in water quality. In addition, the ORSANCO Ohio River 30-day maximum water quality criterion (at least 90% of the fecal coliform densities in the 30-day period are less than 400 cfu per 100 ml) is already met with current SD1 overflows alone. All of the Ohio River segments were in compliance with ORSANCO's Ohio River 30-day geometric mean water quality criterion of fecal coliform densities less than 200 cfu per 100 ml with current SD1 overflows alone.

Taylor Creek

The Taylor Creek model calculates fecal coliform densities in 65 segments representing Taylor Creek and its tributaries. SD1 CSOs and SSOs are located primarily in the lower portion of the creek and its main branches (Woodlawn Creek and Covert Run). Figure 2.43 shows that under current conditions, annual average loads to the creek are largely from runoff sources. Dry weather source loads comprise a larger proportion of the load in this creek compared to the other watersheds. The sources of this load are not well established and cannot be mechanistically modeled, so the dry weather inputs were estimated based on instream data collected during dry weather (note that the WAT! estimates dry weather load as the sum of KPDES and failing septic systems only).

Figure 2.43 Annual Average Fecal Coliform Loads to Taylor Creek (Five-year Typical Period) for Current Conditions

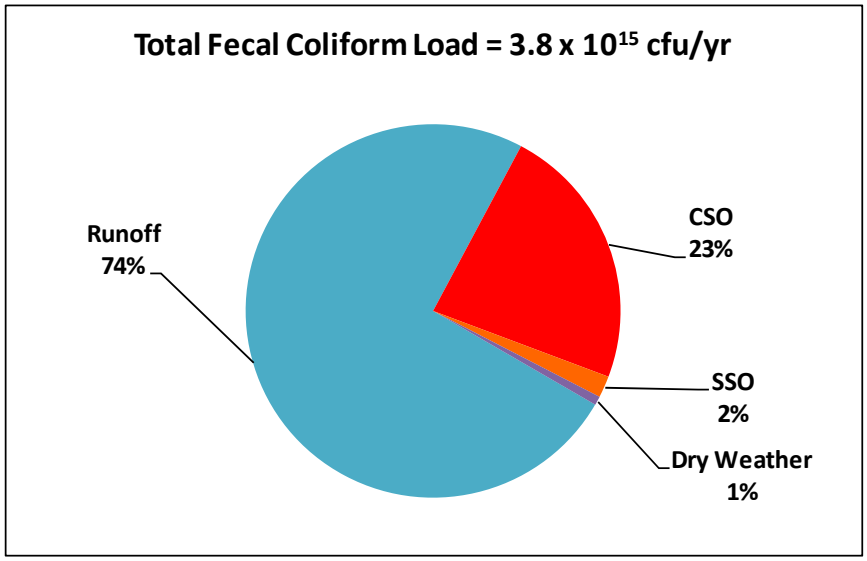


Figure 2.44 shows that water quality in Taylor Creek is poor, as no portion of the creek or its major tributaries (Woodlawn Creek and Covert Run) meets water quality standards for any 30-day period within the recreation season.

Figure 2.44 Taylor Creek Current Conditions-Compliance with Fecal Coliform 30-day Maximum Water Quality Criterion (% of 30-day periods where at least 80% of values < 400 cfu/100 ml)

Samples collected from Taylor Creek during dry weather reflect fecal coliform densities that were significantly higher than the water quality standard numeric criterion. These data were used to inform the model inputs, and the importance of dry weather sources is reflected in the low compliance rate with water quality standards throughout the main stem of the creek. A sensitivity simulation was conducted with the model by zeroing out the dry weather source loads so that their effect on water quality could be evaluated. Compliance rates with the 30-day maximum criterion are shown in Figure 2.45 for this sensitivity.

Figure 2.45 Taylor Creek Current Conditions With No Dry Weather Sources- Compliance with Fecal Coliform 30-day Maximum Water Quality Criterion (% of 30-day periods where at least 80% of values < 400 cfu/100 ml)

The detailed water quality models provided additional insight into current conditions in the modeled streams and the effect of SD1 overflows on instream water quality. Major findings from the modeling are summarized below.

Conclusions

The detailed water quality models provided additional insight into current conditions in the modeled streams and the effect of SD1 sources on instream water quality. Major findings from the modeling include the following points:

- Detailed water quality models were developed for watersheds and streams where water quality is impaired and SD1 overflows were suspected to be a significant contributor of bacteria loads. Application of the models confirms the impairment with respect to fecal coliform but shows that the influence of SD1 overflows on water quality varies by watershed and that other sources of pollution are significant contributors to impairment.

- Water quality in Banklick Creek and Taylor Creek is poor (compliance with water quality standards is < 20%) but this is due to multiple sources, including dry weather and runoff from other (non-SD1 overflows) wet weather sources, in addition to SD1 overflows. A control strategy that addresses dry weather and runoff sources may provide more improvements in instream water quality than control of SD1 overflows alone.

- Because SD1 overflows comprise less than 6% of the total load to the Ohio River, the detailed model was applied to analyze the effects of SD1 overflows

alone on instream water quality. Results showed that both the maximum and the 30-day geometric mean criteria could be met if other sources were not present. This suggests that SD1 overflows are not significantly impacting water quality in the Ohio River and SD1 should prioritize controls in watersheds where water quality is more impaired than in the Ohio River.

- Because the lower 5 miles of the Licking River are within SD1's combined sewer system area, CSO loads are calculated to have a larger water quality effect on this reach than on other streams assessed with detailed models. Taken together, current conditions in the Licking River are affected by both SD1 overflows and background sources which points to the need for a watershed based approach that addresses the multiple sources of pollution contributing to water quality impairment. However, water quality in the lower Licking River is better than the smaller watersheds (e.g. Banklick and Taylor) that are affected by multiple source types.

2.3 Future Conditions

Using the water quality and infrastructure models discussed in Section 2.1.1 and 2.1.2., forecasts of future land cover and population changes were developed to allow for simulation of runoff, and dry and wet weather sewer overflows for the 2030 future conditions.

The 2030 future condition was developed for assessing the controls needed for the Full System Bounding Analysis. This horizon was selected for analysis for several reasons:

- very little growth is expected to occur in the combined sewer system beyond 2030;
- this horizon coincides with the Consent Decree deadline of 2025;
- a 20-year planning horizon is typical for regional development planning; and,
- little information about development beyond 2030 is available.

These forecasts were developed by analyzing land use changes, projected population growth, commercial/industrial growth, and potential redevelopment in the combined sewer areas.

2.3.1 Development of Future Land Cover Conditions

Current land use categories (e.g., residential, commercial, agriculture) were intersected with land cover conditions to assign "signatures" for each land use based on the current mix of land covers (e.g., developed open space, forest, water). Future land use conditions from Boone, Campbell and Kenton County Planning, supplemented with information input by planning agency staff, local officials and the work of the Northern Kentucky Area Planning Commission, were then mapped by applying the current land cover mixes to future land uses.

Certain areas were assumed to have little or no land cover change into the future. For example, if both the current and future land use in an area is agriculture, then no new

development would be estimated for that area. Some land covers that were not changed include water, wetlands, and high intensity development. Also, parklands, steep slopes, and riparian areas were assumed to be unchanged into the future.

2.3.2 Population Growth

Projections of population growth for master planning are challenging and often overly optimistic. The projected future 2030 population was determined by analyzing historical growth patterns, both spatially and quantitatively, to account for the highly site-specific projected development. Information used to develop future conditions included county comprehensive plans; previous growth studies; sewer tap connection data from 2001 through 2007; and Traffic Analysis Zone data.

This analysis was conducted for the current Dry Creek WWTP service area, and adjusted for growth forecasts using the sewer tap connection data. Analysis of the 2001 to 2007 sewer tap data indicated that connection rates have averaged 1,899 per year (1,027 in Boone County; 692 in Kenton County; and 180 in Campbell County). Historic growth rates in Campbell County may be somewhat low compared to future growth due to a 10-year sewer connection ban prior to the Eastern Regional WRF going online to replace the failing Alexandria plant. Future flows for the Western Regional WRF were developed from previous studies using the same process and are not discussed in detail in this section.

The average sewer tap rates were used to develop future residential flows and acreage within each service area. An average of 2.3 homes per acre was used to convert the number of sewer connections to acreage, which is based on historical housing densities across the region. These values were converted to population by applying a population density of 6.2 people per acre by using an average of 2.7 people per tap connection (based on historical population densities across the region). Table 2.48 shows the expected population increases through 2030 by county.

Table 2.48 Estimated Population Increase from 2008-2030 by County

County	1990 Population	2008 Estimated Population	Projected 2030 Increase[1]	% Increase Over 2008
Boone	57,589	115,231	68,132	59%
Kenton	142,031	157,629	34,630	22%
Campbell	83,866	87,038	5,940	7%
Total	283,486	359,898	108,702	30%

Note:
1. Dry Creek and Western Regional service areas only.

Table 2.48 shows that the majority of growth is expected to continue to be in the Boone County area, which includes the Western Regional and Taylorsport Pump Station service areas.

2.3.3 Commercial/Industrial Growth

The above analysis pertains only to the residential portion of growth in SD1's service area. The next stage of the analysis was to estimate the commercial/industrial growth. The current land use information was used to estimate the amount of commercial/industrial growth relative to residential growth. The appropriate residential/non-residential growth ratio (acres of residential growth to non-residential growth) was applied to define the extent of commercial/industrial growth. In most cases, the ratio was 4 acres of residential growth to 1 acre of non-residential growth.

2.3.4 Projections in the Combined Sewer Service Area

The combined sewer area consists of the older river cities and is, for the most part, built out. An analysis of empty parcels in the combined service area indicates development/redevelopment could increase dry and wet weather-related flows due to an increase in impervious surface area from roofs and pavement. In the last few years, several new developments have been built in the combined sewer service area and others are currently being planned.

The biggest challenge was to estimate the extent of growth, and, more importantly impervious area growth. An analysis of recent impervious area growth trends, as well as estimates of available land, resulted in an approximate increase of 10 impervious acres per year in the combined sewer service area between 2008 and 2030, for a total of 220 additional impervious acres due to additional development/redevelopment. Due to the uncertain spatial distribution of this growth, this increase was applied assuming that growth would be concentrated in areas that had less than 50% impervious area under current conditions.

2.3.5 Modeling Future Dry and Wet Weather Flows

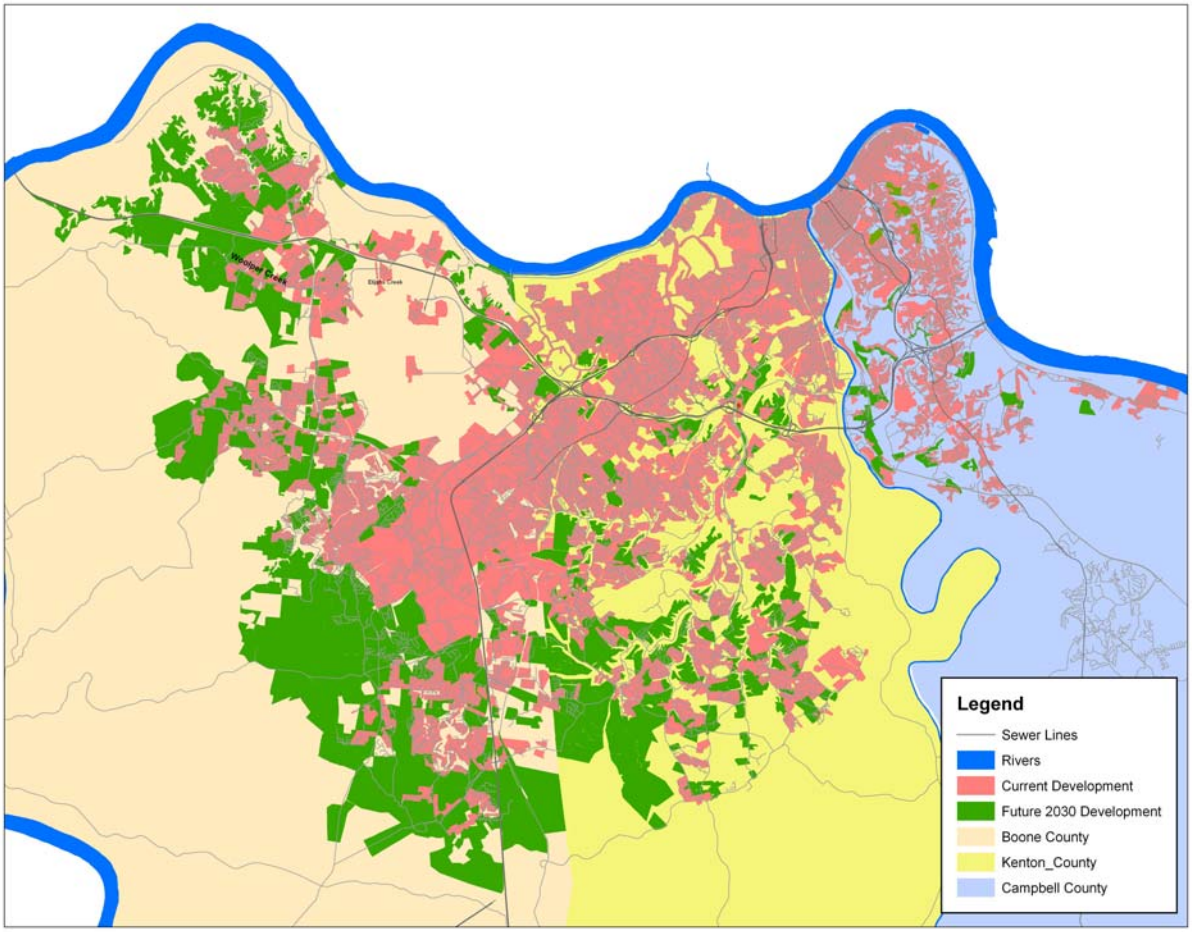
The infrastructure hydraulic model was used to simulate changes in dry and wet weather-related flows for the future conditions. The future population growth described in Table 2.48 and the commercial/industrial growth were added to the model as new subcatchments for the 2030 condition. These new subcatchments are shown in Figure 2.46 relative to the existing modeled subcatchments. The figure graphically depicts the fact that most of the growth is expected to occur in the western portions of the service area.

Dry weather base flows were applied to these subcatchments assuming 270 gallons per household per day, which includes 75 gallons per capita per day (gpcd) sanitary flow and 25 gpcd for base infiltration. This value was derived after a review of flow monitoring data taken from 5- to 10-year old developments with typical residential flow patterns.

Wet weather flows from new development were represented following the same modeling approach used in the calibration of existing service areas. Runoff surfaces to represent infiltration and inflow were applied based on a percentage of the total developed acreage. These percentages were developed by analyzing the flow

monitoring data from a wide range of recent developments throughout the SD1 service area. Runoff in the combined system for future development was simulated using similar runoff surfaces for current development.

Figure 2.46 Infrastructure Model Representation of Future (2030) Development



2.3.6 Water Quality Impacts of Future Development

The detailed water quality models described in Section 2.1.1 (Banklick Creek, Licking River, Taylor Creek, and the Ohio River) were applied to simulate a "no control" scenario based on estimated 2030 land cover and infrastructure conditions. This "no control" scenario serves as a baseline for evaluating relative benefits of various control scenarios on instream water quality considering future conditions. Under the "no control" scenario, the number of locations and frequency and total volume of CSOs and SSOs are projected to increase in each of these watersheds, compared to current conditions.

The "no control" scenario for 2030 was compared to the 2007 baseline (current conditions) with the detailed models. The effect of future conditions was evaluated by comparing model results during the recreation season (May 1 to October 31) to five

measures, including current KDOW water quality standards (note: Ohio River model results were compared to ORSANCO water quality standards):

1) "**30-day Max**": The tributary models were evaluated with respect to compliance with the State's 30-day maximum fecal coliform criterion (at least 80% of days within a 30-day period have densities less than 400 cfu per 100 ml) while the Ohio River model results were evaluated with respect to ORSANCO's 30-day maximum fecal coliform criterion (at least 90% of days within a 30-day period have densities less than 400 cfu per 100 ml).
2) "**30-day GM**": Compliance with the State's 30-day geometric mean[11] fecal coliform criterion (200 cfu per 100 ml).
3) "**Daily SSMax**": Number of days where the density was less than 400 cfu per 100 ml as a single sample maximum.
4) "**Rec season GM**": Geometric mean density.
5) "**Max Conc**": Maximum density.

The 30-day Max tends to be the most difficult to meet in water bodies impacted by wet weather sources because the frequency of storm events often causes instream densities to exceed 400 cfu per 100 ml more than six days (20%) in a 30-day period. The Daily SSMax was used in some cases because it provides a better illustration of differences in water quality for the scenarios (e.g. current vs. future conditions) run through the models. The Rec Season GM and Max Conc metrics were used because they are concentration-based evaluation tools rather than compliance-based tools, which are a different, and in some cases, more insightful, basis to evaluate model results. Table 2.49 presents a list of the primary and secondary measures used to evaluate each model's results. The primary measure was selected to evaluate benefits of different controls (gray infrastructure, green infrastructure, or watershed controls) because it best illustrates differences in scenario results. The secondary measures added to the interpretation and insight of the model results, and when useful, are discussed in this and other sections. The evaluation metrics also differ by river because the characteristics of the streams differ from each other.

Table 2.49 Evaluation Measures Used with Each Water Quality Model

Model	Primary Evaluation Measures	Secondary Evaluation Measures
Banklick Creek (HSPF)	Daily SSMax (#3 above)	30-day Max (#1) Rec season GM (#4)
Lower Licking River (EFDC)	30-day Max. (#1)	30-day GM (#2) Rec season GM (#4)
Taylor Creek (SWMM)	Daily SSMax (#3)	30-day Max (#1) Rec Season GM (#4)
Ohio River (EFDC)	30-day Max. (#1)	Max Conc. (#5)

[11] The geometric mean is typically used to represent the true "average" of bacteria densities, because there is a tendency for the range of counts to include several very high values that are not representative of the majority of the densities and skew the value of the arithmetic average density.

A comparison of current (2007) to future (2030 baseline) conditions shows additional water quality deterioration is calculated for each of the four modeled waterways, but that future impacts vary by waterway. Specific findings include:

- The entire length of Banklick Creek experiences approximately 20 additional days in the recreation season with densities greater than 400 cfu per 100 ml (Figure 2.47).
- The lower Licking River, experiences decreased compliance with the State's 30-day maximum fecal coliform criterion,[12] with compliance decreasing by an additional 10-20% from current conditions to an overall future compliance rate of 20-40%. This portion of the Licking River receives the majority of the CSO and SSO volume in the watershed (Figure 2.48).
- Instream bacteria densities are calculated to increase slightly in the future in Taylor Creek compared to current conditions, reflecting additional bacteria loadings from increased development. Figure 2.49 compares the geometric mean (or average) densities of 2007 and 2030 conditions in Taylor Creek and its tributaries. As noted previously, the Taylor Creek watershed is highly developed and the majority of Taylor Creek (including Woodlawn Creek and Covert Run) currently does not meet water quality standards during the recreation season.
- Good water quality is predicted in the Ohio River in the future, considering the impact from SD1 sources alone (Figure 2.50). A slight decrease in the percent of the 30-day periods complying with ORSANCO's 30-day maximum fecal coliform standard occurs in the 2030 baseline compared to current conditions (90% currently to 89% in the future, shown as the yellow cells along the Kentucky bank). However, the extent of this slight decrease in compliance rates is limited to the small portion of the river below the Licking River confluence that receives SD1 CSO overflow volume. As with current conditions, future SD1 sources alone do not impair water quality on the Ohio side of the river.

[12] Kentucky's water quality standards include a criterion where the fecal coliform density of no more than 20% of samples during a 30-day period can exceed 400 cfu per 100ml.

Figure 2.47 Comparison of Number of Days per Recreation Season in 2007 and 2030 Baseline Scenarios that Fecal Coliform Densities in Banklick Creek Watershed are Less than 400 cfu/100 ml

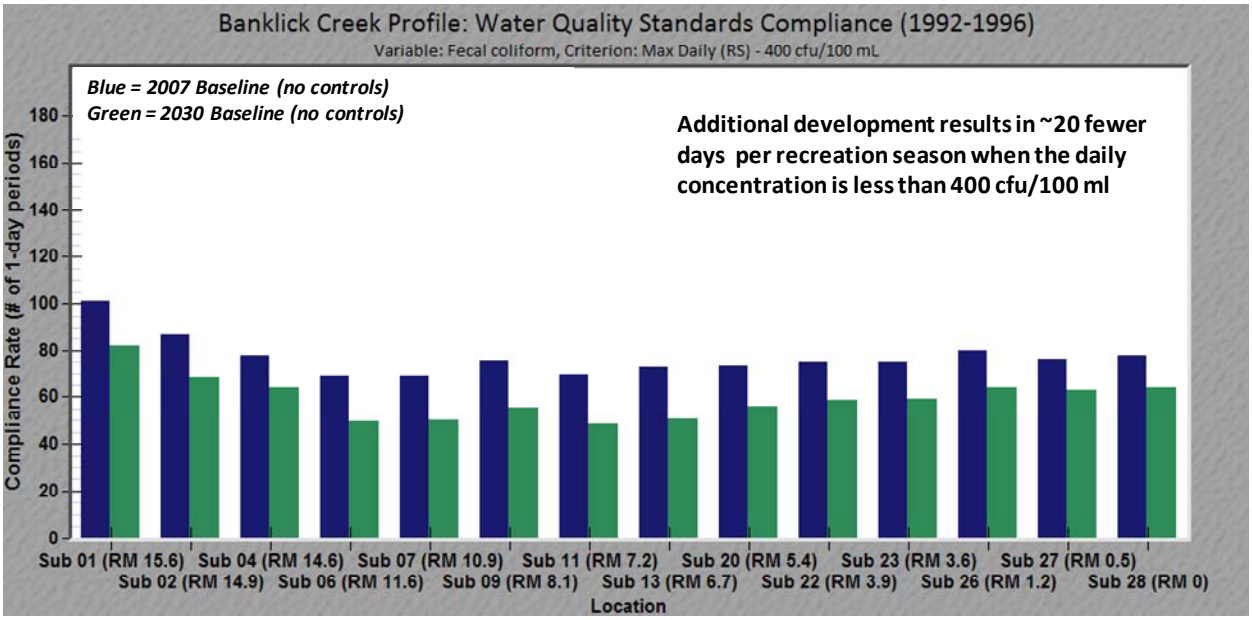


Figure 2.48 Comparison of Compliance with 30-day Maximum Fecal Coliform Water Quality Standard in the Lower Licking River in 2007 and 2030 Baselines

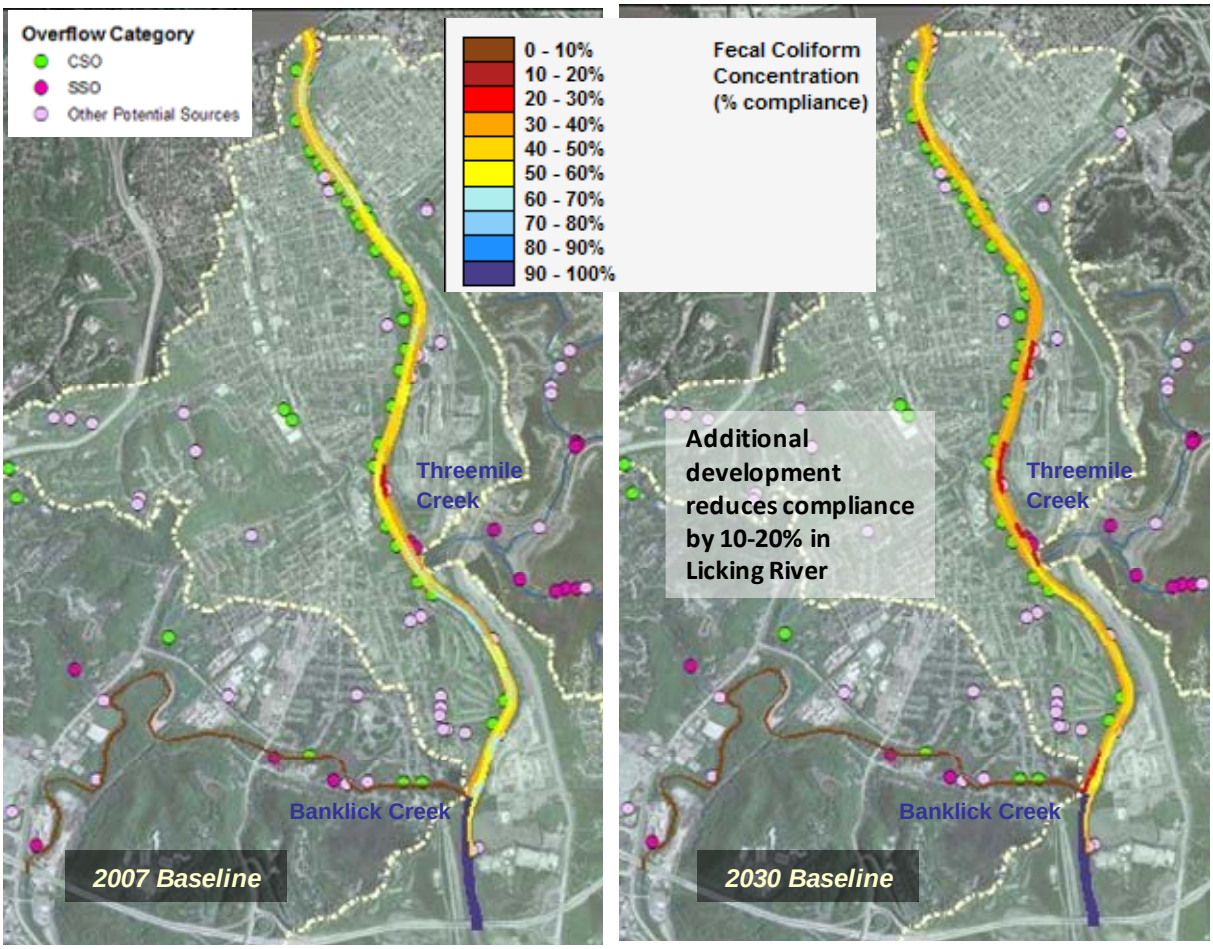


Figure 2.49 Comparison of Recreation Season Geometric Mean Concentrations in the Taylor Creek Watershed in 2007 and 2030 Baseline Scenarios

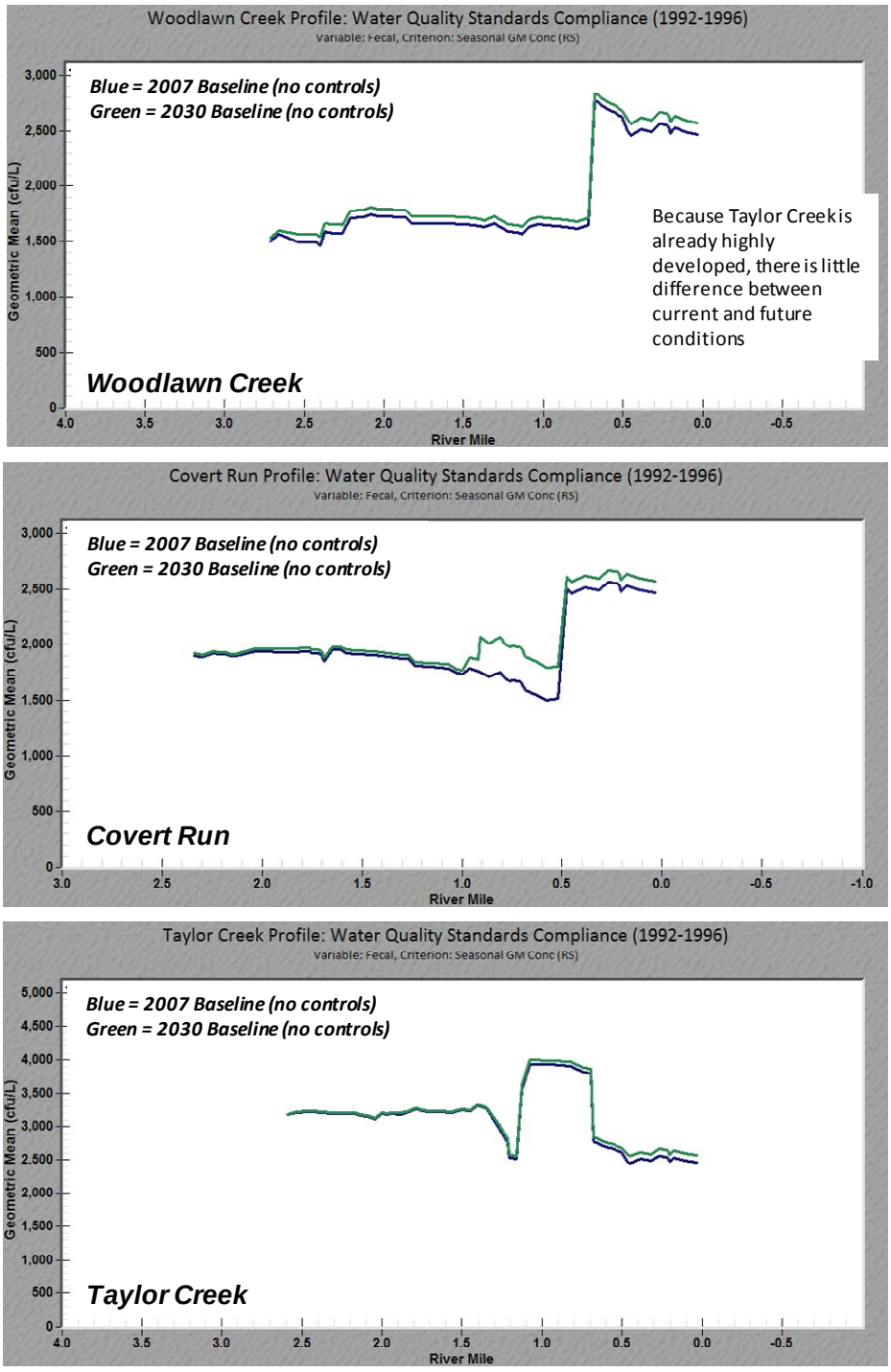
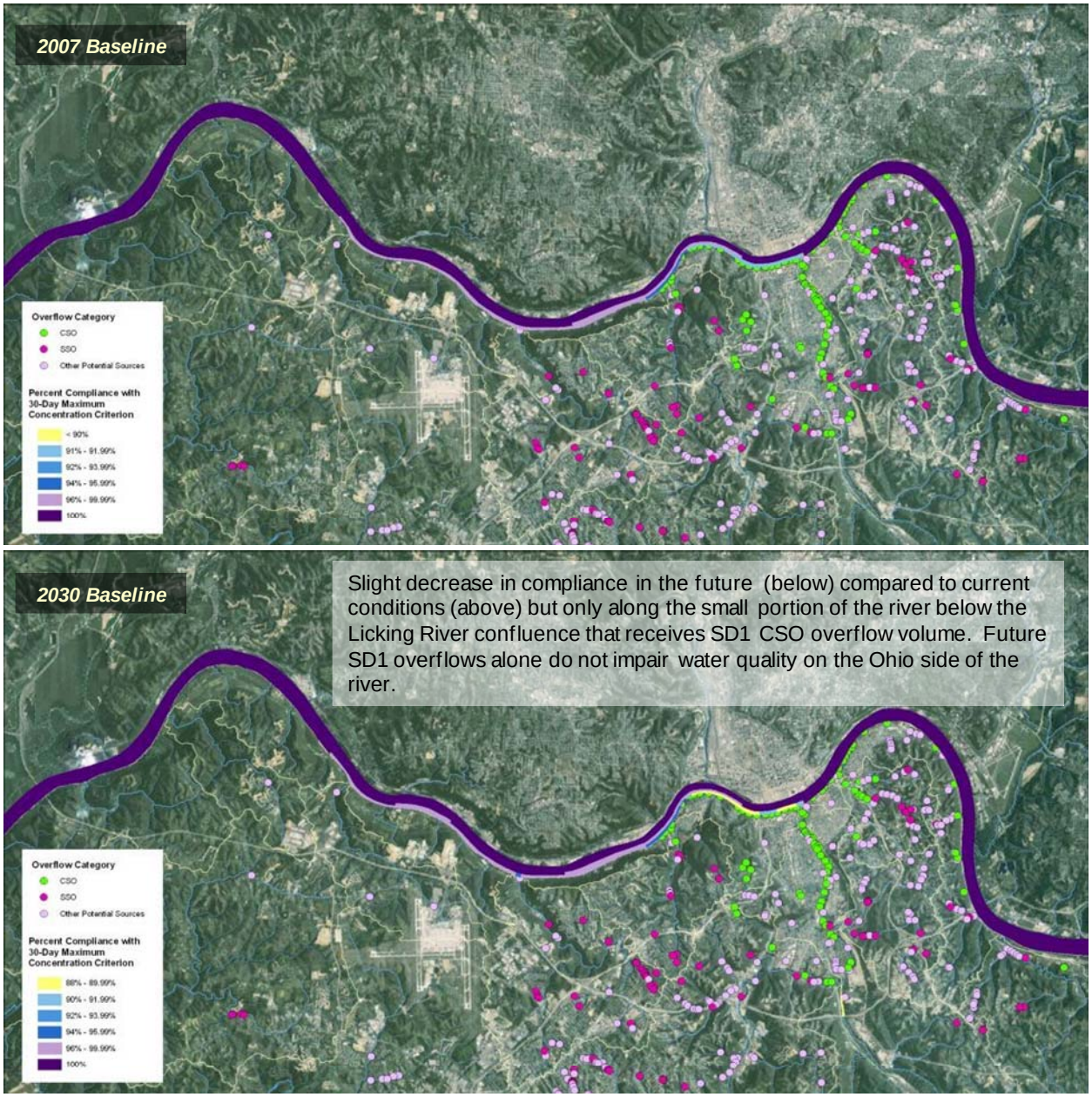


Figure 2.50 Comparison of Compliance with ORSANCO's 30-day Maximum Fecal Coliform Water Quality Standard in the Ohio River in 2007 and 2030 Baseline Scenarios



2.4 Dry Creek WWTP Plant Capacity Study

The overall capacity of the Dry Creek WWTP was assessed and documented in SD1's Nine Minimum Controls Report approved March 12, 2008 (SD1, 2008e). During that evaluation, it was determined that there were no low-cost solutions to increase treatment capacity. During the Watershed Planning effort, a more rigorous analysis was

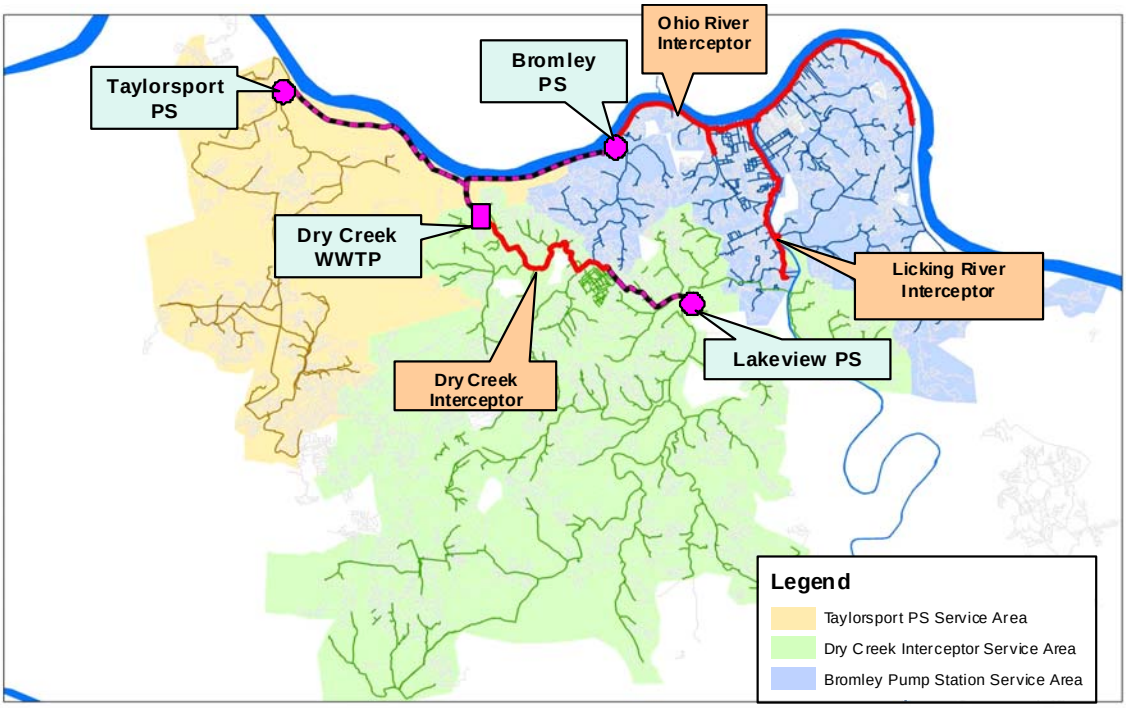
conducted to evaluate the potential and costs for significantly increasing treatment capacity at the Dry Creek WWTP. This analysis included a review of preliminary, primary, secondary treatment and disinfection. The following discussion is an abbreviated version of the analysis that is included in Section 4.4 of the approved Nine Minimum Controls Report along with a summary of the results of the refined assessment.

2.4.1 Capacity Assessment

The majority of flow in SD1's system, and all combined sewer flow, is conveyed and treated at the Dry Creek WWTP, a secondary wastewater treatment facility which was constructed in the late 1970s to provide treatment to surrounding communities. At the time of construction, SD1 was only responsible for the main trunk lines leading to the plant and operation of the plant. Figure 2.51 shows the current service area to the Dry Creek WWTP. A portion of the current service area will be rerouted to the Western Regional Sewer System and WRF, which is expected to be completed in 2013.

The Dry Creek WWTP was originally designed for an average daily flow capacity of 30 MGD and a wet weather peak capacity of 72 MGD. The facility was modified in 1991 to include additional primary and secondary treatment units. These improvements were designed to increase the average daily flow capacity of the plant to 46.5 MGD with a peak hour flow of 93 MGD. The maximum sustained secondary capacity as designed was 55.5 MGD. Currently operations staff route any flows above 55 MGD around the secondary system and combine those flows with secondary effluent prior to disinfection. Routing is achieved via a motorized gate and Parshall flume.

Figure 2.51 Current Dry Creek WWTP Service Area



Capacity-related modifications at the plant have been ongoing since 2002. In 2002 and 2003 the existing rectangular grit removal units were replaced with two 50 MGD vortex grit removal units. The project also included the addition of sodium hypochlorite storage and feed for influent odor control and effluent disinfection to replace gaseous chlorine. Since 2003, the plant has also received regular upgrades to achieve higher efficiency with solids processing and improve secondary clarification. Table 2.50 summarizes the recent historical flows to the Dry Creek WWTP.

Table 2.50 Historical Flows to Dry Creek WWTP 2003-2007

Flow Criteria	Flow (MGD)	Peaking Factor
Minimum Day[1]	10.2	0.29
Average Annual[1]	34.9	1.00
Maximum 30-Day[1]	46.8	1.34
Maximum 7-Day[1]	69.4	2.10
Maximum Day[1]	85.2	2.57
Peak Hour[2]	97.1	2.78

Notes:
1. Based on plant flow data from January 2003 to July 2007
2. Based on hourly peak flow data from January 2006 to December 2006

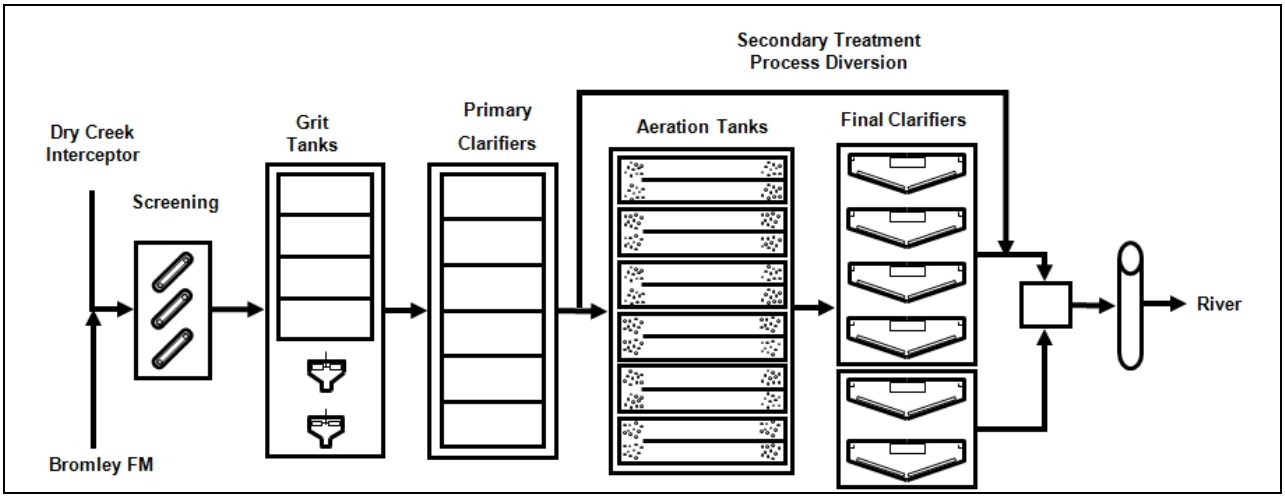
2.4.2 Summary of Existing Process Units

A summary of the major unit treatment processes and associated equipment is provided in Table 2.51, and a schematic of major liquid stream unit processes is shown in Figure 2.52.

Table 2.51 Summary of Major Liquid Stream Processes at the Dry Creek WWTP

Unit Process	Description of Equipment	Number of Process Units
Influent Screening	Mechanically cleaned Continuous cleaning field Aquaguard (Parkson Corp). 3 mm slotted opening 4 foot screening field width	3
Influent Flow Measurement	Lakeview Outfall – 5 foot throat width Influent – 10 foot throat width	1 each
Grit Removal	*Vortex* 20 foot diameter *Rectangular* 84.5 foot long 11 foot wide (top); 4 foot 8 inches (bottom) 5 foot average depth	*Vortex – 2* *Rectangular* (Not in service – equipment removed)
Primary Clarifiers	Rectangular clarifiers Sludge withdrawal at influent end 178 foot long 48 foot wide 12 foot average depth	6
Aeration Basins	Two pass plug flow Fine bubble diffusers 195 foot long 40 foot wide (total) 25 foot deep Tank volume – 1.46 MG / tank	6
Aeration System	Roots horizontal split case multi-stage blowers 2 @ 40,000 scfm 1 @ 20,000 scfm	3 total
Secondary Clarifiers	Circular – suction type sludge withdrawal 131 foot diameter 14 foot sidewater depth	6
Effluent Disinfection	Sodium hypochlorite for disinfection / sulfur dioxide for dechlorination 66-inch outfall pipe used for disinfection	1 outfall pipe

Figure 2.52 Simplified Liquid Stream Process Schematic for the Dry Creek WWTP



Influent flow to the Dry Creek WWTP comes from two sources: the Bromley forcemain and the Lakeview Outfall / Dry Creek Interceptor. The flow from the Bromley forcemain includes flow from Bromley Pump Station and the Taylorsport Pump Station which is manifolded to the Bromley forcemain. The flow from the Lakeview Outfall / Dry Creek Interceptor includes pumped flow from the Lakeview Pump Station and direct connected gravity sewer systems. Flow from the Bromley Pump Station is derived from combined sewer systems, while flow from the Lakeview system and other direct connected gravity sewers is derived from separate sewer systems.

2.4.3 Optimization of Wet Weather Capacity

SD1 has committed significant capital funds and resources to increase the reliability and capacity of the Dry Creek WWTP in recent years. A summary of major capital improvement projects at the Dry Creek WWTP and their associated benefit relative to optimization of wet weather capacity are summarized in Table 2.52.

Table 2.52 Summary of Major Projects at the Dry Creek WWTP Since 2003

Project Name / Year	Description of Improvements	Benefit to Wet Weather Capacity
Primary Clarifier Rehabilitation - 2003	Replacement of chain and flight mechanisms Rehabilitation of existing gear drives	More effective sludge removal capacity More reliable primary clarifier operation
Grit Removal and Sodium Hypochlorite Modifications – 2002/2003	Installation of two vortex grit removal units in place of existing rectangular grit tanks Installation of sodium hypochlorite for influent odor control and effluent disinfection to replace gaseous chlorine	More effective and reliable grit removal during wet weather and elevated river stage levels.
Secondary Clarifier Rehabilitation – 2005/2006	Physical rehabilitation of collection mechanisms Rebalancing of rotating mechanisms	More reliable operation of secondary clarifiers
Aeration Fine Bubble Diffuser Replacement – 2006	Replacement of existing fine bubble tube diffusers in aeration basins	Increased oxygen transfer efficiency
Influent Screen Rehabilitation - 2007	Replacement of moving parts of existing screens	Increased reliability of influent screens
Dewatering Centrifuge Replacement - 2009	Replacement of the existing dewatering centrifuges	Increased hydraulic capacity and reliability of solids treatment
Decommissioning of Zimpro Solids Treatment Process (2008/2009)	Decommissioning and removal of Zimpro solids treatment system.	Less sidestream loading to secondary process during both average and wet weather conditions.

SD1 has performed the above improvements cost effectively; in some cases using internal labor to install / implement improvements. Other minor improvements have also been made to the plant to increase reliability of existing unit processes.

2.4.4 Dry Creek WWTP Wet Weather Capacity

The capacities of individual unit processes based on historical documented capacity and the current evaluation are shown in Table 2.53.

Table 2.53 Current Dry Creek WWTP Capacity

Unit Process	Number	Peak Sustained Capacity
Influent Screening	3	75
Influent Flow Measurement	1	128
Grit Removal	2	100
Primary Clarifiers	6	102.6
Aeration Basins	6	57
Secondary Clarifiers	6	55.5
Effluent Disinfection	1	93

When diversion around secondary treatment is considered for treatment of combined sewer flows, screening and effluent disinfection are the limiting unit processes relative to capacity. As a result, any improvements to unit processes within the liquid train must be accompanied by improvements to both screening and effluent disinfection capacity.

2.4.5 Summary of Dry Creek WWTP Unit Process Evaluation

Based on the current analysis of the existing unit processes at the Dry Creek WWTP, no low cost process modifications were identified that would significantly increase the capacity or reliability of the plant. Therefore, the current maximum sustained primary treatment capacity at the Dry Creek WWTP is 75 MGD and the maximum sustained capacity through secondary treatment is 55.5 MGD. Several options for modifications of larger scope and cost were identified, and further evaluation of these options was conducted as part of system-wide alternative evaluation for the Watershed Plans.

2.4.6 Treatment Plant Improvements Evaluation

During the Watershed Planning effort, a more rigorous analysis was conducted to assess the potential of larger modifications to the Dry Creek WWTP, beyond the initial Nine Minimum Controls analysis for low-cost controls. The analysis evaluated the costs and capacity improvements at each stage of treatment. This is critical since the WWTP receives all of the flow from the combined sewer system. The following is a summary of this more rigorous assessment which was used to develop costs for the Full System Bounding Analysis and identify projects for inclusion in the Integrated Plan for 2025 and the Five-year Improvement Program.

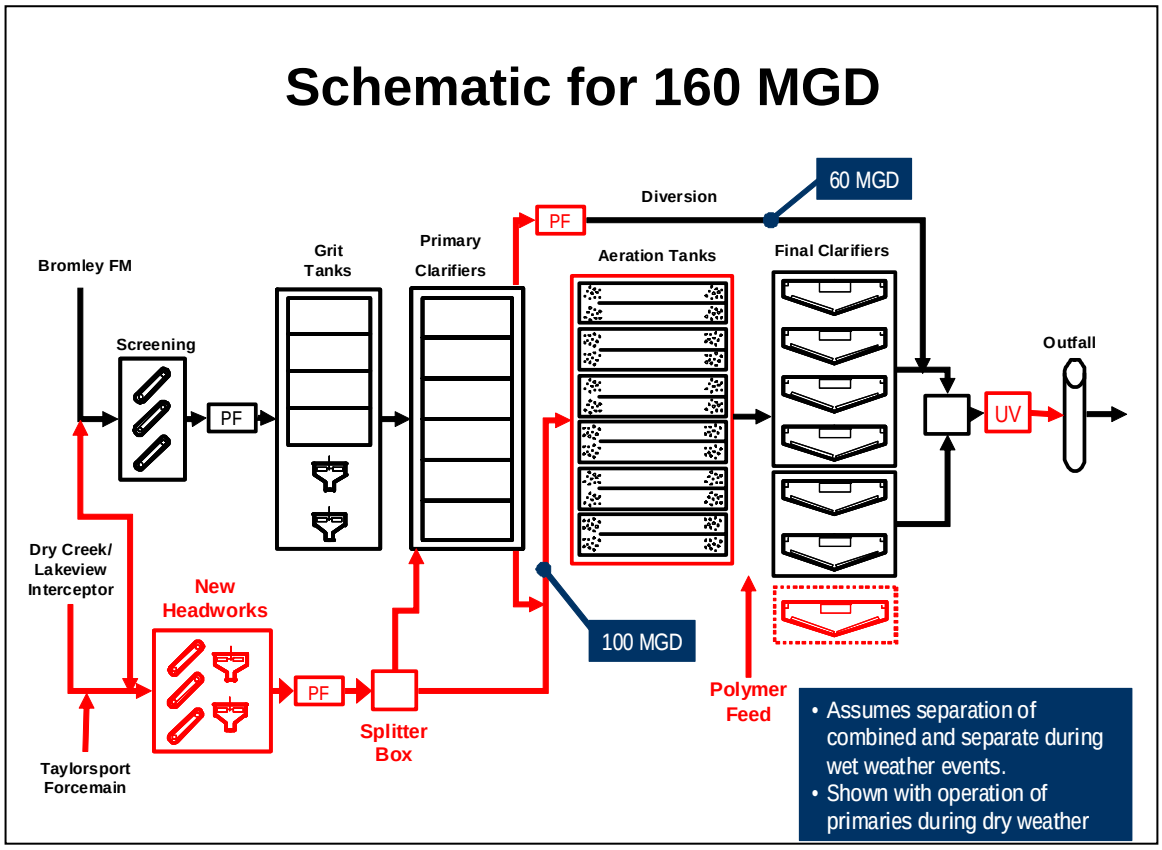
- **Preliminary Treatment:** Add a new headworks facility with a firm capacity of 100 MGD which would increase the firm capacity of the entire headworks to 175 MGD.
- **Primary Treatment:** Existing total capacity is 100 MGD with little or no modifications. There are several options for increasing wet weather capacity and providing a minimum of primary treatment for combined sewer flows. Flexibility can be provided to allow treatment of all flows through the primary clarifiers or treatment of only a portion of the flows (the remainder of the flows would bypass primary treatment and be fed directly to the aeration basins for secondary

treatment). Therefore all flows will receive at least primary level treatment. In addition, provisions can be made to allow separation of separate sewer and combined sewer flows in primary treatment. Other options are also available to optimize wet weather operation (i.e. chemically enhanced primary treatment).

- **Activated Sludge:** Increase capacity to up to 100 MGD for peak flows (including step feed, and Return Activated Sludge storage). Capacity beyond 100 MGD through existing tankage appears cost prohibitive and there is essentially no space available for additional activated sludge tankage.
- **Secondary Clarifiers:** Make miscellaneous improvements to existing tanks and add an additional clarifier to increase firm capacity to 100 MGD.
- **Effluent Disinfection**: Increase disinfection capacity to at least 160 MGD with ultra-violet disinfection.
- **Outfall**: Any capacity beyond current outfall capacity of 170 MGD will be cost-prohibitive unless an outfall on Dry Creek for wet weather discharge is permissible.

The preliminary analysis (Appendix 7-A) indicates that the fully maximized plant capacity is 100 MGD sustained wet weather flow through secondary (not indefinitely but for an extended period) and 160 MGD sustained through primary minimum treatment plus disinfection. The improvements that are being considered for maximizing wet weather capacity at the Dry Creek WWTP are primarily related to maintaining operation during peak flows, preventing washout of the secondary treatment system, and meeting required effluent quality during short peaks in flow. While these improvements will have inherent benefit relative to reliability during dry weather flows, they do not correspond to a direct increase in rated dry weather capacity because these improvements are only possible to handle peak wet weather flows for short durations. Figure 2.53 shows a schematic representation of the improvements that were assessed.

Figure 2.53 Potential Dry Creek WWTP Improvements to Increase Wet Weather Capacity for Short Durations



The assessment of cost and improvements to wet weather capacity identified the headworks and secondary clarifiers as two favorable projects to include in SD1's Watershed Plans.

The Five-year Improvement Program includes the new Dry Creek headworks facility (Section 7.2.6) with a capacity of 100 MGD for a total of 175 MGD for the entire headworks and will increase peak sustained primary/disinfection capacity to 93 MGD. Also included in the Five-year Improvement Program is the Western Regional Water Reclamation Facility which will remove base flow and allow for increased peak wet weather capacity from the Bromley system.

Other improvements are included in the Integrated Plan for 2025 to increase the peak wet weather primary/disinfection treatment capacity to 160 MGD and the peak sustained secondary treatment capacity to 100 MGD. The detailed analysis for these improvements is included in Appendix 7A. This will allow all separate sanitary flow that reaches the plant to receive full secondary treatment. Average dry weather flow capacity will not be affected.

2.5 Summary

SD1's extensive characterization effort provides an understanding of the region that goes beyond what is gained through more traditional programs. With this understanding, SD1 can develop watershed-based solutions that will be more cost-effective and provide increased improvement in water quality and public health for the ratepayers of Northern Kentucky. SD1 has developed calibrated hydraulic and water quality models that provide a reasonable representation of the sewer system and water quality in the watersheds. These tools allow SD1 to have confidence in their results for use in making informed decisions for the Watershed Plans.

SD1 has compiled waterway and watershed-specific information to characterize current instream conditions, assess the relative impact of different sources and identify opportunities to implement green infrastructure and watershed controls. Recent data show that elevated levels of bacteria occur in the majority of sampled streams during dry and wet weather conditions. Data from some stream segments indicate violations of dissolved oxygen, pH, metals and/or temperature criteria. Some streams in the region exhibit relatively good water quality but poor biological conditions, and flooding and streambank erosion are common problems in many watersheds.

Major findings from the sewer system and water quality modeling are the following:

- Application of the models confirms impairment of recreational uses (with respect to fecal coliform). The influence of SD1 overflows on water quality varies by watershed and models show that other sources of pollution are significant contributors to impairment.
- Water quality in Banklick Creek and Taylor Creek is poor (compliance with water quality standards is < 20%) but this is due to multiple sources, including dry weather and other wet weather-related sources, in addition to SD1 overflows. A control strategy that addresses dry weather and storm water runoff sources may provide more improvement in instream water quality than control of SD1 overflows alone.
- Because SD1 overflows comprise less than 6% of the total load to the Ohio River, an analysis of the effects of these loads alone on instream water quality using the detailed model indicates that the criteria are met in a typical recreation season. This suggests that SD1 overflows are not significantly impacting water quality in the Ohio River and SD1 should prioritize controls in watersheds where water quality is more impaired than in the Ohio River.
- Because the lower 5 miles of the Licking River are within SD1's combined sewer system area, CSO loads are calculated to have a larger water quality effect on this reach than on other streams assessed with the detailed models. Taken together, current conditions in the Licking River are affected by both SD1 overflows and background sources. However, water quality in the lower Licking River is better than the smaller watersheds (e.g. Banklick and Taylor) that are affected by multiple source types.

These models show that the benefit of controlling a given SD1 overflow is highly variable and depends on the characteristics of the watershed (such as flow and other

sources present). This points to the need for a watershed-based approach that addresses the multiple sources of pollution contributing to water quality impairment.

SD1's understanding of Northern Kentucky watersheds, sewer infrastructure, and green infrastructure opportunities gained through characterization provides the basis for identifying controls to maximize instream benefits. The following were all informed by this characterization effort: the metrics, the Integrated Plan for 2025 (Section 3), Prioritization (Section 6) and the Five-year Improvement Program (Section 7).

Section 3
INTEGRATED PLAN FOR 2025

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3.1 INTRODUCTION

3.1.1 Integrated Plan for 2025 Purpose

SD1 completed a Five-year Improvement Program and a Full System Bounding Analysis for 2025 with the Watershed Plans submitted in June 2009. The Five-year Improvement Program and benefits are described in Sections 6 and 7, and the Full System Bounding Analysis is described in Appendix 3-A. Pursuant to an August 23, 2010 agreement between SD1 and the Agencies, SD1 has revisited the solutions from the 2025 Full System Bounding Analysis and developed the Integrated Plan for 2025 presented in this section[1]. The Integrated Plan describes SD1's proposed system-wide solution set that would be necessary to address all overflows by December 31, 2025 so as to meet the requirements of the Consent Decree and CSO Control Policy (hereinafter the "Integrated Plan for 2025").

As agreed with the Agencies, the Integrated Plan for 2025 that has been developed presents the preliminary plan that will achieve compliance obligations of the Consent Decree without regard to whether the plans are affordable. As with the June 2009 full-system solution in the draft Watershed Plan, SD1 has conducted and presents an affordability analysis for the Integrated Plan for 2025 in Section 4. The affordability analysis demonstrates the Integrated Plan for 2025 would also impose unwarranted and unreasonable financial burdens and hardships on the communities served by SD1 and is beyond SD1's financial capabilities. Accordingly, although SD1 believes the Integrated Plan for 2025 is the most cost-effective and beneficial plan that would eliminate SSOs and remedy CSOs in conformance with the CSO Control Policy, SD1 has determined it is unaffordable and relief from the December 31, 2025 Consent Decree deadline is therefore necessary through a material modification of the Consent Decree. Relief from the December 31, 2025 deadline could be afforded through a number of mechanisms recognized by the CSO Control Policy and KRS 224.16-040, including extensions of deadlines, affordability reviews in conjunction with five-year Watershed Plan updates, Use Attainability Analyses, or combinations thereof. Consistent with the parties' agreement, the form and extent of the relief is not being addressed in this Integrated Plan. Rather, the purpose of the Integrated Plan for 2025 is to determine the most cost-effective approach to eliminate SSOs and address CSOs by December 31, 2025 consistent with the Consent Decree[2].

[1] The parties' agreement regarding resubmittal of the Watershed Plan to include an integrated approach to achieve the goals of the Consent Decree by December 31, 2025 was set out in a letter dated August 23, 2010.

[2] To the extent that standards for addressing CSOs and SSOs are subsequently amended by U.S. EPA or Kentucky, through for example, revised water quality standards or affordability criteria, SD1 reserves the right to revise the Integrated Plan for 2025 in subsequent five-year plan submittals.

3.1.2 Background Sources Impacting Water Quality and the Integrated Watershed Approach

The Full System Bounding Analysis described in Appendix 3-A showed that the various solution concepts fall short of fully achieving water quality standards for bacteria in streams due to the presence of sources, some unknown, other than CSOs and SSOs. Modeling analyses with SD1 overflows completely removed showed limited benefit in meeting water quality standards (KDOW's 30-day maximum criterion) due to the numerous other bacteria sources impacting the waterway[3]. Figure 3.1 shows compliance with KDOW's 30-day maximum criterion using 2030 full build-out conditions assuming no controls are implemented. Figure 3.2 shows compliance with the same water quality standard assuming all of SD1's CSO and SSO overflows are completely removed using the same 2030 full build-out conditions. Comparison of these two figures show that the benefit from removing SD1 overflows is limited both in spatial extent and additional improvement (in terms of increasing the percent of time that a stream segment is in compliance). The waterways still do not meet this water quality criterion when CSO and SSO overflows are completely removed from the system. Similar results, described in Appendix 3-A (Section 2.1), were obtained in the analysis for the Watershed Plans submitted in June 2009. There are numerous other sources impacting water quality in the Ohio, Licking, and other major waterways that are beyond SD1's control.

The water quality problems and pollutant sources in the watersheds are complex (see Section 2). SD1's Consent Decree is the first in the country to be based on a watershed management approach. This approach provides a mechanism and flexibility for SD1 to assess watershed problems within its jurisdiction that are not easily addressed within the Clean Water Act framework. SD1 has used this approach to develop its Integrated Plan for 2025 to achieve water quality improvements more quickly while putting CSOs and SSOs into context with other pollutant sources in the watersheds within SD1's jurisdiction. SD1 has developed this Integrated Plan for 2025 to help address water quality from other sources so as to maximize water quality benefits while eliminating SSOs and fully conforming to the CSO Control Policy for addressing CSOs. In this regard the Integrated Plan for 2025 would result in reduced pollutant loadings from sources beyond just sewer overflows and which, pursuant to the Consent Decree, may be considered and credited toward CSO controls as offsets.

[3] The KDOW water quality standard of primary concern is bacteria. The standard provides that "Fecal coliform … content shall not exceed 400 colonies per 100 ml in twenty (20) percent or more of all samples taken during a thirty (30) day period for fecal coliform…"

Figure 3.1. Estimated Compliance with 30-day Maximum Fecal Coliform Water Quality Standards in 2025 Without Overflow Control

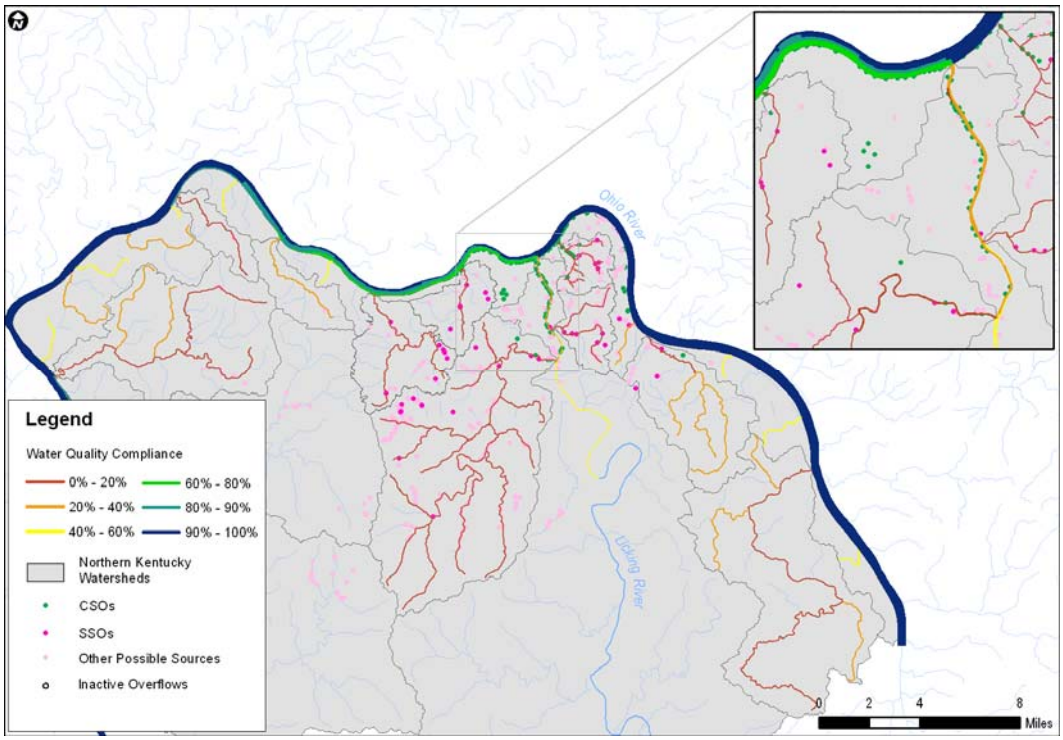
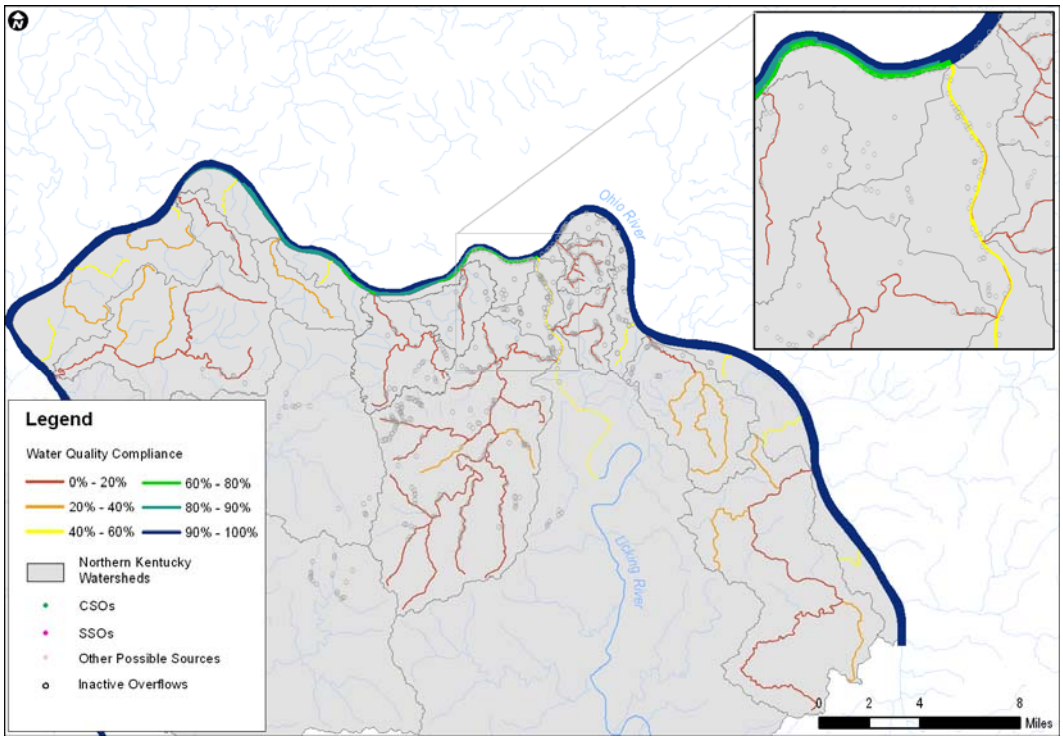


Figure 3.2. Estimated Compliance with 30-day Maximum Fecal Coliform Water Quality Standards in 2025 with NO SD1 Overflows



SD1 conducted further analysis and updated these Watershed Plans to include a preferred Integrated Plan for 2025 to be completed by December 31, 2025 as provided in paragraph 39(b) of the Consent Decree. The Integrated Plan for 2025 incorporates the results of more detailed analyses of both green infrastructure and watershed controls, as well as consideration of policy/regulation and partnership opportunities.

The Full System Bounding Analysis, presented in Appendix 3-A, was a more traditional evaluation, beginning with the development of an overflow-focused solution consisting of gray infrastructure controls spanning the entire service area. SD1 then evaluated the benefits of this overflow-focused control solution on each waterway/watershed. The Integrated Plan for 2025 focuses on a solution set that optimizes water quality improvements in each waterway. The analysis process began by eliminating SSOs, then evaluating the maximum water quality benefit and corresponding level of CSO control achieved for each waterway pursuant to the CSO Control Policy. Appropriate controls were elevated and designed based first on implementation of green infrastructure, followed by additional gray infrastructure controls to achieve the identified level of control (or higher) that maximizes water quality benefit and conforms to the CSO Control Policy. Additional improvement in water quality is achieved elsewhere in the watershed through watershed controls, policies, and regulations for managing runoff from development, and partnership opportunities, consistent with the Consent Decree and watershed management approach described by EPA (EPA 2008). This section presents the resulting Integrated Plan for 2025 to meet the following objectives:

1. Eliminate SSOs[4];

2. Conform to the CSO Control Policy based on a presumption control demonstration;

3. Improve water quality (e.g. bacteria and nutrient reductions, hydrological improvements) beyond that achieved by traditional overflow controls by identifying and implementing watershed control projects through one or more programs; and

4. Prevents additional degradation of waterways in the future by requiring pollutant control with policies and regulations.

Implementation of a more traditional path of overflow control would typically achieve objectives #1 and #2. Implementation of SD1's Integrated Plan for 2025 expands the benefits to include #3 and #4 and is considered more cost-effective.

[4] The two-year level of service is based on controlling the two-year, six-hour design storm under saturated antecedent moisture conditions. The level of service was confirmed by applying the model over a continuous simulation period of a typical year (1970) to verify that no overflows occurred. This meets the definition of elimination of recurring capacity-related SSOs approved by EPA and Kentucky.

This section describes the Integrated Plan for 2025, how the different components were developed, and the benefits of this plan. This is the current optimum plan for SD1 that balances meeting Consent Decree and regulatory requirements, optimizing improvements in water quality, achieving other environmental protections and benefits, and evaluating cost-effectiveness, and local considerations. The Integrated Plan for 2025 will build on SD1's considerable progress to date in controlling SSOs and CSOs.

3.2 OVERVIEW OF THE INTEGRATED PLAN FOR 2025

The preferred Integrated Plan for 2025 contains four components (described later) that reflect the following observations from the Characterization and Bounding Analysis presented in Sections 2 and Appendix 3-A, respectively:

1. Targeting dry weather and runoff sources of pollution can provide cost-effective improvement in compliance with water quality standards, often over a larger geographic area.

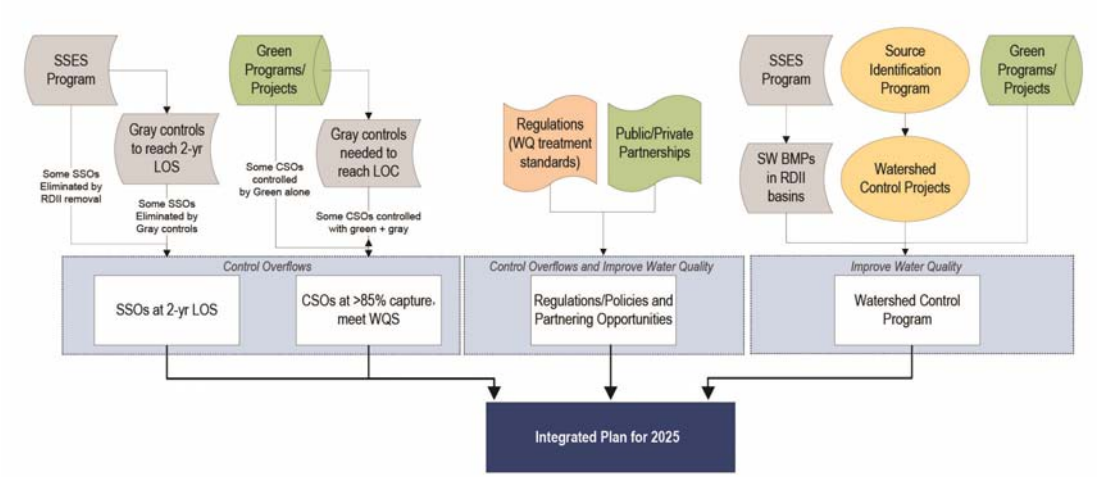
2. High levels of overflow control provide diminishing instream water quality standards compliance returns.

3. Green infrastructure in both the combined and separate sewer systems offers the opportunity to return portions of the watersheds to their natural hydrologic conditions; this reduces pollutant loads to waterways, and provides other non-quantitative benefits, such as opportunities for partnerships that allow SD1 to cost share on the implementation of these green techniques and help provide community support and education.

This Integrated Plan for 2025 incorporates additional analyses and planning conducted since the initial submission of the Watershed Plans in June 2009. SD1 used water quality-based evaluations that are based on the typical five-year period (1992-1996) rainfall data to develop the Integrated Plan for 2025. However, there is still significant uncertainty in the control design and modeling assumptions for the 2025 planning horizon; therefore, this Integrated Plan (beyond the first five-year detailed Plan) remains preliminary in nature. The Plan and associated assumptions will be refined and updated (in each five-year planning cycle) as more information and data become available.

An overview of the Plan is provided in Figure 3.3. A summary description of each component of the Plan is described in this section. Additional detail describing the analysis, development, and implementation of each component follows in Section 3.3. The benefits of the Plan, including end-of-pipe measures, compliance with water quality standards, and other water quality benefits are described in Section 3.4.

Figure 3.3. Schematic of SD1's Integrated Plan for 2025



The Integrated Plan for 2025 contains four components:

1. **SSO elimination:** SSOs have been eliminated by designing controls for each SSO to achieve at least a two-year level of service (based on controlling the two-year, six-hour design storm with saturated antecedent moisture conditions). For the SSO analysis, SD1 built upon the experiences from the ongoing Vernon Lane and Lakeside Park public and private source inflow and infiltration (I/I) removal projects (see Five-year Improvement Program described in Section 7). SD1 used these experiences to evaluate options for removing I/I using sanitary sewer evaluation surveys (SSES), public sanitary and storm sewer system rehabilitation and replacement based on an asset management approach, and private source I/I removal. Inflow and infiltration reductions following this approach will be completed first, and then followed, where necessary, with additional gray infrastructure to achieve at least a two-year level of service at each individual SSO location.

2. **CSO long-term control plan:** SD1 provides a level of CSO control that meets the Presumption Approach (minimum of 85 percent capture[5]) and uses detailed water quality models to demonstrate that remaining CSO discharges can reasonably be expected not to cause an instream water quality standard violation when the remedial plan is complete. SD1's CSO control program was developed as described in the bullets below.

    a. SD1 is maximizing green infrastructure in the combined area based on a more detailed analysis of opportunities as well as

[5] As stated in the CSO Control Policy in Section II.C.4.a.ii, percent capture is the "elimination or the capture for treatment … by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual basis."

implementing system-wide green programs to achieve water quality benefits. The identified green infrastructure projects remove and treat storm water from approximately one-third of the combined area (2,349 of the 6,931 acres), a total of 562 million gallons per year (MG/yr) of storm water from the combined sewer system (CSS). (This estimate is based upon the typical five-year period (1992-1996) used to evaluate the water quality benefits).

Green infrastructure programs initiated throughout the combined and separate sewer system will tend to produce water quality benefits at a parcel-level scale, but implementation rates are difficult to forecast for the 2025 planning horizon needed for the Integrated Plan. Evaluation of these programs will be refined in each of the five-year planning cycles permitted in the Consent Decree.

b. SD1 used a water quality-based approach to identify the level of CSO control in each waterway that optimizes water quality benefit. This analysis demonstrates that the preferred presumption approach capture of 85 to 94 percent is reasonable in light of the circumstances evaluated. This level of control was determined by applying the detailed water quality models for a knee-of-the-curve analysis of control level versus instream water quality improvement. The models were also used to confirm that the level of control allowed the remaining CSO discharges to meet water quality-based requirements, assuming other sources are addressed within the remedial period.

c. After assessing the control level that can be achieved through the green infrastructure projects and programs, SD1 conducted an alternatives analysis to identify the most cost-effective set of gray infrastructure controls to add to the green infrastructure projects and programs that would conform with the CSO Control Policy. A combination of transport and treat, equalization, and local ballasted floc high rate treatment (HRT) and disinfection were identified as the most appropriate gray infrastructure control technologies, based on cost, percent capture, feasibility of siting regional control facilities, and protection of instream water quality standards.

   Modeling of the selected CSO solution, comprised of green and gray infrastructure controls, indicates that 20 CSOs are eliminated (based on the modeled condition), and many of the remaining CSOs are controlled at a higher level of control than the target. None of the CSOs or control facilities discharges untreated volume more frequently than the targeted level.

Modeling analyses of the typical five-year period (1992-1996) indicate the remaining untreated CSO volume discharging to local waterways will be approximately 178 MG/yr, which achieves at least 85 percent capture.

This CSO Plan optimizes the water quality benefit to the waterways while achieving the percent capture that meets the Presumption Approach in the CSO Control Policy of Section II.C.4.a.ii (minimum 85 percent capture). The water quality modeling analysis supports the reasonable expectation that the proposed control level for CSOs will ensure that remaining CSO discharges will meet the water quality requirements in the CSO Control Policy after full implementation of the Integrated Plan for 2025. The analysis accounts for elimination of SSOs and implementation of green infrastructure and watershed controls as described in this plan, and assumes that other sources of bacteria will be largely controlled by the end of the plan implementation period. Although additional refinements and adjustments to the CSO solution will be conducted in future five-year planning cycles (so that new information, project performance monitoring data and detailed design considerations can be incorporated into the solution), the benchmarks of assuring a minimum of 85 percent capture will be maintained throughout the analyses to ensure that the implemented solution conforms to the CSO Control Policy.

3. **Watershed Control Program:** SD1 has conducted data and modeling analyses to determine the potential water quality benefits from watershed controls that could be used to cost-effectively enhance and offset the level of CSO control. Current results indicate that more water quality improvement can be achieved by targeting non-overflow pollutant sources in the watershed than by reducing the overflows to a higher level of control than presented in the Integrated Plan. The effectiveness of all controls will be re-evaluated in five-year cycles.

   SD1 will use a programmatic-based approach to identify opportunities to reduce pollutant loads with the watershed decentralized controls. This Watershed Control Program includes use of the SSES Program to identify opportunities to control storm water runoff in areas of the sanitary sewer system prone to high I/I and the Source Identification Program (SIP) to identify source control opportunities elsewhere in the watershed. Lastly, water quality improvement projects near the combined system will be addressed through the Green Infrastructure Program.

   Each of these programs is described in more detail in the following sections, but it should be noted that the Integrated Plan for 2025 and benefit results presented here reflects preliminary, screening-level

analyses. Specific projects within each program will be identified, evaluated, and designed in the five-year planning cycles.

Projects identified through these programs will typically control runoff from storm water catchment areas larger than five acres. The analysis used for this Plan is based on managing the runoff produced from the first 0.8 inches of rainfall (note: approximately 80 percent of the storms in this area are less than 0.8 inches, based on 50+ years of precipitation data from the Greater Cincinnati/Northern Kentucky International Airport). In addition, in approximately 45 percent of the separate sewer system, which is characterized as having excessive I/I, both storm water quantity and quality will be addressed by treating the runoff produced from the first 0.8 inches of rainfall through best management practices (BMPs) and reducing peak storm water runoff rates to a level that minimizes hydromodification in the local waterways. The actual amount of runoff control from individual projects may vary based on site-specific conditions. Regional watershed controls, such as retention basins or wetlands, which have upstream drainage areas greater than one square mile, will also be considered where feasible as part of SD1's Watershed Control Program.

4. **Policy/Regulations and Partnership Opportunities**: This category includes ordinances, regulations, and policies that provide additional control measures beyond SD1's investment in SSO, CSO and watershed control initiatives. For example, SD1 has recently developed a proposed water quality treatment standard, as required by the KPDES Phase II Municipal Separate Storm Sewer System (MS4) General Permit. Per the permit, permittees are required to develop a post-construction water quality treatment standard to require new development projects to implement controls to manage the runoff produced the 80th percentile precipitation event. This permit condition will require new development projects to manage the runoff produced from the first 0.8 inches of rainfall for any new impervious area with a water quality BMP. This regulation will go into effect in October 2011.

   A key element of SD1's overall strategy is to identify partnership opportunities throughout the community. As described in Section 2, there are several groups actively working to protect the waterways, green space and riparian corridors in Northern Kentucky. SD1 is actively involved with these groups, providing them with access to data and reports to facilitate planning and implementation of projects. In addition, local watershed groups are also actively working to protect, improve and enhance watersheds and waterways in Northern Kentucky. SD1 continues to partner with other groups and initiatives in Northern Kentucky to provide technical support for planning and implementation of riparian buffers and stream restoration initiatives.

SD1 conducted a wide review of potential partners that could help fund and implement controls. There are numerous public agencies in Northern Kentucky with plans to invest significant amounts of money over the next decade in the construction and upgrade of public infrastructure including streets, schools, parks, highways and public housing. Each public project represents an opportunity to incorporate green infrastructure.

Because of these four components, the Integrated Plan for 2025 is the best plan to meet the goals of the Consent Decree. In summary, SD1's Integrated Plan for 2025 achieves the following[6]:

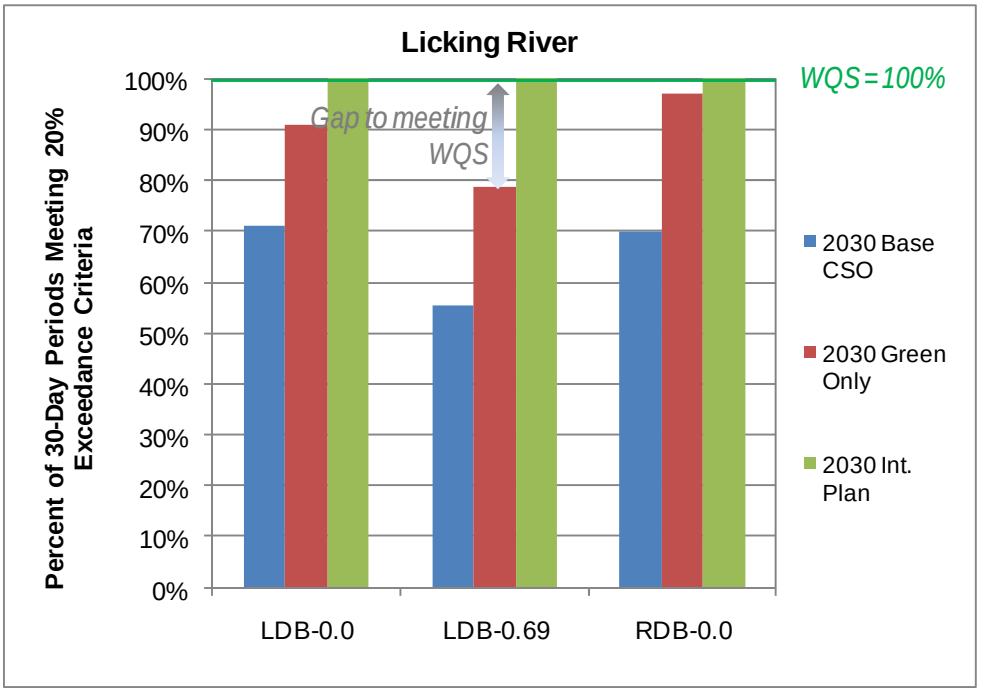
- Elimination of SSOs at a saturated condition two-year, six-hour design storm level of service;
- Elimination of 20 CSOs based upon modeling using a typical five-year rainfall evaluation period;
- Elimination of 1,287 MG/yr of CSO during the typical five-year period from the completion of the Five-year Improvement Program and additional green and gray infrastructure projects identified for the Integrated Plan for 2025;
- A minimum of 85 percent and up to 94 percent capture based upon rainfall events for a typical year (1970) period;
- Treatment of 562 MG/yr of storm water during the typical five-year rainfall period through green infrastructure in the CSS;
- Reduction in the storm water runoff quantity and improvement in the quality of runoff in the separate sewer system, while at the same time eliminating SSOs through an asset management based approach to public and private source I/I removal; and
- Emphasis on green infrastructure through projects in the CSS area and programmatic controls and partnership opportunities in both the separate and CSS area.

In addition, modeling demonstrates the presumption approach capture criteria (minimum 85 percent capture) is protective of water quality criteria for fecal coliform for Banklick Creek, Taylor Creek, the Lower Licking River, and the Ohio River taking into account the assumed control of other sources that are beyond SD1's jurisdiction during the implementation period. Figure 3.4

[6] SD1's Integrated Plan for 2025 (beyond the Five-year Improvement Program) is preliminary because of the watershed planning process and reliance on green infrastructure and watershed controls to assist in achieving the objectives of the Consent Decree. The anticipated performance outcomes listed in this plan should therefore not to be construed as specific performance commitments or standards.

demonstrates that the Integrated Plan for 2025 comprised of green and gray infrastructure technologies will meet KDOW's 30-day maximum water quality criterion with other sources controlled. Results are shown for three critical locations on the river where water quality is most impacted by CSOs. Neither the "No Control" (labeled as "2030 Base CSO" and shown as the blue bars) nor the "Green Infrastructure Only" (labeled as "2030 Green Only" and shown as the red bars) scenarios will meet water quality standards at all times. However, the Integrated Plan (labeled as "2030 Int. Plan" and shown as the green bars) meets this standard at all locations at all times in the typical five-year period.

Figure 3.4. Percentage of 30-day Periods Meeting the 30-Day Maximum Water Quality Criterion in Licking River (CSO Sources Only)



Note: The locations shown on the x-axis are:
LDB-0.0 is the left descending bank (west bank) at river mile 0 (the mouth).
LDB-0.69 is the left descending bank at river mile 0.69.
RDB-0.0 is the right descending bank (east bank) at river mile 0 (the mouth).

Benefits of the Integrated Plan that uses a watershed-based approach include more water quality improvements over more stream miles than a traditional, overflow-control-only plan (defined as CSOs at four overflows per year and SSOs eliminated). As presented in Table 3.1, the Integrated Plan for 2025 is estimated to achieve:

- An increase in the number of days during the recreation season where fecal coliform levels are less than 400 colony forming units per 100

milliliters (cfu/100 ml) - a commonly used benchmark for safe recreating conditions;

- A reduction in instream bacteria levels (characterized by the geometric mean level of fecal coliform in cfu/100 ml over the recreation season);
- A reduction in total bacteria load from the watersheds and a reduction in total nitrogen and phosphorus loads from the three-county area; and
- Improvement in water quality in 89 stream miles as compared to 8.8 miles with the traditional approach.

Table 3.1. Anticipated Water Quality Benefits of SD1's Integrated Plan for 2025

Waterway	Number of Days in Recreation Season Less Than 400 cfu/100 ml (Count of Days)			Recreation Season Geometric Mean Fecal Coliform Density (cfu/100 ml)			Stream Miles Improved by Control Measures	
	Baseline (No Control)	Traditional Plan	Integrated Plan	Baseline (No Control)	Traditional Plan	Integrated Plan	Traditional Plan	Integrated Plan
Banklick Creek	67	84	108	1,080	556	310	1	19.1
Licking River	111	121	122	136	105	96	4.8	9.2
Taylor Creek	5.5	5.5	6.3	2,628	2,572	2,224	0.2	2.5
Fourmile Creek	102	109	110	446	323	305	2.1	9.5
Pleasant Run Creek	92	92	94	387	385	364	0.7	3.4
Ohio River	150	157	156	14	6	7	55.4	73.0
Twelvemile Creek	103	103	104	329	329	315	0	10.4
Threemile Creek	77	79	81	540	511	481	0	4.3
Dry Creek	83	88	90	514	426	402	0	7
Elijahs Creek	118	118	119	250	250	245	0	4
Sand Run	83	83	84	488	484	467	0	5.8
Total							64.2	148.2

Notes:

1. Model results are shown for the 2030 future complete build-out condition using a high-rate treatment alternative for 2025 that resembles the Integrated Plan for 2025.
2. Results for the CSO waterways (Banklick Creek, Licking River, Taylor Creek) are averaged from model segments comprising the CSO receiving portion of the waterway. Results for the Ohio River are provided at river mile 471.3, just downstream of the Willow Run CSO and corresponds to the location where the largest CSO impact on the Ohio

River occurs. Results for the remaining waterways are provided at the mouth of the waterway. Results are not shown for Big Bone Creek, Gunpowder Creek or Woolper Creek because the models representing these areas are still being constructed and verified.

3. There are 184 days in the Recreation Season (May 1 through October 31, inclusive).
4. The Ohio River model simulations did not include loads from upstream or Ohio-side sources. The reported numbers of stream miles improved for the Ohio River were calculated as the streamwise distance between the downstream extent of the study area (river mile 516.6 at the Boone County line) and the most upstream control for each scenario.

As set forth in Section 4, however, the Integrated Plan with a deadline of December 31, 2025 is not affordable. Accordingly, the parties will need to evaluate mechanisms for affording relief from the December 31, 2025 deadline (and/or other performance criteria) so as to allow the proposed plan to be implemented without creating an undue hardship on the ratepayers.

3.3 DEVELOPMENT OF INTEGRATED PLAN COMPONENTS

This section provides more substantive descriptions of each component comprising the Integrated Plan for 2025. It includes details on the additional analyses conducted since the submission of the Plan in June 2009 and how these additional analyses informed the selection of controls for the Integrated Plan for 2025.

3.3.1 SSO Elimination

The first step in developing the SSO elimination solution was to prioritize the SSOs for elimination. This is described in detail in Section 6 but can be summarized as follows. In general, the prioritization effort was based on evaluating a series of factors, including annual activation frequency, public health risk, Consent Decree Appendix D listed overflows, and proximity to integrated solutions or early action projects. The impact of these factors on each overflow were then used to identify high priority overflows and areas from which solutions were developed to control the overflow.

The Five-year Improvement Program submitted as part of the original 2009 Watershed Plan submittal focused on public health risk areas. Section 7 describes in detail how the projects in the Five-year Improvement Program will address these very high priority overflows. This section focuses on developing a plan for eliminating remaining overflows in accordance with the Consent Decree and the priorities described above.

The overall strategy for eliminating the remaining SSOs is to continue SD1's efforts to maximize I/I reduction, which will significantly reduce overflows, renew crumbling infrastructure, and reduce public health risk. This approach is fundamental to SD1's asset management based approach to renewing both the sanitary and storm sewer infrastructure on a neighborhood by neighborhood level to not only remove I/I and renew the existing infrastructure, but to also reduce storm water runoff peak flows (quantity) and

improve runoff quality through the implementation of green infrastructure. After the efficacy of I/I removal is measured, additional gray infrastructure improvements will be implemented to address remaining I/I. Since this program is one component of the Five-year Improvement Program, the benefits and cost-effectiveness of this approach are described in Section 7 in the context of the specific projects identified in the first five years. The following paragraphs describe the overall approach that was applied for the development of this Integrated Plan.

3.3.1.a Priority Inflow and Infiltration Source Identification and Removal

Through system-wide flow monitoring conducted in 2007 and 2008, SD1 developed estimates of rainfall derived inflow and infiltration (RDII) for the entire separate service area by conducting continuous simulations of the monitoring period with the hydraulic model (continuous simulations can accurately represent antecedent moisture conditions). Those estimates were used to develop the calibrated model that was used as the basis for analyzing future solutions. Following the calibration, SD1 used the percent of rainfall converted to RDII (R-value) to evaluate the potential for I/I removal to be an effective solution component throughout the system.

Any areas which demonstrated that more than two percent of annual rainfall was being converted to RDII were identified as candidates for SSES activities. These areas were further evaluated to determine if SSES activities would provide a cost-effective approach to SSO control. Areas with no tributary SSOs and areas with R-values between two and five percent that were not cost-effective to address I/I investigation and removal were excluded. Inflow and infiltration removal activities are planned in all locations where the R-value is greater than five percent and in many locations where the R-value is between two and five percent. The following sections show where I/I removal is planned before additional gray controls are implemented. In addition, Section 7 shows where inflow and infiltration removal are part of the Five-year Improvement Program.

SD1 identified a subset of their separate service area to perform SSES activities and develop recommendations for I/I removal. SSES activities, while located across the system, will be evaluated based on their overall impact to the local sewersheds.

A schematic of the Dry Creek and Western Regional systems showing the proposed sewersheds following the Five-year Improvement Program is shown in Figure 3.5. A schematic of the Bromley and Eastern Regional systems is shown in Figure 3.6. The blue blocks correspond to wastewater treatment plants or pump stations (PSs), and the green blocks correspond to sanitary sewershed areas (discussed in the following subsections).

Figure 3.5. Schematic of Dry Creek and Western Regional Sanitary System Areas (Following the Five-year Improvement Program)

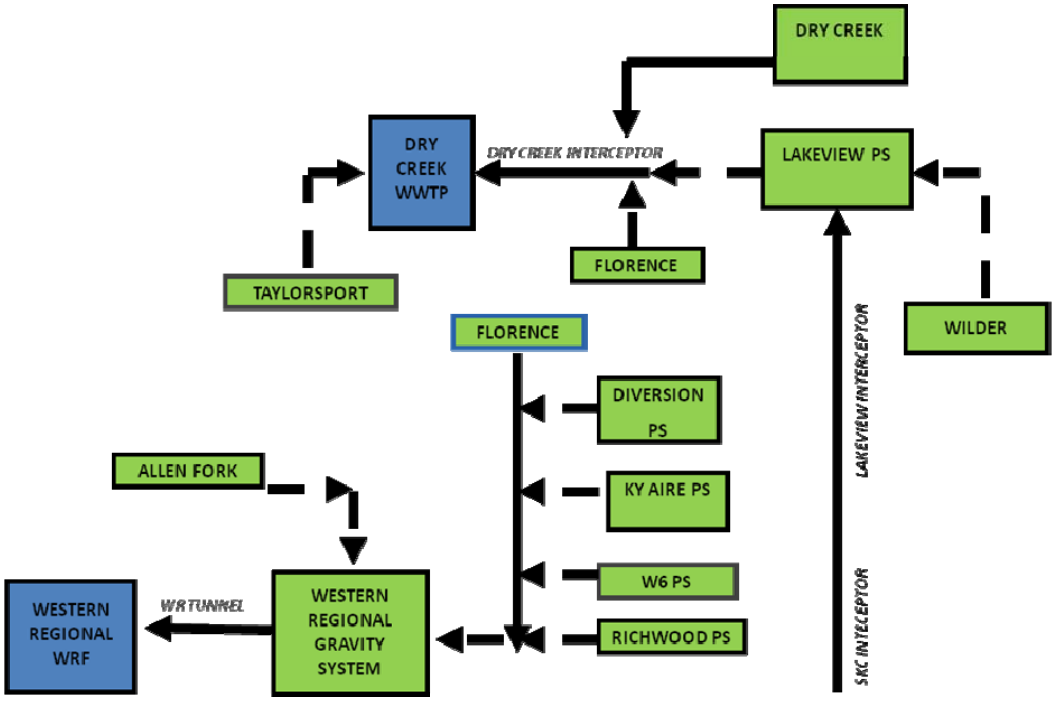
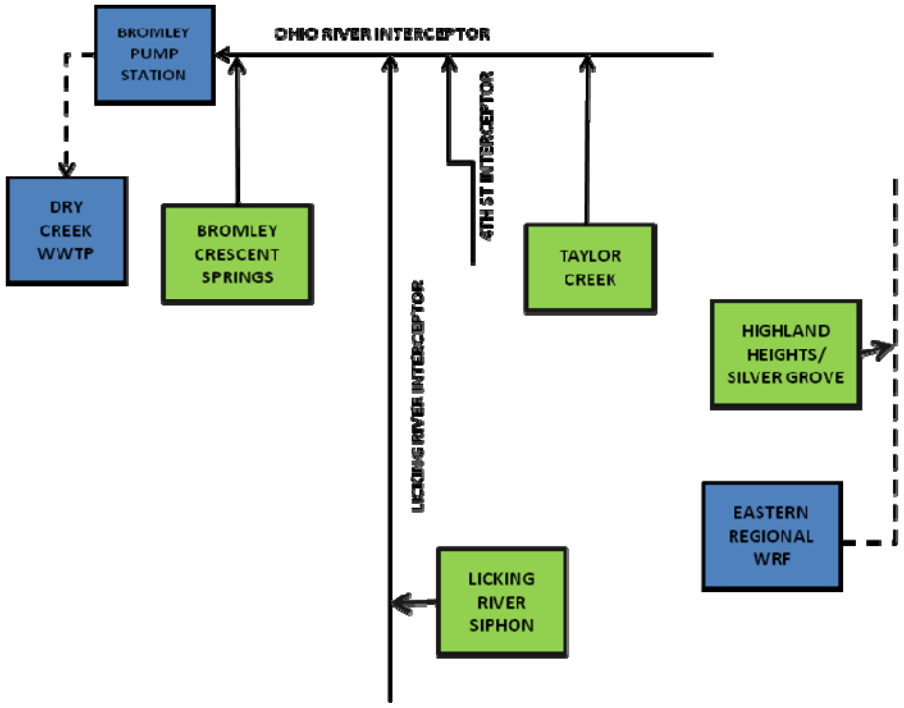


Figure 3.6. Schematic of Bromley and Eastern Regional Sanitary System Areas (Following the Five-year Improvement Program)



The prioritization of SSES activities across the SD1 system is based on a number of factors:

1. SSO volume – Of the six major sewersheds, the highest volume SSOs provide the highest potential for significant benefit through I/I removal. SD1's program will focus efforts in high volume locations as a priority following the Five-year Improvement Program. Table 3.2 below shows the sewersheds where I/I removal activities are planned, along with the projected SSO volume remaining after the Five-year Improvement Program is completed (based on the 1970 typical year).

Table 3.2. Sewershed Ranked by SSO Model Volume after Five-year Improvement Program (1970 Typical Year)

Rank	Sewershed	Model Simulated SSO Volume (MG)
1	Licking River Siphon	52.3
2	Lakeview Pump Station	44.7
3	Highland Heights / Silver Grove	20.8
4	Taylor Creek	5.3
5	Dry Creek	1.2
6	Bromley Crescent Springs	1.1

2. Public Health Impact – In the Five-year Improvement Program, SD1 is focusing efforts on SSOs with public health impacts; SD1 has already addressed the most critical locations. If future conditions change through development or land use changes, impacts on public health could accelerate specific I/I removal projects.

3. Coordination with Other Projects – Coordination with local communities' street improvement and neighborhood improvement programs provides opportunities for cost savings and will be considered in scheduling SSES activities.

SSES activities will focus on the identification and removal of illegal private source connections such as downspouts, area drains, and yard drains as well as the rehabilitation of public sewers that are in poor condition and subject to significant I/I.

Costs estimated for I/I removal projects include both a public and private source component. Based on analysis of testing and monitoring data to date, the benefit associated with comprehensive private and public source I/I removal was estimated to be a 50 percent reduction in RDII volume. As additional projects are implemented and monitored, more refined estimates of the benefits of the I/I projects will be developed.

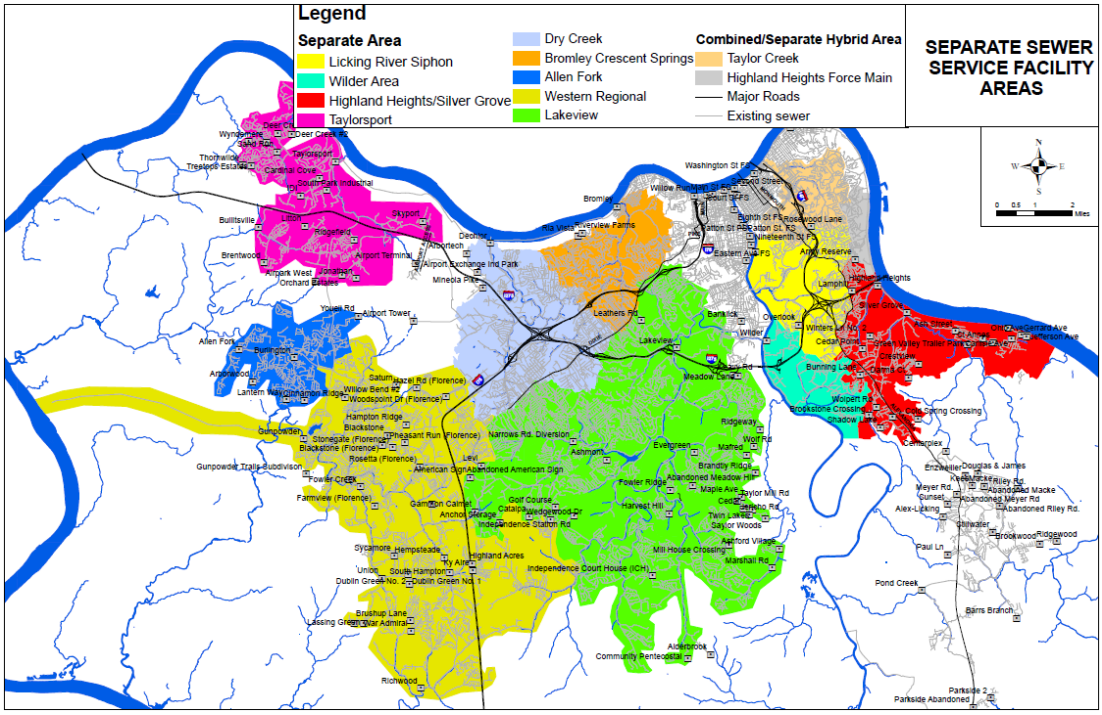
Following the incorporation of the I/I removal projects, additional gray infrastructure will be required to convey flow from a two-year design storm under saturated conditions. Based on the RDII removal and application estimates in the hydraulic model for 2030, gray infrastructure was sized for the elimination of SSOs in this two- year, six-hour design storm event.

The runoff characteristics within the hydraulic model were modified to simulate the RDII removal. The model was run to simulate the post-I/I removal conditions and with the Five-year Improvement Program implemented using the 2030 future build-out condition. The model results from this run were used to size and cost the gray infrastructure improvements to achieve the targeted level of service. Therefore, improvements are a combination of overflow elimination and traditional facility planning.

3.3.1.b Control Solutions for Each Sanitary System Sewershed

The separate sewer system was divided into distinct sewersheds for the purposes of grouping projects. These sewersheds tend to follow natural watershed boundaries and therefore match well with the overall watershed approach. Figure 3.7 shows the delineation of these areas.

Figure 3.7. Sanitary Sewershed Area Groupings for Control Evaluation for the Integrated Plan



The extent of the infrastructure improvements required to meet the two-year design storm level of service and estimated future development for the individual sewersheds are discussed in the following subsections. The size of

improvements, when constructed, may be adjusted based on actual I/I removal results. Maps showing the locations of improvements are included. Areas where I/I removal activities are planned are shown in light red. These areas also represent locations where storm water BMPs will be implemented to achieve reductions in storm water runoff quantity and improvements in runoff quality. Table 3.3 summarizes the identified control activities in each sewershed.

Table 3.3. Sanitary System Control Solution Components by Sewershed

Sewershed Area	Control Solution Summary	Included in Five-year Program?
Licking River Siphon	1. Inflow and infiltration removal 2. Local storage 3. Upsized conveyance to Dry Creek WWTP	1. Yes 2. No 3. No
Lakeview	1. Redirect flow to Western Regional WRF 2. Inflow and infiltration removal 3. Local storage tank 4. Upsized conveyance to Dry Creek WWTP and Western Regional WRF 5. New W6 Pump Station and force main	1. Yes 2. Yes 3. No 4. No 5. No
Highland Heights / Silver Grove	1. Ash St. Pump Station 2. Inflow and infiltration removal 3. New linked pump stations and storage basins 4. Upsized conveyance to Eastern Regional WRF	1. Yes 2. Yes 3. No 4. No
Taylor Creek	1. Inflow and infiltration removal 2. Upsized conveyance to Dry Creek WWTP	1. Yes 2. No
Dry Creek	1. Inflow and infiltration removal 2. Upsized conveyance to Dry Creek WWTP	1. Yes 2. No
Bromley-Crescent Springs	1. Inflow and infiltration removal 2. Upsized conveyance to Dry Creek WWTP	1. No 2. No
Western Regional	1. New pump stations 2. Local storage at Western Regional WRF 3. Upsized conveyance	1. No 2. No 3. Yes
Allen Fork	1. Redirect flow to the Western Regional WRF 2. New pump station 3. Upsize conveyance to Western Regional WRF	1. Yes 2. No 3. No
Taylorsport	1. New pump stations 2. Upsized conveyance to Western Regional WRF	1. No 2. No
Wilder	1. New pump station 2. Local storage 3. Upsized conveyance	1. No 2. No 3. No

Each of these sewersheds and control solutions are discussed in more detail in the following subsections.

3.3.1.c Licking River Siphon Sewershed

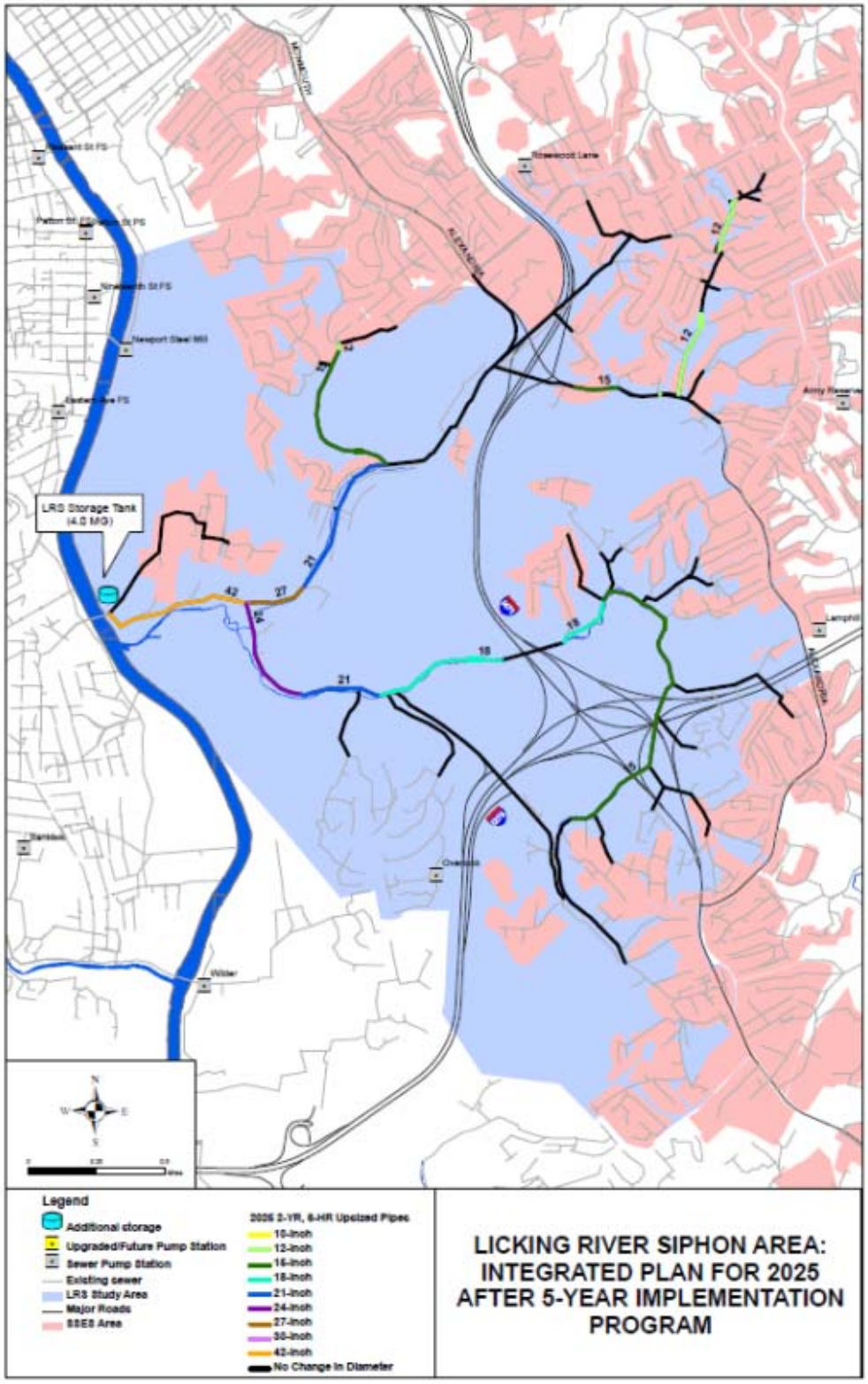
Following the implementation of the above described I/I removal activities, the Licking River Siphon sewershed is still projected to have recurring SSOs. For remaining SSOs upstream in the system, conveyance to the Siphon and the outlet of the sewershed was initially identified as the preferred solution because it was deemed the most cost-effective solution. However, this basin is tributary to the SD1 combined interceptor system, which remains capacity limited in wet weather. Increased conveyance through the Siphon would require significant upgrades to the combined infrastructure along the entire Licking and Ohio River interceptors to avoid increasing CSO volume. Given these constraints, the selected gray infrastructure control technology to achieve the targeted service level is the construction of a storage tank prior to the Siphon under the Licking River.

The Licking River Siphon Storage Tank consists of a surface storage tank with ancillary facilities, including a pump station and conveyance piping. The storage tank will attenuate and store flows above 3 million gallons per day (MGD) for treatment at the Dry Creek Wastewater Treatment Plant (WWTP) via the Licking River Interceptor and Bromley Pump Station. A summary of the facilities required for the two-year level of control is shown in Table 3.4 and a map showing the locations of the required improvements is shown in Figure 3.8.

Table 3.4. Licking River Siphon SanitarySewershed Improvements

Area with Inflow and Infiltration removal activities (acres)	1,211
Licking River Siphon (LRS) Storage Tank (MG)	4.0
Upsized conveyance pipe (ft)	28,361

Figure 3.8. Licking River Siphon Sanitary Sewershed Improvements after Five-Year Implementation Plan



3.3.1.d Lakeview Pump Station Sewershed

The Lakeview sewershed is projected to have remaining SSOs following the proposed I/I reduction and completion of the Five-year Improvement Program, The basin will have significantly lower overflow volume after the construction of the Western Regional system and related improvements included in the Five-year Improvement Program (described in Section 7) because most of the SSO volume will be diverted to the new facilities.

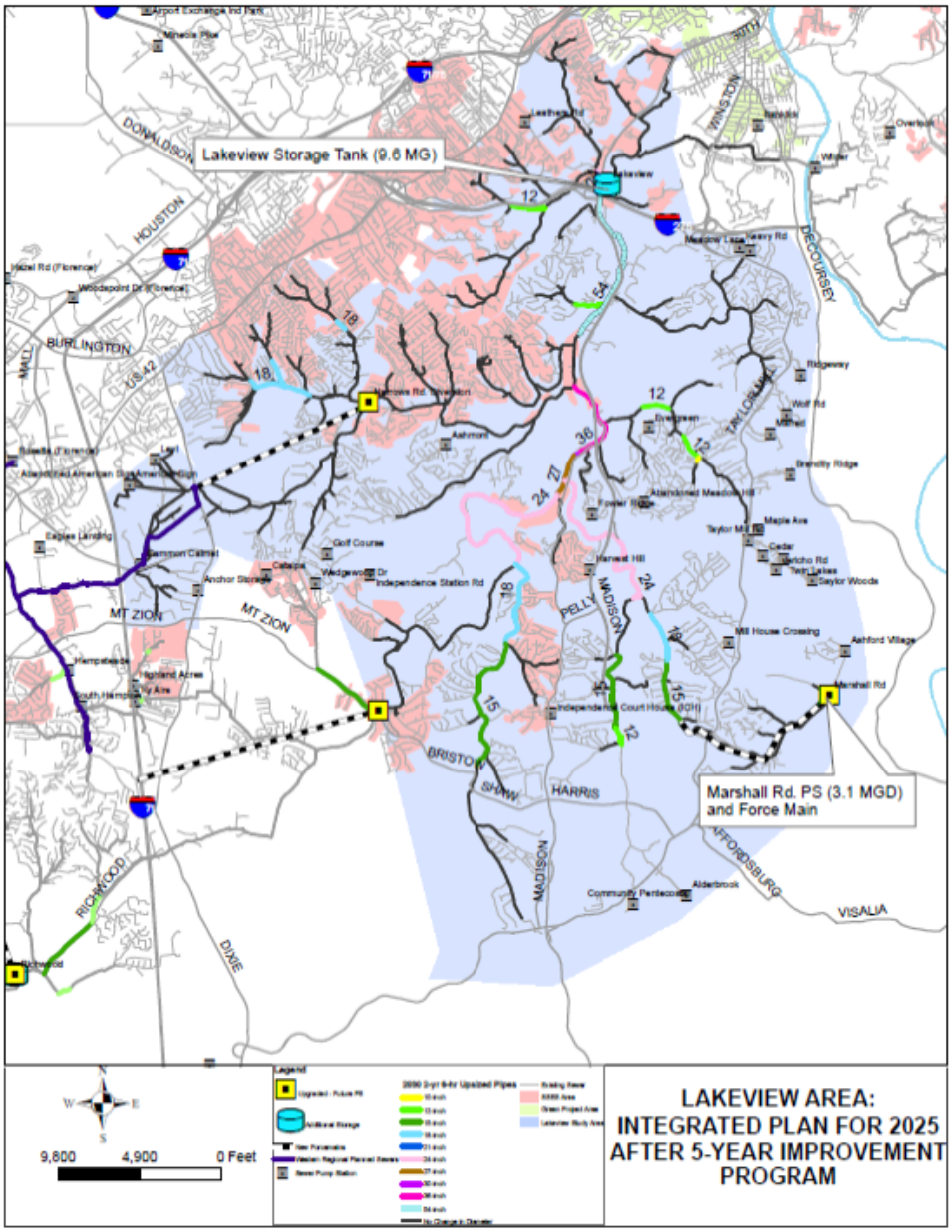
In addition to diverting flow to the new Western Regional system, additional solutions for addressing the remaining SSOs in the Lakeview sewershed include diverting Richwood PS and constructing a new pump station (W6 – located near MH 2300123 along Bristow Road) to relieve flows from the Lakeview system. Increased conveyance and the construction of a local storage tank at Lakeview PS will also address SSOs remaining after the I/I removal projects have been completed. Timing of the future conveyance and pump station projects is dependent on growth in the southern portion of the Lakeview basin and will be monitored closely following the completion of the Western Regional system. The Lakeview storage tank will store flows that exceed the upgraded capacity of the pump station and will be drained following the storm event to be treated at the Dry Creek WWTP.

A summary of the facilities required for the two-year design storm level of service is shown in Table 3.5 and a map showing the locations of the required improvements is shown in Figure 3.9.

Table 3.5. Lakeview Pump Station SanitarySewershed Improvements

Area with inflow and infiltration removal activities (acres)	5,918
Lakeview PS Storage Tank (MG)	9.6
Upsized Conveyance Pipe (ft)	84,894
Marshall Rd. PS (MGD)	3.1
Marshall Rd. Forcemain (ft)	9,600

Figure 3.9. Lakeview Pump Station Sanitary Sewershed Improvements



3.3.1.e Highland Heights/Silver Grove Sewershed

The Highland Heights / Silver Grove solution includes a suite of new and upgraded pump stations and connecting conveyance pipes that redirect flow from the Dry Creek WWTP service area to the Eastern Regional Water Reclamation Facility (WRF). The intent is to relieve the existing combined Ohio River interceptor, as well as to eliminate local SSOs and CSOs within the sewershed through the upgraded facilities. Many of the facilities are discussed in Section 7 as part of the Five-year Improvement Program.

The Highland Heights / Silver Grove solution consists of several facilities linked together as illustrated in Figure 3.10. The facilities include:

- New Lester Lane Pump Station;
- New Bivouac Pump Station;
- Upgraded Highland Heights Pump Station;
- New Highland Heights Equalization Basin;
- Upgraded Silver Grove Pump Station;
- New Silver Grove Equalization Basin;
- New Ash Street Pump Station (5-year plan);
- New Ash Street Equalization Basin;
- Upgraded Crestview Pump Station; and
- Elimination of the Ripple Creek Pump Station.

While the Ash St. Pump Station construction and Ripple Creek Pump Station elimination are included in the Five-year Improvement Program, the remaining projects will be designed and constructed after local I/I removal efforts are completed. The volume removed through the I/I projects is critical to correctly sizing the gray infrastructure. In addition, future growth in the existing Eastern Regional basin may influence the impacts of the proposed system improvements on flows at the Eastern WRF.

A summary of the facilities required for the two-year design storm level of control is shown in Table 3.6 and a map showing the locations of the required improvements is shown in Figure 3.10 and Figure 3-11.

Table 3.6. Highland Heights/ Silver Grove Sanitary Sewershed Improvements after Five-year Improvement Program

Area with inflow and infiltration removal activities (acres)	1,192
Lester Lane PS (MGD)	2.46
Bivouac PS (MGD)	1.05
Highland Heights PS (MGD)	2.5
Highland Heights EQ (MG)	1.16
Silver Grove PS (MGD)	3.5
Silver Grove EQ (MG)	0.85
Upsized conveyance pipe (ft)	14,772
Ash Street EQ (MG)	0.02

Figure 3.10. Highland Heights Sanitary Sewershed Improvements after Five-year Improvement Program

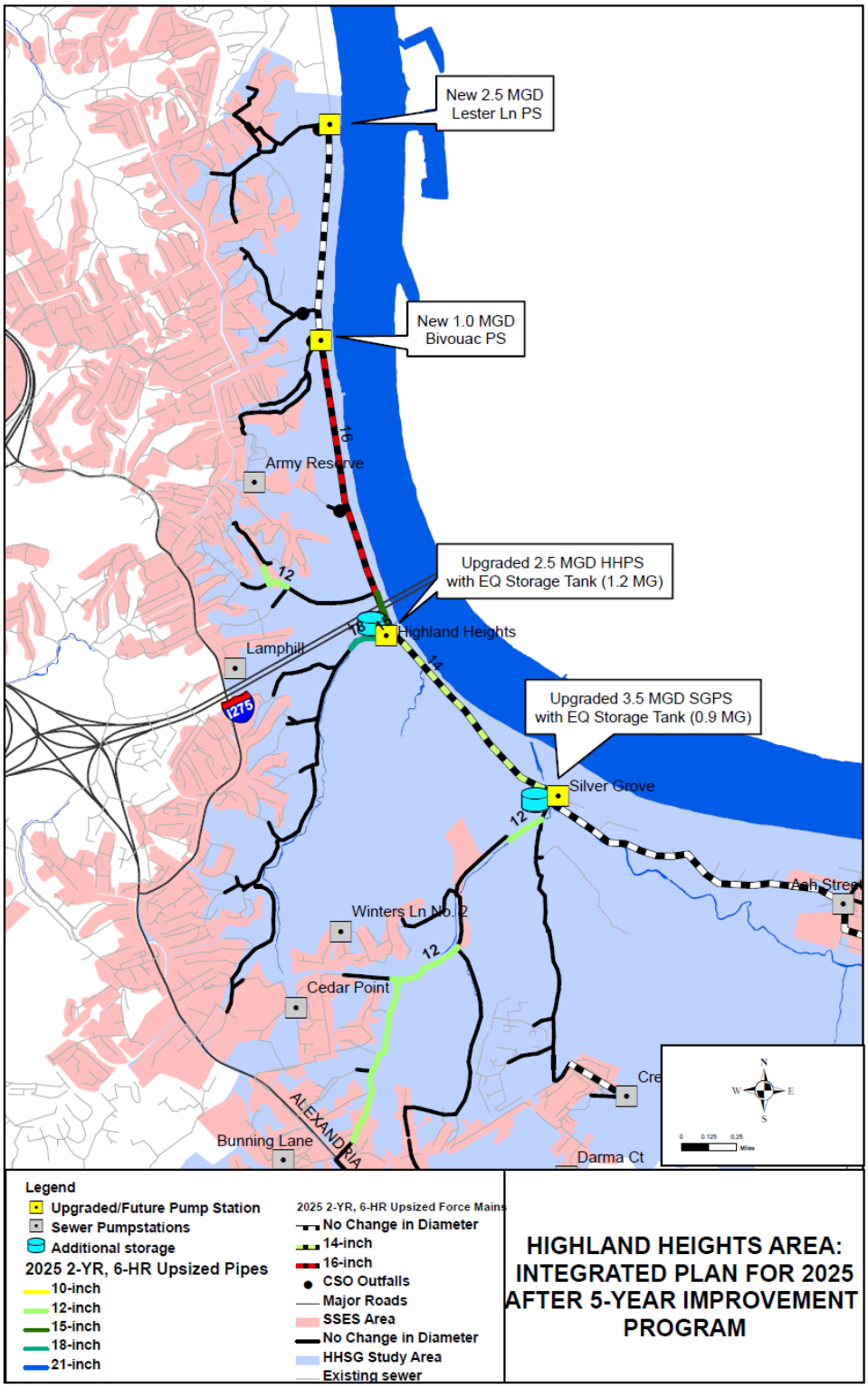
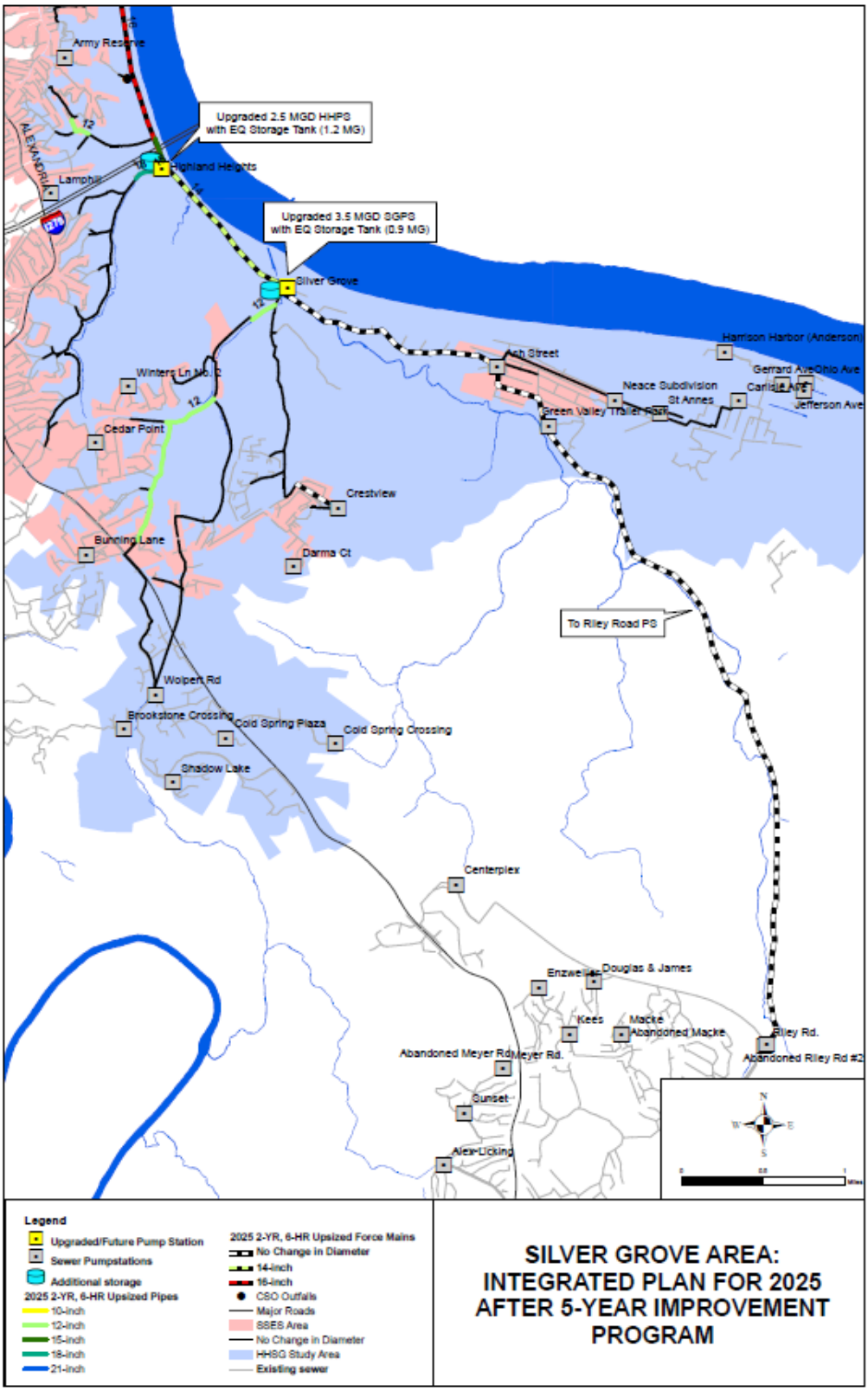


Figure 3.11. Silver Grove Sanitary Sewershed Improvements after Five-Year Improvement Program



3.3.1.f Taylor Creek Sewershed

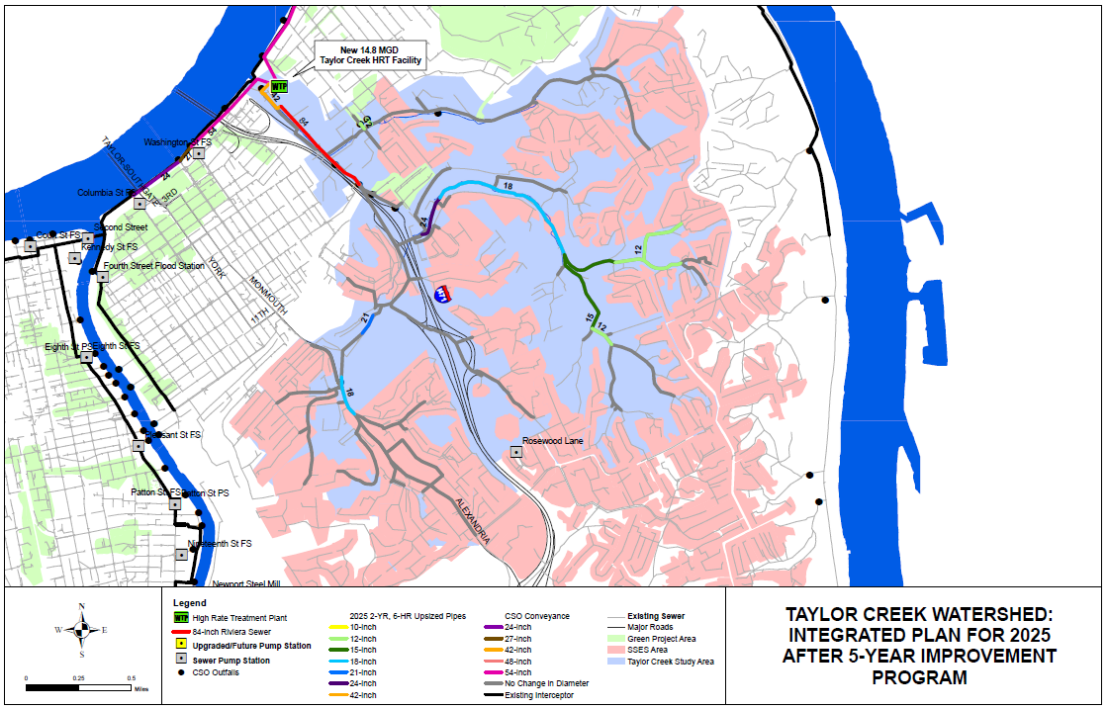
The Taylor Creek sewershed includes both combined and separate areas. Following the I/I removal activities in the separate portions and the implementation of green infrastructure in the combined portions of the sewershed, additional conveyance will be conveyed to the Riviera trunk sewer which also conveys combined flows to the Ohio River interceptor. A portion of this sewer will be replaced with an 84-inch large diameter in-line storage pipe that will eliminate a CSO along the trunk sewer. Combined flows in excess of the capacity of the Ohio River Interceptor will be treated at the Taylor Creek HRT facility that is part of the CSO control solution and is described in Section 3.3.2.

A summary of the improvements required for the two-year design storm level of control is shown in Table 3.7 and a map showing the locations of the required improvements is shown in Figure 3.12.

Table 3.7. Taylor Creek Sanitary Sewershed Improvements

Area with inflow and infiltration removal activities (acres)	1,239
Upsized conveyance pipe (ft)	18,395

Figure 3.12. Taylor Creek Sanitary Sewershed Improvements after Five-year Improvement Program



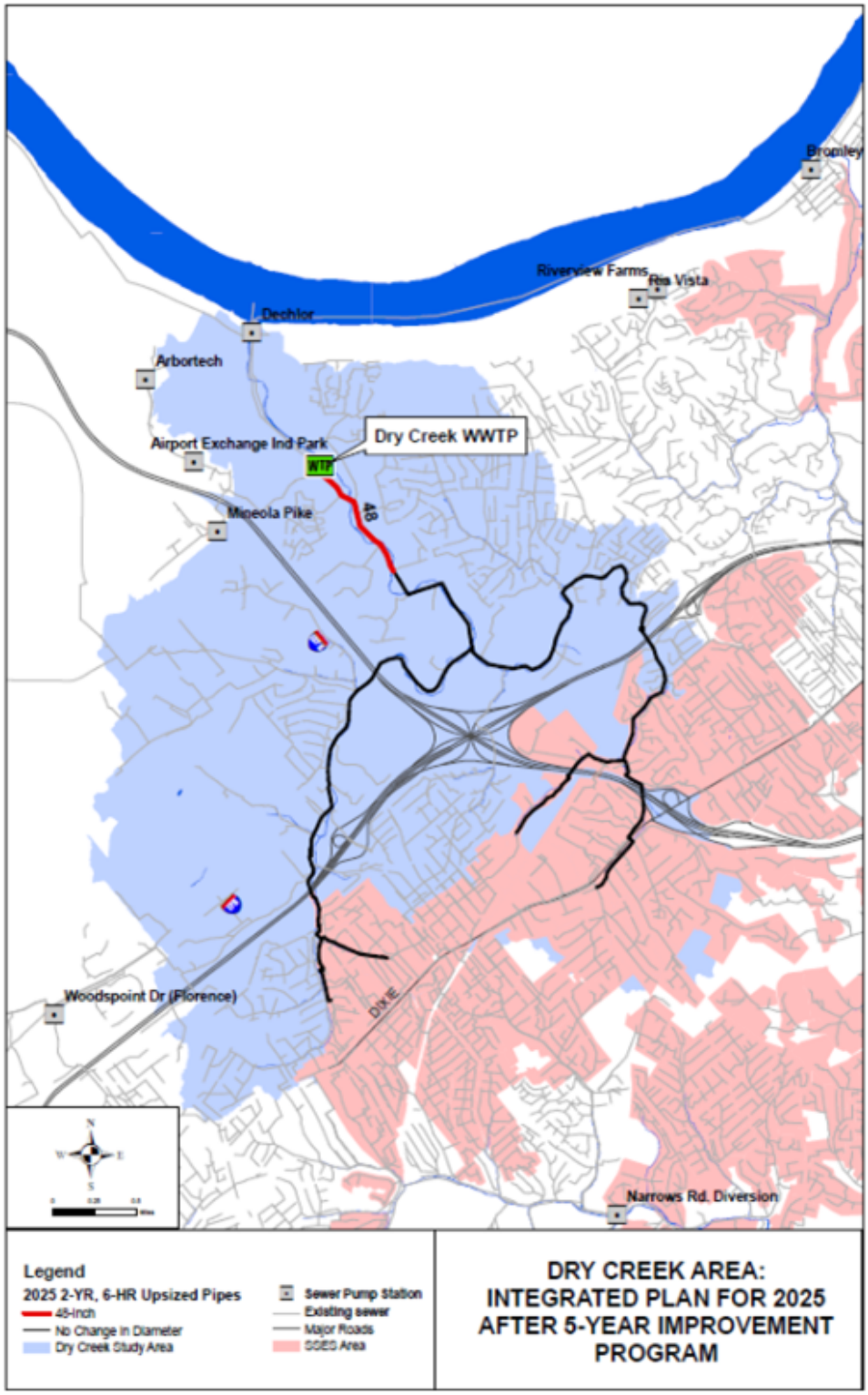
3.3.1.g Dry Creek Interceptor Sewershed

Modeling indicates that the area tributary (by gravity) to the Dry Creek WWTP will have all current SSOs eliminated through the I/I removal efforts and the projects in the Lakeside Park priority area as described in Section 7. Some limited conveyance improvements will still be required in the future to address projected growth. This is projected to be approximately 4,300 feet of 48-inch sewer that will replace the existing Dry Creek interceptor and will convey flows to the Dry Creek WWTP. A summary of the improvements required for the two-year design storm level of control is shown in Table 3.8; a map showing the locations of the required improvements is shown in Figure 3.13.

Table 3.8. Dry Creek Interceptor Sanitary Sewershed Improvements

Area with inflow and infiltration removal activities (acres)	1,515
Upsized conveyance pipe (ft)	4,300

Figure 3.13. Dry Creek Interceptor Sanitary Sewershed Improvements after Five-year Improvement Program



3.3.1.h Bromley-Crescent Springs Sewershed

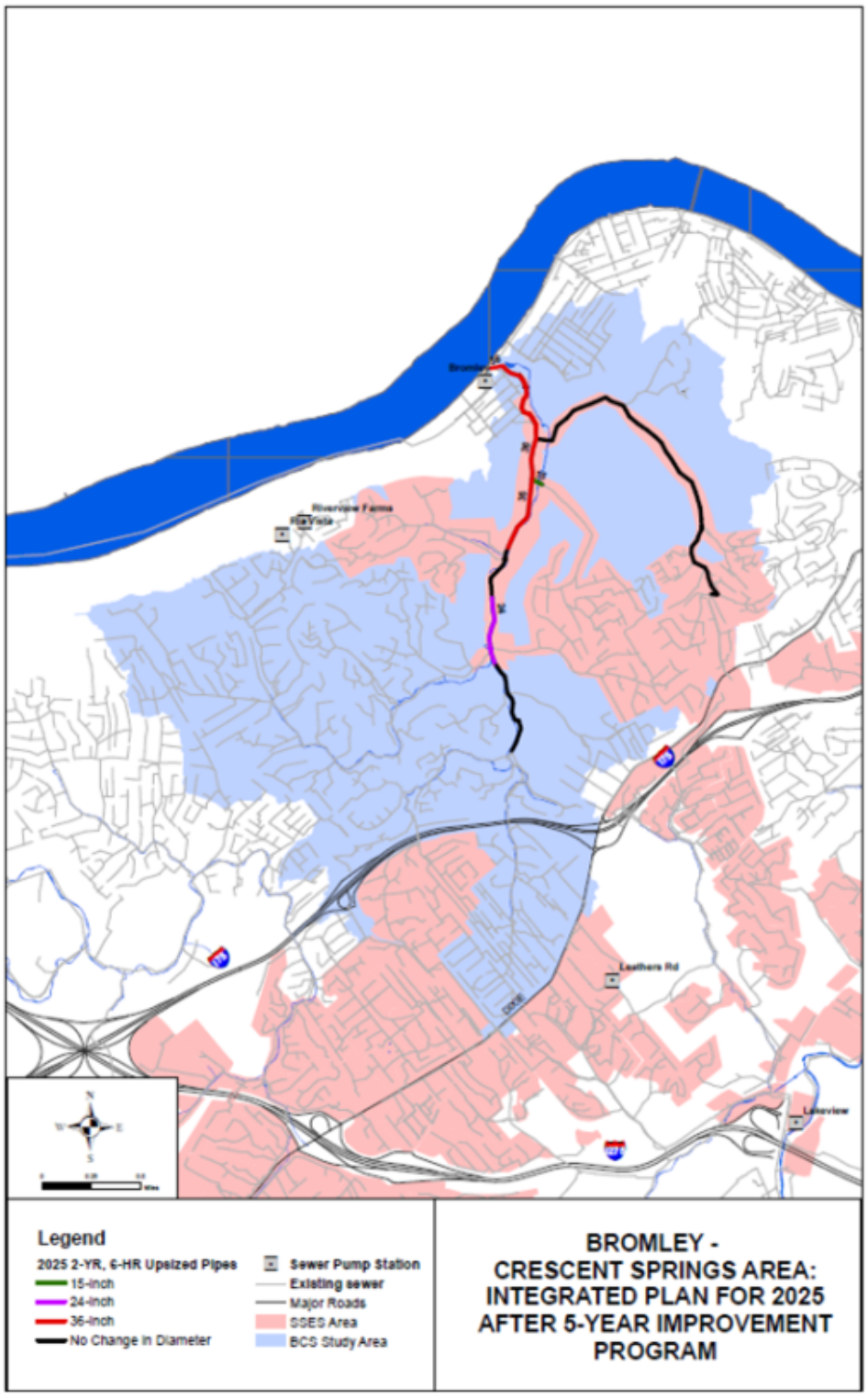
Following the estimated benefits obtained from I/I removal, increased conveyance is required to eliminate SSOs in the sewershed. This sewershed discharges into the combined system near Bromley Pump Station, which currently does not have excess capacity. Following the Bromley Pump Station upgrade to 60 MGD (note: this project is described in Section 2), more flow will be conveyed to the Dry Creek WWTP; the increased conveyance will eliminate the remaining SSOs.

A summary of the improvements required for the two-year design storm level of control is shown in Table 3.9 and a map showing the locations of the required improvements is shown in Figure 3.14.

Table 3.9. Bromley Crescent Springs Sanitary Sewershed Improvements

Area with Inflow and Infiltration Removal Activities (acres)	1,081
Upsized Conveyance Pipe (ft)	7,332

Figure 3.14. Bromley Crescent Springs Sanitary Sewershed Improvements after Five-year Improvement Program



3.3.1.i Western Regional Sewershed

The Western Regional improvements included in the Five-year Improvement Program significantly reduce the load on the Dry Creek WWTP and tributary conveyance systems and use the capacity of the newly constructed Western Regional WRF. The result is a significant reduction in SSOs as described in Section 7.

These improvements form the foundation to support additional projects that will maximize the treatment capacity of the new Western WRF, as well as the available wet weather capacity with the Western Regional tunnel. The Western Regional system will continue to provide a platform for eliminating SSOs in the Lakeview system. The construction of the W6 Pump Station is planned to send increased flows to the Western Regional system and relieve the existing Lakeview system. This facility includes both a pump station and forcemain, as well as a gravity connection to the Frogtown sewer.

In addition, within the Western Regional system, additional facilities will likely be needed for wet weather control at some point to accommodate projected growth and development. These facilities are included in the planned costs for 2030 based on current assumptions. These facilities include:

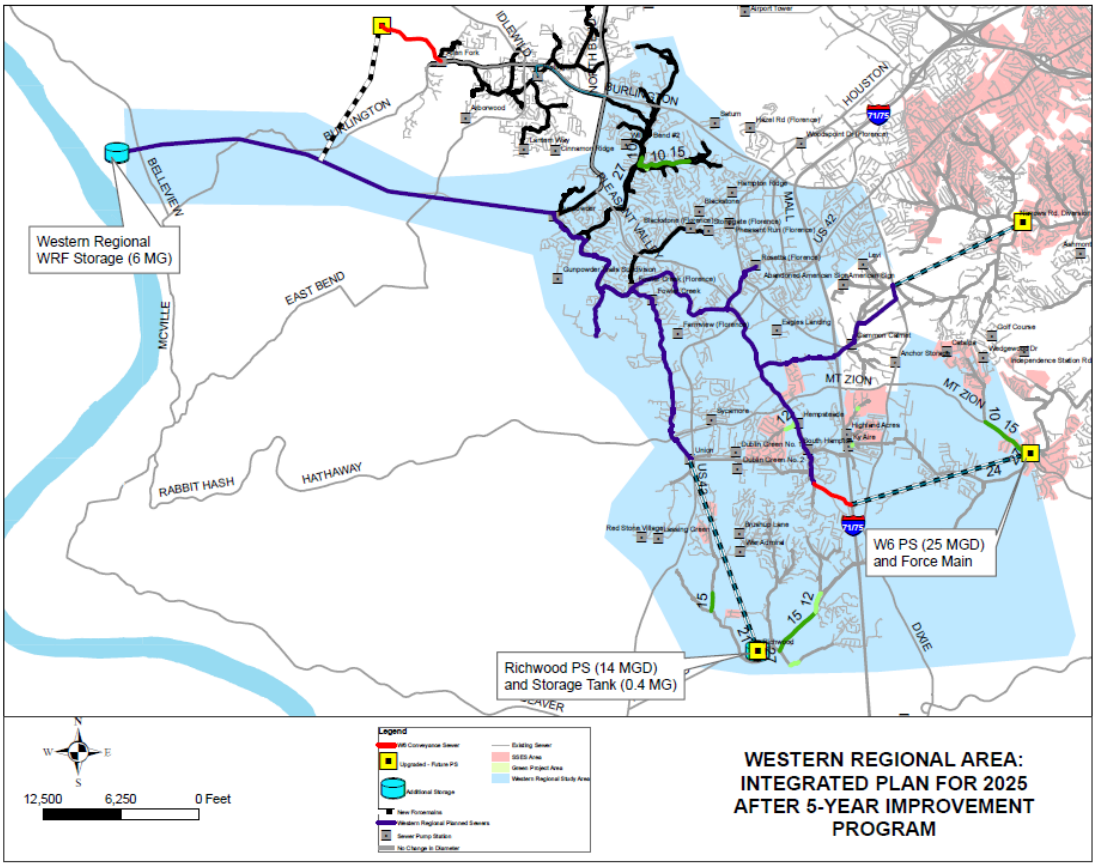
- Richwood Pump Station/Force Main and Equalization Basin;
- Local Western Regional Conveyance; and
- Western Regional WRF Equalization Basin.

A summary of the improvements described above is shown in Table 3.10, and a map showing the locations of the required improvements is shown in Figure 3.15.

Table 3.10. Western Regional Facility Planning Improvements

Richwood PS (MGD)	14
Richwood EQ (MG)	0.4
Western Regional WRF EQ (MG)	6.0
W6 PS (MGD)	25.4
Upsized conveyance pipe (ft)	56,562
W6 conveyance pipe (ft)	3,600

Figure 3.15. Western Regional Sanitary Sewershed Improvements after Five-year Improvement Program



3.3.1.j Allen Fork Sewershed

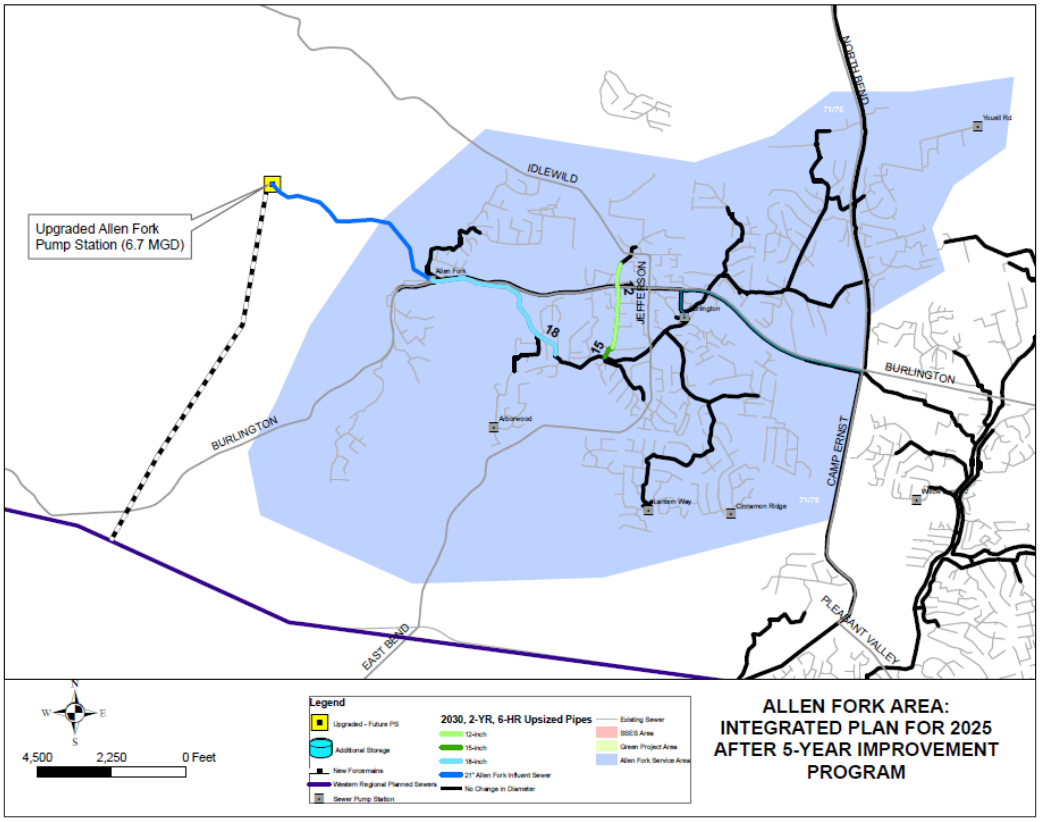
The Allen Fork sewershed consists of the land tributary to the Allen Fork and Burlington Pump Stations. The construction of the Burlington Pump Station in 2006 greatly reduced the frequency of sanitary overflows in the Allen Fork area. In addition, the implementation of the Western Regional improvements (described in Section 7) will eliminate current overflows in the area by expanding the capacity of the Burlington Pump Station and routing the flows to the Western Regional Tunnel. Future improvements will likely be needed in this area to address future growth. The overall plan is to implement additional conveyance upsizing and then construct a new Allen Fork Pump Station further downstream of the existing Allen Fork Pump Station to provide service for future growth. This new Allen Fork Pump Station will discharge directly to the new Western Regional Tunnel, which will, in turn, provide more capacity at the Burlington Pump Station.

A summary of the improvements described above is shown in Table 3.11 and a map showing the locations of the required improvements is shown in Figure 3.16.

Table 3.11. Allen Fork Sanitary Sewershed Improvements

New Allen Fork PS (MGD)	6.7
Upsized Conveyance	16,150

Figure 3.16. Allen Fork Sanitary Sewershed Improvements



3.3.1.k Taylorsport Sewershed Facility Planning Improvements

The Taylorsport Pump Station service area will have a substantial reduction in wet weather flows following the turning of flows to the Western Regional System as described in Section 7. This area, though, is projected to have significant growth by 2030 due to the available land and recent growth patterns. Upgrades to existing pump stations, as well as increased conveyance piping to convey flows from the new service areas are planned for this area to provide wet weather capacity.

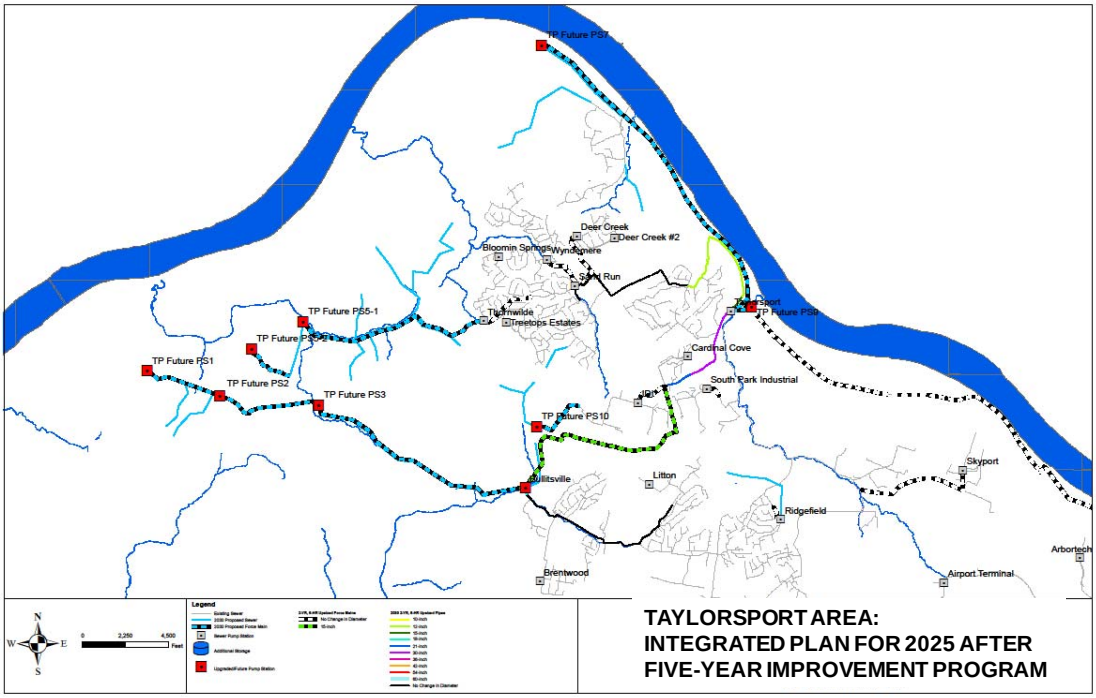
In addition, the Taylorsport force main currently manifolds into the Bromley Pump Station force main, reducing the efficiency of both stations. The upgraded condition includes de-coupling the Taylorsport Pump Station from the Bromley System by constructing a new Taylorsport force main that discharges directly to Dry Creek WWTP.

A summary of the improvements required for the two-year design storm level of control is shown in Table 3.12 and a map showing the locations of the required improvements is shown in Figure 3.17.

Table 3.12. Taylorsport Sanitary Sewershed Improvements

Upsized Bullitsville PS (MGD)	5.5
New pump stations	10
Upsized conveyance pipe (ft)	178,416

Figure 3.17. Taylorsport Sanitary Sewershed Improvements after Five-year Improvement Program



3.3.1.l Wilder Sewershed Facility Planning Improvements

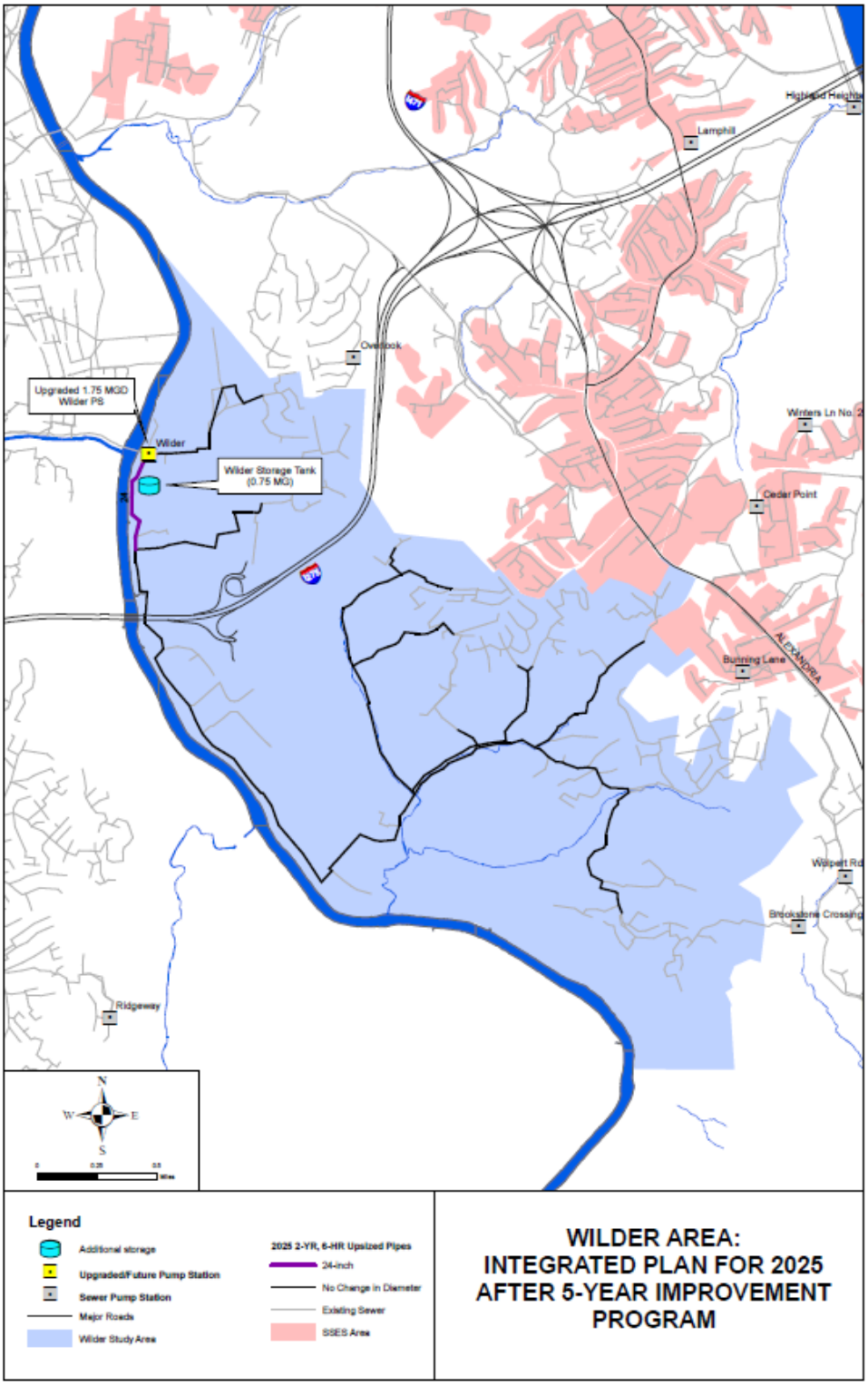
Currently, the area tributary to the Wilder Pump Station does not have any SSOs; however, projected future growth will likely make facility upgrades necessary in the future to maintain the current level of service. Wilder Pump Station is tributary to Lakeview Pump Station, so conveying additional flow downstream is not cost-effective due to the capacity limitations at Lakeview. Therefore, local storage and a pump station upgrade has been identified as the solution to attenuate and store excess wet weather flows for treatment at Dry Creek WWTP. The preliminary location of the tank will be adjacent to the pump station.

A summary of the improvements required for the two-year design storm level of control is shown in Table 3.13 and a map showing the locations of the required improvements is shown in Figure 3.18.

Table 3.13. Wilder Sanitary Sewershed Facility Planning Improvements

Upgraded Wilder PS (MGD)	1.75
Wilder EQ (MG)	0.8
Upsized conveyance pipe (ft)	2,349

Figure 3.18. Wilder Sanitary Sewershed Facility Planning Improvements after Five-year Improvement Program



3.3.1.m Summary of SSO Control/Facility Planning Costs

Table 3.14 below summarizes the projected capital costs to implement the improvements described above by watershed. These costs are broken down into components specific for overflow elimination and for costs to address system growth (facility planning). Sewer rehabilitation is also divided into structural rehabilitation and additional rehabilitation for enhanced I/I removal.

Table 3.14. SSO Elimination / Facility Planning Costs (2014 to 2025) after Five-year Improvement Program

Item	Capital Cost (2009 Million $)
SSO Elimination	
Bromley Crescent Springs	$ 6.3
Highland Heights Silver Grove	$ 47.1
Lakeview Pump Station	$ 101.5
Licking River Siphon	$ 42.7
Taylor Creek SSO	$ 17.4
Private Source Removal	$ 43.1
Public I/I Removal	$ 204.5
Subtotal, SSO Elimination	**$ 462.6**
Structural Rehabilitation / Renewal	**$ 197.1**
Facility Planning Improvements	
Allen Fork	$ 20.7
Lakeview Pump Station	$ 19.1
Dry Creek Interceptor	$ 6.5
Taylorsport	$ 71.0
Wilder	$ 13.5
Western Regional	$ 123.1
Subtotal, Facility Planning Improvements	**$ 253.9**
Total SSO / Facility Planning Cost	**$ 913.6**

3.3.2 CSO Control

The CSO Long-term Control Plan developed by SD1 relies on a combination of green infrastructure and gray infrastructure technologies to achieve the necessary reduction in CSO volume, duration and activations. This section presents the results of the analysis to maximize the use of green infrastructure in the combined (and separate) sewer systems (Section 3.3.2a); establishment of the water-quality based target levels of controls for CSOs (Section 3.3.2.b); and the approach used to develop the gray infrastructure controls for CSOs (Section 3.3.2.c). Discussion of the analysis done to develop the watershed controls is described in Section 3.3.3.

This section describes the analysis, identification and implementation of green infrastructure projects and programs for the Integrated Plan for 2025 in detail. SD1 is "leading with green" throughout the study area by preferentially implementing green infrastructure to reduce CSOs and improve water quality, prior to the implementation of gray infrastructure controls. For this section, green infrastructure is specific to CSO control, but the controls described are not limited geographically to the CSS area (as green infrastructure will be applied system-wide as discussed in Section 3.3.2.a).

3.3.2.a Maximizing Green Infrastructure Controls

Green infrastructure opportunities were identified on a larger regional scale (for system-wide application), and as part of a detailed evaluation of the CSS for more specific project implementation. The identification of opportunities was based on the features and characteristics described in Section 2.1.3. In addition to identifying locations for implementation of green controls, it is important for SD1 to develop relationships with potential project partners. Successful green partnerships allow SD1 to cost share on the implementation of these green techniques and help promote community support and education. Partnerships are discussed in more detail in Section 3.3.4.

The green opportunities are presented here in increasing levels of refinement, beginning with system-wide green approaches and green programs, and then, finally, resulting in specific locations where green projects may be implemented in the CSS area. The system-wide green approaches will help SD1 inform and direct development strategies and help develop key partnerships to further commitment to the implementation of green infrastructure. This section describes the opportunities at the following levels:

- **System-wide Green Infrastructure Opportunities:** These are high level, long term strategies developed by SD1 to help improve the water quality in Northern Kentucky. These strategies do not result in specific projects in the integrated solution, but will be used to guide project selection in future plans and identify potential demonstration projects during the five-year planning periods. This evaluation also resulted in the identification of system-wide green programs that are part of the Integrated Plan.

- **Combined Sewer Area Green Infrastructure Opportunities Analysis:** Green infrastructure can be used to help reduce the volume of storm water runoff that enters the CSS; it can also improve the quality of runoff that might result from separation efforts. The first step in identifying potential locations for green projects was to conduct a high-level review of each combined sewershed for green opportunities. The results will be used to inform the watershed planning process throughout the life of the Consent Decree. Details of this analysis are provided in Appendix 3-B.

  SD1 reviewed the results of the opportunities and then identified specific locations for the implementation of green infrastructure. These locations were reviewed in more detail to select green projects that are implementable, inform the overall green approach, and make an immediate impact on water quality. The process for identifying specific green infrastructure projects is described in Section 6 and the projects themselves are presented in Section 7.

3.3.2.a.1 System-wide Green Infrastructure Opportunities

Northern Kentucky possesses a valuable inventory of rivers, streams, creeks, and aquatic habitat. The system-wide green infrastructure opportunities include a continual effort to protect and restore the hydrologic network that mimics the natural water balance in Northern Kentucky. The approach includes:

- Conservation and restoration;
- Implementation of design protocols to reduce the impacts of runoff;
- Protection, enhancement, and connection of forests;
- Promotion of transportation corridors as greenway connections;
- Support of regional planning and low impact development; and,
- Offload of runoff to natural systems.

The components of these principles, which represent SD1's guiding philosophy to green infrastructure, are described in more detail in Appendix 3-B.1.

3.3.2.a.2 System-wide Green Programs

One outcome of the green infrastructure evaluation efforts described above was the development of a green infrastructure program structure that could be implemented not only in the combined system, but throughout SD1's service area. Through either financial or technical support, SD1 plans to implement green infrastructure on a regional level in an effort to maximize the reduction of runoff entering the CSS and improve water quality in Northern Kentucky. These program elements will also raise public awareness regarding the responsibility that individuals have in protecting and enhancing local water resources. The following section describes the various incentive programs for residential and non-residential property owners, in both the combined and separate sewer system areas, to receive financial or technical assistance from SD1 for the implementation of green infrastructure elements.

Green Program Elements

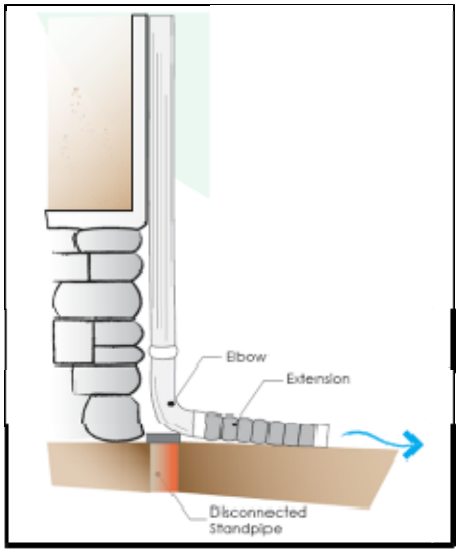
Disconnection - Redirection - Infiltration Program (DRIP)

As part of the Integrated Plan for 2025, SD1 has created the Disconnection - Redirection - Infiltration Program (DRIP) to assist residential property owners with the implementation of green infrastructure features. This voluntary program is available to all property owners within SD1's storm water service area. The green storm water practices eligible for funding through DRIP include:

- Downspout disconnection,
- Rain barrels, and
- Rain gardens.

Downspout Disconnection:

Downspout disconnection is an effective way to reduce the amount of storm water runoff entering the sewer systems; disconnection also provides additional environmental benefits such as promoting ground water recharge and improving water quality. Downspout disconnection is a public education and outreach effort to educate homeowners on the importance of storm water management using green infrastructure in both the separate and combined sewer systems. Downspout disconnection is especially important in the CSS, as it may result in a direct reduction of CSO volume.



Residential rooftops account for approximately 28 percent of the impervious area within the CSS. By disconnecting roof downspouts, a significant portion of this impervious area can be removed from the CSS. Because downspout connections to the CSS are not illegal, SD1 will use a financial incentive to encourage homeowners to actively participate in DRIP, resulting in greater reductions in storm water runoff entering the combined sewers.

Using available GIS data, the total square footage of residential rooftops was calculated for each CSO basin. To estimate the potential storm water reduction from this program, each basin was given an “effectiveness” rating of high, medium, or low. The rating was based on criteria such as soil conditions, lot size and density of the homes. This rating is intended to account for the storm water removed during the disconnection that somehow flows back into the CSS through either direct or indirect means; it is expected that even if a downspout is disconnected from the CSS, some of the redirected runoff still has the potential to re-enter the CSS. For the purposes of this evaluation, it was assumed that only 60 percent of the homes have downspouts directly connected to the CSS. Therefore, when performing the individual sewershed analysis, only 60 percent of the total roof area was available for disconnection. An effectiveness rating was assigned to each sewershed to determine the effective roof area in each basin that could be disconnected from the combined system. Using aggressive estimates for each program variable, it has been estimated that if fully implemented, the downspout disconnection program could remove approximately 25 percent of the assumed connected single family roof area from the CSS.

In addition to voluntary participation in DRIP, SD1 will perform targeted downspout disconnection in pilot areas over the first five years to determine the feasibility of achieving disconnection of 25 percent of non-priority area

downspouts by 2025. These pilot areas will allow SD1 to monitor and refine assumptions used to determine effectiveness of this program. With the initial aggressive assumptions used, it will be important to generate data on the percentage of homes/downspouts that may realistically be disconnected over a certain timeframe. Once the pilot programs have been completed, these assumptions will be re-evaluated and adjusted as necessary

Rain Barrels:

Through DRIP, rain barrels serve as another public education and outreach effort to incentivize property owners to disconnect downspouts and use green infrastructure for storm water management. SD1 initiated a rain barrel program in 2009 to assess public interest in green technologies. During the course of 2009 and 2010, SD1 successfully sold 300 rain barrels. Based on this participation, SD1 is more aggressively pursuing the residential implementation of green infrastructure, particularly through downspout disconnection, rain barrels, and rain gardens.

SD1 will promote the use of rain barrels in both the CSS and separate sewer system through informational brochures, DRIP workshops, and presentations at various public meetings. SD1 will ensure continued communication with rain barrel owners through annual reminders about proper operation and maintenance of rain barrels and periodic satisfaction surveys.

Rain Gardens:

Rain gardens on residential properties promote complete downspout disconnection, redirection, and infiltration of storm water runoff. Removing storm water from the sewer systems has several benefits including ground water recharge and water quality improvements. Rain gardens are also an effective way of removing residential rooftop runoff from the CSS, reducing CSO volume.

As with the rain barrel component of DRIP, SD1 will promote the use of residential rain gardens through informational brochures, DRIP workshops, and presentations at various community meetings. In addition to financial support, SD1 will provide technical support to homeowners who install a rain garden on their property. Part of this technical assistance will include annual maintenance reminders and checklists, as well as satisfaction surveys. Homeowners will be required to complete a maintenance agreement,

agreeing to properly maintain the rain garden to ensure maximum benefits are achieved.

The green infrastructure elements included in DRIP will be implemented on a regional level in an effort to maximize the reduction of runoff entering the CSS and provide water quality benefits in the separate system. These programs will also raise public awareness of the responsibility that individuals have in protecting and enhancing local water resources. Funding for voluntary residential projects implementing downspout disconnection, rain barrels and/or rain gardens will be part of the annual DRIP budget; DRIP funding will be provided on a first come, first serve basis.

For the purposes of implementing DRIP in the combined system, a disconnection of 25 percent of the residential roof area, outside of specific green infrastructure CSO reduction projects, was incorporated into the hydraulic model. Based on this area, it has been assumed that 9,300 residential properties in the combined system will participate in DRIP during the implementation of the Integrated Plan for 2025. At an average of $500 per property, the total program budget for DRIP is $4,665,000 in the CSS. For the separate sewer area, it was assumed 300 properties, at $500 per property, would participate in DRIP during the implementation of the Integrated Solution, with a total program budget of $150,000. Therefore, the total budget for DRIP, as part of the Integrated Solution for 2025 is $4,815,000.

The complete DRIP program will begin in fiscal year 2012. After the first three years, SD1 will evaluate the success of DRIP in both the combined and separate sewer systems to determine how the program should be adapted for future years. Factors to be evaluated will include awareness and participation in DRIP, promotion techniques, and results of satisfaction surveys. Table 3.15 summarizes the DRIP budget for the Integrated Plan.

Table 3.15. DRIP Implementation and Budget Summary

	FY-2012 to FY-2014		
	Combined System	Separate System	Total
Number of Properties per Year	100	20	120
Annual Budget	$50,000	$10,000	$60,000
Number of Years	3	3	3
Total Number of Properties	300	60	360
Total Budget	$150,000	$30,000	$180,000

	FY-2015 to FY-2025		
	Combined System	Separate System	Total
Number of Properties per Year	821	20	821
Annual Budget	$410,500	$10,000	$420,500
Number of Years	11	11	11
Total Number of Properties	9,031	220	841
Total Budget	$4,515,000	$110,000	$4,625,000

Total DRIP Budget FY-2012 to FY-2025	$4,665,000	$140,000	$4,805,000

Green Infrastructure Project Partnership Program (GrIPP)

In addition to working with residential property owners to implement green infrastructure practices, SD1 has developed a partnership program for non-residential properties within the combined and separate sewer systems. By implementing GrIPP, SD1 will incentivize and increase the implementation of storm water features on non-residential properties. SD1 finds extreme value in implementing green infrastructure through project partnerships, as approximately 60 percent of land within SD1's service area is privately owned. Implementations of green techniques such as bioinfiltration and vegetated roofs will contribute to the success of SD1's storm water quantity and quality goals.

Bioinfiltration:

Bioinfiltration is expected to be one of the leading types of green controls utilized for GrIPP. Reducing the runoff associated with impervious surfaces throughout the combined system has a direct impact on the sewer system capacity. In addition to the benefits provided in the CSS, incorporating bioinfiltration features in the separate sewer system will help improve water quality in waterways. As mentioned previously, parking lots and roads contribute to a significant amount of the hard surfaces within the combined system. By retrofitting these areas with vegetation through the use of bioinfiltration or rain garden techniques, SD1 can reduce storm water runoff, promote ground water recharge, maximize evapotranspiration, and improve water quality in Northern Kentucky.

Vegetated Roofs:

Vegetated roofs, or green roofs, are vegetated areas that are designed as part of a roof system and can be used on commercial, industrial or residential roofs. Data from monitored vegetated roof systems indicate a significant reduction in annual runoff from these systems when compared to more traditional metal or asphalt roofs.

SD1 has established itself as a regional leader in green technology by constructing an award winning vegetated roof on its headquarters facility. Thousands of visitors from all over the world have toured this facility and had an opportunity to walk out on the vegetated roof.

SD1 recognizes the value that green roofs represent in terms of storm water reductions to the CSS and water quality improvements in the separate sewer system. SD1 expects that green roofs will be another green control utilized in GrIPP partnerships for storm water management.

GrIPP in the Combined Sewer System:

Non-residential properties in the CSS will be eligible to receive funding from SD1 to incorporate green infrastructure elements into redevelopment projects, street improvement projects, and partnership projects. The following highlights the partnership opportunities and GrIPP budget for the combined system.

Redevelopment Projects:

As part of the green opportunities analysis in the CSS, it was assumed that 15 percent of currently developed non-residential parcels greater than one acre would be redeveloped at a rate of one percent per year over the duration of the Consent Decree. Based on proposed changes to SD1's redevelopment regulations, it was assumed that redevelopment projects will be required to implement green practices to effectively reduce the annual runoff from redeveloped parcels by fifteen percent. SD1 will examine each redevelopment project to identify any additional green controls that may be implemented to further reduce combined sewer overflow volume.

These assumptions were incorporated into the hydraulic model, and found to provide a benefit of approximately three million gallons in CSO reduction. Based on these assumptions, and taking into account the one percent annual redevelopment rate (approximately three sites per year) over the duration of the Consent Decree, a program budget of $450,000 for redevelopment projects in the CSS has been incorporated into the Integrated Plan. SD1 will use this budget to implement green features on redevelopment sites to achieve CSO volume reduction. SD1 will start implementing this program in fiscal year 2012. It is important to note that SD1 will evaluate the success of this standard over time once it is implemented. As the standard is evaluated and evolves, SD1 will need to adjust program budgets to appropriately reflect program costs.

Project Partnerships:

Beginning in 2010, SD1 began to establish partnerships for implementing green infrastructure in the CSS; most of these partnerships have been established with public entities. However, as discussed previously, the majority of land within SD1's service area is privately owned. This makes partnerships with both private and public entities important in the success of SD1's green infrastructure program. For this purpose, SD1 has included $3.2

Million, over a the course of the Consent Decree, to partner with non-residential property owners to incorporate green features on individual sites.

The goal of partnership projects within the CSS is to cost-effectively remove storm water from the combined system by utilizing green infrastructure. SD1 is currently preparing a funding application that will help evaluate the cost and benefit of proposed partnership projects. This application will assist SD1 in performing a business-case evaluation to determine the appropriate level of funding for a submitted project. In the CSS, SD1 will evaluate the cost per gallon of storm water removed as the main ranking criteria for the green components of a project. Funding may be requested for any green feature proposed on a site that provides a CSO volume reduction. SD1 reserves the right to fund the design and construction of all components or only certain portions of green features being proposed, based on the results of the business-case evaluation. Funding for these projects will be awarded on a first come, first serve basis.

These specific partner opportunities have not been included in the hydraulic model at this time.

Green Streets:

In addition to redevelopment projects and partnership projects, SD1 will partner with cities and counties to incorporate green storm water features in proposed roadway improvement or reconstruction work. SD1 has assumed 7.5 percent of the road area within the CSS, excluding highways, will be redirected to green features during the implementation of the Consent Decree. This information was incorporated into the hydraulic model, and the CSO reduction benefits have been calculated. Taking into account the 7.5 percent retrofit rate, a program budget of $2.37 Million for retrofitting streets to incorporate green features in the CSS has been developed for the Integrated Plan. SD1 will begin these project partnerships in fiscal year 2012. SD1 will evaluate the success of implementing this program in the first three years to determine appropriate adjustments; the budget for this program will need to be appropriately adjusted as this program is evaluated.

A total GrIPP budget of $6.02 Million for non-residential green partner projects in the CSS has been incorporated into the Integrated Plan for 2025. Table 3.16 provides a summary of the GrIPP components in the combined system.

Table 3.16. GrIPP Implementation and Budget Summary in the Combined System

Component	Start Year	FY-2010 to FY-2014 Budget	FY-2015 to FY-2025 Budget	Total
Redevelopment	2012	$90,000	$360,000	$450,000
Partnerships	2010	$854,000	$2,346,000	$3,200,000
Green Streets	2012	$360,000	$2,010,000	$2,370,000
	Total	$1,304,000	$4,716,000	$6,020,000

GrIPP in the Separate Sewer System

Non-residential properties in the separate sewer system will also be eligible to apply for funding of green infrastructure through GrIPP. GrIPP funding in the separate sewer system will be used to implement green infrastructure on redevelopment projects and properties that choose to implement green infrastructure to improve water quality.

Redevelopment Projects:

Based on proposed changes to SD1's redevelopment regulations in the separate system, redevelopment projects will implement green practices to manage the runoff produced from the first 0.4 inches of rainfall utilizing a site BMP. SD1 will evaluate each redevelopment project for the opportunity to implement cost-effective green controls that go beyond the proposed regulation. Assuming three, two-acre redevelopment projects per year, a program budget of $700,000 for non-residential redevelopment projects in the separate system has been incorporated into the Integrated Plan for 2025.

The redevelopment regulations will take effect in fiscal year 2012. However, as the program evolves, these regulations are subject to change. SD1 will evaluate the effectiveness of these regulations and adjust the program and program budgets as necessary.

Project Partnerships:

In addition to redevelopment projects, SD1 plans to partner with other non-residential property owners, cities, and counties within the separate system to incorporate green storm water features on existing sites. Partnership funding for the separate sewer system will be based upon a business-case evaluation. SD1 will evaluate the cost per gallon of storm water treated and the associated pollutant reduction, with a focus on bacteria as the main ranking criteria. The main goal of project partnerships in the separate sewer system is to provide water quality improvement to storm water runoff entering the storm sewer system and natural drainage ways. SD1 reserves the right to

fund the design and construction of all components or only certain portions of green features on the project site, based upon results of the business-case evaluation. Funding for these projects will be awarded on a first come, first serve basis.

Beginning in 2010, SD1 began establishing partnerships for implementing green infrastructure. SD1 recognizes the importance of continuing these partnerships to help meet the Consent Decree goals. Therefore, SD1 has included $1.6 Million, from fiscal years 2010 to 2025, for project partnerships within the separate system.

A total program budget of $2.3 Million for non-residential green partner projects in the separate sewer system has been incorporated into the Integrated Plan for 2025. Table 3.17 provides a summary of the GrIPP components in the separate system.

Table 3.17. GrIPP Implementation and Budget Summary in the Separate System

Component	Start Year	FY 2010 - 2014 Budget	FY 2015- 2025 Budget	Total
Redevelopment	2012	$150,000	$550,000	$700,000
Partnerships	2010	$429,000	$1,171,000	$1,600,000
	Total	$579,000	$1,721,000	$2,300,000

Benefits of DRIP and GrIPP in the Combined System

To determine the benefits of implementing such a program in the CSS, the following assumptions have been incorporated into the hydraulic model:

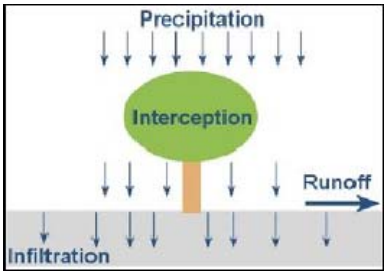
- 25 percent of residential roofs, outside of CSO Reduction Projects, will be targeted for disconnection;
- One percent of commercial properties will be redeveloped with green infrastructure features each year, for 15 years during implementation of the Consent Decree;
- 7.5 percent of the roadway area will be redeveloped and directed to green features per year, for 15 years during implementation of the Consent Decree; and
- Additional partnership opportunities, not related to redevelopment, have not been included in the hydraulic model.

Using these assumptions, the hydraulic model calculates an additional CSO reduction of 17 MG for the Integrated Plan for 2025.

Technical Support

In addition to providing financial incentives for green infrastructure through DRIP and GrIPP, SD1 will also provide technical assistance to interested property owners and organizations who wish to incorporate tree plantings or buffers into their property or project. Urban reforestation and riparian buffer zones will help SD1 achieve the watershed goals by reducing the amount of storm water runoff and improving water quality.

Urban Reforestation Support



Urban reforestation is the practice of enhancing and restoring vegetative cover in urban areas. Trees provide natural control of storm water runoff as well as other benefits such as improved air quality, increased wildlife habitat, and cooler temperatures.

The cost of trees varies substantially depending on the size and type of tree and the location for the proposed planting. Approximately 826 acres of canopy cover exist in the CSS today. This represents 14 percent of the CSS land area. American Forests has established a goal of 15 percent canopy cover for typical Central Business Districts and 25 percent canopy cover for urban residential land use (American Forests, 2001; American Forests, 2008). A CITYgreen™ analysis was performed that showed the existing tree canopy in the CSS provides 36 MG of storage volume for a 2.75 inch, two-year, 24-hour rainfall event, CITYgreen's programmed design storm. Using storage costs at $2.00/gallon, this storage volume represents more than $70 Million in benefit to SD1. Based on the estimated benefits that trees provide to SD1 and the community, SD1 will encourage and promote tree planting programs throughout the community, with a focus on the CSS. SD1 will support the work of third party groups interested in reforestation in Northern Kentucky by providing technical support for third party implementation. For example, if a third party wants to determine the benefits of the reforestation project, SD1 can perform a CITYgreen analysis as described above to quantify the benefits. Assistance provided by SD1 could be used by third parties to leverage existing grant monies or as required matching funds for new grant applications.

Riparian Buffer Support

Riparian corridors can help to protect sewer and other public infrastructure adjacent to waterways, reduce sediment and erosion problems, improve water quality, increase natural infiltration, and enhance aquatic and riparian habitats. Stream buffers can be protected and preserved by establishing requirements such as stream buffer ordinances to prevent and/or minimize the disturbance of these vulnerable areas.

Riparian buffers provide multiple benefits, including controlling runoff volumes and improving public health through bacteria load reduction (Section 6.2.4). Review of recent literature indicates that riparian buffers can achieve 23 to 99 percent reduction in annual loading rates for bacteria (Roodsari et al. 2005, Sullivan et al. 2007). The Watershed Assessment Tool (WAT!) estimates that implementation of buffers under current conditions could reduce annual bacteria load by approximately three percent in the entire SD1 study area. Load reductions in the individual watersheds were estimated to be between 0.3 percent (Pleasant Run, Taylor Creek) and 7.8 percent (Big Bone and Twelvemile Creeks).

SD1 will support the work of multiple third party groups already working on buffer implementation and conservation in Northern Kentucky. SD1 will provide technical support for third party implementation and ordinance support for Planning and Zoning agencies. For example, if a third party wants to pursue a buffer opportunity, SD1 can apply the detailed modeling tools to quantify benefits. Assistance provided by SD1 could be used by third parties to leverage existing grant monies or as required matching funds for new grant applications.

Summary of Green Programs

The system-wide green programs will give SD1 the opportunity to demonstrate a cost-effective and sustainable approach to storm water management while working to reduce overflow volume and improve water quality.

SD1 has budgeted $13.13 Million as part of the Integrated Plan for 2025 to implement these system-wide green programs. Table 3.18 summarizes the green program budget.

Table 3.18. Green Program Summary for Integrated Plan for 2025.

Integrated Solution for 2025 Green Program Summary	
Program Component	Program Budget
DRIP	
Combined System	$4,665,000
Separate System	$140,000
GrIPP	
Combined System	
Redevelopment	$450,000
Green Streets	$2,370,000
Partnerships	$3,200,000
Separate System	
Redevelopment	$700,000
Partnerships	$1,600,000
Total Green Program	$13,125,000

3.3.2.a.3 Combined Sewer Area Green Infrastructure Opportunities Analysis

Initial Combined Sewer Area Green Infrastructure Opportunities

In addition to identifying opportunities for green programs throughout Northern Kentucky, a detailed evaluation was performed on the CSS to identify initial green project opportunities to reduce CSO discharges. The identification and prioritization of green infrastructure opportunities within the CSS was conducted at a small scale, with opportunities evaluated by CSO sewershed. Each CSO sewershed with an active overflow was reviewed for potential green opportunities. For the purpose of consistency, a standard set of information was compiled for each sewershed and served as the basis for identifying candidate green opportunities. This information included:

- CSO statistics (number of overflows, average annual overflow volume, duration of overflow, and drainage area);
- Percent imperviousness;
- Land use;
- Properties classified as publicly owned;
- Rooftops greater than 10,000 square feet in area;
- Parking lots greater than 15,000 square feet in area;
- Single family homes;
- Percent tree cover;
- Number of catch basins;

- Direct entry points of streams and drainage channels to the CSS; and
- Catch basins on SD1's repair list.

The goal of this exercise was to examine each delineated sewershed and present a series of candidate locations/study areas for implementation of green infrastructure. The result was the generation of opportunity maps of individual sewersheds, each with specific green opportunities identified. This assessment was not intended to provide a detailed evaluation of each of the identified opportunities, but rather to understand the magnitude, distribution and types of green solutions across the CSS. The green opportunities maps and the detailed explanation of the identification process for green infrastructure can be found in Appendix 3-B.1 for each of the evaluated CSO basins.

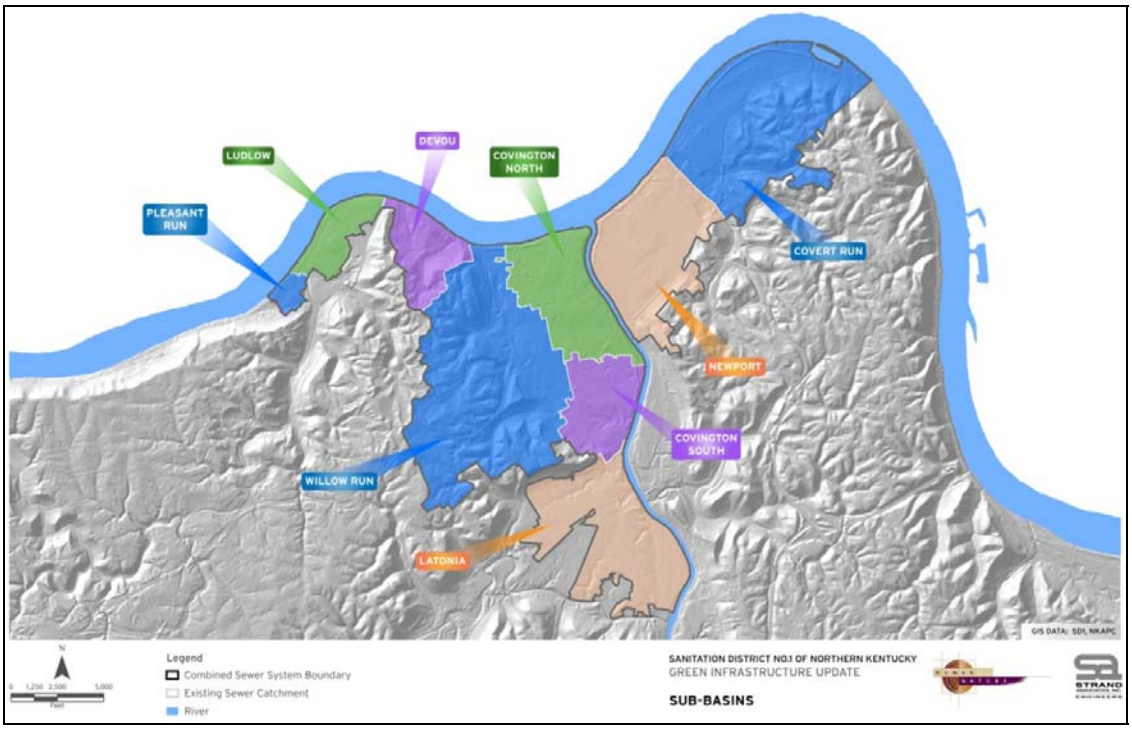
Refined Combined Sewer System Green Infrastructure Analysis

After the completion of the opportunities mapping and the identification of the initial green opportunities within the CSS, a more detailed green infrastructure analysis was performed. Each sub-basin was further evaluated to identify opportunity areas where green infrastructure projects would reduce or remove storm water runoff from the combined system. The green strategies considered in this evaluation include storm water separation, large scale retention/detention basins, and typical green infrastructure features such as bioinfiltration, green streets, and downspout disconnections to both reduce storm water quantity and improve water quality.

The identified projects were characterized into two categories, "removed" or "transferred." Removed projects completely remove or separate storm water runoff from the combined system using green infrastructure and strategic storm separation techniques. Transferred projects direct runoff to green features but ultimately discharge back into the combined system. In addition to the identified projects, it is anticipated that additional projects will be identified through partnerships with both public and private entities interested in incorporating green infrastructure into other planned activities.

As part of the refined analysis the combined system was divided into nine sub-basins or study areas shown in Figure 3.19. The sub-basins are Pleasant Run, Ludlow, Devou, Covington North, Covington South, Latonia, Newport, and Covert Run. The findings of this most recent analysis are summarized below by sub-basin.

Figure 3.19. Refined Green Infrastructure Analysis Sub-Basins



The following section highlights the proposed projects, costs, and CSO reductions for each of the nine sub-basins.

Covert Run Sub-Basin

There are currently 15 projects recommended for the Covert Run Sub-Basin. Based on a review of the current conditions, there are two very large direct entry points which allow large amounts of storm water runoff to flow directly into the CSS. Strategic separation is recommended to remove these two entry points with the construction of a proposed separate storm sewer located along Main Street and Vine Street in the City of Dayton. Four smaller strategic separation projects are also proposed throughout the sub-basin.

In addition, several water quality features and site BMPs are proposed. These include parking lot retrofits at St. Anthony's and Diocese of Covington properties, street bump outs along Fairfield Avenue, and bioinfiltration at Bellevue Beach Park. Four of the proposed projects are on the outer edge of the combined system providing water quality improvements to already separated storm water runoff. Table 3.19 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefit that can be achieved collectively with the proposed green infrastructure projects in the Covert Run Sub-Basin. Please see the Covert Run Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.19. Green Infrastructure Opportunities in Covert Run Sub-basin

Covert Run Sub-Basin Summary		
Sub-Basin Area (Acres)		1,381
Current Annual CSO Volume (MG)		64
Number of Projects		15
Proposed Storm Sewer (Feet)		16,550
Water Quality Features		23
	Bioinfiltration/Infiltration	11
	Detention/Retention	2
	Site BMPs/Offloading	10
Area Removed from the CSS (Acres)		287
Area Transferred within the CSS (Acres)		3
Total Area Impacted (Acres)		290
Total Project Construction Cost*		$12,417,500
Total Project Capital Cost*		$19,371,300
Total Annual CSO Volume Removed (MG)		18

*Includes both CSO reduction projects and water quality only projects

Covington North Sub-Basin

Ten projects are proposed for the Covington North Sub-Basin. One of the more significant opportunities identified in this basin is an urban redevelopment project. The Housing Authority of Covington was recently awarded a Hope VI Grant to redevelop the Jacob Price Housing Project. SD1 is working with the Housing Authority and the project developer to incorporate green infrastructure features into the site design. In addition to this project, the updated green opportunities evaluation identified several other locations for strategic separation and bioinfiltration features in the vicinity of the Jacob Price project to remove additional storm water runoff from the CSS.

Strategic separation has been identified for the industrial area along Madison Avenue that will connect to Byrd Alley and discharge to a water quality feature before discharging to the Licking River. A proposed underground storage facility located under the Gateway Community College parking lot is proposed to provide detention of storm water runoff from approximately eight acres. This proposed facility will discharge back to the combined sewer but will provide peak flow attenuation. In addition, conversations with the City of Covington have identified several blocks along the river front between 3rd and 5th Street for future redevelopment. With redevelopment, storm water runoff will be offloaded from the CSS, directed to water quality-based BMPs and conveyed to the Ohio River through new separate storm sewers. Table 3.20 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefit that can be achieved collectively with the proposed green infrastructure projects. The Covington North Existing Conditions and Overview Maps in Appendix 3-B.2 provide the location of the proposed projects.

Table 3.20. Green Infrastructure Opportunities in Covington North Subbasin

Covington North Sub-Basin Summary	
Sub-Basin Area (Acres)	664
Current Annual CSO Volume (MG)	296
Number of Projects	10
Proposed Storm Sewer (Feet)	13,400
Water Quality Features	17
Bioinfiltration/Infiltration	3
Detention/Retention	2
Site BMPs/Offloading	12
Area Removed from the CSS (Acres)	123
Area Transferred within the CSS (Acres)	8
Total Area Impacted (Acres)	131
Total Project Construction Cost	$10,076,200
Total Project Capital Cost	$15,718,872
Total Annual CSO Volume Removed (MG)	59

Covington South Sub-Basin

Currently six projects are planned within the Covington South Sub-Basin. These proposed projects include street separation and downspout disconnection that will be directed to an infiltration basin near 18th Street and Garrard Street, strategic separation at Holmes High School, and deep infiltration opportunities near 17th Street and Kellogg Street.

Table 3.21 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects in the Covington South Sub-Basin. Please see the Covington South Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.21. Green Infrastructure Opportunities in Covington South Subbasin

Covington South Sub-Basin Summary	
Sub-Basin Area (Acres)	445
Current Annual CSO Volume (MG)	229
Number of Projects	6
Proposed Storm Sewer (Feet)	3,430
Water Quality Features	4
Bioinfiltration/Infiltration	2
Detention/Retention	0
Site BMPs/Offloading	2
Area Removed from the CSS (Acres)	35
Area Transferred within the CSS (Acres)	9
Total Area Impacted (Acres)	44
Total Project Construction Cost	$1,348,500.00
Total Project Capital Cost	$2,103,660.00
Total Annual CSO Volume Removed (MG)	13

Devou Sub-Basin

Three proposed projects have been identified in the Devou Sub-Basin. Two opportunities are large strategic separation projects to remove several direct storm water entry points from the combined system. The runoff associated with these separation projects would be directed to three water quality features prior to discharging to the Ohio River. Table 3.22 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects. Please see the Devou Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.22. Green Infrastructure Opportunities in Devou Subbasin

Devou Sub-Basin Summary	
Sub-Basin Area (Acres)	356
Current Annual CSO Volume (MG)	16
Number of Projects	3
Proposed Storm Sewer (Feet)	10,600
Water Quality Features	3
Bioinfiltration/Infiltration	0
Detention/Retention	3
Site BMPs/Offloading	0
Area Removed from the CSS (Acres)	214
Area Transferred within the CSS (Acres)	0
Total Area Impacted (Acres)	214
Total Project Construction Cost	$6,650,400
Total Project Capital Cost	$10,374,624
Total Annual CSO Volume Removed (MG)	12

Latonia Sub-Basin

There are six proposed projects in the Latonia Sub-Basin, including four small strategic separation projects, two proposed water quality features, and use of existing natural drainage to convey offloaded storm water runoff directly to the Licking River and Banklick Creek. In addition, the proposed project along James Avenue will remove a significant area (approximately 100 acres) from the combined system using strategic separation, downspout disconnection, and a series of water quality features.

Table 3.23 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects in the Latonia Sub-Basin. The previously identified Church Street project area is also located within this sub-basin; however, the components and project cost are not included in this summary because they are represented in Section 7, The Five-year Improvement Program. Please see the Latonia Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.23. Green Infrastructure Opportunities in Latonia Subbasin

Latonia Sub-Basin Summary	
Sub-Basin Area (Acres)	962
Current Annual CSO Volume (MG)	120
Number of Projects	6
Proposed Storm Sewer (Feet)	15,800
Water Quality Features	11
Bioinfiltration/Infiltration	0
Detention/Retention	11
Site BMPs/Offloading	0
Area Removed from the CSS (Acres)	287
Area Transferred within the CSS (Acres)	0
Total Area Impacted (Acres)	287
Total Project Construction Cost	$10,129,900
Total Project Capital Cost	$15,802,644
Total Annual CSO Volume Removed (MG)	58

Ludlow Sub-Basin

SD1 has identified seven small projects in the Ludlow Sub-Basin. Each of these seven projects utilizes strategic separation to remove storm water runoff from the combined system and direct the newly separated flow to existing natural features and/or proposed water quality features.

Table 3.24 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects. Please see the Ludlow Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.24. Green Infrastructure Opportunities in Ludlow Subbasin

Ludlow Sub-Basin Summary	
Sub-Basin Area (Acres)	245
Current Annual CSO Volume (MG)	42
Number of Projects	7
Proposed Storm Sewer (Feet)	3,300
Water Quality Features	2
Bioinfiltration/Infiltration	2
Detention/Retention	0
Site BMPs/Offloading	0
Area Removed from the CSS (Acres)	41
Area Transferred within the CSS (Acres)	0
Total Area Impacted (Acres)	41
Total Project Construction Cost	$1,321,800
Total Project Capital Cost	$2,062,008
Total Annual CSO Volume Removed (MG)	10

Newport Sub-Basin

There are seven proposed project areas in the Newport Sub-Basin. Much like the Covington North Sub-Basin, several blocks have been identified along the Ohio and Licking Rivers for future redevelopment. As these properties are redeveloped, storm water runoff will be directed to BMPs and conveyed directly to local waterways through new storm sewer infrastructure resulting in a reduction of flows in the CSS. Additional storm sewers and a water quality feature are also proposed in a number of locations surrounding these redevelopment areas.

Table 3.25 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects in the Newport Sub-Basin. Please see the Newport Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.25. Green Infrastructure Opportunities in Newport Subbasin

Newport Sub-Basin Summary	
Sub-Basin Area (Acres)	939
Current Annual CSO Volume (MG)	199
Number of Projects	8
Proposed Storm Sewer (Feet)	4,000
Water Quality Features	7
Bioinfiltration/Infiltration	0
Detention/Retention	1
Site BMPs/Offloading	6
Area Removed from the CSS (Acres)	116
Area Transferred within the CSS (Acres)	0
Total Area Impacted (Acres)	116
Total Project Construction Cost	$5,127,500
Total Project Capital Cost	$7,998,900
Total Annual CSO Volume Removed (MG)	37

Pleasant Run Sub-Basin

There are four proposed project areas in the Pleasant Run Sub-Basin. Each of these projects uses strategic separation to remove storm water runoff from the combined system and directs the newly separated flow to existing natural features and/or proposed water quality features.

Table 3.26 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects. Please see the Pleasant Run Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.26. Green Infrastructure Opportunities in Pleasant Run Subbasin

Pleasant Run Sub-Basin Summary	
Sub-Basin Area (Acres)	68
Current Annual CSO Volume (MG)	5
Number of Projects	4
Proposed Storm Sewer (Feet)	2,950
Water Quality Features	2
Bioinfiltration/Infiltration	1
Detention/Retention	1
Site BMPs/Offloading	0
Area Removed from the CSS (Acres)	17
Area Transferred within the CSS (Acres)	0
Total Area Impacted (Acres)	17
Total Project Construction Cost	$1,832,000
Total Project Capital Cost	$2,857,920
Total Annual CSO Volume Removed (MG)	2

Willow Run Sub-Basin

Five proposed project areas have been identified in the Willow Run Sub-Basin. Four of these projects are associated with a major interstate corridor improvement project currently being planned by the Kentucky Transportation Cabinet. As part of the I-75 lane expansion project, KYTC is proposing to construct a new separate storm conveyance system to convey roadway runoff directly to the Ohio River. SD1 has initiated discussions about expanding the scope of this project to integrate additional areas for storm separation throughout the watershed. This project represents a tremendous opportunity to partner with KYTC and capitalize on a major roadway improvement project to provide a large conveyance system that allows approximately 1,000 acres of the Willow Run Sub-Basin to be removed from the CSS.

Several of the projects identified in the Green Infrastructure Concept Plan, shown in Appendix 3-B.2, are currently in the construction phase including the Terraced Reforestation and the KYTC Basin Retrofit. Over 25 water quality features are included within this study area to provide water quality treatment to the separated storm flow, including a series of water quality based features within Goebel Park in Covington. SD1, KYTC, and the City of Covington have been working together to create a redevelopment plan for the park that provides new community assets and large water quality treatment elements.

Table 3.27 describes the types of strategies to remove storm water from the CSS and provides estimates of the associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects in the Willow Run Sub-Basin. It is important to note SD1 has assumed the cost for new storm sewer along I-75 will be covered by KYTC as part of the Brent Spence Bridge project. SD1 will continue to coordinate with KYTC to develop a cost-sharing partnership for the implementation of this project. In addition to cost-sharing, the implementation of the proposed green infrastructure projects relies on the schedule for the Brent Spence Bridge Project. Please see the Willow Run Existing Conditions and Overview Maps in Appendix 3-B.2 for the location of the proposed projects.

Table 3.27. Green Infrastructure Opportunities in Willow Run Subbasin

Willow Run Sub-Basin Summary	
Sub-Basin Area (Acres)	1,871
Current Annual CSO Volume (MG)	486
Number of Projects	5
Proposed Storm Sewer (Feet)	39,430
Water Quality Features	29
Bioinfiltration/Infiltration	4
Detention/Retention	20
Site BMPs/Offloading	5
Area Removed from the CSS (Acres)	1,229
Area Transferred within the CSS (Acres)	27
Total Area Impacted (Acres)	1,256
Total Project Construction Cost	$38,245,400
Total Project Capital Cost	$59,662,824
Total Annual CSO Volume Removed (MG)	280

Summary of Green Infrastructure CSO Reduction Projects

In conclusion, over 60 green infrastructure projects, with 98 water quality features have been proposed for SD1's CSS. These projects have been ranked and prioritized for the Integrated Plan for 2025 based on a number of factors including:

- Watershed and waterways;
- Cost per gallon benefit;
- Projects related to the Jacob Price Hope VI Grant project area have been moved to the top of the list, due to the Jacob Price project schedule; and
- Projects related to the I-75 Corridor and Brent Spence Bridge project have been moved to the end of the list, due to the bridge project schedule.

As SD1 continues to foster partnerships and further evaluate the combined system for green infrastructure opportunities, the list of proposed projects will be adjusted. In addition, SD1 will use public health concerns and flooding issues to revise the ranking and schedule of proposed projects as needed. As specific projects are selected for inclusion in future five-year watershed plan submittals, the specific details of individual projects and project components will be refined and optimized to achieve a desired cost-benefit ratio.

Table 3.28 summarizes the types of strategies to remove storm water from the nine sub-basins in the CSS that are described above. The table provides estimates of associated costs and CSO reduction benefits that can be achieved collectively with the proposed green infrastructure projects in the combined system.

Table 3.28. Green Infrastructure CSO Reduction Projects

Green Infrastructure CSO Reduction Projects		
Number of Projects		64
Proposed Storm Sewer (Feet)		109,460
Water Quality Features		98
	Bioinfiltration/Infiltration	23
	Detention/Retention	40
	Site BMPs/Offloading	35
Area Removed from the CSS (Acres)		2,349
Area Transferred within the CSS (Acres)		47
Total Area Impacted (Acres)		2,396
Total Project Construction Cost		$87,149,200
Total Project Capital Cost		$135,952,752
Total Annual CSO Volume Removed (MG)		489

Modeling of Green Infrastructure CSO Reduction Projects

The potential CSO reduction benefits associated with the proposed green projects were estimated using SD1's hydraulic model under 2030 build-out conditions and the 1970 typical year. The proposed green projects were categorized into three different groupings or "tiers" as described below. CSO reduction values associated with each tier of projects was determined separately. The cumulative benefit of all the projects is determined by summing the reductions of the individual tiers.

Tier 1

Tier 1 projects correspond to specific areas identified as part of the detailed CSS green infrastructure opportunities analysis. These projects assume integration with other major future projects planned in Northern Kentucky and will require direct investment by SD1. For modeling purposes, Tier 1 projects included two subcategories of projects - "removed" and "transferred". Removed projects are those that completely remove or separate storm water runoff from the combined system using green infrastructure and strategic separation techniques. Transferred projects direct storm water runoff to a green infrastructure feature, but discharge residual runoff back into the combined system. Table 3.29 summarizes the assumptions used when incorporating Tier 1 projects into the hydraulic model.

Table 3.29. Tier 1 Project Assumptions for CSO Model

Tier 1 Project Assumptions For CSO Reduction Modeling		
Removed Projects		% of Area Removed
Roadways and Parking lots		100%
Pervious Surfaces		100%
Residential Rooftops		
	Linked to specific green feature	50%
	Not linked to specific green feature	25%
Non-Residential Rooftops		
	Linked to specific green feature	50%
	Not linked to specific green feature	0%
Transferred Projects		
15% reduction of annual runoff from project site		

Based on these assumptions, approximately 2,300 acres were modeled as removed, and 47 acres were modeled as transferred from the combined system. The Tier 1 projects resulted in an annual reduction of approximately 489 MG/yr of CSO.

Tier 2

Tier 2 projects evaluated the impacts of commercial redevelopment on the combined system. As part of the post-construction storm water regulations within the combined sewer area, redevelopment properties will be required to reduce existing site runoff by 15 percent. Using this parameter and the assumption of one percent redevelopment rate per year, Tier 2 Projects will reduce CSO volume by an additional 3 MG/yr. These assumptions are further detailed in GrIPP, outlined in Section 3.3.2.a.2.

Tier 3

Tier 3 projects include residential downspout disconnection and green street partnerships for those areas within the combined system that are outside of the Tier 1 specific project areas. For the purposes of the Tier 3 modeling, it was assumed that 25 percent of the downspouts on single family residential buildings would be targeted for disconnection over 14 years, and 7.5 percent of public streets will be converted to green streets during this same timeframe. The Tier 3 Projects reduced annual CSOs by approximately 14 MG/yr. These assumptions are further detailed in DRIP and GrIPP, outlined in Section 3.3.2.a.2.

Impact of Green Infrastructure CSO Reduction Projects

Based on the combination of Tier 1, Tier 2, and Tier 3 projects, SD1's Green Infrastructure Program reduces annual CSO volume by a total of 506 MG, or 35 percent, for the 1970 typical year using 2030 build-out conditions.

3.3.2.b Determination of Level of Control Target

The Full System Bounding Analysis presented in Appendix 3-A illustrated the difficulty in meeting water quality standard bacteria criteria in the watersheds when pollutant loads from all sources, including dry weather and nonpoint runoff sources, are included. As shown Figure 3.2, the waterways do not meet water quality standards, even in the absence of CSO and SSO overflows. Therefore, the determination of an appropriate level of CSO control needed to consider the water quality impact from two perspectives: with and without these other sources.

The Bounding Analysis included evaluations of full system solution concepts of CSO control at 0, 4 and 18 overflows per year (overflows/year). The analysis demonstrated that increasing levels of overflow control provide diminishing returns with respect to improvements in water quality (see Figure 3.4 in Appendix 3-A) or meeting water quality standards. Because there was little to no improvement in water quality between controlling at 18 overflows/year and 4 overflows/year in most of the waterways, SD1 revisited its approach for identifying an appropriate level of CSO control for this Plan.

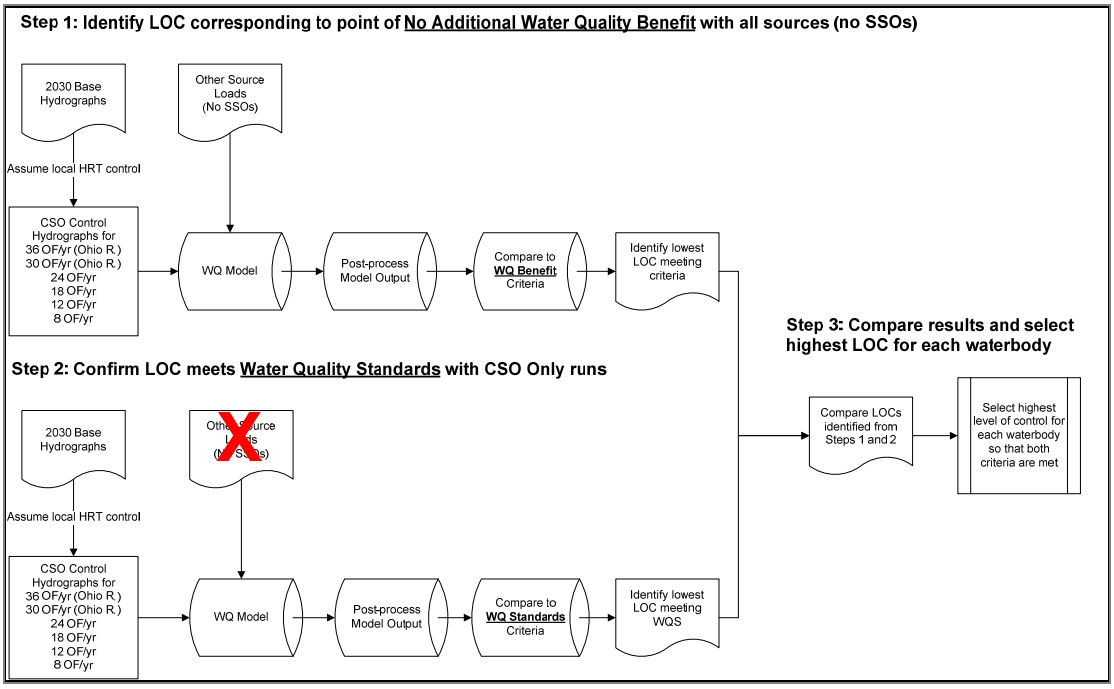
SD1 expanded the range of CSO control levels so that control alternatives that were waterway specific could be developed. The goal of this analysis was to identify the optimum level of control (LOC) for CSOs discharging to each waterway. This optimum level of control was selected as the point where remaining CSOs would not cause or contribute to instream water quality violations assuming other sources were ultimately controlled within the plan period. An additional goal of the analysis was to identify where CSO control did not provide any additional water quality benefit when including existing effects of all pollutant sources. For this analysis, additional water quality benefit was defined as gaining at least one additional day per year when the fecal coliform density was less than 400 cfu/100 ml. Compliance with water quality standards was evaluated using KDOW's 30-day maximum criterion (e.g. no more than 20 percent of fecal coliform densities in a 30-day period can exceed 400 cfu/100 ml), because it has been the more restrictive standard criterion. The equivalent ORSANCO 30-day maximum criterion (e.g. no more than ten percent of fecal coliform densities in a 30-day period can exceed 400 cfu/100 ml) was used to evaluate compliance in the Ohio River.

The analysis process is shown in Figure 3.20. The water quality modeling consisted of three steps:

(1) Run the models with all sources of pollution (assume, however, that SSOs have been eliminated). Evaluate the control level where "no additional water quality benefit" occurs due to bacteria loads from other sources;
(2) Run the models with ONLY the CSO overflows and evaluate the control level where "water quality standard compliance" occurs; and
(3) Compare the levels of control identified from Step 1 and Step 2 and select the highest (e.g. most restrictive) level of control.

SD1 grouped CSOs by waterway and developed a range of control levels for each group assuming local high rate treatment (HRT) as the control technology for each group. The levels of control evaluated in Banklick Creek, the Licking River and Taylor Creek were 24 overflows/year, 18 overflows/year, 12 overflows/year and 8 overflows/year. The CSOs discharging to the Ohio River, which has substantial dilution potential, were also evaluated at 36 overflows/year and 30 overflows/year. The CSOs in Fourmile Creek and Pleasant Run Creek have limited impact on water quality in the creeks themselves because of their close proximity to the mouths; the CSO volume from these overflows were input directly to the Ohio River in the water quality models.

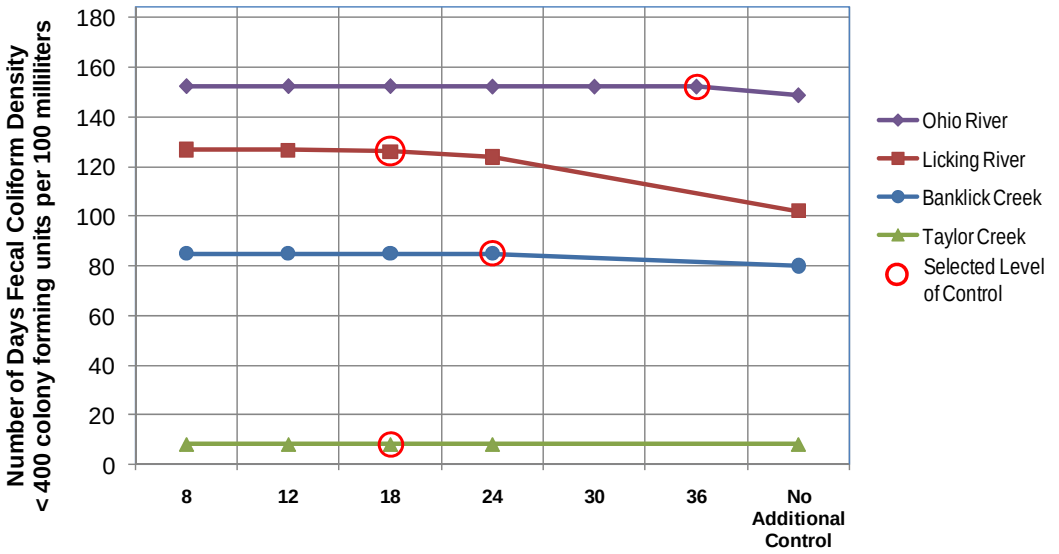
Figure 3.20. Process for Identifying Water Quality-Based CSO Level of Control



SD1 simulated the different levels of control in the detailed water quality models; SD1 then generated a "knee-of-the-curve" for each waterway to identify the point where additional control does not result in additional water quality benefit. This point, which is waterway-specific, defines the target level of control endpoint for evaluating whether the green infrastructure opportunities provided sufficient control, or whether additional gray infrastructure was needed to reduce the CSO volume and number of activations. Results varied by waterway. Figure 3.21 summarizes the "knee-of-the-curve" results for each of the CSO-impacted waterways.

The results summarized in Figure 3.21 show that the appropriate level of control varies by waterway. For Banklick Creek and the Ohio River, the level of control identified (24 overflows/year and 36 overflows/year, respectively) was the same level for both water quality benefit and meeting water quality standards endpoints. In Taylor Creek, the water quality benefit endpoint was 24 overflows/year, but the level of control needed to meet the water quality standard was 18 overflows/year. The reverse was observed in the Licking River: the water quality benefit endpoint was 18 overflows/year, but the level of control needed to meet water quality standards was 24 overflows/year. For both of these waterways, the higher level of control (18 overflows/year) was selected as the final level of control target. For all waterways, modeling analysis showed that assuming all other non-overflow sources are controlled during the Plan implementation period, the remaining CSOs would not cause or contribute to water quality standards violations for fecal coliform bacteria.

Figure 3.21. Knee-of-Curve Identifying CSO Level of Control in each CSO Waterway



Evaluation Criteria	Ohio River	Licking River	Banklick Creek	Taylor Creek
Water Quality Benefit	36	**18**	24	24
Meets Water Quality Standards	**36**	24	**24**	**18**

Figure 3.21 also provides insight into the sensitivity of each of the waterways to CSO loads. Taylor Creek is generally unaffected by changes in CSO control; loads from other sources are so large that the resulting knee of the curve in this analysis is a flat line, and the number of days less than 400 cfu/100 ml is less than five percent (approximately eight days) in all scenarios. The Ohio River is also generally unaffected by changes in CSO control but, unlike Taylor Creek, this waterway has capacity to assimilate CSO loads so the number of days less than 400 cfu/100 ml hovers around 90 percent (approximately 152 days), and even at the lowest level of control (36 overflows/year), there is sufficient dilution capacity in the river so that differences between the lowest and highest levels of control are minimal. The Licking River is the most sensitive to CSO loads and shows the most benefit of providing control relative to the base (no control) scenario.

3.3.2.c Approach to Developing Gray CSO Controls

As described in Section 3.3.2.a, SD1's CSO control program will lead with green infrastructure which will significantly reduce (>500 MG per year) the annual volume of untreated CSOs. However, to achieve the desired level of control in each waterway and assure that at least 85 percent capture and treatment of wet weather flow, additional gray controls will be needed.

The gray controls alternatives analysis was done initially as part of the full system bounding solution where multiple levels of control were evaluated (described in Appendix 3-A). This was first done by evaluating various control strategies including regional storage, regional HRT, and deep tunnel storage. Deep tunnel storage along with regional HRT sized at 4 overflows/year was selected as the preferred "traditional" solution.

However, as the analysis in Section 3.3.2.b shows, there is no water quality benefit (in terms of number of days where fecal coliform densities are less than 400 cfu/100 ml) in targeting a level of control higher than those shown in Figure 3.21 (approximately 18 to 36 overflows/year). Therefore, a new analysis was done to select a preferred solution that more closely matched the target level of control identified in Section 3.3.2.b for each waterway. These target levels of control are 18 overflows/year in the Licking River and Taylor Creek, 24 overflows/year in Banklick Creek and 36 overflows/year in the Ohio River. This was done by sizing and costing facilities at the target level of control in each waterway, and ensuring that the sizing achieved a minimum of 85 percent capture.

The analysis focused on four general alternatives, all of which were sized and costed based on the full implementation of the green projects listed above. These alternatives can be summarized as follows:

- Six regional storage facilities (EQ);
- Six regional high rate treatment facilities (HRT);
- Combination of regional storage (at two locations) and HRT (Hybrid); and,
- Combination of a deep storage tunnel and HRT.

It is important to note that the actual sizes of the gray infrastructure that would be built will depend on the measured success of the aggressive implementation of the green projects identified in Section 3.3.2.a. For example, in Banklick Creek, the 10-year green and gray infrastructure project (described in Section 7 and in Section 3.3.2.c.4 below) to separate the Church Street CSO area is projected to reduce the frequency of CSOs to approximately 12-13 overflows/year. Since this project appears to result in a higher level of control than the targeted 24 overflows/year identified through the water quality analysis described in Section 3.3.2.b, this project was the only solution considered in Banklick Creek. However, SD1 may revisit the Banklick Creek CSO solution after the Five-year Improvement Program so that the measured success of the first phase of the Church Street CSO separation project can be considered. This will include evaluating solutions where CSOs are controlled to the target level of control of 24 overflows/year.

In addition to sizing the controls to reduce the CSO overflows to the target level of control, other control considerations included achieving at least 85

percent capture to meet the requirements of the Presumption Approach and cost-effectiveness. It is important to note that the initial sizing target was based on meeting a specified frequency of untreated overflows. Therefore, various control technologies were sized to meet the selected target frequency but resulted in a range of remaining overflow volumes. Table 3.30 summarizes the estimated cost, untreated CSO volume in the 1970 typical year, and percent capture for each alternative at the target level of controls.

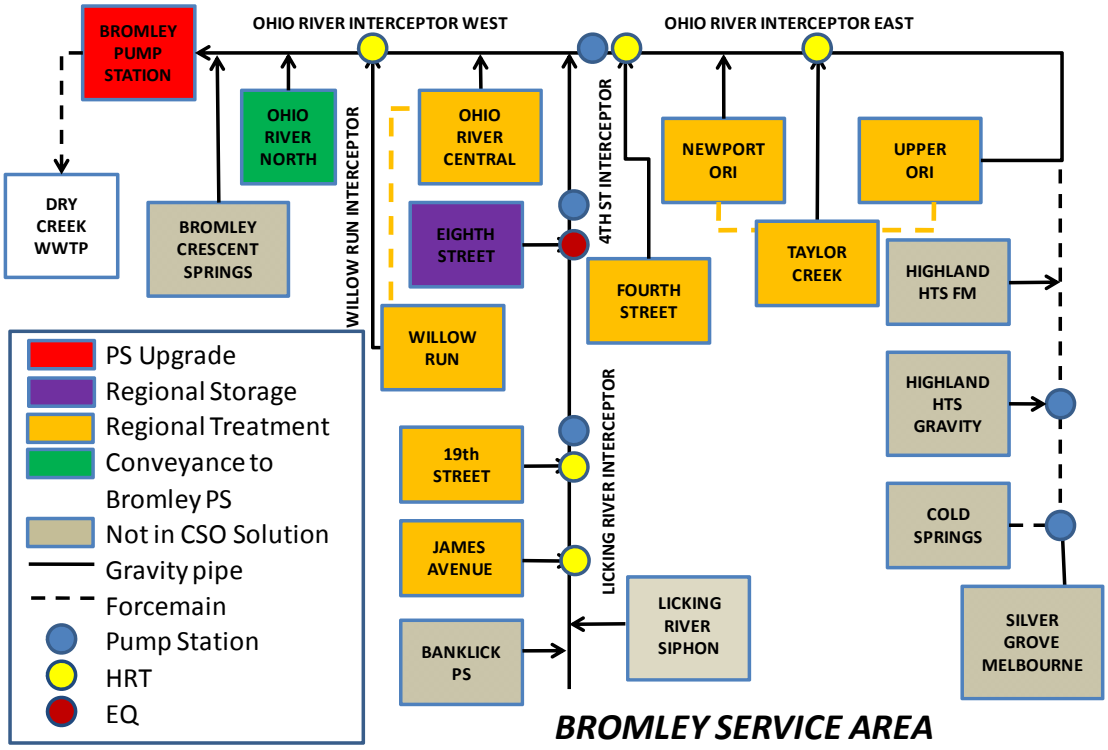
Table 3.30. Comparison of CSO Control Alternatives for Target Level of Control

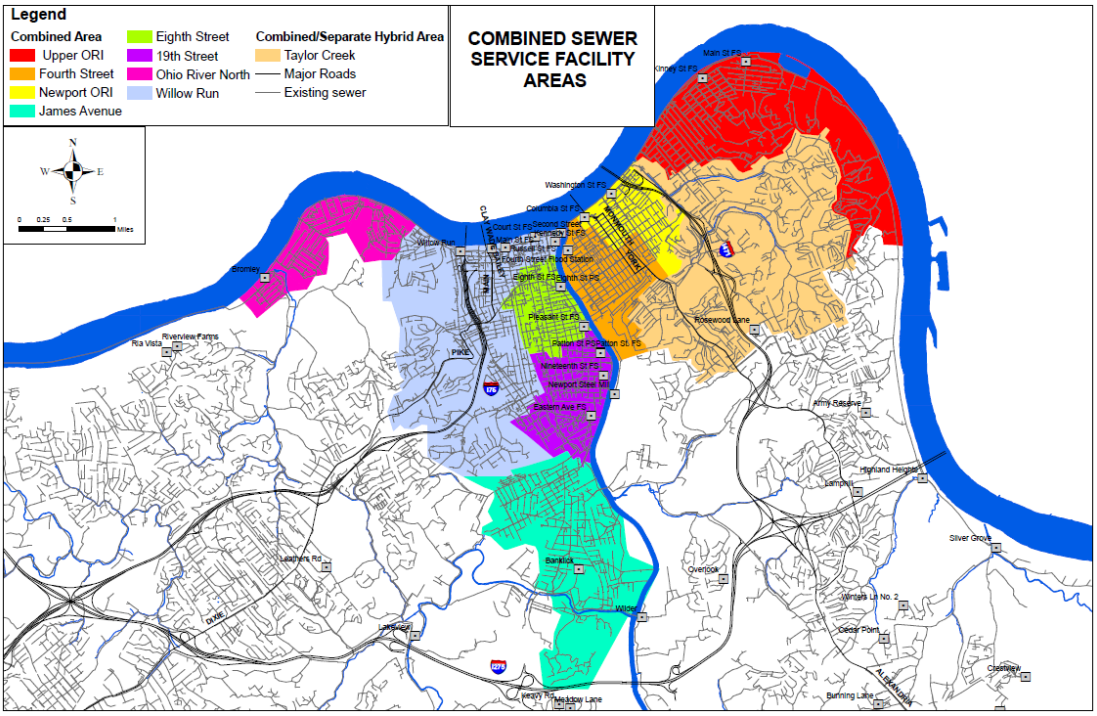
Alternative	Untreated Overflow Volume (MG)	% Capture	Estimated Capital Cost (Million $)
All Storage (EQ)	584	85%	$298
All High Rate Treatment (HRT)	246	93%	$344
Hybrid (EQ at 1 Location, HRT at 5 locations)	226	94%	$337
8’ Deep Tunnel and HRT	329	91%	$400

As Table 3.30 shows, the all storage option is the least costly but the overflow volume is the greatest. The deep tunnel solution, which was selected as the traditional full-system solution as described in Appendix 3A, is the most expensive but is in the middle in terms of percent capture. The all HRT and hybrid solutions have similar capture that far exceed the Presumption Approach requirement. Since the hybrid solution has a slightly lower cost, it was selected as the preferred solution for addressing the remaining overflows after implementation of the Five-year Improvement Program and green infrastructure. A schematic of the selected CSO solution and an overview of the CSO facility areas is shown in Figure 3.22.

A further analysis of the presumption control levels for CSOs was conducted to assure the plan would reasonably be expected to not cause or contribute to a water quality (in terms of bacteria) violation. That modeling analysis shows that, assuming other non-CSO sources are controlled within the implementation period, remaining CSOs would not cause or contribute to a water quality violation. Further, water quality modeling of other watershed controls (discussed in Section 3.3.3.a.1) showed that these controls provide additional benefit (beyond CSO controls) and therefore should be candidates for offsetting a higher level of CSO control.

Figure 3.22. Schematic and Overview of CSO Control Solution Areas.





The next step was to refine the preferred solution for each watershed. Following is a description of the preferred solutions for each watershed.

3.3.2.c.1 Ohio River East and Taylor Creek CSOs

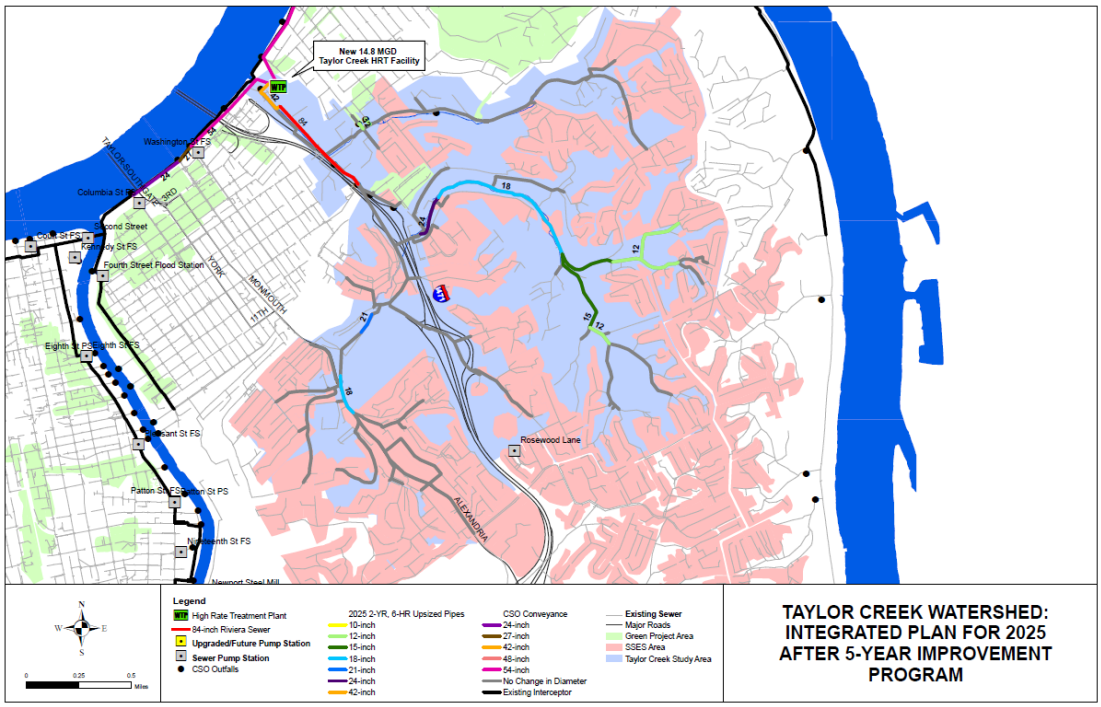
Taylor Creek HRT

The target level of control is 18 overflows/year in Taylor Creek and 36 overflows/year in the Ohio River East watershed in a typical year. Overflows in both watersheds can be addressed using the preferred solution of construction of a 14.8 MGD ballasted flocculation HRT (Kruger Actiflo or other ballasted technology) facility near the confluence of Taylor Creek and the Ohio River (with associated consolidation piping) and would discharge to the Ohio River. This facility would provide a high degree of settling and disinfection and would meet the minimum treatment requirements for CSO.

The target level of control at the facility is 36 overflows/year while the target level of control at individual outfalls is no more than 12 overflows in the typical year. This will be achieved by diverting additional flow into existing pipes or by diverting flow to new consolidation sewers sized to convey the flows to the HRT. All flow that reaches the HRT at or below 14.8 MGD will receive full design treatment while flow in excess of that will receive, at minimum, screening for solids and floatables control.

Figure 3.23 shows the location of the Taylor Creek HRT along with associated consolidation piping. Figure 3.23 also shows the locations of green infrastructure projects within the Taylor Creek and Ohio River East areas. It is important to note that the conveyance to the Taylor Creek HRT through the Taylor Creek area provides a level of control of 13 overflows/year in the typical five-year period, which exceeds the target of 18 overflows/year.

Figure 3.23. CSO Control Solution in Taylor Creek and Ohio River East Watersheds after Five-year Improvement Program



3.3.2.c.2 Licking River CSOs

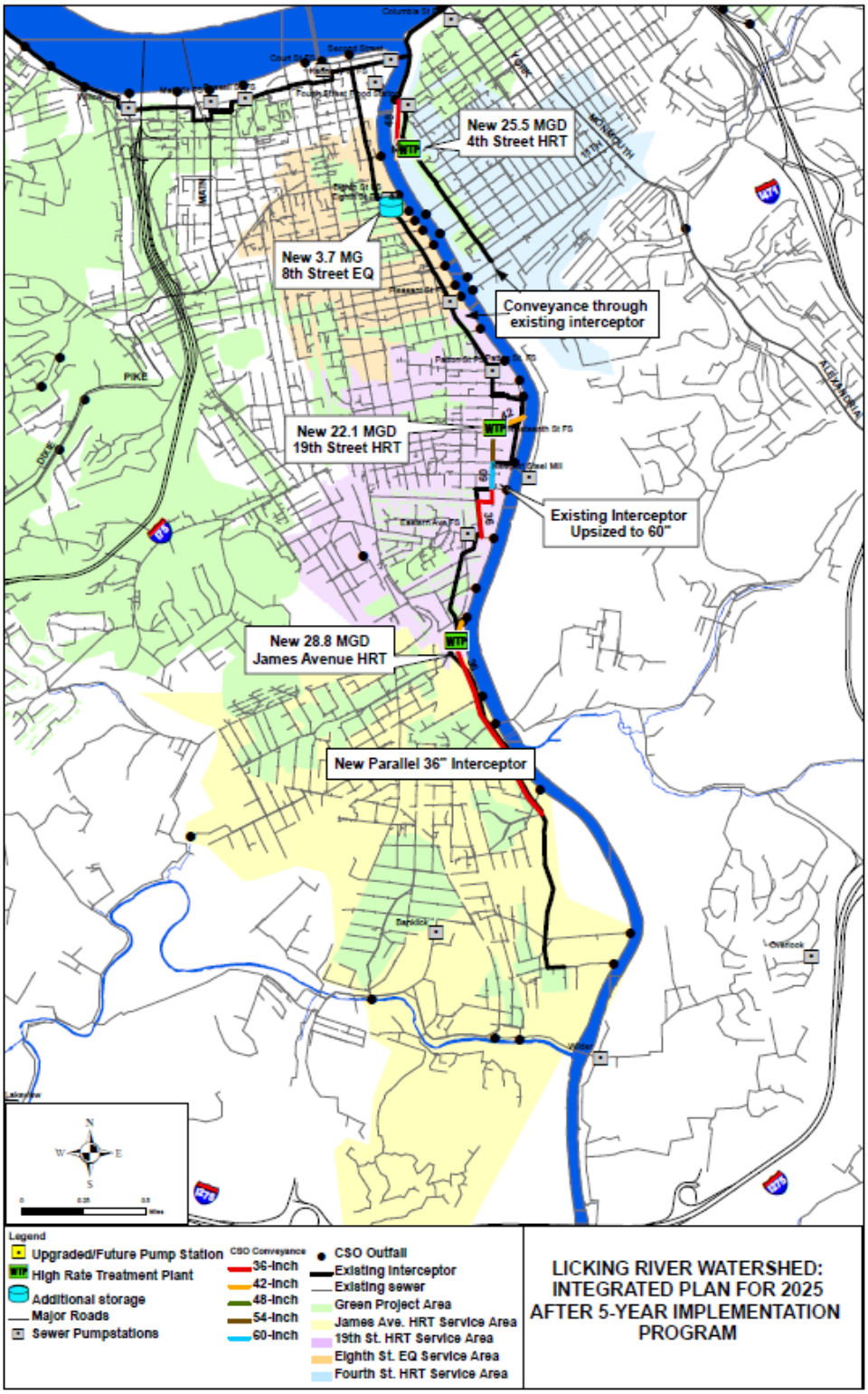
The target level of control for CSOs along the Licking River is 18 overflows/year. Gray infrastructure controls were sized based on remaining overflows after implementation of green infrastructure improvements. The gray infrastructure controls include three HRT facilities and one regional storage tank facility along with associated consolidation piping. The locations of the HRT facilities have been preliminarily identified as 4th Street, 19th Street and James Avenue. The regional storage tank location has been identified near the 8th Street CSO.

As with the Ohio River East CSOs, consolidation piping to each control facility will allow for a higher level of control at each individual CSO outfall. For the Licking River CSOs, the initial target for conveyance piping is to reduce activations of local CSOs to an average of four per year. All flows that are at or below the HRT design flows (targeted at 18 overflows/year and shown in Table 3.31) will receive full treatment through ballasted flocculation. Flow exceeding the design capacity of the HRT facilities, will, at a minimum, receive screening and be conveyed back into the interceptor. Table 3.31 below summarizes the facilities along the Licking River and Figure 3.24 shows their locations.

Table 3.31. Licking River CSO Control Facilities.

Facility	Design	Sizing
4th Street HRT	Design flow rate (MGD)	25.5
	Storage volume (MG)	0.2
	New conveyance pipe (ft)	1,834
8th Street Storage Tank	Storage volume (MG)	3.65
	New conveyance pipe (ft)	648
19th Street HRT	Design flow rate (MGD)	22.1
	Storage volume (MG)	0.2
	New conveyance pipe (ft)	3,284
James Avenue HRT	Design flow rate (MGD)	28.75
	Storage volume (MG)	0.2
	New conveyance pipe (ft)	6,707

Figure 3.24. Licking River CSO Facility Locations after Five-year Improvement Program



3.3.2.c.3 Ohio River North Watershed: Ohio River Central, Willow Run and Ohio River North CSOs

The Ohio River North Watershed CSOs span the banks of the Ohio River from the confluence of the Licking River and Ohio River to the Bromley Pump Station, which sends the combined flow to the Dry Creek WWTP. The target level of control for these CSOs is 36 overflows/year and includes overflow events occurring along the Ohio River east of the confluence with the Licking River. The Ohio River North CSOs were divided into three groups. The first two groups of overflows (known as the Ohio River Central and Willow Run CSOs) starts at the confluence of the Licking River and Ohio River and ends at the Willow Run CSO. The next group starts just west of the Willow Run outfall and extends to the Bromley Pump Station.

The largest outfall by volume in the entire CSO service area is the Willow Run CSO. This CSO was identified as a Priority Area and is discussed at length in Section 7 and includes several projects in the first five years that will significantly reduce overflows. Nevertheless, there will still be significant work required after the Five-year Improvement Program to bring the Willow Run area within the target level of control. There is a great deal of uncertainty regarding the future configuration within the Willow Run area, especially considering the construction of the new Brent Spence Bridge across the Ohio River and the significant amount of green infrastructure work being planned for this area as described in Section 3.3.2 above.

Therefore, any current plan is preliminary in nature and heavily dependent on the final configuration of the freeway and bridge. As currently planned, the remaining CSOs in the Ohio River Central and Willow Run CSO areas, after implementation of the green infrastructure improvements, will be diverted to a 48 MGD ballasted flocculation HRT facility that would reduce overflows to approximately 18 in the typical year in the Ohio River Central and Willow Run CSO areas. This exceeds the target level of control locally but was sized to match the targeted 36 overflows/year along the entire Ohio River. In other words, to achieve a total of 36 untreated events in a typical year, this particular location was controlled to 18 untreated events since not all overflow events to the Ohio River are concurrent. There is some concern about the feasibility of locating the treatment facility near Goebel Park in the future due to the number of unknowns regarding the bridge construction and other plans for the park. However, at this point, an HRT in this location was selected as the preferred option. Figure 3.28 shows the location of the HRT along with the consolidation sewers that will convey flow to the facility. As with the other Ohio River overflow locations, individual CSO outfalls, other than the facility locations, were targeted for approximately 12 untreated overflows in a typical year with flows that reach the HRT up to 48 MGD capacity receiving full HRT treatment and disinfection and flows in excess of 48 MGD receiving coarse screening.

The second group of CSOs will be controlled by the construction of a new parallel interceptor that will convey the necessary flows to the Bromley Pump Station, which will be upgraded to a capacity of 60 MGD versus its current capacity of approximately 35 MGD. This increase in conveyance to the Dry Creek WWTP will allow these CSOs to meet and exceed the target level of control without the need for storage or another HRT. The capacity of 60 MGD was selected because the current force main has a capacity of 60 MGD and its use will therefore be maximized.

Figure 3.25 shows the locations of the consolidation sewers to an upgraded Bromley Pump Station. Table 3.32 shows a summary of the Ohio River North CSO facilities.

Figure 3.25. Ohio River North CSO Facilities after Implementation of the Five-year Improvement Program

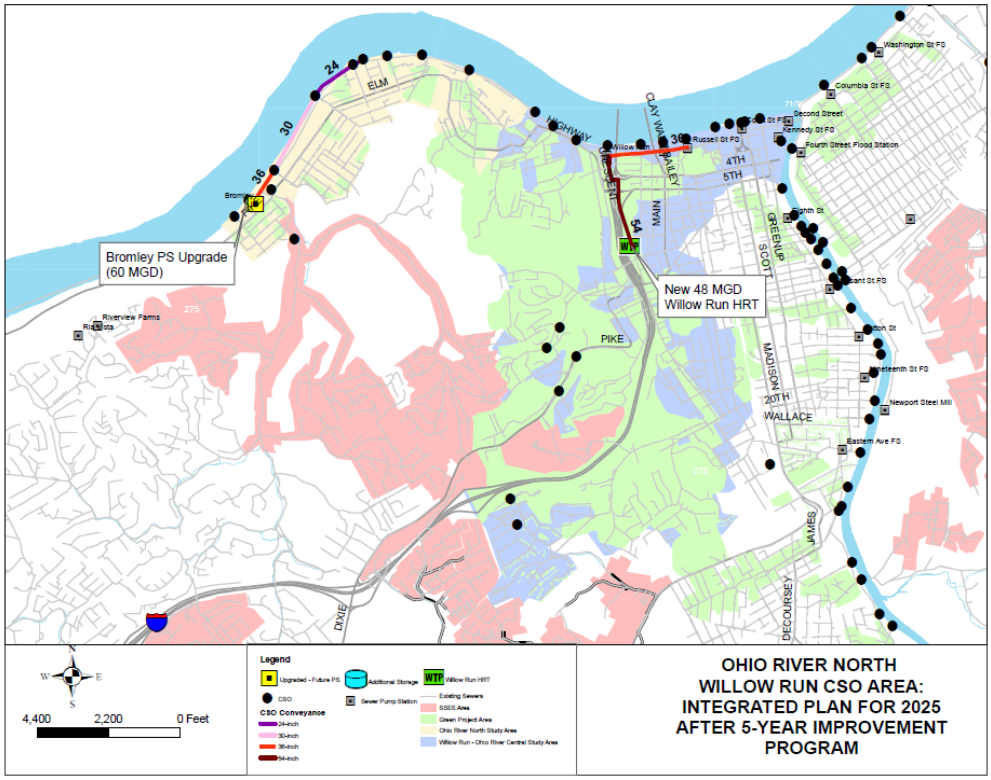


Table 3.32. Ohio River North CSO Improvements

Facility	Design	Sizing
Willow Run HRT	Design flow rate (MGD)	48
	Storage volume (MG)	0.5
	New conveyance pipe (ft)	5,600
Bromley PS Upgrade	Design Flow Rate (MGD)	60
	New conveyance pipe (ft)	5,281

3.3.2.c.4 Banklick Creek CSOs

The target level of control for the Banklick CSOs is 24 overflows/year. The Church Street CSO is the largest and most active CSO in this watershed. The green infrastructure opportunities analysis identified separation and treatment of the Church Street CSO basin as a potential project area. Because of public health concerns caused by the condition of the existing infrastructure in the Church Street CSO basin, this area was made a priority for the Five-year Improvement Program. (Note: The prioritization process is described in Section 6 and the Five-year Improvement Program is described in Section 7). Potential control alternatives were considered and an integrated green and gray infrastructure alternative was selected as the solution for this basin (see Section 7 for details on the alternatives analysis and selected solution).

The integrated green and gray solution uses green controls to reduce runoff entering the Church Street infrastructure, which will reduce the overflow volume and activation frequency of the CSO. The solution use a low-lying drainage swale to locate a biofiltration basin to detain and reduce pollutant load in the separated storm water before being discharged directly to Banklick Creek. The gray component of the project includes replacing and upsizing the piping that conveys volume to the Dry Creek WWTP. The final project also reduces overflow volume and activations at two nearby CSOs in the watershed.

The project components will be completed in phases (see Section 7 for details). After completion of the first phase, it is estimated that the annual Church Street CSO activation frequency will drop to 38 activations, discharging 19 MG in a typical year. After all phases are completed, it is estimated that the annual Church Street CSO activation frequency will be 12-13 overflows per year and total volume will be approximately 4 MG in a typical year. Since this project exceeds the target level of control of 24 overflows/year, this project was carried forth as the assumed solution for the Integrated Plan for the Banklick CSOs. However, it should be noted that after the first phase of the project, SD1 will evaluate the results and data obtained and determine if additional phases are needed, and if the solution should be revised so that the CSOs are controlled to the target level of control of 24 overflows/year.

3.3.2.d CSO Cost Summary

The total cost for the CSO improvements identified in the Integrated Plan for 2025 is $344.2 Million, beyond the cost of the Five-year Improvement Program and the green infrastructure program. These costs are shown in Table 3.33.

Table 3.33. CSO Facility Cost Summary Including Associated Conveyance Piping.

Location	Hybrid Selection	Capital Cost (2009 Million $)
Ohio River North	Conveyance to Bromley	$ 5.4
Willow Run	HRT	$ 62.1
4th Street	HRT	$ 32.3
8th Street	Storage	$ 28.7
James Avenue	HRT	$ 42.4
19th Street	HRT	$ 34.5
Taylor Creek / East Ohio River Interceptor	HRT	$ 45.6
Dry Creek WWTP Improvements / Taylorsport Force Main	Implement	$ 62.0
Church Street	Additional	$ 5.2
Bromley Pump Station Upgrade	Implement	$ 26.0
Total CSO		**$ 344.2**

3.3.2.e Conformance with CSO Control Policy

Identified green infrastructure has the potential to remove approximately one-third of the combined area (2,349 of the 6,931 acres) and 562 MG/yr of storm water from the CSS. Additional gray infrastructure control technologies, specifically local HRT facilities, are needed for some CSO basins to achieve the required level of control that meets the presumption approach of the CSO Control Policy. The final CSO control plan results in a minimum of 85 percent and up to 94 percent capture of wet weather flow. .

The table below shows the percent capture calculation, using modeled volumes from the typical year simulation.

Table 3.34 Percent Capture Calculation

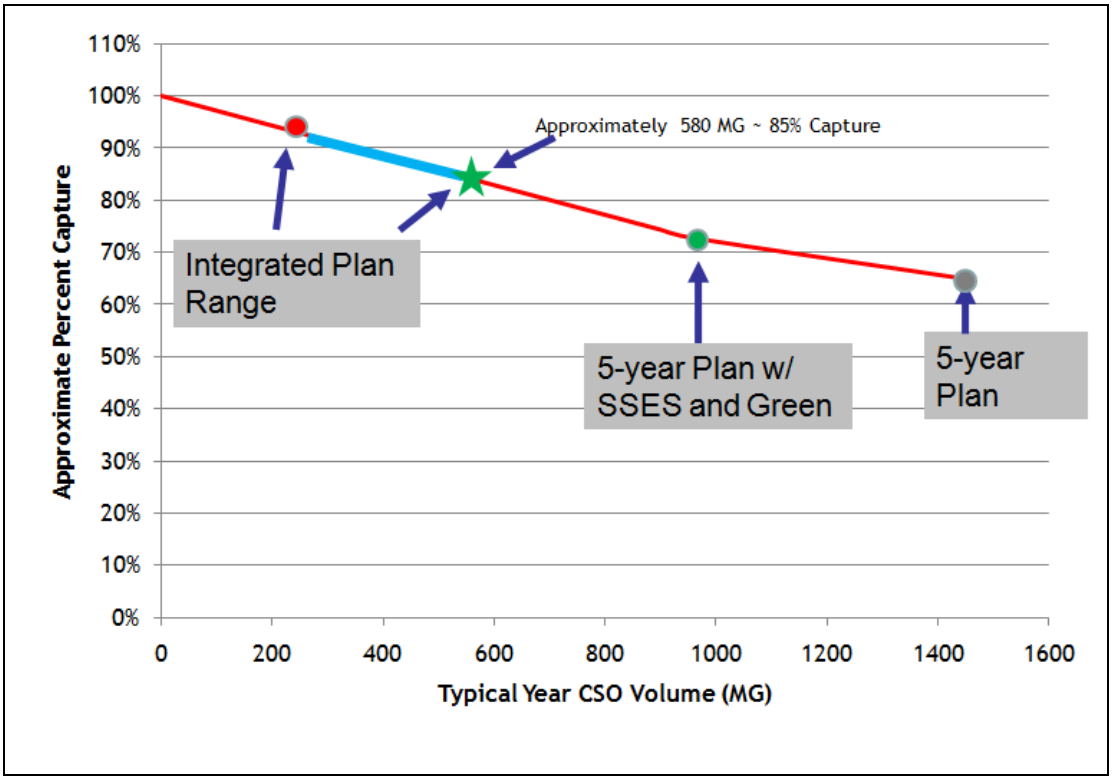
Category	Typical Year Annual Volume (MG)
Storm water entering combined system[1]	2,075
Sanitary flow during wet weather	1,557
Total Combined Flow (TCF)	3,632
Untreated CSO (CSO)	226
Percent Capture [(TCF)-(CSO)]/(TCF)	93.8%

Notes: 1. This does not include volume prevented from entering combined system through green infrastructure.

The final CSO control plan was modeled with the detailed water quality models to provide reasonable assurance that the controls would conform with the water quality-based requirements of the CSO Control Policy. The calculated fecal coliform densities in the models were compared with the water quality criteria for KDOW and ORSANCO. The modeling showed that the water quality criteria would not cause or contribute to violation of instream water quality standards for bacteria by the end of the implementation period, if other sources of bacteria beyond CSOs will be controlled and SSOs will be eliminated. Other sources beyond overflows must be addressed, through Total Maximum Daily Load calculations or otherwise, to assure water quality standards are achieved. The Integrated Plan also provides additional water quality benefits by addressing some of the other watershed sources of pollution through regional controls and other programs, as offsetting reductions to the level of CSO control, as discussed in Section 3.4.

Figure 3.26 shows the progression of the program in controlling CSOs. It demonstrates the benefits of the integrated approach, showing significant increase in control with the implementation of green infrastructure, and then the construction of additional gray controls to achieve a higher level of control while maximizing water quality benefit for the dollar spent.

Figure 3.26. Percent Capture of Wet Weather Flow by Level of Implementation of CSO Control



3.3.3 Watershed Control Program

SD1 has conducted data and modeling analyses to determine the potential water quality benefits from watershed controls that could be used to cost-effectively enhance the level of CSO control, providing offsets that are not typically considered in a traditional CSO long-term control plan. This section describes the analysis of different kinds of watershed controls. Results indicate that more water quality improvement can be achieved by targeting non-overflow pollutant sources in the watershed than by reducing the overflows to a very high level of control.

SD1 will use a programmatic-based approach to identify opportunities to reduce pollutant loads in the watershed. This Watershed Control Program includes use of the SSES Program to identify opportunities to control storm water runoff in areas of the sanitary sewer system prone to high inflow and infiltration, and the Source Identification Program (SIP) to identify source control opportunities elsewhere in the watershed. Lastly, water quality improvement projects near the combined system may be addressed through the Green Infrastructure Program.

Each of these programs is described in this section, but it should be noted that the Integrated Plan presented here reflects preliminary, screening-level analyses. Specific projects within each program will be identified, evaluated and designed in the 5-year planning cycles. Projects identified through these programs will typically control runoff from storm water areas larger than five acres. Regional watershed controls, such as retention basins or wetlands, which have upstream drainage areas greater than one square mile are also considered as part of SD1's Watershed Control Program.

The analysis used for this Plan is based on managing the runoff produced from the first 0.8 inches of rainfall (note: approximately 80 percent of the storms in this area are less than 0.8 inches, based on 50+ years of precipitation data from the Greater Cincinnati/Northern Kentucky International Airport). However, the actual amount of runoff control from individual projects may vary based on site-specific conditions.

A wide range of bacteria removal efficiencies have been reported for specific watershed control technologies (e.g. retention basins, wetlands, bioretention basins, biofiltration basins, etc.). SD1 has assumed a conservative bacteria removal efficiency of 50 percent for watershed controls, although higher removal rate assumptions of 65 to 70 percent may better represent the central tendency of the removal efficiencies reported in peer-reviewed literature.

This section describes the analysis of watershed control opportunities and the programmatic approaches that SD1 will use to identify, evaluate and implement these controls.

3.3.3.a Analysis of Watershed Control Opportunities

The term "watershed control measure" is used to describe a project or program that is intended to reduce or prevent pollutant loading to waterways from storm water runoff or other non-overflow sources in the watershed. The emphasis on pollutant reduction differentiates these controls from green infrastructure which is primarily focused on mitigating hydrologic impacts (although some green projects also offer water quality benefits). Watershed control projects could include retention basins, wetlands, bioretention basins, biofiltration basins, or other controls designed for pollutant reduction. These measures are meant to complement control measures directed at wet weather point sources like CSOs and SSOs. The Consent Decree for SD1 states that:

> "If Watershed Plans identify…nonpoint sources…that are contributing to water quality impairment…the Watershed Plans shall also identify…control measures…to offset the level of CSO controls or to delay the elimination of an SSO…" [paragraph 39(b)(4)]

Based on this provision in the Consent Decree and the recognition that monitoring data has demonstrated significant non-CSO/SSO sources of bacteria loading to waterways in the SD1 service area, a process was undertaken to identify opportunities for watershed control measures and to evaluate the potential benefits and costs of these opportunities. Because the identification and assessment of watershed controls was driven by the Consent Decree, the following guiding principles were identified for watershed controls:

- Focus on bacteria control; and
- Consider wet weather control first; then evaluate dry weather flow controls.

The process for identifying watershed control opportunities is an outgrowth of the "watershed approach" supported by SD1 that emphasizes a holistic approach to water quality improvement in Northern Kentucky. Appendix 3-C presents a detailed description of the methods and findings of SD1's watershed control opportunity analysis but is summarized here.

3.3.3.a.1 Watershed Control Opportunity Analysis

Several types of watershed control measures were evaluated in support of SD1's watershed planning effort. For each type of control measure, a rigorous opportunity analysis was conducted to identify where projects of each type could feasibly be sited in target watersheds where waterways are potentially affected by CSOs. Modeling and other technical evaluations were performed to estimate the potential benefits of each control measure type, which are defined as follows:

- **Regional Watershed Control Measures:** Regional watershed control measures are relatively large opportunities for retention basins or constructed wetlands, typically with upstream drainage areas greater than one square mile. Because regional control measures target relatively large drainage areas, they typically involve centralized interception and treatment of water in streams, both perennial and intermittent. Two major forms of regional watershed controls were considered: instream and side-stream. Instream regional controls were temporarily suspended as an option following EPA and KDOW feedback on the June 2009 Watershed Plans.
- **Decentralized Watershed Control Measures:** Decentralized watershed control measures, such as storm water wetlands, bioretention / biofiltration basins, or enhance retention basins are storm water control measures with upstream drainage areas smaller than one square mile, but typically greater than five acres. Decentralized watershed control measures are designed to control storm water runoff closer to the source, as compared to regional control measures which are sited adjacent to streams to improve water quality some distance downstream from source areas. Decentralized watershed controls may be new projects built for water quality improvement or they may be retrofit projects involving redesign of existing storm water basins to enhance storm water quality.
- **Stream Restoration:** Stream restoration commonly refers to a range of activities intended to improve the function or aesthetics of a stream. In the context of SD1's watershed planning effort, stream restoration refers to projects that integrate in-channel pools, channel lengthening, and riparian floodplain reconnection to increase hydraulic residence time, thereby increasing bacteria die-off. Activities that were evaluated in detail include in-channel practices, riparian buffer restoration, and livestock exclusion.

Regional Watershed Controls

After reviewing the potential site opportunities in the priority watersheds, several watersheds were eliminated from further consideration for the first set of Watershed Plans:

- Ohio River East, Ohio River North and Pleasant Run watersheds were eliminated because few opportunities were identified and because they contain relatively small tributaries to the Ohio River; flows from those storm water catchments are much smaller than the flow of the Ohio River. This makes it unlikely that watershed controls in those watersheds could make a measurable improvement in Ohio River water quality.

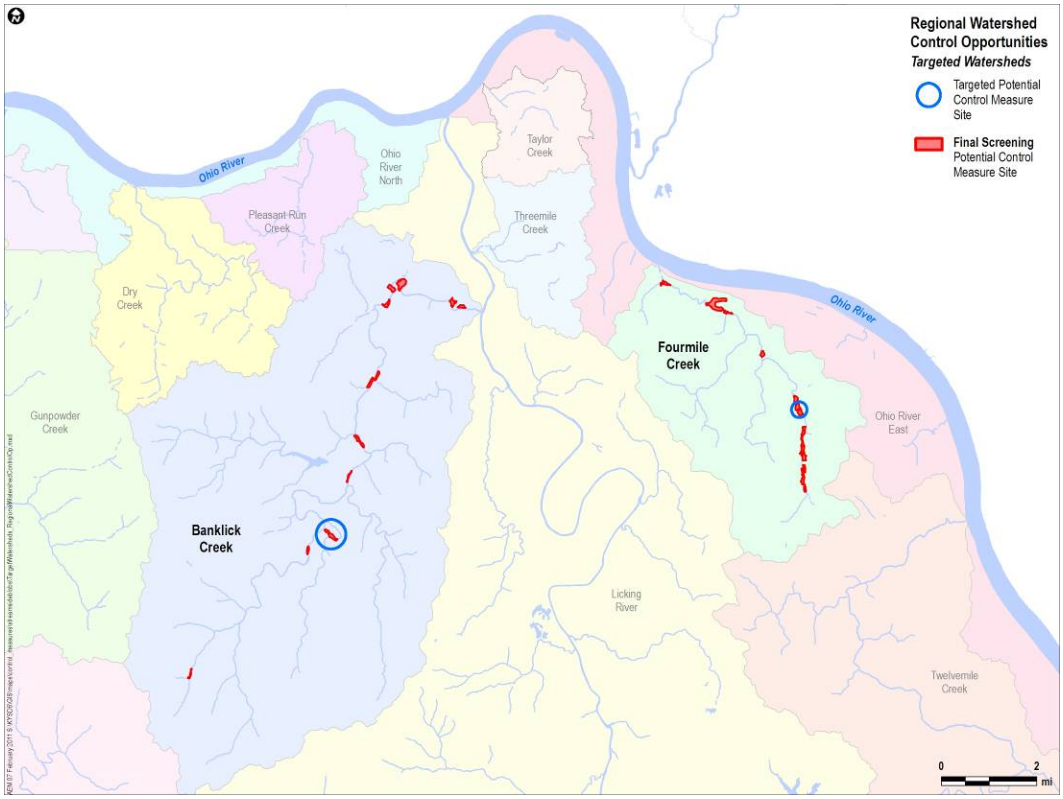
- The Licking River was eliminated because the identified opportunities are on relatively small tributaries to the Licking outside of the SD1 service area and the flow in the Licking is very large compared to the flows of these tributaries. It is unlikely that watershed controls on those small streams would have a significant impact on water quality in the Licking River.

- Threemile Creek watershed was eliminated from consideration because only one opportunity was identified and the flow of Threemile Creek is relatively small compared to the Licking River. Also, as with control opportunities in the Ohio River tributaries, the identified opportunities are located at the lower end of the watersheds so that very few stream miles of the watersheds could be improved.

- Taylor Creek watershed was eliminated because no siting opportunities were identified.

This left only the Banklick and Fourmile as the two remaining watersheds with potential sites for regional watershed control measures. One potential site in the Banklick Creek watershed is located in Brushy Fork and the another potential site in is the Fourmile Creek watershed located in Fourmile Creek itself (shown Figure 3.27).

Figure 3.27. Location of Regional Control Measure Site Opportunities Selected for Modeling Analysis



At each location, the following variations of regional control measures were modeled to evaluate potential water quality benefits:

- **Side-stream constructed wetlands** – Constructed wetlands located in the floodplain area, adjacent to the stream. Low-head boulder weirs (one foot or less in height) would allow flow to pass under normal dry weather conditions, but would create a backwater effect under wet weather conditions sufficient to divert wet weather flows out of the channel and into the wetland. Water would flow through the wetland by gravity and re-enter the stream channel downstream.
- **Side-stream wet weather basins** – Off-channel ponds constructed in the floodplain, adjacent to stream. No instream structures would be used, but structures on the bank would allow water to flow from the stream into the basin when a design stage is reached during wet weather.

The modeling results, combined with the outcome of the opportunity analysis, led to the following conclusions regarding the opportunities and benefits of regional watershed control measures:

- Limited opportunities for regional watershed controls of suitable size were identified. In most cases, site opportunities larger than ten acres

in size will be required to accommodate sufficiently large watershed controls, along with site amenities (e.g., access roads).

- Because the size of the regional watershed control measure is proportional to the size of the contributing drainage area, very large drainage areas cannot be managed using regional watershed controls due to lack of sufficient space.
- Implementation of regional watershed controls on tributaries can have a substantial water quality improvement benefit on the tributary, but may not have significant water quality benefit on the downstream waterway.

Because of the limited opportunities and the modeled benefits, SD1 has decided not to pursue regional watershed control measures in the first five-year planning period, beyond the ongoing Banklick Creek constructed wetland. Work will continue on the Banklick regional wetland and monitoring will provide valuable data to inform future control measure design. It should also be noted that the opportunity analysis conducted here assumed that minimum excavation would be desirable in constructing regional watershed control measures, to keep costs down. However, as more monitoring data are obtained and sources are better understood, there may be situations where sites requiring more excavation to build a regional control measure become more attractive.

Decentralized Watershed Controls

Decentralized control measures in SD1's watershed planning process are intended to control runoff from areas typically larger than five acres, which means that certain control measure types are appropriate whereas others are not. The types of control measures considered in this analysis include:

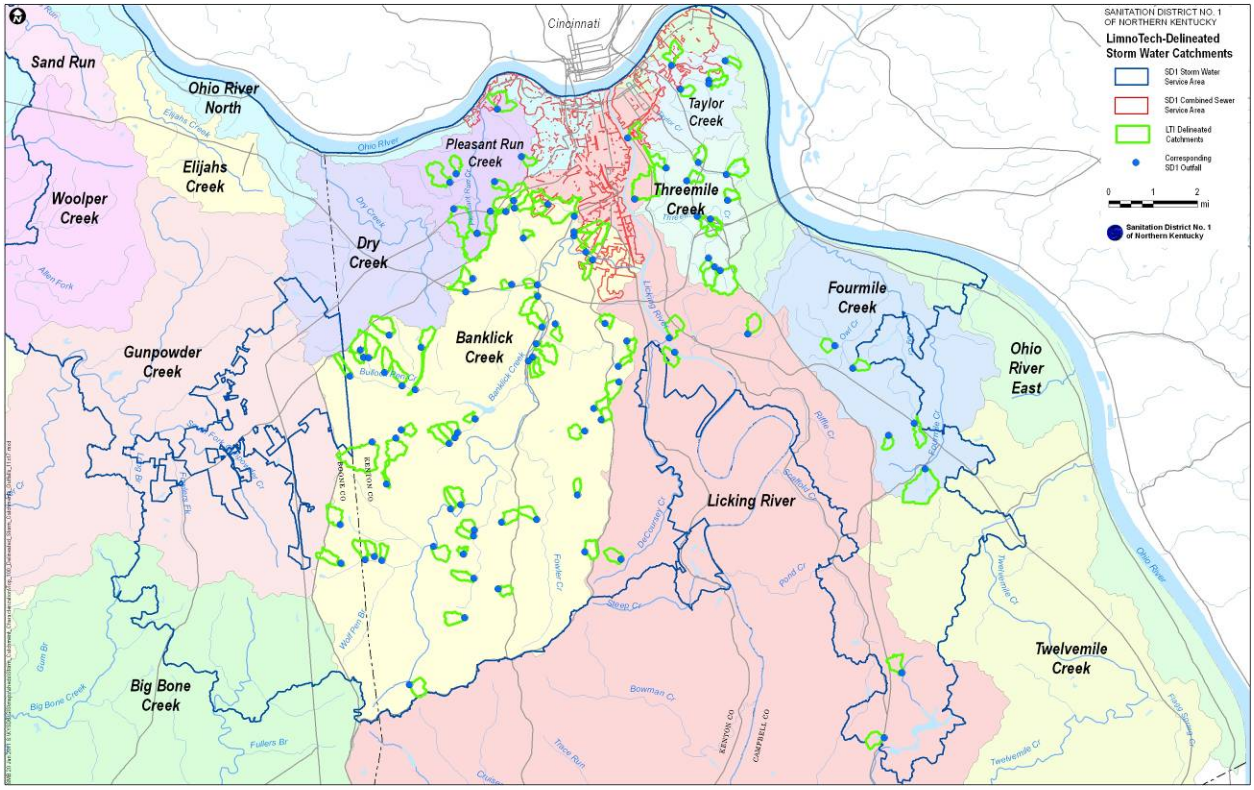
- Storm water wetlands;
- Bioretention/biofiltration basins (conventional detention basins modified to incorporate bioretention or biofiltration features into the basin to provide water quality improvement benefits); and
- Enhanced retention basins (conventional retention basins modified to incorporate forebays or other improvement features to the basin to provide water quality improvement benefits).

Wetlands, detention basins, and retention basins are all commonly used storm water control measures for drainage areas over 5 acres. Detention basins have the potential to be adapted to include bioretention and/or biofiltration functions to provide additional water quality treatment and retention basins can be modified with additional water quality improvement features as noted above.

An initial analysis of opportunities was conducted so that water quality benefits from these controls could be evaluated with the water quality models. As noted above, this analysis represents a “first cut” evaluation; the results provide information on potential opportunities rather than explicit projects that SD1 is committing to complete. Projects will be identified and designed in the five-year planning cycles so that site-specific investigations can be completed, and additional monitoring and data can be incorporated into the decision-making process.

As with the regional control opportunity analysis, the watersheds containing CSOs or discharging into CSO-impacted waters were targeted for this planning cycle. These watersheds were the Licking River, Banklick Creek, Threemile Creek, Fourmile Creek, Taylor Creek, and Pleasant Run Creek. Because the focus of decentralized watershed controls is on treating storm water, spatial data describing existing storm water infrastructure were used as a starting point in the opportunity identification process. The overall distribution of catchment size, as determined using Network Analyst, was used to determine a reasonable size cutoff to identify target catchments for control measure opportunity analysis. The area cutoff was set to 22 acres to provide a sufficient number of catchments for storm water control opportunities for this initial analysis. Overall, 100 catchments in the six priority watersheds were targeted and their catchments refined. Figure 3.28 depicts the delineated storm water catchments in green with corresponding major outfalls in blue.

Figure 3.28. 100 Delineated Storm Water Catchments in Northern Kentucky



Catchments selected for further analysis for the decentralized controls were further assessed as follows:

Step 1. Characterize selected catchments to describe: catchment area, watershed, water quality volume, percent imperviousness, type of impervious land, land use, city, county, ownership, hydrologic soil group, presence of hydric soils, R factor, sewer type and aerial imagery observations.

Step 2. Calculate the water quality volume to estimate the control measure volume needed for water quality improvement. For this application, this is the volume needed to manage runoff produced from the first 0.8 inches of rainfall.

Step 3. Calculate the area needed to accommodate the water quality volume in Step 2. This area is calculated for a range of depths between three and ten feet, to cover a range of potential controls that have different depths such as wetlands and storm water basins.

Step 4. Identify potential locations for siting controls. This analysis is conducted using GIS, and considers characteristics of the catchment such as existing land use and state of development, presence of

forested areas, proximity to streams, presence of storm water conduits upstream of the outfall, apparent sources of bacteria loading, and ownership.

Step 5. Identify suitable types of control measures for the locations identified in Step 4, including wetlands, basins, retrofits of existing basins/ponds, and daylighting storm water conduits.

Step 6. Apply detailed models to estimate the water quality benefit of the potential controls.

Using this desktop analysis, a number of potential locations were identified as preferred candidate sites and targeted for site inspection to provide an on-the-ground assessment of site conditions and to help evaluate control measure opportunity. To test the approach, site visits were conducted for 26 of the top 100 catchments. The site visits indicated that most of the locations are suitable candidates for either new projects or retrofits. Based on these findings, the decision was made to include decentralized watershed controls as a component of the overall water quality improvement program for SD1.

Because of the focus of decentralized watershed controls on controlling pollutant loading from storm water, they have a great deal in common with two other water quality improvement programs dealing with storm water:

- Storm Water Control in RDII Priority Areas – SD1 has identified Priority Areas for elimination of rainfall-derived infiltration and inflow (RDII) from the separate sanitary system to address SSOs. In conjunction with these RDII priority removal projects, SD1 plans to implement storm water control measures to manage storm water.
- Storm Water Management Program– New storm water regulations require implementation of storm water control measures to manage runoff produced from the first 0.8 inches of rainfall from new development. This is discussed in more detail in Section 3.3.4.

To varying degrees, the timing and location of these two programs and the implementation of decentralized storm water control measures are somewhat uncertain. Because the specific nature of projects under each program and the exact timing and spatial distribution of the projects are not defined at this time, the three programs and policies are considered as related water quality improvement programs for watershed planning purposes and were modeled as a single program.

Stream Restoration

In the context of SD1's watershed planning effort, stream restoration refers to projects that integrate in-channel pools, channel lengthening, and riparian floodplain reconnection to increase hydraulic residence time, thereby

increasing bacteria die-off. SD1 conducted a focused evaluation to identify potential stream restoration opportunities. The objective of this effort was to identify locations within priority watersheds where restoration actions, specifically in-channel practices, riparian buffer restoration, and livestock exclusion, might result in a reduction in problem bacteria levels.

A detailed GIS evaluation was conducted across portions of SD1's service area to identify segments within priority watersheds that may offer stream enhancement or restoration options for reducing or controlling problem bacteria inputs. In total, 211 stream miles were reviewed to identify stream restoration opportunities.

While there are many good reasons to perform stream restoration and increasing stream channel length, as discussed here would likely provide significant ancillary benefits, the cost of this type of project cannot always be justified solely on the bacteria reduction benefit. Therefore, SD1 will not be including stream restoration as a central component of its water quality strategy in this watershed planning program.

Summary of Findings

The analysis of the watershed control measures that were evaluated led to the following conclusions:

- Regional Watershed Control Measures: limited opportunities, beyond those identified in the Five-year Improvement Program, exist where the benefits of such projects could be demonstrated. SD1 will complete construction of the Banklick regional wetland and conduct monitoring as planned, to gain knowledge about the design and performance of such control measures.
- Decentralized Watershed Control Measures: SD1 intends to develop some new decentralized watershed control measures in target watersheds in the first Five-year Improvement Program. These projects will be a component of an overall program of nonpoint source control implemented by SD1.
- Stream Restoration: Based on the potential benefits and costs of projects to integrate in-channel pools, lengthen channels, and reconnect riparian floodplains, it was concluded that very large projects involving creation of miles of new stream channel would be required to achieve desired benefits and that the cost associated with these projects would not justify the limited benefits. Additionally, large-scale implementation of riparian buffers would be required to achieve significant water quality benefits related to bacteria reduction. Although SD1 recognizes that there are several ancillary benefits that can potentially be realized from stream restoration and riparian buffer projects, these projects will not be included as a central component of the water quality strategy in this planning cycle. However, SD1 will

continue to pursue partnerships with entities such as watershed groups to provide technical support for these initiatives.

3.3.3.a.2 SSES/RDII Storm Water Control Opportunities Analysis

Concurrent to the SSES activities, SD1 is focusing on the improvement of storm water quality and peak flow reduction in these SSES project areas. These projects are intended to result in a holistic solution that addresses the problem that removing inflow and infiltration from the sanitary system often creates by taxing an already underperforming storm water system. Upgrading the storm water infrastructure to address both new and existing storm flows is a critical component when improving the overall performance of all systems in the area.

The impact of pollutants from storm water on the local waterways has been well documented and is a significant source of impairment based on system-wide analysis. In addition to pollutant loading, the local streams in Northern Kentucky have undergone severe hydromodification due to high peak flows from developed areas. These peak flows have disrupted and eroded stream channels and have also endangered infrastructure, including utilities and roadways; forcing SD1 and the other local utilities, cities, counties, and Kentucky Transportation Cabinet into costly repairs to maintain portions of the utilities and road network constructed in close proximity to the region's waterways.

Peak flow reduction and storm water quality improvement through local green infrastructure has a direct benefit to both the quality of local streams and through potential cost savings on replacement of gray infrastructure resulting from eroded stream channels. To evaluate the potential benefits of these installations on water quality, SD1 examined several types of green infrastructure and their performance in both a 0.8-inch rainfall event (80th percentile rainfall event) and over the 1970 typical year.

SD1 investigated three different rain garden configurations and sizes to provide water quality treatment for storm flows within a typical residential zone of SD1's service area. The configurations were designed to treat a ten-acre medium-density residential area similar those found in the Fort Thomas, Fort Wright, and Fort Mitchell residential districts. The average lot size and impervious area characteristics were determined in GIS and inputted into the WinSLAMM program to evaluate the performance of the various rain garden configuration / size combinations.

WinSLAMM was used to generate the event runoff volume and calculate the percent reduction of storm water runoff volume for each rain garden alternative and size. Although WinSLAMM cannot directly model bacteria reduction, the percent reduction of runoff volume and bacteria load can be roughly approximated to occur on a one to one basis.

The investigated sizes include a footprint of 7,260 square feet (0.17 acres or 1/60th of the total drainage area), 14,520 square feet (0.33 acres or 1/30th of the total drainage area), and 29,040 square feet (0.67 acres or 1/15th of the total drainage area).

The examined configurations include a rain garden, a rain garden with stone storage, and a biofilter lay-out. The rain garden alternative is comprised of only one feature: a three-inch deep surface ponding area. The rain garden with stone configuration contains a four-inch deep surface ponding area that can infiltrate into an 18-inch deep layer of porous soil, which then drains into a two-foot deep layer of crushed stone storage. The biofilter configuration consists of a one-foot deep surface ponding area that infiltrates into 18-inches of porous soil. The soil layer then drains into a perforated pipe underdrain and a two-foot deep layer of crushed stone storage.

Table 3.35 presents the analysis results for the 0.8-inch rainfall event (the April 29, 1970 event was utilized for simulation).

Table 3.35. Bioretention Analysis Results for 0.8" Rainfall Event (April 29, 1970).

Configuration	% Runoff Volume Reduction	Surface Ponding (hours)	Surface Ponding after Rain (hours)	Below Ground Ponding after Rain (hours)
7,260 sq. ft. rain garden	33%	37.2	32.16	n/a
7,260 sq. ft. rain garden/w stone	100%	7.2	2.16	88.32
7,260 sq. ft. biofilter	59%	7.08	2.04	53
14,520 sq. ft. rain garden	68%	38.4	33.36	n/a
14,520 sq. ft. rain garden/w stone	100%	6	0.96	34.4
14,520 sq. ft. biofilter	100%	6	0.96	34.4
29,040 sq. ft. rain garden	100%	15.2	10.16	n/a
29,040 sq. ft. rain garden/w stone	100%	6	0.96	11.6
29,040 sq. ft. biofilter	100%	6	0.96	11.6

The results indicate that even the smallest footprint and most basic rain garden configuration will provide a benefit for runoff volume in the majority of storm events that occur in the typical year. Table 3.36 presents the analysis results for the 1970 typical year.

Table 3.36. Bioretention Analysis Results for 1970 Typical Year.

Configuration	% Runoff Volume Reduction	Number of Events with > 24 hours Surface Ponding	Number of Events with > 72 hours Sub-surface Ponding
7,260 sq. ft. rain garden	40%	27	n/a
7,260 sq. ft. rain garden/w stone	76%	10	5
7,260 sq. ft. biofilter	55%	0	0
14,520 sq. ft. rain garden	64%	15	n/a
14,520 sq. ft. rain garden/w stone	95%	4	3
14,520 sq. ft. biofilter	78%	0	0
29,040 sq. ft. rain garden	84%	4	n/a
29,040 sq. ft. rain garden/w stone	100%	0	0
29,040 sq. ft. biofilter	94%	0	0

The overall results show, that for a ten-acre existing residential area, even the installation of a 7,260 sq ft rain garden can have a significant impact on the runoff volume. Given additional available land, larger facilities can demonstrate an even greater impact on storm water volume, peak flow and runoff quality. Depending on the available land, the size of the facility can be determined, and the impact on water quality, peak flow, and the waterway can be estimated based on available modeling. A pilot project is currently being designed in the Vernon Lane project area in Ft. Thomas to properly design and site these green infrastructure opportunities to achieve storm water runoff peak flow reduction to minimize and prevent existing hydromodification and filter the runoff to achieve at least a 50 percent reduction in bacteria loading to the waterways to improve water quality. This work is being coordinated with and designed in concert with the RDII removal and sanitary and storm asset renewal work as described in Section 7.

3.3.3.b Watershed Control Implementation Programs

Watershed control projects will be identified, analyzed and implemented through one of three programs SD1 has initiated as part of the Integrated Plan for 2025. These programs include:

1. Source Identification Program (SIP): This program will be used to identify opportunities for watershed controls in storm water catchments areas as well as opportunities to address dry weather sources.

2. RDII/SSES Program: This program will be used to identify opportunities to control and treat storm water runoff in sanitary sewer basins prone to high inflow and infiltration.

3. Green Infrastructure Program: This program, described in Section 3.3.2.a.2, will be used to achieve water quality benefits inside and outside the combined sewer area in residential and commercial areas through public-private partnerships.

SD1 is using a programmatic approach for watershed controls to maintain flexibility in prioritizing projects and incorporate additional knowledge and monitoring data in the decision-making process. As such, specific projects within each program can be identified, evaluated and designed in the five-year planning cycles specified in the Consent Decree. Each of these programs is described in more detail below.

3.3.3.b.1 Source Identification Program

Monitoring data collected by SD1 over the last three years indicates that several watersheds have persistent elevated bacteria densities during dry weather periods as well as wet weather periods. As noted in Section 2.2.6, current bacteria water quality standards are applied over a 30-day period. Because rainfall affects instream densities for roughly one-third of the days in a 30-day period, dry weather conditions have far more influence on compliance with water quality standards than their relative loading contribution might suggest. Therefore, to improve water quality, it is prudent to reduce the magnitude of dry weather sources in the watersheds having elevated bacteria densities, as well as to address wet weather sources such as CSOs and storm water runoff.

With respect to dry weather sources of bacteria, there are numerous potential sources, including failing septic systems or straight pipe discharges, livestock access to streams, wildlife, and illicit or cross connections to municipal separate storm sewer systems (MS4). SD1 has developed an approach to identify potential dry weather sources, develop recommendations and remedies that correct these sources and reduce their impact on waterways. The program is intended to complement current SD1 programs, such as the Illicit Discharge Detection and Elimination Program, by focusing on areas informed by instream data and by expanding the scope to include evaluation of other potential dry weather sources.

With respect to storm water runoff, the opportunity analysis discussed in the preceding section demonstrated that opportunities exist for new or retrofit projects to enhance water quality in storm water runoff. However, almost no data are available to identify where storm water pollutant loading priority areas might exist.

In 2009, SD1 updated plans to implement a Source Identification Program (SIP) that will generate watershed data to identify and verify sources of bacteria loading to streams in the SD1 service area. Although originally conceived as a program to identify dry weather sources of bacteria loading,

SD1 has modified the SIP to include wet weather bacteria sources as well. As such, the SIP will provide the means for prioritizing decentralized watershed control measures identified using the opportunity analysis approach described above and in Appendix 3-C. The SIP will identify potential wet and dry weather sources so that effective remedies can be identified and implemented holistically.

The SIP protocol and pilot application in the Banklick Creek watershed is described in detail in Appendix 3-D. The SIP contains four steps:

1. Study Area Assessment and Prioritization;
2. Initial Watershed Assessment;
3. Field Reconnaissance; and
4. Action Plan.

SD1 has completed Step 1 by analyzing existing information across the study area to identify watersheds that appear to have dry weather impacts and has prioritized eight watersheds for investigation. These watersheds are Banklick Creek, Threemile Creek, Taylor Creek, Dry Creek, Pleasant Run, Sand Run, Fourmile Creek, and Woolper Creek. Elevated dry weather bacteria measurements have also been observed in the small tributaries in the Ohio River West watershed.

Within each watershed, existing data and information will be used to identify potential “hot spots” of elevated dry and wet weather bacteria loading so that the field reconnaissance (Step 3) can be conducted more efficiently. If instream data indicate wet weather source impacts, a desktop analysis of decentralized watershed control opportunities may also be conducted to support identification of potential storm water source controls and locations using methods similar to those described in Section 3.3.3.a.

The field reconnaissance step is intended to gather the necessary information to identify specific source loading inputs and/or to assess the feasibility of siting wet weather source controls. For dry weather source investigations, the activities in this step include field surveys where crews walk the prioritized stream reaches during dry weather conditions to identify locations of flowing pipes and/or unusual instream conditions, as well as noting potential polluted runoff areas associated with non-CSO/SSO overflow related wet weather sources. Locations for additional monitoring will also be identified and subsequently sampled, including, if appropriate, samples for bacteria source tracking analysis. The results from this step will be used to assess what further actions should be taken to locate the sources of the bacteria, update information from Step 2 (initial watershed assessment), refine the models, and develop an action plan. For wet weather source investigations, the field

reconnaissance may be more focused on assessing storm water catchment areas for potential BMP siting.

The components of the action plan include developing recommendations to further identify specific sources and identifying the types of potential control projects that could be considered for future Updated Watershed Plans. Factors that will be included in evaluating specific control projects include responsible party, funding mechanism, water quality benefit, and feasibility of implementation. Ultimately, this information will lead to working with other partners, such as the local Conservation Districts, Northern Kentucky Health Department and KDOW to address potential projects or enforcement.

3.3.3.b.2 Rainfall-Derived Inflow and Infiltration / Sanitary Sewer Evaluation Survey Program

As noted previously, a tremendous potential benefit to increase storm water management in the SD1 system exists. The implementation of storm water BMPs in areas of high RDII provides an opportunity to provide a holistic benefit to the SD1 separate service area, providing for improvement of both the separate sanitary and storm networks simultaneously.

The implementation of this storm water management program is designed to coincide with work done to eliminate I/I in the SD1 sanitary system. In many neighborhoods with high I/I, the storm system is inadequate and in need of repair. Many of the storm sewers are in poor condition and flooding and poor drainage exist throughout the SD1 service area, creating a nuisance and potentially hazardous conditions for residents. In addition, the storm water runoff quality leaving these areas is poor.

Concurrent with the public and private source projects to be completed at the local neighborhood level to eliminate illegal connections to the sanitary system and reduce I/I, improvements will also be made to the storm system to implement water quality BMPs through the use of green infrastructure and reduce water quantity through peak flow reduction to decrease hydromodification in Northern Kentucky streams. This work will also inherently involve renewing the storm sewer assets and reducing localized flooding problems through the implementation of these green BMPs and peak flow reduction projects.

This approach of renewing the sanitary sewer system through public and private I/I removal projects; renewing the storm sewer system through public infrastructure rehabilitation/replacement; and implementation of green BMPs that improve water quality and achieve peak flow reduction has many benefits. This approach:

- Can eliminate overflows rather than moving them downstream;

- Focuses on fixing current sanitary and storm assets and reduces and in some areas eliminates additional large capital expenditures for new assets;

- Removes I/I over time so future conveyance, operations and maintenance and treatment expenditures are less;

- Fits into SD1's green infrastructure approach, where problems are addressed near their source;

- Addresses storm water runoff through green infrastructure to improve water quality and reduce water quantity; and

- Holistically addresses multiple sources of pollution in a single project.

The factors that govern the prioritization of I/I removal will impact the implementation of these improvements and the overall timing of local storm water BMP construction. The schedule for the RDII/SSES program is based on a number of factors, including:

- Public Health Impact –Impacts on public health will define specific I/I removal projects.

- SSO volume –The highest volume SSOs provide the highest potential for significant benefit through I/I removal. SD1's program will also focus efforts in high volume locations as a priority following the five-year improvement program.

- Coordination with Other Projects – Coordination with local communities street improvements, neighborhood improvement programs, and illicit detection areas provides opportunities for cost savings and for developing holistic projects that achieve multiple local priorities.

In addition to these factors, local flooding and/or severe hydromodification concerns may accelerate a planned storm water BMP project and may determine the specific timeline for that location.

SD1 anticipates that this storm water management work will be completed within the same timeframe as the I/I removal programs. There are several principles that will guide the magnitude and goals of implementation on a location by location basis:

- Q critical – SD1 has worked to identify magnitude of flow in local streams which cause hydromodification and will seek to develop and implement controls that limit the number of events which exceed this threshold, allowing time for streams to recover and natural habitats to be restored. This work with Q critical and developing green infrastructure-based controls for existing neighborhoods is innovative

and ground-breaking. SD1 is one of the first in the country to perform this work.

- Instream sampling – As SD1 continues its instream sampling, the need for increased storm water controls in specific watersheds or subwatersheds may become apparent due to elevated bacteria levels. Enhanced controls in these locations as part of this program will help to address the worst water quality problems in Northern Kentucky.

- Local site restrictions – In existing neighborhoods, there may be limited available land to construct new storm water management facilities. SD1 will work with local homeowners to maximize the efficiency of improvements, but in some cases, the existing development may limit the extent or effectiveness of proposed controls.

System-wide evaluation has shown substantial benefits that can be derived from the development of these local storm water controls. The magnitude and extent of these controls will vary by location and need and will be evaluated with the I/I removal projects to determine the most cost-effective suite of controls.

SD1 is currently exploring the potential impact of this program and the types of available controls as part of the Lakeside Park and Vernon Lane projects and will use that information to help guide the remainder of the implementation of the program. As additional areas are developed, that feedback will help to further shape and refine the program for future Watershed Plans.

3.3.3.b.3 Green Water Quality Projects

Because the Green Infrastructure Program will be used to achieve water quality benefits inside and outside the combined sewer area, it was described in detail in the CSO Control section (Section 3.3.2.a.2).

3.3.4 Policy/Regulation and Partnership Opportunities

This control type represents opportunities for SD1 to leverage investment in pollutant controls with private and public entities. It includes opportunities to supplement SD1's initiatives with:

1. Newly developed policies and regulations that mitigate storm water runoff;

2. Public and private partnerships to implement green infrastructure practices; and,

3. Partnerships with entities such as watershed groups to provide technical support for reforestation, riparian buffer and stream restoration initiatives.

Policy/regulations and partnership opportunities are discussed in the following subsections.

3.3.4.a Policy/Regulation

This category includes ordinances, regulations and policies that provide additional control measures beyond SD1's investment in SSO, CSO and watershed control initiatives. Under SD1's Phase II permit for Northern Kentucky's MS4, SD1 is required to develop several water quality-related treatment standards.

SD1 has recently developed a water quality treatment standard, as per the Phase II MS4 permit, requiring developers to treat the runoff produced from the first 0.8 inches of rainfall for any new impervious area with a water quality BMP. This regulation will go into effect in October 2011.

3.3.4.b Partnership Opportunities

A key element of SD1's overall strategy is to identify partnership opportunities throughout the community. As described in Section 2, there are several groups actively working to protect the waterways in Northern Kentucky area. SD1 conducted a wide review of potential partners that could help fund and implement controls.

There are numerous public agencies in Northern Kentucky with plans to invest significant amounts of money over the next decade in the construction and upgrade of public infrastructure including streets, schools, parks, highways and public housing. Each public project represents an opportunity to incorporate green infrastructure.

In addition, local watershed groups are also actively working to protect, improve and enhance watersheds and waterways in Northern Kentucky. SD1 is well positioned to partner with these groups to provide technical support for riparian buffers, stream restoration initiatives, and decentralized watershed control projects.

<u>Green Partnership Opportunities</u>

Controlling storm water at the source is an important principle of green infrastructure. Impervious surfaces such as streets, parking lots, and rooftops are the major sources of runoff in the combined sewer area. While a considerable amount of land within the combined sewer area is publicly owned (24 percent including roadways), SD1 owns a very small percentage (0.2 percent) of this land. Therefore, in order for SD1 to effectively implement

a source control strategy, partnerships with local property owners are essential.

In recent years Northern Kentucky has been the beneficiary of considerable development and redevelopment activities. As the trend continues, development and redevelopment projects in the combined sewer area represent opportunities for SD1 to partner with both public and private entities to encourage, incentivize and/or fund the construction of green infrastructure to reduce runoff entering the combined sewers. Incorporating green techniques into a site plan is most effectively accomplished if the green components are developed early in the planning process. While retrofitting is a viable option and should be explored, incorporating green elements into new and redevelopment projects at their early stages is certainly the most cost-effective approach for implementation of green practices.

A key element of SD1's overall green strategy is to identify partnership opportunities throughout the community. There are numerous public agencies in Northern Kentucky with plans to invest significant amounts of money over the next decade in the construction and upgrade of public infrastructure including streets, schools, parks, highways and public housing. Each public project represents an opportunity to incorporate green infrastructure. By coordinating the design and construction of green controls into planned public and private projects, SD1 will realize runoff reduction benefits at a fraction of the cost compared to retrofitting green controls after the planned projects are built.

SD1 has initiated discussions with several agencies to promote partnering opportunities on green infrastructure projects including:

- Northern Kentucky Area Planning Commission,
- Kentucky Transportation Cabinet,
- City of Covington,
- City of Dayton,
- City of Bellevue,
- City of Newport,
- City of Park Hills,
- City of Taylor Mill,
- Housing Authority of Covington,
- Campbell County Planning Commission,
- Kenton County School District,
- Notre Dame Academy, and
- Banklick Creek Watershed Council.

Significant effort was made to identify a list of potential and/or planned projects that may provide SD1 with a good opportunity to partner or cost share with each of these entities. SD1 has already successfully partnered on three green design projects, to be constructed in 2009, including a green

street with the City of Covington, a bioswale with the City of Fort Thomas and the Northern Kentucky Water District, and a rain garden with the St. Elizabeth Medical Center in Covington. By continuing to promote these types of relationships, SD1 increases the utilization of green techniques for runoff reduction. Through meeting with potential partners, SD1 has identified more than 50 areas with planned or potential development or redevelopment projects in the combined sewer area.

Furthermore, the strength of green infrastructure requires bringing together people and programs engaged in various initiatives, and focuses on bridging the gap between conservation activities and other planning efforts. It is important to understand that successful green infrastructure initiatives require considering the perspectives of various stakeholders in the public, private and nonprofit sectors. SD1 has been in discussion with several of these stakeholders including but not limited to:

- Vision 2015,
- Licking River Greenway,
- Brent Spence Bridge project,
- Devou Park Master Plan,
- St. Elizabeth Medical Center,
- Area Planning Commissions,
- Northern Kentucky Urban and Community Forestry Council,
- Local Stakeholders, and
- Unincorporated areas.

For SD1 to successfully and cost effectively develop this green urban core, it is important to capitalize on opportunities to partner on the implementation of these green techniques. The green infrastructure component of the watershed planning process should be considered a set of “living” principles that are modified and updated periodically to remain relevant as the community and region continue to grow and evolve. SD1 will continue to participate in key projects throughout Northern Kentucky as well as forge relationships with key stakeholders identified as part of the green infrastructure evaluation.

Summary

SD1 conducted a wide review of potential partners that could help fund and implement green controls. As part of this effort, SD1 is meeting with cities in the CSS to discuss planned and proposed capital projects, both public and private, that may occur within the city during the timeframe associated with the implementation of the Watershed Plans. This outreach effort by SD1 should allow for the early identification of green infrastructure partnership opportunities.

3.4 BENEFITS OF INTEGRATED PLAN

The analysis of the Integrated Plan continues the modeling work presented in Appendix 3-A. Rather than approaching the 2025 solution purely conceptually as in Appendix 3-A, SD1 embarked on a modeling analysis of the benefits of the components comprising the Integrated Plan for 2025. Additional information will be necessary to refine the Integrated Plan in the subsequent five-year planning cycles. This Plan, however, represents SD1's proposed initial approach to the final endpoint of complying with the Consent Decree by December 31, 2025.

SD1 used the hydraulic and water quality models to evaluate the water quality benefits of the Integrated Plan relative to a traditional overflow control plan that eliminates SSOs and controls CSOs to a high level (e.g. 4 overflows/year). These simulations were conducted using the 5-year typical water quality simulation period (1992-1996) for the 2030 future build-out condition.

The traditional control plan scenario was developed as part of the Bounding Analysis presented in Appendix 3-A. The bounding analysis scenario that used gray infrastructure solution concepts to control CSOs at 4 overflows/year and SSOs at a 5-year level of service was used to represent the Traditional Plan in this comparison.

The Integrated Plan scenario was developed using the results of the analyses described in Section 3.3. SSOs were eliminated in all of the scenarios except the "No control" baseline. CSOs were simulated assuming completion of the Five-year Improvement Program, maximum implementation of green infrastructure projects and addition of gray infrastructure (a combination of transport and treat, equalization storage, and local ballasted floc HRT and disinfection). Watershed controls throughout the system were assumed to manage runoff produced from the first 0.8 inches of each rainfall event with a 50 percent removal efficiency of fecal coliform. The same control design assumptions were applied to areas potentially affected by policies and regulations, such as new development.

A specific goal of the analysis was to demonstrate that the presumption approach for CSOs at 85 percent capture (or higher) in conjunction with SSO elimination and controls on other sources would ensure that CSOs do not cause or contribute to water quality standards violations by the end of the implementation period. The water quality model results for the 1992-1996 typical period were compared to current bacteria water quality standards to determine compliance rates, and to the 2030 Baseline No Control to evaluate improvements in water quality. Four bacteria density measures were used to compare scenarios, depending on the characteristics of the waterway and the purpose of the comparison (also used in the Full System Bounding Analysis). These bacteria density measures are as follows:

- Measure #1: The first measure consists of counting the number of days in the five recreation seasons (i.e., all recreation seasons in the five-year simulation period) where the maximum bacteria densities were less than 400 cfu/100 ml. This measure is conservative, because Kentucky's water quality standards allow 20 percent of the fecal coliform measurements in a 30-day period to exceed 400 cfu/100 ml. This is one of the two measures used to determine water quality benefit;
- Measure #2: The second measure consists of calculating the percent of 30-day periods in the five recreation seasons where 80 percent or more of the hourly values were less than 400 cfu/100 ml; this provides a more direct comparison to the current Kentucky water quality 30-day maximum standard. This is one of the two measures used to determine compliance with water quality standards;
- Measure #3: The third measure consists of calculating the percent of 30-day periods in the five recreation seasons where the geometric mean of the hourly values was less than 200 cfu/100 ml; this again provides a more direct comparison to the current Kentucky water quality 30-day geometric mean standard. This is one of the two measures used to determine compliance with water quality standards and
- Measure #4: The fourth measure consists of calculating a geometric mean of the hourly fecal coliform densities calculated by the model across the five recreation seasons. This measure is not directly related to a current water quality standard, but provides a concise indication of average conditions across the five-year period. This is one of the two measures used to determine water quality benefit.

The models were also used to evaluate specific components of the Integrated Plan for 2025, such as quantifying the water quality benefits of maximizing green infrastructure in the combined system after the Five-year Improvement Program is completed. Because of the difficulty in forecasting specific watershed control projects and other factors, such as the location and types of new development, the models were run for a range of watershed control program assumptions so that a range of potential benefits could be estimated. The model results can be used with the cost information described in Section 4 to make cost-effective decisions on implementing watershed projects.

The WAT! model was also applied for the three scenarios described above (No control, Integrated Plan and Traditional Plan) to compare differences in bacteria and nutrient loads among the scenarios.

3.4.1 End-of-Pipe Measures of CSO Control

The Integrated Plan for 2025 eliminates SSOs and controls CSOs to a level that conforms with the CSO Control Policy. The CSO level of control was determined based on water quality in the CSO-impacted waterways

(described in Section 3.3.2.b), which resulted in target levels of control of 18 overflows/year in the Licking River and Taylor Creek, 24 overflows/year in Banklick Creek and 36 overflows/year in the Ohio River. Table 3.36 provides overflow statistics for the preferred solution that was simulated in the water quality models for the 1992-1996 typical period. Overflow purposes are alos provided for the typical year (1970) for comparison purposes. In some CSO basins, identified green infrastructure projects achieved or exceeded the target level of control; however, in most CSO basins, additional gray infrastructure controls were needed to achieve the target level of control across the CSOs discharging to each waterway. SD1 sized a combination of transport and treat, equalization storage, and local ballasted floc HRT and disinfection facilities (described in Section 3.3.2.c) using typical year (1970) rainfall to reach the target level of control. System-wide percent capture therefore varied between 85 to 94 percent, depending on the gray infrastructure solution.

The controls were then simulated for the five-year typical period (1992-1996) to evaluate the water quality benefits to local waterways. Note, however, that controls and solutions presented in the Plan have not been optimized. Actual activations, volumes and hours of overflow at individual CSOs may differ as additional information and analyses are conducted to inform the final control projects for the final 2025 solution.

Table 3.37. below summarizes the components of flow in the combined system in the typical year simulation after full implementation of the 2025 Integrated Plan. The results below were taken from the hydraulic model. As the table below indicates, total flow entering the combined system is approximately 6,747 MG/yr, with storm water accounting for approximately 2,075 MG/yr. These numbers do not include the volume removed due to green infrastructure. Implementation of the CSO control plan will leave only 226 MG/yr of untreated CSO volume. The sustained secondary treatment capacity of Dry Creek WWTP is projected to be 100 MGD.

Table 3.37. Model Predicted Volume after Full Implementation of 2025 Integrated Plan

Category	Typical Year Annual Volume (MG)
Total flow entering combined system[1]	6,747
Storm water entering combined system[2]	2,075
Combined system flow receiving full secondary treatment	5,787
Combined system flow being treated through HRT facilities	731
Untreated CSO	226
Flow at Dry Creek WWTP bypassing secondary	3
Storm water removed from combined system by green infrastructure	562

Notes: 1. This includes flow to Bromley PS, flow treated by HRT, and untreated CSO.
2. This does not include volume prevented from entering combined system through green infrastructure.

Because the Integrated Plan eliminates SSOs by controlling them to a two-year level of service[7], the end-of-pipe results from the hydraulic model are focused on remaining CSO volume. Table 3.398 provides a summary of the average annual CSO activations, volume and hours of overflow discharging to each waterway under the different control scenarios evaluated for this Plan for the five-year simulation period. These control scenarios include: Baseline (assuming future 2030 landuse conditions with no additional controls); implementation of the Five-year Improvement Program; full implementation of green infrastructure projects (in addition to the Five-year Improvement Program); the Integrated Plan for 2025; and a traditional plan. Note that the Five-year Improvement Program scenario was simulated using 2013 conditions while all of the other scenarios were simulated using 2030 future build-out conditions. Differences between 2013 and 2030 conditions may confound the comparison of the two Five-year Improvement Program scenarios.

[7] The two-year level of service is based on controlling to the two-year, six-hour design storm under saturated antecedent moisture conditions. The level of service was confirmed by applying the model over a continuous simulation period of a typical year (1970) to verify that no overflows occurred.

Table 3.38. Integrated Plan End-of-Pipe Statistics for Individual CSOs for the Typical Year and Typical 5-Year Periods[8]

Watershed	Outfall ID	CSO Name	Annual Events			Annual Volume (MG)		Annual Hours	
			1970	1992-1996	Target	1970	1992-1996	1970	1992-1996
Ohio River North	1320112		0		36	0		0	
Ohio River North	1350155	Park Hills-Dixie Highway	0		36	0.00		0	
Ohio River North	1380132	Amsterdam/Parkvale	1		36	0.07		1	
Ohio River North	1380146		0		36	0.00		0	
Ohio River North	1440204	Scott Street	7	0	36	3.53	0.00	10	0
Ohio River North	1440508		6	5	36	0.32	0.20	7	6
Ohio River North	1440206	Garrad Street	7	6	36	0.39	0.26	9	7
Ohio River North	1440209	2nd Street at Russell	7	9	36	2.66	1.86	9	11
Ohio River North	1470089	Philadelphia Street	8	9	36	0.38	0.28	15	17
Ohio River North	1470093	Johnson Street	8	10	36	1.69	1.30	10	12
Ohio River North	1480185	Wright Street	6	7	36	0.49	0.39	17	17
Ohio River North	1480187	Willow Run	7	7	36	17.84	10.80	13	11
Ohio River North	1490132	Parkway at Highway	8	8	36	1.26	0.75	14	15
Ohio River North	1490172	Swain Court	0	0	36	0.00	0.00	0	0
Ohio River North	1500131	Altamont Street	8	8	36	1.24	0.93	18	20
Ohio River North	1710114	Kenner Street	8	8	36	0.52	0.33	9	10
Ohio River North	1710116	Adela Street	8	9	36	1.51	1.06	10	11
Ohio River North	1710119	Butler Street	8	9	36	0.69	0.47	12	13
Ohio River North	1710121	Carneal Street	8	8	36	0.73	0.49	14	14
Ohio River North	1710124	Ash Street	8	8	36	0.76	0.50	14	14
Ohio River North	1720109	Lagoon Street	8	6	36	2.09	1.10	9	7
Ohio River North	1730259	Pleasant Street	8	7	36	0.55	0.33	9	8
Ohio River North	1730262		0		36	0.00		0	
Ohio River North	1730263	Rohman Street	7	5	36	0.39	0.22	7	6

[8] SD1's Integrated Plan for 2025 (beyond the 5-year detailed plan) is preliminary in nature because of the watershed planning process and reliance on green infrastructure and watershed controls to assist in achieving the objectives of the Consent Decree. The anticipated performance outcomes listed in this plan should therefore not be construed as specific performance commitments or standards.

Watershed	Outfall ID	CSO Name	Annual Events			Annual Volume (MG)		Annual Hours	
			1970	1992-1996	Target	1970	1992-1996	1970	1992-1996
Licking River	0960064	15th Street	0	0	18	0.00	0.00	0	0
Licking River	0980073	12th Street (Covington)	4	3	18	0.06	0.03	4	4
Licking River	0980080	13th Street	0	0	18	0.00	0.00	0	0
Licking River	0980081	Pleasant Street	4	5	18	3.59	2.13	4	6
Licking River	1420142	8th Street	4	4	18	2.64	1.40	4	4
Licking River	1420144	9th Street	0	0	18	0.00	0.00	0	0
Licking River	1420145	10th Street	4	4	18	0.12	0.08	4	5
Licking River	1420146	Robbins Street	0	0	18	0.00	0.00	0	0
Licking River	1420147	11th Street	0	0	18	0.00	0.00	0	0
Licking River	0910066		0	0	18	0.00	0.00	0	0
Licking River	0910068	Eastern Avenue	4	4	18	3.16	1.35	5	5
Licking River	0930102	Durrette Avenue	0	0	18	0.00	0.00	0	0
Licking River	0930103	20th Street	3	3	18	0.12	0.06	3	3
Licking River	0930104	17th Street	3	1	18	0.13	0.02	3	1
Licking River	0930105	19th Street	4	3	18	1.96	1.02	4	4
Licking River	0930106	16th Street	3	1	18	0.03	0.01	3	1
Licking River	0960063	Patton Street	3	2	18	0.68	0.28	3	3
Licking River	0730129	Fitzsimmons Street	4	4	18	0.29	0.14	4	5
Licking River	0790086	4th Street	3	4	18	3.73	1.93	3	4
Licking River	0840111		0	0	18	0.00	0.00	0	0
Licking River	0840112	10th Street	3	4	18	0.17	0.44	3	4
Licking River	0840116	12th Street	3	3	18	0.57	0.31	3	4
Licking River	0870078	Park Drive	4	4	18	0.30	0.16	5	6
Licking River	0870079	Southern Avenue	4	3	18	0.68	0.33	5	4
Licking River	0880081	34th Street	3	4	18	1.07	0.48	4	4
Licking River	0880082	33rd Street	3	5	18	0.27	0.16	3	5
Licking River	0910065	James Avenue	4	3	18	2.63	0.88	4	3
Licking River	1880090	45th Street	4	1	18	0.12	0.05	10	4
Licking River	1880091	44th Street	4	3	18	0.59	0.30	12	10
Ohio River East	0330100	Tower Hill Road	3	2	36	0.01	0.01	4	3
Ohio River East	0360079	Marina on Mary Ingles Highway	6	8	36	0.04	0.04	17	20
Ohio River East	0570089	McKinney Avenue	7	12	36	13.46	15.72	23	46

Watershed	Outfall ID	CSO Name	Annual Events			Annual Volume (MG)		Annual Hours	
			1970	1992-1996	Target	1970	1992-1996	1970	1992-1996
Ohio River East	0570090	Main Street	4	2	36	1.03	0.43	5	3
Ohio River East	0600094	Foote Avenue	8	8	36	0.49	0.33	10	10
Ohio River East	0600096	O'Fallon Avenue	6	5	36	0.13	0.08	7	6
Ohio River East	0600097	Ward Avenue	8	9	36	1.23	0.95	11	11
Ohio River East	0600104	Van Voast Avenue	2	0	36	0.01	0.00	2	0
Ohio River East	0610071	Tayor Avenue	7	7	36	1.38	0.89	9	8
Ohio River East	0610072	Washington Avenue	8	11	36	0.75	0.67	17	24
Ohio River East	0620075	Patchen Avenue	7	7	36	1.10	0.72	9	8
Ohio River East	0620077	Lafayette Avenue	6	5	36	0.15	0.07	7	6
Ohio River East	0650090	Riviera Drive	8	9	36	0.64	0.59	22	25
Taylor Creek	0650098	Tiger Lane	8	11	18	3.13	3.63	22	31
Ohio River East	0630061	Linden Avenue	7	6	36	0.94	0.54	8	7
Ohio River East	0640090	Washington Avenue	7	7	36	3.07	2.10	9	9
Ohio River East	0770096	Saratoga Street	7	7	36	0.56	0.36	9	8
Ohio River East	0790084	Columbia Street	7	7	36	1.18	0.78	9	9
Banklick Creek	1850158	Church Street	11	9	24	4.24	4.24	44	50
Banklick Creek	1870032	Decoursey Street	4	4	24	0.18	0.13	4	5
Banklick Creek	1870200	47th Street CSO	16	13	24	1.12	0.95	34	35
Banklick Creek	1840130	Latonia	12	10	24	0.68	0.55	14	12
Ohio River North	Willow Run HRT (1480147)		18	18	36	48.90	49.49	41	47
Licking River	Eighth St. HRT (1420142)		8	5	18	15.78	10.14	60	32
Licking River	Patton St HRT (0930105)		16	12	18	11.34	8.76	24	17
Licking River	James HRT (0910065)		18	14	18	10.98	9.58	26	22
Licking River	4th St HRT (0790086)		15	12	18	7.64	6.66	18	15
Ohio River east	Taylor Creek HRT (0650090)		36	26	36	35.50	26.45	63	50
Banklick Creek	Subtotal, Banklick Creek CSOs		20	13	24	6.21	5.87	71	65
Licking River	Subtotal, Licking River CSOs		22	17	18	68.64	46.70	81	52
Taylor Creek	Subtotal, Taylor Creek CSOs		8	13	18	3.13	3.98	22	37
Ohio River East	Subtotal, Ohio River East CSOs		36	26	36	61.65	50.75	70	80
Ohio River North	Subtotal, Ohio River North CSOs		18	18	36	86.01	70.75	47	50
Total						225.65	178.05		

Table 3.39. CSO End-of-Pipe Statistics for Integrated Plan for 2025 Evaluation Scenarios (Annual Average of the Five-year Typical Period at 2030 Conditions)

	Baseline (No Control) (2030)	Five-year Improvement Program (2013)	Five-year Improvement Program + Green Infrastructure (2030)	Integrated Plan (2030)	Traditional Plan (2030)
Annual Events (Activations per Year)					
Banklick Creek	89	38	38	13	7
Licking River	93	94	87	17	6
Ohio River	106	106	102	26	5
Taylor Creek	34	28	13	13	5
Annual Volume (Million Gallons per Year)					
Banklick Creek	74	11.9	11.8	5.9	10.2
Licking River	885	470	413	47	44
Ohio River	1,260	925	516	121	69
Taylor Creek	12.2	15.2	4.0	4.0	0
Total Volume	*2,232*	*1,422*	*945*	*178*	*124*
Annual Hours (Hours per Year)					
Banklick Creek	1,182	265	265	65	42
Licking River	1,502	620	487	52	32
Ohio River	1,486	756	716	80	28
Taylor Creek	129	97	31	37	7

Note:

CSOs located in Fourmile Creek and Pleasant Run Creek are included in the tallies for the Ohio River. CSOs in these watersheds are located near the mouths of these tributaries and will tend to have more impact on the Ohio River than the tributary itself.

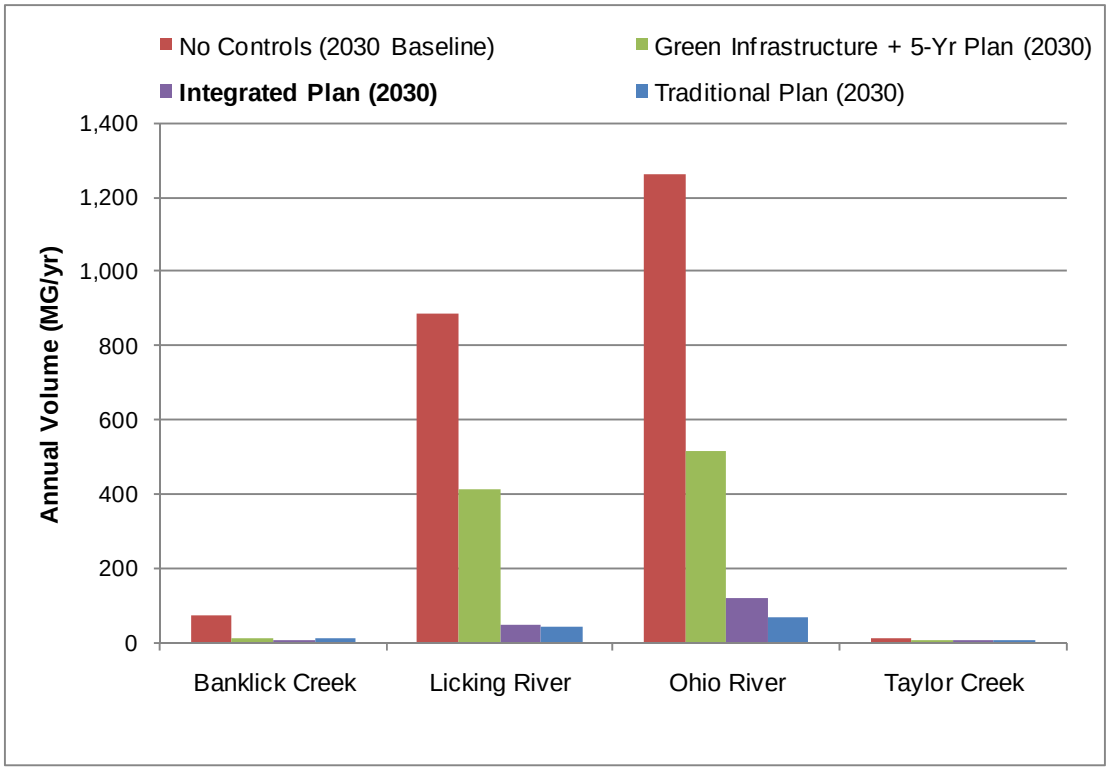
The Integrated Plan for 2025[9] results in approximately 13 overflows/year in Banklick and Taylor Creek, 17 overflows/year in Licking River and 26 overflows/year in the Ohio River during the five-year simulation period rather than the designed activation frequencies of 18 overflows/year (Licking River and Taylor Creek), 24 overflows/year (Banklick Creek), and 36 overflows/year (Ohio River). Although the design period (1970) and the water quality evaluation period (1992-1996) had "typical" rainfall characteristics with respect to historical averages, there are differences between the two periods that may have resulted in the observed differences in activations in each of the waterways. In some instances (Banklick Creek), the reduced number of activations likely also reflects the results simulated in identified integrated

[9] As discussed in Section 3.3.2.c, the gray infrastructure solutions will be evaluated in subsequent watershed planning cycles, as more information is obtained, particularly with respect to the anticipated implementation and performance of green infrastructure.

green and gray infrastructure projects that achieve a higher control than the target level of control.

CSO volumes summarized in Table 3.39 are shown graphically in Figure 3.29. As the figure illustrates, the Integrated Plan for 2025 achieves a similar level of volume reduction as the Traditional Plan, with the exception of the Ohio River where modeling has shown that water quality is relatively insensitive to CSO discharges.

Figure 3.29. CSO Volume by Receiving Water for 2030 Integrated Plan Evaluation Scenarios



3.4.2 Green Infrastructure Project Benefits in Combined System

To quantify the water quality benefits of maximizing green infrastructure in the combined system after the Five-year Improvement Program is completed, hydrographs representing these projects were generated with the hydraulic model and input to the Banklick Creek HSPF watershed model, the Taylor Creek SWMM model and the Lower Licking/Ohio River EFDC model. The effect of the identified green infrastructure projects on the CSO waterways were evaluated with two "green only" scenarios that were analyzed for the following objectives:

- Can SD1 meet water quality standards using green infrastructure alone for the Integrated Plan? The models were run with the CSO volume

remaining after implementing the green infrastructure projects; all other sources were not included.

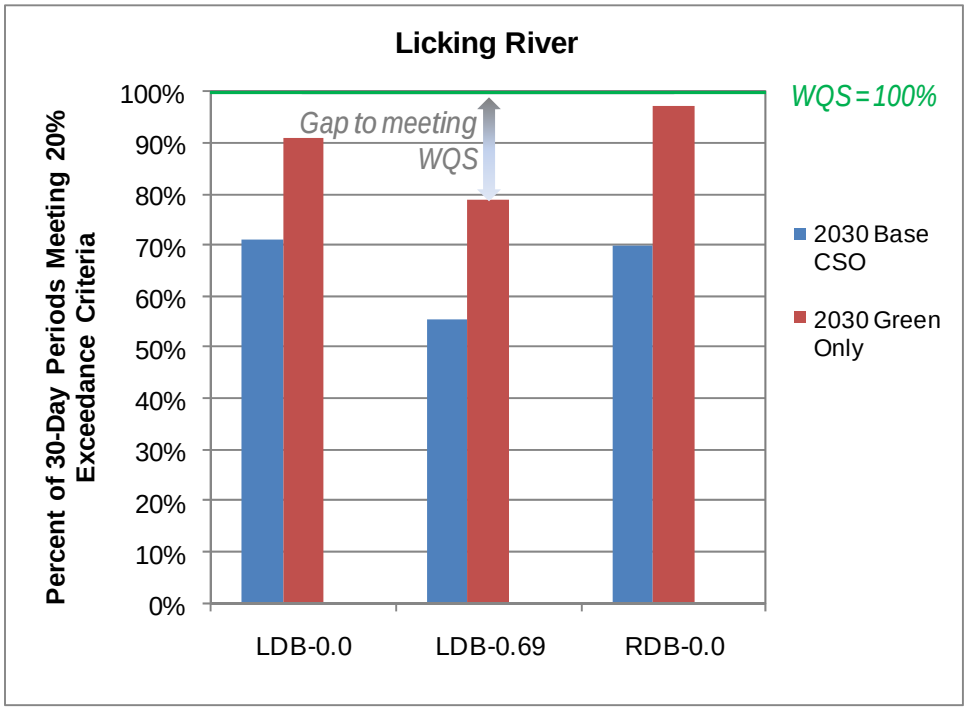
- How much water quality benefit can be obtained from green infrastructure? The models were run with pollutant loads from all sources (except SSOs, which were assumed to be eliminated), including CSO volume remaining after green infrastructure projects, and benefit was based on reductions in recreation season geometric mean density.

3.4.2.a Comparison to Water Quality Standards- Green Infrastructure

The model results for the "Green Only" scenario were compared to the baseline "No CSO control" scenario to quantify how much incremental benefit results from the green infrastructure projects. Both scenarios were compared to the KDOW 30-day maximum water quality standard to evaluate progress towards meeting the water quality criteria.

Results are shown at three locations in the Licking River in Figure 3.30. These three locations are locations where the baseline "No Control" scenario indicated water quality is most impacted from SD1's CSOs.

Figure 3.30. Percentage of 30-day Periods Meeting 30-Day Maximum Water Quality Standard Criteria in Licking River



Note: The locations shown on the x-axis are:
LDB-0.0 is the left descending bank (west bank) at river mile 0 (the mouth).
LDB-0.69 is the left descending bank at river mile 0.69.

RDB-0.0 is the right descending bank (east bank) at river mile 0 (the mouth).

As this figure illustrates, green infrastructure projects applied to the CSOs discharging to the Licking River improves compliance by 20-30 percent. However, green infrastructure alone does not meet the criteria at all times. This indicates that additional gray infrastructure is needed to reduce CSOs to help attain current water quality standards.

Results are shown for key locations in each waterway in Table 3.40.

Table 3.40. Percentage of 30-day Periods Meeting the 30-Day Maximum Water Quality Standard Criteria

Waterway	Location	2030 Baseline CSO	2030 Green Only CSO
Licking River	LDB RM 0.0	71%	91%
	LDB RM 0.69	56%	79%
	RDB RM 0.0	70%	97%
Banklick Creek	RM 1.2	100%	100%
	RM 0.5	95%	100%
	RM 0.0	95%	100%
Ohio River	LDB RM 469.90	100%	100%
	LDB RM 470.32	98%	100%
	LDB RM 471.2	88%	100%
Taylor Creek	Mouth (RM 0)	98%	100%

Results in Banklick Creek, Taylor Creek and the Ohio River show that these waterways meet the 30-day maximum criterion with the green infrastructure projects (after implementing the Five-year Improvement Program described in Section 7). This suggests that the Five-year Improvement Program and green infrastructure projects may provide sufficient control to meet water quality standards in these waterways. In Banklick Creek, however, the Five-year Improvement Program and green infrastructure projects have a higher number of CSO activations (38 overflows/year) than the target level of control (24 overflows/year). The Integrated Plan CSO solution simulated for Taylor Creek uses the results from the Five-year Improvement Program and green infrastructure projects. However, because the Licking River CSOs require additional gray infrastructure to achieve the necessary level of control and these waterways (and the Ohio River CSOs) are in close proximity to the Licking River CSOs, gray infrastructure controls were developed for these CSOs for the Integrated Plan (described in Section 3.3.2.c).

3.4.2.b Green Infrastructure Benefits

The benefits of green infrastructure projects were assessed by running the models with all of the pollutant sources included. These simulations put the benefits of green infrastructure projects into context with the other sources.

Benefits were assessed with the recreation season geometric mean density evaluation metric. Results are compared to the 2030 Baseline No Control scenario. Both simulations assume SSOs are eliminated.

Figure 3.31 shows the results for Banklick Creek. Because green infrastructure projects were maximized in the CSS area, instream benefits are limited to the portion of the stream adjacent to the CSOs, near the downstream end of the creek. Note that despite decreasing the CSO volume by 35 percent (system-wide, ~50% in Banklick Creek watershed based on Church St. project described in Section 7), the geometric mean density decreases by 12 percent (~82 cfu/100 ml) as a result of implementing green infrastructure projects during and after the Five-year Improvement Program is completed. This suggests that targeting control of other sources in the watershed may yield more benefit than overflow control alone.

Figure 3.31. Fecal Coliform Recreation Season Geometric Mean Density Results for Baseline and Green Infrastructure Scenarios in Banklick Creek

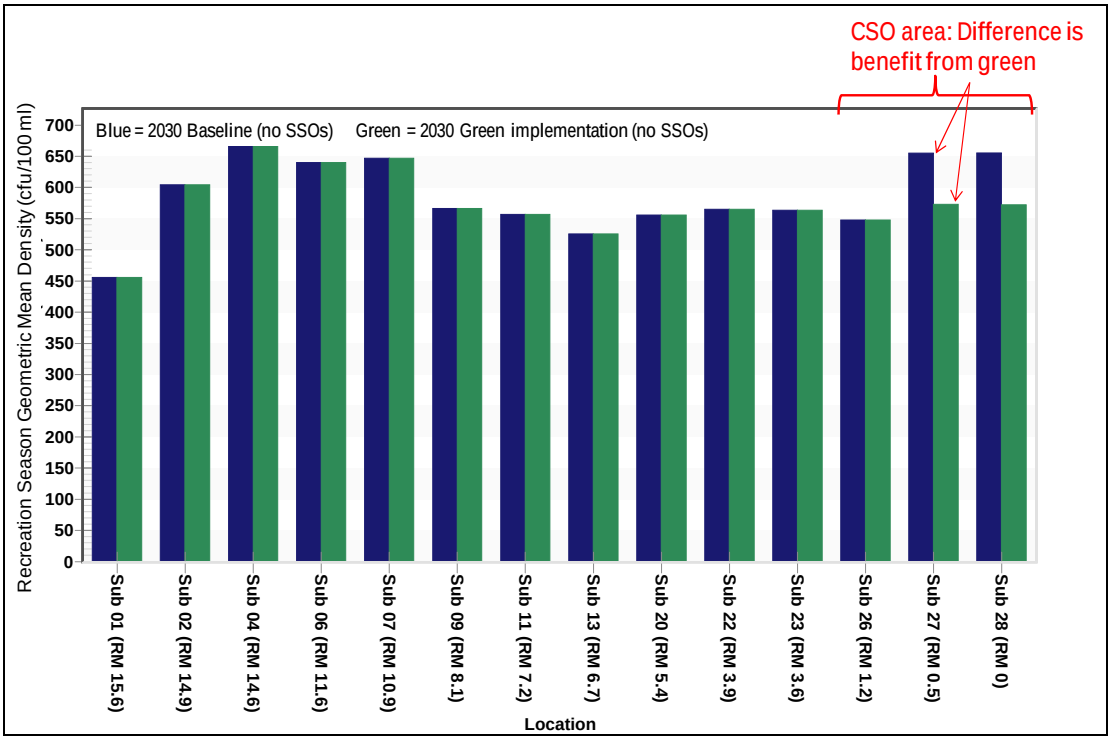


Figure 3.32 and Figure 3.33 compare the fecal coliform recreation season geometric mean density along the left descending bank and mid-channel of the Licking River, respectively. Benefits of CSO control are highest along the banks of the river rather than mid-channel.

Figure 3.32. Comparison of Fecal Coliform Recreation Season Geometric Mean Density in the Left Descending Bank of the Licking River

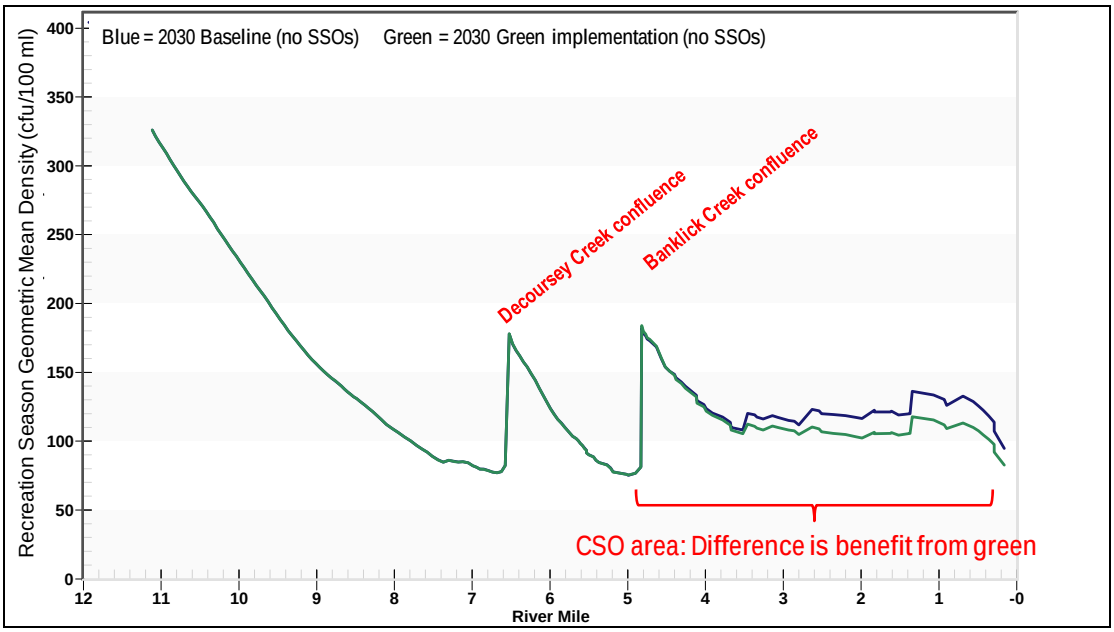
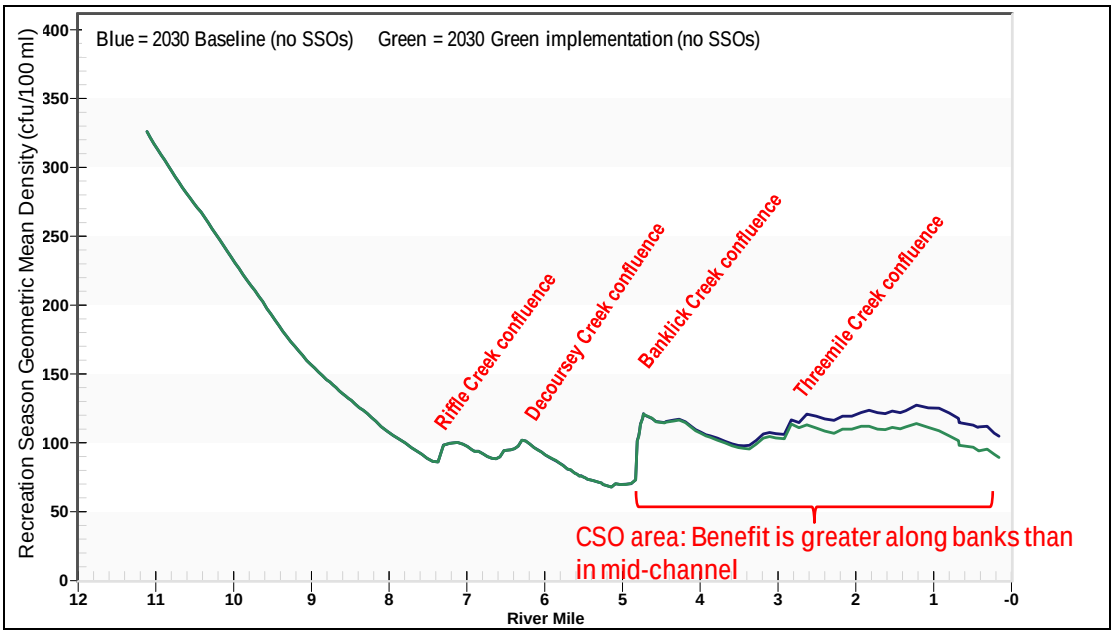


Figure 3.33. Comparison of Fecal Coliform Recreation Season Geometric Mean Density in the Mid-Channel Portion of the Licking River



The green infrastructure projects reduce the recreation season geometric mean density by 12 percent on average, decreasing from a riverwide average of 124 cfu/100 ml to 109 cfu/100 ml. Reductions at individual locations (e.g. model grid cells) ranged from four percent to 24 percent.

The green infrastructure scenario has approximately five extra days per year when the daily average density is less than 400 cfu/100 ml (during the recreation season) compared to the baseline "no control" scenario in Banklick Creek and the Licking River. The number of days when the daily average density is less than 400 cfu/100 ml (during the recreation season) increases by a maximum of 2.5 days in Ohio River.

Results from the green infrastructure scenario indicate that green infrastructure not only significantly reduces CSO volume, but also provides improvements in water quality in the waterways receiving CSO discharges. However, to comply with current water quality standards, additional gray infrastructure controls are needed. Better water quality benefit may be obtained by targeting control of non-overflow sources in the watersheds.

3.4.3 Integrated Plan Benefits

To quantify how the Integrated Plan in the combined system meets the water quality-based requirements of the CSO Control Policy, hydrographs representing the Integrated Plan were generated with the hydraulic model and input to the Banklick Creek HSPF watershed model, the Taylor Creek SWMM model and the Lower Licking/Ohio River EFDC model. (Note: CSOs in Fourmile and Pleasant Run Creeks were input directly to the Ohio River in the modeling runs because their proximity to the mouths of the creeks limits their impact on creek water quality).

The effect of the CSO solution (identified green infrastructure projects and gray infrastructure controls) on the CSO waterways were analyzed with two Integrated Plan scenarios for the following objectives:

- Will the CSO solution for the Integrated Plan, which includes both green and gray infrastructure, meet the water quality criteria? The models were run with the CSO volume remaining after implementing the Integrated Plan projects in the CSS area. Other sources were not included.

- How much water quality benefit can be obtained from the Integrated Plan compared to a traditional overflow-control-only scenario? The models were run with pollutant loads from all sources (except SSOs, which were assumed to be eliminated) and benefit was based on reductions in recreation season geometric mean density and increases in days with average fecal coliform density less than 400 cfu/100 ml. CSOs were simulated with the Integrated Plan solution and compared

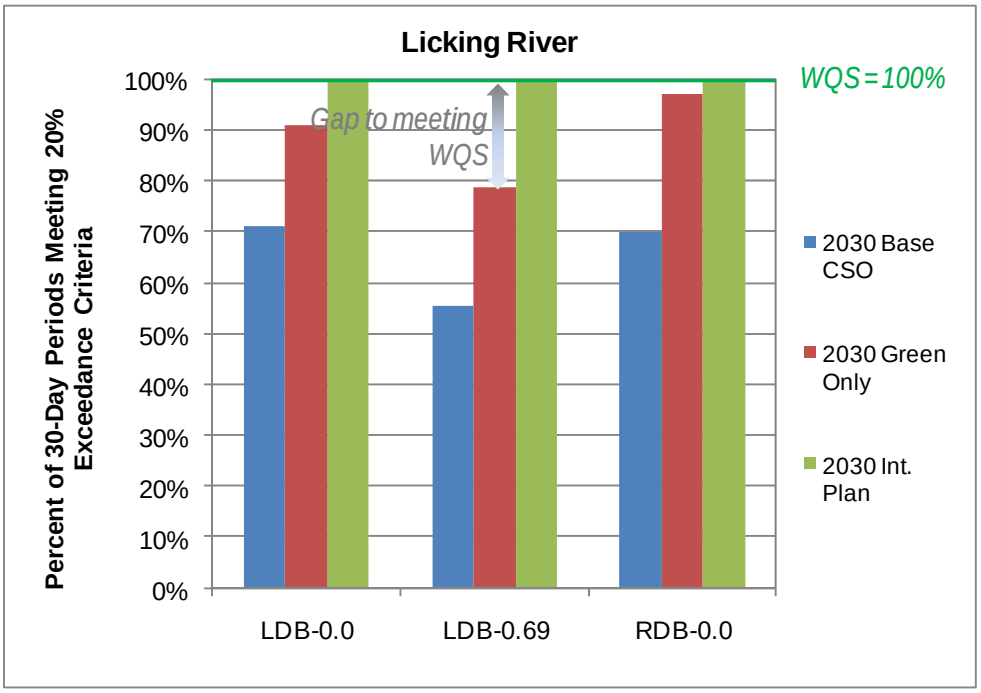
to a Traditional Plan with CSOs simulated at 4 overflows/year. Watershed controls and Policy/Regulation effects were included in the Integrated Plan but not in the Traditional Plan, which is overflow-focused.

3.4.3.a Comparison to Water Quality Standards – Integrated Plan

The model results for the Integrated Plan scenario were compared to the baseline "No CSO control" and "Green Only" scenarios to quantify how much incremental benefit results from the Integrated Plan projects. All scenarios were simulated with CSO loads as the only source to the waterways. Results were compared to the KDOW 30-day water quality standard. This analysis builds on the analysis presented in Section 3.4.2.a.

Results are shown at three locations in the Licking River in Figure 3.34. These three locations are locations where the Baseline "No control" scenario indicated water quality is most impacted from SD1's CSOs.

Figure 3.34. Percentage of 30-day Periods Meeting the 30-Day Maximum Water Quality Standard Criteria in Licking River (CSO Sources Only).



Note: The locations shown on the x-axis are:
LDB-0.0 is the left descending bank (west bank) at river mile 0 (the mouth).
LDB-0.69 is the left descending bank at river mile 0.69.
RDB-0.0 is the right descending bank (east bank) at river mile 0 (the mouth).

As this figure illustrates, green infrastructure projects in the CSOs discharging to the Licking River improves compliance by 20 to 30 percent. However, green infrastructure alone does not meet the criteria at all times. Once the

gray infrastructure is added to the solution, CSOs meet the criteria at all times.

Results are shown for key locations in each waterway in Table 3.41.

Table 3.41. Percentage of 30-day Periods Meeting the 30-Day Maximum Water Quality Standard Criteria (CSO Sources Only)

Waterway	Location	2030 Base CSO	2030 Green Only	2030 Integrated Plan
Licking River	LDB RM 0.0	71%	91%	100%
	LDB RM 0.69	56%	79%	100%
	RDB RM 0.0	70%	97%	100%
Banklick Creek	RM 1.2	100%	100%	100%
	RM 0.5	95%	100%	100%
	RM 0.0	95%	100%	100%
Ohio River	LDB RM 469.90	100%	100%	100%
	LDB RM 470.32	98%	100%	100%
	LDB RM 471.2	88%	100%	100%
Taylor Creek	Mouth (RM 0)	98%	100%	100%

As this table illustrates, all of the CSO waterways will meet the water quality-based requirements in the CSO Control Policy once the Integrated Plan is implemented.

3.4.3.b Water Quality Benefits of Integrated Plan Compared to Traditional Solution

This section describes the benefits of the Integrated Plan relative to a baseline "no control" scenario and to a more traditional overflow control scenario. The Traditional Plan scenario is based on the full system solution concept presented in Appendix 3-A where CSOs were controlled system-wide to four overflows/year and SSOs were controlled to a five-year level of service.

Results from each model are described in detail separately below. However, taken collectively, the following observations are consistent throughout the models:

- Although the traditional solution results in less CSO volume than the Integrated Plan (124 MG/yr vs. 178 MG/yr on average over the five-year typical period), the Integrated Plan results in more or equal water quality benefit (using both days less than 400 cfu/100 ml and recreation season geometric mean density as evaluation criteria). These results are summarized in Table 3.42.

Table 3.42. Water Quality Benefits Comparison for the No Control, Integrated Plan and the Traditional Plan Scenarios in CSO Waterways

CSO Waterway	Number of Days in Recreation Season Less Than 400 cfu/100 ml (Count of Days)			Recreation Season Geometric Mean Fecal Coliform Density (cfu/100 ml)		
	Baseline (No Control)	Traditional Plan	Integrated Plan	Baseline (No Control)	Traditional Plan	Integrated Plan
Banklick Creek	67	84	108	1,080	556	310
Licking River	111	121	122	136	105	96
Taylor Creek	5.5	5.5	6.3	2,628	2,572	2,224
Ohio River	150	157	156	14	6	7

Notes:

1. Results for each waterway are the average results for the CSO portion of the waterway. Results for the Ohio River are provided at river mile 471.3, just downstream of the Willow Run CSO and corresponds to the location where the largest CSO impact on the Ohio River occurs.
2. There are 184 days in the Recreation Season (May 1 through October 31, inclusive).
3. Model results are shown for the 2030 future complete build-out condition.
4. The Ohio River model simulations did not include loads from upstream or Ohio-side sources.

- Because the Integrated Plan addresses other sources that limit the benefit of overflow control, the Plan provides more water quality benefit in watersheds that do not have CSOs discharging to their waterways. These results are summarized in Table 3.43.

Table 3.43. Water Quality Benefits Comparison for the No Control, Integrated Plan and the Traditional Plan Scenarios in non-CSO Waterways

Waterway	Number of Days in Recreation Season Less Than 400 cfu/100 ml (Count of Days)			Recreation Season Geometric Mean Fecal Coliform Density (cfu/100 ml)		
	Baseline (No Control)	Traditional Plan	Integrated Plan	Baseline (No Control)	Traditional Plan	Integrated Plan
Fourmile Creek	102	109	110	446	323	305
Pleasant Run Creek	92	92	94	387	385	364
Twelvemile Creek	103	103	104	329	329	315
Threemile Creek	77	79	81	517	492	464
Dry Creek	83	88	90	514	426	402
Elijahs Creek	118	118	119	250	250	245
Sand Run	83	83	84	488	484	467

Notes:

1. Model results are shown for the 2030 future complete build-out condition.
2. Results for these waterways are provided at the mouth of the waterway. Results are not shown for Big Bone Creek, Gunpowder Creek or Woolper Creek because the models representing these areas are still being constructed and verified.
3. There are 184 days in the Recreation Season (May 1 through October 31, inclusive).

- Results of the water quality standards comparison are summarized in Table 3.44 for the 30-day maximum fecal coliform water quality standard criterion. These simulations were conducted assuming all sources were present (with the exception of the Ohio River where sources outside of the SD1 service area were neglected). Because the Integrated Plan addresses other sources that enhance the benefit of overflow control, the Plan meets the water quality-based requirements in the CSO Control Policy (e.g. meeting water quality standards) more frequently than the Traditional Plan with the exception of Taylor Creek and the Ohio River. Taylor Creek does not meet the criteria at any time for all three scenarios because loads from dry weather sources drive compliance with the 30-day criterion in that watershed.

Table 3.44. Comparison to 30-Day Maximum Fecal Coliform Water Quality Standard for the No Control, Integrated Plan and the Traditional Plan Scenarios

Waterway	Percent of 30-day Periods Meeting the 30-Day Maximum Fecal Coliform Water Quality Standard (Percent of 30-Day Periods)		
	Baseline (No Control)	Traditional Plan	Integrated Plan
Banklick Creek	1.5%	2.8%	8.2%
Licking River	31.8%	44.9%	46.1%
Taylor Creek	0	0	0
Ohio River	79.6%	83.4%	82.5%
Fourmile Creek	15.4%	15.4%	19.2%
Pleasant Run Creek	14.2%	14.2%	16.4%
Twelvemile Creek	13.0%	13.0%	14.1%
Threemile Creek	3.4%	3.4%	3.7%
Dry Creek	1.8%	1.8%	3.9%
Elijahs Creek	32.3%	32.3%	34.2%
Sand Run	2.7%	2.7%	3.9%

Notes:

1. The KDOW 30-day Maximum Water Quality Standard criterion is that no more than 20% of values within a 30-day period (recreation season) may exceed 400 cfu/100 ml. The equivalent ORSANCO standard was used for the Ohio River and states that no more than 10% of values within a 30-day period (recreation season) may exceed 400 cfu/100 ml.
2. Results for each waterway are provided at the mouth of the waterway. Results for the Ohio River are provided at river mile 471.3, just downstream of the Willow Run CSO and corresponds to the location where the largest CSO impact on the Ohio River occurs.
3. There are 154 30-day periods in the Recreation Season (May 1 through October 31, inclusive).
4. Model results are shown for the 2030 future complete build-out condition.
5. Results are not shown for Big Bone Creek, Gunpowder Creek or Woolper Creek because the models representing these areas are still being constructed and verified.

- The combination of CSO and watershed controls in the Integrated Plan result in more improvements in water quality benefit along more stream miles than the Traditional Plan, as shown in Table 3.45. (Benefit was defined as stream miles that would be impacted by gray, green, or watershed controls).

Table 3.45. Stream Miles Improved Under the Integrated Plan, the Traditional Plan and No Control Scenarios

Waterway	Stream Miles Improved by Control Measures	
	Traditional Plan	Integrated Plan
Banklick Creek	1	19.1
Licking River	4.8	9.2
Taylor Creek	0.2	2.5
Ohio River	55.4	73.0
Fourmile Creek	2.1	9.5
Pleasant Run Creek	0.7	3.4
Twelvemile Creek	0	10.4
Threemile Creek	0	4.3
Dry Creek	0	7
Elijahs Creek	0	4
Sand Run	0	5.8
Total	**64.2**	**148.2**

Notes:

1. SSOs are eliminated in the comparison of the scenarios.
2. Model results are shown for the 2030 future complete build-out condition.
3. Results are not shown for Big Bone Creek, Gunpowder Creek or Woolper Creek because the models representing these areas are still being constructed and verified.
4. Results for the Ohio River were calculated as the streamwise distance between the downstream extent of the study area (river mile 516.6 at the Boone County line) and the most upstream control for each scenario."

- The combination of CSO and watershed controls in the Integrated Plan result in more qualitative benefits (that are difficult to measure quantitatively) than the Traditional Plan, as shown in Table 3.46.

Table 3.46. Comparison of Non-Quantitative Benefits of Integrated Plan and Traditional Solution

Evaluation of	Factor[2]	Metric[1]	Traditional Solution[3]	SD1 Integrated Plan[3]
System performance	3	Maximization of existing treatment capacity	++	+
	4	Reduction in surface runoff contribution to the combined system	-	+
	3	Reduction in number of overflow events	++	+
	3	Reduction in overflow volume	++	+
	3	Enhancement of Nine Minimum Controls program	++	+
Bacteria reduction	4	Overall watershed reduction of instream bacteria densities	+	++
	3	Increased attainment of bacteria water quality criteria	+	++
	4	Percent bacteria load reduction by watershed	+	++
	4	Length of stream reach with reduced bacteria densities	+	++
Cost	6	Construction cost vs. water quality improvement	+	++
	6	Construction cost vs. all benefits	+	++
	6	Capital cost	n/a[3]	n/a[3]
	6	Annual operations and maintenance cost	n/a[3]	n/a[3]
Ecological, human health and other additional benefits	2	Reduction in public health risk	+	++
	1	Reduction in flooding and increase in infiltration	-	++
	1	Improvements in aquatic habitat and biological scores	-	+
	1	Stabilization of streambanks to reduce erosion	-	+
	1	Reductions in other pollutants or water quality violations	+	++
	1	Preservation of green space	-	+
	1	Provide opportunities to connect public lands/greenways	-	+
	5	Provide opportunities for community involvement and partnering	-	+

Notes:

[1] The scoring system used in this table was:

+ = the metric is improved by the solution type

++ = in instances where both solution types improve the metric, this score is used to indicate the more effective solution type

- = the metric is not addressed by the solution type

n/a = the metric was not evaluated.

[2] The Factors in Table 3.47 are matched against the factors from the Consent Decree (IV.D.39) defined as follows:

1 Environmental impact
2 Public risk
3 Regulatory requirements
4 Degree of water quality improvement expected to be achieved
5 Public input
6 Cost-effectiveness

[3] A value of n/a indicates that the metric was not evaluated due to uncertainty in the estimated values.

3.4.3.b.1 Water Quality Benefits in Banklick Creek

The Banklick Creek HSPF watershed model was applied to evaluate the relative instream water quality benefits of the Integrated Plan compared to a Baseline "No Control" and to a Traditional Plan. Water quality benefits were based on the fecal coliform recreation season geometric mean density (measure #4 from Section 3.4) and percent of recreation season days where the average density was less than 400 cfu/100 ml (measure #1 from Section 3.4). Model results are shown in Figure 3.35 and Figure 3.36 for recreation season geometric mean density and days less than 400 cfu/100 ml, respectively.

The percent of time that fecal coliform levels are calculated to meet KDOW water quality standards are shown in Figure 3.37 and Figure 3.38. Figure 3.37 shows percent of 30-day periods during the recreation season that meet the Commonwealth's 30-day geometric mean criterion of 200 cfu/100 ml (measure #2 from Section 3.4). Figure 3.38 shows the percent of 30-day periods during the recreation season that meet the Commonwealth's 30-day maximum standard (measure #3 from Section 3.4).

Figure 3.35. Fecal Coliform Recreation Season Geometric Mean Density in Banklick Creek for Integrated Plan, Traditional Plan and No Control Scenarios

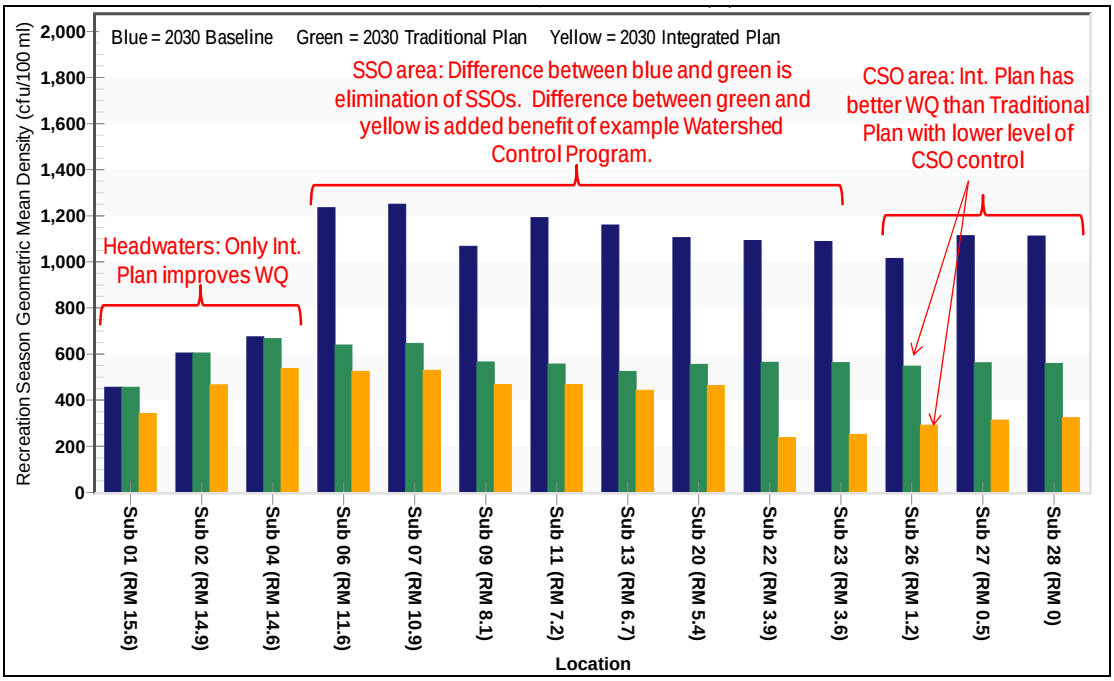


Figure 3.36. Percent of Days During Recreation Season Fecal Coliform Density is Less than 400 cfu/100 ml in Banklick Creek for Integrated Plan, Traditional Plan and No Control Scenarios

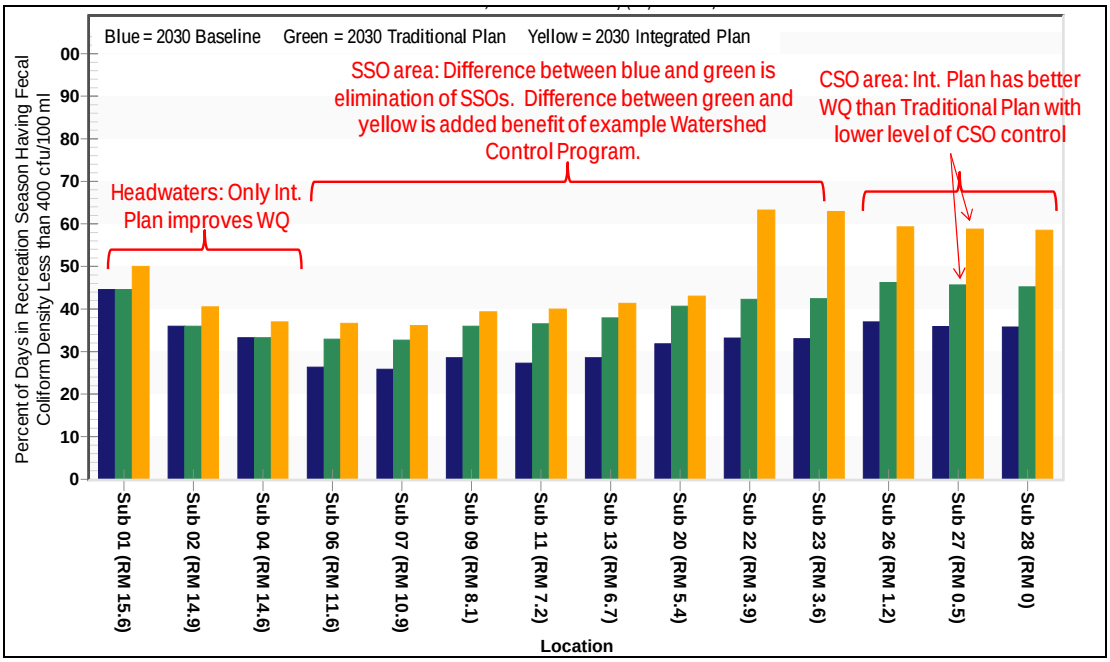
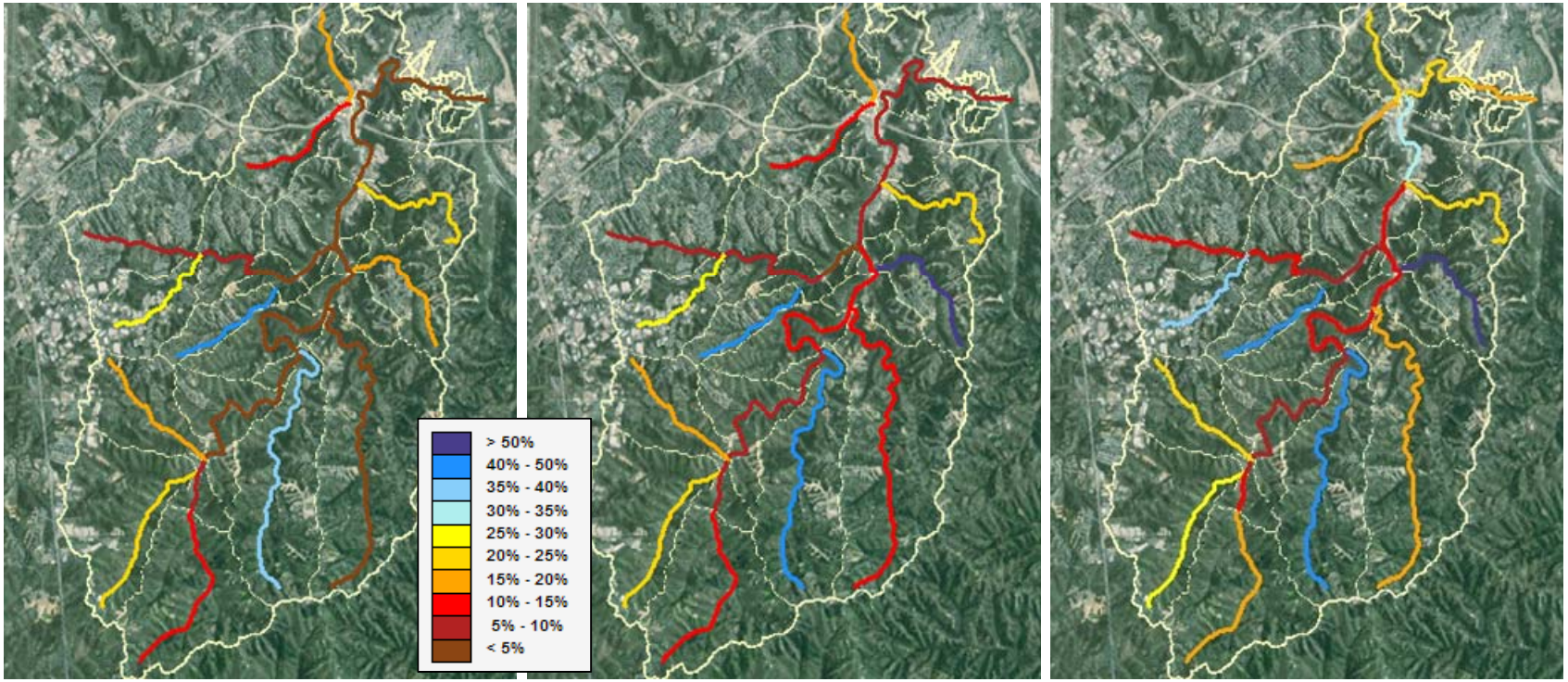


Figure 3.37. Percent of 30-Day Periods During Recreation Season Meeting 30-Day Geometric Mean Density Water Quality Standard in Banklick Creek for Integrated Plan, Traditional Plan and No Control Scenarios



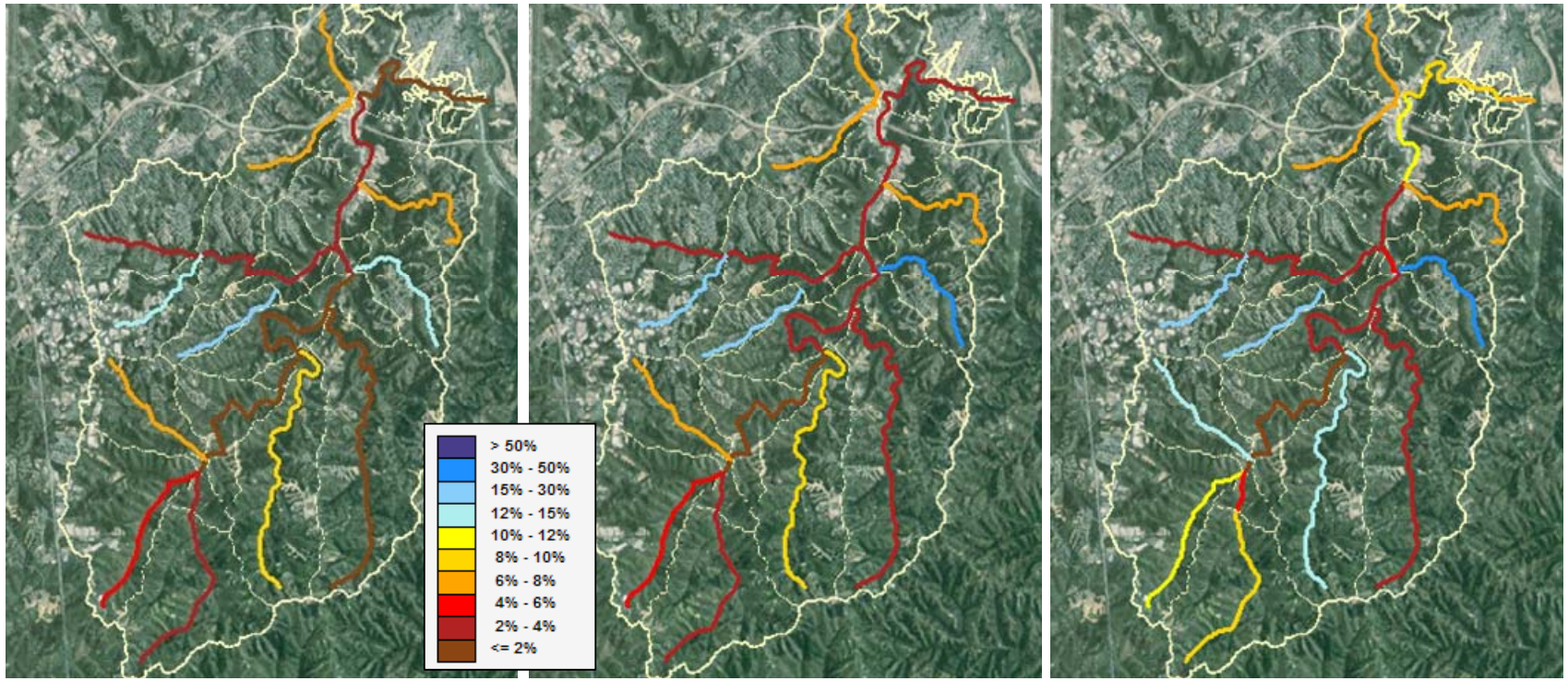
2030 Baseline (No Control)

2030 Traditional Plan (No SSO, CSO at 4 OF/yr)

2030 SD1 Integrated Plan (No SSO, CSO at 12 OF/yr, Watershed Controls)*

Note: * Integrated Plan modeled with 12 overflows/year but equivalent results were obtained with CSOs at 24 overflows/year.

Figure 3.38. Percent of 30-Day Periods During Recreation Season Meeting 30-Day Maximum Water Quality Standard in Banklick Creek for Integrated Plan, Traditional Plan and No Control Scenarios



2030 Baseline (No Control)

2030 Traditional Plan (No SSO, CSO at 4 OF/yr)

2030 SD1 Integrated Plan (No SSO, CSO at 12 OF/yr, Watershed Controls)*

Note: Integrated Plan modeled with 12 overflows/year but equivalent results were obtained with CSOs at 24 overflows/year.

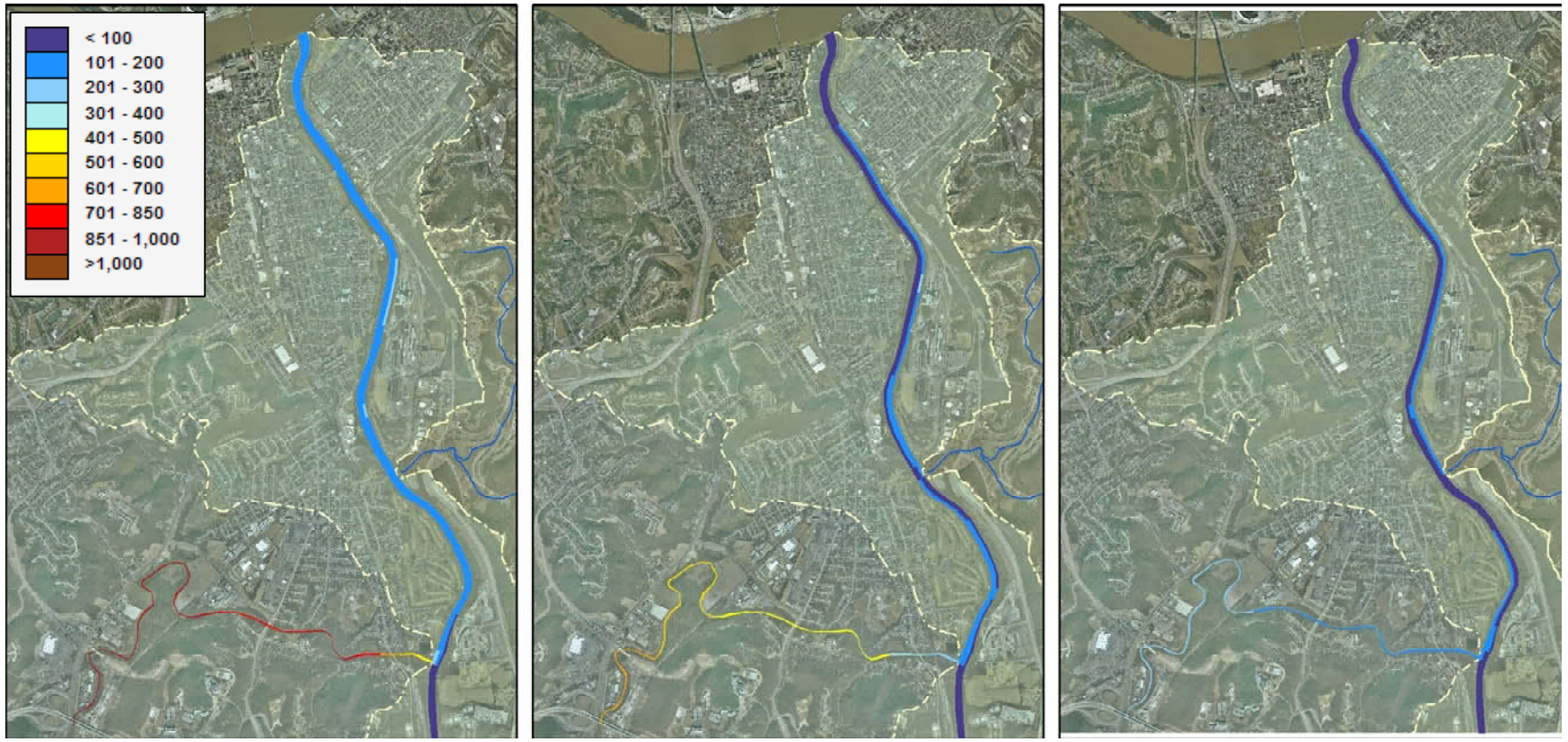
Results show that the Integrated Plan provides greater benefit in Banklick Creek for both criteria along more stream length and provides a greater benefit than a Traditional Plan that is limited to gray infrastructure that targets overflow control alone. The Integrated Plan has a higher frequency of CSO activations (maximum of 12 or 24 overflows/year) than the Traditional Plan (maximum of 4 overflows/year) shown in these figures; however, the water quality benefit is greater throughout the entire stream length due to the inclusion of controls that target other sources in the watershed. These results show that the Integrated Plan offers potentially greater benefit than a Traditional Plan in the Banklick Creek watershed.

3.4.3.b.2 Water Quality Benefits in Licking River

The Lower Licking River EFDC water quality model was applied to evaluate the relative instream water quality benefits of the Integrated Plan compared to a Baseline "No Control" and to a Traditional Plan. Water quality benefits based on the fecal coliform recreation season geometric mean density (measure #4 from Section 3.4) and percent of recreation season days where the average density was less than 400 cfu/100 ml (measure #1 from Section 3.4). Because this model is two-dimensional and represents the Licking River with three lateral segments, model results are shown for recreation season geometric mean density in Figure 3.39 and for percent of recreation season days less than 400 cfu/100 ml in Figure 3.40.

The percent of time that that fecal coliform levels are calculated to meet KDOW's water quality standards are shown in Figure 3.41 and Figure 3.42. Figure 3.41 shows percent of 30-day periods during the recreation season that meet the Commonwealth's 30-day geometric mean criterion of 200 cfu/100 ml (measure #2 from Section 3.4). Figure 3.42 shows the percent of 30-day periods during the recreation season that meet the Commonwealth's 30-day maximum standard (measure #3 from Section 3.4).

Figure 3.39. Fecal Coliform Recreation Season Geometric Mean Density in the Licking River for Integrated Plan, Traditional Plan and No Control Scenarios

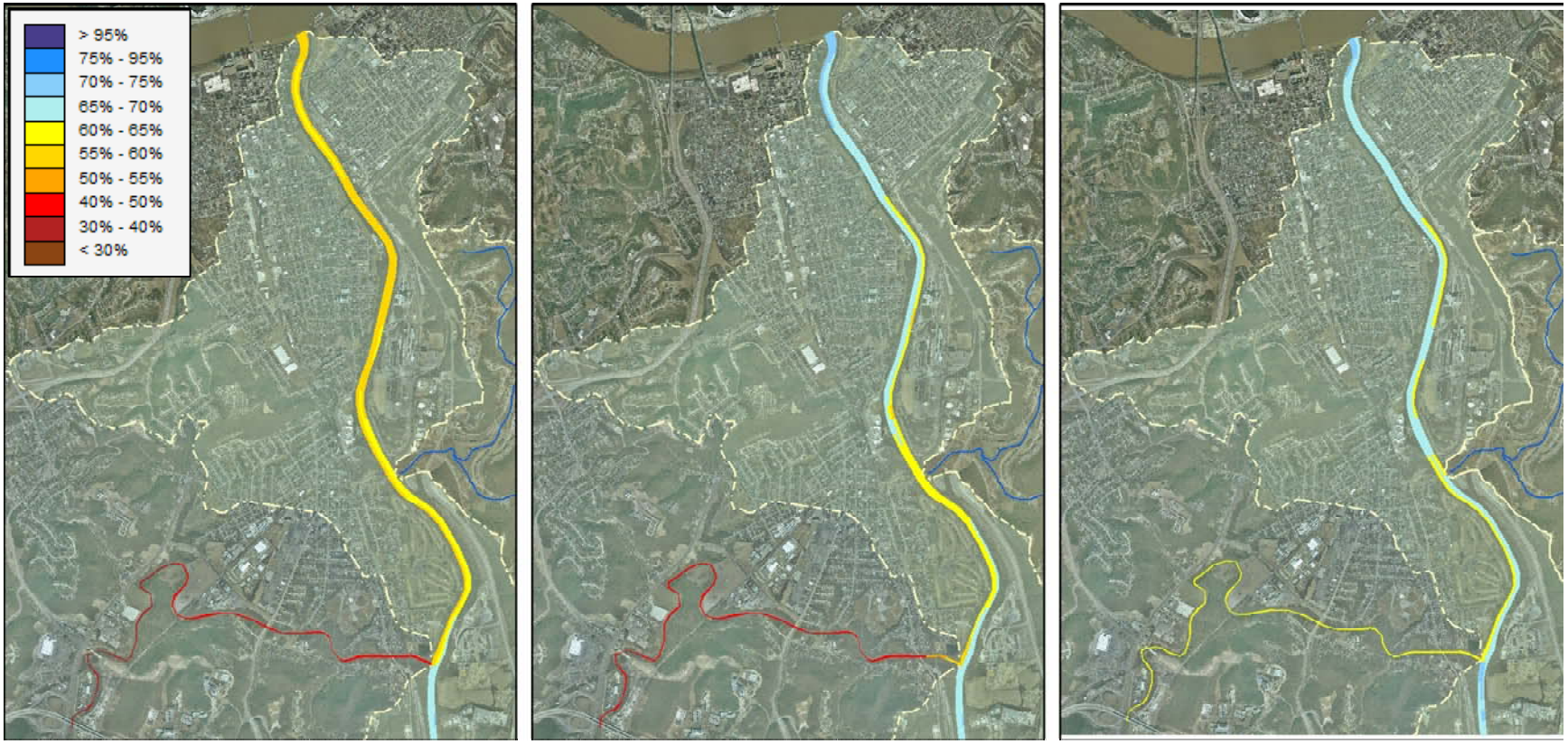


2030 Baseline (No Control)

2030 Traditional Plan (No SSO, CSO at 4 OF/yr)

2030 SD1 Integrated Plan (No SSO, CSO at 17 OF/yr, Watershed Controls)

Figure 3.40. Percent of Days During Recreation Season Fecal Coliform Density is Less than 400 cfu/100 ml in the Licking River for Integrated Plan, Traditional Plan and No Control Scenarios

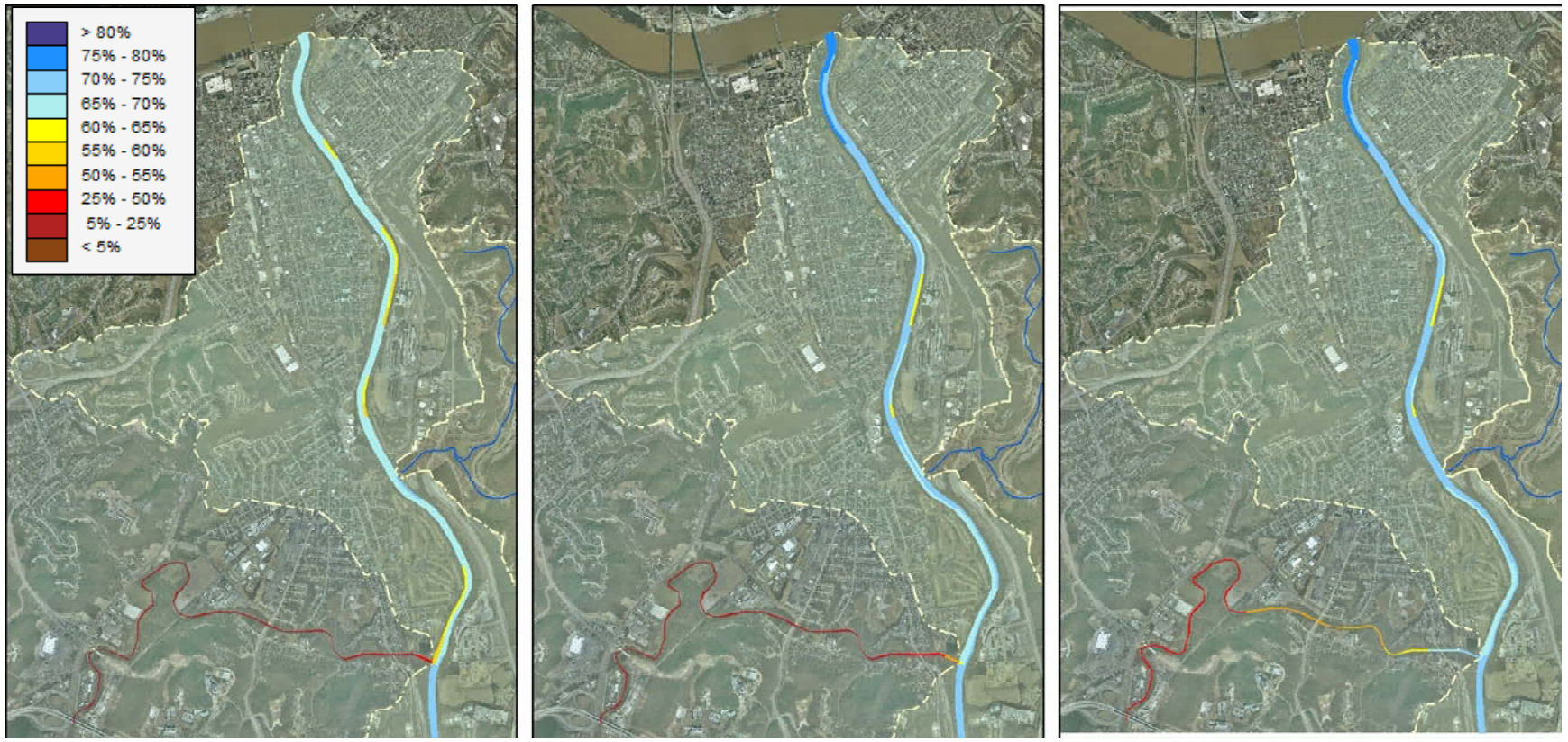


2030 Baseline (No Control)

2030 Traditional Plan (No SSO, CSO at 4 OF/yr)

2030 SD1 Integrated Plan (No SSO, CSO at 17 OF/yr, Watershed Controls)

Figure 3.41. Percent of 30-Day Periods During Recreation Season Meeting 30-Day Geometric Mean Density Water Quality Standard in the Licking River for Integrated Plan, Traditional Plan and No Control Scenarios

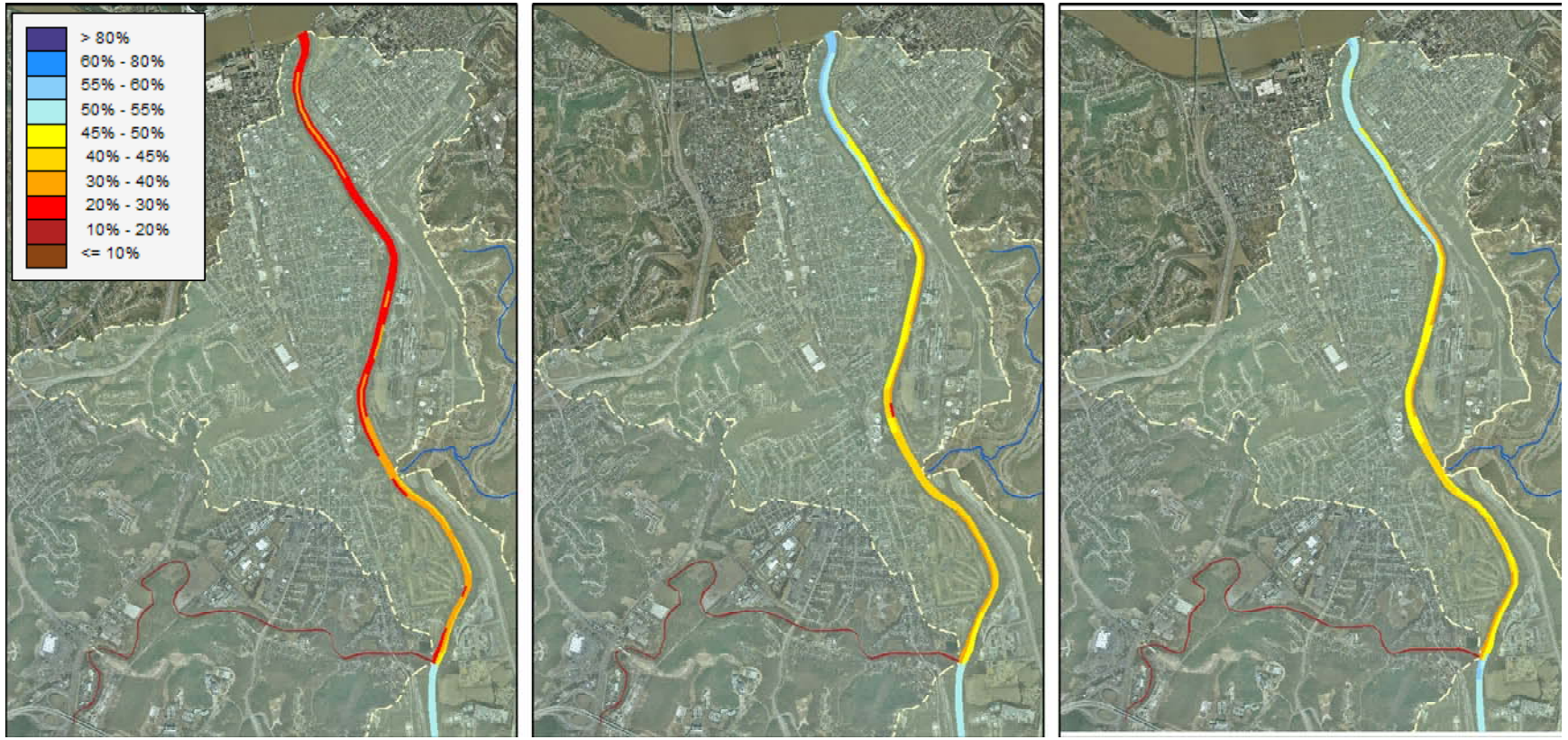


2030 Baseline (No Control)

2030 Traditional Plan (No SSO, CSO at 4 OF/yr)

2030 SD1 Integrated Plan (No SSO, CSO at 17 OF/yr, Watershed Controls)

Figure 3.42. Percent of 30-Day Periods During Recreation Season Meeting 30-Day Maximum Density Water Quality Standard in the Licking River for Integrated Plan, Traditional Plan and No Control Scenarios



2030 Baseline (No Control)

2030 Traditional Plan (No SSO, CSO at 4 OF/yr)

2030 SD1 Integrated Plan (No SSO, CSO at 17 OF/yr, Watershed Controls)

Although the Integrated Plan has a higher frequency of CSO activations (maximum of 18 overflows/year) than the Traditional Plan (maximum of 4 overflows/year), the water quality benefit and compliance with water quality standards is greater throughout nearly the entire stream length due to the inclusion of controls that target other sources in the watershed. Upstream of the CSO area, the Integrated Plan provides more benefit than the Traditional Plan, largely because of planned or recently implemented policies and regulations that address runoff from new development and from storm water controls proposed for existing development in SSES areas. This shows that the Integrated Plan offers potentially greater benefit AND higher compliance with water quality standards than a Traditional Plan in this watershed.

3.4.3.b.3 Water Quality Benefits in Ohio River

The Ohio River EFDC water quality model was applied to evaluate the relative instream water quality benefits of the Integrated Plan compared to a Baseline "No Control" and to a Traditional Plan. Water quality benefits were based on the fecal coliform recreation season geometric mean density (measure #4 from Section 3.4) and percent of recreation season days where the average density was less than 400 cfu/100 ml (measure #1 from Section 3.4).

Because this model is two-dimensional and represents the Ohio River with five lateral segments, model results are shown for the left descending bank (Kentucky bank) only because this is the portion of the model most impacted by SD1 overflows and loads from other watershed sources. Results are shown for the recreation season geometric mean density in Figure 3.43 and days less than 400 cfu/100 ml in Figure 3.44 respectively.

Although the graphics show model simulated results downstream to Markland Dam, the model is not well constrained beyond river mile 490, nor are Kentucky sources downstream of the Woolper Creek confluence (~RM 500). Pollutant loads from the Ohio side of the Ohio River and upstream sources were also not included in the model simulations.

Figure 3.43. Fecal Coliform Recreation Season Geometric Mean Density in the Left Descending Bank of the Ohio River for Integrated Plan, Traditional Plan and No Control Scenarios

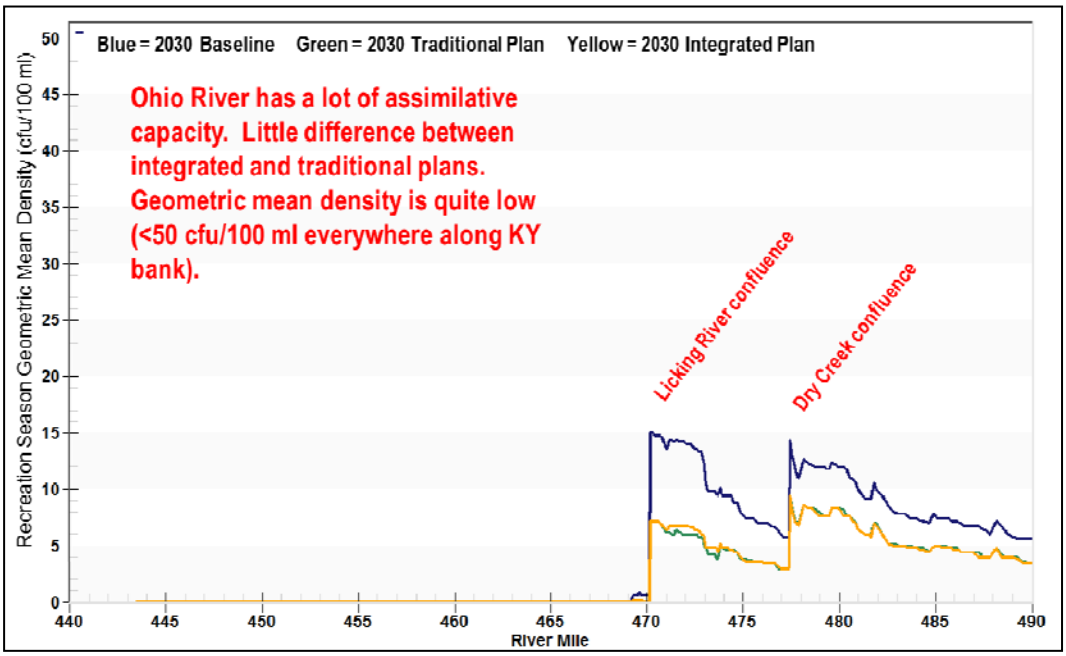
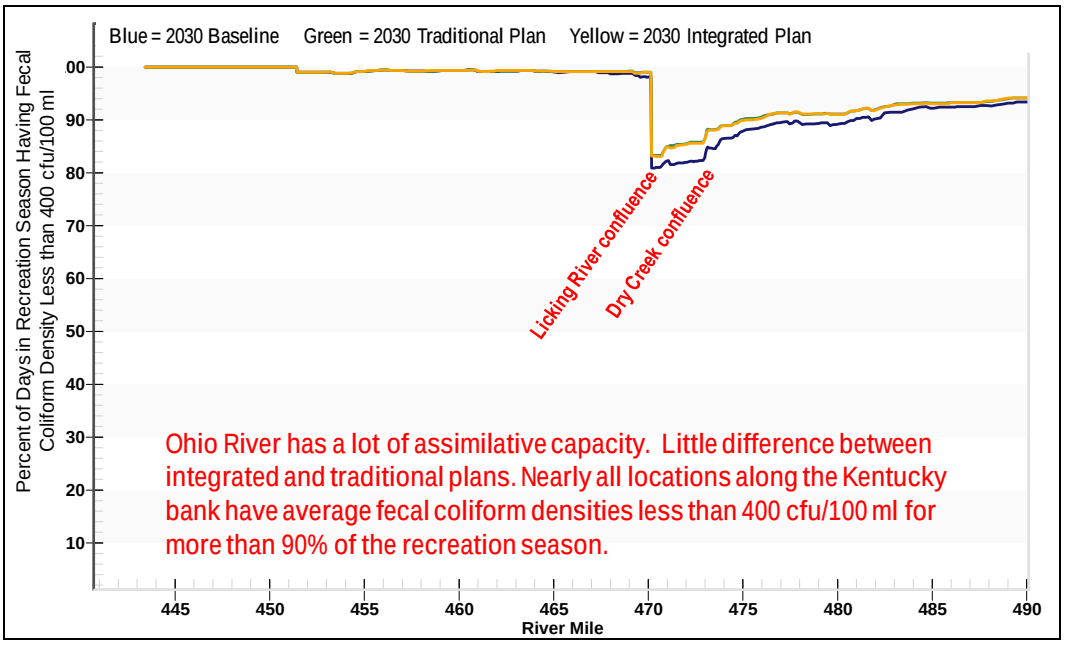


Figure 3.44. Percent of Days During Recreation Season Fecal Coliform Density is Less than 400 cfu/100 ml in Left Descending Bank of the Ohio River for Integrated Plan, Traditional Plan and No Control Scenarios



Results show that the Integrated Plan and Traditional Plan provide comparable benefit for both of the evaluation measures. These results illustrate more effectively that the Ohio River is relatively insensitive to CSO discharges because of the little differences in benefits between the two control plan scenarios. The Integrated Plan has a higher frequency of CSO activations (maximum of 26 to 36 overflows/year) than the Traditional Plan (maximum of 4 overflows/year) shown in these figures, yet the water quality benefit is similar along the entire stream length due to the inclusion of controls that target other sources in the tributary watersheds. This shows that the Integrated Plan offers potentially a more cost-effective benefit than a Traditional Plan in this waterway.

3.4.3.b.4 Water Quality Benefits in Taylor Creek

The Taylor Creek SWMM watershed model was applied to evaluate the relative instream water quality benefits of the Integrated Plan compared to a Baseline "No Control" and to a Traditional Plan. Water quality benefits are based on the fecal coliform recreation season geometric mean density (measure #4 from Section 3.4). Model results are shown in Figure 3.45 for the Taylor Creek mainstem. Figure 3.46 is a map-based comparison that illustrates results in the tributaries.

Figure 3.45. Fecal Coliform Recreation Season Geometric Mean Density in the Taylor Creek for Integrated Plan, Traditional Plan and No Control Scenarios

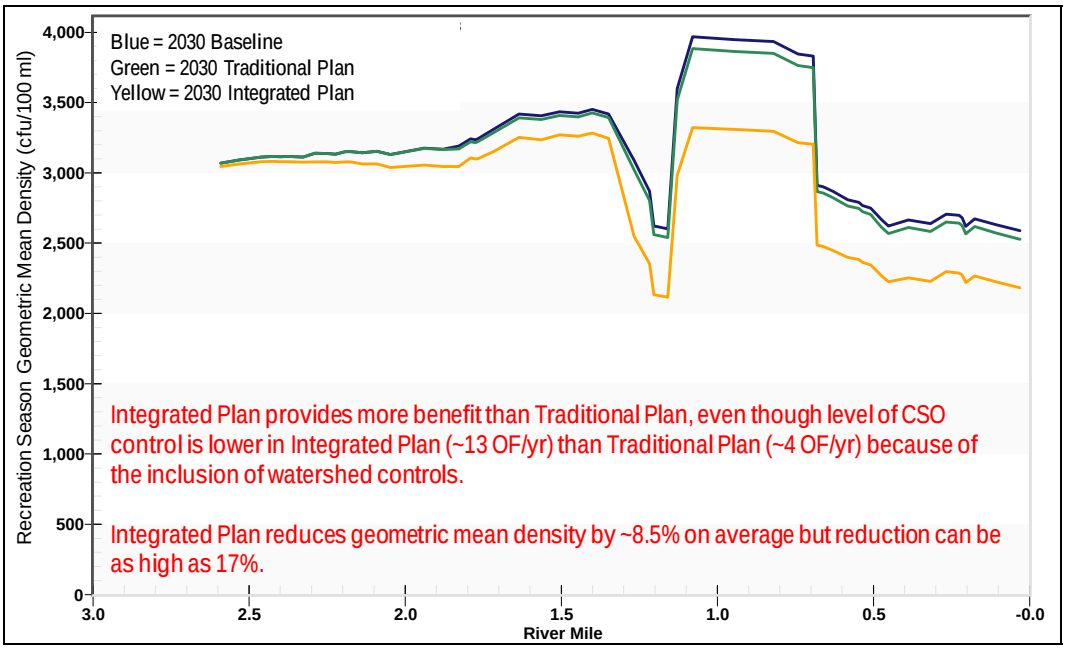
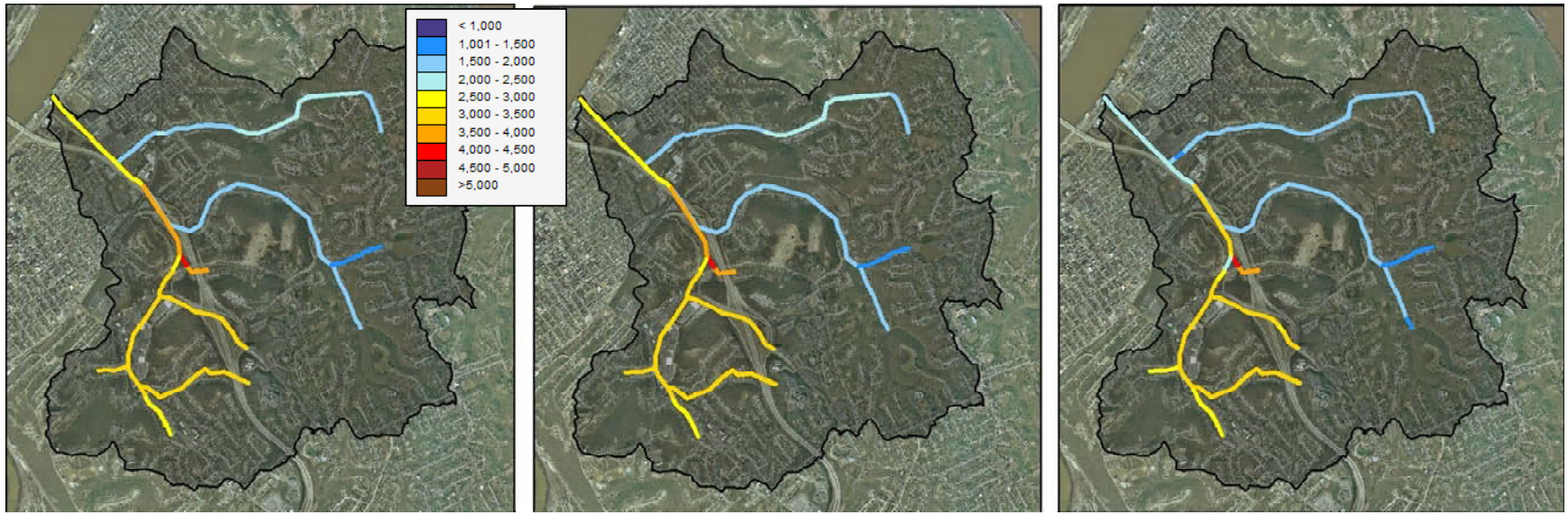


Figure 3.46. Fecal Coliform Recreation Season Geometric Mean Density (cfu/100 ml) in the Taylor Creek for Integrated Plan, Traditional Plan and No Control Scenarios



2030 Baseline (No Control)

2030 Traditional Plan (No SSO, CSO at 4 OF/yr)

2030 SD1 Integrated Plan (No SSO, CSO at 13 OF/yr, Watershed Controls)

* Note: Integrated Plan modeled with 13 overflows/year but equivalent results were obtained with CSOs at 18 overflows/year.

Results show that the Integrated Plan provides benefit along more stream length and provides a greater benefit than a Traditional Plan that is limited to gray infrastructure that targets overflow control alone. The Integrated Plan provides more benefit along the CSO portions of Taylor Creek. The Integrated Plan has a higher frequency of CSO activations (maximum of 18 overflows/year) than the Traditional Plan (maximum of 4 overflows/year) shown in this figure, yet the water quality benefit is greater throughout the entire stream length due to the inclusion of controls that target other sources in the watershed. Similar benefits were observed in the major subwatersheds of Covert Run and Woodlawn Creek.

Outside the CSO area, the Integrated Plan provides more benefit than the Traditional Plan, largely because of planned or recently implemented policies and regulations that address runoff from new development and from storm water controls proposed for existing development in SSES areas. This shows that Integrated Plan offers potentially greater benefit than a Traditional Plan in this watershed.

3.4.3.b.5 Water Quality Benefits in Non-CSO Watersheds

The Integrated Plan was compared to a Baseline "No Control" scenario and a Traditional Plan scenario in the non-CSO watersheds using the Ohio River Tributary HSPF watershed model. Neither the Traditional Plan nor the Integrated Plan include CSO control because there are no CSOs in these watersheds. The Traditional Plan includes SSO elimination only while the Integrated Plan includes both SSO elimination and watershed controls obtained via programmatic and regulatory mechanisms described in Section 3.3.3 and 3.3.4, respectively. Differences between the Integrated Plan and Traditional Plan results reflect the benefits obtained from the initial analysis of controlling sources in the watersheds.

Results for the subwatershed comprising Fourmile Creek are shown in Figure 3.47 for the fecal coliform recreation season geometric mean density evaluation measure (measure #4 from Section 3.4). Results for the subwatersheds comprising Twelvemile Creek are shown in Figure 3.48. Results for the remaining tributaries in this model are shown in Figure 3.49.

Figure 3.47. Fecal Coliform Recreation Season Geometric Mean Density in the Fourmile Creek for Integrated Plan, Traditional Plan and No Control Scenarios

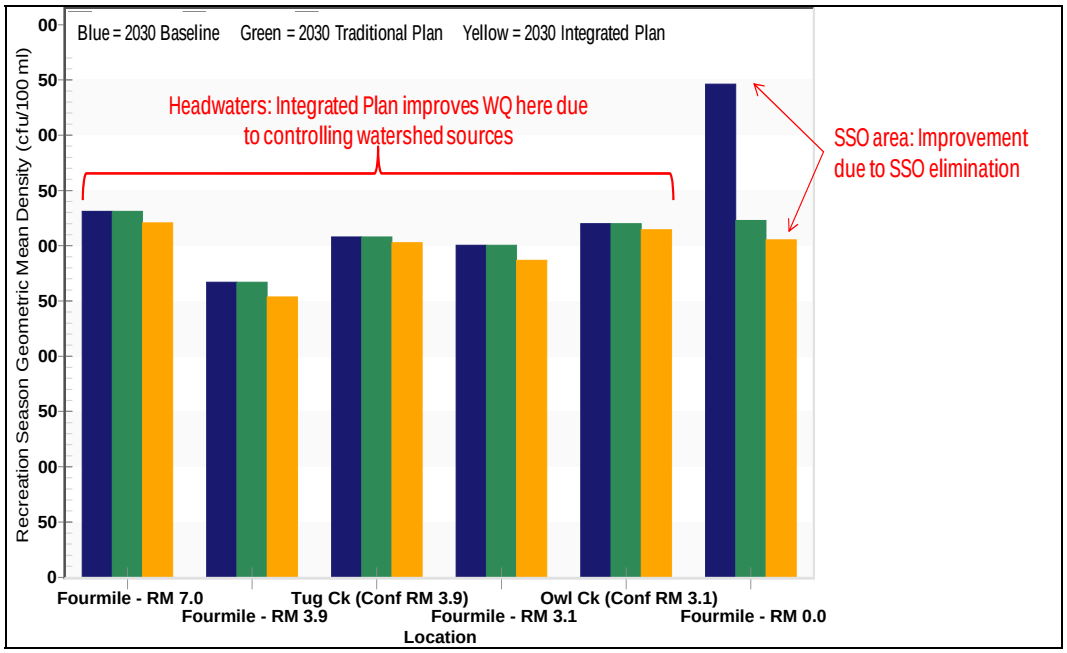


Figure 3.48. Fecal Coliform Recreation Season Geometric Mean Density in the Twelvemile Creek for Integrated Plan, Traditional Plan and No Control Scenarios.

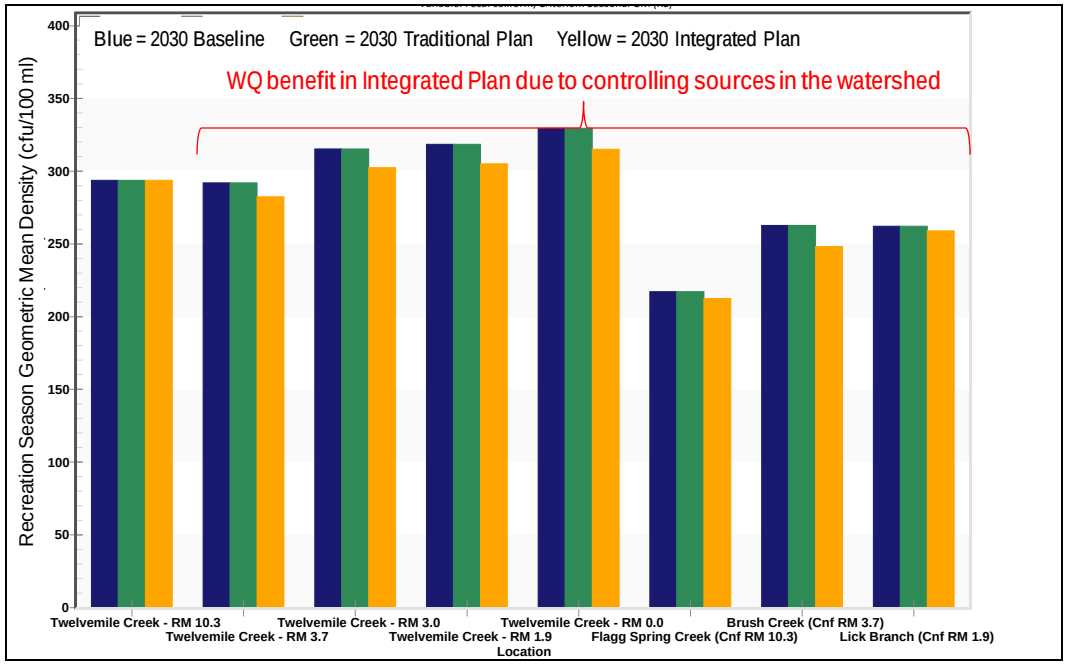
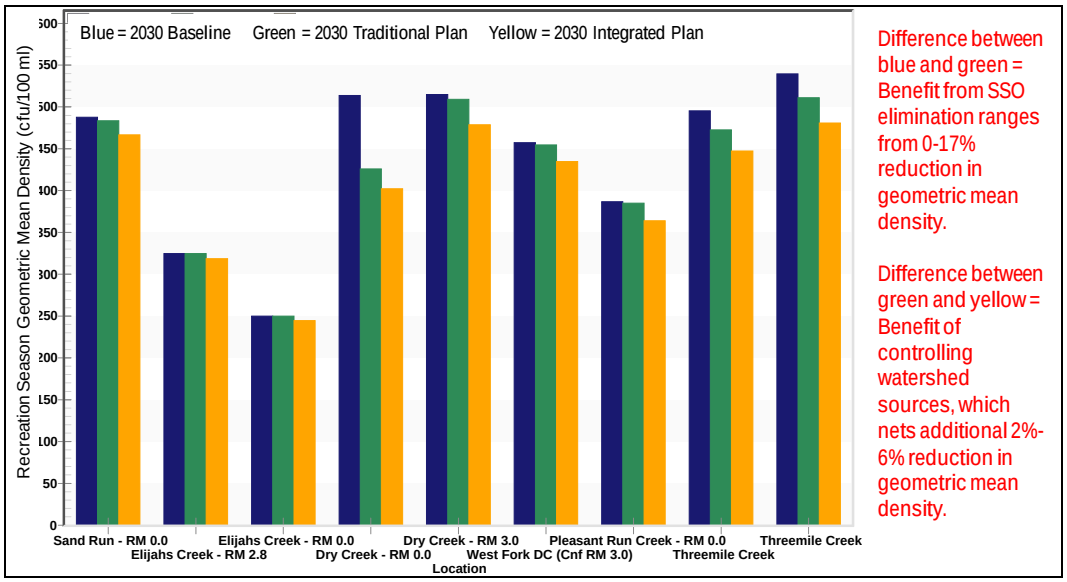


Figure 3.49. Fecal Coliform Recreation Season Geometric Mean Density in the Ohio River Tributaries for Integrated Plan, Traditional Plan and No Control Scenarios



Model results show that water quality benefits vary by watershed. Eliminating SSOs result in reductions in the recreation season geometric mean density between zero percent (some watersheds do not have any SSOs) and approximately 30 percent (Fourmile Creek). Adding in watershed controls results in benefits throughout the watersheds that increase the reduction in geometric mean density from two percent (Elijahs Creek) to six percent (Threemile Creek), depending on the watershed. Results at the mouths of these tributaries are also summarized in Table 3.47.

The Integrated Plan provides more benefit than the Traditional Plan, largely because of planned or recently implemented policies and regulations that address runoff from new development and from storm water controls proposed for existing development in SSES areas.. This shows that the Integrated Plan offers potentially greater benefit in these watersheds than a Traditional Plan that is limited to overflow control alone.

3.4.4 Watershed Program Range of Benefits

Because of the uncertainty in forecasting where specific watershed control projects are cost-effective, SD1 wanted to understand the benefits of the different watershed control programs and regulations separately from the benefits of other controls included in the Integrated Plan. The development of modeling assumptions for the Integrated Plan model simulations was presented in Section 3.3.3 and 3.3.4. These analyses and associated modeling assumptions reflect preliminary analyses of opportunities rather

than discrete projects. The identification and design of actual projects will be conducted in the five-year planning cycles.

Because of the uncertainty in forecasting the benefits of the Watershed Control Program and the effect of new policies and regulations over the next 15-20 years, SD1 conducted a sensitivity analysis that evaluated different implementation assumptions for these components of the Integrated Plan. The portion of the 2030 watershed area represented by controls preliminarily identified in the watershed control programs (e.g. source identification program, SSES program, and green infrastructure) and regulations is provided in Table 3.47. Sensitivity analyses were conducted by approximately doubling and halving the area identified in the initial analysis. In some watersheds, the area could not be doubled if the bulk of the initial controlled area estimate was due to regulating runoff from new development. The actual percent of area "controlled" in each sensitivity analysis is also provided in Table 3.47.

Table 3.47. Portion of Watersheds Modeled with Controls of Watershed Sources in 2030 Model Simulations of Integrated Plan

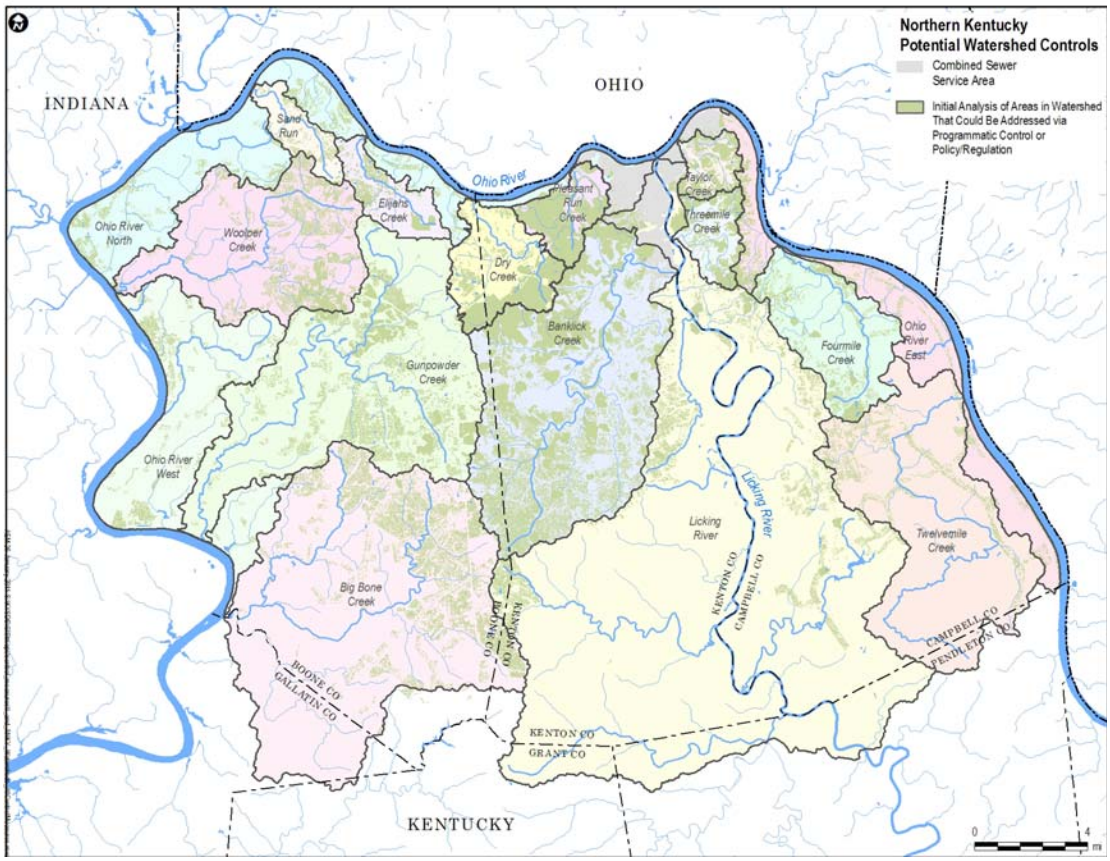
Watershed	Total Watershed Area (acres)	Percent of Watershed Addressed via Watershed Controls and Regulations	Area Addressed in 2X Sensitivity	Area Addressed in 0.5X Sensitivity
Banklick Creek	37,252	43.5%	78.2%	21.7%
Dry Creek	7,929	37.9%	71.9%	18.9%
Elijahs Creek	4,306	22.0%	42.2%	11.0%
Fourmile Creek	11,368	17.6%	33.8%	8.8%
Licking River	108,969	5.0%	7.0%	2.5%
Pleasant Run Creek	4,181	71.9%	94.9%	36.0%
Sand Run	3,173	15.5%	30.2%	7.7%
Taylor Creek	2,708	53.4%	NC	NC
Threemile Creek	3,751	46.4%	79.3%	23.2%
Twelvemile Creek	29,518	6.4%	12.2%	3.2%

Note: The analysis was not conducted in Gunpowder Creek, Big Bone Creek, Woolper Creek or the small watersheds draining directly to the Ohio River because the water quality models are being developed (Gunpowder, Big Bone) or the area is too small relative to the waterway (Ohio River direct drainage) to show any sensitivity to the amount of watershed controls considered.

Figure 3.50 illustrates how the percentages in Table 3.47 were developed. This map does not illustrate specific projects or a commitment to implementing controls to reduce runoff from the areas indicated. Rather, it reflects the cumulative effect of the initial analyses conducted by SD1 to identify potential opportunities, as described in Section 3.3.3 and 3.3.4.

Because of the difficulty in forecasting conditions in 2030 and the need to collect project-based performance data on controls implemented in the first five-year plan, decisions on when and where to implement watershed controls will be determined as part of each five-year planning cycle.

Figure 3.50. Initial Estimate of Watershed Areas Potentially Controlled by Programmatic or Regulatory Initiatives



The Banklick Creek and Ohio River Tributary HSPF watershed models were used in this sensitivity analysis. The area controlled by the Watershed Control Programs and Policies and Regulations were assumed to reduce bacteria densities by 50 percent produced from storm water runoff from the first 0.8 inches of each rainfall event.

Results for Banklick Creek are shown in Figure 3.51. Results for Fourmile Creek are shown in Figure 3.52. Results for the other tributary watersheds in the Ohio River Tributary model are shown in Figure 3.53. Since very little of the area of Twelvemile Creek was considered for watershed source controls, model results from this watershed are not presented.

Figure 3.51. Fecal Coliform Recreation Season Geometric Mean Density in Banklick Creek for Watershed Control Implementation Sensitivity Scenarios

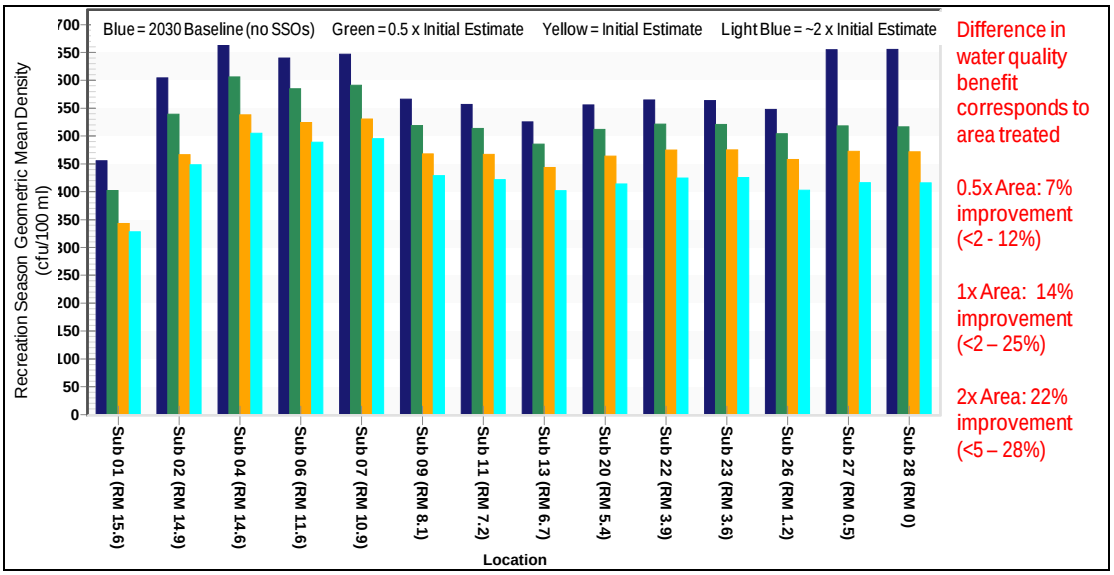


Figure 3.52. Fecal Coliform Recreation Season Geometric Mean Density in Fourmile Creek for Watershed Control Implementation Sensitivity Scenarios

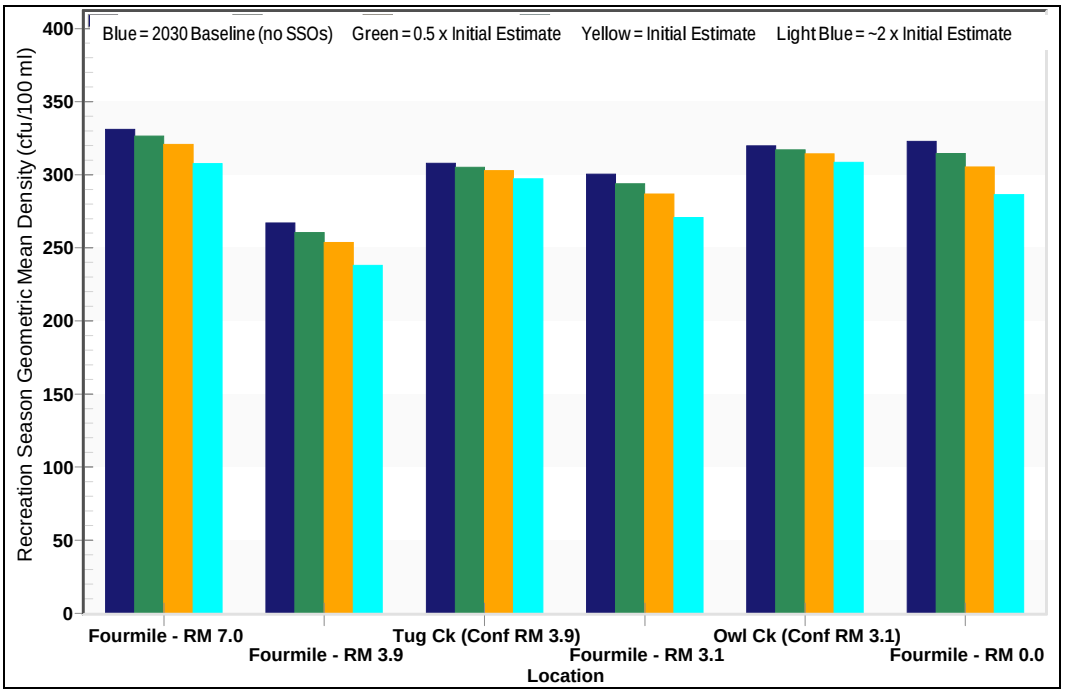
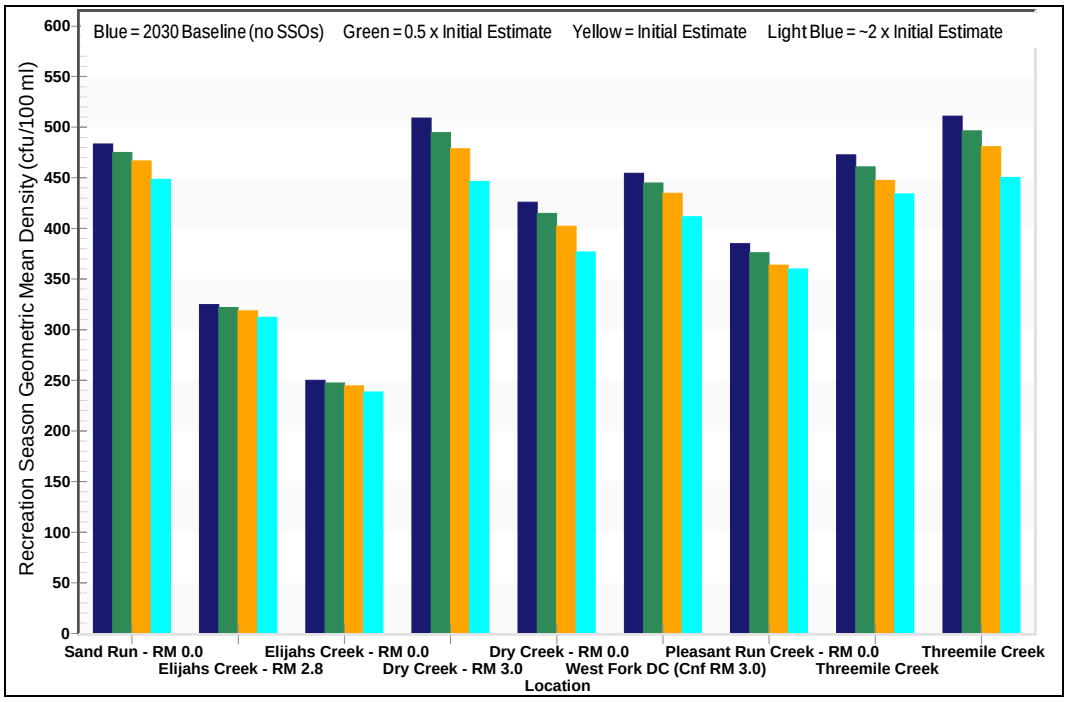


Figure 3.53. Fecal Coliform Recreation Season Geometric Mean Density in Ohio River Tributaries for Watershed Control Implementation Sensitivity Scenarios



A tabular summary of the model results are shown in Table 3-48. Results indicate that the relationship between area addressed with watershed controls and reduction in recreation season geometric mean density is roughly linear in all of the watersheds. If the area addressed by watershed controls is doubled, the percent reduction in the geometric mean density is also roughly doubled.

Table 3.48. Percent Reduction in Fecal Coliform Recreation Season Geometric Mean Density for Each Watershed Source Control Implementation Scenario

Watershed	Area Controlled Relative to Initial Estimate of Watershed Control Program Area		
	0.5 X	1 X	2 X
Banklick Creek	7.0%	14%	22%
Dry Creek	2.5%	5.3%	11%
Elijahs Creek	1.0%	2.0%	4.2%
Fourmile Creek	1.7%	3.6%	7.7%
Pleasant Run Creek	2.4%	5.5%	6.5%
Sand Run	1.7%	3.5%	7.2%
Threemile Creek	2.7%	5.6%	10%
Twelvemile Creek	1.5%	3.2%	6.8%

This analysis also indicated that compliance with water quality standards does not appreciably increase if control of watershed sources is increased. There are several reasons for this. First, as noted in the Watershed Control Opportunity analysis described in Section 3.3.3 and Appendix 3-C, watershed controls are most effective when they can treat runoff from a large portion of a subwatershed or watershed. This is why regional controls, like the Banklick wetland included in the Five-year Improvement Program (described in Section 7), are so effective at "treating" runoff. The controls included in the Watershed Control Program and Policy/Regulations implementation reflect smaller scale opportunities associated with storm water catchments or subdivision-scale BMPs. Many areas at this scale need to be implemented to realize a significant increase in compliance with water quality standards.

Second, SD1 used a conservative estimate of bacteria removal efficiency of 50 percent for watershed controls so the remaining load in the "treated" runoff may still be well above the water quality standard criteria of 400 cfu/100 ml and 200 cfu/100 ml. A literature review of removal efficiencies suggest that using a removal efficiency of 65 to 70 percent would reflect the median efficiency compiled from the literature. In addition, SD1 plans to conduct project-specific performance-based monitoring (described in Section 8) as controls are implemented. These data will provide site-specific data on removal efficiencies that can be incorporated into the models with each of the five-year updates to the Watershed Plans.

The results of the sensitivity analysis will be used to refine the initial evaluations of watershed control opportunities in the next five-year planning cycle.

3.4.5 Watershed Assessment Tool Application

A final evaluation of the benefits of the Integrated Plan was conducted with the Watershed Assessment Tool (WAT!), which calculates the potential of different source types to deliver bacteria and nutrient loads to the waterways. Results from the WAT! can be thought of as calculating the annual bacteria loading potential of different sources throughout the study area. WAT! was used to calculate the loading potential of the Baseline "No Control" scenario, the Integrated Plan and the Traditional Plan. The same data sources that informed the detailed models were also used for the WAT! application. Results by watershed are shown in Table 3.49.

Table 3.49. WAT! Fecal Coliform and Nutrient Load Comparison for the Integrated Plan, Traditional Plan, and No Control Baseline Scenario

Watershed	Total Bacteria Loads ,10^{14} units			Total Nitrogen Loads, 10^{4} units			Total Phosphorus Loads, 10^{3} units		
	Baseline	Traditional Plan	Integrated Plan	Baseline	Traditional Plan	Integrated Plan	Baseline	Traditional Plan	Integrated Plan
Banklick Creek	195	117	91	19.5	19.3	15.6	66.3	65.7	53.6
Licking River	488	231	227	41.0	39.6	38.5	143	139	135
Taylor Creek	31.6	21.5	17.2	1.34	1.30	1.01	3.31	3.22	2.51
Fourmile Creek	39.7	17.4	16.0	4.96	4.91	4.47	18.6	18.4	16.8
Pleasant Run	32.4	30.4	20.1	2.09	2.08	1.44	5.70	5.68	3.96
Ohio River	424	104	114	55.4	53.4	52.5	151.9	147.3	143.6
Twelvemile Creek	68.9	68.9	67.6	18.2	18.2	17.8	88.8	88.8	87.1
Threemile Creek	38.4	32.4	24.7	2.11	2.10	1.66	6.06	6.02	4.98
Dry Creek	131	75.9	62.9	4.61	4.50	3.77	10.7	10.4	8.7
Elijahs Creek	25.3	25.3	22.0	1.92	1.91	1.73	4.78	4.78	4.40
Sand Run	4.46	4.45	4.11	1.46	1.46	1.34	4.69	4.69	4.25
Woolper Creek	79.5	32.9	30.1	8.70	8.70	7.78	33.0	32.7	29.3
Gunpowder Creek	57.8	57.3	52.5	17.6	17.6	16.0	64.6	64.6	58.8
Big Bone Creek	104	100	95	20.6	20.6	18.9	74.4	74.4	68.4
Total	**1,720**	**919**	**844**	**200**	**196**	**182**	**676**	**666**	**621**

3.5 CONCLUSIONS

The Integrated Plan is the best plan to meet the goals of the Consent Decree. In summary, SD1's Integrated Plan for 2025 achieves the following, based on current modeling calculations and assumptions about effectiveness of green infrastructure:

- Elimination of SSOs at a saturated condition two-year, six-hour design storm level of service;
- Reduction in the storm water runoff quantity and improvement in the quality of runoff in the separate sewer system, while at the same time eliminating SSOs through an asset management based approach to public and private source I/I removal.
- Elimination of 20 CSOs during a typical five-year water quality evaluation period;
- Elimination of 1,287 MG/yr of CSO during a typical five-year water quality evaluation period due to the completion of the Five-year Improvement Program and additional green infrastructure projects identified for the Integrated Plan for 2025;
- Ensuring a minimum of 85 percent capture and up to a projected 94 percent capture and treatment of wet weather flow in the CSS;
- Treatment of 562 MG/yr of storm water during the typical five-year period through green infrastructure;
- Emphasis on green infrastructure through projects in the CSS area and programmatic controls and partnering opportunities in both the combined and separate sanitary sewer system areas;
- An increase in the number of days during the recreation season where fecal coliform levels are less than 400 cfu/100 ml (a commonly used benchmark for safe recreation conditions);
- A reduction in instream bacteria levels (characterized by the geometric mean level of fecal coliform cfu/100 ml over the recreation season);
- Maximum improvement to instream water quality over more stream miles as compared to the Traditional Plan; and
- More reduction in bacteria, total nitrogen, and total phosphorus load from the watersheds as compared to the Traditional Plan.

The affordability analysis demonstrates the Integrated Plan for 2025 would impose unwarranted and unreasonable financial burdens and hardships on the communities served by SD1 and is beyond SD1's financial capabilities. Accordingly, although SD1 believes the Integrated Plan for 2025 is the most cost-effective and beneficial plan that would eliminate SSOs and remedy CSOs in conformance with the CSO Control Policy, SD1 has determined it is unaffordable and relief from the December 31, 2025 Consent Decree deadline (and/or other performance criteria) is therefore necessary through a material modification of the Consent Decree. Relief from the December 31, 2025 deadline (and/or other performance criteria) could be afforded through a number of mechanisms recognized by the CSO Control Policy and KRS 224.16-040, including extensions of deadlines, affordability reviews in conjunction with five-year Watershed Plan updates, Use Attainability Analyses, or combinations thereof. Consistent with the parties' agreement, the form and extent of the relief is not being addressed in this Integrated Plan. Rather, the purpose of the Integrated Plan for 2025 is to determine the most cost-effective approach to eliminate SSOs and address CSOs by December 31, 2025 consistent with the Consent Decree.

Section 4
Economic Characterization

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SECTION 4. ECONOMIC CHARACTERIZATION

As an environmentally and fiscally responsible utility with a proven record of customer service, SD1 recognizes the need for ongoing and carefully selected infrastructure investments. This is clearly shown in the evaluation of controls presented in Section 3. SD1's watershed planning process is not a new initiative, but rather the continuation of an institutional philosophy towards pollution control that has been in place for many years. Projects like the Western Regional program are part of SD1's long-term vision since the mid-1990's to protect human health and improve water quality through proven infrastructure controls. The watershed plans presented in this document continue that philosophy, and the Five-year Improvement Program was developed in the context of past and committed investments and the ability of the local ratepayer base to fund SD1 operations.

The timing of SD1's current watershed planning is unique, in that it began in the early stages of the ongoing national economic crisis, the most severe such crisis in generations. The full extent of the crisis, in terms of impacts and duration, is highly uncertain, even to economic experts. There is, however, little doubt that the crisis has not ended, and its impact will be felt at the regional and national levels for many years to come. As a result, the financial capability precedents for wet weather control established as part of Consent Decree negotiations over the past 10 to 15 years may no longer be valid, as the economic paradigm that those precedents were based on has changed.

This section presents SD1's financial capability for funding wet weather controls in these uncertain times. It begins with an overview of SD1's financial framework and presents national and regional economic metrics that impact SD1's decisions on future investments. Funding scenarios and affordability implications are then provided for two time frames – the full Consent Decree implementation period ending in 2025 and the first five-year improvement cycle in the watershed planning process.

4.1 Finances

SD1 is a fiscally responsible utility actively managing its budgetary process, bond ratings, and rate structure to ensure consistency and equity to its ratepayers.

As a ratepayer-funded utility, SD1 is governed by three county Judges Executive and a Board of Directors. The three Judges Executives are elected officials who serve four-year terms on the same election cycle. The most recent elections for the Judges Executives were held in November 2010, with the regional economy and SD1 financial commitment being a central theme in the election dialogue. The eight Directors serve four-year staggered terms. Such Directors may be reappointed. Four directors are appointed by the County Judges Executive of Kenton County, two are appointed by the County Judges Executive of Campbell County, and two are appointed by the County Judges Executive of Boone County. County representation is based on the populations of the three counties.

SD1 is required to maintain a fiscally conservative accounting by its Board of Directors. The minimum debt service coverage required by SD1's bond indenture is 125 percent;

however, the Board of Directors has set a goal of 150 percent. The Board of Directors has also required that SD1 maintain at least $15 Million in the Infrastructure Repair and Replacement fund and at least $5 Million in the Self Insurance Fund. In addition, SD1 is required to keep three months of average operating expenses in the Operation and Maintenance Reserve Fund at all times. Due to SD1's credit worthiness and sound financial operations, SD1 is able to borrow money at a relatively low interest rate. This is because of a Moody's bond rating of Aa2 and a Standard & Poor's bond rating of AA.

SD1 has used a customized 20-year ProForma tool since 2002 to project expenses and revenue needed to meet those expenses. The ProForma also indicates SD1's capacity to borrow and meet required coverage rates. User rates are then structured and calculated to meet total expense requirements. The ProForma was initially developed by outside rate consultants and is continually refined by SD1 as an in-house financial planning tool.

User fees are evaluated and adjusted annually or biannually based on system needs using the ProForma. The process begins at the end of the calendar year by analyzing needs for the upcoming fiscal year (FY), which begins on July 1. SD1 also consults with a financial advisor and engages independent third parties to evaluate rates and revenue needs.

SD1 rate adjustments require approval by the Board of Directors and elected Judges Executive. After SD1 determines that a rate adjustment is warranted, the approval process consists of two readings at the Board of Directors' meetings with the 30-day comment period between the readings. Upon the Board's second approval, the rate adjustment is presented to the Judges Executive for their consideration and approval. This process was amended by SD1 in early 2009 to include a voluntary public hearing in each of the three counties to be conducted in addition to the 30-day comment period.

4.1.1 Overview of SD1 Budgeting Process

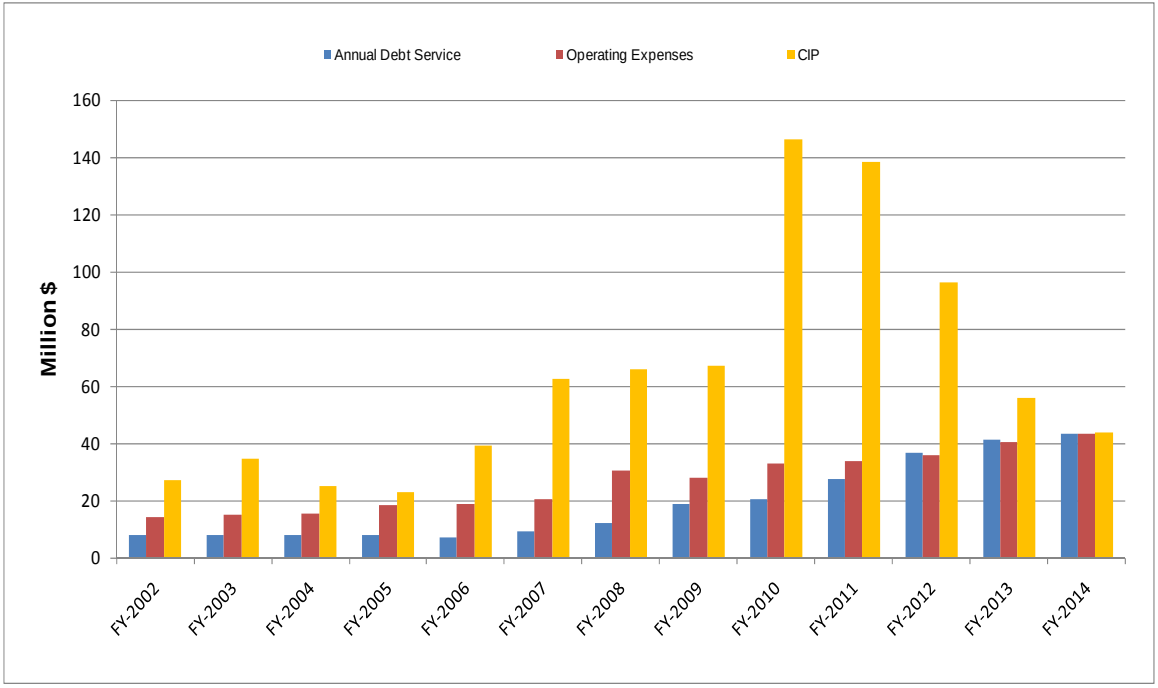
SD1's structured budgeting process enables all operating departments to execute SD1's mission and vision in a fiscally responsible manner and provide cost-effective services to ratepayers. This budgeting process provides SD1 with a clear understanding of the organization's financial needs and obligations, which results in the ability to adequately manage debt service, categorize expenses, plan for future needs, and properly manage assets and infrastructure.

SD1's Operating and Maintenance (O&M) and Capital Improvement Program (CIP) budgets are created by department directors, submitted to and approved by first the Board of Directors and then the Judges Executive of Boone, Campbell, and Kenton counties, and set into effect the beginning of each fiscal year (July 1). O&M and CIP costs are determined by the department directors through collaboration with staff. Draft budgets are formed by reviewing historical data and trends, and line item projections for the coming year. SD1's accounting team assists in developing this financial information for each department. Once each department has a draft budget, SD1's management team collectively reviews the document and makes any necessary adjustments. This review process occurs multiple times before it is sent to the Board of Directors, with the budgeting process typically beginning approximately six months prior to the beginning of

the fiscal year. The Board of Directors and then the Judges Executive have final review and approval before the budget is enacted.

Figure 4.1 below represents SD1's historical and anticipated (for the next 5 years) debt service, O&M, and CIP expenses. As depicted in the figure, the projected annual debt service continues to grow as the Initial Watershed Projects are implemented (i.e., large increase in CIP budget). Although O&M increases every year to maintain the commitments of CMOM and NMC activities, the debt service increases at a higher rate and surpasses projected O&M in 2012. As described in Section 4.1.2, the debt balance outstanding as of June 30, 2008 was $236.2 Million, a net increase of $98.2 Million of new debt from one year before, and is expected to increase over the next five years from implementation of the Five-year Improvement Program.

Figure 4.1 SD1 Expenses: Annual Debt Service, O&M, and CIP



The O&M budget preparation process includes calculations of expected needs and costs provided by seven operating departments[1]. Through this analysis, each department reviews historical data and a projection of the current fiscal year's actual expenses. The overall budget is then developed based on projected calculations using known and anticipated revenues and expenses associated with completing SD1's work over the next fiscal year. Expenses for each department are organized into six overarching categories: Personnel; Contract Services; Administrative & Office Operations; Utilities, Fuel Oil & Chemicals; Vehicle Operations; and Miscellaneous.

[1] SD1's seven operating departments are Dry Creek WWTP, Collection System, Administration, Engineering, Storm Water, Field Technical Services, and Eastern Regional WWTP.

The CIP budget is planned on a rolling, five-year cycle and is updated, at a minimum, on an annual basis. The CIP budget is tracked continuously throughout the year to make sure costs are trending as intended. SD1 CIP personnel analyze, project, plan, and finance capital improvement needs through the use of comprehensive engineering studies and extensive industry knowledge. All projects in the CIP budget are currently organized into the following categories:

- Construction Projects
  - Collection System Improvements
  - Wet Weather Improvement Projects
  - Eastern Regional
  - KTC Sewer Rehab/Repair
  - Pump Station
  - Treatment Plants
  - Western Regional
  - Other Capital Projects
- Capital Programs
- Fixed Asset Purchases

Although a five-year planning horizon is used, the Board of Directors and Judges Executive approve the upcoming fiscal year budget on an annual basis.

4.1.2 Funding Mechanisms

SD1's O&M and debt service are currently funded through rates and fees. The CIP Program is funded through rate revenue, bonds, and loans from the State Revolving Fund.

Rates and Fees

Rates and fees provide the majority of SD1's operating revenues through sewer charges levied against customers pursuant to the approved rate schedule (see Appendix 4-A for the Rate & Fee Schedule for Fiscal Years 2010 and 2011). SD1's operating revenues include the following sources:

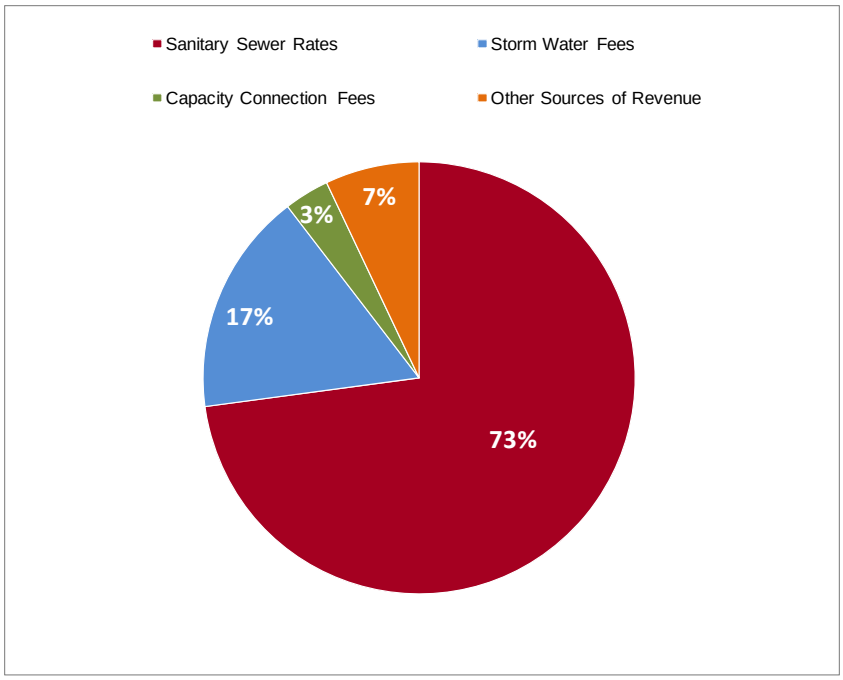
- Sanitary sewer rates
- Storm water fees
- Capacity connection fees
- Other sources of revenue, including:
  - Industry surcharge rates
  - Sludge hauling/dumping
  - Plan review
  - Inspections
  - Permitting
  - Tapper certification
  - Contractual services
  - Project reimbursements
  - Investment income
  - Bad debt recoveries
  - Penalties and fines

- o Credit card fees
- o Turn-off fees

A breakdown of the percent each source contributes to SD1's total operating revenue in 2009 is shown in Figure 4.2. This revenue is also used to transfer cash into the following funds:

- Debt Service Reserve
- O&M Fund
- Self Insurance Fund
- Improvement, Repair & Replacement Fund

Figure 4.2 Operating Revenue Streams



Although SD1 receives adequate funding from its operating revenue sources to fund its O&M commitments, these sources do not provide sufficient funding to also support the CIP. SD1 is therefore required to borrow money from other sources. The actual FY-2010 funding sources were 32 percent from user rates and fees and 68 percent from borrowed money. The borrowed amount consisted of four issues of 2010 bonds and the Western Regional WRF state revolving fund loan.

Revenue Bonds

Due to SD1's credit worthiness and solid, sound financial operations, SD1 is able to borrow money at a relatively low interest rate because of a Moody's bond rating of Aa2 and a Standard & Poor's bond rating of AA.

Revenue bonds are bonds issued by an agency that is commissioned to finance public works. The debt service for such proceeds is primarily payable from revenue generated

by the utility, such as user rates and fees. Since 1998 through 2009, SD1 has issued nearly $300 Million in revenue bonds, as demonstrated in Table 4.1. No new bonds were issued in fiscal year 2009; therefore, the debt balance outstanding decreased $5.7 Million because of payments. The debt balance outstanding as of June 30, 2008 of $236.2 Million is a net increase of $98.2 Million of new debt from one year prior (June 30, 2007 balance of $138.0 Million), and a net increase of $144.6 Million of new debt from two years prior (June 30, 2006 balance of $91.6 Million).

Table 4.1 Bonds Payable

Bond Series	Original Par Amount	Interest Rate Range	Final Maturity	Balance Outstanding as of June 30, 2009
1998A	$55,425,000	4.75%	2008	$0
2001A	$52,685,000	4.5 – 5.0%	2031	$45,820,000
2005A (1998A Refinance)	$35,175,000	4.0 – 4.25%	2018	$34,440,000
2006	$50,000,000	4.3 – 4.375%	2036	$49,120,000
2007	$102,000,000	4.0 – 5.0%	2038	$101,165,000
Total	$295,285,000	--	--	$230,545,000

During fiscal year 2010, SD1 issued a Series 2009 and Series 2010 Revenue Bonds in the amount of $54.9 Million and $75.0 Million, respectively, to continue funding of the Initial Watershed Projects.

Proceeds from the sale of these revenue bonds are used to pay a significant portion of the costs associated with SD1's CIP, including reimbursement for prior capital expenditures. In addition, bond proceeds are used to make provisions for underwriting discount and original discount, to pay the costs of the Municipal Bond Insurance Policy, and to pay the necessary costs and expenses incident to the issuance and delivery of the bonds.

State Revolving Fund

State Revolving Funds provide long-term, low-interest loans to local governments or individuals for capital investments. Established by the Clean Water Act Amendments of 1987, State Revolving Funds are intended to be administered and operated by the states to provide a permanent source of financing for state and local government water quality projects. KDOW, through an interagency agreement with the Kentucky Infrastructure Authority, provides Kentucky communities with low-interest loans from the State Revolving Fund to comply with the requirements of the Clean Water Act. In recent years, SD1 has been able to fund the following projects through this loan program.

- Eastern Regional Water Reclamation Facility (WRF) – $33 Million over a 20-year term with a 3.2 percent interest rate
- Western Regional WRF – $70 Million over a 20-year term with a 1.2 percent interest rate
- Dry Creek Clarifier Rehabilitation Project – $4.473 Million over a 20-year term with a 2.2 percent interest rate

With the passage of the American Recovery & Reinvestment Act of 2009 (ARRA), the Kentucky Infrastructure Authority received $49 Million in additional funds for the Clean Water State Revolving Fund. SD1 submitted an extensive list of project applications for ARRA funding, and four were selected. Green infrastructure was the focus of all four of the selected projects, and their combined total cost was approximately $4.3 Million. Two projects are funded (combined debt balance of $147,405 at June 30, 2010) based upon 52.1 percent principal forgiveness, and a 2.2 percent interest rate and a 20 year maturity.

4.1.3 Current Rate Structure

This section provides a description of SD1's current rate structure for both sanitary and storm water services. For a comprehensive listing of approved rates and fees for fiscal years 2010 and 2011, see Appendix 4-A.

Sanitary Sewer Service Rates

Residential

SD1's residential sanitary sewer user rates are calculated based on water consumption information supplied by one of the three water districts in Northern Kentucky – the Northern Kentucky Water District, Boone County Water District, and Florence Water District. All residential sanitary sewer bills are based on a customer's highest water consumption during the winter months. The term "winter months" is defined by the time frame in which each water district reads the main water meter (typically covering the months from October through April). Once the "highest water consumption" number has been established, the sanitary sewer bill is based on that usage for the next four quarters until the following winter when the water meter readings will be re-evaluated. Each customer is charged a flat rate per each Hundred Cubic Feet (HCF) of water used during this specified time frame, with a minimum bill of 2 HCF per month.

Residential - Unmetered Service

In the event that a lot, parcel of land, building or premises discharging sewage uses water supplied on other than a metered basis, the owner or occupant may be required by SD1 to install a water meter or other measuring device. Once the meter has been installed, the readings from this meter will determine the sewer rate, rental, and charge (as described above). Pending the installation of such meter, however, the rates, rentals, or charges for sanitary sewer services are based on a flat rate depending on the number of rooms in the building.

Non-Residential

Commercial and industrial users are billed using a three-tiered system of actual water consumption for each quarter, with a minimum bill of 2 HCF per month. The three tiers are as follows:

- 0 – 5,000 HCF
- 5,001 – 25,000 HCF
- Over 25,000 HCF

Surcharge for High Concentration Effluent

For the purpose of providing funds to SD1 to properly treat and dispose of sewage loadings in excess of normal strength sewage, and to provide funds for the increased cost of operation and maintenance resulting from these sewage loadings, SD1 implements surcharge rates for high concentration effluent. These consist of an established schedule of rates, rentals, and charges for the use and the services rendered by the sewage works and facilities of SD1 in respect to the collection, transmission, treatment and disposal of other than normal strength sewage. These surcharge rates are charged to and paid by the owner or occupant of each lot, parcel of land, building or premises discharging sewage, water or other liquid wastes, directly or indirectly connected with the sewage works and facilities of SD1. This schedule of surcharges for other than normal strength sewage services is computed and based upon the presence on an average daily basis of suspended solids, biochemical oxygen demand, and total Kjeldahl nitrogen.

Storm Water Fees

A combination of storm water user fees and plan review and inspection fees pay for the cost of implementing the Regional Storm Water Management Program and the region's growing storm water system needs. SD1 utilizes an impervious area rate methodology as the basis for funding the regional storm water utility. The rate structure also includes procedures for non-residential properties to obtain credits to reduce their effective fee.

Residential Fees

Based on a statistical analysis of residential properties in Boone, Campbell and Kenton counties, it was determined that the average impervious area per property is 2,652 square feet. Based on this data, SD1 has designated an equivalent residential unit equal to 2,600 square feet. All residential properties are charged a single flat monthly fee based on one equivalent residential unit.

Non-residential Fees

Non-residential property owners are billed a monthly storm water user fee based on the total amount of impervious area on their property. Impervious areas include roofs, patios, walkways, sidewalks, driveways, parking lots, and roadways. The impervious areas for the non-residential properties within the designated storm water service area were calculated using aerial photography and GIS methods. The non-residential property user fee is based on the number of equivalent residential units that are represented by the impervious area of the property using $4.30 (FY-2009 rate) per 2,600 square feet of impervious area.

Exemptions

SD1 has determined that all properties within the designated storm water service area are subject to the storm water user fees with the following exceptions: public streets and roads, properties within the service area classified as agricultural land use by the Property Valuation Authority, and unimproved properties.

Additional Fees

SD1 charges a plan review and an inspection fee for new development and re-development that occurs within the identified storm water service area in Boone, Campbell and Kenton counties.

Credits

SD1 has established a policy to provide credits against the storm water fees for non-residential properties in an effort to provide equity and consistency in the application of the fee to individual properties. Credits can be granted for best management practices that address a combination of water quantity and/or water quality impact reductions.

A total maximum of an 80 percent credit against the fee may be granted. The following criteria apply in determining credits:

- The credit will be applied by reducing the number of billable equivalent residential units;
- The property parcel can qualify for both water quantity and water quality credits;
- The maximum allowable water quantity credit percentage equals 35 percent;
- The maximum allowable water quality credit percentage equals 50 percent;
- The adjusted equivalent residential units includes the credit for both water quantity and water quality; and,
- The minimum equivalent residential unit is one.

4.2 Economic Factors

SD1 is in the difficult position of developing a long-term infrastructure improvement program in the midst of a national economic crisis of unprecedented proportions. While SD1's obligations as a utility must and will continue through such a crisis, it would be irresponsible for SD1 to not consider these economic times in developing their wet weather improvement program. In the words of President Obama in his address to Congress on February 24, 2009, "the day of reckoning has arrived," and the nation will be forced to sacrifice "worthy priorities" as the crisis continues (Obama, 2009).

As a ratepayer funded utility, SD1 is obligated to make some very difficult decisions in balancing the customer's ability to pay with desired wet weather improvements. Like every other household in the United States, the households of Northern Kentucky are feeling the impact of the economic crisis across all income levels. This section presents some of the real economic factors impacting SD1, starting at the national level and then focusing on the crisis in Northern Kentucky.

4.2.1 The National Economic Crisis

The national economy began what has been termed the Great Recession in the last quarter of 2007, with economic conditions continuing to worsen well into 2009. In September, 2010, the National Bureau of Economic Research (NBER), the official entity tasked with determining when economic downturns begin and end, concluded that while the recession officially ended in June 2009, it "did not conclude that economic conditions since that month have been favorable or that the economy has returned to operating at normal capacity" (CNNMoney.com, 2010). Further, the NBER stated that "economic activity is typically below normal in the early stages of an expansion, and it

sometimes remains so well into the expansion," and acknowledged the risk of a double-dip recession with the explanation that “the committee decided that any future downturn of the economy would be a new recession and not a continuation of the recession that began in December 2007" (CNNMoney.com, 2010). In terms of factors that impact typical households, the housing market continues to struggle, the mortgage and foreclosure crisis has not abated, and unemployment remains at historically high levels, even in the first quarter of 2011.

This climate of recession and economic downturn is being fueled by several factors, including:

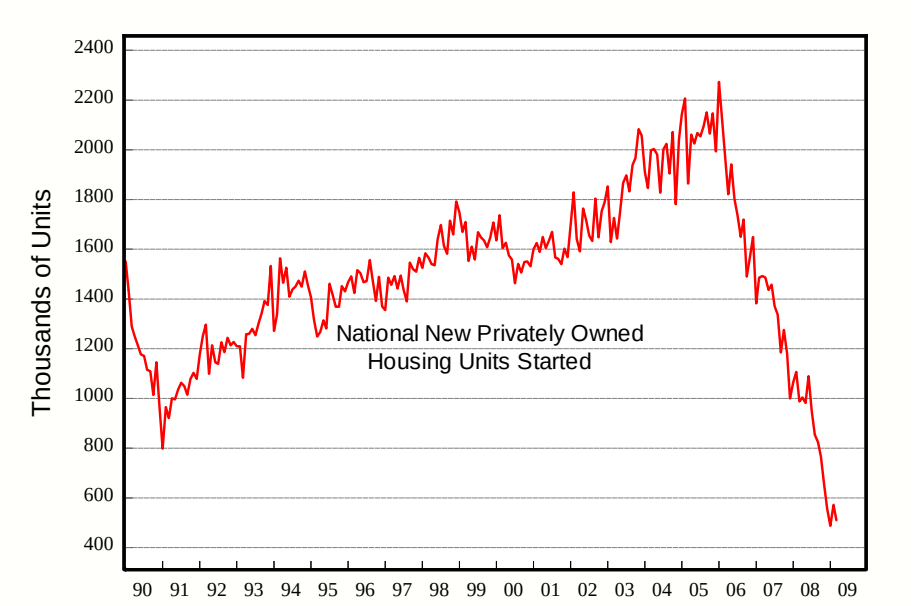
- Rising energy costs,
- Decline in the housing market, and
- Instability of financial institutions, as evidenced by the collapse of major firms in the industry.

The three national factors listed above all have direct impacts on Northern Kentucky and SD1. The rising cost of energy has an ongoing effect, as energy costs account for 11.8 percent of SD1's operating budget. And the impacts are not expected to be over – even though the energy costs for fuel, natural gas and electricity stabilized in 2009, the market pricing forces are highly unstable at this time (as evidenced by the current price of oil).

A decline in the housing market impacts growth in the economy, and vice-versa, creating a self-perpetuating downturn until conditions improve. As a result, the severe decline in the housing market has been tied heavily to the extreme decline in the economy. From 2000 to 2007, Boone County was the 2nd fastest growing county in Kentucky. As such, the collapse of the housing market in Northern Kentucky has taken a significant toll on the local economy. With the collapse of this market, along with foreclosures, SD1 anticipates future increases in default collection trends.

Figure 4.3 is excerpted from the 2009 Regional Economic Outlook prepared by the Northern Kentucky Chamber of Commerce (Northern Kentucky Chamber, 2009a) and shows the national trend for housing starts has recently plummeted to historic lows.

Figure 4.3 National Housing Starts [1]



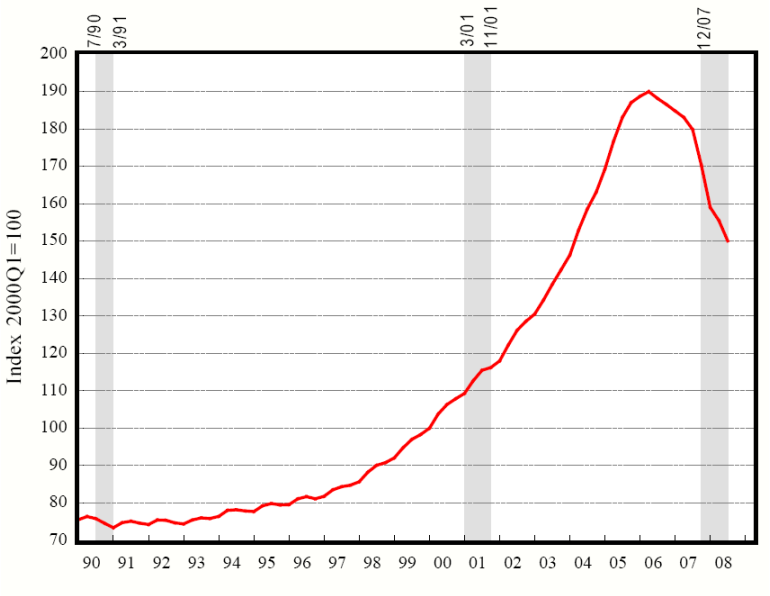
Note: [1]Information from 2009 submittal, but core economic trends remain similar through 2011.

Many experts also agree that while the duration of the residential housing slump is hard to predict, the downturn will continue for the foreseeable future. The 2009 Regional Economic Outlook concludes that the "weakening economy will continue to weigh on housing demand" (Figure 4.4).

> The worst may not be over for the housing market. As unemployment climbs, foreclosures are likely to multiply, exacerbating an already difficult combination – more houses being dumped onto the market even as the pool of potential buyers grows increasingly smaller. Housing prices continue to slump in many markets. The Standard & Poor's/Case-Shiller Index of home prices declined 16.6 percent in August from the year before, following a 16.3 percent drop in July. The index has fallen every month since January 2007. Sales continue to fall along with prices. New single-family home sales fell 5.3 percent to an annualized pace of 433,000 in October. On the positive side however, builders are slashing inventories at a rapid pace. While the weakening economy will continue to weigh on housing demand, the decline in mortgage rates raises the possibility that sales could start to recover in the second half of 2009.

The 2011 Regional Economic Outlook concludes that in prior recessions, it has often been housing that first turned upward and led the U.S. out of a recession. That is not a likely scenario for the current recovery - where a very slow recovery is expected in the housing market.

Figure 4.4 Standard & Poor's/Case-Shiller U.S. National Home Price Index [1]



Note: Shaded area represents U.S. economic recessions as determined by NBER since 1990.

Note: [1]Information from 2009 submittal, but core economic trends remain similar through 2011.

In addition, the unprecedented collapse of national financial institutions has led to an extreme tightening of the credit market, resulting in a larger spread in interest rates as well as skepticism in the bond market. Historically, municipal bonds have been a straightforward financing mechanism with stable expectations and requirements; however, many utilities have recently found that bond issues in the current economic climate are more challenging and more expensive than in the past.

These economic factors have eroded business and consumer confidence and led to tightening of the credit markets and continued elevated unemployment. Some significant national challenges for the future include:

- Continued weakening of financial institutions
- Disarray in the financial markets
- Declining household wealth
- Weak domestic demand
- Deteriorating labor market
- Unstable auto and retail sales
- Pending bankruptcy and layoffs across many sectors

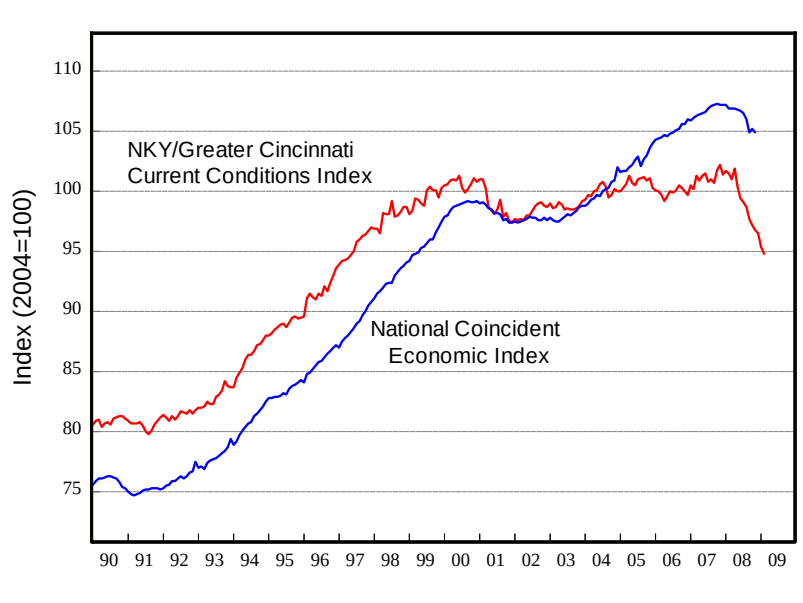
4.2.2 Local Economic Factors

Many regional organizations maintain and track economic indicators in Northern Kentucky. The following summary is excerpted from the 2009 Regional Economic Outlook and illustrated in Figure 4.5 (Northern Kentucky Chamber, 2009a). The concerns expressed in this summary are especially telling, given that the mission of a

chamber of commerce is to generate optimism and promote the business environment in its area of influence.

> The *Northern Kentucky/Greater Cincinnati Current Conditions Index* (CCI) dates the latest regional economic peak in November 2007 with aggregate economic activity declining since that time…The national economy last peaked in December 2007, marking the beginning of a recession in the U.S. economy. The regional slowdown is already more than a year in duration, mirroring nearly exactly the start of the national decline. If the national recession and accompanying regional slowdown continue into the second half of 2009 as expected, the regional economy will be in the midst of its longest contraction since the 18-month decline in the CCI of 3.97 percentage points, in 2000/2001.

Figure 4.5 Trends in the NKY/Greater Cincinnati Current Conditions Index [1]



Note: [1]Information from 2009 submittal, but core economic trends remain similar through 2011.

This regional data suggests that the local economy will track very closely to the national economy, and there are clear indications that this is already occurring. While in the midst of the economic boom of the past six years, SD1 customers in the three county service area have benefited from reliable and high-paying jobs, increasing home values, and economic growth. With the emergence of the ongoing economic crisis, however, unemployment has dramatically increased in the past several years and remains at historically high levels, as shown in Table 4.2. The Northern Kentucky Chamber of Commerce in their 2011 Regional Economic Outlook (2011a) anticipates that even with job growth, the unemployment rate is not forecasted to decline much as the labor market improves. It is anticipated that discouraged workers will come back into the labor market keeping the unemployment rate high throughout 2011.

Table 4.2 Northern Kentucky Unemployment Rates

County	January 2008 [1]	January 2009 [1]	January 2010 [2]	December 2010 [3]
Boone	4.8%	7.9%	9.9%	8.8%
Campbell	5.3%	7.9%	11.1%	10.5%
Kenton	5.4%	8.6%	10.7%	10.0%

Notes:
[1] Northern Kentucky Chamber of Commerce, 2009c.
[2] Northern Kentucky Chamber of Commerce, 2010.
[3] Northern Kentucky Chamber of Commerce, 2011b.

A similar and related downturn can be seen in the median household income (MHI) measures throughout the region. As reported in Northern Kentucky Chamber of Commerce, 2009a,

> Unfortunately, the industries with the greatest number of job losses are also among the highest paying industries in the region. The average wage for all jobs in the region is $43,984. Within the manufacturing sector the average wage per job is $54,256 or 23 percent above average. The average wage in health care, which had the most gains over the past year, is just slightly below average at $43,618.

The realities of this data and projections have had a significant impact on regional MHI levels as additional jobs are lost, especially jobs that are higher paying than average. Based on information from the U.S Census Bureau and American Community Survey (see Appendix 4B), all three counties in SD1's service area have experienced declining MHI levels in at least one of the past several years; Boone County in 2008, Campbell County in both 2008 and 2009, and Kenton County in both 2007 and 2009. In the 2011 Regional Economic Outlook (2011a), after a steep decline of over ten percent in 2009 alone during the recession, manufacturing employment is starting to see modest recovery in 2010 of one to two percent. 2011 is forecasted to also increase another one percent. This may begin the modest reversal of the decline in higher paying jobs.

4.2.3 Impacts on SD1

The national and regional issues outlined above significantly impact the ratepayers of Northern Kentucky. SD1's ability to pay for asset management and Consent Decree related improvements are directly related to the following:

- Ability to collect customer rates
- Ability to increase rates to cover rising costs
- Ability to obtain funding for project needs
- Ability to maintain strong credit rating
- Cost of funding

The lingering recession and continuing weak economic climate will clearly impact customer's ability to pay increased sewer rates. As consumer purchasing power and discretionary spending decreases, ratepayers will have less money available to spend on non-essential goods and services. As unemployment remains high, the credit market tightens, foreclosures increase and the costs of goods and services increase due to inflation, ratepayers will ultimately not be able to afford an increasing sewer bill.

There is growing public sentiment to reduce taxes and reduce spending, which has already been targeted directly at SD1's rate structure and financial framework.

With the uncertainty of the economic forecast, it is logical to assume it will become at least more difficult and perhaps impossible for SD1 to obtain rate increases to fund future projects during the economic crisis. As the nation moves out of these economic conditions and the credit market regains strength, it may be more reasonable to resume rate increases at some point in the future. While the official Great Recession may have ended in June 2009, many functional drivers of the economic crisis have clearly continued into 2011, with unemployment remaining around nine to ten percent. These conditions have already stimulated public outcry against rate increases, no matter how good the intentions of SD1's program.

One of SD1's greatest concerns is the cumulative impact of regional economic stresses on affordability and the ability to raise rates, maintain coverage requirements, and ultimately protect credit ratings. SD1's strong history of being able to raise rates to cover costs has helped maintain an AA or better rating. As noted previously, SD1 is governed and operated by a Board of Directors, consisting of eight Directors, who serve four-year staggered terms. The Board of Directors is appointed by the three elected Judges Executive, who serve four-year parallel terms.

On March 17, 2011, House Bill 26 was signed into law (effective June 8, 2011). This new law will require SD1 to submit all proposed rate increases of greater than five percent to the three county fiscal courts. On March 22, 2011, SD1's Board of Directors approved 15 percent rate increase for FY-2012 and FY-2013. For FY-2014 and thereafter, SD1 will have to submit any increase greater than five percent to the fiscal courts and unless at least two of the three fiscal courts approve the rate increase, the increase cannot occur.

The cost of funding in the bond market is directly related to a utility's credit rating. In recent years, the rate spread between A and AAA rated borrowers was not significant. However, the turmoil in the bond market has caused a marked rate gap to develop below the AA rating mark. In 2009, the difference in bond financing between an AA and an A rated borrower on a 20-year, $100 Million note was approximately $19 Million. A large ingredient in the market's assessment of the creditworthiness of a borrower is their ability to generate or increase rates and maintain safe coverage levels. SD1 has a successful history with both, but if pushed to leverage more credit and increase rates to maintain coverage, the pushback may result in a slippage of the utility's credit rating. While SD1's credit ratings remain strong, this concern was specifically articulated in the Standard & Poor's summary brief explaining its assessment of SD1's 2010 rating (Standard & Poor's, 2010):

> Lessening these strengths, in our view, are sizable capital needs geared toward satisfying the terms of the district's consent decree. The challenge of maintaining positive financial operations, which includes timely approval of future rate increases while financing these needs, is another tempering factor.

> While we expect the district to maintain at least good financial operations, a significant decrease in liquidity and coverage while the district addresses its capital plan could pressure the rating downward.

If this happens, more money will go to interest payments and less to fund solutions with environmental benefit. For these reasons, SD1 has to be fiscally responsible and not ask the Board of Directors or more importantly, the public to support and pass extremely high rate increases.

As an operating utility, SD1 has no choice but to negotiate a path through the current economic crisis. To do this, SD1 will rely on and follow the core values, as stated in SD1's strategic plan (SD1, 2008i):

> The core values of our organization provide the foundation for how work is conducted on a daily basis. They are the attitudes and beliefs that make SD1's culture unique and define our operating principles. Core values provide a constant in a surrounding environment that is forever changing.

Four of the eight core values in SD1's strategic planning (SD1, 2010b) align directly with the watershed philosophy of the Consent Decree:

- Environmental Stewardship
- Fiscal Responsibility
- Innovation & Excellence
- Servant Leadership

SD1's past history has proven that these core values are taken seriously and will remain guiding principles into the future. But, in the midst of this economic crisis, there is a need to be pragmatic and responsible and focus spending and efforts on projects and programs that have the biggest impact for the money spent. With the credit market in flux and the long-lasting negative effects of a reduced credit rating, it is SD1's responsibility to maintain commitments to current projects and expand the watershed program only by the amount that can be afforded and legitimately encumbered without adversely impacting customers or the utility's credit rating.

4.3 Committed Obligations

As an operating utility, SD1 has ongoing obligations to operate and maintain their current assets and provide required customer service. These "asset management" costs are not discretionary, as they reflect the cost of doing business as a utility to fix failing pipes, maximize existing capacity and assure future capacity, and prevent loss of service and basement backups. These projects include high priority sewer repairs and replacements, a number of Consent Decree required programs, improvements at pump stations and treatment facilities, and capital purchases.

In addition, SD1 is committed to completing the implementation of the Initial Watershed Projects as outlined in Exhibit D of the Consent Decree. SD1 has estimated to spend approximately $158 Million from inception to end of fiscal year 2009 towards the Initial Watershed Projects. Once implemented, these improvements become operating assets and add to the asset management costs required to operate the utility.

Table 4.3 summarizes the major categories of ongoing asset management and the future cost of the Initial Watershed Projects. The five-year funding levels required for these committed obligations are shown in Figure 4.6.

Table 4.3 Committed Obligations

Category	Type	Five-Year Funding Requirements [1] (Million $)
Committed Projects for Asset Management		
High-priority Sewer Projects	Critical sewer rehabilitation / replacement projects; Projects include Van Deren, Highland Pike, Wayman's Branch	$10.1
Nine Minimum Control Program	Element of Nine Minimum Controls Program, Consent Decree requirement	$2.1
River's Edge Inline Storage and Solids & Floatables Project	Upsizing of 8,000 feet of Ohio River Interceptor as part of a new development to provide inline storage and solids & floatables control for 2 CSOs; CSO reduction	$5.2
Capacity Management Operation Maintenance Program	Consent Decree requirement; Projects include Pump Station Back-up Power, South Park Industrial PS Overflow Elimination and CSAP	$11.0
Consent Decree Planning, Implementation, Management	Necessary to ensure effective implementation of overall Consent Decree program	$12.2
Improvements at Dry Creek Wastewater Treatment Plant	System maintenance, increased treatment capacity	$28.8
Pump Station Projects	Pump station asset management and elimination	$14.9
Ongoing Sewer Rehabilitation / Repair projects	Rehabilitation / replacement based on CSAP and Cities opportunities; Identified projects include Crestview PS Overflow Elimination, South Hampton PS Overflow Elimination, Union PS Overflow Elimination, Bellevue Replacement Sewer, Avon Drive Sewer	$42.0
Storm Sewer Rehabilitation / Repair	Storm water asset management	$11.0
Capital Purchases (vehicles, construction equipment, etc.)	Equipment	$6.6
Initial Watershed Projects [2]		
Completion of Eastern Regional collection system projects	Initial Watershed Projects	$2.7
Western Regional Wastewater Treatment Plant, Conveyance System (Tunnel) to Western Regional WRF, and Collection System projects	Initial Watershed Projects	$258.5
SD1 Adjustment for FY-2010 Actual CIP [3]		
Amount removed in FY-2010 actual CIP to account for amount expensed, and less interest capitalized		($8.9) [3]
	Total	$396.1

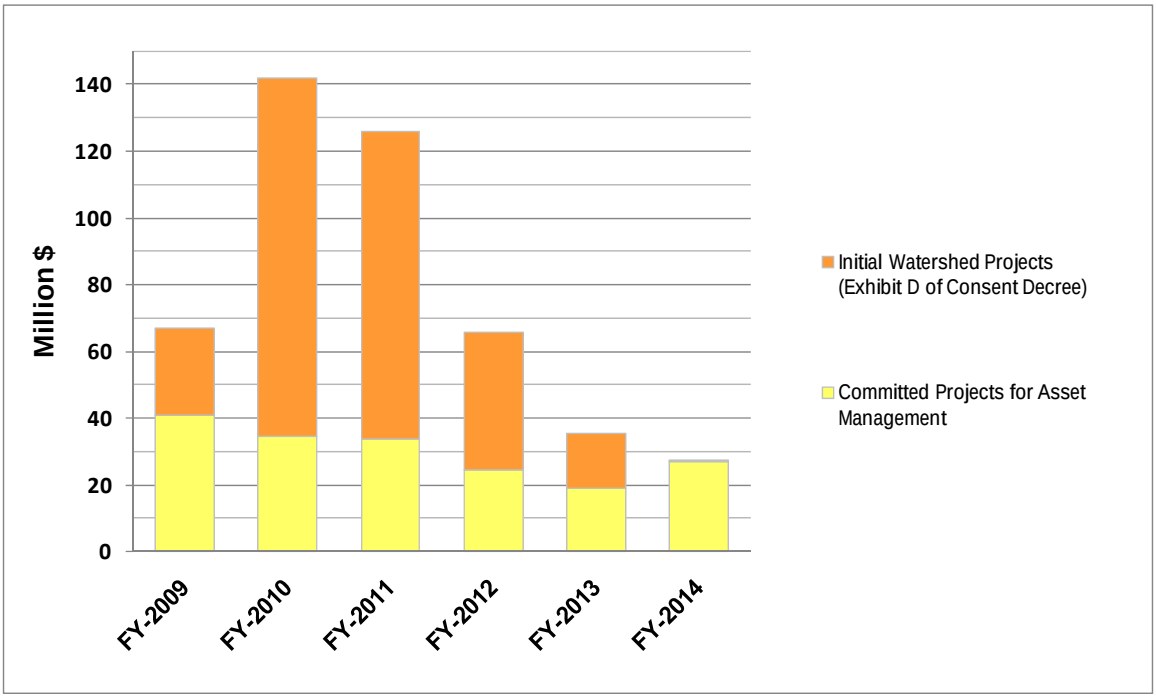
Notes:

[1] Five-year funding between FY-2010 (actual) and FY-2011 to FY-2014 (budgeted) in Million $.

[2] SD1 has estimated to spend approximately $158 Million from inception through FY-09 for the Initial Watershed Projects. The estimated cost to complete all Initial Watershed Projects is $261 Million.

[3] SD1 audited FY-2010.list of CIP spending and SD1 Financial Statements for the Years Ended June 30, 2010 and 2009 (SD1, 2010a). When FY-2010 is graphically represented in figures, the reduction has been applied proportionately to the Committed Projects and Initial Watershed Projects such that total FY-2010 actual amount is $146.2 Million.

Figure 4.6 Funding Requirements for Committed Obligations



4.4 Financial Capability Assessment Process

The requirement for Five-year Improvement Program cycles incorporated in SD1's Consent Decree creates a unique challenge in assessing financial capability and affordability. Under the "traditional" approach incorporated in most wet weather Consent Decrees, affordability considerations and constraints are assessed in terms of the full cost of a program over the full implementation period. EPA's *Guidance for Financial Capability Assessment and Schedule Development* (EPA, 1997) provides a two-phase process for assessing a utility's ability to fund a full wet weather program. The metrics developed per the guidance are associated with full program costs, and they are typically used to support a negotiated agreement on a utility's total financial commitment to the full program. With SD1's approach, these full program affordability impacts must be considered, but additional affordability impacts on a shorter five-year implementation time scale must also be evaluated.

To address this challenge, it was necessary for SD1 to develop and consider affordability measures for two controlling time horizons (note that both time horizons start in 2009, when the first set of watershed plans were submitted):

- A 16-year time horizon, ending in 2025, associated with the full Consent Decree implementation period. The traditional affordability metrics are relevant for this time horizon, and provide a framework for assessing SD1's financial capability to fund a program that meets the ultimate goals of the Consent Decree.
- A five-year time horizon, ending in 2014, associated with the first five-year plan. Because this represents less than the full program period, the traditional affordability metrics such as the Residential Indicator are not directly applicable measures. Rather, SD1 identified the rate adjustment schedule as the controlling indicator for determining an affordable Five-year Improvement Program.

The following sections present the specific analysis performed for each of these two time horizons under SD1's financial capability assessment.

4.5 EPA Financial Capability Analysis for the 2025 Program

While originally intended strictly for CSO LTCP development, the Guidance for Financial Capability Assessment and Schedule Development has increasingly been applied to broader wet weather management programs (EPA, 1997). This is at least in part due to the fact that it remains the only published regulatory wet weather guidance on financial capability and affordability considerations.

The guidance provides a two-phase process for assessing a utility's ability to fund a full wet weather program. The metrics developed per the guidance are associated with full program costs over a full implementation period, and they are typically used to support a negotiated agreement on a utility's total financial commitment to the full program.

This section presents a summary of the financial capability assessment performed by SD1 per the EPA guidance. A detailed presentation of this assessment, including all of the calculation worksheets, is presented in Appendix 4-B. Note that all costs included in this assessment are in 2009 dollars, consistent with the submittal year for the first set of watershed plans.

4.5.1 Projection of Potential Full Program Costs

The financial capability assessment process begins with a projected full program cost for required wet weather controls, expressed in 2009 dollars. Per SD1's Consent Decree, the requirement for the watershed program is "control of discharges from CSO outfalls consistent with the CSO Control Policy, the elimination of SSOs and Unpermitted Discharges in the Sewer System, and the improvement of water quality in the receiving waters" (Consent Decree, 2007). The CSO Control Policy states that "a primary objective of the long-term CSO control plan is to meet water quality standards, including the designated uses through reducing risks to human health and the environment by eliminating, relocating or controlling CSOs to the affected waters" (EPA, 1994).

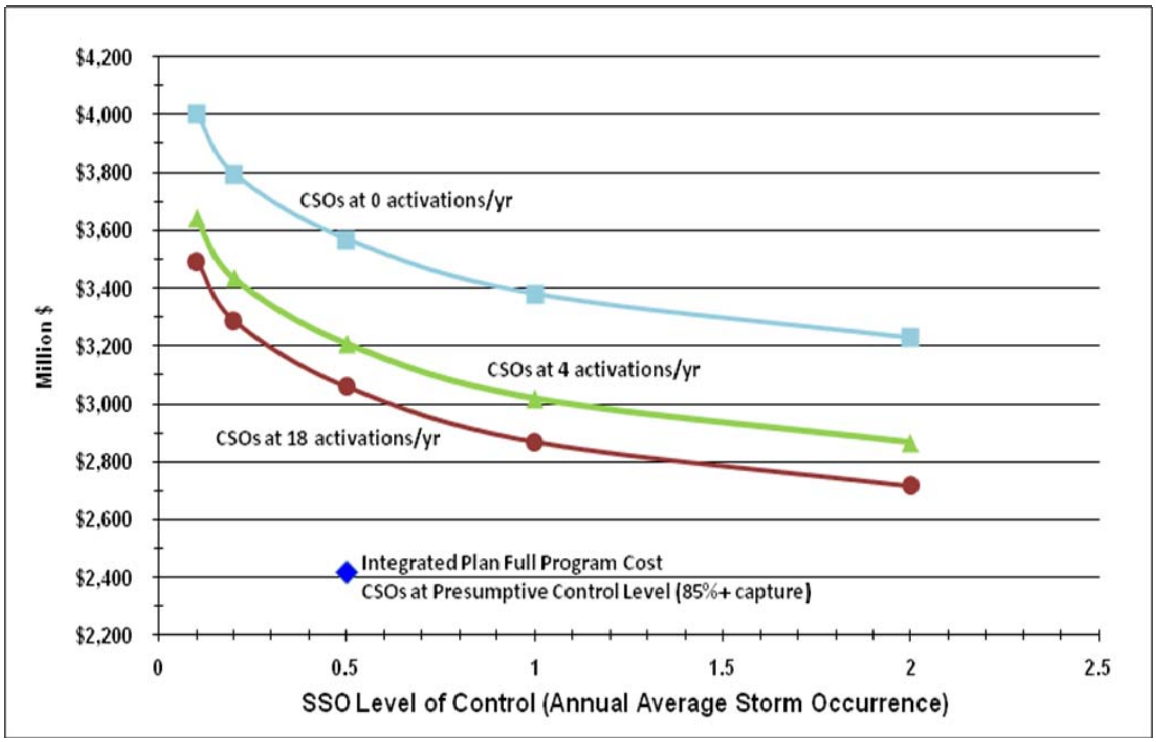
Therefore, the Consent Decree directly, and the CSO Control Policy by reference, require SD1 to assess a control program that eliminates SSOs and controls CSOs to a high enough level to allow current water quality requirements to be met in local waterbodies (using either the Presumption Approach or Demonstration Approach as outlined in the Policy). This is the purpose of the Integrated Plan for 2025 presented in

detail in Section 3 – i.e., to develop, size, and cost an integrated solution that eliminates SSOs and controls CSOs to meet water-quality based requirements.

Figure 4.7 shows a summary of relevant cost-benefit information from the analysis presented in Section 3 and Appendix 3A, using Full Program Costs. The cost-benefit curves represent the Full-System Bounding Analysis (Appendix 3A) over a range of control levels, which as explained previously was performed to assess the relative benefits of implementing traditional gray infrastructure solutions. The Integrated Plan for 2025 (Section 3) is represented by a single point on Figure 4.7. The Integrated Plan achieves, more cost-effectively than any of the Bounding Analysis gray infrastructure solution concepts, a high level of SSO control (2-year design storm) and the presumption control level for CSOs (85%+ capture of inflow to the CSS) to meet the water-quality based requirements of the CSO Policy. The cost figures shown on the figure represent 2009 dollars. The Full Program Costs for the Integrated Plan for 2025 were the basis for the formal EPA financial capability assessment analysis presented below.

The Full Program Costs consist of the projected costs of the Integrated Plan for 2025 as well as the costs for the committed obligations of asset management for infrastructure and Initial Watershed Projects, and the anticipated obligations of potential future effluent limits for nutrients (i.e., nitrogen and phosphorus) at the treatment plants. Again, it is important to note that these “asset management” costs are not discretionary, as they reflect the cost of doing business as a utility to fix failing pipes, maximize existing capacity and assure new capacity, prevent loss of service and basement backups, and comply with anticipated new nutrient regulations. The cost for SD1 to implement this full program is $2.4 Billion, in 2009 dollars. While the EPA financial capability assessment analysis requires the use of current dollars, it is worth noting that this program is estimated to cost $3.3 Billion in future dollars, i.e., sum of the annual capital budgets from FY-2010 to FY-2026. The future dollar implications of the program are discussed in Section 4.5.6.

Figure 4.7 Projected Full Program Costs for Full-System Bounding Analysis Solutions and the Integrated Plan for 2025 (2009$)



4.5.2 Phase One: The Residential Indicator

The Residential Indicator represents the household cost of wastewater treatment, including wet weather control, as a percentage of household income. The Residential Indicator is calculated by first determining the total annual cost of wastewater treatment and wet weather control. A portion of the total cost is then allocated to residential customers based on the percentage of total flow generated from these customers. Finally, the total residential cost is allocated amongst the total number of households in the community to determine the wet weather controls implementation cost per household. Once the wet weather controls implementation cost per household is determined, the Residential Indicator is calculated by dividing the wet weather controls implementation cost per household by the MHI of the community, and is compared to the EPA criteria for classifying the financial impact as “low,” “mid-range,” or “high.” Table 4.4 shows EPA’s criteria for classifying the financial impact based on the calculated Residential Indicator.

Table 4.4 EPA Residential Indicator Financial Impacts

Financial Impact	Residential Indicator (Cost as a % of MHI)
Low	Less than 1% of MHI
Mid-Range	1% – 2% of MHI
High	Greater than 2% of MHI

Full details on the Residential Indicator calculation, including development of the wastewater treatment and wet weather control costs, are presented in Appendix 4-B. A summary of the controlling variables and calculations, and the resulting Residential Indicator, is provided below. The annual costs associated with the projected wastewater treatment and wet weather control costs are based on the Full Program Cost of the Integrated Plan for 2025 of $2.4 Billion as presented above and in Appendix 4-B.

The annual costs of wastewater treatment and wet weather control, in 2009 dollars, are presented in Table 4.5.

Table 4.5 Annual Costs of Wastewater Treatment and Wet Weather Control

Cost Category		Annual Cost (2009 Million $)
Current Wastewater Treatment Costs	Operations and Maintenance	$24.9
	Debt Service	$18.8
Projected Wastewater Treatment and Wet Weather Control Costs	Operations and Maintenance	$26.6
	Debt Service	$175.6
	Total	$245.9

To estimate cost per household, two steps are required – first, determine the residential share of the total annual cost, and second, divide by the number of customer households.

- Step 1: Based on average water consumption data, approximately 61.6 percent of SD1 water consumption was associated with residential customers. This percentage was used to estimate residential wastewater flow and the residential share of total annual cost at $151.5 Million.
- Step 2: Given 89,971 residential households, the annual cost per household is $1,684.

To determine the appropriate MHI to use in the financial capability assessment, multiple statistical sources were evaluated for MHI data within the Northern Kentucky region. Data were reviewed from the U.S. Census Bureau 2000 census (United States Census Bureau, 2009), the U.S. Census Bureau's "CenStats" database United States Census

Bureau, 2009b), U.S. Census Bureau American Community Survey (United States Census Bureau, 2009a), and the Tri-Economic Development Corporation (Tri-County Economic Development Corporation (TRI-ED), 2009). Based on the Federal nature of the Consent Decree and the amount of available information, the MHI information obtained from the U.S. Census Bureau's "CenStats" data was utilized for all years except 2009, where American Community Survey 1-Year Estimates were used since "CenStats" data was not available. The 2009 weighted MHI average of the three counties (Boone, Campbell and Kenton) by household, which SD1 serves, was calculated as $55,840.

The MHI data did not have to be adjusted to represent 2009 conditions (the year of interest), since 2009 data was available and used directly for this 2011 update. However, MHI adjustments through time were performed to support selected additional considerations (presented below), using an annual inflation factor. The average Consumer Price Index (CPI) during the past ten years (2001 through 2010) for the region that includes Ohio, Kentucky and Indiana was used as the annual inflation factor.[2] The "ten-year average CPI" for this region was calculated by removing the highest and lowest annual CPI from the ten-year period and averaging the remaining eight values. Utilizing this calculation method the average CPI was found to be 2.31 percent.

Given an annual cost per household of $1,684 and an MHI for the entire service area of $55,840, the Residential Indicator for the projected Full Program Cost is 3.0 percent. This clearly places SD1 in the "High Financial Impact" category on a service-area wide basis.

When assessed in terms of specific lower-income communities within SD1's service area, financial impact as measured by the Residential Indicator is even higher. The seven lowest income communities (approximately 39% of the households of the three counties) have a 2009 MHI of approximately $38,000. For residents with income that falls within this group, the Residential Indicator becomes 4.4 percent of household income, which puts the burden well above the "High" boundary range of two percent.

4.5.3 Phase Two: Permittee Financial Indicators

The second phase of the financial capability assessment involves calculating financial capability indicators. These indicators are intended to provide insight on the community's overall financial strength and ability to secure the funding necessary to implement the wastewater treatment and wet weather controls. An overall financial capability indicator is based on six individual indicators that assess debt, socioeconomic, and financial management conditions in the community. These six indicators are as follows:

- Debt Indicators

[2] US Department of Labor, Bureau of Labor Statistics (ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt)

  - Bond rating
  - Overall net debt as a percent of full market property value
- Socioeconomic Indicators
  - Unemployment rate
  - Median household income
- Financial Management Indicators
  - Property tax revenues as a percent of full market property value
  - Property tax revenue collection rate

The EPA has established guidelines for interpreting these indicators and their associated impact on the overall financial capability of SD1. A full assessment of the indicators, including background data and references used to establish them, is presented in Appendix 4-B. Note that many of the measures used to develop the indicators are based on data available in 2009, consistent with the submittal year of the first set of watershed plans. While this is appropriate for the purpose of the analysis, it is also important to recognize that many of the key economic indicators for the Northern Kentucky region – for example, unemployment rate, foreclosure rate, and MHI – continue to be very weak even in 2011.

Once the financial capability indicators are developed, they are compared to indicator benchmarks provided in the EPA guidance, and scored according to these benchmarks. A "Strong" rating is assigned three points, a "Mid-Range" rating is assigned two points, and a "Weak" rating is assigned one point. An overall score is then calculated as the simple average of the six indicator scores. Based on this analysis, SD1 has an overall Financial Capability Indicator score of 2.50, which corresponds to a "Mid-Range" financial capability indicator rating based on the EPA methodology. Table 4.6 provides a summary of the financial indicators, scores associated with each indicator, and the average score for all indicators.

Table 4.6 Summary of SD1 Financial Capability Indicators

Indicator	Actual Value	Indicator Range	Score
Bond Rating	AA	Strong	3
Overall Net Debt as a Percent of Full Market Property Value	1.7%	Strong	3
Unemployment Rate[1]	9.3%	Mid-Range	2
Median Household Income	$55,840	Mid-Range	2
Property Tax Revenues as a % of Full Market Property Value	1.14%	Strong	3
Property Tax Revenue Collection Rate	95.4%	Mid-range	2
Overall Financial Capability Indicator Score		Mid-Range	2.50

Note: [1] Unemployment rate based on 2009 average

4.5.4 The Financial Capability Matrix

Under the EPA methodology, the results of the Residential Indicator and the Financial Capability Indicators assessment are combined into a Financial Capability Matrix to

evaluate the level of financial burden that wastewater treatment and wet weather control costs may impose on SD1. The original purpose of the matrix in the 1997 CSO Guidance document was to assist the utility and regulatory agencies in establishing a CSO control implementation schedule (EPA, 1997). As noted previously, however, application of the guidance has broadened over the years, and the Financial Capability Matrix is now considered an indicator of overall financial burden from a wet weather program rather than strictly a schedule determinant. This is especially true in Consent Decree situations like SD1's, since the long-term control plan schedule has already been established by the Consent Decree. The Financial Capability Matrix is shown in Table 4.7.

Based on a Residential Indicator of 3.0 percent and a Financial Capability Indicator Score of 2.50, the Financial Capability Matrix indicates that implementation of the wet weather controls associated with the Integrated Plan for 2025 is a "High Burden" for SD1. Clearly, with a Residential Indicator of 3.0 percent and a High Burden from the Financial Capability Matrix, SD1 ratepayers cannot afford an improvement program configured towards the goal of eliminating SSOs and controlling CSOs to meet water-quality based requirements, even by EPA financial guidelines.

Table 4.7 Financial Capability Matrix

Financial Capability Indicator Score	Residential Indicator (Cost Per Household as a % of MHI)		
(Socioeconomic, Debt and Financial Indicators)	Low (Below 1%)	Mid-Range (Between 1.0 and 2.0%)	High (Above 2.0%)
Weak (Below 1.5)	Medium Burden	High Burden	High Burden
Mid-Range (Between 1.5 and 2.5)	Low Burden	Medium Burden	High Burden
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

4.5.5 Impact of Additional Factors on Financial Capability Assessment Calculations

The previous section presented the financial capability assessment calculations for a $2.4 Billion 2025 program based on direct application of the EPA methodology (EPA, 1997). This is an important first step in assessing the financial implications and affordability of a program required to meet the goal of eliminating SSOs and controlling CSOs to meet water-quality based requirements. The guidance also allows for the introduction of local economic factors as part of the assessment, to provide additional insight into the financial impact from a potential control program:

> It must be emphasized that the financial indicators found in this guidance might not present the most complete picture of a permittee's financial

> capability to fund the CSO controls…permittees are encouraged to submit any additional documentation that would create a more accurate and complete picture of their financial capability.

SD1 believes that the continuing national and regional impacts of the current economic crisis justify two types of adjustments to the Financial Capability Indicators used in the financial capability assessment:

- First, estimates of indicators based on recent history currently carry a much higher degree of uncertainty than at any time since the guidance was released in 1997. Many core economic indicators (e.g. unemployment and median home values) deteriorated at a startling rate during the recession and remain at depressed levels even in 2011. Therefore, the full year values used in the analysis, many from 2008, may not properly represent the current climate.
- Second, the grading of two key indicators (unemployment rate and MHI) relative to a national norm presupposes that the national norm represents a relatively healthy economy. This is clearly not the case in today's economic climate. For example, the continuing high unemployment in Northern Kentucky may equal, or even be lower than, the national average – but clearly does not indicate a "mid-range" or "strong" local condition.

Given these considerations, SD1 suggests that four of the financial indicators deserve to be assessed in a modified fashion in order to truly reflect their intended purpose. This in turn results in a substantive change in the overall Financial Capability Indicator score, which is directly relevant to the interpretation of the financial capability assessment results. The indicators, and the recommended adjustments, are as follows:

- **Overall net debt as percent of full market value**: Calculating this indicator requires an estimate of "market value of property" within the service area. For the base financial capability assessment analysis presented above, this was done in the typical fashion, using information from local communities based on 2007 and 2008 data. However, these data do not incorporate the recent precipitous decline in property values experienced by homeowners across the nation, which has not rebounded even as of 2011. Assuming a 20 percent reduction in property values, on average, since the source data were developed changes the indicator value to 2.1 percent and the associated range to "Mid-Range."

- **Unemployment rate**: The base financial capability assessment analysis presented above estimated regional unemployment based on a five-year average from 2004 – 2008. This is a reasonable approach, and typical for a financial capability assessment analysis. The calculation results in an estimated unemployment rate of 9.3 percent for 2009; this is equal to the national average of 9.3 percent for 2009. Being within one percent of the national average results in an indicator range of "Mid-Range." Regardless of the comparison to a national average, SD1 believes that the significant rise in regional unemployment over the past several years and the real potential for unemployment to remain elevated warrants a range of "Weak."

- **Median household income**: For the 2011 update, 2009 MHI data was available to use for the financial capability assessment calculation. The 2009 weighted MHI average of the three counties (Boone, Campbell and Kenton) by household, which SD1 serves, was calculated as $55,840. In the 2009 submittal, the previously developed regional 2009 MHI estimate was $58,400 based on a documented MHI from 2007, inflated based on an average consumer price index from the past 10 years from 1999 to 2008 (2.58%). The documented MHI for 2009 was approximately $2,500 less than the adjusted MHI for 2009. Both approaches resulted in an MHI range of "Mid-Range" when compared to a national average MHI. However, as presented previously in the discussion of local economic factors, MHI is expected to trend with unemployment in Northern Kentucky, and so will remain stagnant or at best show a modest increase below historical CPI levels. This regional trend is a better MHI indicator than a relative comparison to a national average, and given the ongoing economic concerns SD1 believes that the associated range for MHI should be "Weak."

- **Property tax revenue collection rate**: As calculated in the base financial capability assessment, the property tax collection rate is approximately 95 percent, putting SD1 in the "Mid-Range" range. However, the rapid rise in foreclosures is a well-documented national concern, and one that will undoubtedly lead to some decrease in property tax collection rates in virtually all municipalities. If property tax collection rates across the region were to decrease by less than five percent, this indicator would fall into the "Weak" range.

Assuming these changes, SD1's Financial Capability Indicator score drops from 2.5 to 1.8, as shown in Table 4.8. While still in the same High Burden box in the Financial Capability Matrix, a score of 1.8 puts SD1 beyond the midpoint of that particular range (towards additional burden), and approaching the highest burden box available in the matrix. This emphasizes that the Integrated Plan for 2025, configured towards the goal of eliminating SSOs and controlling CSOs to meet water-quality based requirements is cost-prohibitive by EPA financial metrics.

Table 4.8 Summary of SD1 Financial Capability Indicators – Additional Economic Factors

Indicator	Indicator Range	Score
Bond Rating	Strong	3
Overall Net Debt as a Percent of Full Market Property Value	Mid-Range	2
Unemployment Rate	Weak	1
Median Household Income (MHI)	Weak	1
Property Tax Revenues as a % of Full Market Property Value	Strong	3
Property Tax Revenue Collection Rate	Weak	1
Overall Financial Capability Indicator Score	Mid-Range	1.8

4.5.6 Rate Increases and Residential Indicators through Time

As part of providing "any additional documentation that would create a more accurate and complete picture of their financial capability," SD1 believes it is relevant to examine the required rate increases and Residential Indicator through time for the Full Program Cost for the Integrated Plan for 2025. As before, the Full Program Cost is $2.4 Billion (2009 dollars), made up of the Integrated Plan for 2025, committed obligations of asset management and the Initial Watershed Projects, and anticipated effluent limits for nutrients at the treatment plants. The time period of interest is the current implementation period required by the Consent Decree, i.e. from 2009 to 2025.

To assess the year-by-year impacts of implementing the $2.4 Billion program, a preliminary engineering schedule was developed to represent a typical sequence for designing and building the full system Integrated Plan for 2025 presented in Section 3 by 2025. The schedule through 2025 is presented in Section 8. The sequencing allowed for a projection of capital expenditures by year, the required bonding schedule to cover those capital expenditures, and the increase in O&M costs as new facilities become operational.

In order to fully account for SD1 obligations on an annual basis, the projection of capital expenditures through 2025 included the following components of the Full Program Cost:

- **Committed Projects for Asset management of wastewater and storm water systems**: The projections for asset management costs over the first five years were presented previously, in Section 4.3. Beyond the first five years, the CIP annual costs were escalated at a constant rate of three percent to account for inflation. Since the Integrated Plan for 2025 has a large rehabilitation component for rainfall-derived inflow and infiltration removal and structural benefits, the sewer rehabilitation category was reduced in FY-2015 to account more for emergency and high criticality projects. As explained previously, these asset management costs reflect SD1's obligation to maintain current infrastructure, and include the cost to fix failing pipes, maximize existing capacity and assure future capacity, and prevent loss of service and basement backups. The programmatic components of these costs, e.g. source reduction, are a critical component of SD1's wet weather management approach.

- **Initial Watershed Projects:** The projections for Initial Watershed Project costs (i.e., Eastern Regional and Western Regional WRFs) over the first five years were presented previously, in Section 4.3.

- **Five-year System-wide and Basin Projects:** The 2009 submittal defined and developed the Five-year System-wide and Basin Project (Section 7) for the first five years of the Consent Decree. For this 2011 update, the System-wide and Basin Projects were identified separate from the post five-year plan since they were well developed and already incorporated into SD1's current five-year CIP budget.

- **CSO Control Projects:** The Integrated Plan for 2025 as discussed in Section 3 provides a level of CSO control that meets the Presumption Approach and uses detailed water quality models to demonstrate that remaining CSO discharges can reasonably be expected not to cause an instream water quality standard violation when the integrated plan is complete. SD1 is preferentially implementing green infrastructure projects and programs first to reduce CSOs and improve water quality, prior to the implementation of gray infrastructure controls. SD1's CSO control program was developed as described in Section 3.3.2.

- **SSO Control Projects:** SSOs have been eliminated by designing controls for each SSO to achieve at least a two-year level of service (based on controlling the two-year, six-hour design storm with saturated antecedent moisture conditions). The SSO control approach leads with removing inflow and infiltration (I/I) using sanitary sewer evaluation surveys (SSES), public sanitary and storm sewer system rehabilitation and replacement based on an asset management approach, and private source I/I removal. Inflow and infiltration reductions following this approach will be completed first, and then followed, where necessary, with additional gray infrastructure to achieve at least a two-year level of service at each individual SSO location. The costs of public sewer rehabilitation were divided between SSO Control for I/I reduction and Public Structural Rehabilitation for asset management. SD1's SSO control program was developed as described in Section 3.3.1.

- **Public Structural Rehabilitation:** As part of the I/I reduction removal efforts described in SSO Control Projects, the public sanitary sewer infrastructure will also receive benefits of structural rehabilitation; therefore, a portion of the public rehabilitation costs were applied to SSO Control and a portion to Public Structural Rehabilitation.

- **Watershed and Programmatic Projects:** SD1 will use a programmatic-based approach to identify opportunities to reduce pollutant loads with regional and decentralized watershed controls. This Watershed Control Program includes use of the Sanitary Sewer Evaluation Survey (SSES) Program to identify opportunities to control storm water runoff using best management practices and green infrastructure in areas of the sanitary sewer system prone to high infiltration and inflow and the Source Identification Program (SIP) to identify source control opportunities elsewhere in the watershed. Lastly, water quality improvement projects outside the combined system will also be addressed through the Green Infrastructure Program. SD1's watershed and programmatic projects was developed as described in Section 3.3.3.

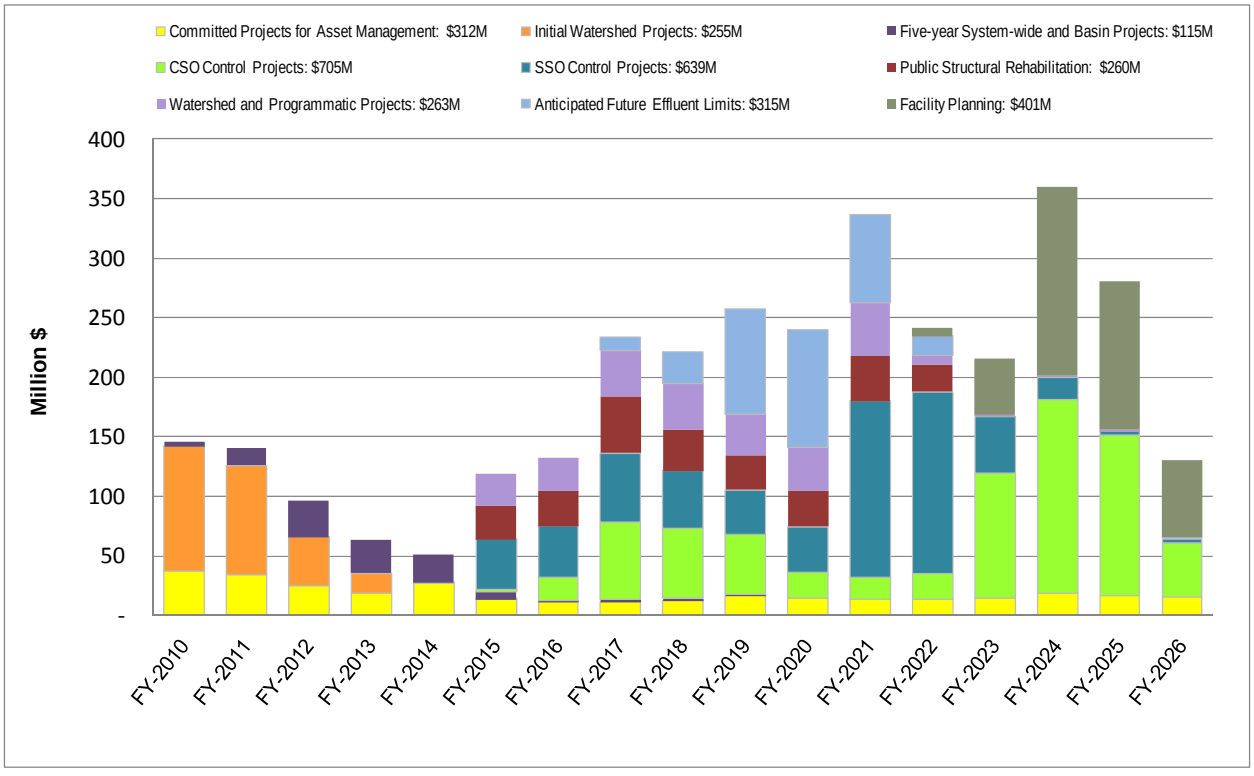
- **Anticipated Future wastewater effluent limits for nitrogen and phosphorus:** SD1 conducted a study to identify the costs to meet anticipated future wastewater effluent limits changes for nitrogen and phosphorus. Due to the time span of the Consent Decree, the costs of these upgrades are included as capital improvements associated with SD1's Full Program Cost.

- **Facility Planning:** Projects associated with the 2030 planning horizon that are not associated with current SSOs were itemized separately as Facility Planning projects. These projects required to be implemented by 2025 provide the trunk sewers and pump stations necessary to ensure new SSOs are not created before 2030.

In addition, several assumptions regarding financial rates – inflation, increase in MHI, bond rates, etc. – were developed to allow projection of financial metrics into the future. These assumptions were based on standard financial practice and are presented in Appendix 4-B.

The resulting annual capital expenditure schedule for the $2.4 Billion (2009$) full program is shown below in Figure 4.8. This schedule and associated annual costs reflect the impact of inflation, resulting in actual expenditures considering future dollar costs through December 2025 (i.e., halfway through FY-2026) of $3.3 Billion.

Figure 4.8 Capital Expenditures by Year to Support Full Program Costs for Integrated Plan for 2025 (Future Dollar Costs of $3.3 Billion over 15 Years)



The capital expenditure schedule shown above in Figure 4.8 clearly reflects a massive investment for a utility the size of SD1. To fund this program, SD1 would be required to raise residential sewer rates at 15 percent or 12.5 percent between FY-2012 until FY-2023 (for the next 12 years) as projected below in Figure 4.9.

Figure 4.9 Projected Rate Increase Schedule Over Implementation Period

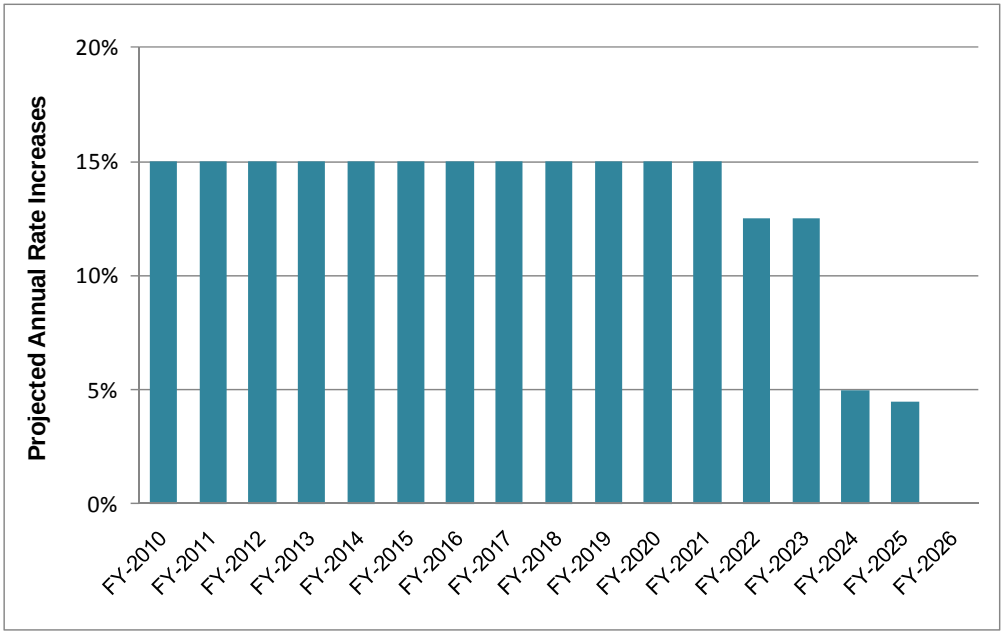
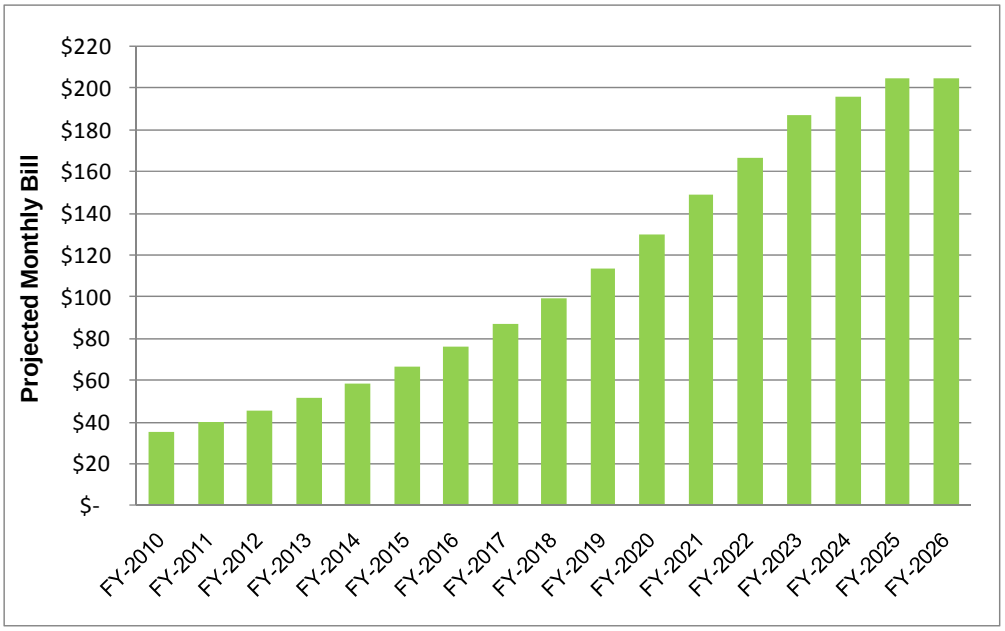


Figure 4.10 presents the resulting projected residential monthly bills by year, in future dollars assuming seven hundred cubic feet (HCF) per month of usage. SD1 uses seven HCF as the average residential usage per month. However, data has shown that the usage has gone down per household over the past couple of years. The actual residential monthly use in FY- 2010 was 6.5 HCF. The actual residential monthly use in FY- 2011 is just below six HCF. As shown in Figure 4.10, the highly aggressive annual rate increases shown above would result in residential monthly bills above $200 per month in 2025.

Figure 4.10 Monthly Rates Schedule Over Implementation Period (Future Dollars)



These monthly bills would translate into Residential Indicators peaking over three percent using SD1's area-wide MHI, and up to 4.5 percent for the group of low-income communities presented previously. The projected annual Residential Indicator for these two groups is shown below in Figures 4.11 and 4.12.

Figure 4.11 Residential Indicators Over the Implementation Period Based on Area-Wide MHI

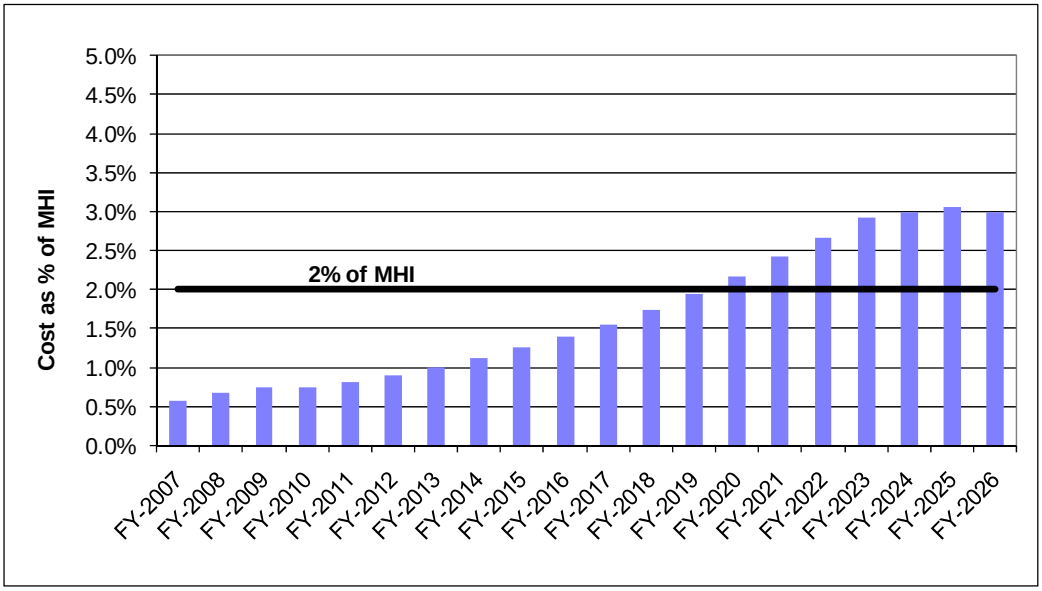
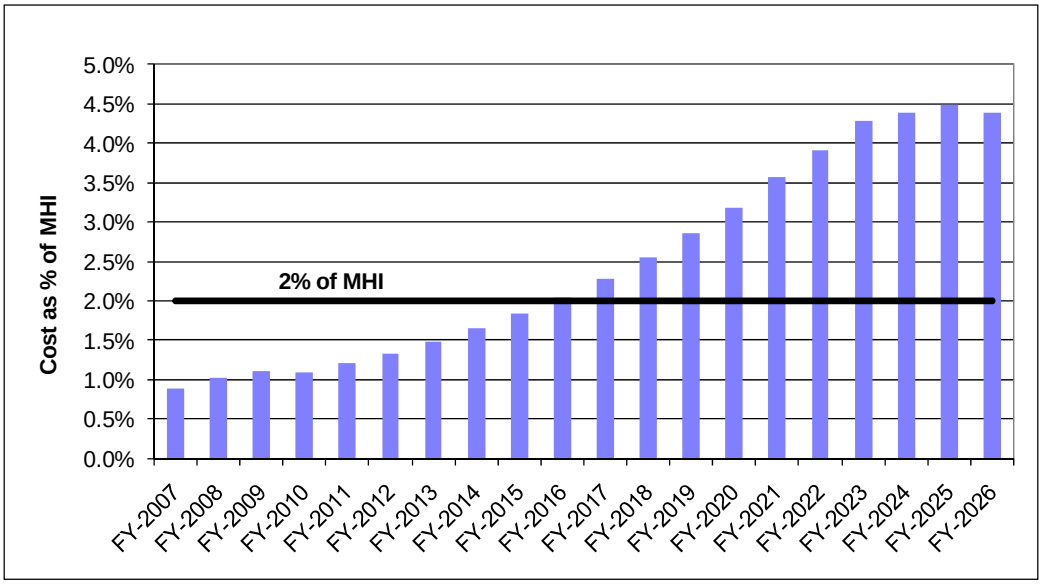


Figure 4.12 Low Income Communities Residential Indicators Over the Implementation Period



The annual measures shown above – rate increases, monthly sewer bills, and Residential Indicator – indicate by any reasonable standard that the Full Program Costs for the Integrated Plan for 2025, sized to meet the goal of eliminating SSOs and controlling CSOs to meet water-quality based requirements, is cost-prohibitive.

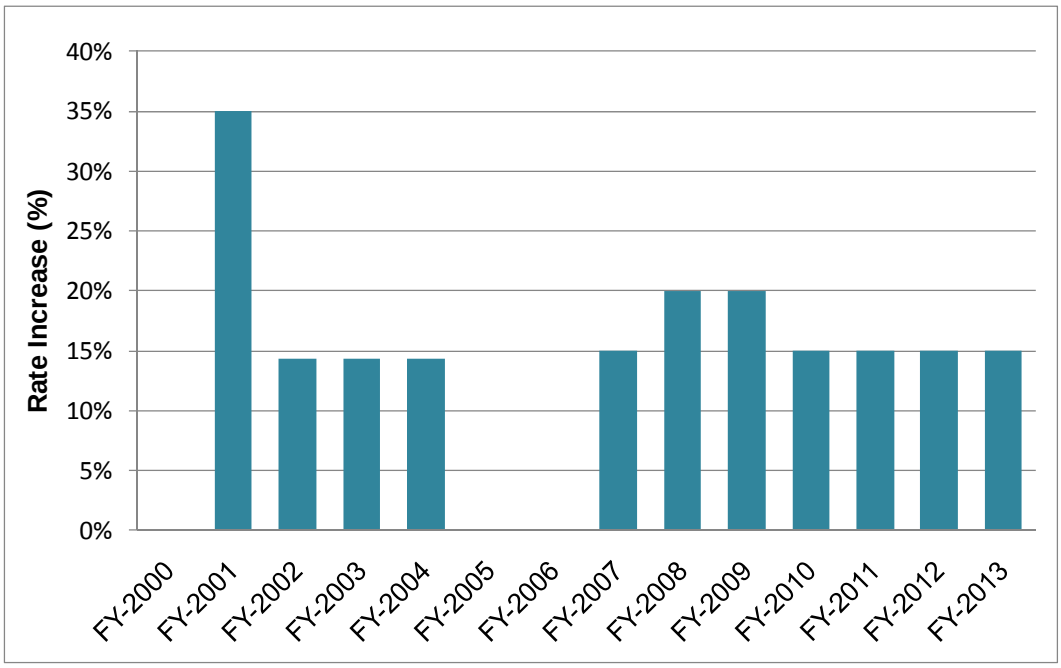
4.6 Rate Adjustments for the Five-Year Program

As explained in Section 4.2, the current economic climate and House Bill 26 make it very difficult for SD1 to confidently project its ability to raise rates beyond currently approved increases. The following discussion first describes SD1's rate adjustment history, then presents the rate adjustment assumptions incorporated into the Five-year Improvement Program.

4.6.1 SD1's Rate Adjustment History

SD1 has implemented a series of rate adjustments over the past 12 years, with recently-approved adjustments in 2012 and 2013, as shown in Figure 4.13.

Figure 4.13 SD1 Rate Adjustments FY-2000 – FY-2013



In FY-2001, SD1 adjusted rates by an increase of 35 percent. At that time, rates had not been adjusted since the 1986 rate decrease, nor increased since the late 1970's; therefore the large rate adjustment had been justified to begin the rate increases needed to help finance new CIP initiatives in the early 2000's.

The average annual rate increase for the period shown in the figure (2000 – 2013) is 14 percent. While this demonstrates SD1's historical commitment and ability to raise rates to fund improvements, the regional economic concerns presented previously make it highly uncertain that this can be sustained over future years.

It should be noted that the two approved 15 percent rate increases in 2010 and 2011 were approved at the beginning of Northern Kentucky feeling the full brunt of the national economic crisis. This positioned SD1 with the funding to at least initiate significant improvements over the first five-year implementation cycle. Further, the two additional 15 percent rate increases for 2012 and 2013 were approved by the Board of Directors and Judges Executive in March 2011, immediately prior to this 2011 submittal. These increases for FY2010 – FY-2013 demonstrate the commitment by SD1, in particular its Board of Directors and Judges Executive, to fund SD1 initiatives upon demonstration of return on investment in terms of protecting public health and improving water quality. Future increases, however, will inevitably be linked to regional economic conditions in Northern Kentucky and restricted by affordability limitations and House Bill 26.

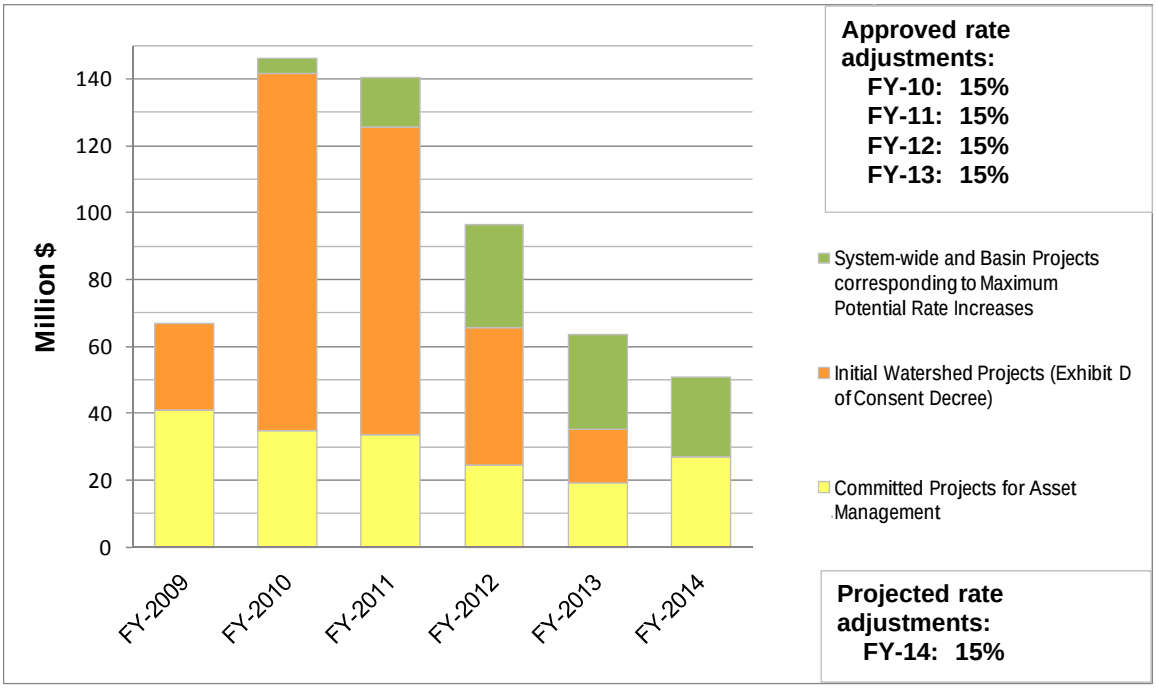
4.6.2 Assumed Rate Adjustment Schedule for Five-Year Improvement Program

SD1's objective in the first Five-year Improvement Program is to complete the Initial Watershed Projects, continue working on asset management efforts, and begin the implementation of system-wide and basin projects that have been identified through the

Watershed Planning process. All of these projects will provide significant improvements in CSO reduction, SSO elimination, public health, and result in water quality benefits for Northern Kentucky's waterways. The Five-year Improvement Program requires an additional rate increase in FY-2014, beyond the currently-approved increases (through FY-2013 inclusive). In order to configure the Five-year Improvement Program, SD1 has assumed an additional 15 percent rate increase in FY-2014. Under this scenario, the average residential customer using seven HCF per month would be paying $35 per month in FY-2010 and projected payment of $59 per month in FY-2014.

With an assumed 15 percent rate increase in 2014, SD1 could fund a total five-year program cost (FY-2010 to FY-2014) of $497 Million. The associated funding schedule is shown in Figure 4.14. The updated 2011 submittal estimates a five-year budget (FY-2009 to FY-2014) of $497 which is $38 Million greater than that described in the 2009 submittal. SD1 had the ability to increase spending in FY-10 to allow for the accelerated construction of the Western Regional Facilities and still maintain coverage due to the low interest loans and aggressive interest rates on bonds which were about to be received based on the current high bond rating.

Figure 4.14 Funding Schedule With Projected Maximum Potential Rate Increase for FY-2014



4.7 Conclusions

SD1 is committed to core values of environmental stewardship and the associated responsibility for protecting public health and improving water quality. As evidenced by the comprehensive watershed planning process presented in this document, SD1 understands the importance of pursuing the goal of eliminating SSOs and controlling CSOs to meet water-quality based requirements. However, given the unprecedented

economic challenges explained in this section, SD1 must account for regional economic realities in establishing the Watershed Plans.

As agreed with the Agencies, SD1 has developed an Integrated Plan for 2025 to present the plan that will achieve compliance with the obligations of the Consent Decree without regard to whether the plans are affordable. The affordability analysis presented above demonstrates the 2025 Integrated Plan would in fact impose unwarranted and unreasonable financial burdens and hardships on the communities served by SD1, and is beyond SD1's financial capabilities. Accordingly, although SD1 believes the 2025 Integrated Plan is the most cost-effective and beneficial plan that would eliminate SSOs and remedy CSOs in conformance with the CSO Control Policy, SD1 has determined it is unaffordable and relief from the December 31, 2025 Consent Decree deadline is therefore necessary through a material modification of the Consent Decree. Relief from the December 31, 2025 deadline could be afforded through a number of mechanisms recognized by the CSO Control Policy and KRS 224.16-040, including extensions of deadlines, affordability reviews in conjunction with five-year Watershed Plan updates, Use Attainability Analyses, or combinations thereof. Consistent with the parties' agreement, the form and extent of the relief is not being addressed in this Integrated Plan. Rather, the purpose of the Integrated Plan is to determine the most cost-effective approach to eliminate SSOs and address CSOs by December 31, 2025 consistent with the Consent Decree.

For the first Five-year Improvement Program outlined in these plans, the impact of and ability to obtain rate increases becomes the control on the extent of proposed projects. Rate increases were just approved in March, 2011, for FY-2012 and FY-2013; however, the Five-year Improvement Program requires a rate adjustment schedule through FY-2014 inclusive.

Therefore, in selecting projects for the first Five-year Improvement Program, SD1 followed two guiding principles:

- Fully evaluate and emphasize the selection of non-traditional green and watershed controls to pursue more cost-effective and increased water quality benefit options than traditional gray infrastructure.
- Focus all controls, including gray infrastructure, on the highest regional priorities – protecting public health, improving water quality, and maintaining current infrastructure assets as cost effectively as possible.

SD1 is confident that projects selected based on these principles are directly aligned with watershed management philosophies and will also support the goals of a wet weather control program.

Section 5
Public Participation

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SECTION 5. PUBLIC PARTICIPATION

SD1's public participation program is focused on educating stakeholders on the issues facing Northern Kentucky, ensuring that the Watershed Plans reflect the goals and concerns of the community, and obtaining input and feedback on the proposed approach for improving Northern Kentucky's waterways. The watershed-based approach presents a unique opportunity to educate the public on larger water quality issues (beyond sewer overflows) and also focuses on the relationships between different pollution sources, environmental impacts of pollution, and the cost-effectiveness of controls to address the various sources.

Since 2007, SD1 has hosted a Watershed Summit, established a Watershed Community Council, presented to local city councils and community groups, conducted surveys and workshops, and coordinated with regulatory agencies, advisory consultants and watershed partners. SD1 has also capitalized upon several ongoing public education efforts to inform and engage the general public.

5.1 Public Involvement during Development of Watershed Plans

5.1.1 Watershed Summit

To launch the watershed planning outreach efforts, SD1 held a Watershed Summit on August 30, 2007. The first hour of the Watershed Summit was held in an open house format, which provided the following environmental organizations the opportunity to host booths to share their mission and watershed protection initiatives with the public:

- Banklick Watershed Council
- Boone, Campbell and Kenton County Conservation Districts
- The Boone Conservancy
- The Campbell County Conservancy, Inc.
- Campbell County Farmland Work Group
- Environmental Quality Commission
- Environmental Protection Agency
- Kenton County Conservancy
- Northern Kentucky University Center for Applied Ecology
- Northern Kentucky Urban and Community Forestry Council
- Licking River Basin Team
- Licking River Watershed Watch
- Sanitation District No. 1
- The Sierra Club of Northern Kentucky
- Split Rock Conservation Park

Following the open house, SD1 delivered a formal presentation educating the attendees on the Consent Decree. This presentation included an audience survey that provided real-time feedback and concluded with an expert panel, including technical leaders from

national consulting firms. The Watershed Summit was also used to solicit volunteers for future involvement and to kick-off the formation of a Watershed Community Council.

5.1.2 Watershed Community Council

In November 2007, SD1 formed and hosted the first meeting of a Watershed Community Council (Council). The purpose of the Council was to share information and help facilitate open, thoughtful discussion on the watershed planning process. The Council is comprised of 53 members from a diverse group of stakeholders, including environmental organizations, home builders, the development community, local government and citizens.

Since its inception, the Council has met eight times[1] and SD1 has received input from the Council on various topics including:

- Consent Decree requirements
- Local watershed challenges
- Watershed Framework
- Community Values Survey
- Watershed Characterization Reports
- Stream Condition Index
- Green infrastructure opportunities (at the site and regional level)
- Review of improvement projects
- Capital budget issues
- Watershed Plan Submittal & EPA Review Process
- Wetland & Reforestation Project Updates

SD1 also established an online blog to provide an opportunity for discussions between the meetings and to solicit feedback.

5.1.3 Community Values Survey

SD1 conducted a Community Values Survey to provide input during the development of the Watershed Plans. The survey assessed community values, local environmental values, the importance of specific project criteria, and the willingness to pay for upgrades to the sanitary sewer system.

The survey was given to the Watershed Community Council and local business and education leaders. A total of 93 participants completed the survey between August 19, 2008 and November 3, 2008. Highlighted below are several compelling findings.

- When considering other federal government, local government and personal quality of life priorities, few listed “environmental protection” as an issue deserving top priority in Northern Kentucky. National security, gas/energy prices, public protection, education, employment, and the state of the economy ranked as top priorities.

[1] Watershed Community Council meetings were held: Nov 27, 2007; Feb 26, 2008; May 20, 2008; Aug 19, 2008; Nov 18, 2008, Feb 17, 2009, May 29, 2010 and Nov 3, 2010.

- More than 80% of respondents held a somewhat to very strong interest in protecting local waterways including the Ohio and Licking Rivers, major creeks and smaller streams in Northern Kentucky.
- Approximately 50% of respondents rated the importance of swimming and/or wading in local waterways, including the Ohio and Licking Rivers, major creeks and smaller streams in Northern Kentucky, as somewhat to very important.
- More than 85% of respondents agreed that improving water quality in Northern Kentucky is important to the region's long-term growth and quality of life and is personally valuable to them and their families.
- A strong majority of respondents have not participated in water-related recreational activities over the past year, but among those who have used the Ohio and Licking Rivers, boating was the primary mode of recreation.
- When asked to rank factors that should be considered when comparing and selecting projects, respondents ranked "reduction of sanitary sewage entering waterways" as the most important criterion. (Table 5.1).

Table 5.1 Initial Community Values Survey Results for Project Selection Criteria

Rank	Criteria
1	Reduction of sanitary sewage entering waterways
2	Reduction of storm water runoff pollutants
3	Public health benefit
4	Criticality of aging infrastructure
5	Cost
6	Reduction in flooding
7	Eco-friendliness
8	Protection of sensitive areas
9	Fish and wildlife benefit
10	Size of population/density receiving direct benefit
11	Aesthetic appeal

- When asked how much they would be willing to pay per month for sewer services in Northern Kentucky to comply with the Federal Clean Water Act and make upgrades to the sanitary sewer system, only 28% of respondents were willing to pay more than $50 per month. (Table 5.2).

Table 5.2 Initial Community Values Survey Results for Respondents Willingness to Pay for Sewer Services in Northern Kentucky

Monthly Cost	Response
$ 0 - $10	19.0%
$11 - $30	25.3%
$31 - $50	**27.8%**
$51 - $70	8.9%
$71 - $90	8.9%
$91 - $110	7.6%
More than $110	2.5%

These survey results indicated that even though respondents were strongly interested in protecting local waterways, there was a clear limit to the amount they were willing to pay for infrastructure and water quality improvement projects. To help Watershed Community Council members better understand the costs associated with infrastructure improvements, SD1 presented example projects at a subsequent Council meeting held on November 18, 2008. Through this presentation, SD1 was able to share the benefits of each project as well as the estimated costs. At the close of this meeting, approximately 20 Council members were resurveyed and asked again to rank project selection criteria and identify how much they would be willing to pay per month for sewer service.

The second survey indicated a change in the project criteria ranking. Most noticeably, project cost went from the fifth priority to the third, just slightly below addressing storm water pollutants (Table 5.3). Another criterion that increased significantly was the size of population/density receiving direct benefit, which increased from tenth to sixth.

Table 5.3 Follow-up Survey Results for Project Selection Criteria

Rank	Criteria
1	Reduction of sanitary sewage entering waterways
2	Reduction of storm water runoff pollutants
3	Cost
4	Public health benefit
5	Criticality of aging infrastructure
6	Size of population/density receiving direct benefit
7	Protection of sensitive areas
8	Reduction in flooding
9	Eco-friendliness
10	Fish and wildlife benefit
11	Aesthetic Appeal

In addition, 60% of the respondents that completed the second survey now said they were willing to pay more than $50 per month for sewer services in Northern Kentucky to comply with the Federal Clean Water Act and make upgrades to the sanitary sewer system.

A summary of the results of the initial survey can be found on SD1's website at www.sd1.org.

5.1.4 Innovative Storm Water Design Workshop

From March 31 to April 3, 2008, SD1 hosted an Innovative Storm Water Design Workshop, which involved a series of public meetings to discuss how green infrastructure approaches could be utilized in Northern Kentucky to protect water resources. The focus of the workshop was reducing storm water runoff to help mitigate combined sewer overflows. Public workshops, roundtable discussions with key constituent groups and individual stakeholder interviews were held to gather input on issues relating to green infrastructure, water resource protection, storm water management, combined sewer overflows, growth and development and quality of life in Northern Kentucky.

The Innovative Storm Water Design Workshop was a component of a technical assistance grant awarded to SD1 by the EPA. The EPA team's technical assistance and the public's input helped provide ideas on how to implement a green infrastructure program in Northern Kentucky and integrate it into the watershed planning process for the Consent Decree. The results of the workshop, including specific strategies, designs and possible applications for green infrastructure, are documented in the *Stormwater Management Handbook: Implementing Green Infrastructure in Northern Kentucky Communities.* The full document and an executive summary can be found on SD1's website.

5.2 Coordination with Other Agencies and Strategic Advisory Team

5.2.1 Regulatory Agency Coordination

In 2007, SD1 began conducting conference calls with KDOW and the EPA to review and discuss progress on the Consent Decree. Coordination with the regulatory agencies was integral to many of the early Consent Decree submittals. Once the initial submittals were completed, meetings were conducted on an as-needed basis[2]. Meetings were conducted via conference call with an online PowerPoint presentation. Topics discussed during the conference calls included:

- Infrastructure characterization
- Pump Station Overflow Elimination Plan
- Capacity, Management, Operation, and Maintenance

[2] In 2007, regulatory agency meetings were conducted on Jul 23, Aug 17, Sep 13, Sep 27, Oct 11, Oct 25, Nov 15, Nov 29, Dec 11, and Dec 20. In 2008, meetings were conducted on Jan 10, Jan 24, Feb 14, and Feb 28. In 2010, meetings were conducted on Jul 22, Aug 12, Aug 26, Sep 8, and Sep 15.

- Pump Station Operation Plan for Backup Power
- Nine Minimum Controls Program
- Green infrastructure
- Water quality monitoring programs
- Watershed Characterization Reports
- Watershed Framework
- Watershed approach pilot study
- Reporting requirements

This coordination proactively addressed concerns and provided the regulators with an introduction to SD1's approach for programs such as the CSO Nine Minimum Controls, Pump Station Backup Power Plan and the Capacity, Management, Operations and Maintenance Self-Assessment.

5.2.2 Strategic Advisory Team

In June 2006, SD1 established a Strategic Advisory Team to provide guidance in addressing the requirements of the Consent Decree. This team is comprised of six individuals with national expertise in various aspects of the water resources industry including infrastructure, watershed planning, utility management and water law[3]. Topics addressed by the Strategic Advisory Team included:

- Lessons learned from other communities
- Watershed-based approach and framework
- Sewer system characterization
- Watershed characterization
- Water quality standards
- Green infrastructure

5.2.3 Local Partnership Agencies

SD1 has also worked to strengthen relationships with other local agencies and watershed partners. Some of these groups include:

- Local planning and zoning agencies
- Boone, Campbell and Kenton County Conservation Districts
- Watershed groups (such as the Banklick Watershed Council, Gunpowder Creek Watershed Initiative, and Licking River Watershed Watch)
- Northern Kentucky Health Department

By working with these watershed partners, water quality pollutant sources that may exist outside of SD1's jurisdiction or service area such as certain land uses, agriculture, and failing septic systems can be more readily addressed. The coordination between SD1 and these agencies will help promote a cohesive, holistic approach to addressing the sources most contributing to water quality impairment.

[3] Strategic Advisory Team meetings were held in Jun 2006, Jul 2006, Aug 2007, Jun 2008, and Feb 2009.

5.2.4 Local Municipal Partnerships

The green opportunities evaluation in the CSS service area identified numerous locations for the placement of green infrastructure features. SD1 met with each of the communities served by combined sewers in which green opportunities had been identified to review the potential green infrastructure projects. Additionally, SD1 and city staff discussed planned and proposed capital projects, both public and private, that may occur within the city during the timeframe associated with the implementation of the Watershed Plans.

The following is a list of cities that participated in these meetings.

- City of Bromley
- City of Covington
- City of Dayton
- City of Fort Wright
- City of Ludlow
- City of Newport
- City of Park Hills
- City of Taylor Mill

The following topics were discussed with each city:

- Results of the combined sewer area green infrastructure evaluation and potential projects identified within the city;
- Planned development and redevelopment projects within the city;
- Proposed development and redevelopment projects within the city;
- Other opportunities or constraints within the city that could effect the implementation of green infrastructure; and
- The opportunity to partner and potentially cost-share on future green infrastructure projects within the city, including green streets.

The objective of these discussions was to verify that the proposed green features were feasible in the context of city operations and future plans within the city. Additionally, SD1 wanted to identify additional opportunities to cost-effectively integrate green infrastructure or otherwise offload storm water from the CSS during the planning and design of future projects.

In addition to providing a CSO reduction benefit, these partnerships allow SD1 to cost share on the implementation of green infrastructure while providing other amenities to the community. This outreach effort by SD1 should allow for the early identification of green infrastructure opportunities. By incorporating these principals into the early stages of the planning process, the ultimate cost to implement green infrastructure should be reduced.

Successful implementation of the proposed green infrastructure program requires significant stakeholder input. SD1 will continue to foster the relationship and coordinate

activities with these local communities in an effort to maximize the overall implementation rates of green infrastructure within the combined system.

5.3 Public Comment on Draft Documents

The Consent Decree requires that key submittals, specifically the Watershed Framework and the draft Watershed Plans, be made available for public comment and review. These comment periods allowed the public to review and provide input on the proposed improvement program and projects.

5.3.1 Watershed Framework

The public comment period for the Watershed Framework was conducted from February 26, 2008 to March 21, 2008. This comment period was then extended until April 9, 2008. The comment period was promoted through the Watershed Community Council, the Council's blog, SD1's website, community presentations, and e-mail reminders.

5.3.2 Watershed Plans

The public comment period for the Watershed Plans was conducted from May 7, 2009 to June 8, 2009. The Draft Watershed Plans were made available at the main library branch in each county and on SD1's website. The Executive Summary was distributed electronically to the members of the Watershed Community Council and Strategic Advisory Team.

During this time, SD1 hosted three public workshops to provide customers with an overview of the Watershed Plans, the specific project and program information, and to solicit feedback and comments on the Watershed Plans. These meetings were held on the following dates:

- Public Workshop 1 (Boone County) May 14, 2009
- Public Workshop 2 (Campbell County) May 19, 2009
- Public Workshop 3 (Kenton County) May 21, 2009

Approximately 41 different individuals attended the public workshops and four written comments were received during the public comment period. The public comments received provided both constructive criticism and support of the draft plan. The following are a selection of comments received:

> **Complimentary of SD1's Public Participation:** "Well staffed and presented…Presenters and Consultants seemed knowledgeable and interested in listening to and educating public who attended….Good job explaining how SD1's approach differs from typical approach and the improved results that are promised".
>
> **Use of Green Initiatives:** "I do applaud the implementation of many "green" initiatives to reduce storm water runoff and improve the quality of water that does eventually wind up in our streams..."

Financial Impacts to the Community: "The enormity of the document pails to the financial ramification our Northern Kentucky community faces trying to deal with the unfunded mandate of the Clean Water Act…You're integrated approach should, if the decisions are made wisely, produce the most cost-effective (most bang for the buck) solution."

Unreasonable Water Quality Standards: "Some members noted that if you eliminated all CSO's, the water quality would only increase by 7%. Their point is that the EPA has asked SD1 to perform a magic trick, remove all human bacteria CSO's and non-human bacteria sources…Before EPA or humans existed here the water quality did not meet EPA requirements. They are asking you to do better than God, on the backs of the Northern Kentucky citizens."

Runoff from Transportation Systems: "Not mentioned, but sure to contribute to pollution are the local, county, state and federal transportation systems. The expansion of the I-75 corridor is a huge example of this. If the additional run off is not mitigated at the source, all money spent and effort made by SD1 won't come up to the impact this one project will have on this area…EPA needs to be made aware that one federal agency is causing Northern Kentucky not to comply with the law and allowance for that need to be made."

The full text of the comments received and SD1's responses to these comments can be found in Appendix 5-A.

5.3.3 2011 Rate Adjustment Hearings

As a result of discussions with State Representative Arnold Simpson, SD1 agreed to host three public rate hearings on the proposed rate and fee adjustments for fiscal year 2012 and 2013. There was a hearing held in each of the three counties within SD1's service area. The details of each of the three hearings are listed below:

- Boone County (Boone County Public Library) January 26, 2011
- Campbell County (Campbell County Middle School) January 27, 2011
- Kenton County (Dixie Heights High School) January 29, 2011

At each hearing, SD1 shared a short presentation that included background information on SD1 and its Consent Decree, SD1's rate history, SD1's proposed rate adjustments and SD1's advocacy efforts as well as SD1's economic impact on the local community. Following the presentation, attendees had the opportunity to share their comments. SD1 recorded comments at each hearing, but did not respond to the comments. SD1 posted responses to commonly asked questions once the public comment period was completed. All comments collected will be shared with SD1's Board of Directors as well as with the three county Judges Executive. Comments will be reviewed before final approval is made of the proposed rate and fee adjustments.

5.4 Public Education Activities

SD1 has employed numerous approaches to engage and inform the general public on issues relating to the Consent Decree. Strategies have included SD1's website, television, print publications, and numerous presentations to local groups.

5.4.1 Website

SD1's website www.sd1.org is designed to provide easy access to information on SD1's wastewater and storm water programs. The website also provides information on:

- Programs & Outreach Activities
- Ongoing Projects
- Federal Court Order (Consent Decree)

The public can submit feedback to SD1, access a library of reports and documents including Consent Decree related documents, review educational programs, and view upcoming events. Additionally, the website provides links to real-time information on weather forecasts, water quality data, and water level information.

5.4.2 Television

In August 2008, SD1 joined with the local ABC affiliate, WCPO, to produce a 3.5 minute segment for "Living Green", a prime-time special series associated with their nightly newscast. The segment discussed protection of water resources, educational programs at SD1's Public Service Park, and the benefits of green infrastructure in the community. The segment ran at 8:00 pm on August 28, 2008.

As part of this educational initiative, SD1 personnel staffed a phone bank to answer calls and questions from the public on how green infrastructure can improve water resources. SD1 also created a related webpage that provided residents with information about what they can do to "go green" and highlighted local businesses and agencies that are utilizing green infrastructure approaches.

5.4.3 Print Publications

SD1 utilizes print publications such as bill inserts and newsletters to disseminate information to the general public on a regular basis. SD1 utilizes "What's Happening", a newsletter published and distributed to every resident and business located in the three counties in SD1's service area, to inform citizens about ongoing programs or educational initiatives. Bill inserts are also used to help educate customers about topics such as proper disposal of grease, personal care products, other household products and storm water pollution detection.

SD1 developed the "Cost of Clean" newsletter to help educate city councils, other elected officials, and interested stakeholders about the challenges Northern Kentucky faces in improving water quality and the associated costs to the community. In addition,

SD1's initiatives have been featured in the following publications and newspaper articles:

- SD1 Promotes 'Green' Projects (3/3/09) – *Community Press and Recorder*
- Rain Barrel Program Provided (2/9/09) – *Kentucky Enquirer*
- Putting Best Management Practices Into Practice (9/08) – *Stormwater Magazine*
- Ohio River Monitoring (Fall 08) – *Moreover* a publication of Thomas More College
- Workshop to Address Water-quality Measures (3/26/08) – *Kentucky Enquirer*
- Want Cleaner Water, Meet Next Week (2/25/08) – *Kentucky Enquirer*
- Some Local Streams 'Impaired' (1/15/07) – *Kentucky Post*

5.4.4 Community Presentations

SD1 consistently works to maintain relationships with local municipal leaders and community groups in Northern Kentucky. SD1 staff participates in meetings and workshops with various community groups and frequently conduct presentations to environmental, development and engineering groups.

In January 2009, SD1 began attending city, county and community group meetings to update local leaders and citizens on the watershed planning efforts and the estimated costs associated with meeting the requirements of the Consent Decree. SD1 representatives have provided presentations to 27 city, county and community groups and a majority of these meetings were aired on local cable stations affording the general public with the opportunity to learn more about SD1's draft Watershed Plans and proposed watershed projects[4].

5.5 Future Public Participation

SD1 is committed to continuing public participation and outreach during the design, construction and implementation of the Five-year Improvement Program to engage and inform the public and build support for future updates to the Watershed Plans and ongoing financing of the program.

The watershed-based approach and emphasis on green infrastructure will require significant public involvement to help identify and implement solutions that address the issues facing Northern Kentucky's rivers and streams. In addition, green programs, such as downspout disconnections, rain barrels, and rain gardens, will require active participation and engagement of area residents.

The watershed-based approach also mandates that the success, priorities, and programs be reevaluated, and updated Watershed Plans be developed after five years. Throughout the five-year updates of the Watershed Plans, SD1 anticipates continuing outreach to the community through advisory groups, educational activities, community

[4] In 2009, city, county and community meetings were attended: Jan 13, Jan 19, Jan 20, Feb 2, Feb 18, Feb 19, Feb 23, Feb 26, Mar 3, Mar 4, Mar 6, Mar 9, Mar 11, Mar 12, Mar 16, Mar 17, Mar 23, Apr 6, Apr 7, Apr 8, Apr 9, Apr 13, Apr 28, May 20 and June 4.

meetings, online and through the media to help solicit input and feedback and build stakeholder support for SD1's commitment to improving Northern Kentucky's watersheds.

Section 6
Prioritization

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SECTION 6. PRIORITIZATION

The economic characterization presented in Section 4 showed that SD1 has already invested significant resources to reduce sewer overflows. This level of investment will continue with the implementation of the Initial Watershed Projects listed in Exhibit D of the Consent Decree and SD1's Committed Projects to maintain current assets. In addition, SD1 has developed an Integrated Plan for 2025 that identifies green, grey, and watershed solutions required to control CSOs and eliminate SSOs as required by the Consent Decree. It is SD1's plan to implement projects associated with these solutions in a systematic fashion, directing attention and investment to projects that provide the greatest benefit to overflow control and improvement of water quality. This prioritization of projects and investment was used to identify specific projects for the first Five-year Improvement Program, described in detail in this submittal, and will be used to identify focus areas for the development of subsequent five-year plans.

The prioritization criteria were developed with input from key stakeholders and are described in this section. In general, the prioritization criteria considered factors such as public health, overflow activation frequency, and demonstration benefits. These criteria were then applied across the system and used to identify Priority Areas. A Priority Area is a watershed, sewershed, or specific overflow location where a project to address sources of pollution has been identified and will be considered for implementation in the next five years. The project may comprise any combination of gray, green, and watershed controls to achieve pollution reduction goals. It is important to note that the resulting projects proposed for these Priority Areas do not include the Initial Watershed Projects listed in the Consent Decree or any of the Committed Projects for existing assets. However, the benefits associated with the Initial Watershed Projects do extend into the selected Priority Areas because the planning for the Initial Watershed Projects utilized many of the same prioritization concepts described here. The prioritization of projects or locations that are not included in the first Five-year Improvement Program will be revisited as part of the update to the Watershed Plans. As part of future plans, a new listing of Priority Areas and projects will be developed and presented.

This section describes the prioritization criteria considered in establishing the Priority Areas. In some cases, examples are provided to demonstrate how the criteria were used to establish the Priority Areas for the first Five-year Improvement Program. It should be noted that a description of all of the projects scheduled to be completed in the first five years, pending available funding, is included in Section 7.

6.1 Stakeholder Involvement – Community Input

It was important for SD1 to obtain input from the community so that their goals and priorities could be considered in the development of the Five-year Improvement Program as well as the overall program. To achieve this goal, SD1 conducted a Community Values Survey (SD1 2008), which is summarized in Section 5.1.3. One of the conclusions from this survey is that the public is concerned about pollution from multiple sources, not just from sewer overflows. The watershed approach is SD1's strategy to coordinate pollutant reduction programs to achieve the most effective

environmental benefits. The watershed approach puts traditional CSO and SSO controls in context with other pollutant sources.

The survey also showed that public health is a very important concern and projects that could provide public health benefits should be made a high priority. Another key result of the survey is that, while reducing pollution and protecting public health are important, the cost to achieve these goals is also an important consideration. The public will support projects if they feel their money is well spent. These conclusions and insights are consistent with the goal of the Watershed Plans to develop a plan that allocates resources and funding to areas where the most benefit can be achieved.

6.2 Priority Area Identification

The first step in the process was to select criteria that were important in considering the urgency in addressing specific concerns in SD1's system. Subsequent to this activity, areas that met one or more of the criteria were identified. Collectively, all of the areas and their ranking against the established criteria were used to develop Priority Areas. Once Priority Areas were identified, projects were developed to address the specific sources of pollution in each Priority Area. In developing these projects, all combinations of controls, traditional gray infrastructure, innovative green infrastructure and watershed solutions, were considered.

6.2.1 Priority Area Criteria

Priority Area criteria were selected by aligning the goals of the Watershed Plans with stakeholder input. The result was the following list of criteria:

Public Health Risk Area: Protection of public health is the number one priority of any public wastewater utility. Therefore, areas where SD1 found high risk of contact with runoff mixed with sewage were the highest focus for the first set of projects as part of the Five-year Improvement Program. In addition, sensitive areas as defined by the CSO Control Policy were identified by watershed (Section 2.2.1) based on various criteria, including proximity to surface drinking water intakes and source water assessment and protection areas. These locations were evaluated for inclusion at Priority Areas.

Consent Decree Pump Station Overflow Elimination Projects (Exhibit E) Scheduled 2014 and Earlier: The Consent Decree deadline for elimination of overflows at certain pump stations falls early in the implementation of the Watershed Plans. Therefore, these pump stations are automatically considered Priority Areas.

Watershed Control Opportunities: Watershed control opportunities are locations where regional and/or decentralized watershed controls could be implemented to offset CSO control and provide measurable results to improve water quality by addressing multiple sources of bacteria, as well as other pollutants. In addition to identified offset locations, SD1 also considered and put a priority on watershed opportunities that could provide performance data on the effectiveness of watershed solutions to inform future plans.

Identified Green Opportunities: Green opportunities are locations where green-based controls could be implemented within a few years and could provide measurable results on the reduction of the volume of overflows in the separate and/or combined service areas. Green opportunities also include system-wide programmatic opportunities without specific locations identified. In these cases, the implementation may be directed by other Priority Areas.

Integration Opportunities: Integration opportunities are areas where a combination of control types (gray, green and/or watershed) could provide more benefit for the same cost as traditional gray controls only. These are typically areas where a public health risk area is coincident with a green or watershed opportunity area.

High Volume CSO and SSO: The largest overflows by volume deserve special consideration due to their magnitude. It is important to note that this does not necessarily mean that they are the greatest water quality impairment risk.

The following sections describe the identification of areas that meet these particular criteria for the first five years. Following a description of the Priority Areas for the first five years, a discussion of the remaining overflows and locations to be addressed by the same procedure as part of subsequent plan updates is presented. It is important to note that cost-effectiveness is a critical consideration for the community and for SD1. The ability to implement controls in a manner that directs funds to projects that provide the greatest benefits was an overarching consideration when identifying these areas.

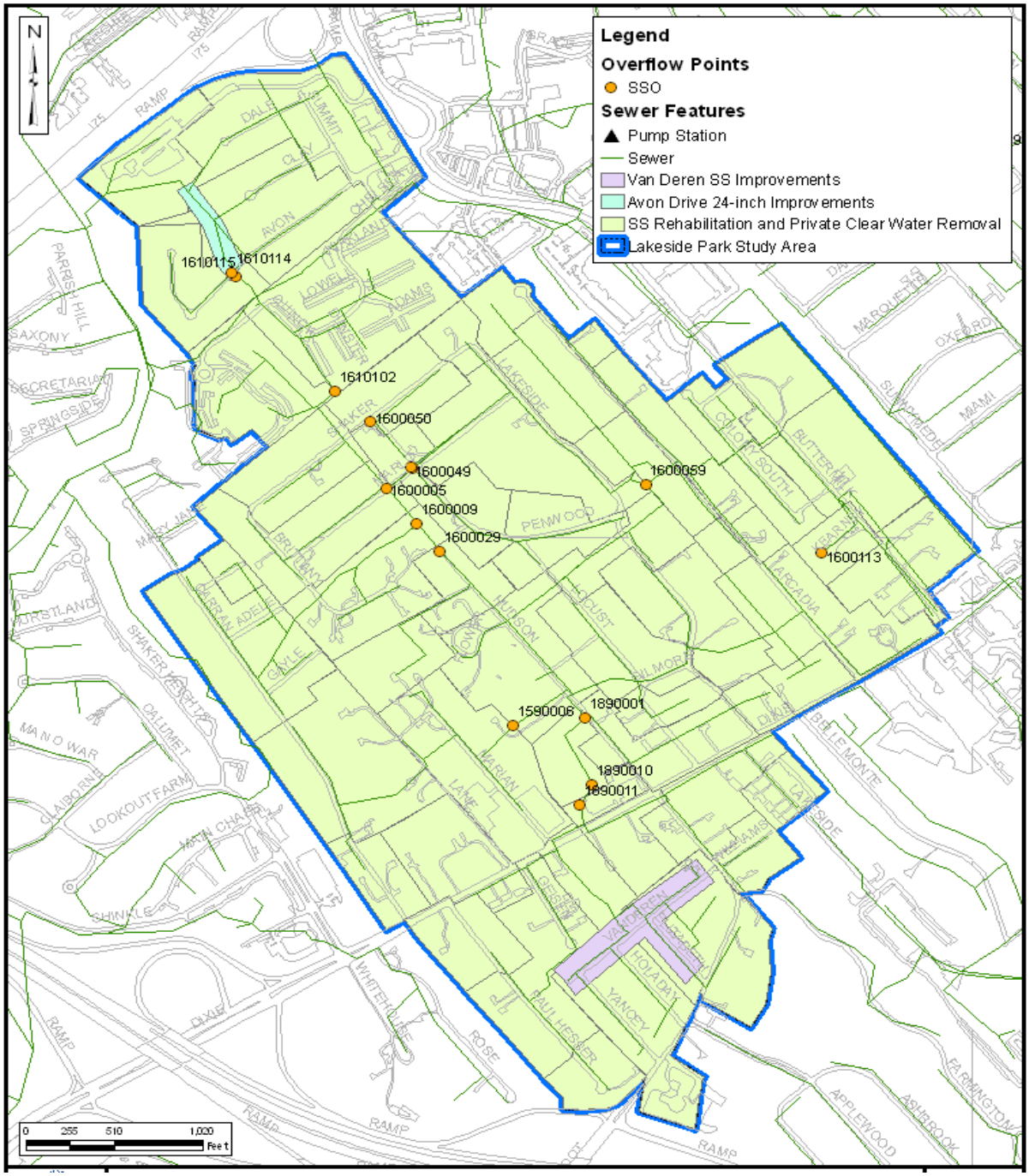
6.2.2 Public Health Risk Areas

Fecal coliform bacteria are indicators of the presence of pathogenic substances in waterways. Therefore, sources of bacteria, such as CSOs and SSOs, represent some level of public health risk. In establishing Priority Areas for the first five years, SD1 has identified four overflow locations that pose a higher public health risk because of their ease of access and frequency of activation. These overflow locations, Lakeside Park, Vernon Lane Area, Silver Grove, and Church Street, are briefly described below. In addition, other sensitive areas, including four watersheds that contain CSOs and a portion of a source water assessment and protection zone 1, (see section 2.2.1) were identified. These include the Licking River, Banklick Creek, Fourmile Creek, and Ohio River East watersheds. These are also described below.

<u>Lakeside Park</u>

The City of Lakeside Park and the City of Ft. Mitchell are located in the Dry Creek watershed and are part of SD1's sanitary sewer system. The "Lakeside Park" area, shown in Figure 6.1, includes sewers that serve portions of both cities. The area is primarily residential and consists of approximately 235 acres, 750 properties, and 1,400 residents, with a sanitary sewer system made up of 59,000 linear feet of pipe and 339 manholes, with an average dry weather flow of 0.2 MGD.

Figure 6.1 Lakeside Park Area



When SD1 took over ownership and operation of the infrastructure from the local communities in 1995, the sewers in the Lakeside Park area had wet weather hydraulic concerns and were not performing to an acceptable standard. Basement backups were occurring, manholes were overflowing, and sewage was entering surface waters during wet weather. Since that time, SD1 has conducted significant rehabilitation and replacement of infrastructure to eliminate basement backups and reduce overflow

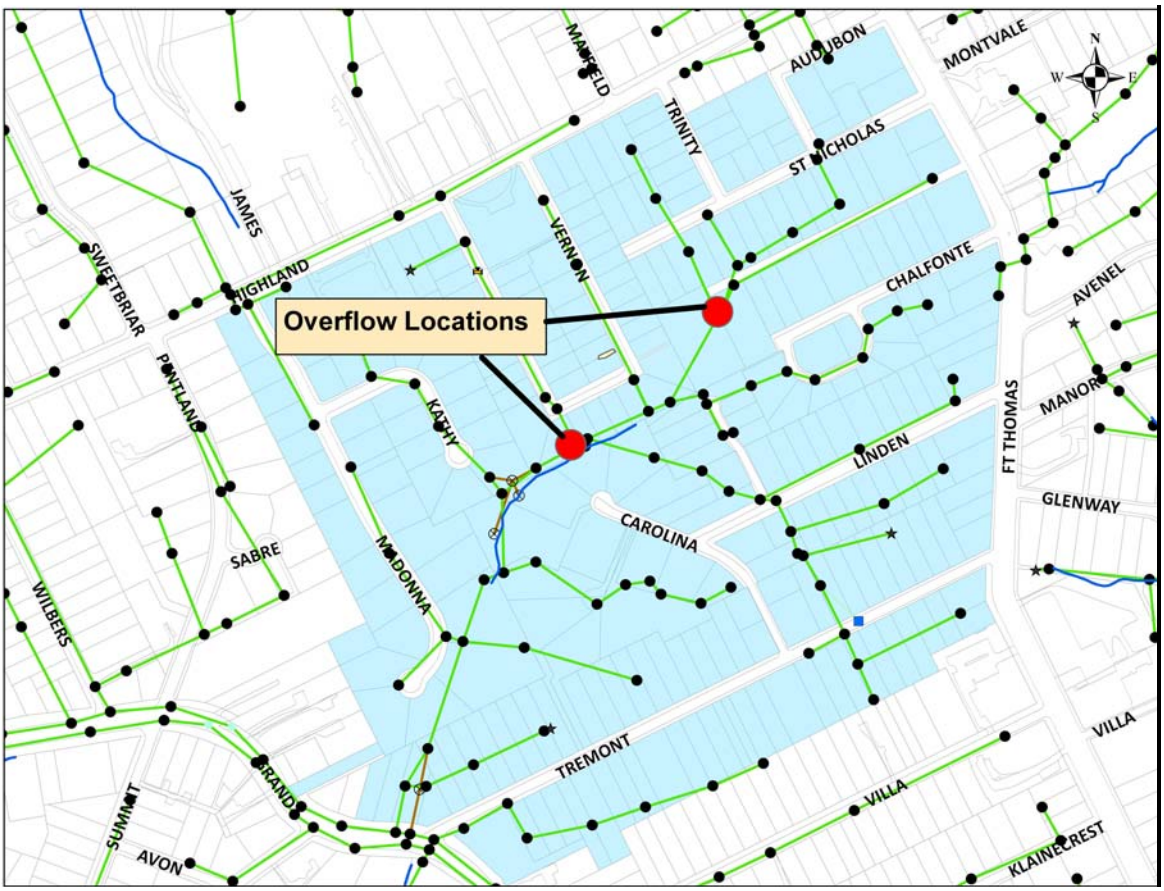
volumes. SSES activities have also occurred in the study area to provide information for past improvements and the current evaluation.

Due to the high concentration of overflow points (14 total) (Figure 6.1) which are in easily accessible public rights of way as well as near public residences, the Lakeside Park area is considered a higher public health risk area.

Vernon Lane Area

The Vernon Lane area is a residential neighborhood of about 270 homes in Ft. Thomas. An overview of the area is shown in Figure 6.2. Two overflow locations are predicted to activate on average five times in a typical year.

Figure 6.2 Vernon Lane Area



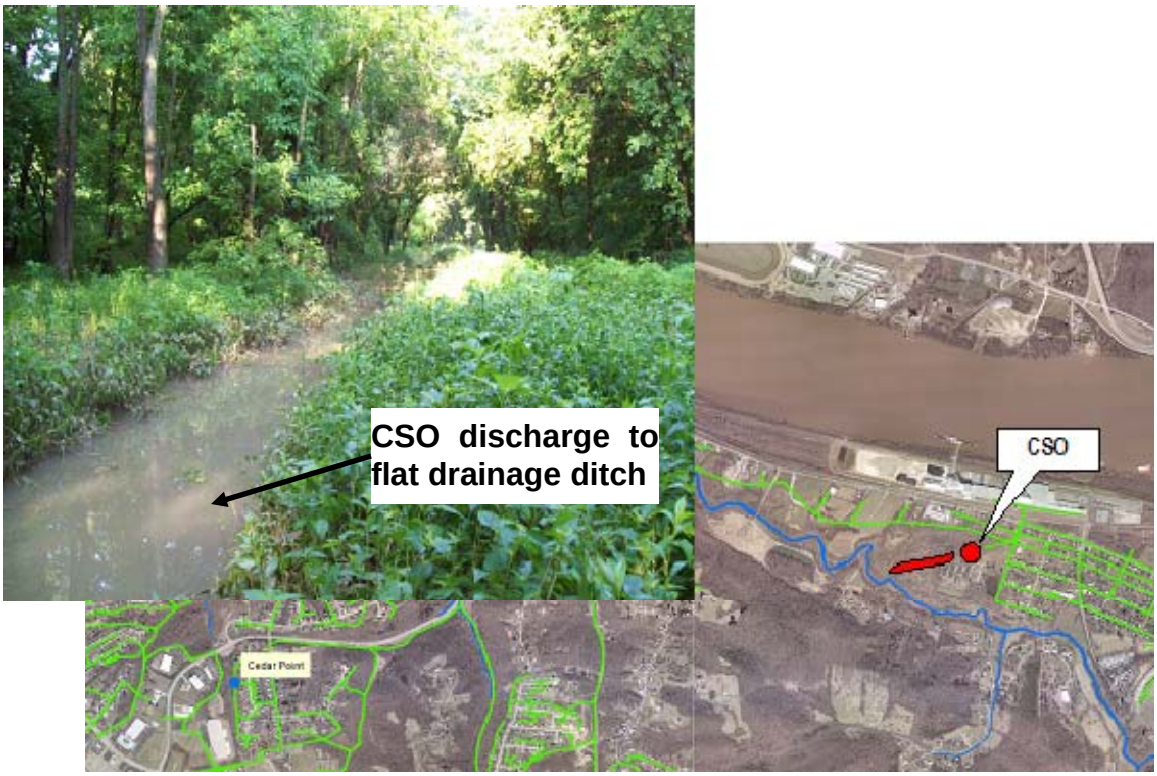
One of the overflows is located in a backyard within 50 feet of a residence. Figure 6.3 shows the location of this overflow. These overflows are a potential public health risk and the Vernon Lane area was selected as a Priority Area.

Figure 6.3 Vernon Lane Overflow Photo

Silver Grove Area

Silver Grove is a small city located in Campbell County, KY along the Ohio River. The area is a partially combined area with an average dry weather base flow of approximately 0.2 MGD. SD1 has found that the older parts of the City have combined sewers with private I/I source connections while newer parts of the City have mostly separate sanitary and storm sewers with private I/I source connections. There is a CSO located at the western end of the downtown area that discharges approximately 29 times per year, for a total annual volume of approximately 2.4 MG into a relatively flat drainage ditch tributary to Fourmile Creek. The CSO discharge is located within a few hundred feet of a mobile home park. The downstream sanitary flow is conveyed to the Silver Grove Pump Station. When the Ohio River is elevated, ground water and Ohio River water enters the pump station through low lying manholes and leaky sewers resulting in sewer overflows near the pump station that discharge a total of approximately 23.2 MG in a typical year. Figure 6.4 shows the location of the CSO relative to downtown Silver Grove.

Figure 6.4 Silver Grove CSO



The Ohio River backwater results in poor drainage and creates a stagnant area where the CSO and downstream SSO discharges linger and cause buildup of sewage sludge. The resulting sludge (Figure 6.5) cannot be removed with heavy equipment because of the poor drainage. In addition, Silver Grove is located within the Fourmile Creek watershed which was identified in Section 2.2.1 as being a surface water source protection area. Therefore, this area is of particular concern and meets the criteria for a Priority Area.

Figure 6.5 Silver Grove CSO Discharge

Church Street Area

The Church Street area includes three CSOs along the downstream end of Banklick Creek, near the confluence with the Licking River. Two of the overflows have relatively small annual activation statistics while the third, Church Street is the largest CSO on Banklick Creek (Table 6.1).

Table 6.1 Overflows at the Church Street Area

Manhole ID	Common Name	Typical Year Activation Frequency	Typical Year Volume (MG)
1870194	47th Street	4	0.20
1850158	Church Street	74	56.20
1870193	Decoursey Ave	23	1.29

Note: Typical year volumes based on hydraulic model results of the typical year rainfall (1970).

Under dry weather flow conditions, wastewater from local combined sewers flows to the Banklick Pump Station where it is then pumped into the Banklick Interceptor and flows downstream to the Dry Creek WWTP. Normal dry weather flow through the pump station is approximately 0.3 MGD.

Under wet weather conditions, the Banklick pump station will pump up to 2.5 MGD; any flow that exceeds this peak capacity of the station will surcharge the upstream system, causing overflows to occur at the three CSO locations noted in Table 6.1.

The drainage area to these CSOs (approximately 152 acres) includes areas of two Northern Kentucky cities (Taylor Mill and Covington) and consists of primarily residential land use.

Wet weather flows can enter the combined sewer system through several different routes. In the areas north of 43rd Street, runoff enters the combined system through catch basins and direct connections of downspouts, sump pumps, and foundation drains. Along the eastern edge of the tributary area, separate storm water sewers convey runoff to the drainage swale that runs between 43rd Street and Banklick Creek.

During heavy rains, the runoff will pool in the lowland swale. Over time, holes have been knocked into manhole chimneys and the combined sewer pipes to provide a means of draining the swale. These connections to the sewer system are one of the reasons why the Church Street CSO is very active. In addition, the holes that have been knocked into the existing infrastructure also provide a relief point when the existing combined sewer surcharges. Over time, this has created a human health concern. Furthermore, the Church Street area is located within the source water protection area for an intake on the Licking River. Figure 6.6 shows holes in the large pipe where surface water mixes with spilled sewage, causing a risk of exposure in a highly accessible location. The breaks in the pipe also represent public risk of injury.

Therefore, this area is of particular concern and meets the criteria as a Priority Area.

Figure 6.6 Broken and Exposed Pipe Along Church Street Trunk

Other Sensitive Areas

As mentioned previously, portions of four watersheds that contain combined sewer overflows were identified in Section 2.2.1 as being within source water assessment and protection zone 1. These are: the Licking River watershed, Banklick Creek watershed, Fourmile Creek watershed, and Ohio River East watershed.

The overflows along the Licking River and in Banklick Creek all occur downstream of the water intake, although the Banklick Creek overflows are within the source water assessment and protection zone 1. The inclusion of Church Street, which is located near the mouth of Banklick Creek, as a Priority Area indicates a commitment to addressing overflows in this area.

Overflows in Fourmile Creek do not discharge directly to the Ohio River and, as described above, tend to stagnate within Silver Grove. However, the inclusion of the Silver Grove area as a public health risk area addresses Fourmile Creek as a sensitive area.

Overflows in the Ohio River East watershed include the Highland Heights Pump Station (17.3 MG in a typical year in and around the pump station) as well as 4 CSOs located

along the downstream forcemain that discharge a total of less than 2 MG in a typical year. These overflows discharge along the hillside into local drainage ditches and do not discharge directly to the Ohio River. The sanitary sewers in the areas tributary to the Ohio River East watershed are known to be in very poor condition and have excessive I/I. Sewer replacement and upsizing would be very expensive due to very unstable slopes in the watershed. Therefore, the Ohio River East watershed will be included as a Priority Area, with efforts focused on addressing the sources of I/I and structural deterioration in the vicinity of the Highland Heights Pump Station as part of System-wide Projects discussed further in Section 7.

6.2.3 Pump Station Overflow Elimination Locations (Exhibit E)

Fourteen (14) pump stations are listed in Exhibit E of the Consent Decree. According to the implementation schedule submitted, all projects have a required completion date no later than December 31, 2014, which is within the first five year implementation timeline. Therefore, these locations are automatically considered for inclusion as Priority Areas. These pump stations are:

- Ripple Creek
- Riley Rd 1
- Harrison Harbor
- Taylorsport
- Lakeview
- Crestview
- Union
- Sunset
- Alex-Licking
- South Park
- Highland Acres
- Kentucky Aire
- South Hampton
- Allen Fork

Projects associated with these pump stations are described and summarized in Section 7.

6.2.4 Watershed Control Opportunities

The term “watershed control measure” is used to describe systems and practices that are intended to reduce pollution from sources other than sewer overflows, such as storm water runoff.. The emphasis on pollutant reduction differentiates these controls from green infrastructure which is primarily focused on mitigating hydrologic impacts. Watershed control projects could include retention basins, constructed wetlands, bioretention systems, biofiltration systems, or other controls designed for pollutant reduction. These measures are meant to complement wet weather point source control measures, such as combined sewer overflow (CSOs) and sanitary sewer overflow (SSOs) controls.

The identification of watershed control opportunities is an outgrowth of the “watershed approach” supported by SD1 that emphasizes a holistic approach to water quality improvement in Northern Kentucky. The remainder of this subsection provides a summary description of SD1’s watershed control opportunity analysis; however, Appendix 3C contains a detailed description of the methods and findings of the watershed control opportunity analysis.

Watershed Prioritization

The SD1 study area is comprised of sixteen watersheds, covering an area of 592 square miles (Figure 6.7). These watersheds range in size from 4.2 to 170 square miles and contain approximately 500 miles of named streams and several thousand miles of unnamed tributaries. Implementation of watershed controls throughout this vast area within the first Watershed Plans is impractical. Therefore, watersheds were prioritized based on the estimated annual CSO volumes within the watersheds. This focus on CSOs in prioritizing watersheds is a practical approach based on the "delay and offset" clause of SD1's Consent Decree. In this first round of watershed planning, only watersheds whose waterways receive CSOs were considered for siting of watershed controls.

Figure 6.7 Watersheds in the Northern Kentucky Study Area (June 2009)

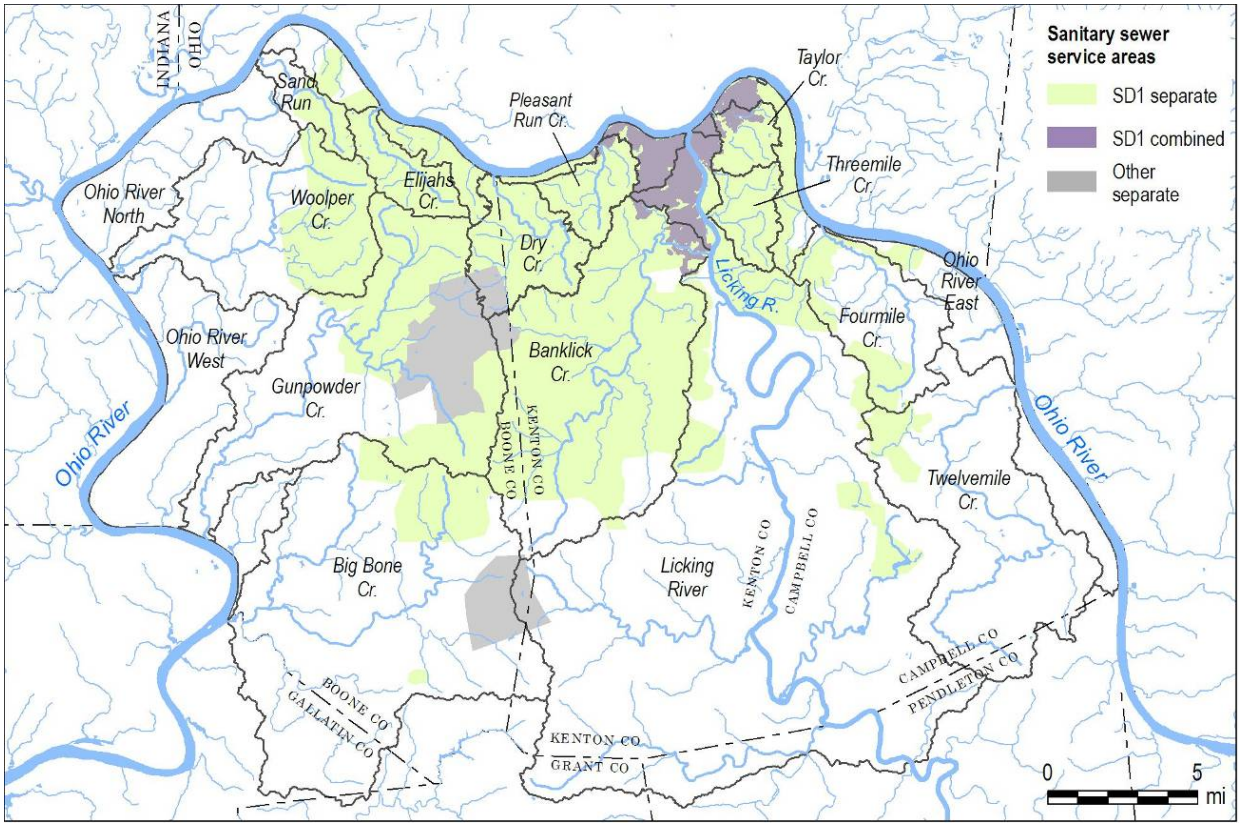


Table 6.2 summarizes information on CSOs in each watershed, including the modeled CSO volumes in the typical year and the rankings based on these values. SD1's Watershed Assessment Tool (WAT!) was also used to estimate total bacteria loads from each watershed as a secondary consideration.

Seven watersheds contain CSOs (Table 6.2) and were the focus of the watershed control opportunity analysis in this round of watershed planning. An eighth watershed, Threemile Creek, was also included because, although it does not contain any CSOs, it

flows into the Licking River, which does receive CSOs. The following eight watersheds were targeted for identification of watershed controls in the first Watershed Plans:

- Banklick Creek
- Licking River
- Ohio River North
- Taylor Creek
- Fourmile Creek
- Ohio River East
- Pleasant Run Creek
- Threemile Creek

Table 6.2 Watershed Prioritization Factors

Watershed	CSO Typical Year Spill Vol. (MG)[2]	CSO Volume Rank	Elevated Bacteria During Dry Weather	Overall Bacteria Load Ranking from WAT!
Banklick Creek	58.8	4	X	7
Big Bone Creek	-	-		12
Dry Creek	-	-	X	5
Elijahs Creek	-	-		8
Fourmile Creek	2.4	7	X	10
Gunpowder Creek	-	-	X	13
Licking River[1]	731.4	2	X	9
Ohio East Tributaries[1]	275.6	3		3
Ohio North Tributaries	793.6	1		1
Ohio West Tributaries	-	-		16
Pleasant Run Creek	2.7	6	X	6
Sand Run	-	-	X	15
Taylor Creek	8.4	5	X	2
Threemile Creek	-	-	X	4
Twelvemile Creek	-	-	X	11
Woolper Creek	-	-		14
Total	1,872.9	-	-	-

Notes:

[1] Includes drinking water intakes

[2] Model calculations are current as of June 2009.

Watershed Controls

The following major types of watershed controls were considered in SD1's overall watershed planning process:

- Regional Watershed Controls: These are relatively large opportunities for retention basins or constructed wetlands, typically with upstream drainage areas

greater than one square mile. Two major forms of regional watershed controls were considered: instream and side-stream.

- Decentralized Watershed Controls: These control measures are somewhat smaller than regional controls and consist of storm water wetlands and bioretention or biofiltration basins (i.e. modified retention basins), and similar controls treating smaller drainage areas, typically less than one square mile.
- Stream Restoration: Stream restoration, consisting of creating "naturalized" instream pools & meanders to increase residence time to promote bacteria die-off. Additionally, riparian buffers were also evaluated as part of the overall stream restoration evaluation.

New regional watershed control measures, consisting mainly of large side-stream constructed wetlands or retention basins with upstream drainage areas greater than one square mile, will not be a focus in SD1's watershed strategy for the first Five-year Improvement Program because limited opportunities were identified in watersheds where the benefits of such projects could be demonstrated. SD1 will complete construction of the Banklick regional constructed wetland and conduct monitoring, as planned, to gain knowledge about the design and performance of such control measures.

SD1 intends to develop new decentralized watershed control measures in target watersheds in the first Five-year Improvement Program. These projects will consist of control measures located to capture and treat storm water from drainage areas of less than one square mile. Several potential projects have been identified and are being investigated, but none have been committed to at this time. These projects may be newly constructed projects or retrofits of existing storm water controls. SD1 expects to complete up to three such projects as part of the first Five-year Improvement Program. These projects will be a component of an overall program of nonpoint source control implemented by SD1.

In the context of SD1's watershed planning effort, stream restoration refers to projects that integrate in-channel pools, channel lengthening, and riparian floodplain reconnection to increase hydraulic residence time, thereby increasing bacteria die-off. An evaluation of potential opportunities was conducted, along with a parallel evaluation of the potential benefits and costs. On this basis, it was concluded that very large projects involving creation of miles of new stream channel would be required to achieve desired benefits and that the cost associated with these projects would not justify the limited benefits. Additionally, riparian buffers were also evaluated as potential water quality improvement measures; however large-scale implementation would be required to achieve significant water quality benefits related to bacteria reduction. Although SD1 recognizes that there are several ancillary benefits that can potentially be realized from stream restoration and riparian buffer projects, these projects will not be included as a central component of the water quality strategy in this planning cycle. However, SD1 will continue to pursue partnerships with entities such as watershed groups to provide technical support for these initiatives.

6.2.5 Identified Green Infrastructure Opportunities

One outcome of the green infrastructure evaluation was the identification of numerous potential projects that would help achieve the goals of the Watershed Plans. Implementing these green projects can demonstrate the benefits of leading with green controls rather than constructing unnecessarily large and expensive gray improvements which may not achieve desired water quality improvement goals. These include stand alone green projects as well as integrated solutions that include both gray and green controls. Green controls will be implemented in both the combined sewer system and separate sewer system to reduce and filter the amount of runoff volume entering the system and ultimately improve water quality. Below is a summary of specific locations that resulted from the comprehensive analyses conducted as part of the development of the Watershed Plans.

Church Street – Green Infrastructure Community Enhancement and Integration Opportunity

The Church Street CSO, identified as a public health risk area with an average annual overflow volume of approximately 56 million gallons per year, is the largest CSO on Banklick Creek. A gray-only solution concept was evaluated for this CSO which consists of a large underground storage tank along with conveyance system upgrades.

SD1 quickly recognized that the Church Street area had potential to serve as an integration opportunity that could provide cost effective CSO reduction while enhancing the neighborhood. The overall integration plan is presented in Section 7.

Lakeside Park & Vernon Lane – Innovative Runoff Integration Opportunities

As described in Section 6.2.2, Lakeside Park is a small residential community in Northern Kentucky located near the intersection of I-75 and I-275. The community is named for a system of privately owned lakes dispersed throughout the neighborhoods. The Vernon Lane area is a residential neighborhood of about 270 homes in Ft. Thomas. Both of these areas are served by a separate sewer system and are impacted by a number of SSOs, resulting in both areas being identified as a public health risk area.

Based on a study previously conducted by SD1, a significant number of illegal private source storm water connections to the sanitary sewer system exist in these study areas. SD1 has evaluated the potential to use green infrastructure elements, such as downspout disconnection, residential and neighborhood rain gardens, and rain barrels, to disconnect storm water from residential properties that are currently being directed to the sanitary sewer system and to reduce the peak flows from the storm sewer system and filter the runoff to improve water quality. The innovative holistic approaches that are being taken to address both SSOs and storm water runoff in these areas and in other SSES areas are further described in Section 3.

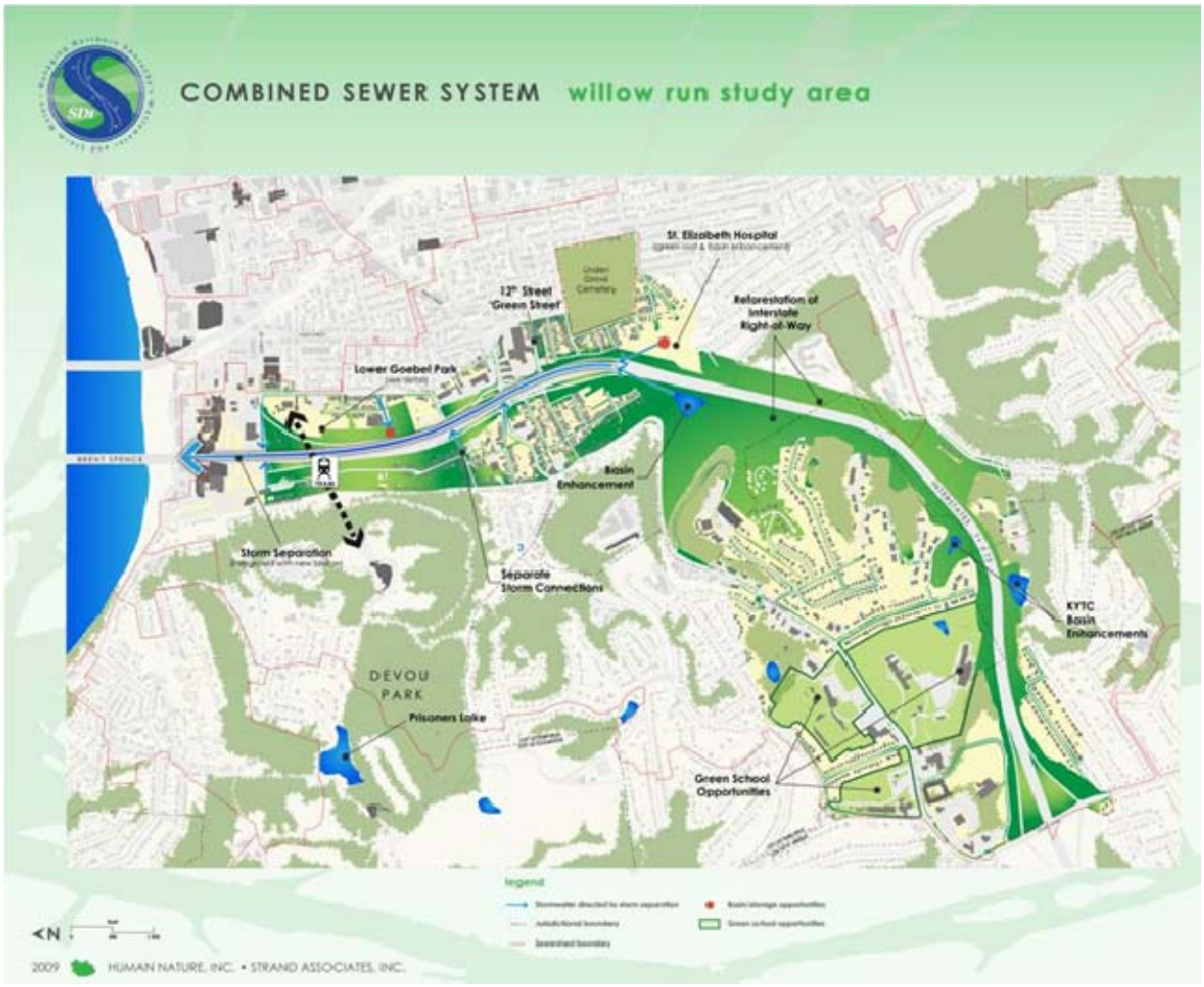
I -75 Corridor Green Infrastructure Concept Plan

One of the most significant outcomes of the evaluations conducted to date was the identification of the I-75 corridor from Kyles Lane north to the Ohio River as a priority focus area with multiple, highly visible green infrastructure opportunities. Through meetings with local entities, a number of potential valuable partnerships emerged. Several green opportunities were identified in this area which is part of the Willow Run

CSO basin. The Willow Run CSO is the largest CSO in the combined sewer system which makes it a Priority Area.

Figure 6.8 shows the green infrastructure opportunities identified for the I-75 Corridor. For a full size image of the I-75 Corridor Green Infrastructure Concept Plan, see Appendix 3-B.2.

Figure 6.8 I-75 Corridor Green Infrastructure Concept Plan



Several opportunities were identified in the development of the I-75 Corridor Green Infrastructure Concept Plan. However, one significant caveat to the development of this concept is the fact that the Kentucky Transportation Cabinet (KYTC) and the Ohio Department of Transportation (ODOT) are currently pursuing funding for the construction of a transportation corridor expansion plan along this stretch of I-75. The expansion plan involves the addition of lanes and, most likely, a new bridge crossing the Ohio River. The current timeline received from KYTC is for construction to start on this corridor and new bridge in the 2019 – 2020 timeframe.

While this significant transportation project is still in the planning phase, the early coordination between SD1 and KYTC has resulted in a number of potential opportunities to integrate project goals and objectives that benefit each agency. For example, KYTC was considering the construction of a new separate storm sewer system to convey the runoff from the new highway system that would discharge directly to the Ohio River. SD1 and KYTC are now evaluating the potential to enlarge this system to offload additional runoff from the combined sewer system. SD1 and KYTC have also discussed the potential for utilizing low lying areas in the City of Covington's Goebel Park for a large biofiltration system that could treat collected storm water runoff prior to discharging to the Ohio River. However, due to the KYTC timeline and magnitude of the transportation corridor expansion, only certain portions of the I-75 Corridor Green Infrastructure Concept Plan will be implemented in the first Five-year Improvement Program. Additional portions of this integrated solution will be evaluated as part of future Five-year Improvement Program cycles. These locations are listed below:

- KYTC Basins – Green Retrofit
- I-75 Terraced Reforestation
- 12th Street – Green Street
- St. Elizabeth Hospital

Small Licking River CSOs

During the green evaluation process, five small CSO basins with low activations were identified along the Licking River where green infrastructure could have a large impact. Included in this area is the Jacob Price public housing development. Field inspections of the site revealed that despite a considerable amount of green space on the property, all the roof downspouts and roadway systems drained directly to the combined sewer system. This appeared to be a prime candidate for downspout disconnection in conjunction with the construction of green controls on site. This assessment led to a meeting with the Housing Authority of Covington (HAC) to discuss potential partner opportunities. HAC has been awarded a Hope VI Revitalization Grant to develop and implement a comprehensive urban redevelopment project in this neighborhood. Since the award of the grant, SD1 has partnered with HAC to incorporate green infrastructure into the Jacob Price revitalization plan. By implementing low impact development features, HAC can disconnect as much runoff from the combined sewer system as possible. SD1 plans to continue partnerships with HAC and the City of Covington to implement green techniques throughout these five small basins, with the goal of reducing the volume of runoff entering the combined system and potentially impacting the small CSOs on the Licking River.

6.2.6 Integration Opportunities

Integration opportunities are areas where there is a high probability that the solution for addressing a public health risk or other water quality problem could include a combination of green, watershed, and traditional gray controls. The green and/or watershed portions of the controls will be implemented first to inform their effectiveness and to provide the opportunity to achieve higher water quality improvements at a lower cost than traditional gray solutions alone.

Integration opportunities were examined in the later stages of identifying Priority Areas. Integration of controls took one of several forms:

- Integration through staging of different control options. For example, an end-of-pipe gray control might be scheduled for a later stage to allow for integration of programmatic opportunities (source control) or green programs (downspout disconnection) in an earlier stage. In particular, source control in high I/I areas emerged as an important component in staging approaches; SD1 believes that source control is a cost-effective first step towards an ultimate solution in high I/I areas, and in some cases, may eliminate the need for a downstream solution to address wet weather flows.
- Integration to complement, or even take the place of, gray infrastructure controls. For example, green or watershed control techniques might be used to incorporate natural features (ponds, ravines) into a runoff control system, eliminating the need to construct traditional storm water pipes.

For Priority Areas made up of waterway reaches with high bacteria levels or projects with the potential for high cost-benefit ratios, the evaluation typically began with green technology or watershed control evaluations. In these cases, integration with traditional gray infrastructure controls was not always an option due to the nature of the area. Waterway reaches with high dry weather bacteria densities may be more effectively addressed through System-wide and Basin Projects (described in Section 7) or through watershed controls rather than traditional gray infrastructure controls.

The integration opportunity process identified the following locations for inclusion as Priority Areas in the first Five-year Improvement Program:

- Church St. Area,
- Lakeside Park,
- Willow Run CSO,
- Lakeview Pump Station,
- Vernon Lane,
- Small Licking River CSOs, and
- Green Pilot Projects.

Section 7 includes the evaluations conducted to identify the extent and timing of integration in these areas.

6.2.7 Highest Volume CSO and SSO

The highest volume CSO discharge in a typical year is the Willow Run CSO which discharges to the Ohio River. It discharges approximately 614 MG in a typical year which is approximately 33 percent of the total annual CSO volume system-wide. The highest volume SSO is the Licking River Siphon SSO, which discharges to the Licking River, discharging 48.9 MG in the typical year or 20 percent of the total SSO volume system-wide in a typical year. The Willow Run CSO area is already considered a Priority Area based on identified green opportunities and will be discussed in detail in Section 7. The Licking River Siphon SSO discharges to the Licking River but is located in the Threemile Creek watershed, which was previously identified as a Priority Area. Activities in this watershed will mainly focus on I/I source reduction due to the

overwhelming amount of I/I in the upstream service area. This approach is discussed in Section 7.

6.2.8 Summary of Candidate Priority Areas for the First Five Years

The identification of Priority Areas described above was an important step in SD1's development of the Watershed Plans because it:

- Recognizes that other pollutant sources and their relative impacts are important considerations;
- Provides a process to address areas with the highest regional priorities first;
- Allows for alternatives other than gray infrastructure to improve water quality;
- Opens the door to address more varied sources of pollution; and
- Directs funds to projects that provide the greatest benefits.

Given the extent of SD1's sewer system and the extensive improvements in the Integrated Plan for 2025 that are necessary to address all overflows (Section 3), it is clearly not possible (nor expected under the Consent Decree) to address all wet weather issues in the first Five-year Improvement Program. In addition, the extent of implementation of projects in the Priority Areas is driven by the availability of funding as described in Section 4. By establishing Priority Areas, SD1 was able to identify and rank the top candidates for potential inclusion in the first Five-year Improvement Program.

The end product of the initial evaluation and integration process was a formal listing of candidate Priority Areas for consideration to implement projects as part of SD1's Five-year Improvement Program. A summary of these Priority Areas and their link to the criteria described in Section 6.1 is shown in Table 6.3.

Table 6.3 Summary of Priority Areas

Priority Areas	Basin	Public Health Risk Area	PSOE[1]	Watershed Opportunity[2]	Green Opportunity	Integration Opportunity	Large Overflow
Allen Fork PS	North		X				
South Park Industrial PS	North		X				
Taylorsport PS	North		X				
Lakeview PS	Central		X		X	X	
Ripple Creek PS	Central		X				
Sunset PS	Central		X				
Alex-Licking PS	Central		X				
Riley Rd 1 PS	East		X				
Harrison Harbor PS	East		X				
Crestview PS	East		X				
Highland Acres PS	West		X				
South Hampton PS	West		X				
Union PS	West		X				
Kentucky Aire PS	West		X				
Lakeside Park	North		X		X	X	
Vernon Lane	Central	X			X	X	
Silver Grove CSO Area	East	X					
Church St. CSO Area	Central	X		X	X	X	
Ohio River East Watershed (near Highland Heights PS)	East	X					
Willow Run CSO Area	North				X	X	X
Threemile Creek Watershed	Central						
Banklick Creek Watershed	Central			X	X	X	
Taylor Creek Watershed	East						
Licking River Siphon SSO	Central						X
Small Licking River CSO Basins	Central				X	X	
Green Pilot Projects	All				X	X	

Notes:

[1] Pump Station Overflow Elimination locations from Exhibit E of the Consent Decree

[2] Denotes the location of watershed improvements. Watershed controls may also be a part of comprehensive RDII projects to address the quality of separated clearwater as well as Qcritical flows. Application of watershed controls in these areas is not called out in the table above since the location of RDII projects for future Five-year Improvement Programs are still being developed.

The Priority Areas shown above represent the focus for the development of projects to be implemented along with the Initial Watershed Projects and Committed projects as part of the first Five-year Improvement Program. The evaluation of these projects is described in Section 7. Selected projects and proposed implementation plans are included in Section 8.

6.3 Remaining SSO Prioritization

Projects to be completed in the first five years will address CSOs and SSOs, but these projects will not address all Priority Areas, nor will they address all of the SSOs in SD1's system. For planning purposes, SD1 developed a prioritization scheme to schedule proposed improvements to eliminate the SSOs remaining following the completion of the Five-year Improvement Program. This effort enabled SD1 to develop schedule and cash-flow projections over the duration of the program. To focus efforts, SD1 organized remaining SSOs by sewershed; individual sewersheds were ranked to determine the appropriate order for implementation of SSO elimination projects. The focus of the analysis was to use the public health impacts as well as the total typical year predicted overflow volume to select the locations that were most critical for elimination. Coupled with the prioritization, scheduling of improvements was conducted to organize the projects into a manageable program that could be effectively implemented. As part of developing Priority Areas for subsequent Watershed Submittals, a comprehensive analysis, similar to that done for the first Five-year Improvement Program, will be completed. As such, the focus for subsequent plans may not be consistent with the Integrated Plan projects listing and schedule. However, for the purposes of developing a schedule and cost for the Integrated Plan for 2025, a prioritization by sewershed was necessary.

6.3.1 2013 SSO locations and Typical Year Volume

The remaining SSO locations were organized based on sewersheds to facilitate the execution of projects for addressing the remaining SSOs following the Five-year Improvement Program. In order to schedule each set of sewershed improvements, for use in developing the Integrated Plan for 2025 as described in Section 3 and Section 8, sewersheds were prioritized based on the model projected typical year overflow volume remaining.

Table 6.4 shows the estimated overflow volume remaining in each sewershed following the completion of the Five-year Improvement Program.

Table 6.4 Sewershed SSO Volumes

Rank	Sewershed	2013 Model Predicted Overflow Volume (MG)
1	Licking River Siphon	52.3
2	Lakeview PS	44.7
3	Highland Heights / Silver Grove	20.8
4	Taylor Creek	5.3
5	Dry Creek	1.2
6	Bromley Crescent Springs	1.1
7	Western Regional	0.7
8	Taylorsport	0.1
9	Allen Fork	0.0
10	Wilder	0.0

Based on the above information, the sewersheds were divided into three categories (Table 6.5):

- **I/I Removal** – These are the sewersheds where significant I/I reduction opportunities have been identified and which are the highest priority following completion of the Five-year Improvement Program. Prior to construction of any gray infrastructure, the I/I removal projects will be implemented, monitored, and modeled to determine the additional appropriate controls that may be required.
- **Priority Gray Infrastructure** – These sewersheds were identified as the highest priority for construction of gray infrastructure, following the completion of the private and public source I/I removal. The top four sewersheds were targeted, but Lakeview PS was excluded due to the magnitude of the projected I/I program; additional time will be necessary to complete the work and monitoring for the Lakeview basin.
- **Facility Planning Gray Infrastructure** – These areas are highly dependent on future growth and so, while projections have been included to account for future growth, allowing for evaluation of the actual growth patterns and I/I from new development is necessary to properly size these improvements.

Table 6.5 SSO Sewershed Categories

I/I Removal Areas	Priority Gray Infrastructure	Facility Planning Gray Infrastructure
Licking River Siphon	Licking River Siphon	Lakeview PS
Lakeview PS	Highland Heights / Silver Grove	Dry Creek
Highland Heights / Silver Grove	Taylor Creek	Bromley Crescent Springs
Taylor Creek		Western Regional
Dry Creek		Taylorsport PS
Bromley Crescent Springs		Allen Fork
		Wilder

Table 6.6 contains a list of all SSOs and their prioritization (Ranking of 1 through 9) following the completion of the Five-year Improvement Program. The prioritization was based on the overall sewershed volume projected by the model and then, within each sewershed, the SSOs were prioritized by their individual volume predicted within the typical year.

As part of future watershed plan submittals, this priority list may change due to additional factors, such as street improvements, local flooding, and/or public health concerns. These issues will influence the scheduling and sequencing of future specific projects beyond the current Five-year Improvement Program.

Table 6.6 SSO Prioritization

MH ID	Basin	Sewershed	Rank	Selected Control	2013 Status
0860001	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150058	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0100002	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0110010	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150065	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0860003	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150064	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150356	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0100001	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150063	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0090009	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150023	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150069	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0150351	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
0860016	Central	Licking River Siphon	1	I/I Removal; Conveyance & Storage	
2300123	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1950PS1	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2110002	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1110067	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1110025	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1570100	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1110161	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2120001	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2120041	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2280011	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2160036	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1110294	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2280012	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1090069	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1760047	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1760048	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2090001	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2090026	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2120002	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1030PS2	West	Lakeview	2	I/I Removal; Conveyance & Storage	
1950199	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1960012	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2030097	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2010PS1	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2010PS2	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2010PS3	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2010PS4	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2020PS2	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2020PS7	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
2280010	Central	Lakeview	2	I/I Removal; Conveyance & Storage	
1040060	Central	Lakeview	2	I/I Removal; Conveyance & Storage	Eliminated
1030PS1	West	Lakeview	2	I/I Removal; Conveyance & Storage	Eliminated
0050PS1	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
0020005	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
0050022	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	

MH ID	Basin	Sewershed	Rank	Selected Control	2013 Status
0060001	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
0060002	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
0300008	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
0020014	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
1920163	Central	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
2150050	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
0010PS5	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
0020PS1	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
1920PS3	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
2150PS1	East	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	
1900PS3	Central	Highland Heights / Silver Grove	3	I/I Removal; Conveyance & Storage	Eliminated
0530083	East	Taylor Creek	4	I/I Removal; Conveyance	
0410019	East	Taylor Creek	4	I/I Removal; Conveyance	
0410010	East	Taylor Creek	4	I/I Removal; Conveyance	
0410068	East	Taylor Creek	4	I/I Removal; Conveyance	
0440074	East	Taylor Creek	4	I/I Removal; Conveyance	
0410011	East	Taylor Creek	4	I/I Removal; Conveyance	
0410036	East	Taylor Creek	4	I/I Removal; Conveyance	
1240008	North	Dry Creek	5	I/I Removal; Conveyance	
2130022	North	Dry Creek	5	I/I Removal; Conveyance	
1610115	North	Dry Creek	5	I/I Removal; Conveyance	
1600029	North	Dry Creek	5	I/I Removal; Conveyance	
1190007	North	Dry Creek	5	I/I Removal; Conveyance	
1600049	North	Dry Creek	5	I/I Removal; Conveyance	
1600059	North	Dry Creek	5	I/I Removal; Conveyance	
1610102	North	Dry Creek	5	I/I Removal; Conveyance	
1160004	North	Dry Creek	5	I/I Removal; Conveyance	
1220029	North	Dry Creek	5	I/I Removal; Conveyance	
1280008	North	Dry Creek	5	I/I Removal; Conveyance	
1590006	North	Dry Creek	5	I/I Removal; Conveyance	
1600005	North	Dry Creek	5	I/I Removal; Conveyance	
1600009	North	Dry Creek	5	I/I Removal; Conveyance	
1600050	North	Dry Creek	5	I/I Removal; Conveyance	
1600110	North	Dry Creek	5	I/I Removal; Conveyance	
1600113	North	Dry Creek	5	I/I Removal; Conveyance	
1610114	North	Dry Creek	5	I/I Removal; Conveyance	
1630012	North	Dry Creek	5	I/I Removal; Conveyance	
1820014	North	Dry Creek	5	I/I Removal; Conveyance	
1830017	North	Dry Creek	5	I/I Removal; Conveyance	
1830020	North	Dry Creek	5	I/I Removal; Conveyance	
1830067	North	Dry Creek	5	I/I Removal; Conveyance	
1890001	North	Dry Creek	5	I/I Removal; Conveyance	
1890010	North	Dry Creek	5	I/I Removal; Conveyance	
1890011	North	Dry Creek	5	I/I Removal; Conveyance	
1680001	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
2290001	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
1730104	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
1690043	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
1560016	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
1560019	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
1560074	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	

MH ID	Basin	Sewershed	Rank	Selected Control	2013 Status
1620001	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
1700025	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
1730110	North	Bromley Crescent Springs	6	I/I Removal; Conveyance	
2320PS3	West	Western Regional	7	Conveyance	
'2380001	West	Western Regional	7	Conveyance	Eliminated
2380PS1	West	Western Regional	7	Conveyance	Eliminated
2280PS1	West	Western Regional	7	Conveyance	Eliminated
2280PS2	West	Western Regional	7	Conveyance	Eliminated
2420PS3	West	Western Regional	7	Conveyance	Eliminated
2420PS6	West	Western Regional	7	Conveyance	Eliminated
2360PS1	North	Taylorsport	8	Conveyance	
2360PS2	North	Taylorsport	8	Conveyance	
2360PS3	North	Taylorsport	8	Conveyance	
2370PS1	North	Taylorsport	8	Conveyance	
2390002	North	Allen Fork	9	Conveyance & Storage	
2390006	North	Allen Fork	9	Conveyance & Storage	
2390008	North	Allen Fork	9	Conveyance & Storage	
2390762	North	Allen Fork	9	Conveyance & Storage	
2390PS1	North	Allen Fork	9	Conveyance & Storage	
1860108	Central	Combined System	NA	Green Infrastructure & Combined Improvements	
1870013	Central	Combined System	NA	Green Infrastructure & Combined Improvements	
2210PS2	East	Eastern Regional	NA	Conveyance	
2230PS3	East	Eastern Regional	NA	Conveyance	Eliminated
2200PS1	Central	Eastern Regional	NA	Conveyance	Eliminated
2450PS2	Central	Eastern Regional	NA	Conveyance	Eliminated

Note: The list of overflow locations presented in Table 6.6 is based on the original list of overflows contained in Exhibit A of the Consent Decree. Improvement projects have addressed several of these overflows and in other cases; inspection has shown no evidence of overflow. However, inspection has shown evidence of overflow at nearby manholes and as such, the list has been used in prioritizing areas for future projects.

6.4 Remaining CSO Prioritization

Similar to the SSO discussion in Section 6.3, following the completion of the Five-year Improvement Program, a significant reduction in system-wide CSO volume is projected but some CSOs will not be completely addressed. Total CSO volume after implementation of the Five-year Improvement Program is projected to be approximately 1,380 MG within the typical year. The focus of the CSO reduction beyond the Five-year Improvement Program is to first maximize the amount of control using green infrastructure, then monitor to identify the required gray infrastructure to meet the targeted level of control. For the green infrastructure projects, 98 green infrastructure features have been proposed for the SD1 combined sewer system. The goals of these projects are to reduce CSO volume, improve water quality, and provide additional storm water management in the combined system by reducing risks for local flooding. These projects have been ranked and prioritized for the Integrated Plan for 2025 based on a number of factors including:

- Watershed and receiving stream;
- Cost per gallon benefit;
- Local flooding and storm water management benefits
- Projects related to the Jacob Price Hope VI Grant project area have been moved to the top of the list; and
- Projects related to the I-75 Corridor and Brent Spence Bridge project have been moved to the end of the list.

As SD1 continues to foster partnerships and evaluate the combined system for green infrastructure opportunities, the list of proposed projects will be evaluated and adjusted. As specific projects are selected for inclusion in the future five-year Watershed Plan submittals, the specific details of individual projects and project components will be refined and optimized to achieve a desired cost-benefit ratio.

While the focus of the Five-year Improvement Program is to implement NMC improvements and address public health issues for locations such as Church Street, the long-term prioritization will be based on the results of the green infrastructure implementation and remaining CSO volume following the completion of the Five-year Improvement Program. Post-monitoring and analysis will confirm the system performance following the completion of those projects and will help to inform the scheduling of improvements based on need.

6.5 Summary

Like most communities under a consent order, SD1 has many overflows that will require attention. Unfortunately, time and resources necessitate a systematic approach to addressing the overflows in a prioritized fashion – where urgent attention is given to the most pressing concerns or locations where performance data will aid in decision making for future plans. To this end, SD1 has established prioritization criteria that were developed based on input provided by the public. These criteria were used to identify the specific Priority Areas for investment and action in the first five years and lay the foundation for how Priority Areas for subsequent Watershed Plan updates will be identified.

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Section 7
Five-year Improvement Program

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SECTION 7. FIVE-YEAR IMPROVEMENT PROGRAM

The Five-year Improvement Program, which is presented in this section, reflects SD1's commitment to implementing cost-effective projects that protect public health, improve water quality and/or maintain current assets. As presented in Section 4, the ability and timing to fully implement the program depends on SD1's ability to obtain adequate funding especially given the current economic climate. The projects included in the Five-year Improvement Program fall into three major categories. These are:

1. ***Initial Watershed Projects***: Strictly speaking, Initial Watershed Projects are construction projects that are listed in Exhibit D of the Consent Decree and have schedule milestones already included. More importantly, these projects alone represent a significant financial commitment in the Five-year Improvement Program to achieve the goals of the Watershed Plans. These projects are presented and discussed in Section 7.1. The benefits of these Initial Watershed Projects align with the Priority Areas defined in Section 6.

2. ***Committed Projects:*** Committed Projects are focused on the rehabilitation and maintenance of assets SD1 currently owns. Included projects may focus on fixing failing pipes, maximizing existing dry and wet weather capacity, addressing loss of service and basement backups, or minimizing wet weather overflows. An investment in the existing infrastructure represents preventative maintenance activities that will enable SD1 to avoid failures (such as new SSOs) that are costly to fix and could pose a threat to public health and the environment. The Committed Projects are presented in Section 7.2.

3. ***System-wide & Basin Projects***: System-wide Projects are long-term projects or programs that SD1 has identified to help achieve the goals of the Watershed Plans. These projects will be initiated within the five-year program horizon and cut across watershed boundaries. The Priority Areas identified in Section 6 will help inform and shape the timing and locations of implementation. Budget targets for these projects were included for the first five years of implementation. The projects are presented and discussed in Section 7.3

   Basin Projects are discrete basin-specific projects that were developed to address sources of pollution in the Priority Areas that were identified in Section 6. Following the evaluation of Priority Areas, SD1 worked through a detailed analysis in each area to develop candidate projects for the Five-year Improvement Program. These Basin Projects are described in Sections 7.4 through 7.7. Each of these sections presents detailed information, including the evaluation, selection, cost, and benefits of each project selected, by Consent Decree basin.

Individual projects may comprise any combination of green, watershed, and traditional gray infrastructure solutions. Full implementation of the Five-year Improvement Program, if feasible, is expected to result in a significant reduction in SSOs and CSOs and will significantly reduce the risk of exposure to sewage in the public health risk

areas identified in Section 6. Table 7.1 summarizes how the project categories listed above align with the Priority Areas identified in Section 6.0. The table shows that all Priority Areas have some project identified as part of the Five-year Improvement Program. Committed Projects are not specifically addressed in Table 7.1 as they describe projects and programs that are not limited to specific Priority Areas.

Table 7.1 Addressing Priority Areas in the Five-Year Program

Priority Areas	Basin	Addressed as Part of		
		Initial Watershed Projects[1]	System-Wide Projects	Basin Projects
Allen Fork Pump Station	North	X	X	X
South Park Industrial Pump Station	North			X
Taylorsport Pump Station	North	X		
Lakeview Pump Station	Central	X	X	X
Ripple Creek Pump Station	Central		X	X
Sunset Pump Station	Central	X		
Alex-Licking Pump Station	Central	X		
Riley Road No. 1 Pump Station	East	X		
Harrison Harbor Pump Station [1]	East			
Crestview Pump Station	East		X	
Highland Acres Pump Station	West	X		X
South Hampton Pump Station	West	X		X
Union Pump Station	West	X		X
Kentucky Aire Pump Station	West	X		X
Lakeside Park	North		X	X
Vernon Lane	Central		X	X
Silver Grove CSO Area	East		X	X
Church St. CSO Area	Central		X	X
Willow Run CSO Area	North		X	X
Ohio River East Watershed (near Highland Heights PS)	East		X	
Threemile Creek Watershed	Central		X	
Banklick Creek Watershed	Central		X	X
Taylor Creek Watershed	East		X	X
Licking River Siphon SSO	Central		X	
Small Licking River CSO Basins	Central		X	
Green Pilot Projects	All		X	

[1] Harrison Harbor was identified as a Priority Area, however, the SSO has already been addressed. See Section 7.5.1 for details.

7.1 Initial Watershed Projects

When ownership and operation of the sanitary sewer system were transferred to SD1, the Northern Kentucky communities wanted a more effective and efficient management of sanitary sewer service. SD1 has proactively improved collection and treatment of sewage through consolidation and investment. As an example, SD1 had begun to evaluate and address capacity concerns within the system prior to the development of the Consent Decree. As part of the approved Regional Facilities Plan, SD1 identified the highest priority concerns so that projects could be constructed to address the priority issues (Woolpert, 2001). Available treatment capacity and SSOs were identified as the highest priority for addressing with immediate projects. The following drivers to develop effective solutions were:

- **Potential Lack of Dry Weather Capacity at Dry Creek WWTP:** SD1 had identified a future lack of dry and wet weather treatment capacity at the Dry Creek WWTP. Future projections showed that the treatment capacity would be a limiting factor in the plant operation at a point in the future, and that a significant upgrade of the average dry weather treatment capabilities of Dry Creek was not a cost-effective alternative. In addition, the ability to treat combined sewer flows is impeded by the amount of capacity taken by high base flows. The removal of base flow with the Western Regional Water Reclamation Facility (WRF) allows for increased peak wet weather capacity from the Bromley (CSO) system.
- **Overflows at the Alexandria WWTP:** The Alexandria WWTP was frequently overwhelmed and forced to bypass flows during wet weather. The existing tributary system was under significant capacity restrictions, and the entire service area was under a moratorium for new connections until the problems could be addressed. Construction of the Eastern Regional WRF replaces the Alexandria WWTP, eliminates sewer overflows and removes of the building moratorium.
- **Known SSOs:** SSO locations that had significant overflow volume or which had the potential to impact public health were identified as the most critical to investigate and address. The Lakeview PS was targeted as a high profile SSO that needed to be addressed in the near-term with any selected alternative. In addition, reduction of flows to both the Taylorsport PS and Lakeview PS upstream sewer systems were also identified as a key component of the proposed sewer system improvements due to the presence of aging infrastructure within those basins. Finally, the known overflow locations in Florence were also identified.
- **Pump Stations with Constructed Bypasses:** Several pump stations in the SD1 system were characterized as being under capacity and contained constructed bypasses. The possible elimination of pump stations with constructed bypasses was also identified as a priority in determining feasible solutions.

Consequently, SD1 developed a set of projects to begin to address these concerns as part of the long-term planning prior to the Consent Decree. These projects were identified as integral to the long-term service of SD1 and serve as the basis for all of the future improvements to be conducted. These projects are listed in the Consent Decree

as the Initial Watershed Projects, and they fall into three main categories for purpose of description:

- Western Regional System
- Eastern Regional System
- System Capacity and Operation Issues
    - Elimination of basement backups
    - Reduction and elimination of SSOs and pump stations with bypasses
    - Elimination of local capacity restrictions
    - Connection of septic system properties to SD1 system
    - Reduction and elimination of CSOs
    - Improved system operation and reduced maintenance to address CMOM and NMC requirements

7.1.1 Western Regional System

Through the analysis conducted within the Regional Facilities Plan, SD1 identified components of a new sewer system facility located in the western portion of the service area that could be constructed to address the lack of capacity at Dry Creek WWTP, several known SSO locations, and pump stations with constructed bypasses (SD1, 2006). The projects for this facility have been previously planned and documented within the Consent Decree as priority projects to be completed and have been identified by SD1 as important to complete in the near-term.

SD1 went through a rigorous analysis to identify, develop, and design the Western Regional improvements. There were two main components to the selected improvements:

- Western Regional WRF
- Western Regional Conveyance System (including pump stations, trunk sewers, and tunnel)

A full list of the components of the Western Regional system is shown in Table 7.2 along with the current estimated completion date. Figure 7.1 shows a map of the proposed improvements.

Table 7.2 Western Regional Initial Watershed Projects

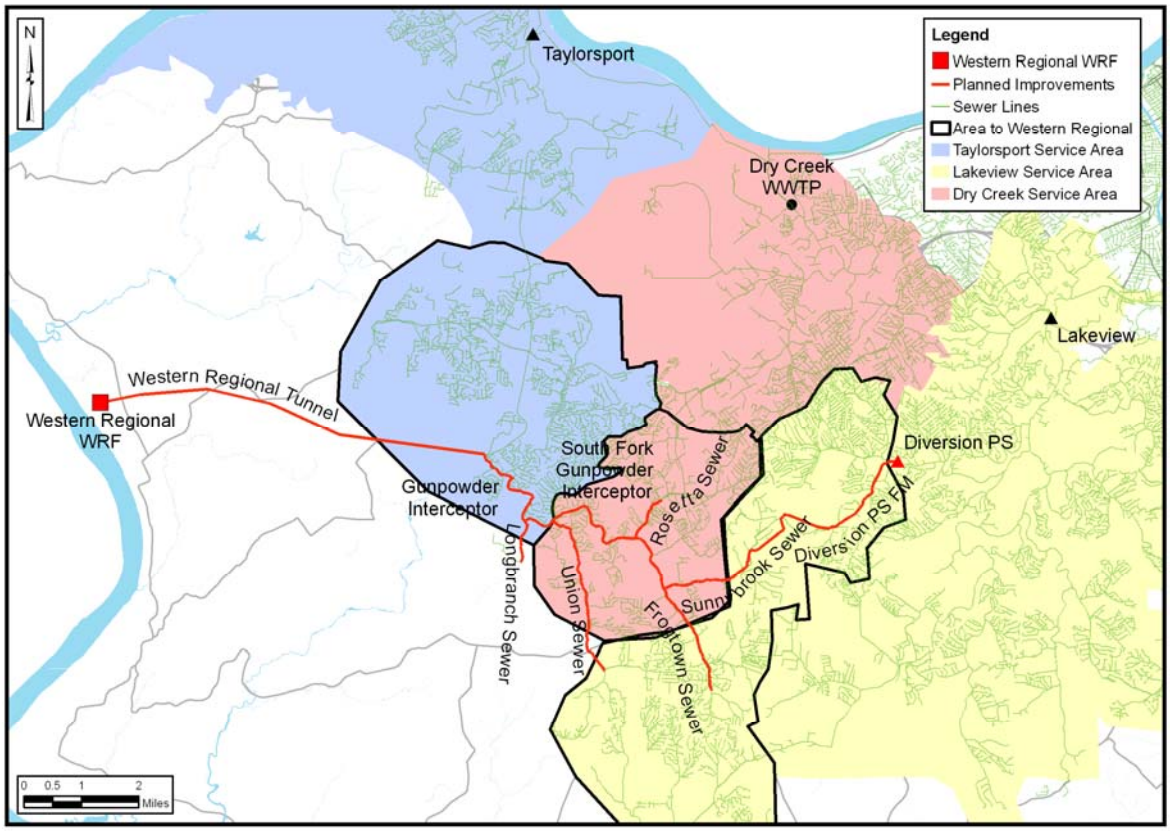
Project Description	Estimated Completion Date	Capital Cost ($Millions)
Western Regional Water Reclamation Facility		
Western Regional WRF	2013	$89.3
Western Regional Conveyance System		
Western Regional Conveyance System to Western Regional WRF (WR Tunnel)	2013	$141.3
Western Regional Sunnybrook Sewer	2013	$7.5
Western Regional – Frogtown Interceptor Sewer	2013	$6.6
Western Regional – South Fork Gunpowder Sewer and Rosetta Sewer	2013	$19.5
Western Regional – Narrows Road Diversion PS	2013	$11.6
Western Regional – KYTC Turkeyfoot Road Forcemain	2006-Completed	$1
Western Regional – Union Sewer (North and South)	2008 - Completed	$6.9
Western Regional – Gunpowder Interceptor Sewer	2013	$14
Western Regional – Turkeyfoot Industrial Road Forcemain	2013	$3.3
Western Regional – Richwood Sewer and Forcemain	Refer to Section 8.3	-
	Total	$301

All of the planned Western Regional improvements are shown in Figure 7.1 and are outlined in more detail below. The outlined areas on the map are areas that are currently tributary to the Dry Creek WWTP that will be disconnected and turned to the Western Regional WRF following completion of all of the improvements. This area represents a significant component of the Dry Creek service area. When complete, the Western Regional improvements will have removed the following from the Dry Creek service area:

- 360 miles of sanitary sewers
- 21,000 acres of tributary area
- 10 MGD average dry weather flow
- 70 MGD peak wet weather flow in a typical year (conveyed to tunnel for storage)

In 2013, the Western Regional WRF is projected to treat four billion gallons of sanitary sewage that would have otherwise been treated at Dry Creek WWTP.

Figure 7.1 Proposed Western Regional Conveyance System and Water Reclamation Facility



Western Regional Water Reclamation Facility

Initially, 20 different locations were evaluated for a new treatment facility before the current location for the Western Regional WRF was selected. Details of the locations and selection process for the Western Regional WRF are in the approved 2001 Regional Facilities Plan (Woolpert, 2001). The new facility will be located along the Ohio River along the western edge of Boone County. The new Western Regional WRF will be a 20 MGD average daily flow treatment facility with the ability to be upgraded in the future as needed.

Western Regional Tunnel and Conveyance

To convey flows to the Western Regional WRF, the alternative selected in the approved updated Regional Facilities Plan (SD1, 2008) was an 8.5-foot diameter tunnel that runs from the current location of the Gunpowder PS to the proposed Western Regional WRF location. This tunnel will convey flows from redirected parts of the existing SD1 sewer system to the new treatment facility. The tunnel project includes a storage/conveyance component of 32,500 feet and a conveyance component downstream of a control gate structure that is approximately 3,600 feet. This tunnel will provide not only conveyance to the Western Regional WRF, but will also provide storage for current and future wet weather flows.

In addition, a network of trunk sewers are being constructed to convey flows to the tunnel; a summary of the main trunk sewer improvements is shown in Table 7.3. The layout of these sewers was optimized to eliminate several SD1 pump stations with constructed bypasses, as well as to provide additional capacity to eliminate overflows within the City of Florence.

Table 7.3 Western Regional Conveyance System Sewer Sizing

Sewer	Length (feet)	Required Size
Gunpowder	13,500	72”
Union	16,700	36”
Longbranch	4,460	36”
South Fork Gunpowder	5,950 / 5,400 / 5,600	54”/60”/66”
Rosetta	4,650	30”
Sunnybrook	15,270	36”
Frogtown	10,860	42”

In addition to the gravity network, SD1 is constructing the Narrows Road Diversion PS, which will have a capacity of 17 MGD. This pump station will redirect a significant portion of flow from the Lakeview system to the Sunnybrook sewer and to the Western Regional WRF. This station will reduce the peak flows within the Lakeview system and will greatly reduce overflows occurring at the pump station.

The upgrade of Richwood PS and the construction of a new forcemain to redirect flows to the Western Regional System were originally included in the Initial Watershed Projects due to the pump station’s potential lack of dry and wet weather capacity and its perceived reduction in overflow volume in the Lakeview system. Based on flow monitoring conducted in 2007 and 2008 and subsequent hydraulic modeling, SD1 has found that the Richwood PS does not bypass during wet weather and has sufficient capacity to convey all dry and wet weather flows. In addition, redirecting the flows from the Richwood PS to the Western Regional system did not significantly reduce overflows downstream in the Lakeview system. The potential future need to construct this project will be based on monitoring the existing upstream and downstream sewer system after the Western Regional WRF is operational. The timing of the upgrade and redirection of the Richwood PS to the Western Regional System will be evaluated based on monitoring the available capacity of the pump station and the downstream Lakeview sewer system. Richwood PS will receive a backup power solution as well to eliminate any overflows due to power outages. SD1 will include an evaluation of the capacity of the Richwood PS in the next watershed plan update.

Projected Benefits

The construction of the Western Regional Conveyance System and Water Reclamation Facility has significant benefit to SD1, both in providing near-term wet weather overflow reduction and elimination, as well as providing flexibility for future capacity needs by reducing flows to the Dry Creek WWTP. The benefits resulting from the implementation of the Western Regional Improvements include:

- Additional dry weather capacity at the Dry Creek WWTP- approximately 10 MGD of average daily flow will be redirected to the Western Regional WRF in 2013.
- Providing treatment for over four billion gallons of sanitary sewage within a typical year, providing increased capacity and enabling increased flows to be directed to the Dry Creek WWTP.
- Reduces overflow volume at five SSO locations in the West Basin in Florence by providing increased downstream capacity (based on Florence Sanitary Sewer Overflow Plan).
- Reduces or eliminates SSOs-Pump Stations in Lakeview, Dry Creek, and Taylorsport tributary systems (included in this list are the impacts of additional Pump Station Overflow Elimination projects made possible through the Western Regional improvements):
    - Union PS (eliminated)
    - South Hampton PS (eliminated)
    - Gammon Calmet PS (eliminated)
    - Gunpowder PS (eliminated)
    - Kentucky Aire PS (eliminated)
    - Highland Acres PS (eliminated)
    - Lakeview PS (>90% reduction in annual overflow volume)
- Reduces or eliminates confirmed SSO locations in Lakeview, Dry Creek, and Taylorsport tributary systems based on typical year model simulations:
    - 1040060 (eliminated)
    - 2380001 (eliminated)
    - 2280011 (reduced)
    - 2300123 (reduced)
    - 2130022 (reduced)
    - 2120001 (reduced)
- Reduces contribution of other potential overflows calculated by the SD1 hydraulic model to occur in the typical year in Lakeview, Dry Creek, and Taylorsport tributary systems. As referenced in Section 2.1.2, these are locations that are calculated to occur by the SD1 hydraulic model but have not yet been field verified and confirmed as recurring SSOs.

Table 7.4 below shows the impact of the Western Regional improvements on overflow reduction within Dry Creek, Taylorsport, and Lakeview systems in the SD1 hydraulic model. Within the Lakeview system, the total overflow reduction is almost 56 MG, an almost 60 percent reduction in volume calculated with the implementation of the planned Western Regional improvements. Additional reduction of almost 4 MG in other portions of the SD1 systems is calculated to occur as well.

In summary, the impacts of the Western Regional improvements are significant and result in a large (59.7 MG) reduction in the volume of overflows that are calculated to occur in the typical year. A summary of the projected benefits following the implementation of the Western Regional Improvements is provided in Section 8.

Table 7.4 Summary of Typical Year Overflow Volume based on Western Regional Improvements

Category[1]	Existing Typical Year Overflow Volume (MG)	Remaining Typical Year Overflow Volume with Western Regional Improvements (MG)[2]
Lakeview SSOs	20.6	5.8
Lakeview Other Potential Overflows	77.6	36.6
Dry Creek and Taylorsport SSOs	1.6	1.1
Dry Creek and Taylorsport Other Potential Overflows	4.7	1.3
Total	104.5	44.8

Notes:
[1]"Other Potential Overflows" are locations at which SD1's 2008 model calculates overflows during the typical year. SD1 has an ongoing field investigation program targeted at these potential overflows, with crews visiting potential sites to assess activity during and after rainfall events; however, coordinated field investigations to confirm model calculations have not gathered sufficient data yet to consider these potential overflow points as recurring SSOs.
[2] Included are the impacts of additional Pump Station Overflow Elimination projects made possible through the Western Regional improvements.

7.1.2 Eastern Regional System

In evaluating the SD1 system as part of the approved Regional Facilities Plan (Woolpert, 2001), it was apparent that the existing Alexandria WWTP (when taken over by SD1) was frequently overwhelmed and forced to bypass flows during wet weather. The existing sanitary system was also under significant capacity restrictions, and the entire service area was under a moratorium for new connections until the problems could be addressed. To address these issues, SD1 developed a plan to provide dry and wet weather capacity through the construction of a new treatment facility and a series of conveyance improvements. The goal of these improvements was to provide additional treatment capacity through the Eastern Regional WRF (located on the site of the existing Alexandria WWTP) and to eliminate existing SSOs in the tributary system.

SD1 went through a rigorous analysis to identify, develop, and design the Eastern Regional improvements. There were two main components to the selected improvements:

- Eastern Regional WRF
- Eastern Regional Conveyance System (including pump stations, forcemains, and trunk sewers)

A full list of the components of the Eastern Regional system is shown in Table 7.5 along with the completion date**.**

Table 7.5 Eastern Regional Initial Watershed Projects

Project Description	Estimated Completion Date	Cost ($Millions)
Eastern Regional Water Reclamation Facility		
Eastern Regional Water Reclamation Facility	2008-Completed	$41.7
Eastern Regional Conveyance System		
Eastern Regional – Contract 1- Pond Creek Forcemain and Gravity Sewer	2008-Completed	$5.7
Eastern Regional – Contract 2- Kahn's Gravity Sewer and Gravity Sewer to the Pond Creek PS	2008-Completed	$4.3
Eastern Regional Contract 3 – Riley Forcemain and Gravity Sewer	2009	$5.7
Eastern Regional Contract 4 – Alex-Licking Forcemain and Gravity Sewer to Contract 1	2008-Completed	$3.9
Eastern Regional Contract 5 – Sunset Forcemain and Gravity Sewer	2009	$0.5
Eastern Regional Contract 6 – Pond Creek PS	2008-Completed	$4.1
Eastern Regional Contract 7 – Riley Road #2 PS	2009	$7.1
Eastern Regional Contract 8 – Alex Licking PS	2009	$2.3
Eastern Regional Contract 8B – Sunset PS Relocation	2010 (see Section 8.3)	$1.8
Total		$77.1

Projected Benefits

With the completion of the Eastern Regional system improvements at a total capital cost of $76.8 Million, SD1 will have addressed a significant number of the issues facing the separate system in this portion of the service area. Benefits include:

- Will eliminate all recurring SSOs in the Eastern Regional tributary system:
  - Alex Licking PS
  - Riley Road No. 1 PS
  - Riley Road No. 2 PS
  - Sunset PS
  - Overflow at existing Alexandria WWTP
- Eliminates eight million gallons of SSO volume in a typical year through elimination of the overflows at both the pump stations and the existing Alexandria WWTP.

7.1.3 System Capacity and Operation Improvements

In addition to the large-scale improvement projects to construct the new Eastern and Western Regional systems, representing a total expenditure of $378 Million, a number of other projects and studies were identified to begin to address capacity and operational issues in other areas across the sewer system. Table 7.6 lists the Initial Watershed Projects listed in Exhibit D in the Consent Decree that were identified, the

drivers and anticipated benefits behind each project, the estimated completion date, and the cost.

Table 7.6 System Capacity and Operation Improvements
Consent Decree Exhibit D - Initial Watershed Projects

Project Description	Project Drivers/Benefits	Estimated Completion Date	Cost ($Millions)
North Basin Initial Watershed Projects			
Strawberry PS Elimination	Eliminate aging pump station	2006 Completed	$0.2
Beechwood Outfall Sewer Replacement	Eliminate local wet weather capacity issue and replace aging infrastructure	2007 Completed	$2.3
Allen Fork Sewer system – Phase I Improvements	Improve dry and wet weather capacity of Allen Fork PS system	2007 Completed	$7.3
East Basin Initial Watershed Projects			
US 27 at Summit Assessment	Connect failing septic systems to SD1 system	2008 Completed	$0.4
Parkside PS Relocation	Replace aging pump station with more efficient pump station. Costs were shared with KYTC as part of their road widening project	2008 Completed	$0.9
Highland Heights PS Study	Study to examine alternatives for overflows in Highland Heights and Sliver Grove	2006 Completed	$0.3
Wilson/Waterworks Road Relief Sewer Study	Study to examine alternatives for eliminating local capacity issues and overflows in Taylor Creek watershed	2008 Completed	$0.04
Pinehill/Skyview Terrace Sewer	Sewer to address local wet weather capacity issue	2006 Completed	$0.3
West Basin Initial Watershed Projects			
American Sign PS Rehabilitation	Replace existing pump station, eliminate local overflow and increase capacity	2008 Completed	$0.5
Duncan Drive Assessment Project	Connect failing septic systems to SD1 system	2007 Completed	$1.0
Central Basin Initial Watershed Projects			
Banklick PS Screening Facility	Improve combined sewer pump station operation and reduce upstream overflows	2006 Completed	$1.2
Stevenson Road Relief Sewer Project Phase II	Eliminate local capacity restriction and reduce SSOs	2006 Completed	$2.1
Latonia Combined Sewer Separation	Reduce CSO volume and eliminate local basement backups	2008 Completed	$2.6
Licking River Sewer Crossing Study	Examine alternatives for reducing and eliminating largest SD1 SSO	2007 Completed	$0.2
McMillan PS Removal	Construct gravity sewer to eliminate failing pump station and forcemain	2006 Completed	$0.7
Meyer Road PS Rehabilitation	Replace aging pump station	2008 Completed	$0.3

Project Description	Project Drivers/Benefits	Estimated Completion Date	Cost ($Millions)
Macke PS Rehabilitation	Replace aging pump station with constructed bypass	2008 Completed	$0.4
Richwood PS Improvements	Improve pump station operation and reduce odors	2006 Completed	$0.3
Patton Street Sewer Study	Examine alternatives to reduce CSO volume	2006 Completed	$0.2
South Hills Outfall	Eliminate CSO and reduce flows to Lakeview PS SSO	2008 Completed	$3.1
Multiple Basins Initial Watershed Projects			
Grit Chamber Projects	Improve operation and effectiveness of combined interceptor system	2008 Completed	$3.8
Fort Wright Illicit Discharge Removal	Find and eliminate illicit connections	2007 Completed	$1.5
Fort Wright Sanitary Sewer Rehabilitation	Rehab existing sewers to reduce I/I and downstream SSOs	2007 Completed	$1.7
Fort Wright Outfall Sewer-Phase II	Sewer to address local wet weather capacity issue	2006 Completed	$1.0
Dry Creek Treatment Plant – Grit Removal Modifications	Improve operation and efficiency of Dry Creek WWTP	2006 Completed	$2.7
Large Diameter Sewer Assessment Program – Phase III	Identify priority repairs and rehabilitation for most critical large diameter sewers	2007 Completed	$0.5
Brookwood Subdivision SSES Study	Identify I/I sources upstream of Lakeview PS to reduce SSO volume	2006 Completed	$0.1
Southern Kenton Drainage Study	Refine model to examine alternatives to address SSOs in Lakeview PS basin	2007 Completed	$0.2
Wilson Road Sewer Assessment Project	Connect failing septic systems to SD1 system	2006 Completed	$0.1
Apple Drive Outfall Sewer	Sewer to eliminate failing treatment plant and address local wet weather capacity issue	2006 Completed	$0.5
Bluegrass Swim Club Sewer Separation	Reduce wet weather I/I into SD1 system	2008 Completed	$0..9
		Total	$36.4

A total of almost $36 Million has been spent to complete the remainder of the Initial Watershed Projects listed in Exhibit D. These projects represent a significant investment by SD1 to improve system performance, reduce wet weather overflows, lessen public health risk and improve water quality.

7.1.4 Summary

SD1 has been working to address the capacity issues of the existing sewer system and had previously identified these Initial Watershed Projects as the foundation for future work. Implementation and the completion of these projects represents significant infrastructure that SD1 has invested in to continue to improve the system and address

overflows. The total projected costs for the construction of all of the Initial Watershed Projects is $415 Million (estimated expenditures of $158 Million through FY-2009). The implementation of the Initial Watershed Projects will have the following benefits on the SD1 sewer system when fully complete:

- Will increase SD1 wet weather treatment capacity by over 50 percent (from 75 MGD to 117 MGD) with the construction of the Eastern Regional WRF (12 MGD) and Western Regional WRF (30 MGD) (increases wet weather capacity by 42 MGD);
- Will result in approximately 68 MG of annual overflow reduction (both from SSOs and from other potential overflows) in the separate system, approximately 30% of the calculated volume in the SD1 system. Table 7.7 has a breakdown of the volume by SSO and category;
- Will eliminate or replace 15 aging pump stations that had been identified as having wet weather capacity issues;
- Will reduce Lakeview PS SSO overflow volume by 90 percent in the typical year;
- Will eliminate some local capacity issues in upstream portions of the SD1 system; and,
- Will reduce overflow volume at five known SSO locations in the City of Florence.

Table 7.7 Summary of Typical Year Overflow Volume based on Initial Watershed Projects

Category[1]	Existing Typical Year Overflow Volume (MG)	Remaining Typical Year Overflow Volume with Initial Watershed Projects (MG)
Lakeview PS Tributary System		
Lakeview SSOs	20.6	5.8
Lakeview Other Potential Overflows	77.6	36.6
Lakeview System Totals	98.2	42.4
Dry Creek and Taylorsport Tributary System		
Dry Creek and Taylorsport SSOs	1.6	1.1
Dry Creek and Taylorsport Other Potential Overflows	4.7	1.3
Dry Creek and Taylorsport Totals	6.3	2.4
Eastern Regional System		
Eastern Regional SSOs	8.0	0
Impacted Overflows	112.5	44.8
Remaining SSO locations and Other Potential Overflows	129.6	129.6
Total	242.1	174.4

Notes:
[1]"Other Potential Overflows" are locations at which SD1's 2008 model calculates overflows during the typical year. SD1 has an ongoing field investigation program targeted at these potential overflows, with crews visiting potential sites to assess activity during and after rainfall events; however, coordinated field investigations to confirm model calculations have not gathered sufficient data yet to consider these potential overflow points as recurring SSOs.

Within the Lakeview system, the total overflow reduction within a typical year is almost 56 MG, an approximately 60 percent decrease in volume with the implementation of the planned Western Regional improvements. Within the Eastern Regional system, all recurring SSOs are shown to be eliminated following the completion of the planned projects. Combined, the Initial Watershed Projects result in an approximately 30 percent overall system-wide reduction in calculated overflow volume in the separate system in a typical year. The extensive investment in the Initial Watershed Projects provides significant benefits in overflow reduction and system operation and provides a foundation for the implementation of the remainder of the Five-year Improvement Program.

7.2 Committed Projects

In addition to funding projects associated with the first Watershed Plans, SD1 has an obligation to operate and maintain current assets and meet other obligations. Investment in projects focusing on rehabilitation and maintenance of SD1 assets is critical to fixing failing pipes, maximizing existing dry and wet weather capacity, preventing loss of service and basement backups, reducing I/I, and minimizing wet weather overflows. These projects are described in this section and are summarized in Table 8.4. Committed Projects include:

- High Priority Sewer Projects (Section 7.2.1)
- Nine Minimum Control Program Projects (Section 7.2.2)
- River's Edge Inline Storage and Solids & Floatables Project (Section 7.2.3)
- Capacity Management Operation Maintenance Program (Section 7.2.4)
- Consent Decree Planning, Implementation, and Management (Section 7.2.5)
- Improvements at Dry Creek WWTP (Section 7.2.6)
- Pump Station Projects (Section 7.2.7)
- Ongoing Sewer Rehabilitation / Repair Projects (Section 7.2.8)
- Storm Sewer Rehabilitation / Repair Projects (Section 7.2.9)
- Capital Purchases (Section 7.2.10)

7.2.1 High Priority Sewer Projects

SD1 has identified sewers in the service area in critical condition and in need of rehabilitation or replacement. These projects rehabilitate or replace existing failing pipes to restore or increase capacity of the existing sanitary system and help to reduce overflows. Example projects already identified include:

- Van Deren Sanitary Sewer Improvements (North Basin) – See Section 7.6.4 Lakeside Park Priority Area;
- Highland Pike Sewer Replacement (Central Basin) – Emergency project to install a sewer via horizontal directional drilling to replace a damaged sewer resulting from a landslide; and,

- Wayman's Branch Sewer Replacement (Central Basin) – Installation of a new sewer via horizontal directional drilling to replace an existing sewer exposed in the Wayman's Branch Creek and in danger of failing.

Additional sewer projects will be identified as SD1 continues to monitor and assess their existing infrastructure during the Five-year Improvement Program. As projects are identified, they will be budgeted from the Ongoing Sewer Rehabilitation / Repair Projects described in Section 7.2.8.

7.2.2 Nine Minimum Control Program

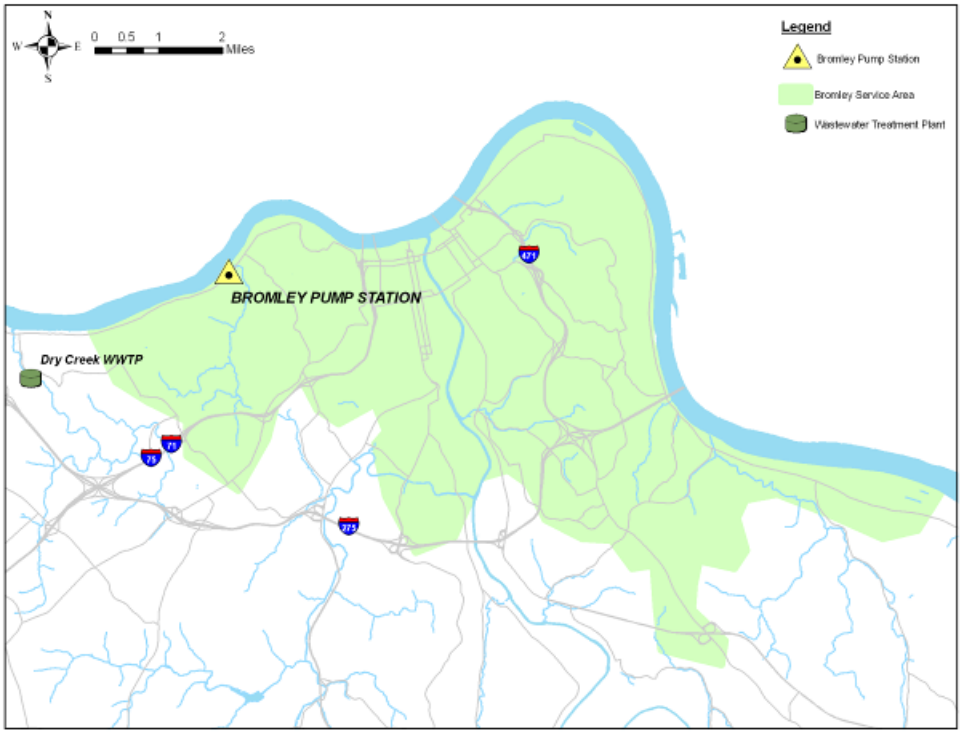
The development and implementation of SD1's Nine Minimum Control (NMC) Program is discussed in detail in the NMC Compliance Report (SD1, 2008e) and the NMC Annual Compliance Report (SD1, 2009c). SD1 has already implemented and completed a number of system improvements under the NMC Program. Modifications to the Bromley PS wet well settings and the Inline Storage Program were implemented to improve system performance and maximize flows to the treatment plant. Static weirs have already been constructed in diversion structures to maximize in-system storage. The effectiveness is currently being monitored to inform future watershed planning decisions.

The Solids and Floatables Control Program consists of improvements designed to keep solids and floatables from leaving the system and entering the local waterways. In addition to controls already established, SD1 intends to spend approximately $2.1 Million in the next five years to continue the implementation of catch-basin retrofits to capture additional solids and floatables before they enter the combined sewer system.

<u>Bromley Wet Well Setting Modifications</u>

The Bromley PS is the largest capacity pump station that SD1 operates, and it conveys all flows from the combined system directly to the Dry Creek WWTP. Figure 7.2 shows the outline of the area serviced by the Bromley Pump Station.

Figure 7.2 Bromley Pump Station Service Area



The Bromley PS has four constant-speed pumps that can be operated in multiple combinations. Two pumps are 900 horsepower (the "large" pumps) and two pumps are 300 horsepower (the "small" pumps). To establish the capacity of the station, pump testing was completed in August 2008. At the time of testing, all four pumps were not run together due to potential impacts of these slug load flows on the Dry Creek WWTP. Table 7.8 shows the pump test results.

Table 7.8 Bromley Pump Station Tested Capacities

Operation Condition (pumps on)	Measured Flows (MGD)
1 small	9
2 small	17.5
1 large	25.4
1 large, 1 small	30
1 large, 2 small	33.5 (FIRM)[1]

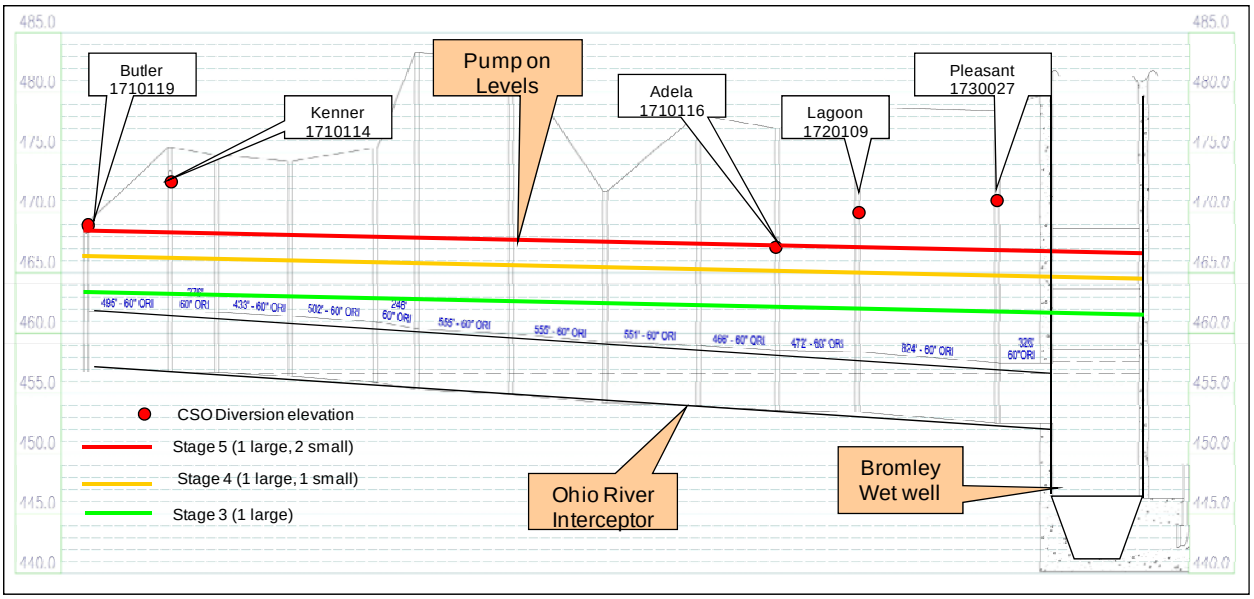
Note: [1] Operational experience indicates that this pump station cannot always be operated up to its firm capacity of 33.5 MGD because certain very heavy rainfall events cause flooding within the headworks of the Dry Creek WWTP.

With the current wet well settings at Bromley Pump Station, the hydraulic grade line in the upstream interceptor is above the crown of the upstream interceptor before the first large pump turns on. Additionally, the wet well level required to trigger the higher stages is very close to the diversion levels in upstream CSOs. During higher wet

weather flows, the hydraulic grade line backs up in the interceptor and causes CSOs to occur due to backflow through the CSO diversions. Figure 7.3 shows the relationship between the wet well settings for pump operation, the interceptor, and the upstream diversion elevations. This figure shows that the CSOs are already overflowing from the interceptor before the 5th stage is triggered. Therefore, there is already significant overflow volume before the full pump station capacity is utilized. .

The current wet well settings were developed to reduce the potential for excessive vibration and cavitation in the pumps, which was found to occur. This occurs because these pumps require a significant amount of "suction head". Suction head occurs on the suction side of a pump, where the pump action creates a low-pressure zone. In some cases, the pressure can drop low enough that the vapor pressure of the fluid can be reached at the ambient temperature, thus resulting in boiling (bubble formation) of the fluid. Boiling, in turn, leads to reduced efficiency of the pumps and can cause pump cavitation and damage.

Figure 7.3 Bromley Pump Station Wet Well Settings



An evaluation was conducted to assess the potential benefit and feasibility of lowering the wet well "On" and "Off" elevations to pump more flow at lower water levels. The evaluation included assessments of:

- Potential cavitation due to Net Positive Suction Head or NPSH,
- Potential for inlet vortexing,
- Bar screen limitations, and
- Cycling issues

Impacts at Dry Creek WWTP

The evaluation used the hydraulic model and a traditional desktop hydraulics analysis to assess hydraulic issues. The results of the desktop analysis showed that the lower stage settings could not be lowered due to vortexing concerns. However, there was

some merit in lowering the "On" settings for the higher stages. The hydraulic model was then used to evaluate the potential benefits of lowering the pump "On" settings as well as lowering the pump "Off" settings. The modeling showed that lowering the wet well settings could potentially reduce CSO volume by nearly 80 MG in a typical year. For comparison, it would take approximately six MG of storage to achieve the same level of benefit that this change provides. The ability to achieve this significant reduction will also be made possible through the proposed new headworks at the Dry Creek WWTP, which is discussed further in section 7.2.6. Clearly, this is a very cost-effective option, and the new "On" settings were implemented by SD1 as part of the NMC program.

Figure 7.4 shows the backwater in the interceptor upstream of the Bromley PS with the new "On" settings for all stages that include a large pump. It shows the higher stages turning on long before the level reaches the diversion elevations. Figure 7.5 shows an example of the model-calculated flow before and after the wet well settings change. The figure shows how much more flow is being pumped with the new settings.

Figure 7.4 New "On" Settings for the Bromley Pump Station

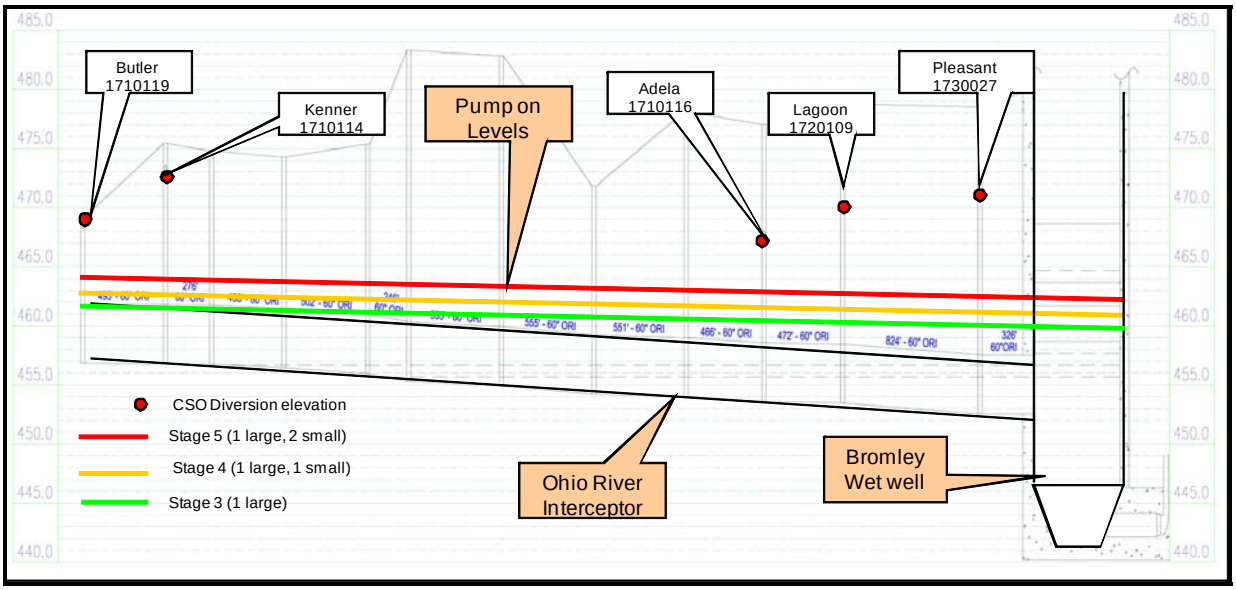
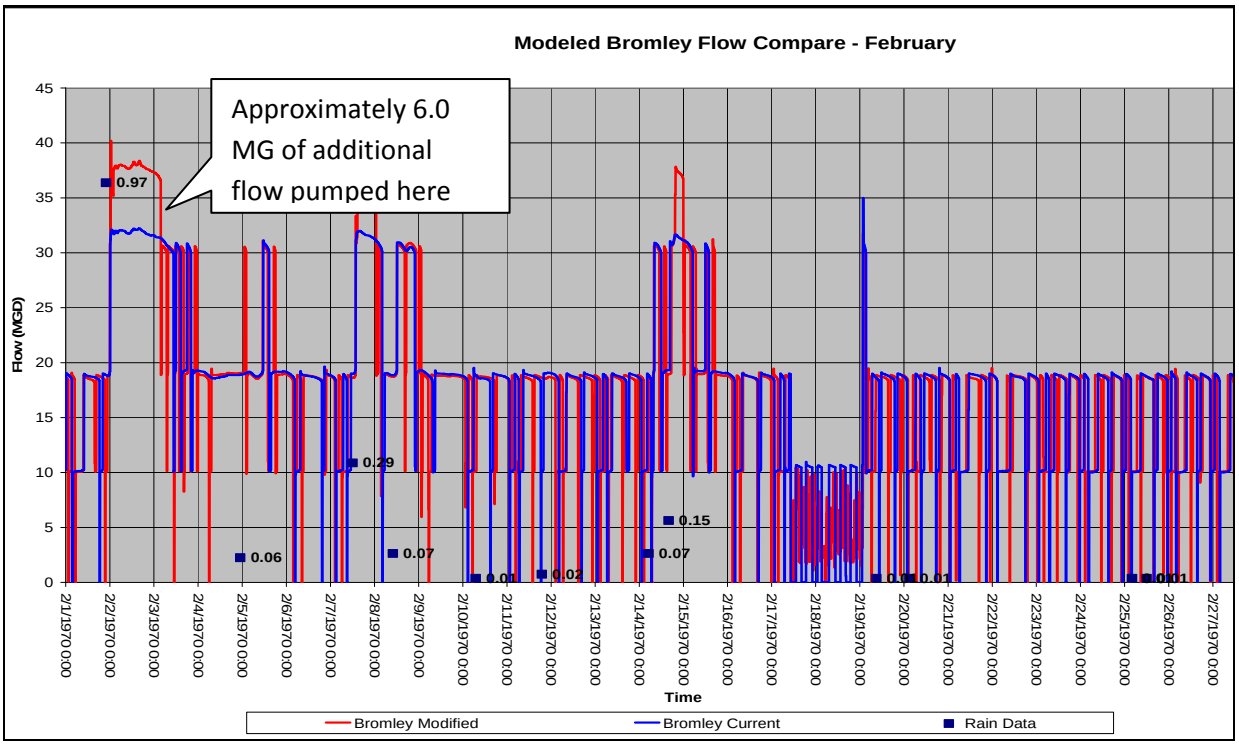


Figure 7.5 Model Output Before and After Bromley Pump Station Wet Well Changes



Inline Storage Program

One key feature of SD1's NMC Program is the evaluation and implementation of inline storage at targeted locations that provide system-wide benefits in overflow reduction. The key term is "system-wide" since raising a weir at one location may reduce local overflows, while concurrently increasing downstream overflows to the same extent, resulting in a zero net benefit. SD1's calibrated model was a critical tool for maximizing the benefits of targeted inline storage while minimizing the potential risks associated with fixed weirs that raise the hydraulic grade line in the incoming trunk sewers. The development of SD1's inline storage program is discussed in detail in the NMC Compliance Report (SD1, 2008e), which also identified nine locations for potential inclusion in the inline storage program. Since the development of that report, SD1 has continued to analyze in-system storage opportunities and benefits. Through these efforts, SD1 has identified a number of additional inline storage opportunities through static weir adjustments.

In addition to static weir adjustments, larger capital projects have been identified. For example, two additional inline storage locations (at the Main Street and McKinney Street diversions) have been created as part of SD1's efforts to identify opportunities for sewer system upgrades in concert with new development. This project is referred to as River's Edge and is discussed as a separate project in Section 7.2.3.

Additional Inline Storage

Bending weirs and other dynamic controls were also assessed as part of the watershed planning process at locations where static weirs were shown to create the potential for flooding or to evaluate the potential for additional benefit. Three locations were evaluated, including Willow Run CSO, James Avenue CSO, and 4th Street CSO. Of these, only Willow Run was identified as a candidate for inclusion in the Five-year Improvement Program. Dynamic control at the James Avenue CSO was shown to provide little additional benefit over the planned static weir. Dynamic control at 4th Street CSO shows some promise, but there is a very large development in the early planning stages that is going to modify a 60-inch sewer tributary to this diversion. SD1 is currently evaluating the developer's plans and will be coordinating any additional modifications to the 4th Street diversion with the sewer system modifications agreed to with the developer. The Willow Run dynamic control facility is described in detail in Section 7.6.5.

The current Inline Storage Program is summarized in Table 7.9 and shown in Figure 7.6. It is important to note that a number of these locations were identified through NMC related activities as known or potential dry weather overflow locations, and thus, the control measures at those sites also provide protection during dry weather.

In addition to the implemented or currently planned inline storage locations, SD1 will continue to evaluate inline storage as opportunities through ongoing asset management activities and as opportunities to partner with developers arise.

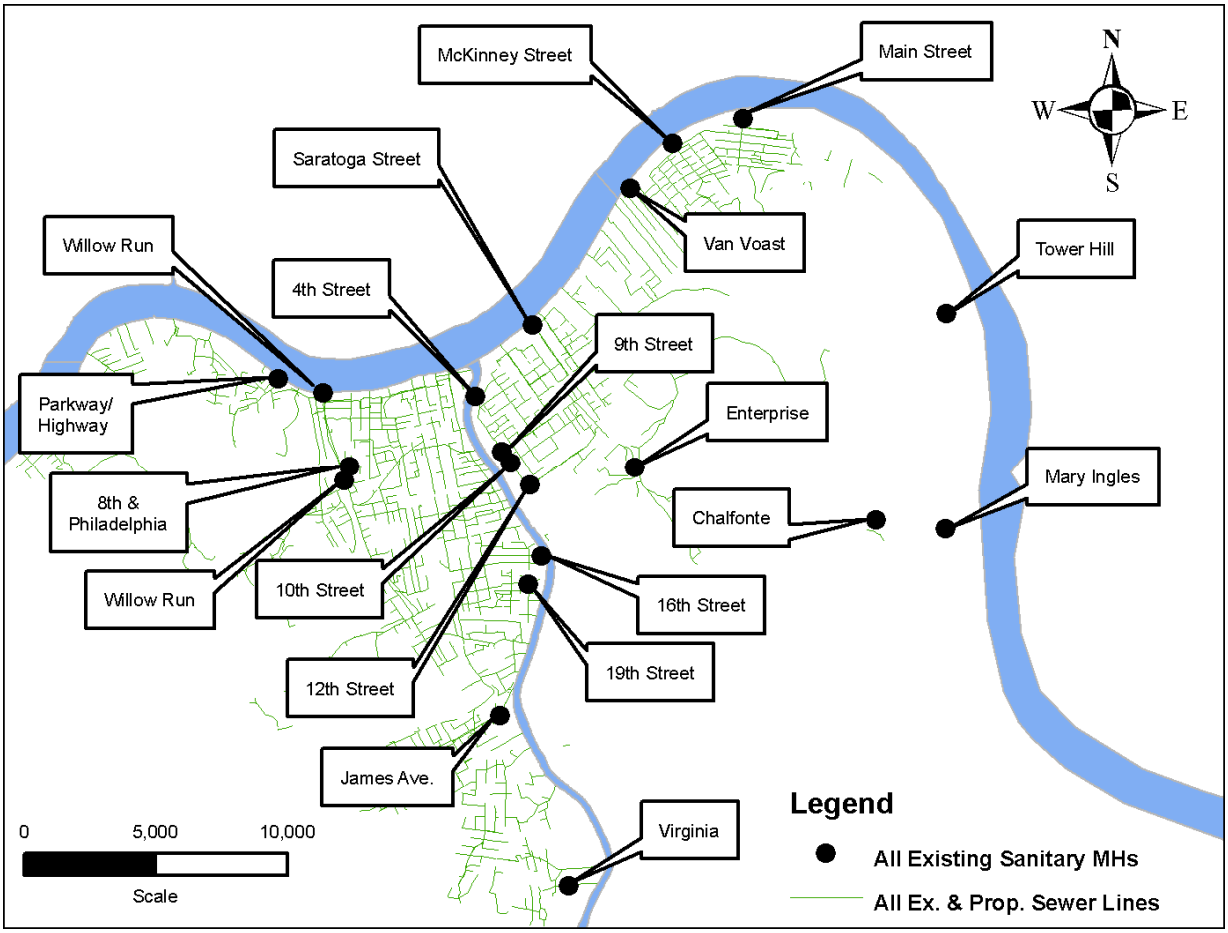
Table 7.9 Inline Storage Program Summary

Diversion	Name	Type of Control	Status	Baseline Activations	Baseline Volume	"With Weir" Activations	"With Weir" Volume
0820001	4th Street	Static Weir	Installed	65	71.38	62	69.99
0840005	9th Street	Static Weir	Installed	65	25.69	2	0.15
0840027	10th Street	Static Weir	Installed	52	2.03	57	3.54
0910064	James Avenue	Static Weir	Installed	100	153.74	66	132.49
1480129	8th & Philadelphia	Static Weir	Installed	77	624.76	76	547.98
1480116	Willow Run Static Weir	Static Weir	Installed				
1490027	Parkway/Highway	Static Weir	Installed	36	11.47	9	1.60
0930066	19th Street	Static Weir & Baffle	Installed	62	28.84	62	28.84
0770006	Saratoga Street	Static Weir	Installed	65	6.55	26	2.28
0930014	16th Street	Static Weir	Installed	3	0.04	0	0.00
0730009	12th Street	Static Weir	Installed	75	2.44	75	1.93
0730028	12th Street	Static Weir	Installed	81	8.31	81	7.17
1880021	Virginia	Static Weir	Installed	21	2.80	16	2.45
0690008	Enterprise	Static Weir	Planned	4	0.11	4	0.07
0600037	Van Voast	Static Weir	Installed	3	0.12	2	0.01
0330099	Tower Hill	Elevated Overflow Pipe	Planned	6	0.15	4	0.08
0340044	Mary Ingles	Elevated Overflow Pipe	Installed	31	1.00	4	0.04
0570030	Main Street	Static Weir & Baffle	Planned	56	36.29	5	2.79
0570011	McKinney Street	Static Weir & Baffle	Planned	62	49.69	18	24.58
	Other Diversions				601		668
	Total				1,623		1,494

Notes:

1) Baseline numbers include no Ohio River Influence and no changes to the Bromley Wet Well Setting
2) "With Weir" numbers include no Ohio River Influence and modified Bromley Wet Well Settings

Figure 7.6 Locations for (or Proposed for) Inline Storage



Solids & Floatables Control Program

The development and implementation of SD1's solids and floatables control program is discussed in detail in the NMC Compliance Report (SD1, 2008e). The program includes the following elements:

- Public education to reduce solids and floatables originating from sanitary waste;
- Street sweeping to reduce solids and floatables originating as street litter;
- Construction site storm water management program;
- Catch basin modifications to capture and remove solids and floatables prior to entering the combined system;
- Grit pits on the interceptor to capture solids and increase flows to treatment; and
- Inline and end-of-pipe controls where effective and feasible to reduce floatables discharged through CSOs.

The NMC Compliance Report identified 15 sites for end-of-pipe and inline solids and floatables control. Controls at some of these sites had to be removed as part of sewer system upgrades. However, additional inline and end-of-pipe solids and floatables control sites have also been identified in the past year. For example, in addition to the

three engineered solids and floatables control sites at Greenup, Main and McKinney Streets that have been described in detail in the NMC Compliance documentation, a new engineered solids and floatable control structure has been designed for the Garrard Street CSO.

Garrard Street

The Garrard Street CSO (1440206) consists of an existing 18-inch vitrified clay pipe outfall to the Ohio River that is currently buried to 90 percent closure in the Ohio River bank and has no headwall. Possibly due to the obstruction of the outfall outlet and deflection of the original pipe joints, combined sewage has caused undermining of backfill to the ground surface in two locations. As part of the design to replace the outfall pipe and install a new headwall with a duckbill check valve to protect against river water intrusion, SD1 decided to add an engineered floatables control chamber. As discussed later in this Section, the Garrard Street CSO is also on the River Water Intrusion list because it is below a river stage of 47 feet.

The pilot engineered solids and floatables control chamber consists of a precast concrete structure with stainless steel baffles designed to trap solids and floatables. A bar rack was designed to operate above the top of the baffle to hold back the captured floatables in the event of a storm greater than a 25-year, 30-minute rainfall. The hydraulic model of the existing system was run for a series of design storms along with the typical year, with no chamber installed, to generate flow and depth information upstream of the Garrard St. CSO. The target for design of the baffle underflow was a one-year storm that could pass underneath the baffle at 1.5 feet per second. In addition, the level of service upstream of the CSO was examined to ensure that in extreme events, the new chamber and duckbill check valve would not exacerbate current conditions and potentially cause basement backups to occur.

SD1 completed the construction of this chamber in 2010. Figure 7.7 shows the solids and floatables control structure.

Figure 7.7 Solids & Floatables Control Structure for Garrard Street CSO

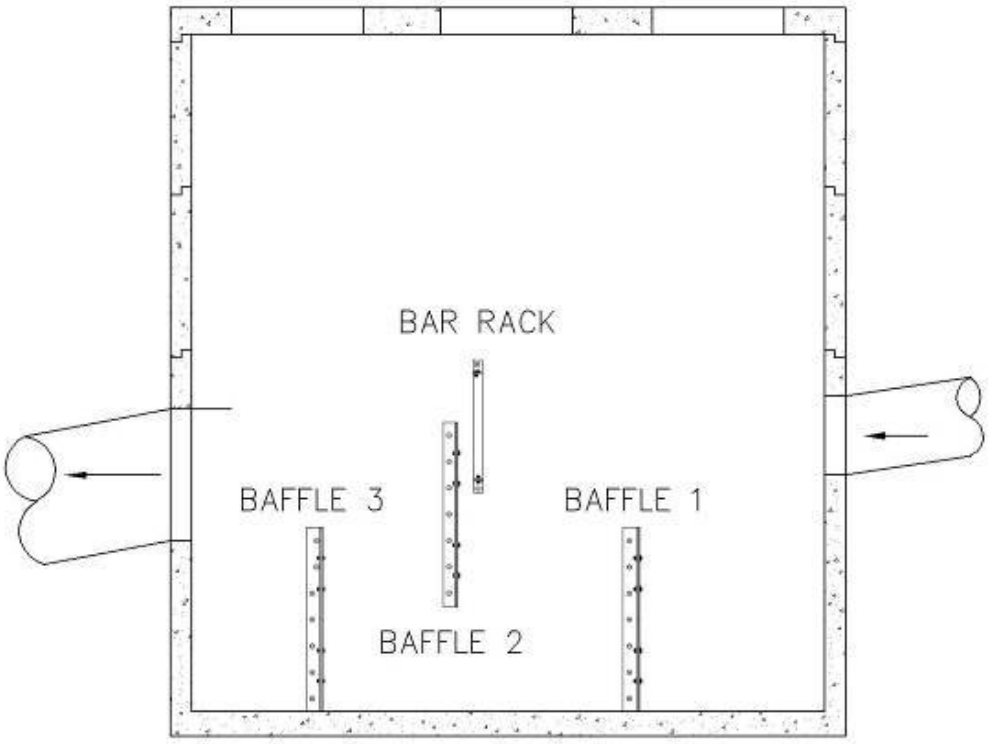


Table 7.10 summarizes the current inline and end-of-pipe simple solids and floatables controls. A full program update is provided in the NMC Annual Compliance Report (SD1, 2010c).

Table 7.10 Current Solids and Floatables Control Program

CSO/Diversion	Name	Type of Control	Status
1490172	Swain Court	Black Net	Installed
0910084	Meiken/Eastern	Black Net	Installed
1440121	Greenup Street	Engineered Solids and Floatables Control Nutrient Separating Baffle Box (solids sump, screen and baffle)	Installed
0650098	Wildcat Run	Black Net	Installed
0340051	Manor Lane	Green Net	Installed
0200069	617 Mary Ingles	Green Net	Installed
0030031	Carmel Manor	Black Net	Installed
0650041	Geiger Avenue	Type "B" Bar Rack	Installed
0770006	Saratoga Street	Weir	Installed
1440156	Garrard Street	Engineered Solids and Floatables Control Baffle Chamber w/Bar Rack Above Baffle	Installed
1420043	10th Street	Baffle	Installed
0930026	17th Street	Baffle	Installed
0330100	Tower Hill	Green Net	Installed
0340050	Lester Ln.	Black Net	Installed
0930050	19th St.	Baffle	Installed
0930066	19th St.	Weir and baffle	Installed
0360079	Anchor Inn	Black Net	Installed
0570030	Main Street	Engineered Solids and Floatables Control Baffle Chamber w/Bar Rack Above Baffle	Installed
0570011	McKinney Street	Engineered Solids and Floatables Control Baffle Chamber w/Bar Rack Above Baffle	Installed

In addition to end-of-pipe controls, SD1 is taking a number of other steps to reduce the amount of solids and floatables being discharged from CSOs to local waterways through the implementation of NMC related activities (SD1, 2008e & 2009c). Significant solids and floatables reductions, beyond those associated with these programs, also occur with CSO reduction and diversion of additional wet weather flow to the WWTP for treatment.

7.2.3 River's Edge Inline Storage and Solids & Floatables Project

During the development of the Watershed Plans, a local developer submitted plans for a new development along the Ohio River in Dayton, Kentucky called River's Edge. As part of the development, the existing Ohio River Interceptor was proposed to be moved and replaced to make room for the new development. This need for replacement provided an opportunity to construct a new interceptor sewer that could provide immediate benefit for CSO control as well as providing flexibility for future CSO control measures. The location of the development is shown in Figure 7.8, and the affected portions of the Ohio River Interceptor are shown in Figure 7.9.

The development proposed to add a significant amount of fill over the Ohio River Interceptor, which functions as a critical main interceptor for the entire combined area. The existing Ohio River Interceptor (24-30 inch pipe) was structurally unable to bear this

additional load, and needed to be replaced. While the project provided a great opportunity for SD1 to cost-share and help bring CSOs into compliance, it presented the difficulty that the developer wanted to begin construction on an aggressive timetable while the Watershed Plans were still in their infancy. Realizing that this portion of the Ohio River Interceptor would have difficult accessibility once this project was completed, SD1 used this opportunity to evaluate what might be required in the long-term to bring area CSOs into compliance and to determine if a portion of the long-term improvements could be constructed now to decrease CSO volume as part of the River's Edge project.

Figure 7.8 River's Edge Development Service Area

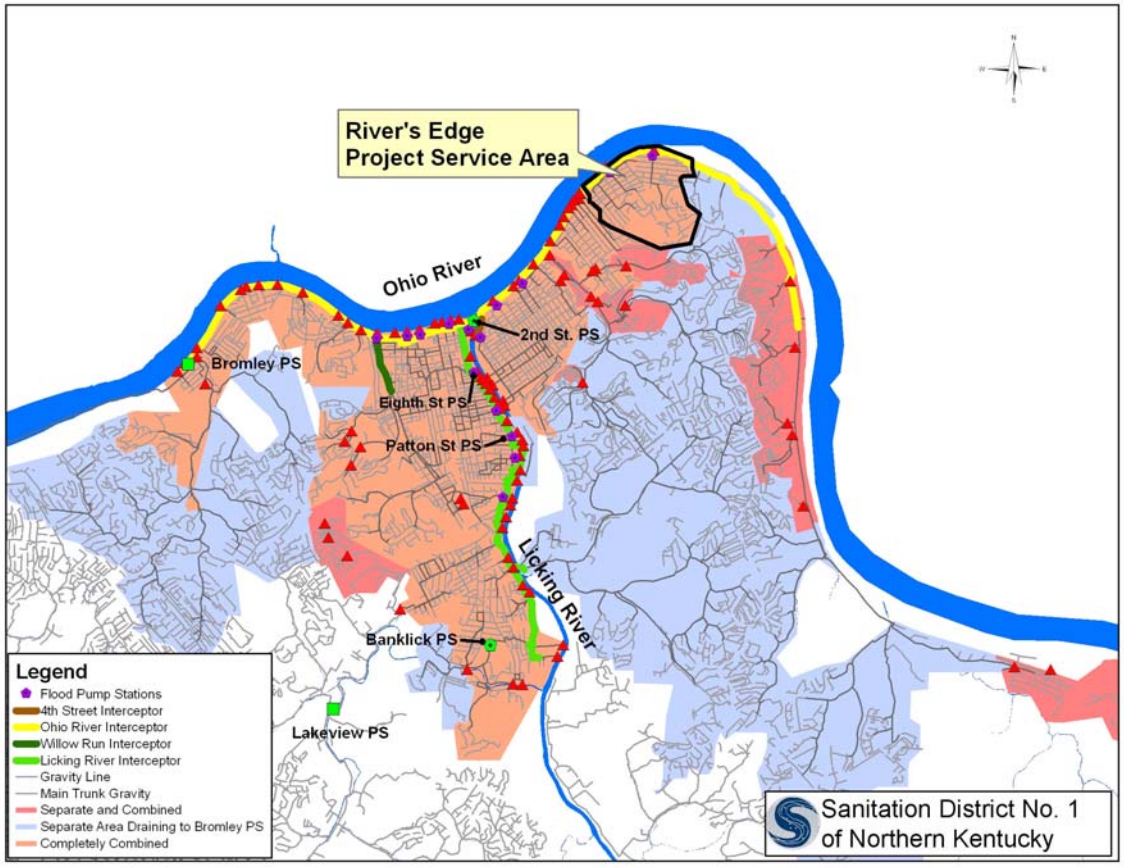


Figure 7.9 River's Edge Development Location

Note: The colored pipes represent portions of the interceptor that needed to be replaced as part of the project. The different colors represent segments between additional inputs into the interceptor from combined sewers.

SD1 considered both storage and conveyance alternatives. After further analysis, it was clear that the necessary space for off-line storage was unavailable since the development included the construction of residential homes and condominiums on most of the existing open land in the area, and because the geotechnical conditions were poor. With the conveyance option, downstream bottlenecks were identified that would serve to reduce the benefit of short-term conveyance improvements unless additional conveyance capacity was provided downstream in the future. In addition, because the full system solution concepts in the Watershed Plans had not been started, SD1 hesitated to select an option that would tie them to a particular approach in this area.

Given these results, the approach changed from a single solution to an option that could provide flexibility in determining the permanent solution while preventing the need to go back after the development is completed to install a very deep sewer in almost entirely fill material. Since the largest conveyance size along the development was an 84-inch diameter pipe, SD1 decided to evaluate the benefits of constructing an 84-inch pipe along the entire approximate 8,000 feet instead of sizing only for pure conveyance. The solution was to install a large enough pipe that could be used for conveyance and inline storage in the near term, but would provide flexibility in the future regardless of the selected final solution in this area. SD1's hydraulic model was used to evaluate the potential reduction in overflow volume from the installation of the 84-inch pipe, which would include about 2.2 MG of inline storage volume.

Subsequent to the original design, the developer wanted to shorten the length of the overall project. This required a redesign of the line so that the same level of service

could be provided with the new design. The most recent model simulations estimate that CSO reduction system-wide will be approximately 56 MG in the typical year. As a result, the new design included approximately 6,600 linear feet of 84-inch and 1,300 linear feet of 110-inch diameter pipe. This large improvement was completed in late 2010.

Figure 7.10 Installation of Terminus Manhole for the River's Edge Development Area

Figure 7.11 Over Excavation and Compaction for the River's Edge Development Area

7.2.4 Capacity Management Operation Maintenance Program

As part of the Consent Decree requirements, SD1 developed a Capacity Management Operation and Maintenance (CMOM) Program. The primary purpose of this self-assessment program is to determine enhancements and modifications that can be made to collection systems' activities to more effectively achieve regulatory compliance and support elimination of SSOs throughout the SD1's service area. SD1 has budgeted approximately $11.0 Million through the end of the Five-year Improvement Program to implement the following programs:

- Pump Station Backup Power,
- Continuous Sewer Assessment Program,
- Targeted Sewer Cleaning Program, and
- Sanitary Sewer Evaluation Program

<u>Pump Station Backup Power</u>

The Pump Station Operation Plan for Backup Power (SD1, 2007b) was developed in 2007 to evaluate SD1's pump stations and address pump station power outages occurring throughout the service area. The plan prioritized SD1's pump stations and each pump station was assigned to a category, designated 1 through 6. The categories helped define in what order a stand-by power solution would be implemented, with category 1 having backup power in place, in design, or in construction. SD1 is currently addressing all category 5 and 6 pump stations as defined in the Pump Station Operation Plan for Backup Power. The category 5 pump stations have wet weather capacity

issues and recorded history of power outages, while the category 6 pump stations were defined as pump stations with wet weather capacity issues without recorded history of power failures. In order to determine the correct size for the backup power solution and address the wet weather issues, the extent of the wet weather problem (peak flows & overflow volume) needs to be monitored. Monitoring and further evaluation of wet weather flow are important because, if a solution is to increase the capacity of the station, any costs incurred to provide back-up power under current conditions are at risk of being lost because the current back-up power sizing may be too small for the future station power needs. Therefore, each of the category 5 and 6 pump stations within the study area has been reviewed and recommendations have been developed for future evaluation methods. Further study is recommended for developing a long-term solution, and in each case, the further study is recommended to include installation of flow meters, as shown in Table 7.11.

Table 7.11 Category 5 and 6 Pump Stations

PS Name	Category	Solution	Further Study Elements
Keavy	5	Further Study	Install flow meters
Meadow Lane	5	Further Study	Install flow meters
Mafred	6	Further Study	Install flow meters
Ridgeway	6	Further Study	Install flow meters
Twin Lake	6	Further Study	Install flow meters
Winters Ln #2	5	Further Study	Install flow meters
Enzweiller	6	Further Study	Install flow meters
Cardinal Cove	5	Further Study	Install flow meters for pilot study
Richwood	6	Further Study	Monitor available PS and downstream capacity

A monitoring pilot study has been planned for the Cardinal Cove PS. Cardinal Cove PS is a category 5 pump station located north of Tanner Road and east of North Bend Road. It has an estimated capacity of 185 gallons per minute (GPM) with one duty pump and one standby pump. During the spring of 2009, SD1 began the first phase of the SSES program by monitoring influent flows at Cardinal Cove PS and performing a pump station draw-down test.

The monitoring pilot study used equipment that tracked pump operation and wet well level in conjunction with time. Rain data were also collected via a nearby rain gauge. Data analysis will confirm if excessive I/I is an issue upstream of Cardinal Cove PS. If wet weather does create a capacity problem, then additional SSES techniques will be employed, possibly including flow monitoring, smoke and dye testing, and CCTV inspection.

A review of the anticipated peak dry weather flow (based on available developable land) will be compared to the firm capacity of the pump station to determine the likelihood of a required capacity increase.

Firm capacity, information collected during the SSES program, and the anticipated future capacity needs of the pump station will be analyzed to determine the best

approach for the backup power solution. Any capacity increases or flow reducing corrective action will be accomplished expeditiously enough to allow the backup power solution at the pump station to be accomplished by the deadline established in the Pump Station Operation Plan for Backup Power.

The Richwood PS is unique in that is the southernmost pump station in the SD1 system and has a large tributary area of approximately 4,000 acres. The pump station conveys flows through 13,000 feet of forcemain before discharging to the Southern Kenton County Interceptor and eventually to the Lakeview PS. As discussed in Section 7.1.1, the long-term plan for this station is to upgrade the pump station and reroute the forcemain to the new Union Sewer and eventually to the new Western Regional WRF. Timing of this upgrade is based on the capacity available at the pump station and in the Lakeview tributary system. Monitoring of this station and the available downstream capacity will determine the need for backup power in order to meet the PS Backup Power Plan deadline of December 31, 2015, as well as the timing of the upgrade.

Continuous Sewer Assessment Program (CSAP)

During interviews and workshops conducted as part of the CMOM program, SD1 identified a need to develop a more proactive collection system inspection, cleaning, and rehabilitation/replacement program, resulting in the creation of the Continuous Sewer Assessment Program (CSAP). The implementation of SD1's CSAP is a critical component of the Watershed Plans. The background and description of the CSAP is described in detail in the NMC Compliance Report and CMOM report (SD1, 2008e, SD1, 2008b). As sewer condition data are compiled and analyzed, rehabilitation/replacement decisions are made with Watershed Plan goals and priorities in mind.

For example, the 12-inch gravity sewer along Donnermeyer Road was found to be in critical condition and is under a building. The hydraulic model revealed that the area is subject to frequent overflows and is capacity limited. There were also ongoing plans to construct a new storm sewer to assist with local flooding problems. SD1 decided to coordinate the two projects to construct a new larger gravity sewer designed to carry peak flows and to eliminate an upstream overflow. A new storm sewer is also being constructed to eliminate upstream flooding and to disconnect private source storm water connections to the combined sewer to reduce downstream overflows. These types of opportunities throughout the sewer system are identified with the CSAP.

The cleaning program as described in the CSAP will impact overflows by efficiently targeting cleaning activities where they can have the most benefit. This will help ensure that overflows do not occur due to preventable blockages and that pipes achieve their designed capacity. One specific application of the cleaning program is the Targeted Interceptor Cleaning Program that is described in the following section.

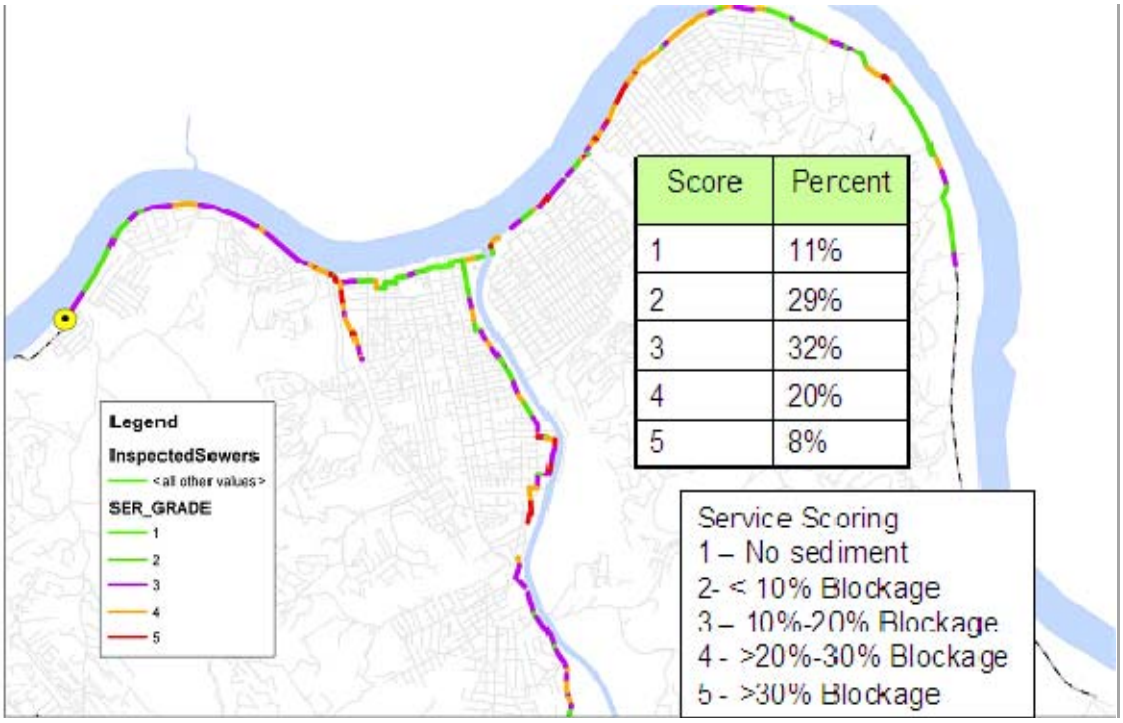
SD1 is investing over $1.8 Million per year on the CSAP to proactively inspect and clean the sewer system.

Targeted Sewer Cleaning Program

In support of the ongoing Consent Decree program, SD1 conducted an inspection of the interceptor sewer system in 2007 using a combination CCTV/Sonar device. Results of

the inspection showed that portions of the interceptor had significant buildup of debris, resulting in poor maintenance (service) grade ratings. Figure 7.12 shows the results of the overall inspection.

Figure 7.12 CCTV/Sonar Inspection Results

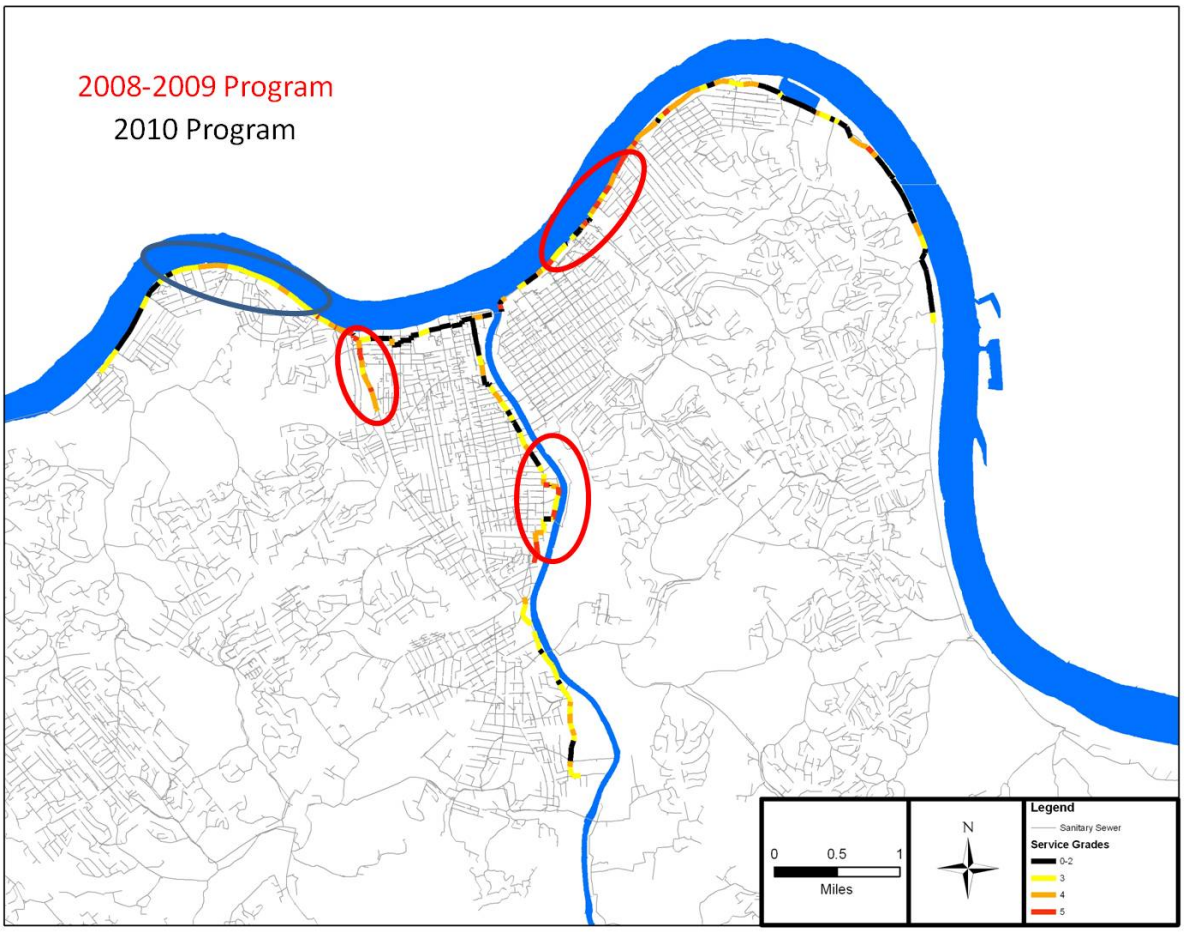


The results show portions of the interceptor with significant accumulations of sediment and debris. SD1's hydraulic model was used to assess the potential benefit of cleaning the accumulated sediment out of the interceptor. This was done by explicitly including the debris measured by the sonar. Based on these results, it is estimated that typical year overflows could be reduced by as much as two Million Gallons.

As part of SD1's compliance with the requirements of the NMC and SD1's CMOM Self-Assessment, SD1 is commencing a large-diameter interceptor sewer cleaning program to improve sewer system conveyance and storage capacity, and improve the overall reliability of SD1's sewer system. The Targeted Sewer Cleaning Program is intended to be an ongoing program that SD1 will include as part of the CSAP. Since cleaning of large diameter sewers with high flows is normally very expensive, sewer lengths with service grades of 4 and 5, as described above, were targeted for cleaning during the first phase of the program. Modeling results showed that targeted cleaning could be almost as effective in reducing overflows as cleaning all pipes. In the first phase of work (2008-2009), SD1's cleaned approximately 31,500 linear feet of interceptor ranging in size from 18-inch to 96-inch and removed approximately 1,500 tons of debris. In the second phase of the work (2010), SD1 cleaned 18,000 linear feet of 60-inch diameter pipe and removed 1,200 tons of debris. Figure 7.13 shows the segments of interceptor cleaned as part of both phases of work. Hydraulic model results indicate that SD1 has

reduced annual CSO volume by approximately 24 million gallons on a system-wide basis by completing this cleaning.

Figure 7.13 Targeted Sewer Cleaning Program



Sanitary Sewer Evaluation Survey (SSES) Program

Another key component of the CSAP is the SSES program. The overall goal of the SSES program is to remove excess I/I that is entering the sanitary sewer system to reduce and eliminate overflows. This approach will also reduce the capital expenditures required on downstream conveyance and treatment and the associated new assets that may be required after SSES work is completed. The key features of the program are to:

- Generally characterize I/I system-wide by hydraulic model subcatchments;
- Prioritize subcatchments based on criteria such as I/I volume, priority control location, and priority location for CCTV;
- Conduct SSES activities in select locations such as smoke testing, dye testing, CCTV and detailed flow monitoring to identify public and private I/I sources;
- Implement improvements designed to cost-effectively remove identified public and private I/I sources; and
- Monitor for effectiveness.

SD1 believes that removing I/I where possible achieves several benefits:

- Reduces or eliminate SSOs and other unpermitted discharges;
- Provides opportunities for green solutions to also address storm water runoff quality and peak flows;
- Results in structural renewal of aging existing sanitary and storm sewers and manholes that are in poor condition;
- Saves maintenance costs by permanently addressing potential service problems like roots;
- Reduces operation and maintenance costs at pumping facilities and WWTPs by reducing flows;
- Reduces WWTP challenges of dealing with highly diluted flows entering the WWTP;
- Saves construction costs on new sewers, pump stations and tanks downstream of affected areas to address the overflows because wet weather flows are reduced; and
- Results in improvements in local storm water flows and water quality when blended with green solutions providing a holistic approach to improving water quantity and quality issues in the service area.

With these benefits come many challenges including costs associated with I/I investigation, effectiveness of repairs, measuring benefit, availability of time, and dealing with private property issues. SD1 understands these challenges and will be dealing with them as the program is implemented.

SD1 is implementing a pilot approach for I/I removal to better understand challenges associated with this program. There are two specific locations where SD1 will conduct I/I removal activities to test effectiveness of the program in the first Five-year Improvement Program. These two areas are Lakeside Park in the City of Lakeside Park and the Vernon Lane area in the City of Fort Thomas. Significant effort has been expended over the last several years to identify and quantify I/I sources using detailed flow monitoring and smoke and dye testing. The next step is to develop an action plan to remove the identified public and private sources. Specific information regarding these locations is included in Section 7.6, North Basin Projects (Lakeside Park) and in Section 7.4, Central Basin Projects (Vernon Lane).

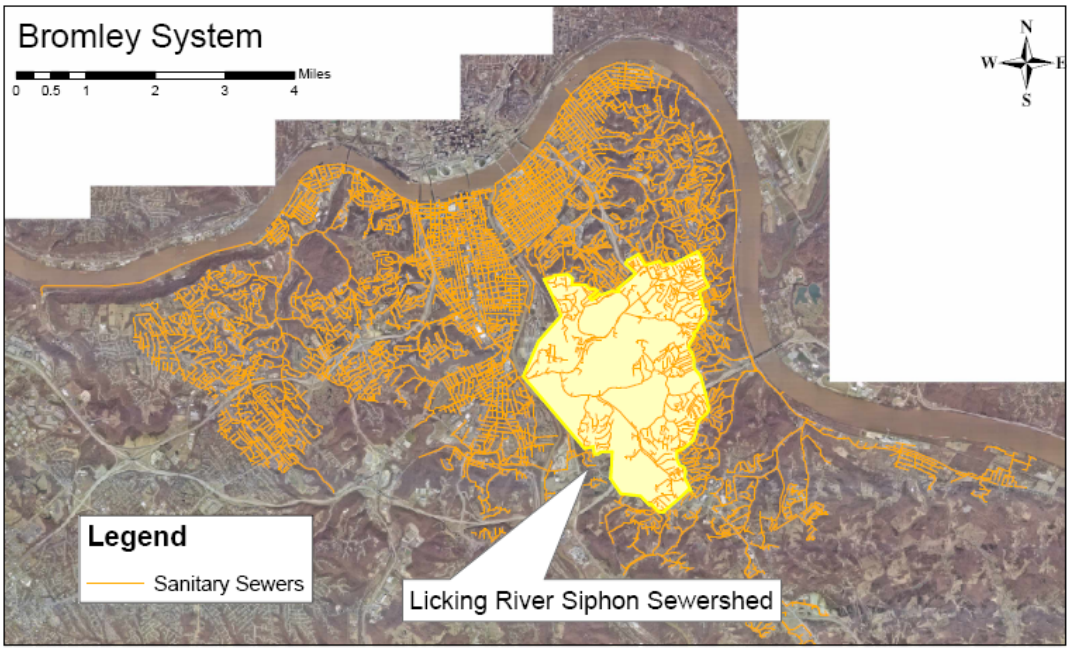
The situation faced in Lakeside Park and Vernon Lane highlights the unique situation that SD1 is in relative to dealing with I/I. Until the mid to late 1990's, SD1 did not own or control the majority of the separate sanitary system. Individual cities did not have sufficient funding to maintain aging infrastructure. In addition, little attention was paid to the storm sewer system, which may make the I/I situation worse in some cases due to inadequate drainage.

Cost-Benefit Analysis of SSES

SD1 conducted a planning-level analysis to assess the feasibility and potential cost-effectiveness of source control through I/I removal versus conveyance and treatment to eliminate SSOs. This analysis was done in several locations across the sewer system with similar results. An example of this analysis is presented below for the area

tributary to the Licking River Siphon that is located in the Central Basin. Figure 7.14 shows the area served by the Licking River Siphon.

Figure 7.14 Licking River Siphon Sewershed

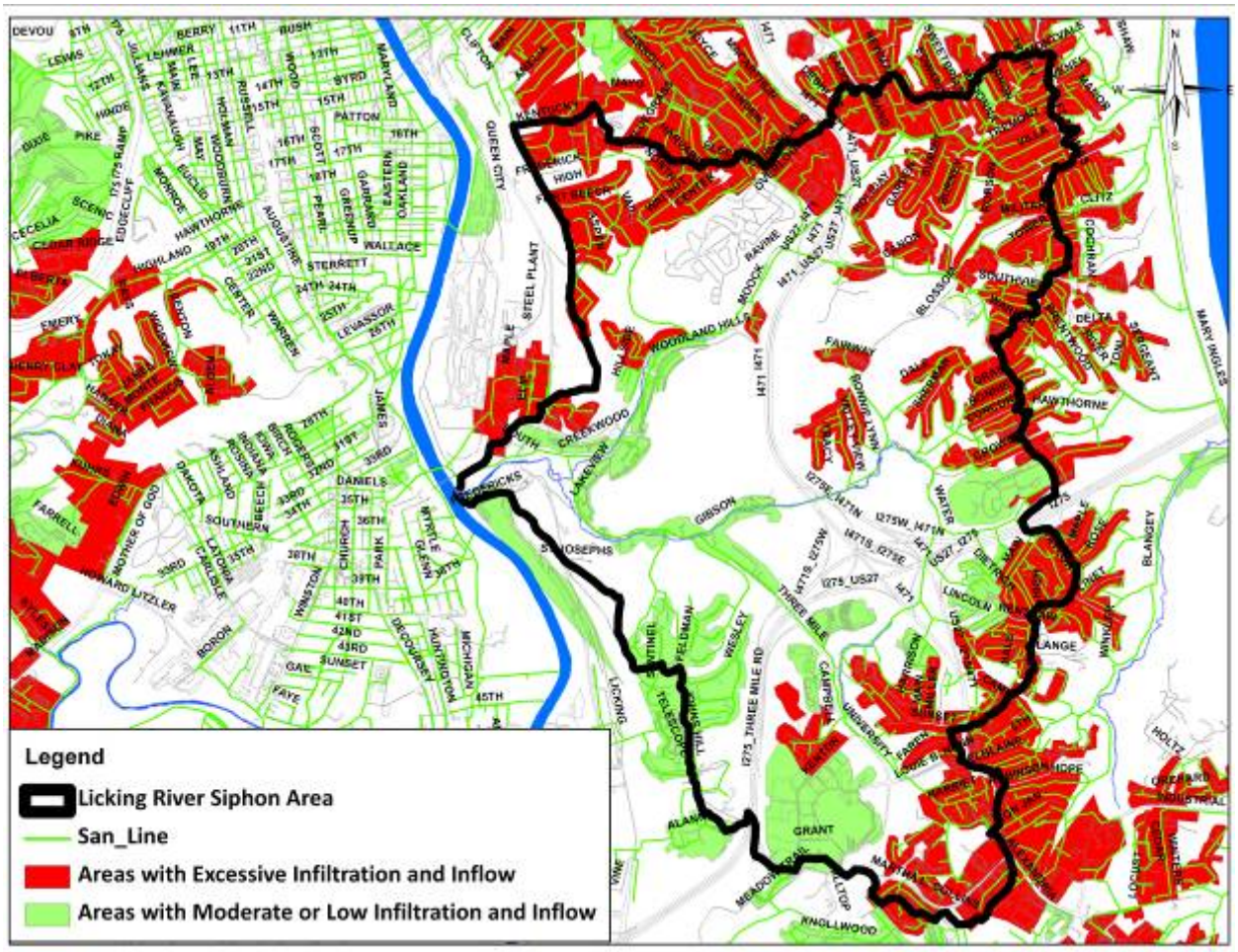


The Licking River Siphon sewershed comprises approximately 4,000 acres and has an average daily flow of 1.4 MGD. A 12-inch inverted siphon conveys flows from the area across the Licking River and into the Licking River Interceptor. During heavy rainfall, the capacity of the 12-inch siphon and the downstream interceptor is exceeded with excess flows bypassing into the Licking River via a 12-inch bypass. The Licking River Siphon has an annual overflow volume of 48.8 MG in a typical year. In addition to the overflow at the siphon, there are overflows in the upstream sewer system.

The system-wide solution costs for SSO elimination for the typical year and five-year design storm conditions were compared with two levels of I/I removal (with reduced convey and treat) versus convey and treat with no I/I removal. Two levels of I/I removal were selected, 25 percent and 50 percent respectively. The 25 percent removal assumes either just public source or just private source I/I removal and the 50 percent removal assumes both public and private source I/I removal.

The “R” value is the estimated percent of the total rainfall in a typical year that enters the sanitary sewer as I/I and is a useful basis for quantifying potential I/I removal. Only subcatchments with an overall “R” value of greater than two percent were assumed for I/I removal; areas with “R” values less than two percent likely have little identifiable I/I and, under most circumstances, are likely not cost-effective for I/I investigation or removal. Figure 7.15 shows the subcatchments in the Licking River Siphon Area with “R” values greater than two percent indicated in red. These areas represent about 80 percent of the total subcatchment area.

Figure 7.15 SSES Priority Subcatchments in Licking River Siphon Area



For the cost analysis, the following activities were assumed for the public source I/I removal portion:

- Cured-in-place pipe lining for all mainline sewers and sealing of liners at manholes;
- Lining of all manholes;
- At least one point repair for each line segment prior to lining; and
- Lining of the lateral/pipe connection and the lateral from the main to the edge of pavement for sewers in roadways and where laterals are in backyards, lining the connection.

The estimated capital cost to implement this rehabilitation is $1.2 Million per mile of sewer in the subcatchment. This value is conservative and was derived from comparing actual rehabilitation costs from past projects in areas across the country. Of this amount, approximately one half comprises traditional structural rehabilitation and replacement and the other half comprises enhancements that will help maximize I/I removal. The enhancements include the lining of a portion of the lateral and more comprehensive manhole lining.

Costs for the private source removal activities were more difficult to estimate due to the significant number of unknowns and variability. Therefore, site-specific data were gathered from recent testing of private properties in the Licking River Siphon area with known high I/I, and costs were then converted to a per acre basis since the I/I is represented by surfaces with specified acreage in the hydraulic model. This approach facilitated efficient and conservative costing. The following activities comprise private source removal. The estimated unit costs and implementation rates are included in parentheses:

- Downspout disconnection ($500 each at 1.5 per acre)
- Area and driveway drain disconnection ($3,000 each at 0.5 per acre)

The overall estimated cost for private source removal is approximately $2,100 per subcatchment acre taking into account additional contingency plus a recent cost-share approach. SSES investigation costs were also included in the assessment. As with the private source removal, SSES investigation costs were converted to a per acre cost. The following activities comprise the investigation activities, which resulted in an estimated cost of $1,260 per subcatchment acre:

- Smoke testing all sewers;
- Dye testing of all private source connections; selected dye flooding of storm sewers which showed smoke; and
- Flow monitoring (one flow meter every 6,000 linear feet of pipe).

Total costs for source removal were developed by applying the appropriate unit price for SSES investigations and public and/or private source removal.

Gray Solution Resizing with Source Removal

The area of surfaces in each subcatchment in the Licking River Siphon sewershed that represent rainfall derived I/I (including ground water) were reduced 50 percent (where "R" values were > 2%) and open system model runs with saturated antecedent moisture conditions were conducted with the typical year and five-year design storms to eliminate overflows. All remedial measures associated with the full system solution were then resized and new cost estimates were developed. The new remedial measure costs were added to the source removal costs estimated above and compared to the convey and treat solution with no source removal. Additional rehabilitation/replacement costs were added to the "no I/I removal" alternative to reflect the fact that many pipes in these areas will require renewal over the planning period and are part of this alternative cost. Table 7.12 and Table 7.13 summarize the results of this planning level assessment.

Table 7.12 Source I/I Removal Cost Comparison for Licking River Siphon with Typical Year Overflow Elimination

Scenario	Rehab and I/I Removal Costs	Gray Upsize and Storage (CIP Cost)	Total ($ Millions)
Convey and Treat	$18.0	$ 76.0	$ 94.0
Source Removal with Reduced Convey and Treat	$ 43.0	$43.2	$ 86.2

Table 7.13 Source I/I Removal Cost Comparison for Licking River Siphon with 5-Year Design Storm Overflow Elimination

Scenario	Rehab and I/I Removal Costs	Gray Upsize and Storage (CIP Cost)	Total ($Millions)
Convey and Treat	$18.0	$ 103.2	$ 121.2
Source Removal with Reduced Convey and Treat	$43.0	$55.7	$ 98.7

Tables 7.12 and 7.13 show that from a cost perspective, I/I removal from public and private sources may be cost-effective. However, when interpreting and evaluating these results, the following should be considered:

- The costs do not include any conveyance cost savings downstream of the siphon;
- The costs do not include cost savings from reduced treatment costs at the Dry Creek WWTP;
- The analysis is a planning level analysis based on available historical data; and
- The ability to achieve the targeted level of I/I reduction is not certain but are based on professional judgment and experience.

The potential benefits of source I/I removal on overflow reduction at the Licking River Siphon were also evaluated by comparing the current level of service in the Licking River Siphon sewershed to source reduction levels of service using a typical year continuous simulation. Table 7.14 summarizes these results:

Table 7.14 Typical Year Spill Volume for Licking River Siphon

Scenario	Typical Year Spill Volume[1] (MG)	Reduction (%)
No I/I Removal	48.8	0
25% I/I Removal	33.4	31%
50% I/I Removal	18.9	61%

Notes:

[1] Typical year continuous simulation of 1970 rainfall assuming no river water intrusion.

Summary of SSES Program

Given the above results and the significant reduction in overflow volumes and cost-savings that can be achieved, SD1 has determined that source control through I/I investigation and removal will be a cornerstone of the overall watershed plan to reduce and eliminate overflows. In addition, source removal has the following benefits:

- Focuses on fixing current deteriorated and end-of-useful life assets rather than building new larger assets at considerably larger costs;
- Removes I/I over time so expenses associated with future conveyance, O&M and treatment expenditures are reduced;

- Removing I/I locally can reduce and eliminate local overflows that have a higher public health and exposure risk;
- Removing I/I locally also provides for reductions and improvements to runoff quantity and water quality of the removed storm water;
- Removing I/I locally fits into the green infrastructure approach, providing not only water quality benefits but also aesthetic benefits and quality of life improvements; and,
- Holistically addresses all sources of storm water entering the sewers and streams at the local level.

SD1 intends to implement a new system-wide program as part of the ongoing SSES work to prioritize and select areas where I/I investigation and removal efforts will be most beneficial. The program is a major strategy in achieving reduction in SSOs and reducing the need for gray upsizing as shown in Section 3. The portion of this program to be implemented in the Five-year Improvement program is described in further detail under Section 7.3.2.

7.2.5 Consent Decree Planning, Implementation, Management

In order to accomplish the goals of the Watershed Plan and meet the requirements of the Consent Decree, SD1 will continue to invest in ongoing planning, implementation, and management activities. Due to the adaptive nature of the Consent Decree, SD1's watershed management program is an iterative approach of characterization, monitoring, modeling, and ranking of challenges and solutions. SD1 has budgeted approximately $12.2 Million over the next five years to continue planning for the Consent Decree programs and collect data to inform future decisions of where to effectively target these efforts. These elements include:

- Hydraulic and Water Quality Model Updates,
- Flow Monitoring,
- Planning efforts for the next Watershed Plans, and
- Watershed Characterization

The general implementation of this program is outlined in Sections 8.4 and 8.7.

<u>Hydraulic and Water Quality Model Updates</u>

As improvements and modifications are made to the SD1 sewer system through the construction of CSO and SSO controls and rehabilitation of existing infrastructure, and as watershed characteristics change through new development, the models developed as part of the watershed planning phase will be updated to reflect current conditions. The updated models will be a critical tool in the next phase of watershed planning. More detailed design models of specific areas may also be desired for future alternatives analysis and sizing of planned CSO and SSO controls. New information from field inspections will also be added and when necessary, will verify that the models are still calibrated for their intended uses.

<u>Flow Monitoring</u>

Flow monitoring within the combined and separate sewer system will be used to support several SD1 needs. The ongoing monitoring is important for SD1 to be aware of the

current performance of the sewer system, provide valuable and useful data for the update of the hydraulic water quality models, and to understand the impacts of different control projects (reduction in CSOs and elimination of SSOs). Flow monitoring will continue to be operated at key locations within the combined and separate sanitary sewer systems to provide data for model updates and quarterly and annual reporting of wet weather CSO and SSO activations.

Planning Efforts for the Second Watershed Plans

SD1's watershed management program is an iterative program of characterization, monitoring, modeling, and ranking of challenges and solutions. SD1 will submit updates to these plans to the Cabinet and EPA for approval every five years, as required by the Consent Decree. As SD1 implements the controls identified in the first set of Watershed Plans, additional information will be collected to assess effectiveness, fill data gaps, refine the watershed management program, and refine the additional controls in the next set of plans. In addition, public input and participation will continue to shape goals and assist in the prioritization of the projects for updated Watershed Plans. Management and implementation of these activities requires coordination and skillful planning by SD1.

Watershed Characterization

As described in Section 2, SD1 has made a significant investment since 1996 to characterize the combined and sanitary sewer systems, as well as the local rivers and streams and their watersheds. SD1 has also expanded the scope of its characterization efforts to encompass other watershed information such as physical and natural features, land use, and inventory of possible pollutant sources and associated pollutant loads. Information gathered from SD1's monitoring will supplement the watershed characterization effort, which will then be used to update the hydraulic and water quality models. To obtain additional data collected by outside agencies, SD1 also intends to maintain contact with the numerous providers of watershed and water quality data that have been identified as part of the watershed planning effort. As new or updated information is obtained, SD1's databases and GIS layers will be updated on an annual basis.

7.2.6 Improvements at Dry Creek Wastewater Treatment Plant

In order to provide the expected level of treatment, SD1 has budgeted approximately $28.8 Million over the next five years to continue their planned maintenance and upgrades to the Dry Creek WWTP. Selected improvements include the following:

- Solids handling and capacity modifications – Construction of a new solids conveyance and storage facility to increase biosolids processing capacity;
- Secondary clarifiers rehabilitation – Rehabilitation of the four secondary clarifiers. Improvements include new mechanisms for optimization of clarifier capacity; and
- Building and siding repairs – Rehabilitation of building siding, windows, roofing, and architecture to address deterioration due to age and process conditions.

Incorporating a new Dry Creek WWTP project into the Basin Projects, SD1 has estimated approximately $17.5 Million in 2009 dollars for the upgrade of the headworks at Dry Creek WWTP:

- New headworks - Construction of a new 100 MGD capacity headworks facility that will take flow directly from the Dry Creek Interceptor and will enable the Dry Creek WWTP to have a firm primary treatment/disinfection capacity of 93 MGD when completed. This improvement will allow for the WWTP to take all of the flow from the Bromley PS, whereas currently pumps are turned off when the current screening capacity is exceeded as described in Section 2.

7.2.7 Pump Station Projects

SD1 owns and maintains129 pump stations in the SD1 service area. As part of the ongoing asset management program, SD1 will continue to identify pump stations in need of repair or maintenance, or identify projects aimed at eliminating the pump station and reducing the risk of SSOs. SD1 has budgeted approximately $14.9 Million over the next five years to conduct projects at pump stations throughout the service area. Example projects include:

- Lakeview Pump Station Surge Protection – Completed the installation of surge tank to protect the force main carrying flow to the Dry Creek system. The Lakeview Pump Station and force main are critical pieces of infrastructure in SD1's system;
- Stressed Pump Station Evaluations – Conducted a high level evaluation of the condition of the pump station's mechanical and electrical equipment and use this information in conjunction with consequence of failure to prioritize pump stations. Rehabilitation investment will be directed to the pump stations with the greatest need; and,
- Meadow Hills Pump Station Removal and Elimination Sewer – Construction of a gravity sewer to remove the existing pump station from service. Removal of a pump station results in energy, operation, and maintenance cost savings.

7.2.8 Ongoing Sewer Rehabilitation / Repair Projects

Aging infrastructure will require inspection, rehabilitation, and repair. SD1 has budgeted approximately $42.0 Million over the next five years in the construction of sewer projects identified under the CSAP program. Projects may also improve system capacity, eliminate a pump station or address a pump station overflow. Several projects already identified include:

- Crestview PS Overflow Elimination (see Section 7.5.3),
- South Hampton PS Overflow Elimination (see Section 7.7.3),
- Union PS Overflow Elimination (see Section 7.7.4),
- Riviera Replacement Sewer (see Section 7.5.4), and
- Avon Drive Sewer (see Section 7.6.4).

Also, as individual cities and Kentucky Transportation Cabinet plan public projects, such as road improvements, SD1 will take advantage of the opportunity to upgrade any existing infrastructure in need of attention.

7.2.9 Storm Sewer Rehabilitation / Repair Projects

Similar to the Ongoing Sewer Rehabilitation / Repair Projects, SD1 will invest in the storm water infrastructure throughout the service area as well. SD1 is responsible for

maintaining storm water systems throughout the service area as of July 1, 2009. Investment in storm water infrastructure is equally as important to reducing overflows and improving system capacity and water quality. Storm sewer projects will utilize green infrastructure wherever possible to retain and filter storm water to reduce runoff and improve water quality. In addition, storm sewer systems in areas of SSES projects will be evaluated along with the sanitary sewers and public and private sources of I/I to develop holistic grey and green infrastructure projects to eliminate I/I, reduce and eliminate local and downstream overflows, reduce runoff and local flooding and improve local water quality. SD1 has committed $11.0 Million over the next five years to upgrading and maintaining their storm water infrastructure. Identified projects include:

- Storm Water Capital Improvement Projects – Rehabilitation of existing and construction of new storm water infrastructure; and
- Master Planning & Master Planning Support – System-wide planning to identify cost-effective strategies for dealing with runoff, natural drainage systems and overall storm water management practices.

7.2.10 Capital Purchases

SD1 will continue to invest in upgrading and purchasing additional vehicles, equipment, and other necessary items to continue effective operation in accordance with our CMOM and NMC programs and to meet the requirements of the CD. SD1 is utilizing capital purchases to improve efficiency and result in reduced operating and maintenance costs in the future. SD1 has budgeted approximately $6.6 Million over the next five years in capital purchases such as:

- Storm Water Vactor Truck and Camera Truck, Vactor Truck Replacements and other vehicle purchases – Required for proper operation and maintenance of SD1's system;
- Capital Equipment Replacement – Replacement of equipment for laboratories, package plants, and electrical equipment at Dry Creek WWTP;
- Safety Equipment – Replacement or addition of safety equipment for multiple operations to provide safe and reliable working conditions for SD1 employees; and,
- Dudley Property Renovation – Acquisition of this property will allow SD1 to consolidate its operations near the administration complex and Lakeview PS by providing additional equipment and vehicle storage. This site was also acquired to serve as the location of the required wet weather storage to eliminate the Lakeview PS SSO as described in Section 3.

7.2.11 Summary of Committed Projects

The Committed Projects describe SD1's commitment to invest in their assets. Projects represent preventative maintenance activities that will enable SD1 to avoid failures (such as new SSOs) that are costly to fix and could pose a threat to public health and the environment. SD1 has budgeted approximately $123.8 Million over the next five years to continue with projects aimed at maintaining their current operation and assets as shown in Table 8.4.

7.3 System-wide Projects

In addition to the Initial Watershed and Committed Projects discussed above, the Five-year Improvement Program incorporates gray infrastructure, green infrastructure, and watershed controls that provide opportunities to reduce sewer overflows, improve water quality, and improve system operation and performance. The impacts of these programs will be monitored and their impacts on the overall full system solution will be assessed as planning decisions are made for future Watershed Plans. The following sections describe the ongoing efforts of SD1 to meet Consent Decree objectives that will be initiated as part of the Five-year Improvement Program.

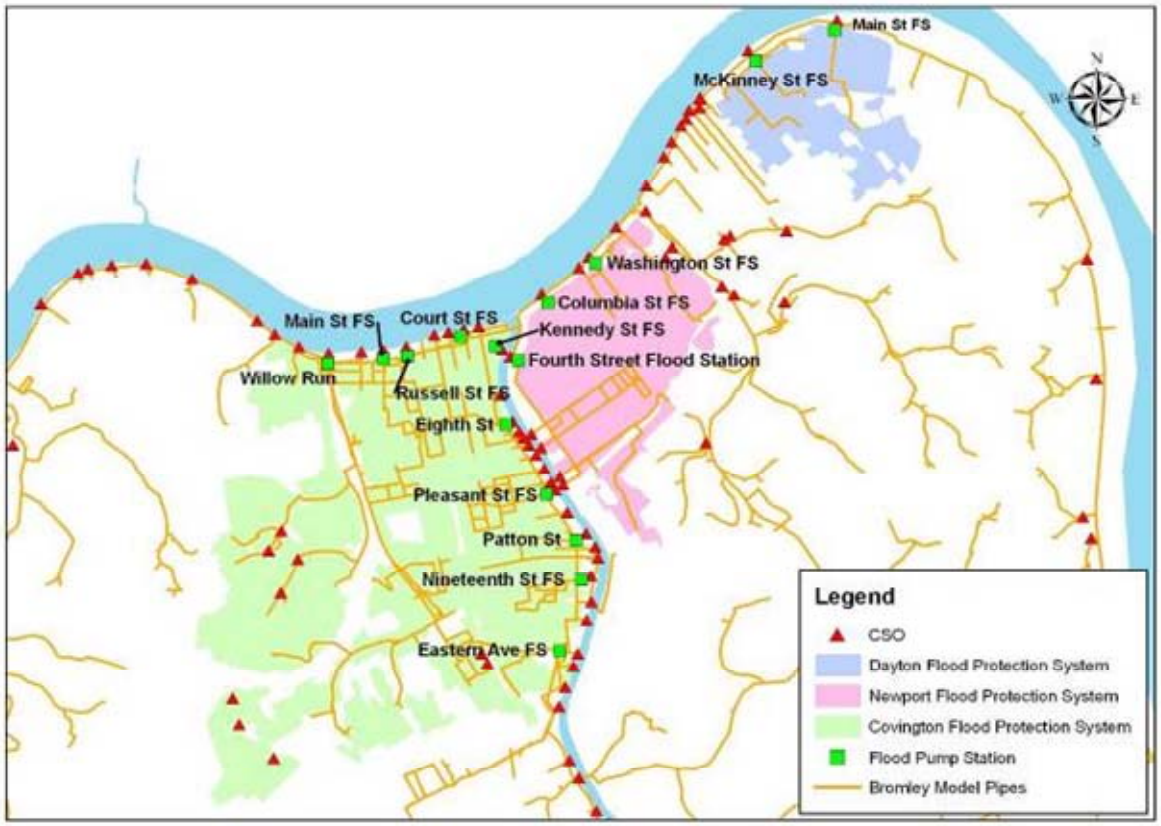
7.3.1 River Water Intrusion Mitigation

Flood Protection System Study

The Consent Decree requires SD1 to ensure that if CSOs occur, they only occur as a result of wet weather and that "this goal shall include addressing those discharges resulting from SD1's compliance with the requirements of the ACOE Ohio River Flood Protection System Pumping Operations Manual" (Consent Decree, 2007). It should be noted that the elevated river stages that activate the USACE Flood Protection System are due to wet weather in the Ohio River drainage basin; these rarely result from local rainfall. Therefore, as a part of the overall watershed planning effort, SD1 conducted a detailed river water intrusion mitigation feasibility analysis. The goal of this analysis was to fully understand the effects that the USACE's Flood Protection System has on SD1's sewer system and identify alternatives to mitigate sources of river water intrusion at outfalls, catch basins in the floodway upstream of diversions, and where the interceptors and manholes are below the water table both under normal and elevated river levels.

The USACE constructed flood protection systems for the Cities of Newport (1951) and Dayton (1986) in Campbell County, and the City of Covington (1955) in Kenton County. The three flood protection systems are now consolidated into the Flood Protection System for Campbell and Kenton Counties (Flood Protection System). The Flood Protection System includes 4.8 miles of earthen levee, 1.7 miles of concrete and steel flood wall, 15 flood pumping stations, and 72 flood control gates (Woolpert, 2001). SD1 owns and operates the 15 flood pump stations and 72 flood control gates under the supervision and approval of the USACE. The local cities of Covington, Newport, and Dayton own and maintain the earthen, concrete and steel flood walls under the supervision and approval of the USACE. The area served by the Flood Protection System, the locations of the flood pump stations, and SD1's CSOs are shown in Figure 7.16.

Figure 7.16 Flood Protection System



The Flood Protection System is operated by SD1 in accordance with the USACE's Flood Protection Operation and Maintenance Manuals (USACE, 1951, 1955, & 1986). When the Ohio River reaches specified river stages during flood conditions, CSO outfall flood gates are closed to isolate the sewer system from high river water. Other sewer system flood gates are opened or closed to isolate portions of the interceptor and combined sewers to re-route sewer flows to the flood pumping stations. The flood pump stations and gates were designed by the USACE to operate to protect the cities from flooding internally due to elevated river levels or during rain events when the flows in the combined sewers could not flow out into the river due to the elevated river levels.

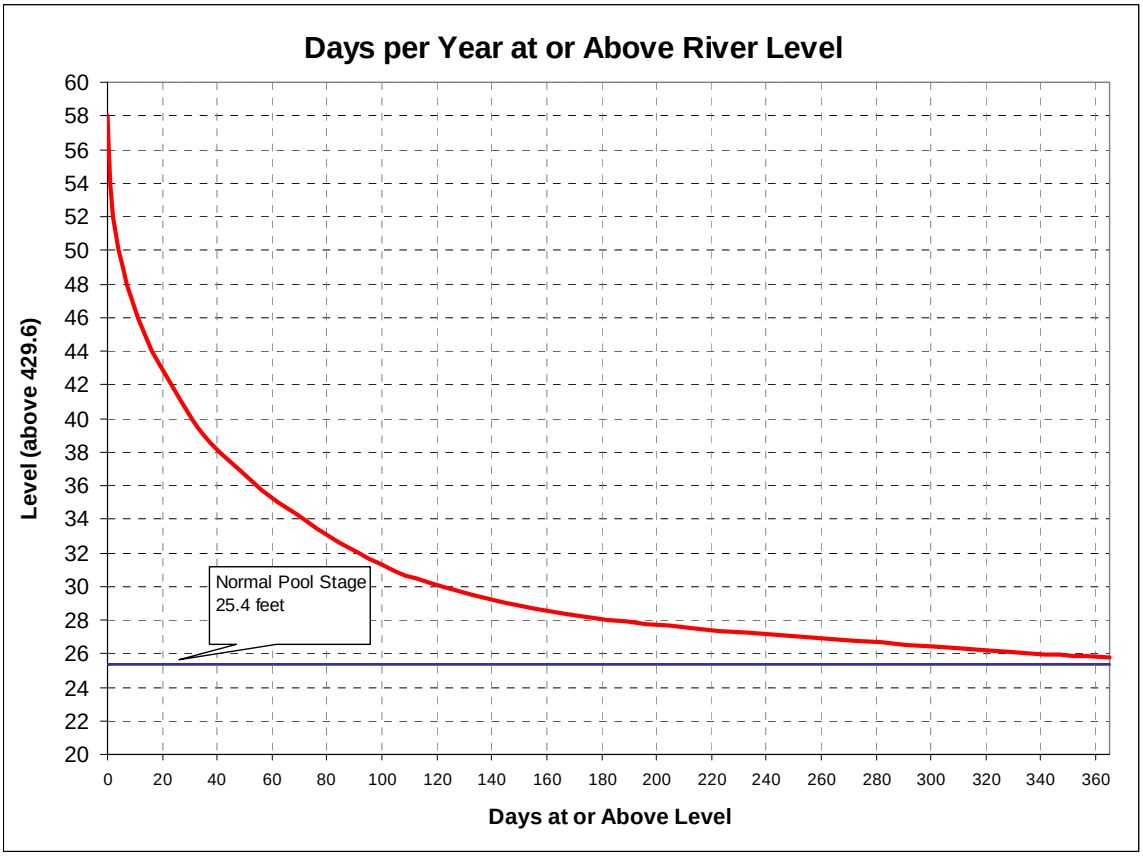
In Covington, the gates are closed on the outfall sewer, with additional gates closed along the interceptor to define drainage basins. The interceptor and combined sewers are then used to convey flow from multiple CSO areas to a single flood station. With this configuration, the interceptor is no longer available to convey flow to treatment.

In Newport and Dayton, the outfall gates are on the combined trunk sewer upstream of the CSO diversion chambers. With this configuration, river water that enters through the CSO outfalls can back up through the diversion and flow down into the interceptor. When this occurs, the interceptor lift stations are shut down. Once the system is isolated, the flood pump stations are placed on-line to pump the sewer flows to the river side of the flood wall or levee until the river levels drop below the flood stage.

Additionally, most of SD1's combined sewer system and outfalls were constructed in the late 1800s and early 1900s and therefore pre-date the construction of the Markland Dam on the Ohio River, which was constructed in the mid-1960s and is located down river from SD1's service area in Gallatin County, Kentucky. Prior to construction of the Markland dam, Ohio River pool stage around Northern Kentucky ranged from 2 to 12 feet.

The deep channel in the Ohio River also generally runs along the Ohio side, and many of SD1's CSO outfalls when originally constructed were extended out to that channel. When the Markland Dam was constructed as part of the USACE's flood protection and river navigation measures, normal pool stage was raised to 25.4 feet (USACE, 2007) putting many of what are now SD1's CSO outfalls along the Ohio and Licking Rivers permanently under water and increasing the frequency of higher river elevations and backups into SD1's combined sewer system. Figure 7.17 shows the frequency of attainment of various river stages based on data from 1970 to 2005. For example in an average year, there are 200 days where the Ohio River is above 28 feet.

Figure 7.17 Frequency of Attainment of Various River Stages



The critical control elevations of diversions throughout SD1's combined sewer system vary substantially, but there are numerous diversions in the system being flooded by the river for some time during each year. For example, when the Ohio River reaches approximately 38 feet in elevation (approximately 41 days per year on average), river

water begins to flow through many CSO outfall pipes located along the Ohio and Licking Rivers and over the CSO diversions and into the interceptor. River water then enters into the interceptors via the diversions causing the entire interceptor system to fill with river water. As a result, Bromley PS shuts down to one small pump at 41 feet so that the Dry Creek WWTP is not inundated with river water and highly dilute sewage. At 44 feet, the flood protection system begins operation at 4th Street in Newport and starts to completely isolate the combined sewer system for flood control. These flood protection systems isolate the CSO outfalls from the Ohio and Licking Rivers and convey all combined sewer flow to the flood pumps, which in turn pump the flow over the flood wall/levee and into the Ohio River. The Covington and Dayton flood systems begin operation at 45 feet and 47 feet and are not fully activated until 64 feet and 49 feet, respectively.

River Water Intrusion Mitigation Evaluation

SD1 initiated a study to investigate the feasibility of preventing the inflow of river water into the interceptor system. The study included an assessment of each outfall and the type of improvements needed to prevent inflow from the river.

The first decision for the analysis was to determine which outfalls would require protection. Therefore, a decision was required defining the maximum river stage that would be prevented from entering the interceptor diversion locations. After a detailed review, it was determined that all outfalls where the interceptor diversion elevation corresponded to a river stage of 47 feet or less would be included in the program. This elevation was selected because it corresponds to the USACE Willow Run Flood PS activation level where gates on the interceptor are closed and flows are isolated and conveyed to the Willow Run Flood PS. The elevation of 47 feet would also allow almost full interceptor system operation. The only exception is the area tributary to the 4th St. Flood Station in Newport, which is called to activate by the USACE at 44 feet, but is an isolated area. Above 47 feet, the interceptor system is called by the USACE to be shut down and the system is in flood protection mode. The only way to continue conveying flow through the interceptor system at river levels above 47 feet and onto the Dry Creek WWTP would be to modify the flood pumping system operational protocol that was designed and developed by the USACE.

The above evaluation led to the development of a program to mitigate river water intrusion up to river stage 47. Table 7.15 shows a listing of the 42 CSO diversions that fall under the threshold of the 47 feet river level.

Table 7.15 River Water Intrusion Outfalls with Diversions below River Stage 47 feet

Location Name	CSO ID	Diversion ID	River Stage at Diversion (feet)	Outfall Pipe Diameter (inches)
4th Street	CSO-0790086	DIV-0820001	27.48	66
Washington Street	CSO-0640090	DIV-0640081	28.60	66
Columbia Street	CSO-0790084	DIV-0790015	30.45	54
Eastern Avenue	CSO-0910065	DIV-0910055 DIV-0910064	35.82	60
8th Street Covington	CSO-1420142	DIV-1420022 DIV-1420025 DIV-1420028 DIV-1420014 DIV-1420018	37.92	84
Adela	CSO-1710116	DIV-1710003	38.03	36
Taylors Bottom	CSO-0650090	DIV-0650084	38.60	30
34th Street Covington	CSO-0880081	DIV-0880017	38.97	48
Patchen Street	CSO-0620075	DIV-0620031	39.26	24
18th Street Covington	CSO-0930105	DIV-0930041 DIV-0930050 DIV-0930056 DIV-0930066	39.39	72
Carneal Street	CSO-1710121	DIV-1710084	39.48	21
Willow Run - Crescent at VW lot	CSO-1480187	DIV-1480103	39.80	60
Saratoga	CSO-0770096	DIV-0770006	39.90	30
Garrard Street Covington	CSO-1440206	DIV-1440156	40.08	18
Ash Street	CSO-1710124	DIV-1710098	40.17	48
Lagoon Street	CSO-1720109	DIV-1720005	40.51	30
Parkway / Highway	CSO-1490132	DIV-1490027	40.54	60
16th Street Covington	CSO-0930106	DIV-0930002 DIV-0930014	40.70	18
Washington Avenue	CSO-0610072	DIV-0610006	41.02	30
20th Street Covington	CSO-0930103	DIV-0930075	41.40	18
Willow Run Diversion	CSO-1480187	DIV-1480116	41.92	120
Riverside Drive	CSO-0630061	DIV-0630001	42.03	42
S. of 13th Street Covington	CSO-0980081	DIV-0980036	42.06	66
Pleasant Street	CSO-1730259	DIV-1730029	42.48	36
33rd Street Covington	CSO-0880082	DIV-0880004	42.51	15
9th Street Covington	CSO-1420144	DIV-1420032	42.61	18
Willow Run – 3rd Street at LS	CSO-1480187	DIV-1480012	42.63	24
Rohman Street	CSO-1730263	DIV-1730008	43.46	30
Kenner Street	CSO-1710114	DIV-1710054	43.61	24

Location Name	CSO ID	Diversion ID	River Stage at Diversion (feet)	Outfall Pipe Diameter (inches)
Main Street Covington	CSO-1470093	DIV-1470032 DIV-1470052 DIV-1470072	43.74	21
Oakland Street Covington	CSO-0910068	DIV-0910005 DIV-0910007 DIV-0910025 DIV-0910027 DIV-0910031	43.87	60
Willow Run – 3rd Street at I-75	CSO-1480187	DIV-1480097	43.95	15
17th Street Covington	CSO-0930104	DIV-0930026	45.48	42
Anchor Inn	CSO-0360079	DIV-0360018	45.90	12
Robinson Street	CSO-1420146	DIV-1420076	46.08	24
Philadelphia Street Covington	CSO-1470089	DIV-1470003	46.12	48
Johnson and River Center Street	CSO-1440209	DIV-1440002 DIV-1440003	46.60	48
11th Street Covington	CSO-1420147	DIV-1420079	46.79	24
Church Street Covington	CSO-1850158	DIV-1850024 DIV-185032 DIV-1850150	46.92	60
6th and Berry	CSO-0540009	DIV-0540009	NA[1]	18
Geiger Street	CSO-0650100	DIV-0650041	NA[1]	24
Donnermyer and Lafayette	CSO-0540044	DIV-0540044	NA[1]	18

[1] These locations have existing local storm water or ground water inflow at elevated river levels and will also be protected as a part of this program.

By protecting CSOs with interceptor diversions below river stage 47 feet, the overall number of days in an average year with elevated river level-induced overflows could be reduced from 41 to 9 days on average.

The planned improvements to protect against river water intrusion generally consist of the installation of duckbill-type check valves, or other method of intrusion protection, on the outfall pipe to provide passive check valve service. Manholes that are below river stage 47 feet will also be made watertight as much is possible. The cost associated with the installation of these valves depends heavily on the manner of installation. The two installation options considered are shown below.

The rubber duckbill style check valves will either be installed on the end of the existing outfall pipes or in chambers constructed upstream of the existing outfall, depending on accessibility to the existing end of pipes. In some locations, the headwalls may be replaced or modified to accommodate the check valves.

- **Rubber duckbill style check valve and new headwall:** These valves will require a new headwall to support the weight and dimensions of the rubber duckbill style check valve, thimbles, and saddles. Figure 7.18 is a photo showing

a duckbill installed in the new Greenup Street outfall. These installations generally cost less than constructing a new chamber.

- **Rubber duckbill style check valve in a new chamber:** This style of installation is needed where the outfall runs along the bottom of the river and is not exposed along the river banks or some other constructability issue prevents end-of-pipe installation. This type of installation is generally more expensive than the external valve due to the need for construction of a below-grade chamber to house the valve. New chambers may be located in advantageous locations to provide easier construction and maintenance access. There are several alternative products that may be considered, which could eliminate the need for a deep chamber at one or more locations. Alternatives will be evaluated during detailed planning and design.

Figure 7.18 Duckbill Check Valve on Greenup St. Outfall

Cost-Benefit of River Water Intrusion Mitigation

The planning level capital cost to install all valves on CSOs subject to river water intrusion up to river stage 47 feet is $10.6 Million. Model simulations estimate that overflow volumes in a typical year could be reduced by approximately 280 MG with these installations. SD1 has been working to protect its outfalls from river water intrusion for some time. A number of outfalls, not listed in the table above, have already been protected and still others have protection planned as part of other ongoing projects. In addition to these projects, SD1 has budgeted an additional $5.0 Million for this program in the next five years to begin addressing the 42 remaining locations. It is estimated that this budget will allow for protection from river water intrusion up to river stage 42 feet. Protection of diversions below the river stage 42 feet will reduce the overall number of days in an average year with elevated river level-induced overflows

from 41 to 23 on average. Section 8.2.3 summarizes the implementation of the River Water Intrusion Mitigation program relative to all the system improvements in the Five-year Improvement Program. While it is expected that the check valves will greatly reduce river water intrusion into the interceptor sewers, SD1 also recognizes that I/I under elevated river levels through pipe joints and manholes may also need to be addressed. It is unknown at this time how much of an issue this will be. Once the check valves are installed, SD1 will monitor the operation of the system and determine the magnitude of river-level induced I/I that may need to be addressed. The costs and fixes associated with this will be evaluated in future updated Watershed Plans.

Summary of River Water Mitigation

Using the hydraulic model, SD1 estimated the additional benefit of implementing components of the committed and system-wide infrastructure improvements, including NMC improvements. The Bromley wet well modifications, static inline storage and river water intrusion mitigation (to 47 feet) represent efforts that reduce combined sewer overflows. Model-calculated volume reductions for these efforts (incremental and total) are shown in Table 7.16. These results show a significant potential for volume reduction up to 379 MG in a typical year by implementing these gray infrastructure improvements in the first five years. It is important to note that the benefits of the river water intrusion program shown in Table 7.16 include protection up to 47 feet. In addition, the reduction of 250 MG of overflow in the typical year does not include any other improvements. The incremental benefit of the River Water Intrusion Protection will change with additional system improvements. For example, Table 8.7 in Section 8 shows an incremental benefit of 281 MG as it helps to fully realize benefits of other system improvements.

The river water intrusion program will extend beyond the first Five-year Improvement Program in order to achieve this level of protection. It is anticipated that SD1 will be able to protect up to river stage 42 feet in the first Five-year Improvement Program. The estimated overflow reduction for protection to 42 feet is 130 MG, which is just over half of the total reduction from protection to 47 feet. The additional benefits of adding dynamic weir inline storage is included and discussed in Section 7.6.5.

Table 7.16 CSO Volume Reductions with System-wide Nine Minimum Control Improvements

Scenario	Total CSO Volume (MG)	Incremental Reduction (MG)	Total Reduction From Current (MG)
Current	1,873	0	0
With River Intrusion Protection	1,623	250	250
Add Fixed inline Storage and Bromley PS Wet Well Modifications	1,494	129	379

Note: River intrusion prevention assumes control to a river stage of 47 feet.

7.3.2 Priority Inflow and Infiltration Source Identification & Removal Program

As discussed in Section 7.2.4, SD1 intends to implement a new program as part of their ongoing SSES work to prioritize and select areas where I/I investigation and removal efforts will be most beneficial. SD1 has budgeted $6 Million over the next five years to implement the Priority Inflow and Infiltration Source Identification & Removal Program. This program is designed to reduce and eliminate SSOs through public and private source I/I removal. This work is in addition to and coordinated with the committed ongoing sewer rehab/replacement work listed in Table 8.4.The areas that will be the initial focus of this program are the Priority Areas identified in Section 6. These include the Lakeview PS area, Taylor Creek, and the area tributary to the Licking River Siphon. These areas are known to have extensive I/I. The timing and extent of implementation in each area will be determined as part of the prioritization phase of the SSES Program.

7.3.3 Source Identification Program

SD1's Source Identification Program is designed to provide a framework for prioritizing watersheds based on available data, identify dry and wet weather sources of bacteria, evaluate opportunities for implementing controls, and support development of an action plan to identify and ultimately address these sources. To date, the SIP has been piloted in the Banklick Creek watershed. A detailed assessment of this watershed has been completed as well as field reconnaissance activities to inventory suspected sources and collect monitoring data to confirm the findings of the field reconnaissance. Within the Banklick Creek watershed, SD1 has initiated construction of a pilot wetland and plans to implement up to three decentralized watershed control projects within the first Five-year Improvement Program, although specific projects have not yet been selected (Section 7.4.8). SD1 has budgeted $3 Million for watershed control pilot projects (including the wetland and planned decentralized controls) in the Five-year Improvement Program. This is based on the overall project cost for the Banklick pilot wetland and an estimated average cost of $3,000/acre "managed" through decentralized controls. SD1 also estimates that the SIP program elements can be initiated in at least one more watershed during this first Five-year Improvement Program.

7.3.4 System-wide Green Programs

As outlined in Section 3, SD1 plans to implement a green infrastructure program on a regional level in an effort to minimize runoff entering the combined sewer system and improve water quality in Northern Kentucky. The proposed green infrastructure program consists of two main components: the Disconnection – Redirection – Infiltration Program (DRIP) and the Green Infrastructure Project Partnerships (GrIPP). Both efforts are also intended to raise public awareness of individual responsibility for protecting and enhancing local water resources. As part of the Five-year Improvement Program, SD1 will begin implementing DRIP and GrIPP, which are green infrastructure incentive programs, for residential and non-residential property owners in both the combined and separate sewer system areas. These programs provide property owners with financial and technical assistance from SD1 for the implementation of green infrastructure elements.

DRIP

Through DRIP, incentive programs for downspout disconnection, rain barrels and rain gardens will be promoted to residential property owners in both the combined and separate sewer systems. Benefits associated with this program include the following:

- Reduces storm water entering the sewer system which results in overflow reduction from combined sewers and I/I reduction into separate sewers;
- Promotes ground water recharge; and,
- Achieves the goal of the watershed approach to improve water quality.

Beginning in 2009, SD1 initiated a rain barrel program to assess public interest in green technologies. During the course of 2009 and 2010, SD1 successfully sold 300 rain barrels. Based on this participation, SD1 is more aggressively pursuing the residential implementation of green infrastructure. The complete DRIP program will begin in fiscal year 2012; initial budgets and assumptions for implementing DRIP in the Five-year Improvement Program are outlined in Table 7.17. However, as with the initial rain barrel program, annual budgets for DRIP will be re-evaluated each year as awareness and participation in the program increases. Ultimately the program will be monitored, evaluated, and appropriately restructured in preparation for the submittal of the updated Watershed Plans scheduled for 2014.

GrIPP

Through GrIPP, non-residential property owners, including cities and counties, will be eligible for financial assistance for implementing green infrastructure on redevelopment projects, streets, and retrofits of existing sites to capture and manage storm water runoff. Non-residential property owners in both the combined and separate systems will be eligible for GrIPP funding.

GrIPP in the Combined Sewer System:

Redevelopment Projects:

As part of the green opportunities analysis in the combined sewer system, it was assumed that 15 percent of currently developed non-residential parcels greater than one acre will be redeveloped over the duration of the Consent Decree. Based on proposed changes to SD1's storm water regulations for redevelopment projects, developers and/or property owners will be required to implement green practices to effectively reduce the annual runoff from redeveloped sites by 15 percent. SD1 will examine each redevelopment project to identify any additional green controls that may be implemented to further reduce combined sewer overflow volume. Assuming three, one-acre redevelopment projects per year, an annual budget of $30,000 has been incorporated in the Five-year Improvement Program. SD1 will start implementing this program in fiscal year 2012.

Project Partnerships:

In addition to redevelopment projects, SD1 plans to partner with cities, counties, and other non-residential property owners to incorporate green storm water features on existing sites. The main goal of these projects is to cost effectively reduce the amount of storm water runoff entering the combined sewer system when compared to more traditional gray controls. SD1 will base funding on a business-case evaluation. This evaluation is based upon the cost per gallon of storm water removed from the combined system to ensure the proposed green infrastructure is cost effective. Funding may be requested for any green feature proposed on a site that provides a combined sewer system overflow volume reduction. SD1 reserves the right to fund the design and construction of all components or only certain portions of green features being proposed, based upon results of the business-case evaluation. Funding for these projects will be awarded on a first come, first serve basis. For this purpose, SD1 has included $854,000 for partnership opportunities in the Five-year Improvement Program, beginning in fiscal year 2010.

Green Streets:

In conjunction with the project partnerships, SD1 recognizes the importance of incorporating green infrastructure into roadway work. SD1 will partner with cities and counties to incorporate green infrastructure into proposed roadway improvement and reconstruction projects. For specific green street partnerships, SD1 has assumed 7.5 percent of the road area, or 158,200 square feet, within the combined system (excluding highways) will be redirected to green features during the implementation of the Consent Decree. For the purposes of the Five-year Improvement Program, SD1 has budgeted $120,000 for the construction of 8,000 square feet of green street features per year, beginning in fiscal year 2012.

GrIPP in the Separate Sewer System:

GrIPP funding is also available for non-residential properties in the separate sewer system. GrIPP funding in the separate sewer system will be utilized to implement green infrastructure on redevelopment projects and properties that choose to implement green infrastructure to improve water quality.

Redevelopment Projects:

Based on the proposed changes to SD1's redevelopment regulations in the separate system, redevelopment projects will implement green practices to manage the runoff produced from the first 0.4 inches of rainfall utilizing a site BMP. SD1 will evaluate each redevelopment project for the opportunity to implement cost-effective green controls that go beyond the proposed regulation. Assuming three, two-acre non-residential redevelopment projects per year in the separate system, an annual budget of $50,000 has been incorporated in the Five-year Improvement Program. SD1 will begin implementing this program in fiscal year 2012.

Project Partnerships:

In addition to redevelopment projects, SD1 plans to partner with other non-residential property owners, cities and counties within the separate system to implement green controls on existing sites to manage storm water runoff. In the separate sewer system,

SD1 will base funding on a business-case evaluation. This evaluation is based upon the cost per gallon of storm water treated and the associated pollutant reduction, with bacteria as the main pollutant of concern. The main goal of these projects is to provide water quality improvements to the storm water entering the separate storm sewer system and natural drainage ways. SD1 reserves the right to fund the design and construction of all components or only certain portions of green features on the project, based upon results of the business-case evaluation. For this purpose, SD1 has included $429,000 for partnership opportunities in the Five-year Improvement Program, beginning in fiscal year 2010.

SD1 will begin implementing each component of GrIPP during the Five-year Improvement Program. During this time, the program components will be monitored, evaluated, and appropriately restructured in preparation for the submittal of the updated Watershed Plans, scheduled for 2014. Table 7.17 highlights the funding for each program during the first five years.

Table 7.17 Five-year Funding for DRIP and GrIPP

Green Infrastructure Program	Implementation Assumptions	Start Year	5-Yr Program Cost
Disconnection - Redirection - Infiltration Program (DRIP)			$180,000
Combined System	$500 per property 100 properties per year 300 properties in first 5 years	2012	$150,000
Separate System	$500 per property 20 properties per year 60 properties in first 5 years	2012	$30,000
Green Infrastructure Project Partnership (GrIPP)			$1,883,000
Combined System			
Redevelopment	$10,000 per acre of redevelopment 3 - 1 acre sites per year 9 properties in first 5 years	2012	$90,000
Green Streets	$15 per square foot 8,000 square feet per year 24,000 square feet in first 5 years	2012	$360,000
Partnerships (private or city/county)	Projects evaluated on an individual basis Based on cost per gallon benefit $127,000 per year from 2010-2011 $200,000 per year from 2012-2014	2010	$854,000
Separate System			
Redevelopment	$50,000 per year for redevelopment 3 - 2 acre sites per year 9 properties in first 5 years	2012	$150,000
Partnerships (private or city/county)	Projects evaluated on an individual basis Based on cost per gallon benefit $64,500 per year from 2010-2011 $100,000 per year from 2012-2014	2010	$429,000
	Total DRIP and GrIPP		$2,063,000

In addition to incentivizing implementation of green infrastructure through DRIP and GrIPP, SD1 will provide technical guidance for property owners, agencies, or other local groups interested in implementing reforestation programs or steam buffer restoration. Assistance provided by SD1 could be used by third parties to leverage existing grant monies or may be incorporated into grant applications to achieve local match requirements.

7.3.5 Demonstration Projects

In addition to the specific programs identified in Section 7.3.3, SD1 has also identified several different types of green technologies that could be implemented over the next five years. Although not all locations have been identified yet, the Priority Areas (discussed in Section 6) and other partnership opportunities may help inform the implementation of these projects as pilot studies. These include but are not limited to: low impact development practices such as green streets, urban planters, green roofs,

rain gardens, retrofitting detention and retention ponds, and removal of direct storm water entry points. SD1 will build and monitor these green controls to develop a better understanding of the performance of green infrastructure in Northern Kentucky. SD1 will specifically look for opportunities to implement and monitor such green demonstration projects and green programs, mentioned above, in the Licking River CSO basins, due to the significance of the CSOs along the Licking River.

SD1 is committed to several demonstration projects that allow for evaluation of the different types of green projects; SD1 has budgeted $4.6 Million over the next five years to build and monitor as many green technology demonstration projects as possible. The results from the demonstration of these techniques will provide SD1 with the necessary information to implement these controls efficiently and cost effectively throughout the SD1 service area.

Example opportunities of the types of projects that will be implemented under this program include:

12th Street – Green Street:

The City of Covington and KYTC have been developing plans for a major road expansion of the 12th Street corridor for almost eight years. SD1, the City of Covington, and KYTC worked closely to evaluate the potential to incorporate green infrastructure elements into this road widening plan. The result has been an innovative design that incorporates roadside planters and a bioswale that collectively reduce the volume of storm water runoff entering the combined sewer system from this new roadway.

St. Elizabeth Hospital:

A new eight-acre hospital facility for St. Elizabeth's was constructed on a formerly undeveloped parcel of land in Covington. SD1 realized the benefits of partnering with St. Elizabeth to incorporate green infrastructure into the site design. As a result of this partnership, potential retrofit of a regional KYTC detention basin into a large rain garden was identified on St. Elizabeth's campus. Construction of this facility began in 2008, and the basin is currently operational.

Jacob Price Project:

During the green evaluation process, the Jacob Price public housing development was identified as a potential candidate for the implementation of green infrastructure components. This site is a 6.7-acre parcel located at the intersection of 11th Street and Greenup in Covington, KY. Field inspections of the site revealed that, despite a considerable amount of green space on the property, all the roof downspouts and roadway systems drained directly to the combined sewer system. This appeared to be a prime candidate for downspout disconnection in conjunction with implementing green infrastructure controls. SD1 subsequently met with the Housing Authority of Covington (HAC) to discuss potential partner opportunities; it was discovered that this facility is scheduled for demolition, and HAC has been awarded a Hope VI Revitalization Grant to develop and implement a comprehensive urban redevelopment project in this neighborhood. Since the award of the grant, SD1 has partnered with HAC to incorporate green infrastructure into the Jacob Price revitalization plan. By implementing low impact development features, HAC can disconnect as much runoff from the

combined sewer system as possible. The Jacob Price project is an example of a potential project to be included as part of the demonstration of green technology.

7.4 Central Basin Projects

This section describes the Five-year Improvement Program projects that are specific to the watersheds in the Central Basin (Licking River, Banklick Creek and Threemile Creek). The projects described in this section were selected from the list of watershed projects and basin projects identified in the Priority Area analysis. These projects include:

- Ripple Creek PS overflow elimination,
- Alex-Licking PS overflow elimination,
- Sunset PS overflow elimination,
- Licking River Siphon Overflow (Threemile Creek watershed Priority Area),
- Vernon Lane Priority Area,
- Church Street Priority Area,
- Lakeview Priority Area, and
- Banklick Creek Watershed Priority Area.

Each project description includes background, an evaluation of potential control alternatives and a conclusion. More complex projects, such as the Lakeview Priority Area, include additional detail on the alternatives, including work-to-date and water quality benefits.

7.4.1 Ripple Creek Pump Station Overflow Elimination

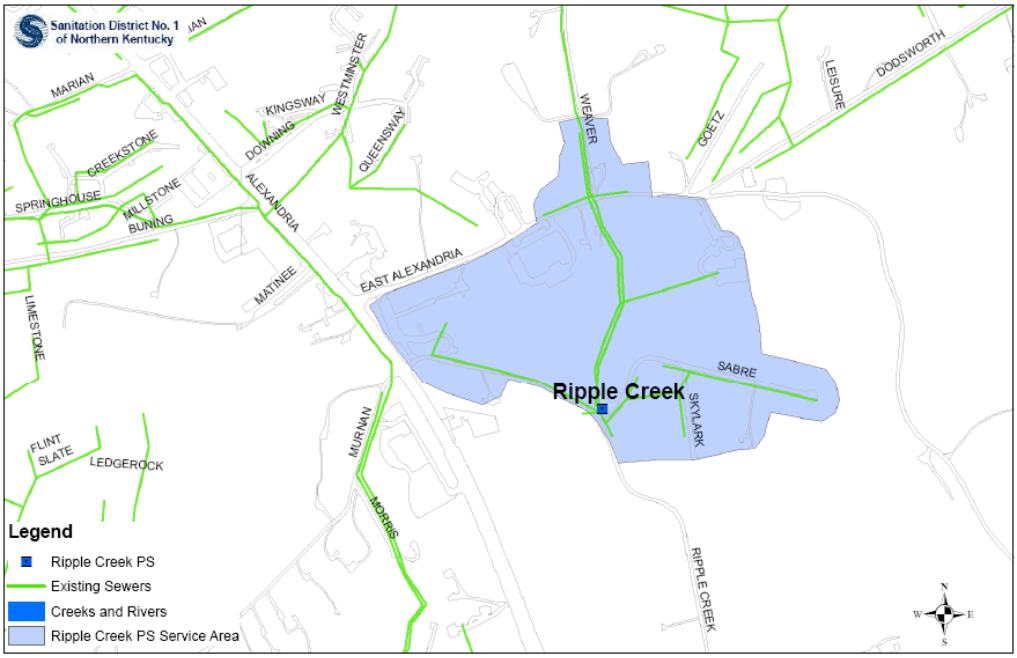
Background

Ripple Creek PS is a very small pump station located near Silver Grove, Kentucky. The pump station discharges to the Silver Grove PS, which is at the very upstream end of the Dry Creek WWTP service area. The pump station contains two dry pit pumps and has a firm capacity of approximately 0.11 MGD. A picture of the exterior of Ripple Creek PS is shown in Figure 7.19. As the picture shows, the pump station is located along a public road.

Figure 7.19 Ripple Creek Pump Station

The service area for Ripple Creek PS is quite small comprising 67 residential properties and 6 non-residential properties, as shown in Figure 7.20.

Figure 7.20 Current Ripple Creek Pump Station Service Area



When the capacity of the pump station is exceeded during large wet weather events, it overflows through a 6-inch constructed bypass to a tributary of Ripple Creek, which discharges to the Licking River. The hydraulic model estimates that the Ripple Creek overflow activates 11 times in the typical year for a total volume of 0.17 MG.

Potential Control Alternatives

The following control alternatives were evaluated to eliminate the overflow at the Ripple Creek PS:

1. New 0.45 MGD pump station and 1,900 linear feet of 6–inch forcemain; and
2. Eliminate pump station with 1,720 linear feet of new gravity sewer to Wolpert PS and add 31,000 gallons of storage at Wolpert PS.

In addition to the solutions above, SD1 conducted SSES activities to determine if I/I removal could eliminate the pump station overflow. The SSES activities included closed circuit television (CCTV), smoke testing, and private property dye testing. The SSES work found that only three properties were connected to the sanitary sewer; this does not provide for much potential I/I removal from private parties. Flow monitoring in the pipe downstream of these connections also showed very little wet weather response. However, I/I is clearly entering the system during very wet conditions. The sewer coming from the north is adjacent to a creek and the pipe is in relatively poor condition. Because almost no private sources were found, the I/I is likely coming from the pipe trench. Therefore, targeted rehabilitation to this sewer will be performed to reduce the I/I.

Table 7.18 shows the preliminary capital costs associated with each alternative sized to eliminate the overflow in a typical year.

Table 7.18 Capital Costs for Overflow Elimination

Alternative	Cost
New 0.45 MGD Pump Station and 1,900 LF 6" forcemain	$1,490,000
1,720 LF of 8" Gravity Sewer + 31,000 gallons of storage at Wolpert PS	$857,000

Conclusions

The costs above show that the gravity sewer option is the most cost-effective alternative for eliminating the overflow at the Ripple Creek PS. The new eight-inch gravity sewer will have adequate capacity to convey peak dry and wet weather flows and the storage at the Wolpert PS will ensure that wet weather flows from Ripple Creek do not cause capacity problems at the Wolpert PS. In addition to the conveyance and storage improvements, targeted sewer rehabilitation will be conducted upstream of the Ripple Creek PS, with the goal of improving the structural performance of gravity sewers in poor condition and to eliminate any I/I entering the older portions of the sewer from ground water. These improvements were completed by December 31, 2010 per the Consent Decree and are currently in operation.

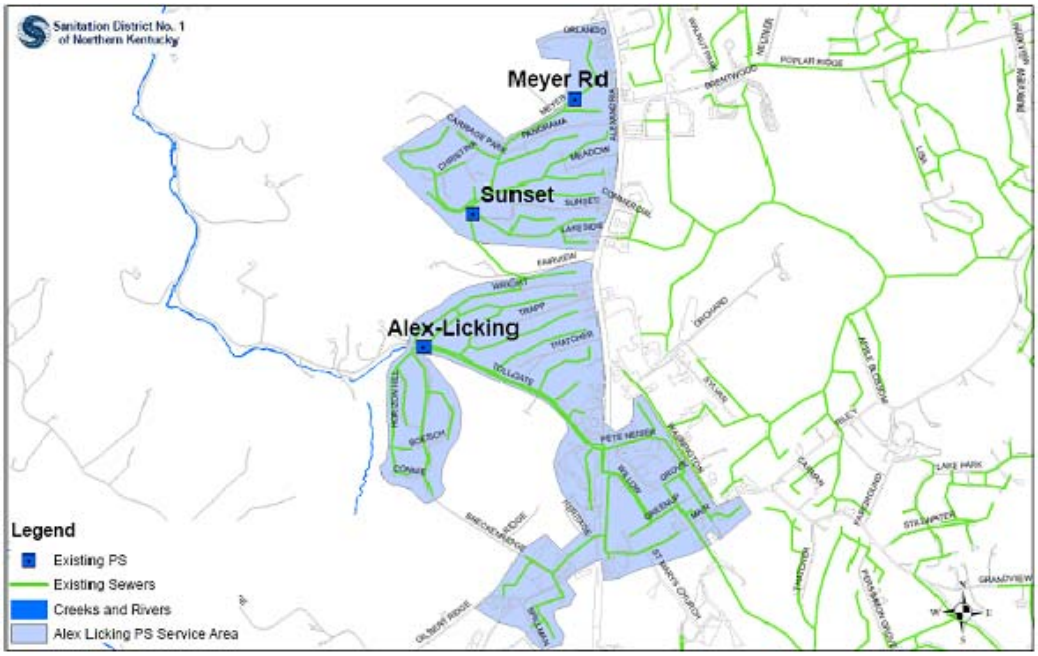
7.4.2 Alex-Licking Pump Station Overflow Elimination

The Alex-Licking PS was replaced in 2008 with a new pump station with a peak capacity of 5.2 MGD (see Figure 7.21). This is a significant capacity increase over the previous pump station capacity of 1.1 MGD. The new pump station has eliminated the bypass and will provide dry and wet weather capacity for current and future growth tributary to the pump station. Figure 7.22 shows the current service area to the Alex-Licking PS. This service area is expected to expand as growth occurs.

Figure 7.21 New Alex-Licking Pump Station

The gravity service area for the Alex-Licking PS is relatively small comprising approximately 330 residences and 62 non-residential customers, but it receives flow from the Sunset PS and is designed to provide capacity for future growth as it occurs.

Figure 7.22 Alex-Licking Pump Station Service Area

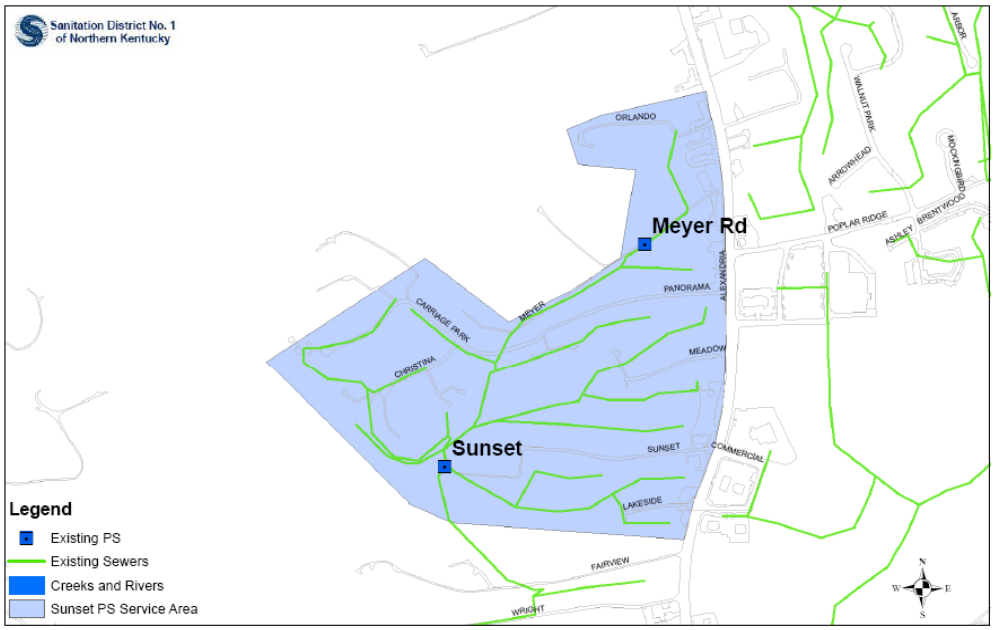


7.4.3 Sunset Pump Station Overflow Elimination

Background

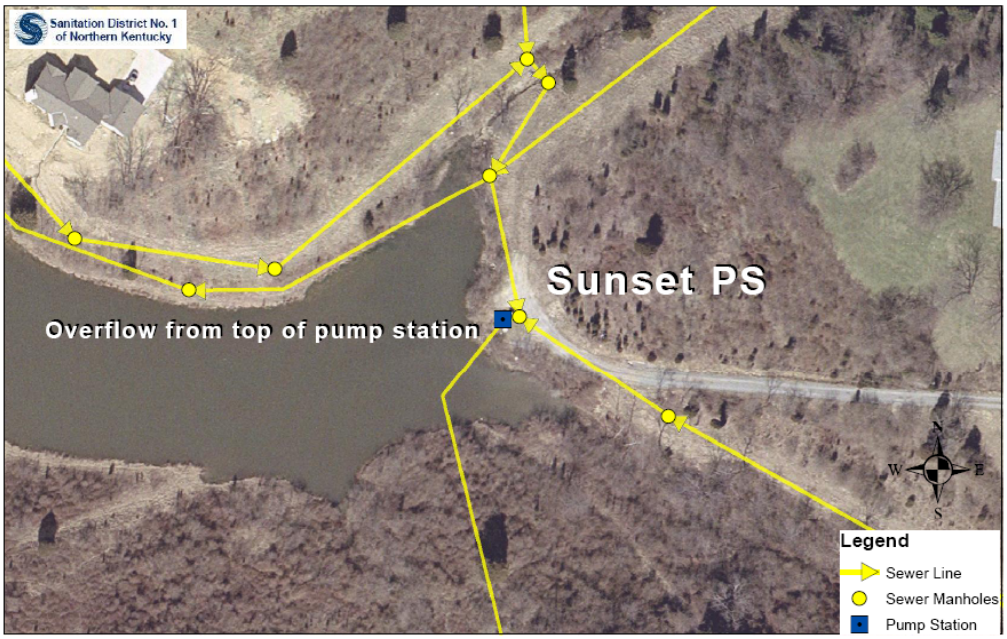
The Sunset PS is located in Alexandria, Kentucky and was taken over by SD1 in 1997. The pump station discharged to the Alexandria WWTP, which was replaced by the new Eastern Regional WRF that came online in September 2007. The pump station uses two Smith and Loveless vacuum prime pumps. The firm capacity of the pump station is 179 GPM. With two pumps running, the flow is 213 GPM. The current service area for Sunset PS is relatively small comprising approximately 158 residential customers and 13 non-residential customers. Figure 7.23 shows the current PS service area.

Figure 7.23 Current Sunset Pump Station Service Area (as of June 2009)



Under dry weather flow, the pump station has sufficient capacity. However, during heavy rainfall, the capacity is exceeded and flow exits the top of the pump station into a lake that drains to Riffle Creek. This pump station is one of several in the Alexandria area susceptible to high peak wet weather flows and was part of the reason that a connection ban was placed on Alexandria in 1996 by the Kentucky Division of Water. Figure 7.24 shows the overflow location at the Sunset PS.

Figure 7.24 Sunset Pump Station Overflow

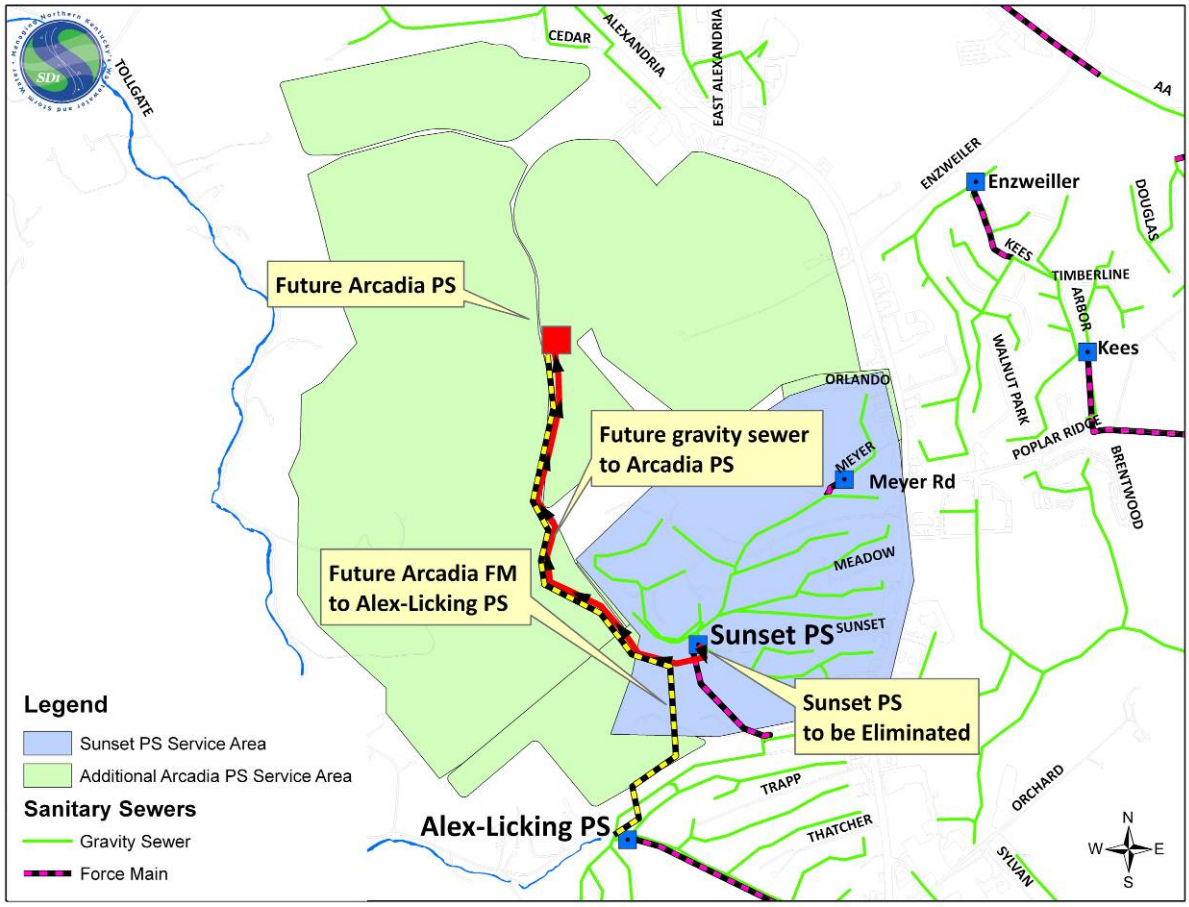


Potential Control Alternatives

The original plan for the Sunset PS was to replace the current pump station with a new 0.77 MGD pump station at the existing site. Subsequently, a private developer proposed to partner with SD1 to construct a new pump station farther north to serve both a new development and the existing Sunset PS area. The new pump station (Arcadia PS) would eliminate the Sunset PS and overflow and have a firm capacity of 1.3 MGD to provide capacity to convey peak dry and wet weather flows for current and future conditions. The new Arcadia PS would discharge to a gravity sewer tributary to the new Alex-Licking PS. The new Arcadia PS and associated gravity sewer and forcemain are currently under design. The original schedule provided in the Pump Station Overflow Elimination Plan stated construction would be complete by spring of 2009. Due to the collapse of the economy, and the housing and lending markets, SD1's partnership with the developer to construct the new pump station has been delayed. Figure 7.25 shows the planned location of the Arcadia PS and its service area.

Because of this delay, SD1 implemented an interim solution to provide the required capacity in the near term to eliminate the overflow. The solution involved construction of a new eight-inch force main and installation of new discharge piping in the existing pump station to allow the existing pumps to increase capacity to the level necessary to eliminate the overflow. A new diesel-driven pump was also provided for redundant capacity and to serve as the backup power solution. This project was completed ahead of the Consent Decree deadline of December 31, 2010.

Figure 7.25 Sunset PS Elimination with Arcadia Pump Station

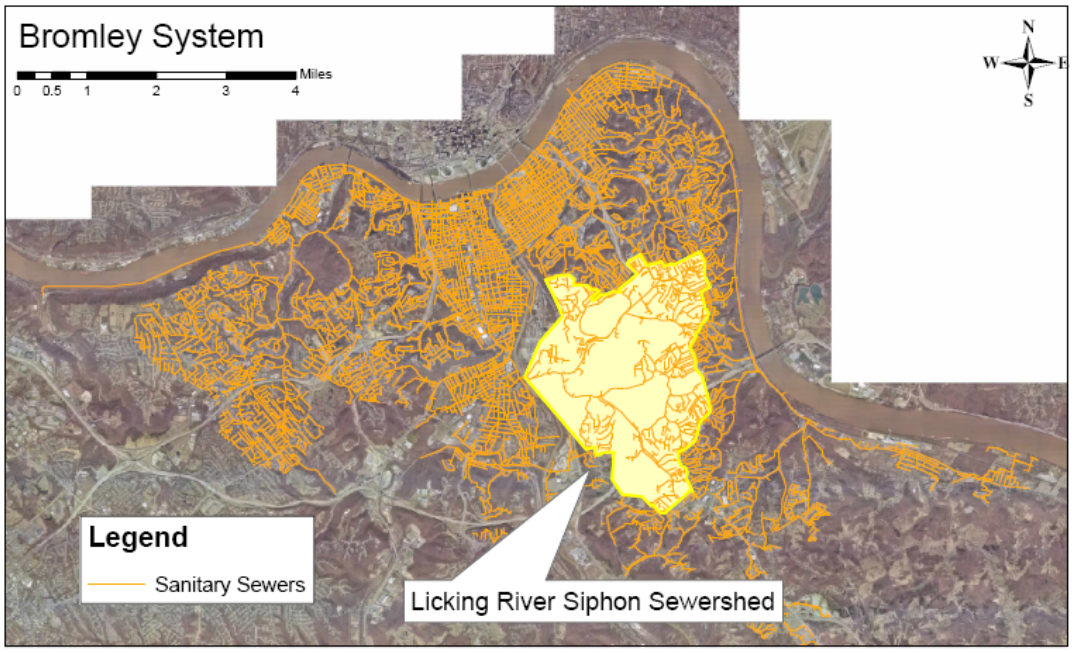


7.4.4 Licking River Siphon Overflow & Threemile Creek Priority Area

Background

The Licking River Siphon conveys separate sanitary sewage under the Licking River from Wilder to the Licking River Interceptor. The Licking River Interceptor is part of SD1's combined sewer system tributary to the Bromley PS, which pumps flows to the Dry Creek WWTP. The service area comprises the entire Threemile Creek watershed, and is approximately 4,000 acres. The service area serves about 12,000 people with an average daily flow of about 1.4 MGD. The chamber upstream of the 12-inch Licking River Siphon includes a 12-inch diameter constructed bypass, which discharges to the Licking River. During wet weather conditions, peak flows from the tributary area exceed the capacity of the Licking River Siphon and some upstream sewers, resulting in SSOs from the Licking River Siphon constructed bypass, as well as from a number of upstream manholes. Figure 7.26 shows the Licking River Siphon drainage area relative to the rest of SD1's sewer system that is tributary to the Bromley PS.

Figure 7.26 Licking River Siphon Drainage Area



SD1 Objectives

SD1's main objectives in this Priority Area are to improve water quality and protect public health. The constructed bypass at the Licking River Siphon is the largest SSO in the SD1 system in terms of typical year volume. Hydraulic modeling results indicate that the Licking River Siphon accounts for approximately 49 of the 53 MG of overflow from the Licking River Siphon drainage area in the typical year. The overflows at this location are impacted by backwater from the downstream interceptor as well as high river levels.

Potential Control Alternatives

Section 3 describes a long term solution for addressing overflows in the Licking River Siphon area involving conveyance to a storage tank to be located at the siphon along with a new parallel siphon to convey more flow to the interceptor. As part of the more detailed planning effort for this Priority Area, SD1 considered other alternatives to address overflows in the Licking River Siphon area. This planning effort identified three potential solutions for eliminating SSOs, including conveyance upsizing and local storage at the Licking River Siphon, conveyance upsizing and additional conveyance to the CSO tunnel, and a new water reclamation facility at the Licking River Siphon. Each of these options was estimated to cost more than $150 Million.

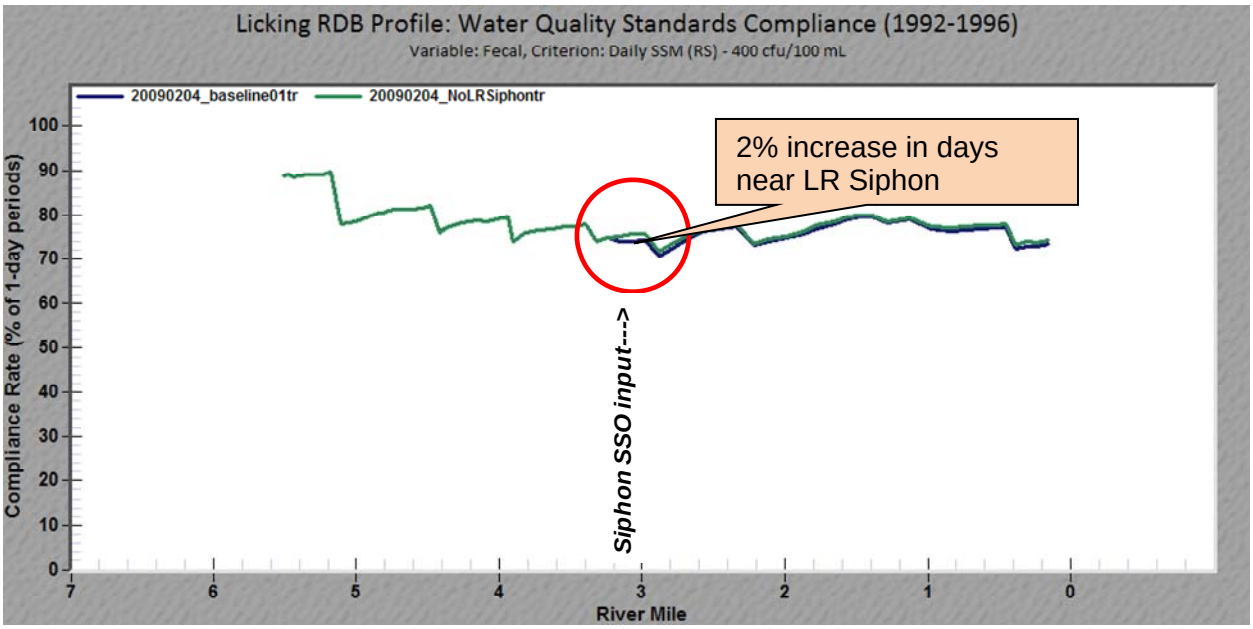
Additionally, SD1 considered a phased approach to implementing area-wide controls aimed at all overflows in the Licking River Siphon area. For the phased approach, SD1 considered options to eliminate or reduce just the Licking River Siphon SSO in the first five years. Alternatives evaluated included a smaller storage tank at the Licking River Siphon, a parallel siphon to increase downstream capacity, or an HRT at the Licking River Siphon. Subsequent modeling of constructing a parallel siphon indicated, that

without other downstream conveyance upgrades that are not planned in the first five years, overflows would actually increase. The HRT was estimated to cost around $16.5 Million. The HRT would not provide full secondary treatment for SSO flow and because of potential permitting issues, may not be able to be incorporated into the eventual area-wide solution. A phased storage alternative was also considered and was estimated to cost approximately $40 Million.

Water Quality Benefit of Eliminating Siphon Overflow

Given the objectives of improving water quality and protecting public health, SD1 evaluated the expected water quality benefits from SSO elimination at the siphon in the first Five-year Improvement Program by applying the detailed Licking River water quality model. The model was applied to simulate instream conditions with and without the siphon overflow. The results showed that the elimination of the siphon overflow would result in negligible water quality benefit. Figure 7.27 shows the percent of recreation days that meet the Kentucky water quality standards of 400 cfu/100 ml. The figure shows that there is a very small benefit (additional 2 recreation days or 2%) at the siphon outfall location and no additional benefit immediately downstream.

Figure 7.27 Water Quality Simulation Results at Licking River Siphon



Note: Green line is without Licking River Siphon overflow. Blue is with overflow

Based on these results, spending significant money to eliminate the Licking River Siphon overflow in the first five years would not significantly improve water quality and help SD1 meet its objectives. Therefore, no significant gray infrastructure is planned in the first set of Watershed Plans at the Siphon overflow in order to eliminate it. However, SD1 is aware that this is the largest SSO in its service area and it must be addressed at some point in the future. Therefore, SD1 conducted an analysis to determine if I/I removal could cost effectively reduce the overflow volume in the near term while reducing the size of gray infrastructure improvements in the future.

This analysis, which is described in detail in Section 7.2 showed that I/I removal could reduce the overall costs associated with eliminating the Licking River Siphon overflow as well as reduce and eliminate local overflows that have a higher public health and exposure risk. Table 7.19 shows the model-calculated overflow reductions at the siphon with two levels of I/I removal. Based on these results, SD1 will conduct SSES activities in the Licking River Siphon area with the goal of finding opportunities to remove significant I/I. Additional gray infrastructure improvements needed to eliminate the remaining overflows will be implemented in subsequent Watershed Plan implementation phases.

Table 7.19 Overflow Reduction at the Licking River Siphon with I/I Removal

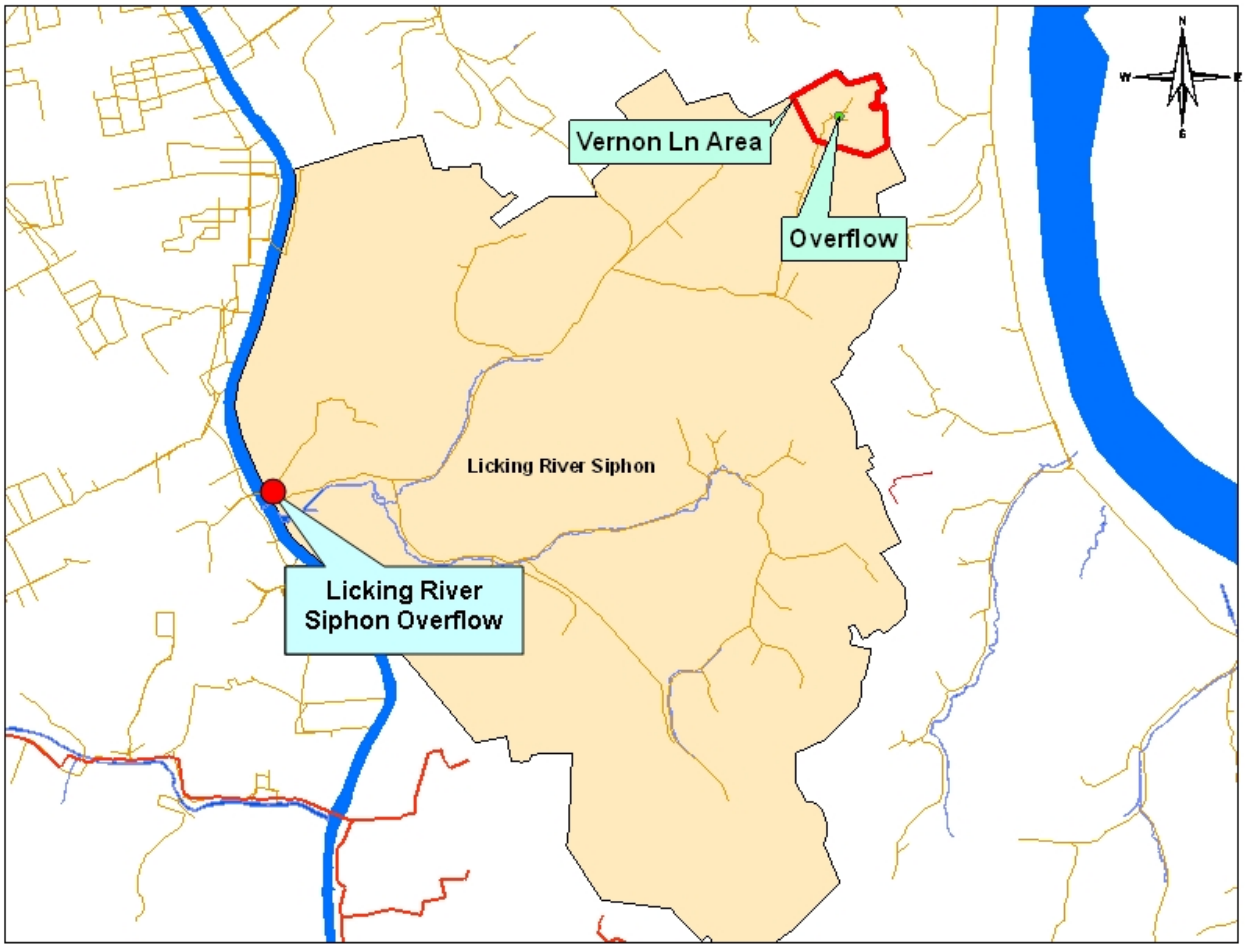
Scenario	Typical Year Spill Volume[1](MG)	Reduction (%)
No I/I Removal	48.8	0
25% I/I Removal	33.4	31%
50% I/I Removal	18.9	61%

7.4.5 Vernon Lane Priority Area

Background

The Vernon Lane area, which is located in the Licking River Siphon drainage area, is considered to be a significant public health risk as described in Section 6. There are two recurring SSOs in the neighborhood area with a total annual overflow volume of 0.26 MG in a typical year. Figure 7.28 shows the location of the Vernon Lane Priority Area and its proximity to the Licking River Siphon.

Figure 7.28 Vernon Lane Priority Area



Because of the high priority of this area and the known high peak flows, and because this system essentially behaves as a combined system, SD1 conducted detailed public and private smoke and dye testing. The testing revealed a significant number of public and private sources of I/I.

Figure 7.29 Vernon Lane SSES Findings

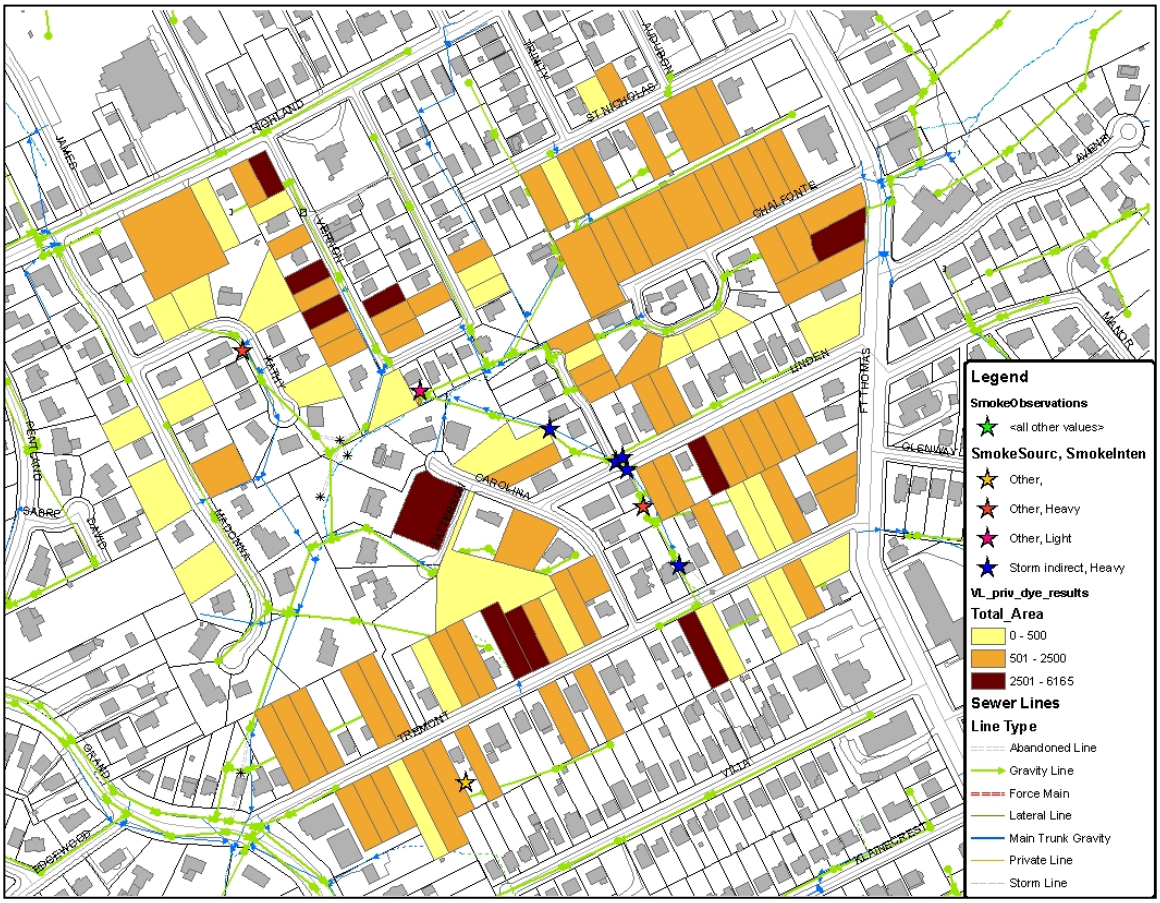


Figure 7.29 shows properties with area tied to the sanitary sewer in color. The shade of the color correlates to the estimated drainage area tributary to the sanitary sewer. The darker the color the greater amount of area tied into the sanitary sewers. The stars represent locations where indirect cross-connections between the storm and sanitary sewers were identified.

The testing results were summarized and the "identified" tributary area was compiled. The results are shown in Table 7.20 and Table 7.21.

Table 7.20 I/I Tributary Area Estimates for Vernon Lane

Source	Number of Sources	Estimated Area (acres)
Downspouts	202 (out of 1,137)	1.72
Area drains/Stairwells	24	0.25
Driveway Drains	35	1.00
Total		2.97 out of 64 total acres

These results show a total area of 2.97 acres identified as draining into the sanitary sewer (the equivalent of a 3.0 acre parking lot tied directly to an 8-inch sewer). Table 7.21 shows a comparison of the estimated peak flow from a 3-acre surface using the

standard rational method compared to hydraulic model simulated peak flows from Vernon Lane for the same storm.

Table 7.21 Peak Flow Contribution from Identified Sources at Vernon Lane

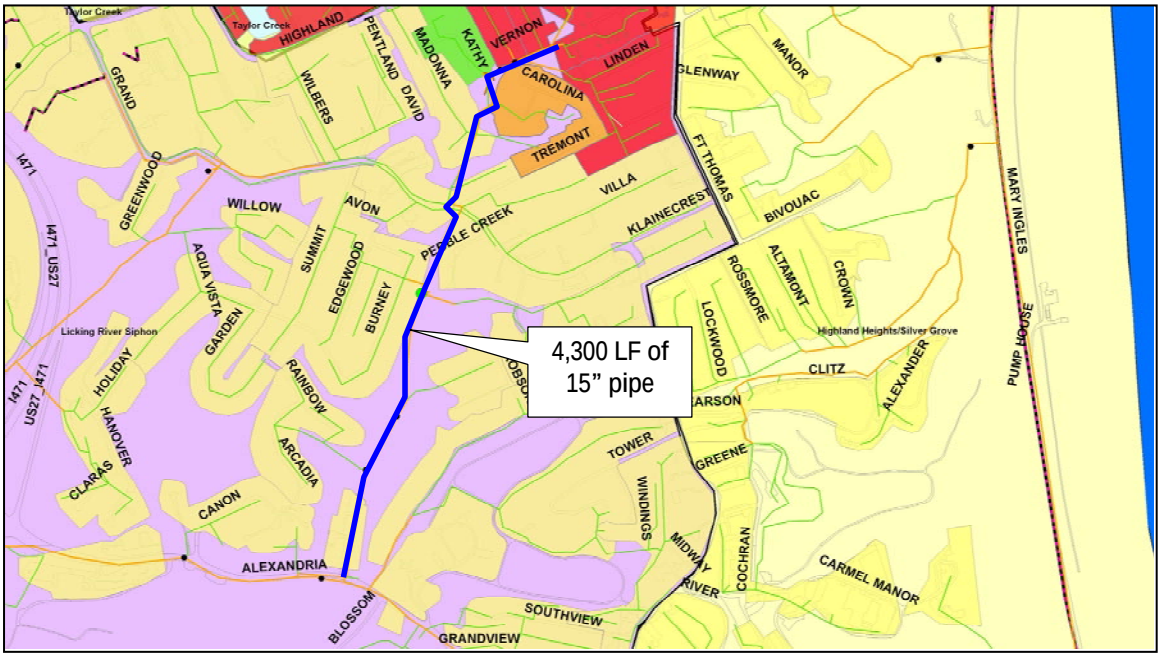
Return Period	Estimated Peak Flow Contribution from Identified Sources (MGD)	Calibrated Model Peak Flows for Entire Area (MGD)	Percent Contribution from Identified Sources
1-year	1.6	2.9	55%
5-year	3.5	4.1	85%

The table above shows that a significant portion of the peak flow is coming from the identified I/I sources. Therefore, it is reasonable to believe that removing these I/I sources could significantly reduce the peak flows from this area. By eliminating 50 percent of the I/I in the Vernon Lane area SD1 can eliminate the 2 recurring high public health risk SSO locations and the corresponding 0.26 MG of overflow volume in the typical year. By removing I/I at the source, downstream overflows in the Licking River Siphon area can also be reduced by 3.3 MG in the typical year.

Potential Control Alternatives

Cost estimates were developed to perform the comprehensive I/I removal and were based on removing identified private I/I sources and comprehensive rehabilitation/replacement of all 1.9 miles of sanitary sewer in the area to achieve at least 50 percent I/I removal in the Vernon Lane area. This cost was then compared to the cost to convey all peak flows downstream to the nearest trunk sewer. Figure 7.30 shows the expected size and alignment of the conveyance sewer to provide the equivalent level of service in the typical year.

Figure 7.30 Vernon Lane Conveyance Option



The conveyance sewer would discharge into an existing 12-inch sewer along Alexandria Pike. Therefore, the overflows in the Vernon Lane area would merely be conveyed downstream without being eliminated. This is a result of the Vernon Lane area being at the very top of the Licking River Siphon drainage area.

Table 7.22 shows a cost comparison between the I/I removal and conveyance options.

Table 7.22 Conveyance and I/I Removal Preliminary Costs For Vernon Lane

Item	Rehabilitation and Private I/I Removal ($ Million)	Conveyance (Typical Year LOC) ($ Million)
Clearwater Removal including green improvements	$0.48	$0
Public[1]	$1.9	$1.9
Additional conveyance[2]	$0	$0.97
Engineering/Cont (40%)	$0.85	$1.1
Total	$3.23	$3.97

Notes:

[1] Costs of $1 Million per mile

[2] Additional conveyance of 4,300 linear feet of 15 inch pipe

This table shows that source I/I removal is more cost effective in a direct comparison and becomes even more cost effective when downstream impacts are considered.

Conclusions

Considering the clear objectives laid out by SD1, the most beneficial action in the first five years is to conduct public and private I/I removal activities in the Vernon Lane Priority Area, with the goal of eliminating the two public health risk recurring SSOs in a typical year. Post construction monitoring will be conducted to verify that the overflows have been eliminated.

7.4.6 Church Street Priority Area

The Church Street Priority Area contains three combined sewer overflows near the mouth of Banklick Creek. Two of the overflows have relatively small annual activation statistics while the third, Church Street is the largest CSO on Banklick Creek (Table 7.23).

Table 7.23 Overflows at the Church Street Priority Area

Manhole ID	Common Name	Typical Year Activation Frequency	Typical Year Volume (MG)
1870194	47th Street	4	0.20
1850158	Church Street	74	56.20
1870193	Decoursey Ave	23	1.29

Under dry weather flow conditions, wastewater from local combined sewers flows to the Banklick PS, and then is pumped into the Banklick Interceptor before flowing downstream to the Dry Creek WWTP. Normal dry weather flow through the pump station is approximately 0.3 MGD.

Under wet weather conditions, Banklick PS will pump up to 2.5 MGD. Flow in excess of this peak capacity will surcharge the upstream sewer system, causing overflows at the three CSO locations noted in Table 7.23.

The drainage area includes approximately 152 acres of mostly residential land use in Covington and Taylor Mill. In the areas north of 43rd Street, storm water runoff enters the combined system through catch basins and direct connections of downspouts, sump pumps, and foundation drains. Along the eastern edge of the tributary area, separate storm water lines convey storm runoff to the drainage swale that runs between 43rd Street and Banklick Creek. During heavy rains, the storm water pools in a lowland swale. Over time, holes were created at manhole chimneys and in two parallel combined sewer pipes (36-inch diameter and 48-inch diameter) that run through the drainage swale to provide a means of draining the swale. These connections to the sewer system are one of the reasons why the Church Street CSO is very active. In addition, the drain holes in the existing infrastructure also provide a relief point when the combined sewer surcharges. Over time, this has created a public health concern.

SD1 Objectives

SD1 objectives for implementing controls within the Church Street basin include:

- Eliminate the public health concern that exists in the Church Street swale;
- Improve the condition of existing infrastructure in the Priority Area;

- Comply with the requirement in the Consent Decree to reduce the activation of CSOs;
- Improve the water quality of Banklick Creek; and
- Identify opportunities to integrate green and gray controls that address both public health and water quality impacts noted above.

Potential Control Alternatives

The potential control alternatives were designed to address SD1's priorities and included options that used gray-only infrastructure components as well as options that integrated smaller gray solutions with green and watershed technologies.

Gray Infrastructure Controls

Two different options were evaluated based on increasing downstream conveyance and storage of wet weather flows.

Conveyance of Overflow to Downstream Locations

Overflow at the Church Street CSO is caused in part by the capacity restriction created by the Banklick PS. One option considered was an increase in capacity of the pump station. However, because the combined system downstream of Banklick PS has very little capacity to accept additional wet weather flows, implementation of this option would result in higher downstream overflows. This was unacceptable to SD1, and the pump station capacity increase option was not carried forward as a viable alternative.

Offline Storage of Wet Weather Flows

Temporary storage of excess wet weather flows was explored as a potential gray solution. During wet weather, flow in excess of the Banklick PS capacity would be stored offline and drained back into the system when peak flow conditions pass at the end of the wet weather event. Available land adjacent to the pump station would be a good candidate for locating an offline storage tank.

Green Infrastructure Controls

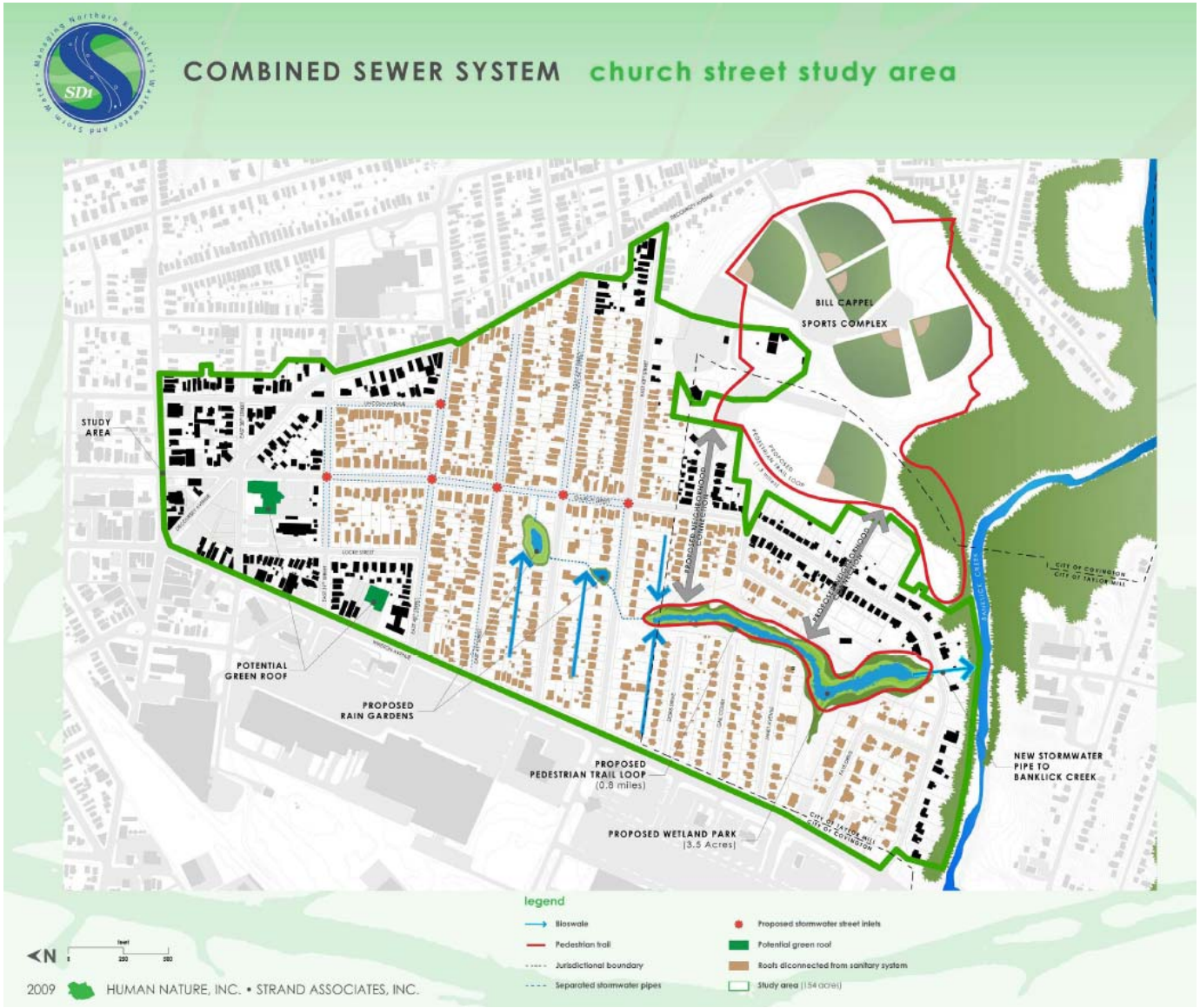
Impervious surfaces cover 34 percent of the Church Street Priority Area. Runoff from that enters the combined sewer system contributes to CSOs; this runoff can be prevented from entering the combined system through direct separation and a neighborhood infiltration network. The infiltration network would involve disconnecting residential downspouts and street inlets and directing storm water through rain gardens and bioswales to a storm water wetland park. By removing the runoff from the combined sewer system, the surcharge in the combined sewer and the discharge volume at the combined sewer overflows could be reduced.

The focus of the green controls evaluation was to identify green project elements that perform several functions – control the surface runoff in the upstream tributary area before it flows into the sewer system, provide a means of treating the separated storm water runoff before being directly discharged to Banklick Creek, and improve the aesthetics of the neighborhood.

Key components of the green solution included strategic separation of street inlets and disconnection of downspouts from residential properties. The heart of the green infrastructure solution for the Church Street Priority Area is a 3.5-acre storm water wetland park. The proposed wetland is located in an existing low-lying area behind residential properties near Church Street. This area would be bordered by a 0.8-mile pedestrian trail loop through restored habitat. Native wetland plants and amended soils provide a valuable, natural filter for storm water before it flows directly into the Banklick Creek.

Two neighborhood connections are proposed. These connections will fully integrate the residential area with the Bill Cappel Sports Complex, as well as a 1.3 mile proposed pedestrian trail loop. Figure 7.31 shows the Church Street Green Infrastructure Concept Plan. For a full size copy of the Church Street Green Infrastructure Concept Plan, please refer to Appendix 3-B.2.

Figure 31 Church Street Green Infrastructure Concept Plan



Evaluation of Alternatives

Gray Infrastructure Alternative - Conveyance of Overflow to Offline Storage Tank

The hydraulic model was used to determine the storage tank sizes required to capture discharge from the Church Street, Decoursey Avenue, and 47th Street CSOs to achieve several levels of control. The resulting tank sizes were then used to generate cost estimates and the water quality models were applied to evaluate the impact of the varying levels of control. The cost of the storage tanks is shown in Table 7.24.

Table 7.24 Estimated Capital Costs for Church Street Gray Infrastructure Alternatives

Level of Control (OF/yr)	Tank Volume (MG)	Storage Facility ($ Million)	Conveyance Pipes ($ Million)	Total Capital Cost ($ Million)
0	8.0	$ 53.3	$8.7	$ 62.0
4	3.3	$ 27.4	$ 5.7	$ 33.1
18	1.2	$ 12.5	$ 3.9	$ 16.4

Integrated Green and Gray Infrastructure Alternative

While the offline storage will reduce the discharge of combined sewage from the Church Street overflow, it does not capitalize on opportunities to integrate green controls with conventional gray infrastructure controls. By controlling runoff at the source through green controls, there is a reduction in the expected overflow volume at Church Street and, therefore, a reduction in the required storage volumes.

In addition, the low-lying Church Street drainage swale is an ideal location for a biofiltration basin where separated storm water flows can be directed for detention and water quality treatment prior to discharge to Banklick Creek. After passing through the basin, the collected storm water would discharge directly into Banklick Creek via a proposed culvert crossing beneath Church Street. Aesthetic benefits could be provided through the installation of a trail and boardwalk system around the perimeter of the biofiltration basin.

Addressing the parallel combined sewer pipes that run beneath the proposed basin is also required under this integrated alternative. While the two existing pipes are in satisfactory condition, concern was raised regarding their condition over the long term. Since the performance of the biofiltration basin is partly reliant on a viable mass of plants, SD1 wanted to avoid the potential for digging up the biofiltration basin to replace the pipes shortly after the plants reach maturity. As a result, several alignments and a cost for a new, single pipe that avoided the basin footprint were examined.

SD1 applied the hydraulic model to determine the pipe size needed to convey the peak wet weather flows from the tributary area. As shown in Table 7.25, the benefit of using a larger sewer was reduced due to the current height of the weir at the Church Street CSO structure. In larger pipes, less of the cross-sectional area can be used due to the elevation of the weir and pipe invert required to connect to the existing CSO structure.

Raising the weir was evaluated, but analysis showed that increasing the weir height from 471.3 to 474.3 increases the projected overflow volume through SSO locations upstream of Banklick pump station from 0.6 MG in the typical year to 1.2 MG. Lowering the diversion structure proved to be a better option since it not only provided a benefit in terms of CSO reduction, but it also did not increase SSO volume.

SD1 decided to invest in installation of a new 72-inch pipe routed around the area proposed for the biofiltration basin, based on the benefit of CSO reduction and avoidance of future disturbance to the biofiltration basin.

Table 7.25 Inline Storage Benefits of Larger Diameter Sewer

Pipe Size	Pipe Slope (%)	Full Capacity (MGD)	Weir Elevation	Existing Elevation		At Lowered Elevation	
				Activations	Volume (MG)	Activations	Volume (MG)
48-inch	0.75	80	471.3	76	32.7	57	24.5
60-inch	0.25	84	471.3	76	32.5	45	21.5
72-inch	0.10	86	471.3	75	32.3	38	19.0

The integrated green/grey infrastructure components will be phased over several years. The first phase will include the disconnection of downspouts from approximately 180 homes, the separation of street load storm water runoff on five streets immediately surrounding the proposed biofiltration basin, installation of approximately 3,000 linear feet of separate storm sewer, construction of a culvert and outlet structure to Banklick Creek, construction of the new 72-inch diameter pipe, and the addition of solids & floatables controls to catch basins along Church Street and separation of these catch basins from the combined sewer system. In addition, the storm water facility will be constructed and have a footprint of approximately five acres, including a 3.5-acre biofiltration basin, access walkway, and sediment forebay. Completion of the initial phase will allow SD1 to monitor the effectiveness of these disconnection techniques and the benefits of the storm water biofiltration basin. Future phases will involve additional disconnection of downspouts and separation of street load storm water runoff from the combined system to maximize the amount of runoff directed to the storm water biofiltration basin.

After completion of this first phase, it is estimated that the annual Church Street CSO activation frequency will drop to 38 activations, discharging 19 MG in a typical year. Estimated costs for these improvements are shown in Table 7.26.

Table 7.26 Estimated Costs for Church Street Improvements

Component	Cost ($ Million)
Grey Cost (new 72-inch sewer, lower diversion structure)	$3.7
Biofiltration Basin	$1.1
Green Infrastructure	$1.4
Total	$6.2

Once all phases of this concept plan are complete, the constructed storm water biofiltration basin will intercept runoff from the upstream drainage area that currently enters the combined system. A total of 103 acres (of both pervious and impervious acreage) is being targeted for removal from the combined system. In addition, storm water inlets to the combined sewers under the Church Street swale can be eliminated, and several locations along the combined sewers can be repaired to reduce infiltration.

For approximating the impact of redirecting the storm water, it was determined that some of the acreage in the upstream drainage area would still contribute to the combined system even with the proposed improvements. Some acreage would still enter driveway drains and locations that are not planned to be disconnected under the current plan. To conservatively assess the impact of this concept program, it was estimated that approximately 83 acres of the total 103 acres (80%) targeted by the improvements would be removed from the combined system. After completion of all phases, it is estimated that improvements in the Church Street system drainage basin would decrease the number of Church Street CSO activations during the typical year from 74 to less than 18, and the overflow volume from 56 MG to approximately 4 MG (for current conditions). The total cost for all phases of the Church Street integrated project is estimated to be $11.9 million. The integrated option results in an overall cost savings of approximately $4.5 million as compared to a traditional gray infrastructure solution.

Conclusions

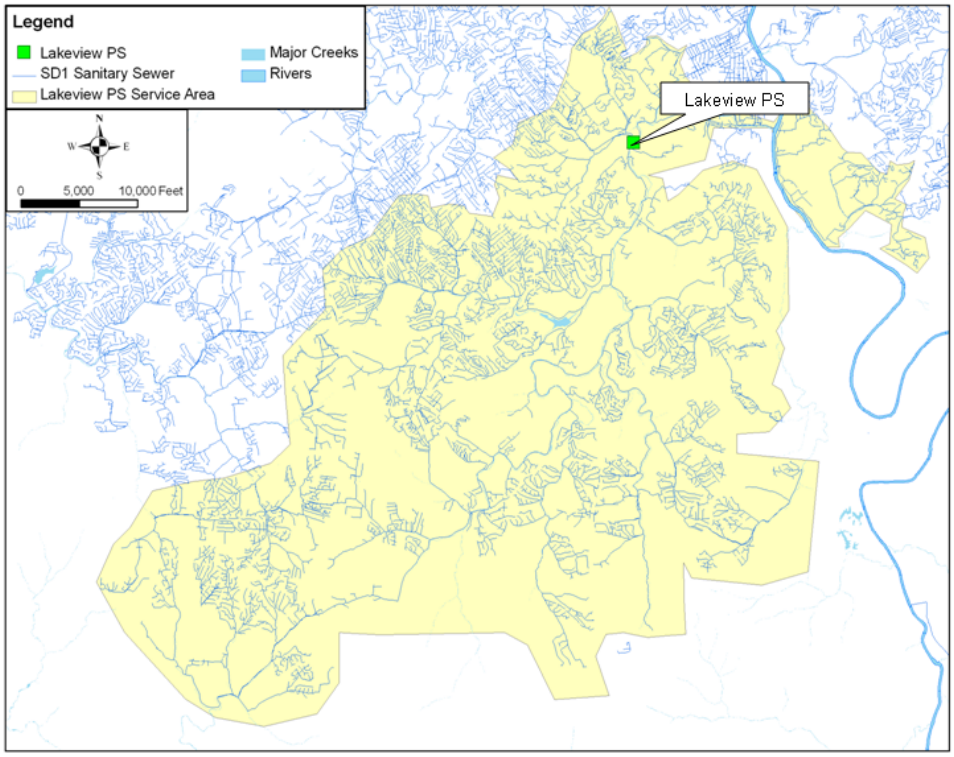
SD1 has developed an innovative approach to reducing the CSOs to Banklick Creek that incorporates both gray and green infrastructure and is more cost-effective as compared to a traditional gray infrastructure approach. This innovative approach not only provides a CSO reduction and water quality improvement, but will also enhance the neighborhood. This approach includes both traditional gray components and green elements that reduce CSO activations and volume, improve the quality of storm water flowing to the stream, and provide both public health benefits and water quality improvements. It is also expected that the project will provide educational opportunities, and opportunities for passive recreation.

7.4.7 Lakeview Priority Area

Background

Constructed in 1973, the Lakeview PS is the largest separate sanitary pump station in SD1's system. This pump station serves an extensive portion of SD1's separate sanitary system in Kenton County and smaller areas in Boone and Campbell Counties (Figure 7.32).

Figure 7.32 Lakeview Pump Station Service Area



The tributary area to the Lakeview PS is served by separate sewers of varying age and condition. During wet weather events, I/I can enter the separate system sewers, increasing flow to the pump station. During some of these wet weather events, the flow to the station exceeds its capacity, causing overflows into Banklick Creek along the trunk sewer upstream of the station and at the constructed bypass at the pump station.

During the development of the Consent Decree the Lakeview PS bypass was highly active, discharging an average of 41 MG per year. Upgrades and improvements to the pumps and the tributary sewer system have since been completed, dramatically reducing the Lakeview PS discharge. These improvements are described in this section. Section 7.4.8, which follows this section, is a companion to this discussion of the Lakeview Pump Station Overflow elimination. Therefore, it is critical that both sections be reviewed so that the significant benefits of this integrated solution can be fully understood.

Improvements to Date

Pump Upgrades

In 2005, the pump station underwent a major upgrade to increase the firm capacity to approximately 17.0 MGD and a peak wet weather capacity of 22.5 MGD that provides a velocity of approximately 7 feet per second in the existing forcemain. The upgrade in capacity resulted in a substantial reduction in overflow volume from 19.3 MG in 2005 to 7.1 MG in 2006, a reduction in overflow of 12.2 MG. At the time of the upgrade, higher capacity options were also evaluated, but determined to be infeasible due to the resulting operating pressures and the condition of the existing forcemain. Furthermore, it was determined that increasing the flow from the Lakeview PS could lead to additional SSOs in the downstream separate sewer area between the Dry Creek interceptor and Dry Creek WWTP.

In 2007 and 2008, the annual reported overflow volume increased from the reported overflow volume in 2006. This is attributed to differences in the rainfall and frequency of long-duration storm events, and also to a decrease in pump capacity. As part of the frequent assessment of pump station performance and system capacity evaluations conducted by SD1, it was determined that the high operating pressures led to premature wearing of the pumps installed in 2005. This resulted in a drop in pump station capacity and a corresponding increase in overflow volume. As part of the Initial Watershed Projects, SD1 plans to replace these pumps with new, more reliable equipment, returning the total capacity of the station to 22.5 MGD. Modeling projections predict that this upgrade would have reduced overflow volumes from 33.5 MG in 2008 to approximately 13 MG.

Through the infrastructure characterization effort, it was determined that the annual bypass volume from Lakeview is highly dependent upon the magnitude and distribution of rainfall during the year. Due to the seasonal influence of rainfall on the performance of the SD1 system, the most critical rainfall variables are total volume and timing. Rainfall that occurs in winter and spring is more likely to cause overflows than rainfall that occurs during the drier fall and summer seasons. Therefore, a critical factor in assessing the annual activation volume is the total rainfall between January and March. The rainfall in this period has the greatest impact on the overflow volume at the Lakeview PS due to the higher ground water table present in the system.

Infiltration and Inflow Reduction Efforts

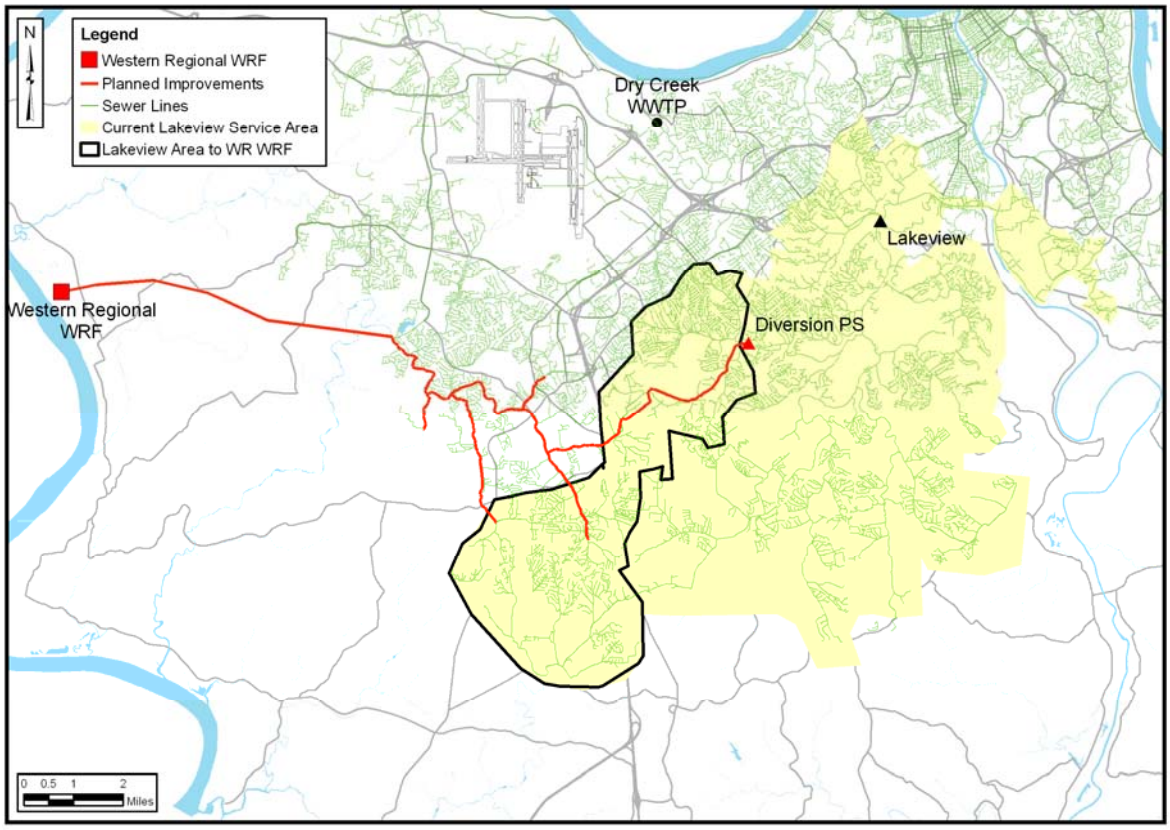
SD1 has conducted basin-wide SSES investigation activities and I/I reduction projects in Fort Wright, Fort Mitchell, the Brookwood subdivision, and the South Hills neighborhood to address extraneous wet weather flows that enter the separate sewer system upstream of Lakeview PS. The goals of these individual projects vary from addressing site-specific concerns to addressing larger issues of wet weather overflows within the system.

Western Regional and Diversion Pump Station

Construction of the Western Regional System (includes Western Regional Conveyance and Storage Tunnel Project and the Western Regional Treatment Plant) is scheduled to be online in 2013. These infrastructure improvements will provide hydraulic relief to a

significant portion of the area tributary to the Lakeview PS as shown in the purple shaded area in Figure 7.33.

Figure 7.33 Diverted Area from Lakeview Pump Station to the Western Regional System



The redirection of flows from the Lakeview service area to the new Western Regional System results in a substantial reduction in the model-calculated overflow volume at the Lakeview bypass and in the upstream sewer system. As shown in Table 7.27, there is a 91 percent reduction over current overflow volumes in the typical year at the Lakeview PS by 2013, with 1 MG remaining. This is a significant reduction in annual discharge volume when compared to the average 41 MG that was discharged before the first pump upgrade in 2005 (an overall 98 percent reduction over pre-2005 levels). In addition, hydraulic model predictions indicate that once the Western Regional System is online in 2013, upstream SSO volume will be reduced by 53 percent in the area tributary to Lakeview. The substantial reduction in overflow volume at Lakeview bypass and in the upstream system will help in addressing public health concerns and water quality issues in the tributary area.

Table 7.27 Benefits of the Western Regional System on the Lakeview Overflow

	2009 Model calculated Overflow Statistics	2013 Model-calculated overflow Statistics (After Western Regional)
Lakeview Bypass Total Volume (MG)	10.6	1 (91% Reduction)
Activation Frequency	17	2 (88% reduction)
Additional System SSO Volume (MG)	87.6	41.2 (53% reduction)

[1]Calculations were based on typical year rainfall

Water Quality Impacts of the Western Regional System

The Western Regional System is predicted to substantially reduce SSO volume and bacteria load to Banklick Creek. Water quality simulations, however, predict only a slight improvement in compliance with water quality standards in response to these reductions from the Western Regional System. As shown in the Figure 7.34, model calculations show that there is an expected increase of five one-day periods where the Banklick Creek near the Lakeview PS bypass (RM 3.6) will comply with water quality standards.

Figure 7.34 Impact of Western Regional System on Banklick Water Quality, Compliance Rate (Lakeview Pump Station is at RM 3.6)

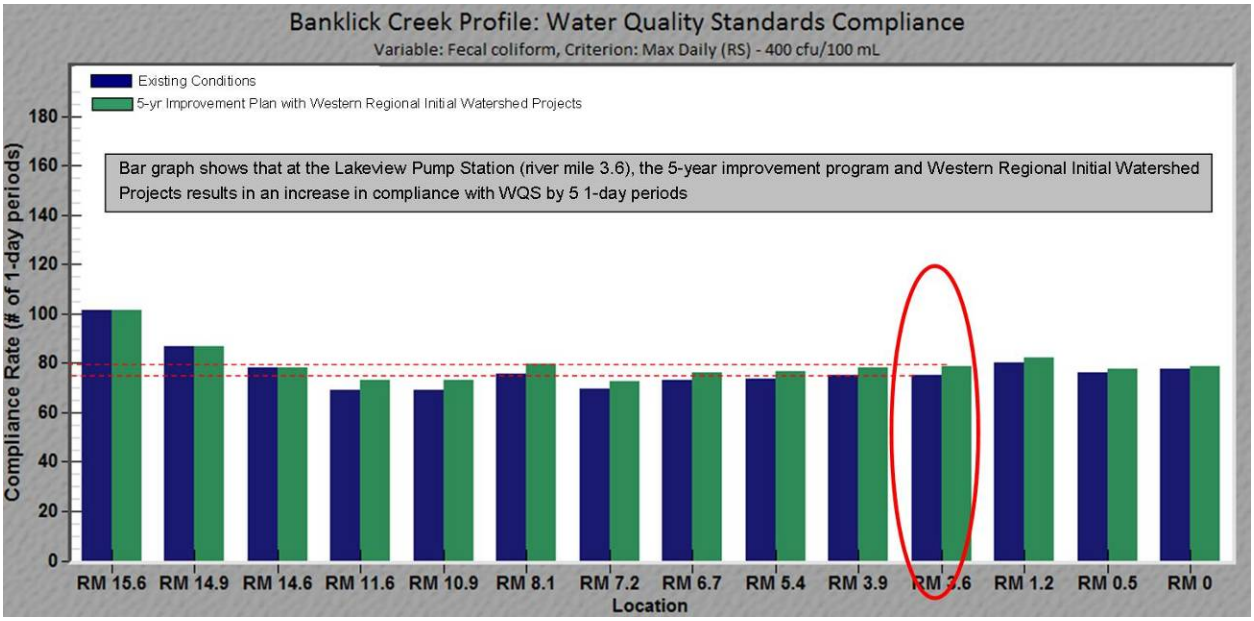
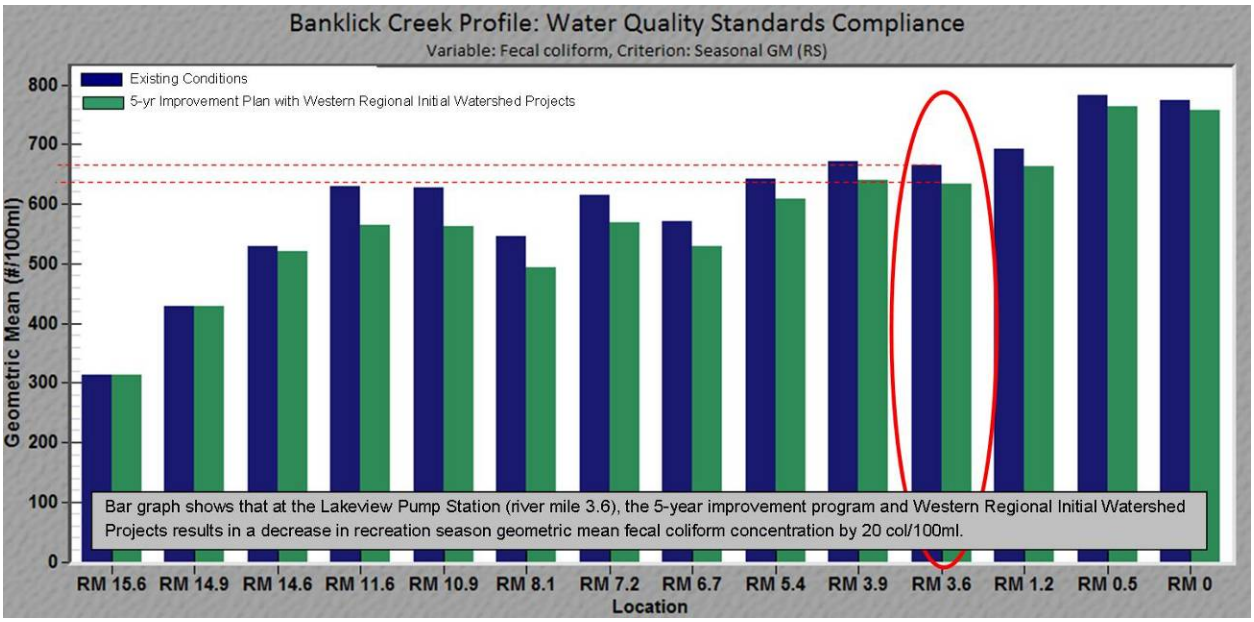


Figure 7.35 shows the calculated impact of the Western Regional System on the geometric mean of the fecal coliform count in Banklick Creek. Similar to Figure 7.34, the Western Regional System shows an improvement in the fecal coliform geometric mean near the Lakeview PS bypass (RM 3.6) of approximately 20 colony forming units per 100 milliliters (cfu/100ml).

Figure 7.35 Impact of Western Regional System on Banklick Water Quality, Geometric Mean (Lakeview Pump Station is at RM 3.6)



The above results show that while the overflow volume at Lakeview and the upstream system are reduced by 91 percent and 53 percent, respectively, a correspondingly small increase of five percent compliance with water quality standards is achieved.

Potential Alternatives to Control the Remaining Overflows

Since the Consent Decree requires elimination of the Lakeview PS bypass, several options were considered to control the remaining overflow volume at Lakeview.

Increase Pump Capacity at Lakeview PS

As part of the recent capacity assessment at Lakeview, options to increase the capacity of the station above 22.5 MGD were evaluated. Options included adding a fifth set of pumps and installing larger capacity pumps. Model simulations show that the Lakeview PS capacity would have to be greater than 31 MGD to eliminate the remaining overflow at the PS. However, this higher flow from the station would further stress the aging forcemain and would send more flow to the downstream system, increasing the volume from downstream overflows. Therefore, this option was not evaluated further.

Direct Flow Connection to the Dry Creek WWTP

As discussed in Section 3, one of the gray infrastructure concepts for eliminating all overflows in the Lakeview system included conveying flow from the Lakeview PS directly to the Dry Creek WWTP. This option could allow for the increase in Lakeview PS capacity, which would eliminate the overflow at the pump station and work to alleviate the upstream overflows in the pump station service area. However, this option is unaffordable and would require a significant investment in upgrading infrastructure to convey flows to the pump station. SD1 determined that it was not reasonable to move

this option forward for more detailed consideration in eliminating the 1 MG of annual overflow at Lakeview PS.

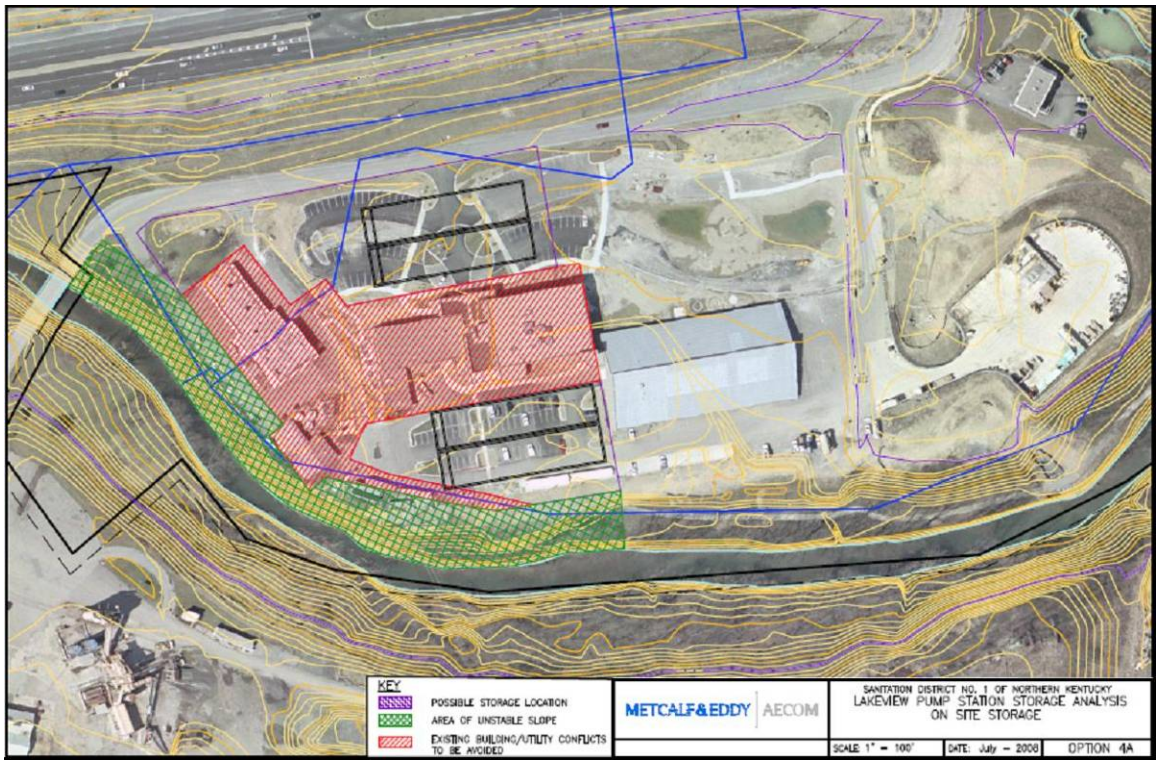
Storage

The use of offline storage was analyzed as an alternative for the elimination of the Lakeview PS bypass. Two different storage options were considered:

- Storage immediately adjacent to the pump station, where the overflow would be hard-piped to a storage structure (Figure 7.36); and
- Upstream storage where flows would be diverted from the interceptor to eliminate the remaining overflow volume at Lakeview (Figure 7.37).

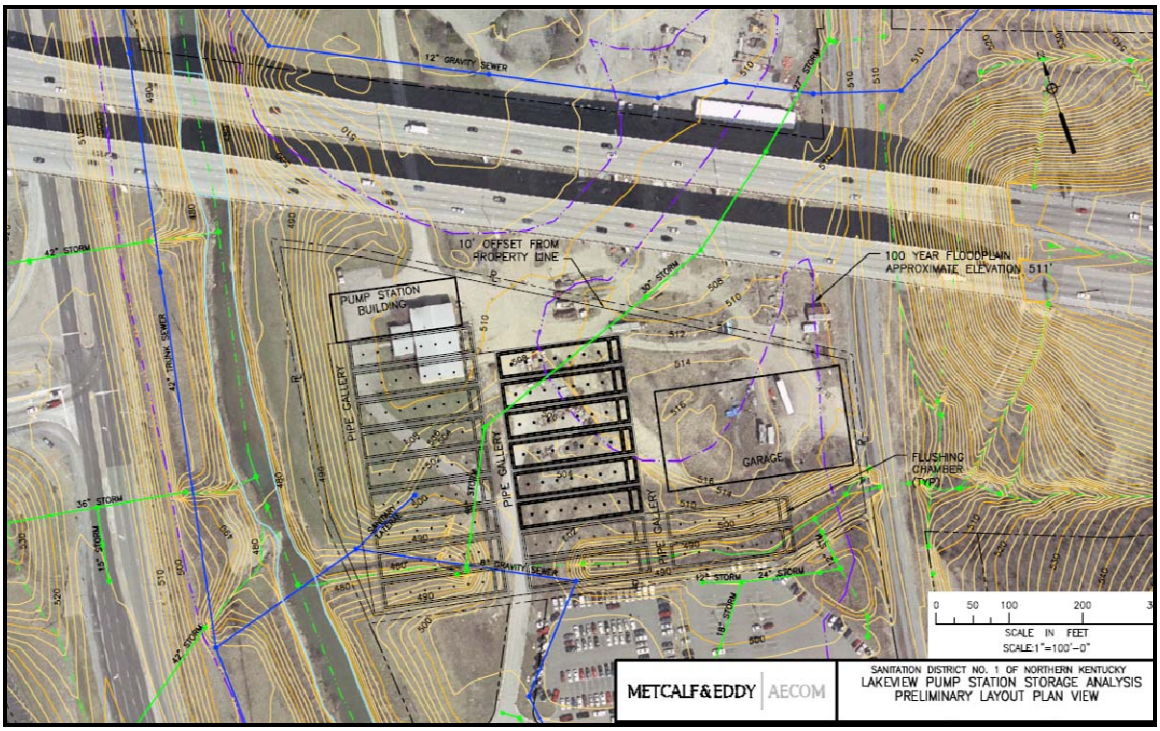
Several different sites were examined to determine the cost of the upstream storage option. Model results indicate the required storage volume for the upstream location was much larger than the required storage volume at the pump station. Furthermore, due to the hydraulics of the interceptor sewer and the flow path through the bypass pipe, the required storage volume increased the further upstream from Lakeview the storage was proposed.

Figure 7.36 Site Analysis for Potential Storage or HRT Unit Adjacent to Existing Lakeview Pump Station



Land availability was limited to avoid encroachment on existing buildings, Lakeview PS and stream bank.

Figure 7.37 Site Analysis for Potential Storage or HRT Unit at Upstream Dudley Site



Site can accommodate some storage using common wall construction but site would be tight and require setback from stream bank.

High-Rate Treatment

As a potential interim solution, HRT was evaluated to treat the remaining overflow from Lakeview. The HRT unit would follow a fine (1/4-inch) screening process (to protect HRT unit processes) which would be followed by disinfection and dechlorination (if necessary) of the treated effluent. HRT was evaluated as a potential option because it is effective at reducing pollutants including bacteria and model results suggest that it may be more cost-effective than storage (due to the relatively low peak flow as compared to the total overflow volume associated with the overflow hydrographs). The peak flows tributary to the Lakeview PS were used to size the required HRT facilities. A drawback of providing a HRT system for the remaining Lakeview overflows is that the facility would activate only three times in an average rainfall year, presenting operational challenges for maintaining equipment and chemicals in a constant state of readiness.

SSES Investigations and I/I Removal

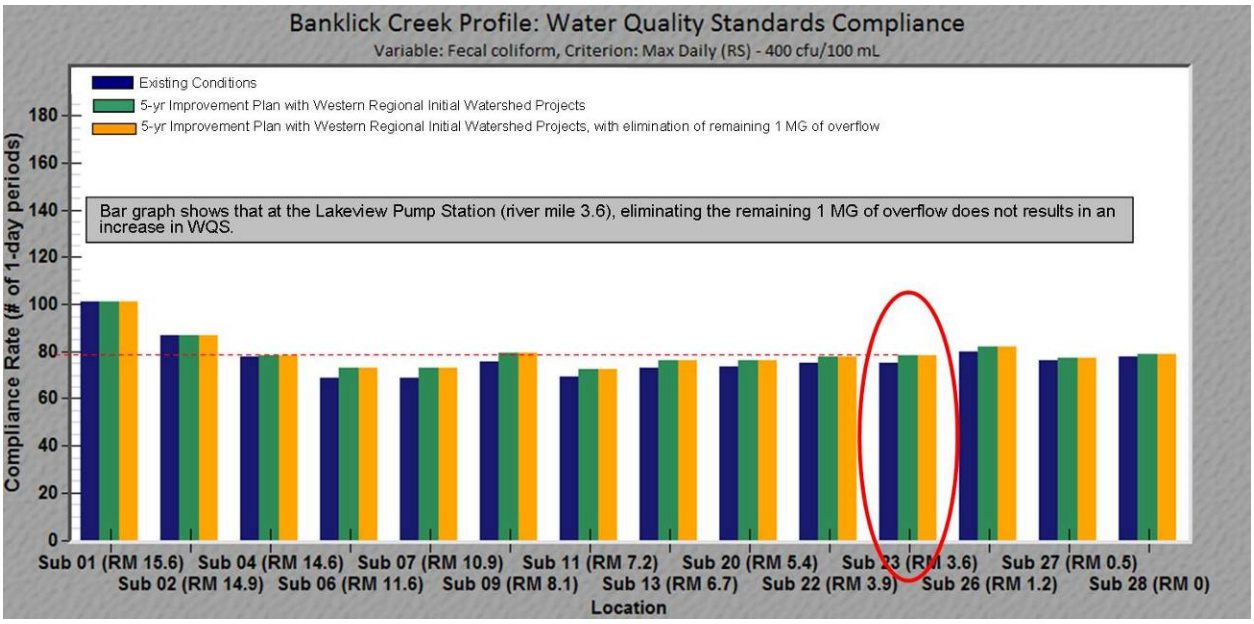
Since the volume of overflow from the bypass following implementation of the Western Regional System will be only 1 MG in a typical year, various levels of I/I removal from the upstream system were considered as an alternative to reduce or eliminate the remaining overflow. The work would be conducted in two phases: SSES investigations to identify locations where I/I removal may be cost effective; and rehabilitation work to remove the I/I.

Evaluation of Alternatives

Storage and treatment alternatives to control the remaining overflow at Lakeview were sized, and the cost for these improvements ranged between $15 Million and $27 Million.

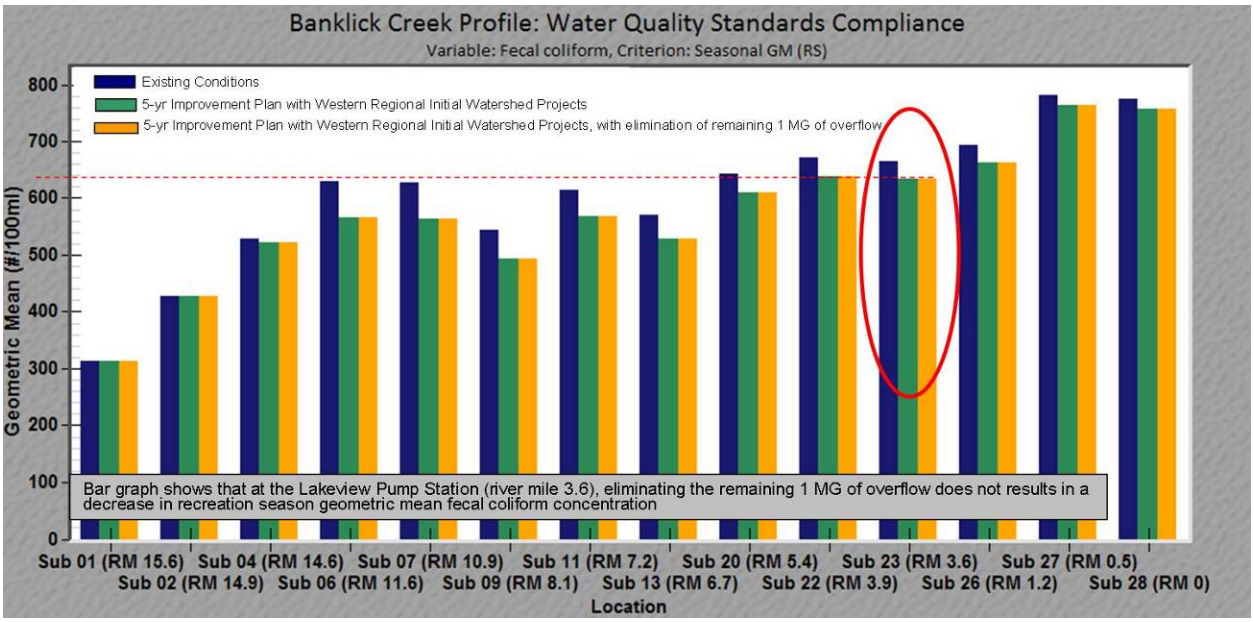
Model results show that eliminating the remaining 1 MG of annual overflow from Lakeview results in no additional water quality benefit in Banklick Creek. Figures 7.38 and 7.39 show the effect of eliminating the remaining 1 MG from the Lakeview PS discharge in terms of the compliance rate with the 400 cfu/100ml criterion and the recreation season geometric mean.

Figure 7.38 Impact of Controlling Remaining Lakeview Overflows on Banklick Water Quality, Compliance Rate (Lakeview Pump Station is at RM 3.6)



Given the investment required to capture or treat the remaining overflow and the absence of benefit to water quality, SD1 determined that investing several million dollars for gray controls at Lakeview was not a cost-effective investment of limited capital funds. Based on these findings, SD1 looked to identify a better combination of integrated solutions that provided a greater public health and water quality benefit and enabled SD1 to direct capital funding to other problem areas in the system that had a much higher public health and water quality impact.

Figure 7.39 Impact of Controlling Remaining Lakeview Overflows on Banklick Water Quality, Geometric Mean (Lakeview Pump Station is at RM 3.6)



Based on SSES identification and removal work that SD1 has successfully implemented in other parts of the Lakeview tributary area, SD1 will initiate SSES work in the remaining Lakeview PS tributary watershed to identify significant sources of I/I. SD1 will then work to implement cost-effective I/I source removal projects through public sewer rehabilitation and private source I/I removal to eliminate public and private sources of I/I entering the sanitary sewer system. The goal is to systematically identify and eliminate I/I upstream of the pump station to cost-effectively improve the overall performance of the sewer system and the associated pump stations. By removing I/I at the source, SD1 is able to cost-effectively rehabilitate its existing sewer assets and eliminate upstream local overflows that are more likely to have high public exposure and greater public health impacts. Also, where feasible, green infrastructure will be implemented to filter and treat the removed runoff. In addition, many of the areas where there is excessive I/I are characterized by inadequate storm sewer systems. By addressing storm water at its source and disconnecting storm water from the sanitary sewer, SD1 is able to improve the local storm water drainage through new storm sewers and green infrastructure, providing for additional local storm water quantity and quality benefits. As discussed in Section 7.2.4., this type of holistic approach to I/I removal will be a cornerstone of the Watershed Plan to reduce and eliminate overflows.

Summary

Since SD1 entered into the Consent Decree, they have made a significant investment in monitoring and improving the performance of the Lakeview PS. In a typical year, the pump replacement project and the Western Regional System will reduce the annual overflow volume from the Lakeview bypass by 91 percent, and will reduce overflows in the upstream system by 53 percent. These reductions are predicted to result in an additional five days of water quality standards compliance in Banklick Creek near the Lakeview PS.

Control of the remaining overflow volume from the Lakeview PS bypass (after implementation of the Western Regional System) could be achieved through construction of a storage tank or installation an interim high rate treatment system. Costs for these controls range from $15 Million to $27 Million. Water quality modeling shows that no additional days of attainment of water quality standards would be gained downstream of the Lakeview PS. In addition, this investment would only address the overflow at the pump station and would not improve the condition of the water quality in the upper two-thirds of the watershed.

This situation presents SD1 with an interesting challenge. While the regulatory impetus is to direct resources at sewer overflows that only occur during rain events (~80 days out of the year) to achieve high levels of wet weather overflow control, model results have shown that far greater water quality and public health benefits can be achieved by directing resources toward the improvement of dry weather conditions (~280 days out of the year) and wet weather flows from other sources, such as runoff.

SD1 through its commitment to watershed based planning has been able to evaluate a wide range of control scenarios including cost-benefit information and has developed an innovative approach to watershed pollution reduction that employs a combination of traditional gray solutions, watershed controls, and regional green infrastructure components to maximize the benefits achieved.

This proposed solution represents an opportunity for SD1, EPA, KDOW, and the Northern Kentucky community to implement holistic and cost-effective solutions that go beyond traditional point source control, are consistent with the goals of the Clean Water Act, and provide the community with tangible benefits.

SD1 is proposing that the solution to address the overflow at Lakeview be focused on the larger issues within the Banklick Creek watershed. The proposed solution includes six components:

- Increase in the pump station capacity and reliability to 22.5 MGD through the planned pumps replacement project;
- Redirect a portion of the Lakeview tributary area to the new Western Regional System and reduce the annual calculated overflow at Lakeview in a typical year by 91% to 1 MG;
- Conduct SSES investigations and targeted, cost-effective, I/I removal in the area remaining tributary to Lakeview to reduce extraneous wet weather flows;
- Implement a Source Identification Program to detect other sources of pollution (dry and wet weather-related sources) identified by monitoring and modeling efforts as discussed in Section 7.2.5;
- Construct a wetland system in Banklick Creek and other decentralized watershed controls to reduce bacteria levels and improve overall water quality in the downstream system as discussed in Section 7.4.8.

With the improvements to the pump station capacity and reliability and the redirection of a portion of the tributary area to Lakeview to the Western Regional WRF System, SD1 has already made a sizable capital investment in controlling the overflows not only at the pump station but in the sewer lines upstream of the station. However, SD1's financial commitment goes beyond these projects and includes the previously

mentioned SSES and Source Identification Program investigations as well as the construction of a regional wetland and decentralized watershed controls.

This combination of traditional gray controls (tributary area diversion, SSES, and I/I projects) and wetland system represents a cost-effective solution and provides a greater overall benefit to the community than a single gray infrastructure solution to contain or treat the remaining 1 MG discharge from the Lakeview bypass. In addition, by delaying further action to eliminate the remaining 1 MG of overflow at the Lakeview PS, SD1 will be able to reallocate approximately $20 Million to the Ash Street PS project in Silver Grove, which will provide approximately 38 MG of overflow reduction in a part of the system where the overflow has a direct public health impact.

SD1 requests consideration that the elimination of 38 MG of overflows in the Silver Grove priority area (see Section 7.5.5), in combination with the significant committed improvements in the Lakeview system and the proposed Watershed Projects in the Banklick Creek Watershed Priority Area (Section 7.4.8) achieve an equivalent of the benefit goals of the overflow elimination at Lakeview as required by the Consent Decree by 12/31/2013:

SD1 strongly believes that elimination of the remaining 1 MG of typical year overflow at the Lakeview Pump Station will be achieved through aggressive I/I removal which will take some time to implement. Additional improvements needed to eliminate all remaining overflows in the Lakeview PS service area will be implemented in subsequent Watershed Plan implementation phases.

7.4.8 Banklick Creek Watershed Priority Area

Both water quality monitoring and modeling indicate poor water quality conditions throughout the Banklick Creek watershed during both dry and wet weather conditions. Both nonpoint and point sources, including SSOs and CSOs contribute to these conditions. The Banklick Creek watershed was identified as a Priority Area because there are multiple opportunities to begin to address the issues in the watershed with gray, green and watershed controls. This watershed has been prioritized for implementing watershed control projects because of their potential to improve water quality and protect public health. Performance data collected on the controls will be used for future planning and decision-making in the other watersheds where watershed control opportunities were identified.

<u>Banklick Creek Regional Wetland</u>

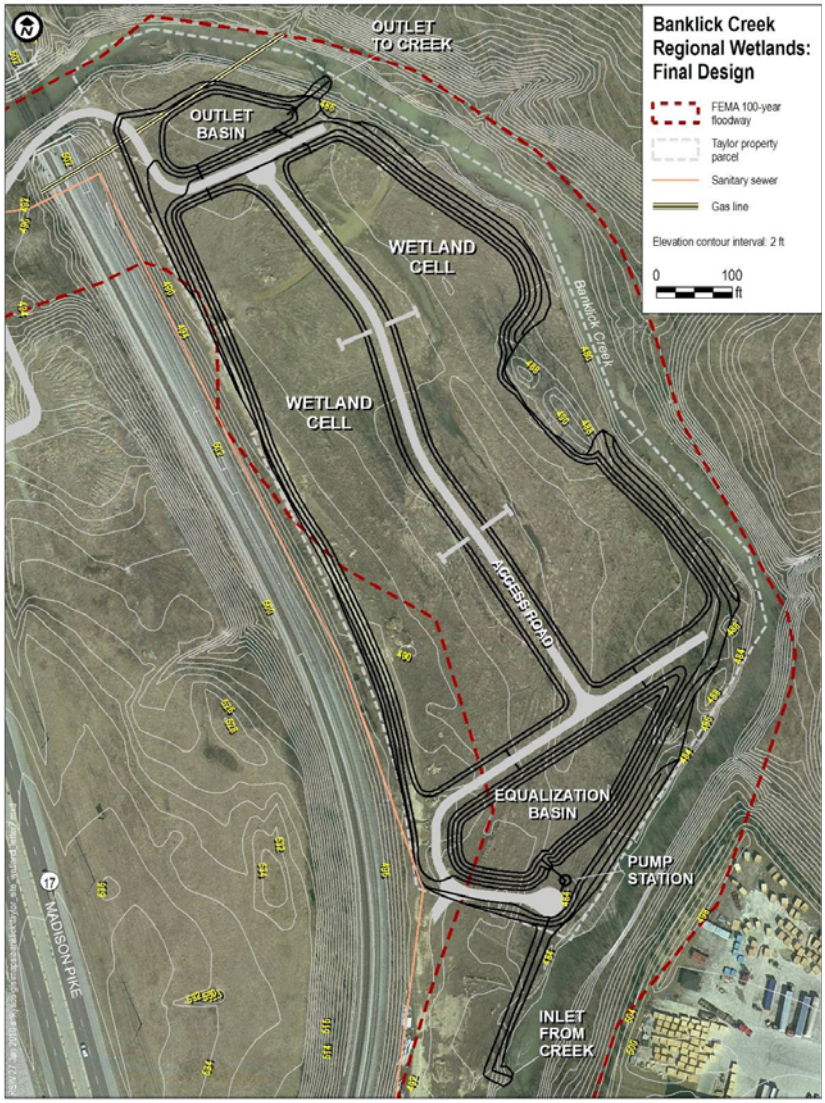
SD1 identified an undeveloped parcel adjacent to Banklick Creek, for siting an approximately 6-acre constructed wetland. A combination of site location and potential upstream pollution sources made this parcel an ideal opportunity for the creation of the Banklick Creek constructed wetland. This site has relatively low-lying topography and direct access to the creek. It is also located upstream of two public access points to Banklick Creek. By positioning the wetland upstream of these locations, which have elevated bacteria during dry weather, the wetland can help protect human health.

The Banklick Creek constructed wetland has been designed as a free water surface (FWS) constructed wetland to address project objectives of reducing pollutants and

providing ancillary habitat benefits at the same time. The final design of the Banklick wetland is shown in Figure 2.41. Additional detail is provided in Appendix 3-C.

This wetland will serve as a pilot project to test the effectiveness of this approach. If successful, this concept can be applied to other locations in this watershed and potentially to other watersheds. The wetland will have the additional benefits of restoring connectivity between Banklick Creek and its floodplain and providing habitat and public education opportunities.

Figure 7.40 Final Design of the Banklick Creek Regional Wetland



The regional constructed wetland was modeled using the Banklick watershed model, assuming a six-acre constructed wetland located downstream of Holds Branch. The results indicate that the wetland could have significant benefits for water quality and public health protection during the recreational season. Because some flow from the

creek is treated every day, in both dry weather and wet weather, the benefits to water quality and public health protection are projected to be significant.

- Immediately downstream of the wetland, the model calculates that the wetland will provide about 31 more days in a typical recreation season below the 400 cfu/100ml bacteria threshold. This represents an increase from 40 percent to 58 percent of the recreational season.
- In downstream reaches (near the mouth of Banklick) the model calculates that, with the wetland, about 95 days of the recreational season will be below 400 cfu/100 ml (a total of 51%), compared to about 76 days without it.

In addition, the model calculates improvement in the geometric mean bacteria density during the recreational season:

- Immediately downstream of the wetland, the geometric mean is calculated to improve from approximately 672 cfu/100ml to approximately 306 cfu/100 ml, about a 54 percent reduction.
- At the downstream end of Banklick Creek, the recreational season geometric mean is calculated to decrease from 782 cfu/100ml to approximately 419 cfu/100 ml, an approximate reduction of 46 percent.

Much of the modeled improvements from the wetland are attributable to the treatment of non-wet weather flows on a daily basis.

Decentralized Watershed Controls

Decentralized watershed control measures are storm water control measures with upstream drainage areas smaller than one square mile, but typically greater than five acres. Decentralized watershed controls are designed to control storm water runoff closer to the source, as compared to regional control measures which are sited adjacent to streams to improve water quality some distance downstream from source areas. Decentralized watershed controls may be new projects built for water quality improvement or they may be retrofit projects involving redesign of existing storm water basins to enhance storm water quality.

The types of control measures considered in this analysis include the following:

- Storm water wetlands,
- Bioretention/biofiltration basins (conventional detention basins modified to incorporate bioretention or biofiltration features into the basin to provide water quality improvement benefits), and
- Enhance retention basins (conventional retention basins modified to incorporate forebays or other improvement features to the basin to provide water quality improvement benefits).

Wetlands, detention basins, and retention basins are all commonly used storm water control measures for drainage areas over five acres. Detention basins have the potential to be adapted to include bioretention and/or biofiltration functions to provide additional water quality treatment and retention basins can be modified with additional water quality improvement features as noted above.

Because the focus of decentralized watershed controls is on treating storm water, SD1 used spatial data on existing storm water infrastructure as a starting point to identify opportunities in the Banklick watershed. A complete description of the opportunity identification procedure is provided in Appendix 3C.

The opportunity identification procedure screened 273 storm water catchments in the Banklick watershed by estimating their drainage areas and ranking them by drainage area size. Ultimately, 63 catchments of greater than 12.5 acres were identified for further screening for potential opportunities. Of these, several were identified as potential candidates for either new control measures or retrofitting of existing control measures. At this point, specific decentralized control projects have not been selected, but SD1 plans to implement up to three decentralized control projects in the first five year cycle.

Because decentralized watershed control measures are designed to control pollutant loading from storm water, they are similar to two other SD1 water quality improvement programs dealing with storm water, discussed elsewhere in this plan:

- Storm Water Control in I/I Removal Priority Areas – SD1 has identified priority areas for elimination of I/I from the separate sanitary system to address sanitary sewer overflows (SSOs). In conjunction with these I/I removal priority projects, SD1 plans to implement storm water control measures to manage storm water.
- Storm Water Management Program – New storm water regulations will require implementation of storm water control measures to manage the runoff produced from the first 0.8 inches of rainfall for new development projects.

To varying degrees, the timing and location of these two programs and the implementation of decentralized storm water control measures are somewhat uncertain. Because the specific nature of projects under each program and the exact timing and spatial distribution of the projects are not defined at this time, the three decentralized control measure programs are considered as related water quality improvement programs for watershed planning purposes and were modeled as a single program.

Water Quality Benefits Analysis

The detailed Banklick Creek watershed model offers a method to compare the instream benefits of different combinations of projects considered in the first five-year planning cycle. Watershed controls may present an opportunity to improve water quality more effectively than a more traditional approach that uses gray infrastructure to address CSOs and SSOs alone. The SD1 Consent Decree states that:

> "If Watershed Plans identify…nonpoint sources…that are contributing to water quality impairment…the Watershed Plans shall also identify planned control measures, if any, for these controls… if a control is to be implemented to offset the level of CSO controls or to delay the elimination of an SSO…"

Monitoring data of SD1's service area has demonstrated significant non-CSO/SSO bacteria loading. Based on this monitoring data and the provision in the Consent Decree, SD1 undertook an analysis to identify opportunities for watershed control

measures, to evaluate the potential benefits of watershed control measures using the Banklick Creek watershed model to explore the "offset or delay" clause for remaining SSO volume after the Initial Watershed Projects (e.g. Western Regional) are implemented.

Note that the watershed controls have significant uncertainty with respect to performance. These scenarios represent sensitivity analyses with the water quality model that are intended to show potential improvements that could be achieved with the control(s) rather than estimated site-specific improvements. Nevertheless, an analysis of whether the benefits of watershed controls approach or exceed the benefits of more gray control of CSO and SSO is useful for making decisions on the timing for implementing controls to address overflow volume remaining after the Initial Watershed Projects are completed.

SD1 included a water quality metric that calculated the number of days during the recreation season where fecal coliform densities were less than 400 cfu/100 ml. This is because evaluating controls based compliance with water quality standards, does not fully capture the benefits of controlling intermittent sources like CSOs and SSOs. Kentucky water quality standards are applied over long periods of time (e.g. enforced for a recreation season, evaluated over a 30-day period, etc.), which allows for both wet and dry days to be considered in compliance. Typically, the periods associated with water quality standard evaluations include many more dry days than wet days (2-3 times more). Therefore, controls that "treat" the water on more days will be more effective in improving compliance with water quality standards than controls that reduce large loads that occur more infrequently (such as sewer overflows). Results for key locations from the Banklick Creek model (Table 7.28) for the project scenarios illustrate this point. More effective control will result in a higher number of days that meet the criterion.

Table 7.28 Water Quality Model Results for 5-Year Project Scenarios at Key Locations in Banklick Creek

Location	Number of days during the recreation season fecal coliform density <400 cfu/100 ml			
	Current Baseline	Initial Watershed Projects[a]	Gray-Only Basin Projects[b]	Pilot Wetland[c]
Near Headwaters (RM 14.6)[d]	78	78	78	78
USGS Gauge (RM 8.5)	76	80	80	76
Upstream of Lakeview PS (RM 3.90)[e]	75	78	78	126
Near Mouth (RM 0.5)[f]	76	77	77	104

Note: Results are the number of days during the recreation season that the fecal coliform density is less than 400 cfu/100 ml.

[a] Initial Watershed Projects affecting the Banklick Creek watershed include the projects associated with the Western Regional WRF facility and associated conveyance (see Section 7.1.1).

[b] Additional basin projects shown in this scenario include use of gray controls alone to address the remaining 1 MG of overflow from the Lakeview PS SSO.

[c] These results represent the 6-acre pilot wetland (see Section 7.4.8). This scenario assumes no improvements will occur upstream of the pilot wetland.

[d] There are no SD1 overflows in this subwatershed.

[e] This location is downstream of the pilot wetland described in Section 7.4.8.

[f] This location is downstream of all SD1 overflows.

Table 7.28 shows that the Pilot Wetland Scenario provides the greatest overall water quality benefit and increases the number of days in the recreation season below 400 cfu/100 ml by an average of 53 percent downstream of the Wetland.

Additional evidence of the benefits of the Watershed Controls is shown in the model results from the decentralized controls described previously. Figure 7.41 shows the modeling results for recreation season geometric mean in Banklick Creek, as a result of the three decentralized control measure programs and Figure 7.42 shows the compliance rate, represented as the percent of days during the recreation season with average bacteria density less than 400 cfu/100 mil.

Figure 7.41 Modeling Results for Recreation Season Geometric Mean in Banklick Creek as a Result of Decentralized Control Measure Programs

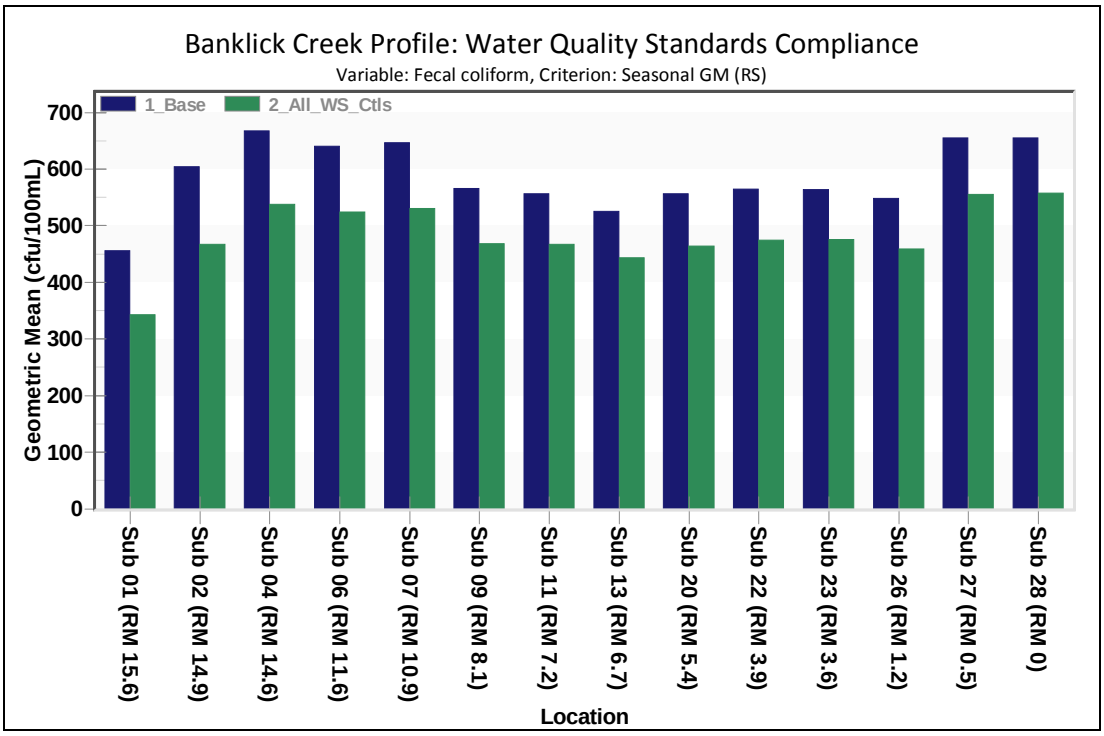
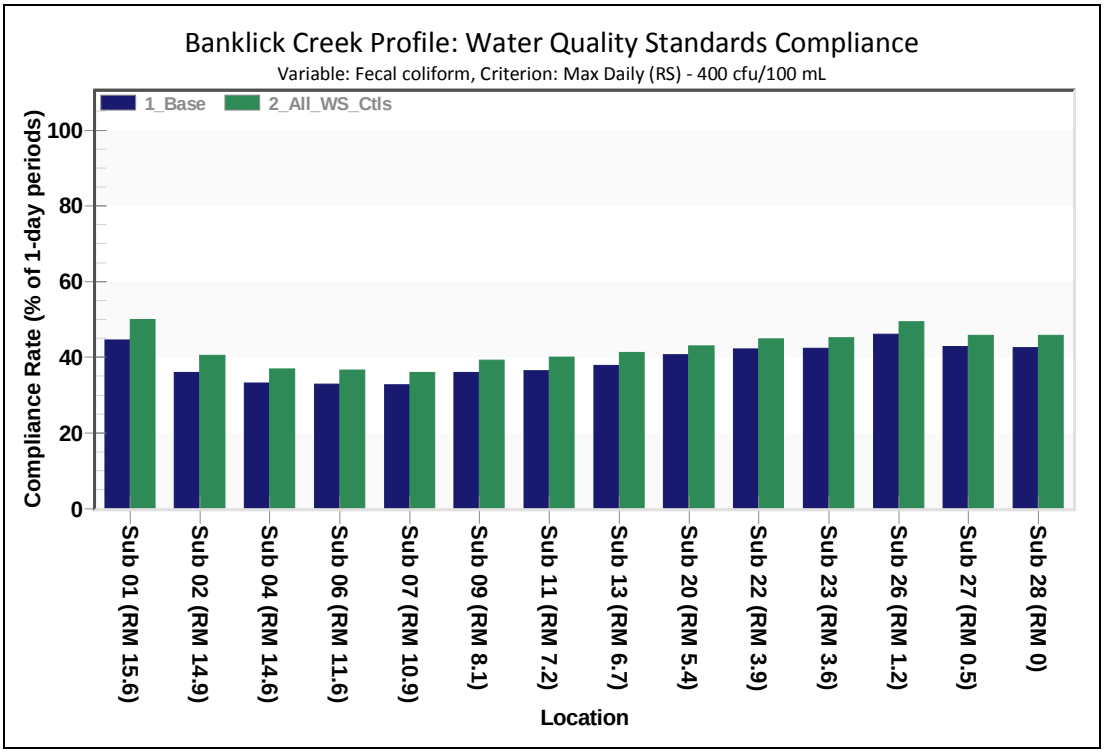


Figure 7.42 Modeled Water Quality Standards Compliance in Banklick Creek as a Result of Decentralized Control Measure Programs



The projected benefits of the wetland and decentralized watershed control measures offer a more effective solution for improving water quality than, for example, investing in a gray solution to control the last 1 MG of overflow at the Lakeview PS, which is shown in this table as the "Gray-only Basin Project" scenario. In addition, watershed controls improve water quality in more length of the creek than controls targeting overflow volume alone.

In this comparison, the benefits of implementing the wetland and decentralized watershed control measures in the first Five-year Improvement Program provides additional support for delaying the elimination of the overflow volume remaining at Lakeview after the Western Regional System comes online, as described in at the end of Section 7.4.7. This analysis is an example of how SD1's watershed approach is consistent with the strategy to coordinate pollutant reduction programs to achieve the most effective environmental benefits.

7.4.9 Summary of Central Basin Projects

Table 7.29 shows a summary of the recommended projects, costs, and benefits for the Central Basin.

Table 7.29 Central Basin Five-Year Projects

Project Name	Benefits	Cost in 2009 Dollars ($Million)
Ripple Creek PS Removal	SSO elimination	$0.9 (Complete)
Alex Licking PS Overflow Elimination	SSO elimination; Initial Watershed Project	Complete – Cost included under Initial Watershed Projects; refer to Table 7.5
Sunset PS Overflow Elimination	SSO elimination; Initial Watershed Project	Cost included under Initial Watershed Projects; refer to Table 7.5
Licking River Siphon Source Identification and Removal	SSO reduction	Cost included under Priority I/I Source Identification & Removal; refer to Table 8.6
Vernon Lane Public & Private Source I/I Removal	SSO elimination, improvements to storm water quantity and quality	$3.2
Church Street (gray, green, and watershed controls)	CSO Reduction, water quality and community improvements	$3.5
Lakeview PS Pump Replacement	Increase capacity and reliability of Lakeview PS	$6.9
Lakeview I/I Source Identification & Removal	SSO reduction	Cost included under Priority I/I Source Identification & Removal; refer to Table 8.6
Watershed Control Pilot Projects – Regional and decentralized controls	Improve dry and wet weather water quality and stream conditions; Reduce public health risk; gather pilot data to inform future Watershed Plans	$3.0
	Total	$17.5

7.5 East Basin Projects

This section presents the projects comprising the Five-year Improvement Program that are specific to the watersheds in the East Basin (Twelvemile Creek, Fourmile Creek, Taylor Creek and Ohio River East). This section includes descriptions of relevant projects from the list of identified watershed projects and basin projects that were identified in the Priority Area analysis. These projects include:

- Harrison Harbor PS overflow elimination,
- Riley Road 1 PS overflow elimination,
- Crestview PS overflow elimination,
- Taylor Creek watershed Priority Area, and
- Silver Grove Priority Area.

Each project description includes background, an evaluation of potential control alternatives and a conclusion. More complex projects, such as the Taylor Creek watershed Priority Area, include additional detail on the alternatives, including work-to-date and water quality benefits.

7.5.1 Harrison Harbor Pump Station Overflow Elimination

Harrison Harbor PS is a small pump station located along the Ohio River just south of Silver Grove. The pump station serves only a few houses and contains two pumps with a firm capacity of approximately 45 GPM. A picture of the exterior of Harrison Harbor PS is shown in Figure 7.43.

Figure 7.43 Harrison Harbor Pump Station

Figure 7.44 shows the current Harrison Harbor PS service area.

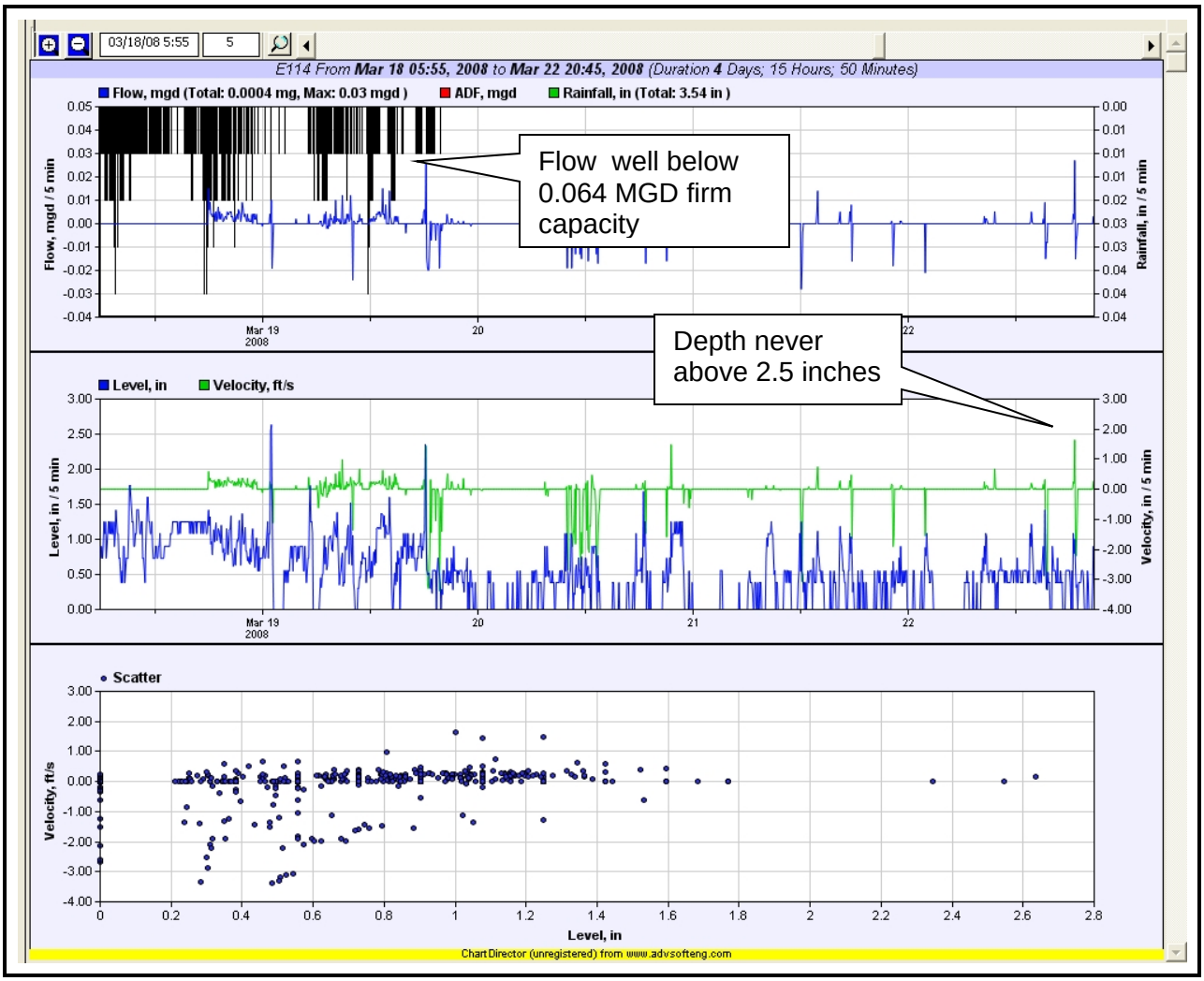
Figure 7.44 Current Harrison Harbor Pump Station Service Area

SD1 has reviewed historical records and has found evidence of only one overflow at this pump station. This overflow occurred when the Ohio River was at flood stage and the PS was shutdown. Aside from this isolated instance, there is no additional evidence of overflows based on SD1's records and field investigations. In addition, operational changes were made after the past overflow event to keep this PS in service during Ohio River flood events.

Flow monitors were installed in all of the incoming sewers to verify that there are no wet weather capacity issues at the pump station. The meters were installed from September 2007 to June 2008. There were very low flows recorded by the meters throughout the entire monitoring period including during wet weather. The station does operate infrequently but the meters were unable to detect a reliable flow due to the small flows tributary to the PS (see Figure 7.45). The figure shows the flow, depth, and velocity in the sewer that enters the pump station after 3.54 inches of rain during a snow melt condition. The figure shows that the flow was never higher than 0.03 MGD and depth was never over 2.5 inches, which means that there was no back-up in the wet well and all flow was pumped. The firm capacity of the pump station 0.064 MGD. The return interval for this event is two to five years. The spill records also demonstrate that there were no overflows from this pump station during calendar year 2008. In addition, a portable generator hookup will be provided as part of the PS Backup Power Plan to ensure no overflows occur due to power outages.

Therefore, it has been clearly demonstrated that this pump station does not have an overflow, and the planned solution is to remove this station from the Exhibit E list to meet the Exhibit E Consent Decree deadline of December 31, 2010 for overflow elimination.

Figure 7.45 Harrison Harbor Influent Flow Data from 3.54 Inch Storm



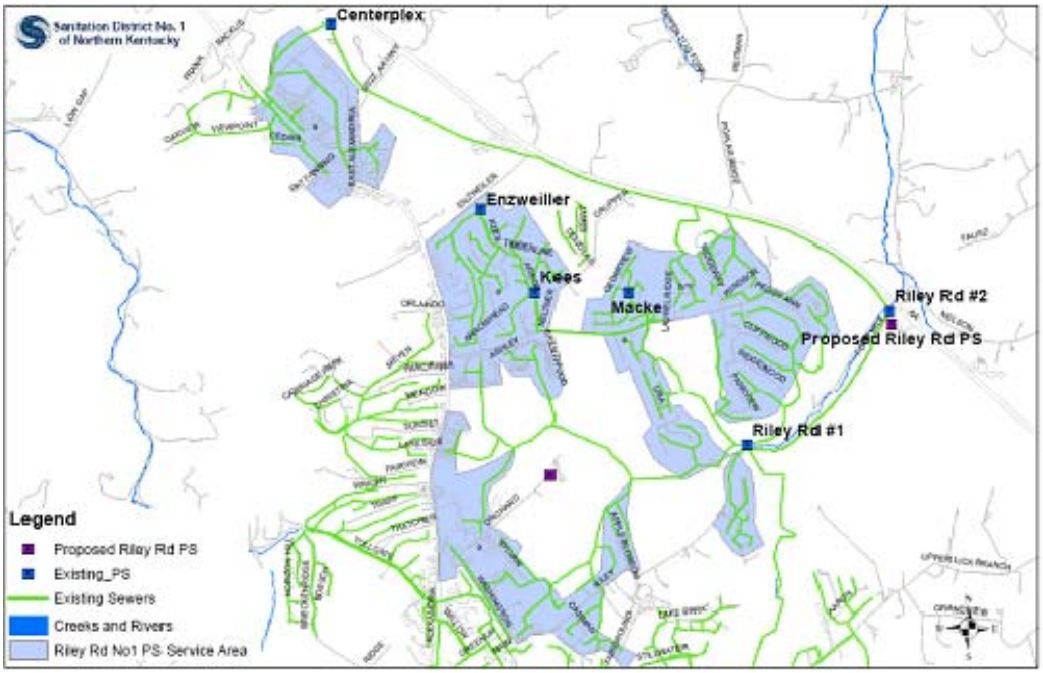
7.5.2 Riley Road No. 1 Pump Station Overflow Elimination

The Riley Road No. 1 PS is located in Alexandria, Kentucky and was taken over by SD1 in 1997. The pump station discharges to the new Eastern Regional WRF. The pump station utilizes two Cornell dry pit pumps. The firm capacity of the pump station is 330 GPM. With two sets of pumps running, the flow is 415 GPM. The pump station has a constructed bypass that discharges to Fourmile Creek, a tributary to the Ohio River. Figure 7.46 shows a picture of the Riley Road No. 1 PS

Figure 7.46 Current Riley Road No. 1 Pump Station

The Riley Road No. 1 PS serves a large portion of the Alexandria service area and is fed by several other pump stations including Riley Rd No. 2, Kees, and Macke. Figure 7.47 shows the current Riley Road No. 1 service area.

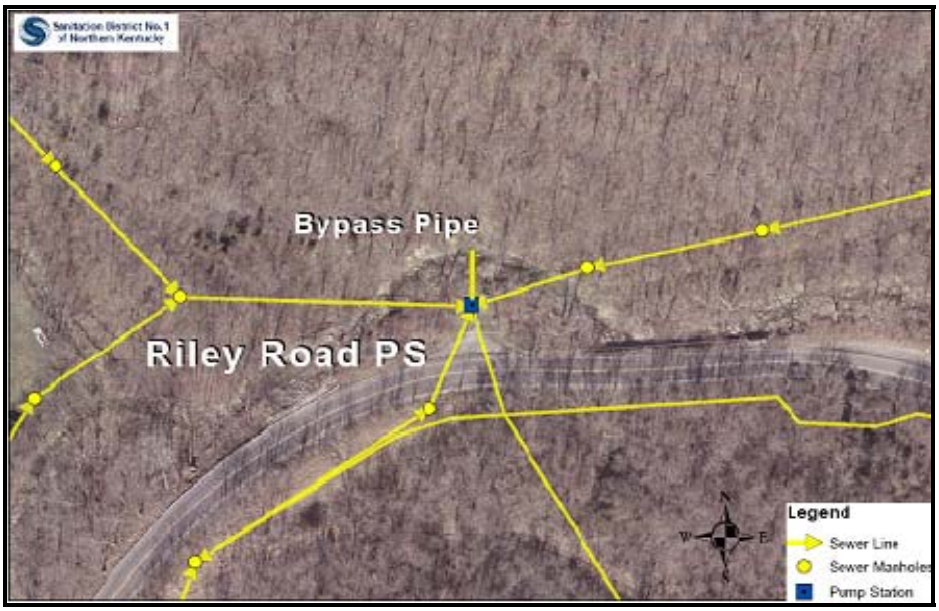
Figure 7.47 Current Riley Road No. 1 Pump Station Service Area



Under dry weather flow, the pump station has enough capacity. However, during heavy rainfall, the capacity of the pump station is exceeded and flow exits the pump station via a constructed bypass into Fourmile Creek. This pump station is one of several in the Alexandria area susceptible to high peak wet weather flows and was part of the reason

that a building moratorium was placed on Alexandria in 1996 by the Kentucky Division of Water. Figure 7.48 shows the bypass configuration at the Riley Rd No. 1 PS.

Figure 7.48 Riley Road No. 1 Pump Station Bypass Configuration



The Riley Road No. 2 PS, which previously discharged to Riley Road No. 1, has been replaced by a new Riley Road PS located next to the existing Riley Road No. 2 PS. The new Riley Road PS is designed to convey peak dry and wet weather flows to eliminate both the Riley Road No. 1 and Riley Road No. 2 PSs and associated overflow. Figure 7.49 shows a picture of the new pump station adjacent to the existing pump station. As the picture shows, the new pump station is a significant upgrade and investment. Construction of the new Riley Road PS has been completed and the PS is in operation ahead of the Exhibit E Consent Decree deadline of December 31, 2010.

Figure 7.49 New Riley Road Pump Station

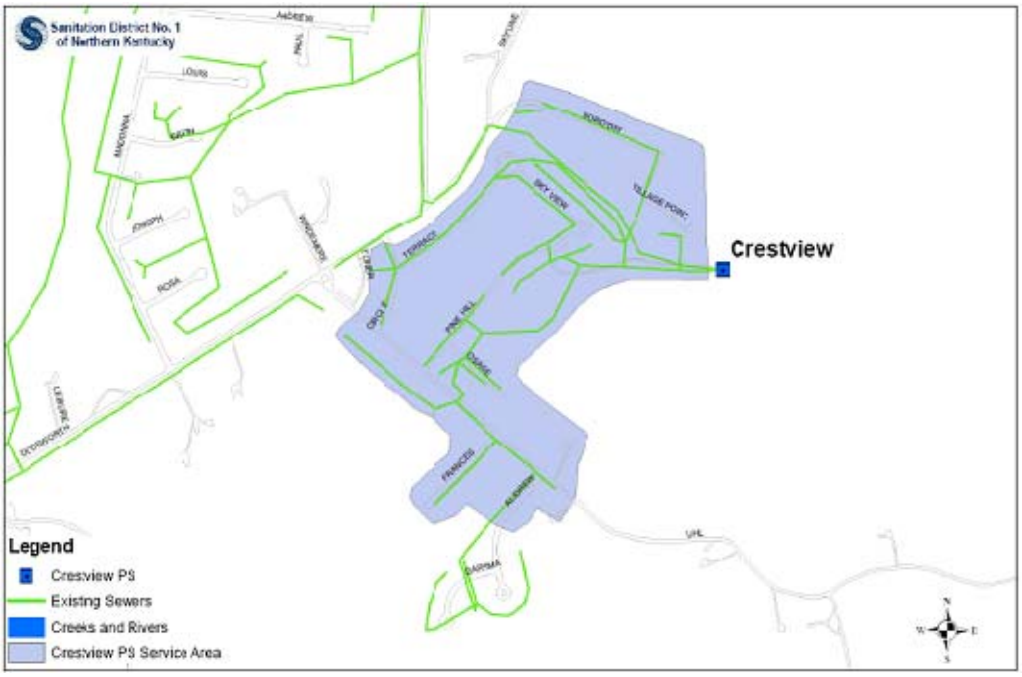
7.5.3 Crestview Pump Station Overflow Elimination

The Crestview PS is located near Silver Grove and pumps to a gravity line tributary to the Silver Grove PS. The pump station contains two pumps and has a firm capacity of approximately 0.44 MGD based on recent drawdown testing. A picture of the exterior of Crestview PS is shown in Figure 7.50.

Figure 7.50 Crestview Pump Station

The current service area for Crestview PS can be seen in Figure 7.51.

Figure 7.51 Current Crestview Pump Station Service Area



During large wet weather events when the capacity of the pump station has been exceeded and during power outages, the pump station overflows through a constructed eight-inch outfall into a tributary of Uhl Creek, which discharges to Fourmile Creek. Figure 7.52 shows the bypass configuration at Crestview PS.

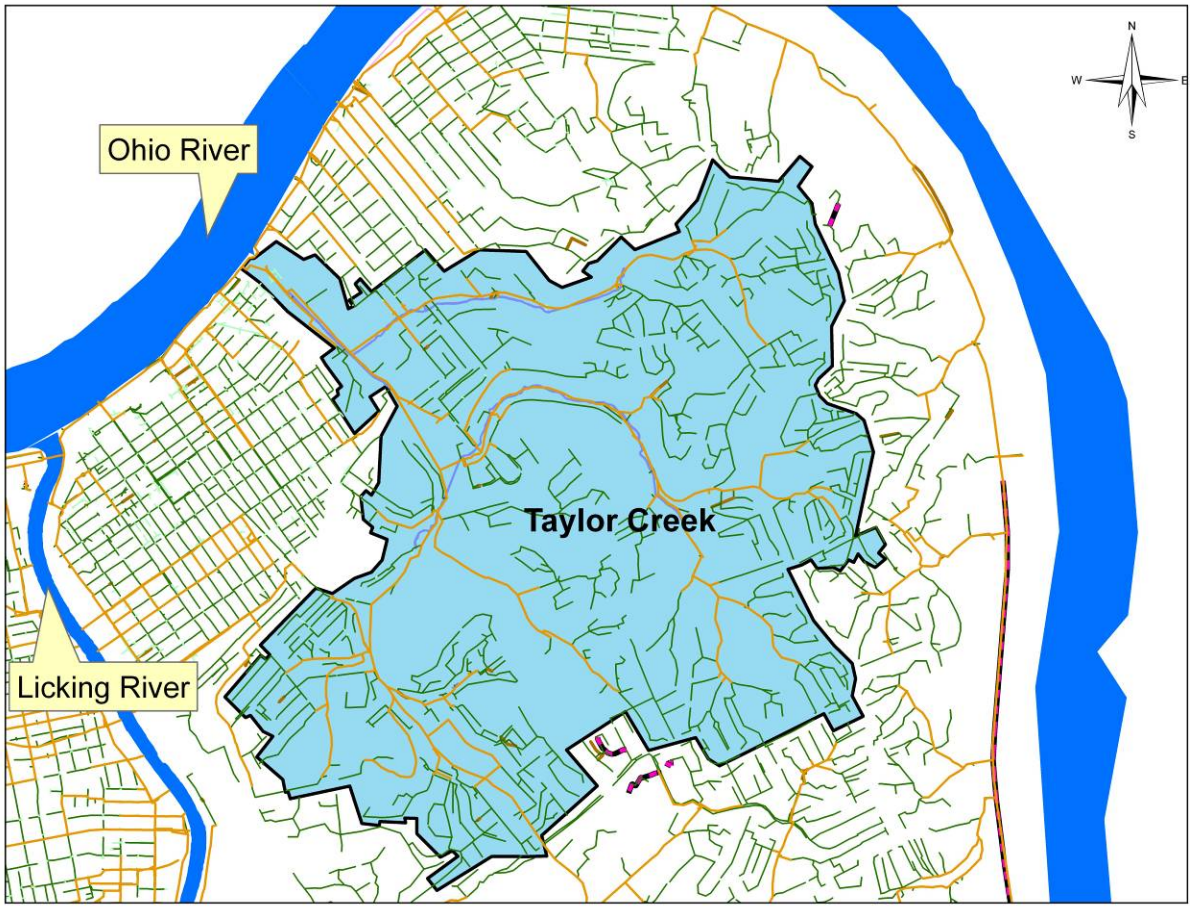
Figure 7.52 Crestview Pump Station Bypass Configuration

Several flow meters have been installed upstream of the pump station to characterize the I/I entering the pump station. In addition to flow monitoring, smoke testing and CCTV inspection has been conducted on the tributary sewers to identify I/I sources and condition of the sewers. The flow monitoring data were used to characterize and calibrate the pump station in SD1's hydraulic model. The data analysis so far indicates that many of the sewers tributary to the Crestview PS are in need of repair or replacement. SD1 is currently rehabilitating and replacing the existing sewers and manholes and a portion of the private property laterals. This work will be completed and post-construction flow monitoring will be conducted to assess the amount of I/I reduction. If the overflow is not eliminated with the above work, then private source I/I removal will be performed to remove the remaining I/I in order to eliminate the overflow at the pump station and meet the overflow elimination date of December 31, 2015 in Exhibit E of the Consent Decree.

7.5.4 Taylor Creek Priority Area

The Taylor Creek Priority Area is a hybrid separate/combined sewer system that encompasses large portions of the City of Ft. Thomas, the City of Newport and the City of Bellevue. The entire area drains through a 24-inch trunk sewer to a single point along the Ohio River Interceptor, and eventually to Dry Creek WWTP via the Bromley Pump Station. The entire sewer system within Taylor Creek comprises gravity sewers with no pump stations. The primarily residential service area comprises approximately 2,500 acres, with an average dry weather flow of approximately 1.3 MGD. Figure 7.53 below shows the boundaries of the Priority Area.

Figure 7.53 Taylor Creek Service Area



The Taylor Creek Priority Area includes seven CSOs and seven recurring SSOs. There are also several other model-predicted overflow locations that have not been field verified to be recurring. The largest overflow is an SSO towards the end of Waterworks Road that overflows approximately 5.5 MG in the typical year. This area is also subject to basement backups due to surcharging of the sanitary sewer. Many of the sewers in the area are vitrified clay and the sewers are generally in poor condition. A majority of the sewers are in the Phase 1 priority area for the CSAP program and are also among the highest in priority SSES scoring.

The other service-related problem in the Taylor Creek area is the fact that the Bellevue portion of the service area is subject to frequent flooding during rain events.

SD1 Objectives

SD1's objective in the Taylor Creek area is to address the most immediate health risk concerns, which are the dry weather bacteria levels and basement flooding along Waterworks Road. In addition, SD1 intends to coordinate overflow improvements in the Taylor Creek Priority Area need with overall structural improvements to the existing sewers.

Potential Control Alternatives

Section 3 outlines the gray infrastructure concepts for the overflows in the Taylor Creek area. As indicated, the cost to address all of the overflows in the Taylor Creek area is substantial. The overflow problems in Taylor Creek are due to extremely high I/I.

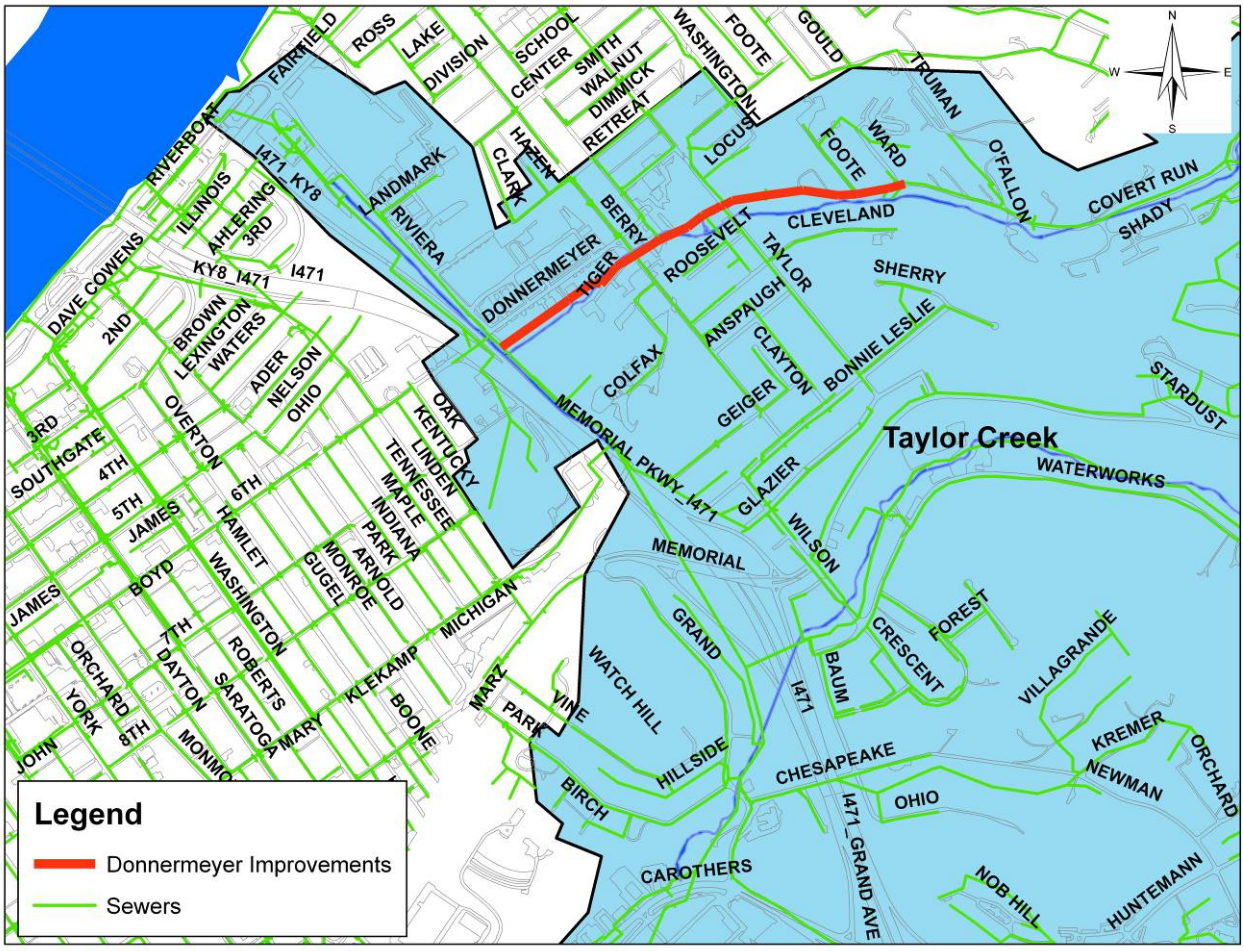
There are also several ongoing and currently planned improvements within the service area that are being implemented as part of opportunities with new development, needed sewer rehabilitation, and as part of storm water improvements. All of the projects will reduce overflows. These current and ongoing projects are:

- Donnermeyer/Covert Run Improvements,
- Newport Pavilion Improvements,
- Bellevue Relief Sewer,
- Wilson/Waterworks Rd. Improvements,
- Riviera Sewer Replacement,
- SSES Activities, and
- Regional Retention.

Donnermeyer/Covert Run Improvements

The Donnermeyer/Covert Run sewer improvements extends from the main 24-inch trunk sewer. Figure 7.54 below shows the proposed sewer replacement in red. This construction is being done as part of overall storm sewer improvements that will reduce basement flooding along Covert Run Road.

Figure 7.54 Proposed Donnermeyer/Covert Run Improvements



This project consisted of the replacement of approximately 3,300 linear feet of 12-inch sewer that was failing. In addition, this section of sanitary sewer is subject to I/I from surface flooding along Covert Run road during heavy rain events. Three CSOs are tied into the proposed improvements. The goal of the improvements was to select the appropriate replacement sewer size such that the new sewer would improve current conditions and reduce CSO volume, while fitting into the overall watershed plan for this area.

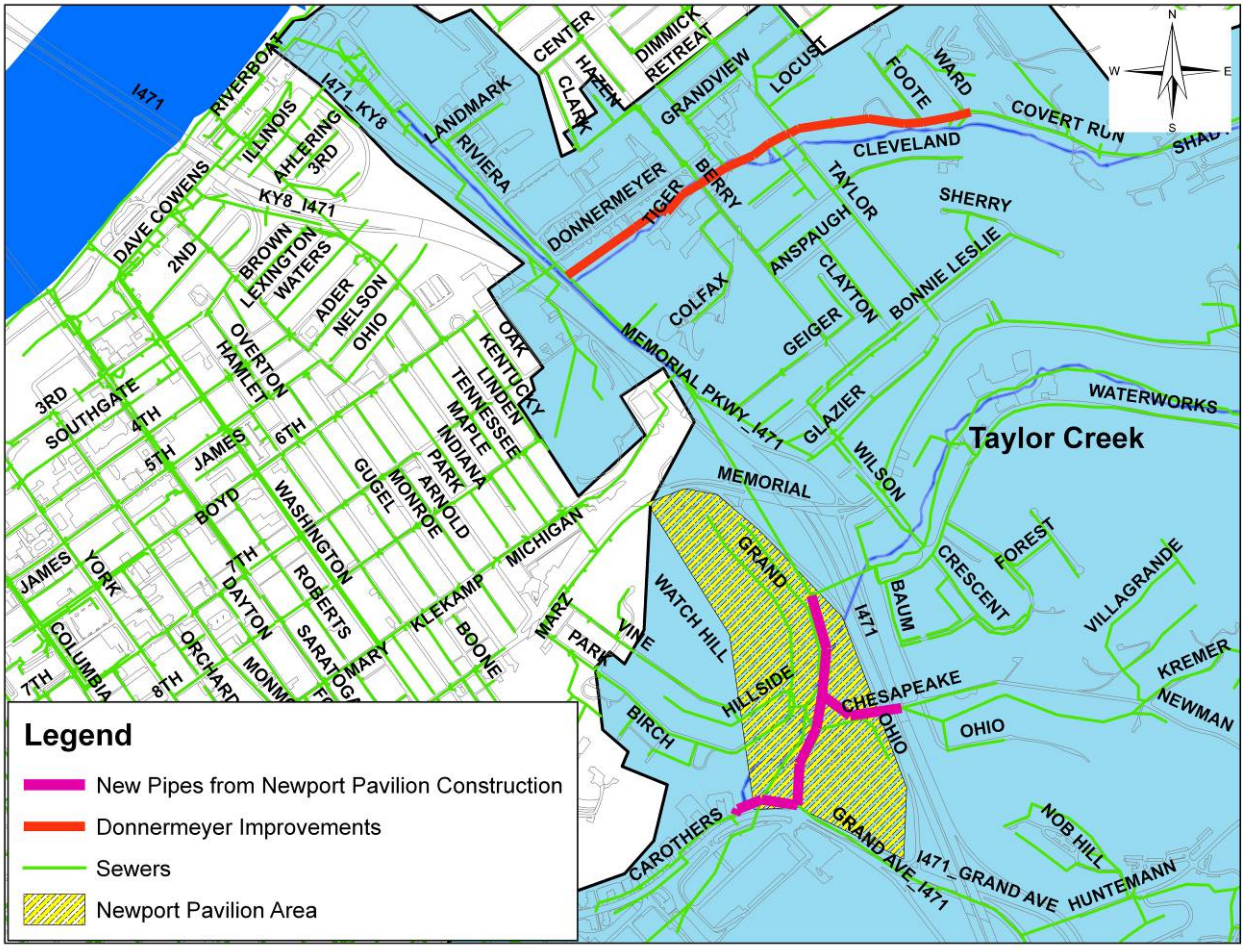
SD1 examined the impacts of constructing 875 linear feet of 84-inch sewer for inline storage to replace the existing 12-inch sewer at the end of Donnermeyer Road. The model results showed that the extra volume provided by the large diameter was not utilized during a typical year storm and that the system-wide overflow reduction was minimal, relative to the estimated construction cost.

SD1 evaluated alternative sewer sizes, and selected replacement sewers ranging in size from 18-inch to 24-inch to convey all upstream flow. This project was completed in 2010.

Newport Pavilion Improvements

The Newport Pavilion is a new commercial development in Newport on the east side of I-471 between Memorial Parkway and Carothers Road. Figure 7.55 below shows the location of the new development and the new sewers constructed as part of the development.

Figure 7.55 Proposed Newport Pavilion Location



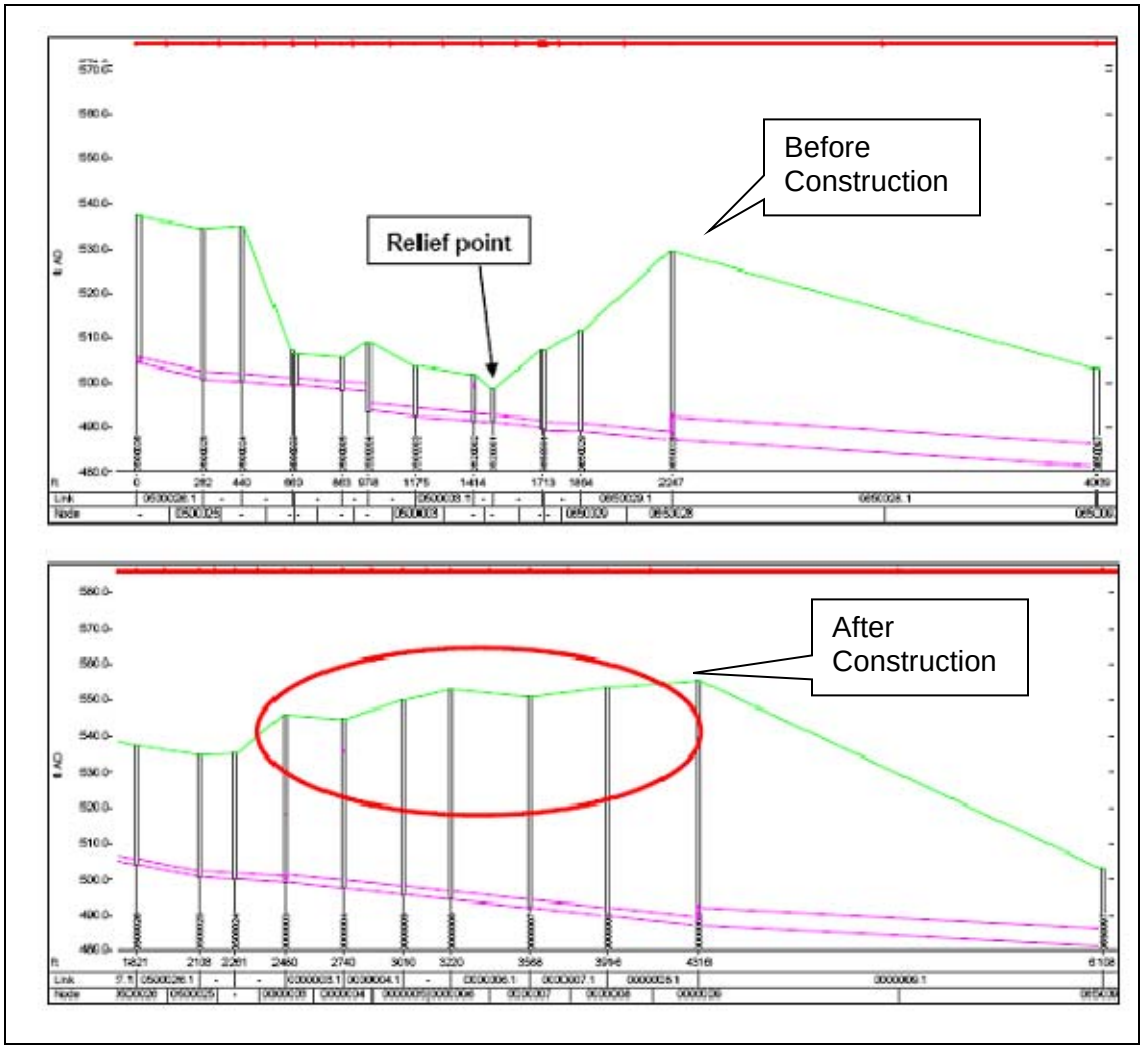
One key issue related to this project was that a large area of land over the sanitary sewer following Grand Avenue to the elliptical 38” x 60” sewer under I-471 would be filled with up to 50 feet of cover, requiring replacement of the existing infrastructure. This project allowed SD1 to cost effectively upsize the existing 21-inch trunk sewer to 30-inch to convey wet weather flows and connect to the existing elliptical 38” x 60” sewer under I-471. This project has been completed and two SSOs have been eliminated.

Bellevue Relief Sewer

One of the consequences of the Newport Pavilion sewer was the fact that flow that would normally have overflowed from the eliminated SSOs may potentially cause

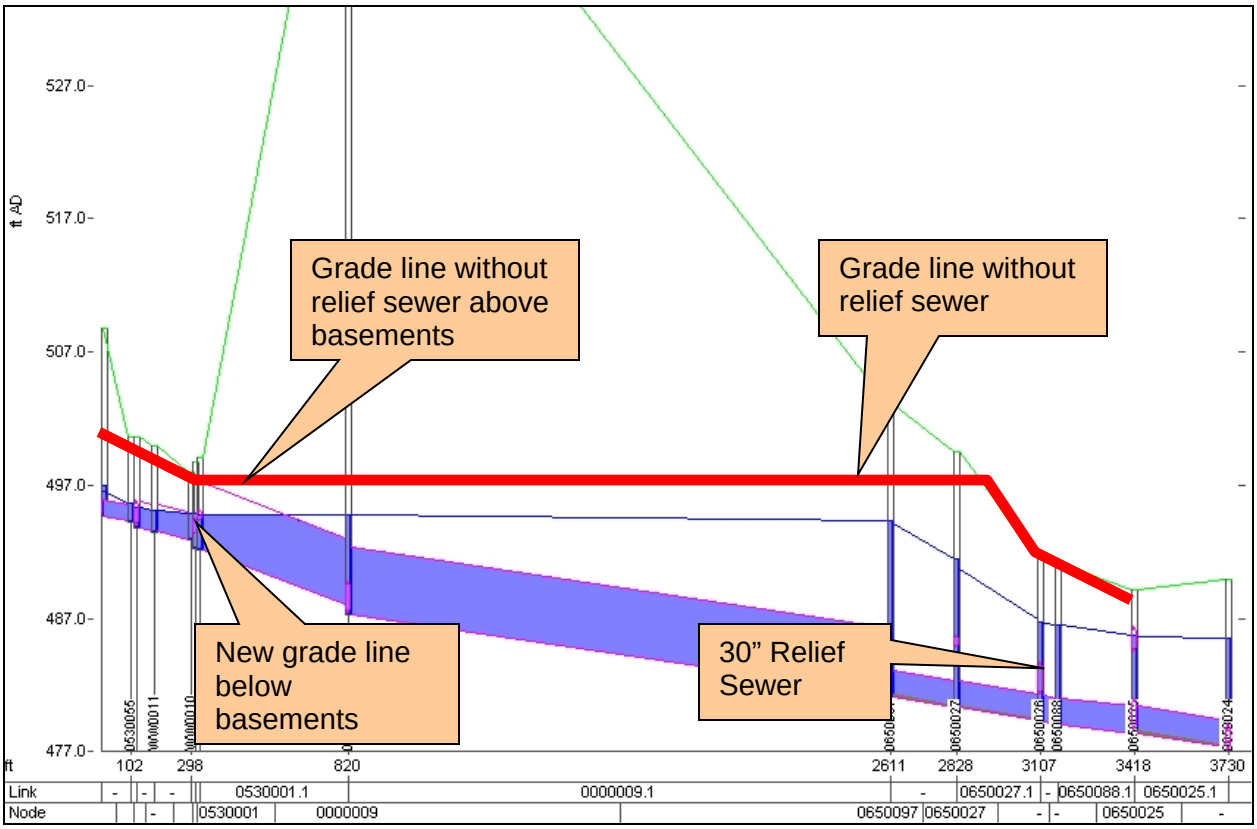
basement flooding along Waterworks Rd. Figure 7.56 shows the impact that the development had on the depth of the sanitary sewer. The previous relief point no longer exists, and resulting peak depth will rise above downstream basement elevations.

Figure 7.56 Model Profile Before and After Construction at Bellevue



To reduce the risk of downstream basement flooding, SD1 constructed a relief sewer downstream of the large 38”x60” diameter pipe. Figure 7.57 shows the relief sewer in profile along with the model calculated peak water levels (grade line) before and after relief sewer construction after a two-year storm event. Note the flat slope of the hydraulic grade line in the vicinity of the relief sewer. This has the effect of lowering the hydraulic grade line up to the far left portion of the figure that represents the location of the basement flooding risk. This project was completed in 2009.

Figure 7.57 Hydraulic Grade Line after Relief Sewer Construction at Bellevue

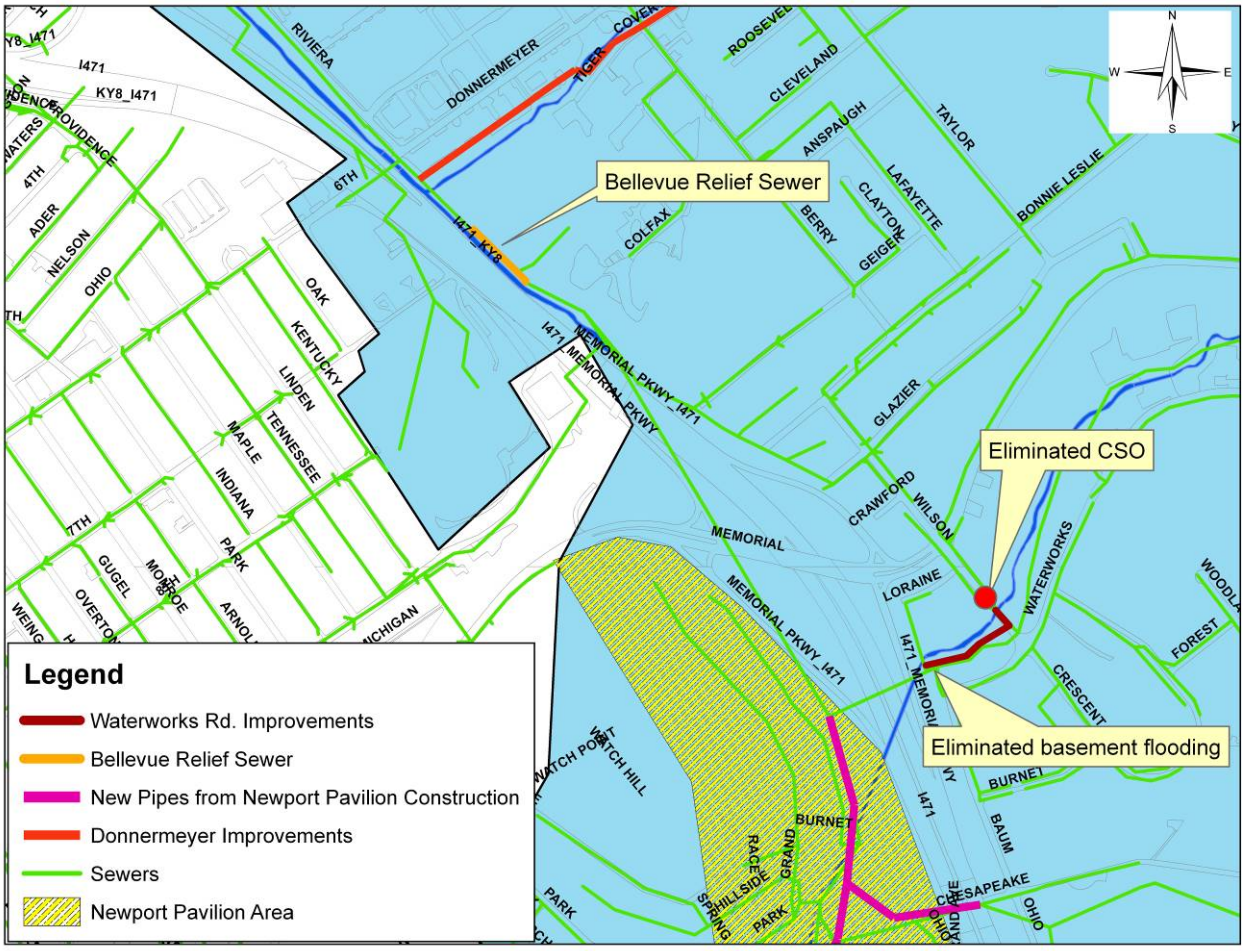


Wilson/Waterworks Rd. Improvements

A companion project to the Bellevue Relief Sewer is the Wilson/Waterworks Rd. improvements, which eliminates an upstream CSO on Wilson Road and the basement backups along Waterworks Road. The improvements included a new 24-inch sewer that replaced an existing 15-inch sewer along Waterworks Road.

These improvements reduced overflow volume, eliminated basement backups, and are sized to convey the required peak flows. Figure 7.58 shows the design of the new gravity sewer, the CSO to be eliminated, and the basement backup area eliminated. This project was completed in late 2009.

Figure 7.58 Wilson/Waterworks Road Improvements

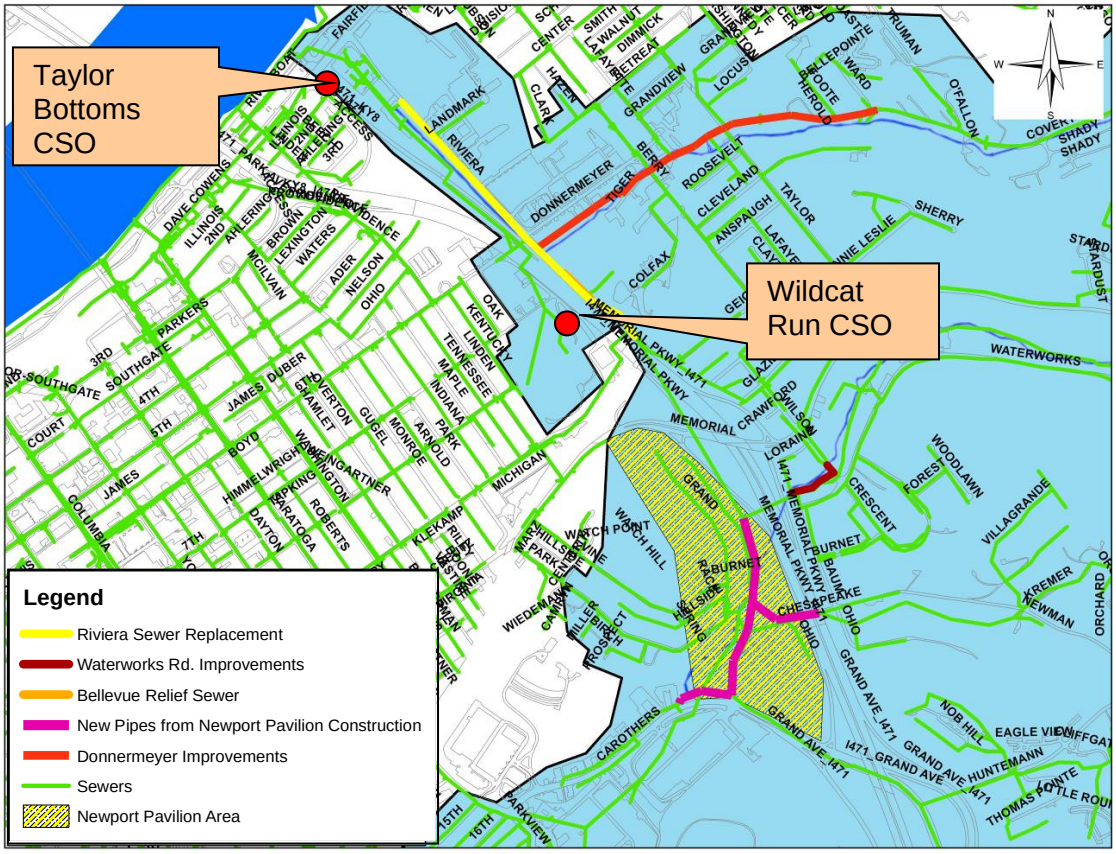


Riviera Sewer Replacement

The Riviera Trunk Sewer is approximately 4,100 linear feet of 24-inch clay pipe that conveys flows from portions of Fort Thomas and Bellevue to the Ohio River Interceptor. Recent inspections of the sewer show that the pipe is in need of being rehabilitated. An analysis conducted as part of the Watershed Planning effort showed that the first 2,800 linear feet of the existing sewer could be replaced with new 84-inch pipe, and three orifice/weir control structures will be installed to provide for 0.8 MG of in-line storage that is expected to reduce overflows by 23 MG. This new pipe would have the capacity to convey peak wet weather flows from upstream areas and will enhance the benefits of the previously mentioned upstream improvements including the Newport Pavilion Sewer, Donnermeyer/Covert Run Sewer Replacement, and the Wilson/Waterworks Rd sewer improvements. This improvement would serve to support future conveyance or treatment options to further address overflows in the area. This project is expected to have a capital cost of $7.5 Million in 2009 dollars and, therefore, will not be completed within the first Five-year Improvement Program; however, it is expected that the design will be completed. It is important to note that the cost-benefit nature of this approach to the sewer replacement will be evaluated in greater detail, and the proposed

replacement solution may change. Figure 7.59 shows the location of the project. The figure shows the vicinity of the Riviera Sewer Replacement project to the previously mentioned Donnermeyer/Covert Run Sewer Replacement and the Bellevue Relief Sewer. The Newport Pavilion improvements and Wilson/Waterworks Road improvements are immediately upstream.

Figure 7.59 Riviera Sewer Replacement Project



SSES Activities

In addition to the significant number of improvements planned and constructed in the Taylor Creek area, SD1 plans to include this area for priority SSES evaluation. As shown in Section 7.2, I/I removal can be a cost-effective way to reduce overflows. According to the SSES prioritization that was done as part of the watershed planning process, the average priority score for Taylor Creek was 2.4 on a scale of 1-3. For comparison, the overall average priority score for subcatchments with "R" values greater than two was 1.75. In addition, model results in a typical year indicate the following:

- 25 percent I/I removal could reduce overflow volume in the Taylor Creek area from 12.3 MG to 7 MG or 43 percent reduction; and
- 50 percent I/I removal could reduce overflow volume from 12.3 MG to 3.2 MG or 75 percent reduction.

The sewers in this area from SD1's CSAP are also in poor structural condition and will likely need replacement in the near future. The above results show that the Taylor Creek area will benefit from SSES activities.

Regional Retention Opportunities

The use of retention basins as controls is appealing in the Taylor Creek watershed because the steep slopes provide natural basin boundaries, limiting the amount of earthwork (and associated costs) needed to construct a retention basin. Although one regional retention opportunity was identified along Waterworks Road due to permitting challenges, the project could not be modified to provide additional water quality benefits. However, the Waterworks Road detention basin is currently under construction to reduce storm water quantity and downstream flooding and is expected to be completed in late 2011..

Conclusions

The Taylor Creek Priority Area is faced with numerous challenges resulting from the high amounts of impervious area and steepness of slopes, the overall age of the sewer system, and the,nature and extent of the capacity problems, which are exacerbated by surface flooding issues, and the problems associated with dry weather-related bacteria sources. The overall cost to address these problems on a large scale is quite significant and is not affordable to implement in the first five years of the Watershed Plan implementation. SD1 strongly believes that the previously mentioned projects will provide significant benefit to the overall Taylor Creek area. In addition to these projects, SD1 proposes to conduct the following activities to support the overall strategy:

- Conduct priority SSES investigation work to identify cost-effective opportunities for I/I removal and to further characterize the overall system;
- Coordinate SSES activities with other CSAP activities to further identify opportunities to address capacity problems and target rehabilitation projects; and,
- Initiate the Source Identification Program to detect other sources of pollution (dry and wet weather-related sources) identified by monitoring and modeling efforts as discussed in Section 7.2.5 and identify projects that can be implemented to address these sources.

7.5.5 Silver Grove Priority Area

The Silver Grove Priority Area is located in Campbell County, KY along the Ohio River. The location and characteristics of the area are shown in Section 6. This area was selected as a Priority Area due to the public health risk posed by the CSO in downtown Silver Grove and the overflows near the Silver Grove PS.

The CSO in downtown Silver Grove is of particular concern because it discharges to relatively flat ground with very poor drainage. In addition, the area is subject to backwater and flooding from the Ohio River. These conditions typically cause additional overflows and poor outlet drainage causes the contaminated water to stagnate, pond and settle pollutants. This issue is further exacerbated by the fact that the ground is swampy, and clean up is practically impossible. Therefore, this area is of particular concern and meets SD1's criteria as a high Priority Area.

SD1 Objectives

SD1's objective in the Silver Grove area is to address the most immediate public health risk concern, which is the CSO near downtown Silver Grove.

Potential Control Alternatives

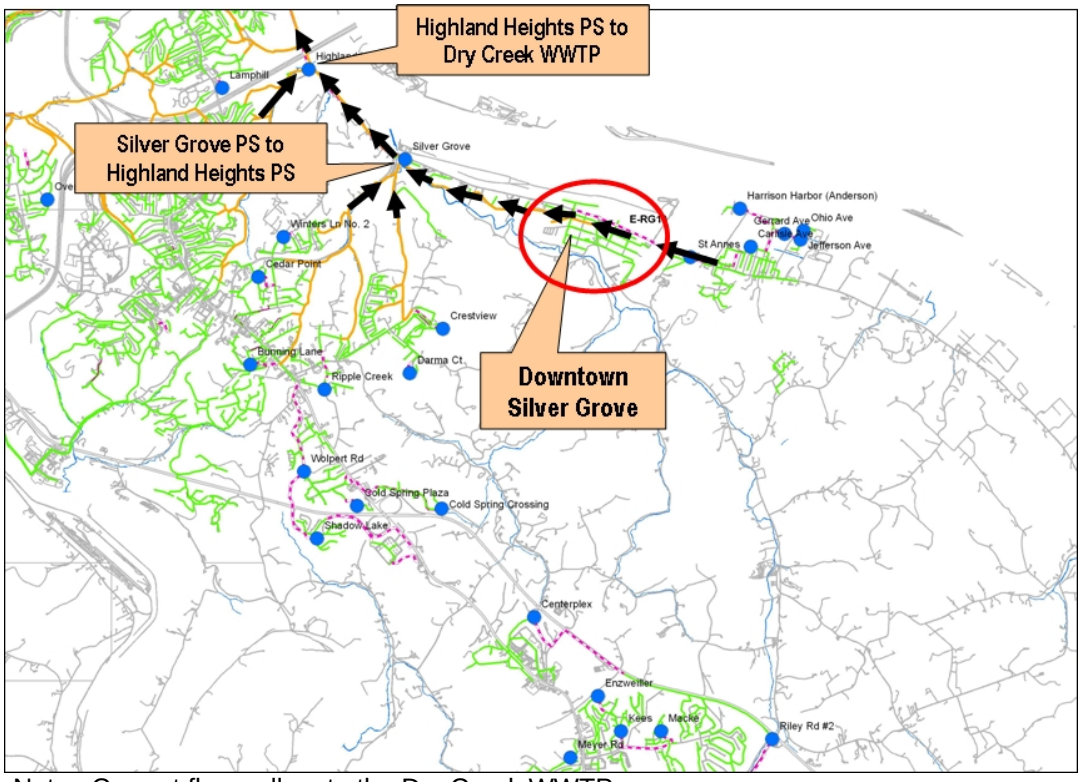
Section 3 outlines the gray infrastructure concepts for the overflows in the area that includes downtown Silver Grove. The portion of the gray-only solution concept that addresses the CSO at Silver Grove is a new 6.0 MGD pump station at Ash Street and a new forcemain to convey the flow to the new Riley Road PS in Alexandria that conveys the flow to the Eastern Regional WRF. This solution, which will result in elimination of the CSO in the typical year, a very high level of control for a CSO, was the starting point for developing the selected control.

Due to the public health concerns, SD1 will provide a higher level of service than forecasted in the gray-only solution concept. Construction of this pump station will eliminate the flow in the leaky 10-inch sewer that conveys flow from downtown Silver Grove to the Silver Grove PS. Below is a list of improvements that will be done to address the Silver Grove CSO:

- Construct the Ash Street PS and forcemain to convey wet weather flows from Silver Grove to the new Riley Road PS for treatment at the new state of the art Eastern Regional WRF;
- Abandon 10-inch gravity sewer that currently conveys flow from downtown Silver Grove to the Silver Grove PS;
- Install new gravity sewer immediately upstream of the Silver Grove PS to convey the remaining flow and to eliminate the intrusion of river water when the river levels are elevated;
- Complete street load sewer separation in downtown Silver Grove; and,
- Install new 12-inch force main from Silver Grove PS and redirect flow from Silver Grove PS to the new Ash Street PS.

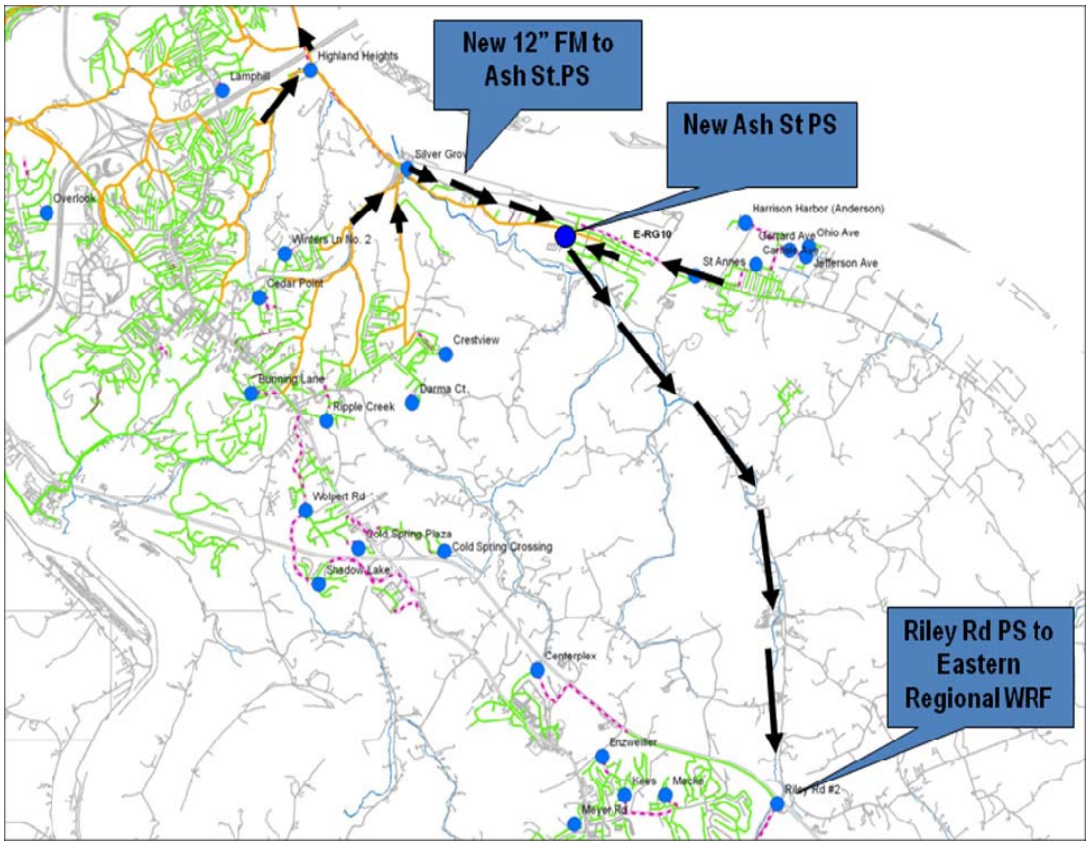
Figures 7.60 and 7.61 show the proposed system modifications graphically.

Figure 7.60 Current Flow Direction from Silver Grove Priority Area



Note: Current flows all go to the Dry Creek WWTP

Figure 7.61 Proposed Flow Direction from Silver Grove Priority Area

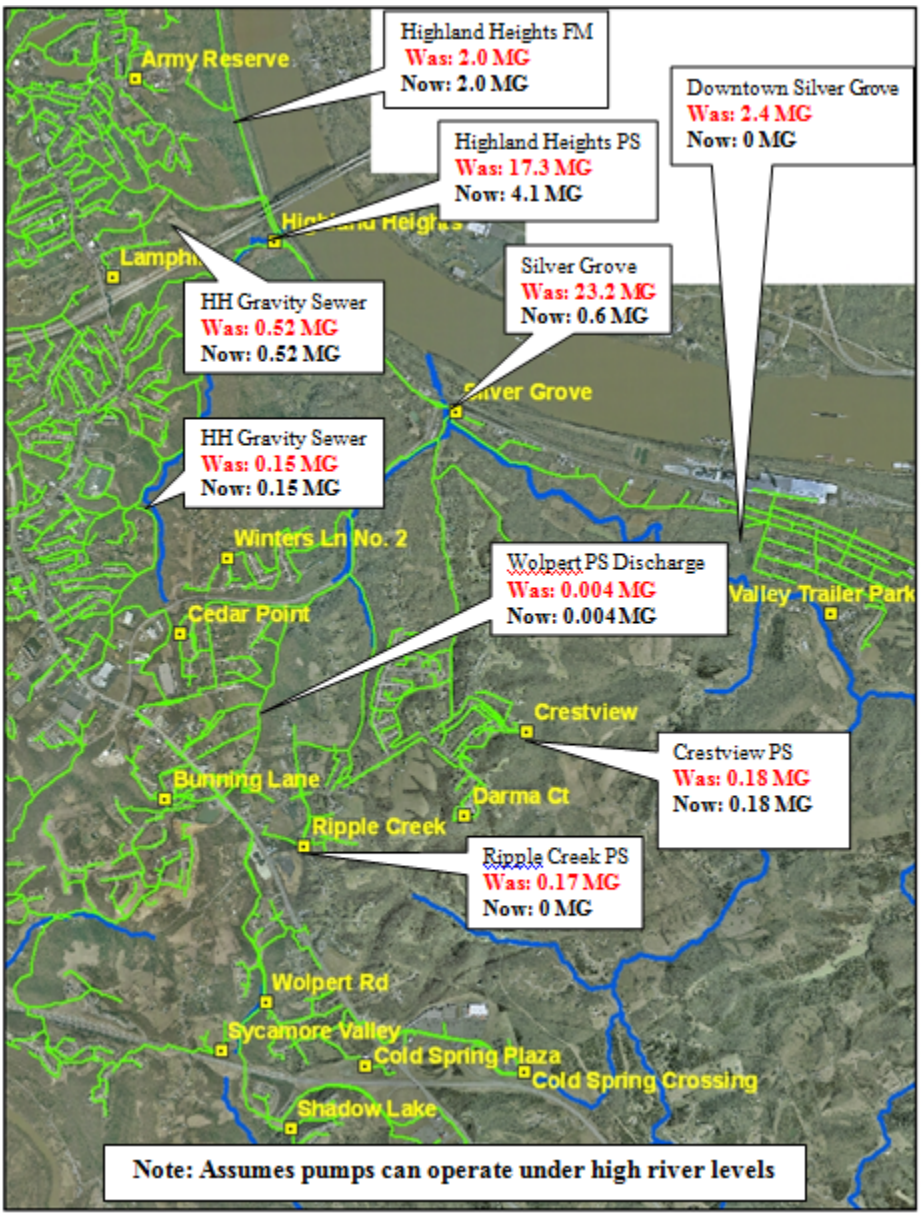


Note: New Ash Street PS will redirect flow away from Dry Creek WWTP to Eastern Regional WRF

Benefits and Conclusions

SD1 will be designing and constructing the improvements listed above. Figure 7.62 shows the model-calculated benefits in the typical year with the implementation of Phase 1.

Figure 7.62 Typical Year Overflow Volumes after Phase 1 for Silver Grove Priority Area Reduction of 38.4 MG



Hydraulic modeling calculates a reduction of 38.4 MG of overflow volume (36 MG SSO reduction and 2.4 MG CSO reduction) and the elimination of the CSO in downtown Silver Grove in a typical year. Another benefit of the Ash Street PS is that it will support other future improvements to convey other flows tributary to the Silver Grove PS and the Highland Heights PS to the Eastern Regional WRF. Implementation of these improvements is estimated to cost $19.3 Million in 2009 dollars and will significantly reduce the public health risk associated with overflows in this area.

7.5.6 Summary of East Basin Projects

Table 7.30 shows a summary of the recommended projects, costs, and benefits for the East Basin.

Table 7.30 East Basin Five-Year Projects

Project Name	Benefits	Cost in 2009 Dollars ($ Million)
Harrison Harbor PS Overflow Elimination	SSO elimination	Complete
Riley Road No. 1 PS Overflow Elimination	SSO elimination; Initial Watershed Project	Complete – Cost included under Initial Watershed Projects; refer to Table 7.5
Crestview PS Overflow Elimination	SSO elimination	Cost included under Ongoing Sewer Rehabilitation / Repair Projects; refer to Table 8.5
Taylor Creek I/I Source Identification & Removal	SSO elimination	Cost included under Priority I/I Source Identification & Removal Program; refer to Table 8.6
Donnermeyer/Covert Run Improvements, Newport Pavilion Improvements, Bellevue Relief Sewer, and Wilson/Waterworks Rd. Improvements	Reduces basement flooding risk and provides conveyance capacity for future improvements in Taylor Creek; SSO elimination	Complete
Riviera Sewer Replacement	Replaces existing sewer to provide wet weather conveyance capacity; CSO elimination	(only engineering part of 5-year Implementation Plan
Ash Street PS and Force main and Silver Grove FM	CSO elimination; SSO reduction; improves public health	$19.3
	Total	$19.8

7.6 North Basin Projects

This section presents the projects comprising the Five-year Improvement Program that are specific to the watersheds in the North Basin (Dry Creek, Pleasant Run, Elijahs Creek, Sand Run, Woolper Creek and Ohio River North). This section includes descriptions of relevant projects from the list of identified watershed projects and basin projects that were identified in the Priority Areas analysis. These projects include:

- Allen Fork Pump Station overflow elimination,
- South Park Pump Station overflow elimination,
- Taylorsport Pump Station overflow elimination,
- Lakeside Park Priority Area, and
- Willow Run Priority Area.

Each project description includes background, an evaluation of potential control alternatives and a conclusion. More complex projects, such as the Willow Run Priority Area, include additional detail on the alternatives.

7.6.1 Allen Fork Pump Station Overflow Elimination

Allen Fork PS is one of the many tributary pump stations to the Taylorsport PS. The Allen Fork PS pumps to the Burlington PS, which pumps to a 24-inch forcemain (merging with flows from the Gunpowder PS) to the Taylorsport PS. The pump station was originally constructed in 1993, has been regularly maintained, and was upgraded in 2004 (Figure 7.63). The pump station currently contains three submersible pumps (one standby) and has a firm capacity of approximately 2.3 MGD and a total rated capacity of 2.6 MGD. Note that the "pump station overflow" does not occur at the pump station itself. The pump station does not have a constructed bypass pipe. Overflows occur at several manholes upstream of the pump station at a low manhole location (MH 2390002).

Figure 7.63 Allen Fork Pump Station

As part of complying with the pump station overflow elimination requirements, SD1 has initiated work to eliminate the Allen Fork PS overflow. SD1 has or is already implementing the following overflow reduction actions:

- **Allen Fork Collection System Improvements - Phase I:** This construction project was completed in 2007. This project constructed the Burlington PS and new upstream sewers to provide additional dry and wet weather capacity and reduce I/I. The Allen Fork PS was rerouted to the new Burlington PS thereby lowering the discharge head of the Allen Fork PS. The lower head increased the capacity of the Allen Fork PS.
- **Allen Fork Collection System Improvements - Phase II:** This SSES project began during the 2007-2008 system-wide flow monitoring to identify additional I/I sources and develop a plan to reduce the I/I. SD1's current program includes ten flow monitors and two rain gauges, some originally installed during the 2007-2008 system-wide flow monitoring program. These methods along with manhole inspection, night weiring, and CCTV inspection are currently being performed. SD1 is currently inspecting sewers using CCTV, and spot checking manholes to identify locations where I/I could be entering the sewer system through openings. SD1 plans to perform smoke and dye testing of areas suspected of having

clearwater connections or leaking laterals (clearwater is defined as direct inflow from private source downspouts, area drains, driveway drains, illegal sump pump waters, and broken floor drains). These areas will be identified from SD1 experience and the current flow monitoring program.

A portion of the solution for the MH 2390002 overflow involves the Western Regional Initial Watershed Projects, which will be completed in time to meet the Allen Fork PS overflow elimination deadline. As described in Section 7.1, SD1 is constructing the Western Regional Conveyance System and the Western Regional WRF. Once these facilities are brought on line in 2013, the Gunpowder Pump Station will be eliminated with a gravity sewer to the Western Regional conveyance system, and the Burlington Pump Station will be redirected to this new gravity sewer and taken off of the Taylorsport Pump Station service area. Burlington Pump Station's new discharge route will lower its discharge head, thereby increasing its capacity. Once Burlington PS increases its capacity, the Allen Fork Pump Station will be able to increase its capacity by installing larger impellers in its pumps.

The Western Regional Initial Watershed Projects and the redirection of the Allen Fork and Burlington pump station flows will substantially reduce and possibly eliminate the overflows at MH 2390002. SD1 will also be performing I/I removal projects upstream of the Allen Fork PS to ensure the Allen Fork Pump Station Overflow Elimination Plan deadline of December 31, 2014 will be met. In addition to the above, SD1 will be evaluating the need for additional solutions to eliminate the Allen Fork PS overflow. Any necessary alternative will be sized to account for the results of redirecting the pump stations to the Western Regional WRF.

7.6.2 South Park Pump Station Overflow Elimination

The South Park Industrial Pump Station is located in Boone County and is one of the many tributary pump stations to the Taylorsport PS. The pump station was originally constructed in 1986 and it operates with two submersible pumps (1 standby). The South Park pump station has a firm capacity of approximately 0.21 MGD based on recent drawdown testing. A picture of the exterior of South Park Pump Station is shown in Figure 7.64.

Figure 7.64 South Park Pump Station

SD1 has completed the SSES program for the South Park PS tributary area described in the Pump Station Overflow Elimination Plan and concluded that there are no capacity related issues at the pump station during wet weather events. The pump station has a relatively large wet well with correctly sized pumps. The upstream sewers were CCTV inspected, and smoke tested, and their flows were monitored for a one year period from 2007 to 2008. The sewers were in good structural condition, the smoke testing did not show illegal connections, and the flow monitoring showed wet weather peaking factors well within the Ten States standards for sewer lines and within the PS's current capacity (Ten State Standards, 2004).

To date, only two overflows have occurred at the South Park PS, and both were due to a power outage. Overflows due to power outages will be eliminated using a backup power solution by 2010 with the completion of SD1's Stand-By Power Improvements Project 5. Project 5 is the fifth round of backup power installations projects completed by SD1 in response to the approved PS Backup Power Plan in the Consent Decree.

Therefore, the proposed solution to eliminate the overflow at the South Park PS will be installation of a backup power solution at the pump station.

7.6.3 Taylorsport Pump Station Overflow Elimination

As documented in the Pump Station Overflow Elimination Plan, a 2004 capacity upgrade at Taylorsport PS eliminated the historical overflow. As previously stated in the Allen Fork PS section, additional flow reduction will occur at Taylorsport PS once flows from Allen Fork PS, Burlington PS, and Gunpowder PS are redirected to the Western Regional conveyance system. A picture of the exterior of Taylorsport PS is shown in Figure 7.65.

Figure 7.65 Taylorsport Pump Station

7.6.4 Lakeside Park Priority Area

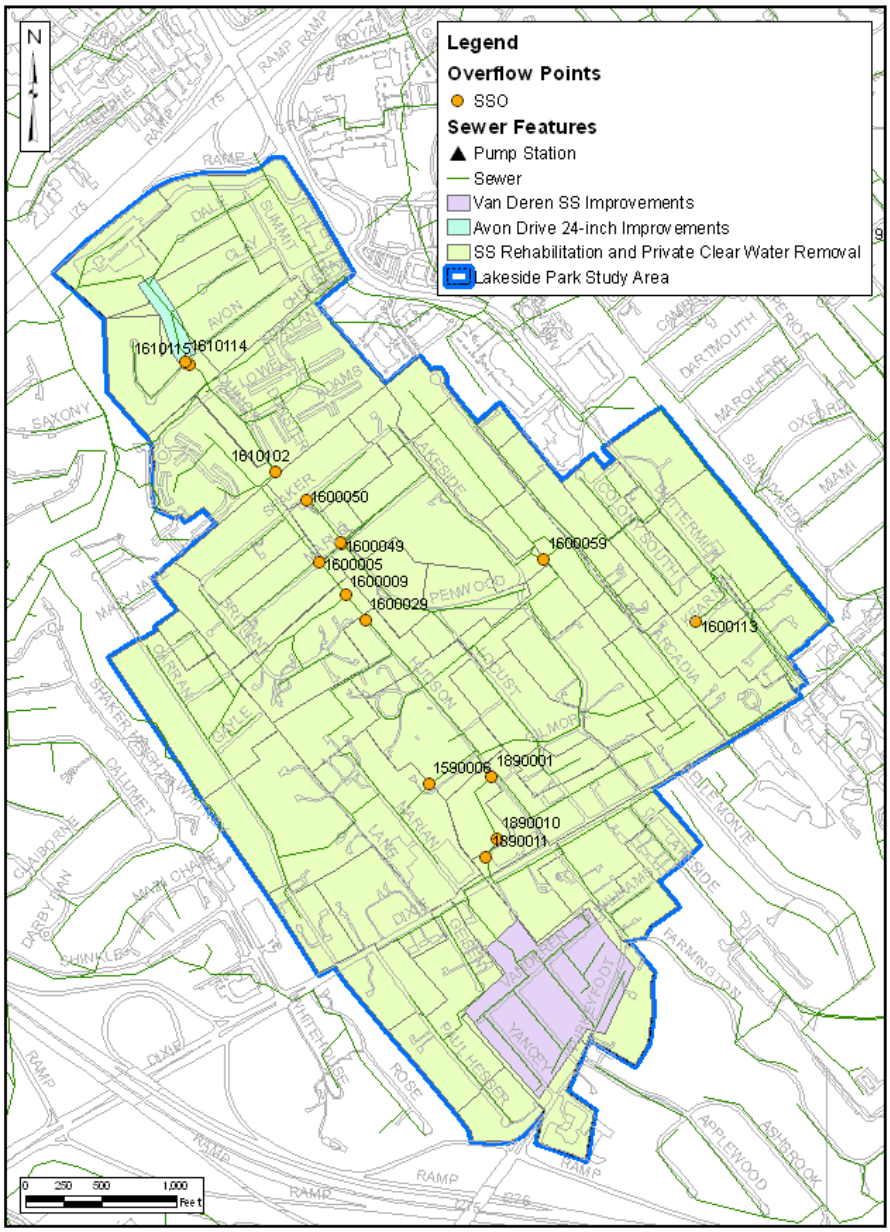
Background

The City of Lakeside Park and the City of Ft. Mitchell are located in the Dry Creek watershed and are served by SD1's sanitary sewer system. Lakeside Park is a small residential community in Northern Kentucky located near the intersection of I-75 and I-275. The community is named for a system of privately owned lakes dispersed throughout the neighborhoods. The Lakeside Park study area, shown in Figure 7.66, includes sewers that serve portions of both the cities. The study area is primarily residential and consists of approximately 235 acres, 750 properties, and 1,400 residents, with a sanitary sewer system made up of 59,000 linear feet of pipe and 339 manholes, with an average dry weather flow of 0.2 MGD.

Until 1995, the sanitary sewer system was owned and maintained by the local communities. When SD1 took ownership of the infrastructure, the sewers in the study area had wet weather hydraulic concerns and were not performing to an acceptable standard. Basement backups were occurring, manholes were overflowing, and sewage was entering surface waters during wet weather. SD1 has invested millions of dollars conducting I/I studies, lining approximately one mile of the public sewer system, flow monitoring and developing the hydraulic model to support a remedy of this situation. Numerous studies have identified illegal clearwater connections to the sanitary sewer from private properties including downspouts, area drains, and driveway drains. Although basement backups have been eliminated by SD1's work to-date, overflows at manholes are still occurring.

The active SSOs are generally along the 12-inch trunk line running down Hudson Drive and continuing through easements towards Ft Mitchell. The overflows leave the manholes and flow down the street prior to entering a stream that then flows directly into a retention pond/lake located in an apartment complex. The most severe of these overflows occurs at MH 1600009. The hydraulic model calculates 0.33 MG of overflow volume from this manhole during a typical year.

Figure 7.66 Lakeside Park Priority Area



SD1 Objectives

The main objective of the Lakeside Park Priority Area evaluation is the elimination of SSOs due to potential public health concerns and water quality impacts in the Dry Creek watershed. Because of the high cost of constructing a traditional gray infrastructure solution (e.g., upsizing of pipes, relief sewers, and/or storage tanks) for the large peak flows in the study area, a second objective was to perform a comprehensive assessment of local I/I issues and determine the cost-effectiveness of source control as an overflow reduction solution. This evaluation was performed in Lakeside Park as part of the watershed planning effort, as a first step in developing a standard approach for I/I reduction analyses for other potentially high I/I areas, such as the Licking River siphon area as described in Section 7.2.4.

Potential Control Alternatives

SD1 performed two evaluations to identify potential control alternatives to meet the Lakeside Park objectives:

- First, SD1 evaluated if there were any short-term, local rehabilitation or replacement projects that would minimize local overflows in the Lakeside Park study area.
- Second, SD1 evaluated alternatives for the overall Lakeside Park Priority Area (upsized conveyance, rehabilitation, and I/I reduction) to eliminate remaining overflows to a desired level of service.

The first evaluation identified two projects, the Van Deren Sanitary Sewer Improvements project and the Avon Drive Sanitary Sewer Improvements project. These two projects will quickly reduce several existing overflows in the study area. The second evaluation identified the Lakeside Park Public Sewer Rehab and Private Source Removal project. The extent of these project areas are shown in Figure 7.66 above.

Evaluation of Alternatives

Van Deren Sanitary Sewer Improvements

The Van Deren Sanitary Sewer Improvements project is located within the City of Lakeside Park. The project was initially identified in response to illicit discharges (sanitary sewage into the storm) detected in the storm sewer outfalls. The Van Deren area is a neighborhood that includes approximately 100 residential parcels and is served with parallel sanitary and storm sewer systems that have 15 common manholes (storm and sanitary sewers share the same manhole). The first goal of the project was to identify all of the illicit connections, both public and private, in order to eliminate them. The second goal was to eliminate the common manholes to reduce wet weather flows and downstream SSO volume.

SD1 performed dye testing of all interior and exterior drains in all 100 residences. Approximately 20 residences were found to have illicit connections into the storm system. A design was completed to eliminate the illicit connections at the property owner's expense; the fix in most cases was to replace the failing sanitary lateral on the private property. In addition, the storm and sanitary sewers were designed to be separated by installing a new sanitary sewer in a new trench and eliminating the

common manholes. The portion of residential sanitary laterals located underneath the pavement will also be replaced.

The project consists of the installation of approximately 3,100 linear feet of eight-inch diameter sanitary sewer pipe, 28 sanitary manholes, 950 linear feet of sanitary lateral replacement, 260 linear feet of sanitary lateral rehabilitation, backfill, road repair, and restoration. Three of the four streets are receiving new sanitary sewers in new trenches, and the fourth street (which has sanitary pipe that is cured-in-place pipe) is receiving cured-in-place lateral linings and common manhole separation.

The project also includes necessary capacity increases to the storm system. The storm portion of the project consists of improvements to 2,500 linear feet of 12 to 30-inch diameter storm pipe, 19 catch basins, and 29 storm manholes. The storm sewers are being completely replaced and upsized on two of the streets, and the other two streets are receiving additional catch basins. In addition, the existing storm outlet pipe to a nearby pond is getting an improved routing layout. This project is being coordinated with the City of Lakeside Park's road reconstruction project to rebuild the three roads and install the new sanitary and storm sewers.

With an estimated capital cost of $1,806,000, the Van Deren Sanitary Sewer Improvement project will eliminate the illicit discharges and is expected to reduce SSOs in the Lakeside Park Project Area by one activation (from 4 to 3 activations) during the typical year at both manholes (1600009 and 1600050), based on modeled I/I reductions. This project was completed in early 2010 and the results of post construction flow monitoring resulted in approximately a 50% reduction in I/I.

Avon Drive Sanitary Sewer Improvements

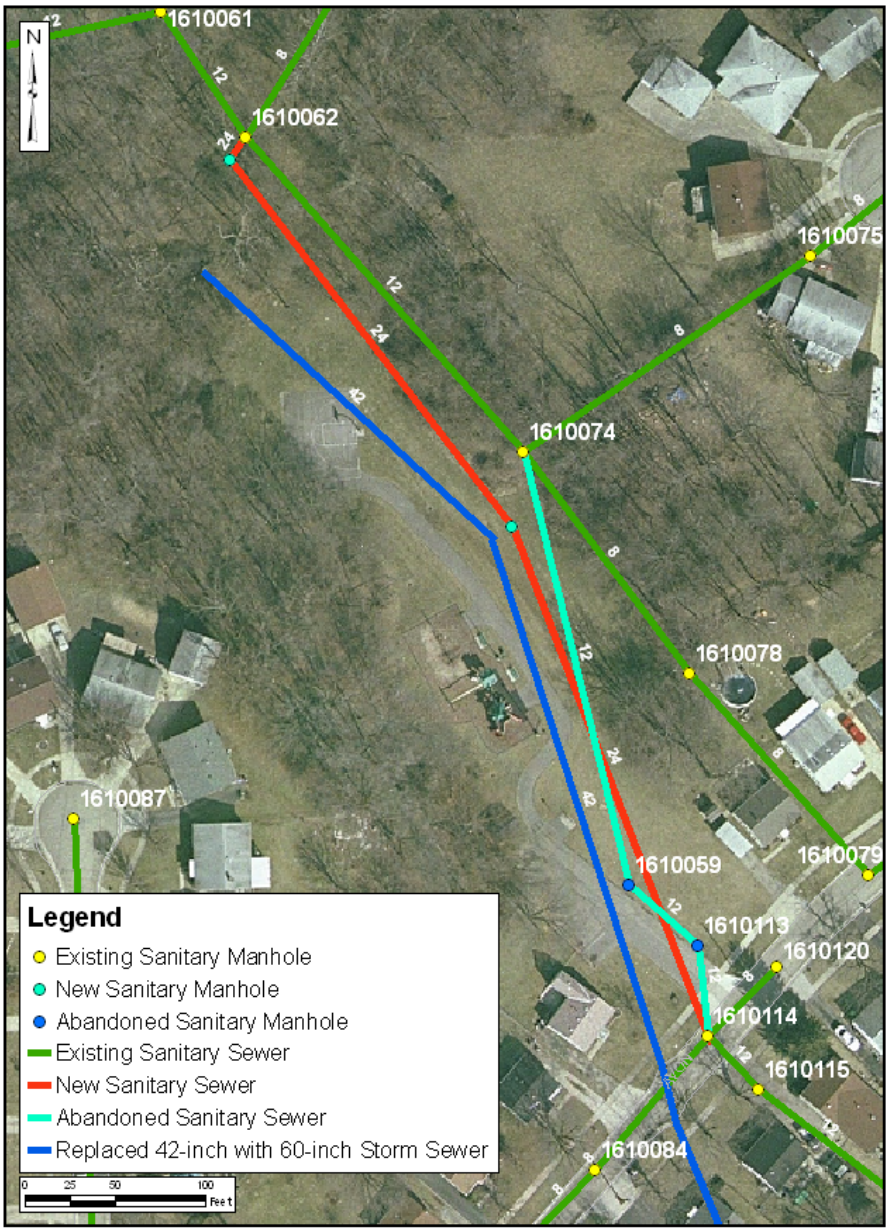
The Avon Drive Sanitary Sewer Improvements project is located within the City of Fort Mitchell, at the most downstream end of the Lakeside Park study area prior to connection to the Dry Creek interceptor. The existing 12-inch diameter sanitary sewer, conveys flow from the Lakeside Park/Fort Mitchell area but lacks wet weather capacity. Due to this capacity limitation, a manhole located in the center of Avon Drive (MH 1610114) overflows during rain events. The proposed 24-inch sanitary sewer will provide additional capacity and eliminate overflows at MH 1610114 removing the public health and environmental impacts of the overflow.

The project consists of the installation of approximately 570 linear feet of 24-inch diameter PVC sewer pipe and four precast manholes and is estimated to cost $208,000. This new 24-inch sewer will replace approximately 350 linear feet of existing 12-inch sanitary sewer. The existing 12-inch sewer will be abandoned. In addition, the 42-inch storm sewer that runs near the sanitary line will be replaced with a 54-inch or 60-inch storm sewer (still being designed), based on the CCTV findings that showed the existing storm sewer had a collapsed section.

Figure 7.67 shows the alignment of the existing sewers and the 24-inch diameter sewer improvements. The alignment of the proposed sewer was determined by minimizing construction conflicts with the parallel 42-inch storm line. The location of this project is within the Avon Drive right-of-way, the City of Fort Mitchell's Crescent Park, and property owned by the Commonwealth of Kentucky, thereby eliminating the need to

purchase easements or work on nearby homeowner's property. This project was completed in 2010.

Figure 7.67 Avon Drive Sanitary Sewer and Storm Sewer Proposed Alignments



Lakeside Park Public Sewer Rehab and Private Source Removal

The second step in SD1's evaluation was to assess comprehensive area-wide solutions for Lakeside Park. These longer-term solutions were examined in terms of costs, benefits, and preferred staging through SD1's Integrated Plan for 2025. The range of solutions included combinations of conveyance, and public and private I/I removal with onsite storm water management.

Six different scenarios were compared that included conveyance, rehabilitation by chemical grouting and cured-in-place pipe to remove infiltration, private source I/I removal with storm water management, and various combinations of these corrective measures. In order to capture the full sustainability and operating costs, the present values for all scenarios were determined over a time period of 25 years. The present value consisted of conveyance (as applicable), public rehabilitation, private removal (as applicable), operations and maintenance, and treatment. The scenarios and their benefits are shown in Table 7.31.

Table 7.31 Lakeside Park Alternatives Evaluation Comparison

Scenario #	1	2	3	4	5	6
Description	Convey Only	Convey with Clearwater Removal (20% Reduction)	Public Rehab Only	Public Rehab with Clearwater Removal	Public Rehab with Resized Convey (20% Reduction)	Public Rehab with Clearwater with Resized Convey (50% Reduction)
Total Scenario Cost (2009 $Million)	$18.1	$21.2	$12.5	$15.9	$16.0	$18.4
Homeowner Costs (2009 $Million)	-	($1.4)	-	($1.4)	-	($1.4)
SD1 Cost (2009 $Million)	$18.1	$19.8	$12.5	$14.6	$16.0	$17.0
Timeliness	2 yr	5 yr	5 yr	5 yr	5 yr	5 yr
Typical Year Overflow Eliminated?	Yes	Yes	0.16 MG remaining	Yes	Yes	Yes
Disturbance to Residents	Low	High	Medium	High	Medium	High
Adds Flow to Dry Creek Interceptor	High	Medium	None	None	Medium	Low
Impact on Green Opportunities	Counter	Parallel	Neutral	Parallel	Counter	Parallel

Based on the results of the evaluation, SD1 selected Scenario 4 (highlighted in Table 7.31 above), a phased rehabilitation approach with private source I/I removal and storm water management. This decision was based on several criteria important to SD1's watershed planning objectives:

- Improve water quality;
- Eliminate overflows in a residential area to protect public health;

- Reduce wet weather flows to downstream systems, benefiting downstream capacity concerns;
- Consistency with SD1's desire for green solutions; and,
- Integration with the overall Watershed Planning for this location

Scenario 4 was the lowest cost alternative to eliminate typical year overflows (based on model results), and was the best fit for SD1's criteria. In addition, this scenario could ultimately be even lower cost, depending on the actual I/I reduction obtained from the improvements.

Based on the ranking and funding factors described in Section 4, the Lakeside Park Priority Area projects will be phased, with the initial phase occurring in the first Five-year Improvement Program. This first phase will include the Van Deren and Avon Drive local projects, rehabilitation of approximately 25 percent (approximately 16,000 linear feet) of the study area's sanitary sewers, and initiation of private source I/I elimination programs with the residents of the area using downspout disconnection, residential rain gardens and rain barrels.

This phased approach has many advantages. The approach will enable SD1 to begin sewer rehabilitation and private I/I removal programs on a demonstrative basis. The programs can provide valuable data and experience as SD1 develops and applies the full program in other areas of the sewer system. The phased approach also allows time for SD1 to measure the results of the Van Deren Sanitary Sewer Improvements and the Avon Drive Sanitary Sewer Improvements projects. It enables the most likely areas for I/I to be rehabilitated first, measures the effects, and adjusts the next phase to achieve the desired level of service most cost-effectively.

This study area has many characteristics that make it a prime candidate for innovative storm water control solutions including:

- Numerous SSOs,
- Prevalence of private source I/I connections,
- A system of privately owned lakes,
- Downstream flooding problems, and
- Expensive traditional gray solutions.

SD1 has decided to undertake a comprehensive evaluation of the study area that not only considers the SSO issue, but also addresses insufficient storm water conveyance and downstream flooding. The goal of this approach is to maximize the benefits to the community for the money invested. This holistic approach minimizes the potential of simply moving the problem to another pipe or another location downstream.

Based on a study previously conducted by SD1, a significant number of private source I/I connections to the sanitary sewer system exist in the study area. SD1 has evaluated the potential to use green infrastructure elements such as downspout disconnection, residential rain gardens and rain barrels to capture runoff from residential properties that are currently being directed to the sanitary sewer system. With the large number of private source I/I connections, the reductions in runoff volume discharging to the sanitary sewer system is likely significant. Additionally, the lake system is being evaluated to determine if small reconfigurations of the outlet control structures can

improve the overall storm water control function of the lakes in an effort to reduce downstream flooding. This effort will also consider the conveyance of the additional storm water that is being removed from the sanitary sewer. Green infrastructure components, such as rain gardens and bioswales, are also being evaluated in an effort to reduce the volume of runoff in the Lakeside Park area.

Conclusions

The three comprehensive projects in Lakeside Park and Fort Mitchell described above are expected to have a significant impact on SSO reduction within the Five-year Improvement Program. Monitoring of these efforts will be performed to evaluate overall performance.

With an estimated capital cost of $1,806,000, the Van Deren Sanitary Sewer Improvement project is expected to reduce overflow activations in the Lakeside Park Priority Area for the typical year based on modeled I/I reductions. The Avon Drive 24-inch Sanitary Sewer Improvement project is estimated to cost $208,000 and is projected to eliminate overflows at MH 1610114. SD1 completed both of these projects in 2010.

SD1 is proceeding with rehabilitation of approximately 25 percent (approximately 16,000 linear feet) of the highest priority sections of the sanitary sewer in the Lakeside Park study area (in addition to the Van Deren Sanitary Sewer Improvements), and private source I/I removal programs and innovative storm water controls in the first Five-year Improvement Program. This work is estimated to cost $5,000,000.

7.6.5 Willow Run Priority Area

Background

Covering portions of the cities of Covington, Park Hills, and Fort Wright, the Willow Run Priority Area includes SD1's largest CSO, generating almost 40 percent of the system's annual CSO volume. This area of SD1's system used to be a natural drainage course called Willow Run Creek. At the turn of the century, this creek was steadily converted to a culvert pipe as infilling and growth occurred in the area. When I-75/I-71 was constructed, the entire drainage course was converted to culverts. Shown on Figure 7.68, the Willow Run CSO outfall is primarily a 10 feet by 12 feet concrete culvert that drains 1,825 acres with seven diversions and four upstream CSOs. The figure also delineates the combined basins in the Willow Run area, along with storm basins where the flows discharge from open channels directly into the combined system.

Figure 7.68 Willow Run Priority Area Summary Map

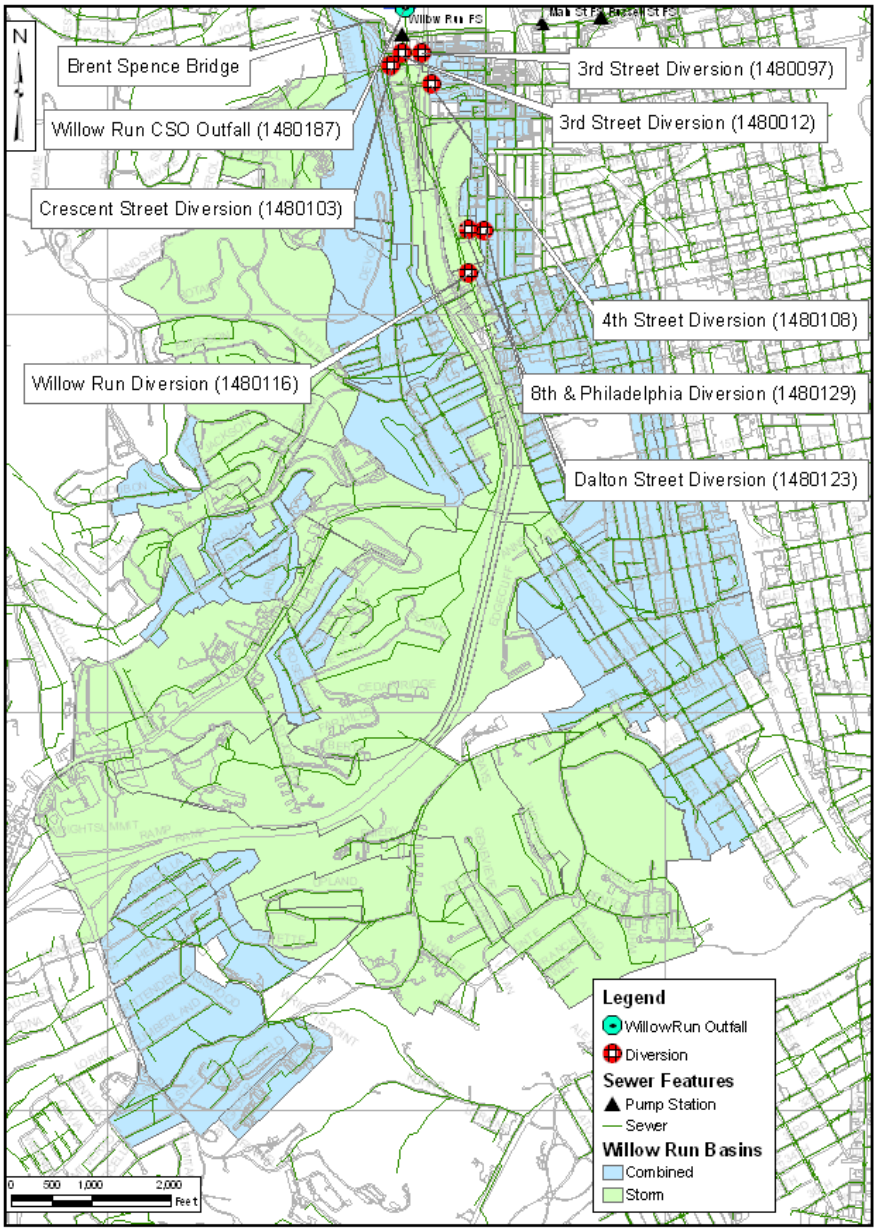


Table 7.32 summarizes the annual overflow statistics for the Willow Run CSO and its four upstream CSOs based on the 2008 hydraulic model. The annual simulations used SD1's selected typical year of 1970 and include high river level operating rules (restricting the Bromley PS to one small pump under high river conditions, Ohio River stage 41 feet and above). Of the seven diversion structures discharging to the Willow Run CSO outfall, the Willow Run diversion at the south end of Goebel Park accounts for most of the overflow volume.

Table 7.32 Willow Run Priority Area – Annual Overflow Statistics for Area CSOs[1]

CSO Outfall ID	Common Name	Direct Discharge to Ohio River?	Typical Year Spill Frequency (Number)	Typical Year Volume (MG)
1480187	Willow Run CSO	Yes	77	614.00
1320112	Dixie Highway and S. Arlington	No	0	0
1350155	Park Hills and Dixie Highway	No	4	0.13
1380132	Amsterdam and Parkvale	No	3	0.24
1380146	Amsterdam and Arlington	No	2	<0.01

[1] Notes: Hydraulic model results based on SD1's current understanding of the combined sewer system (November 2008). Annual simulations use SD1's selected typical year of 1970 and include river influence. Results are based on 5-min output, 7-hr inter-event period; 0.01 MGD peak flow and 0.001 MG volume thresholds.

SD1 Objectives

The Willow Run system emerged as a Priority Area due to a mix of features, and each of these features can be associated with a SD1 objective:

- The area includes the single largest CSO in SD1's sewer system, creating an objective to reduce CSO activity through cost-effective early action projects.
- The Federal Highway Administration (FHA) project to replace/rehabilitate the Brent Spence Bridge will run in parallel with SD1's watershed improvement program and Consent Decree. The bridge project will impact how the Willow Run CSO is addressed since all storm water from the highway and bridge system currently drain through the Willow Run CSO. SD1 is committed to coordinating with the bridge program as appropriate to minimize interference between the two projects and maximize partnering opportunities.
- Despite the urban setting, the combination of green space, surface streams, and the interstate highway corridor provide a backdrop for many green and watershed opportunities. A key SD1 objective is to maximize these opportunities in the first Five-year Improvement Program.

SD1 is committed to reducing overflows from the Willow Run CSO, but to do so cost-effectively without investing dollars that could be wasted because of the Brent Spence Bridge replacement project. With annual overflow volumes exceeding 600 MG, the Willow Run CSO is a classic case where typical control levels require massive and often unaffordable infrastructure solutions, with potentially limited benefits to the waterway (Ohio River).

In addition, large infrastructure projects associated with controlling the Willow Run CSO would potentially conflict with the Brent Spence Bridge Replacement/Rehabilitation Project. With construction expected to start in 2015, the Brent Spence Bridge project will greatly affect the Willow Run CSO drainage basin and outfall for the next several

five-year planning cycles. Listed as functionally obsolete in the National Bridge Inventory, the Brent Spence Bridge and its approaches carry I-71 and I-75 traffic across the Ohio River. As an important river crossing vital to national commerce, the Brent Spence upgrade is a top priority for KYTC, the Ohio Department of Transportation (ODOT), and the cities of Cincinnati and Covington.

Figure 7.69 shows the currently-defined project limits for the Bridge Replacement/Rehabilitation Project, which addresses the current bridge and its approaches. The project will also expand the current highway from six to potentially twelve lanes between the Ohio River and 2,300 feet south of the I-75 and Dixie Highway interchange in Kentucky. With the large overlap between the project limits and the Willow Run CSO outfall pipe, any large infrastructure solutions installed in the short term could be wasted money, since they might require removal with the bridge project.

Figure 7.69 Project Limits of the Bridge Replacement/Rehabilitation Project (FHA, 2008)

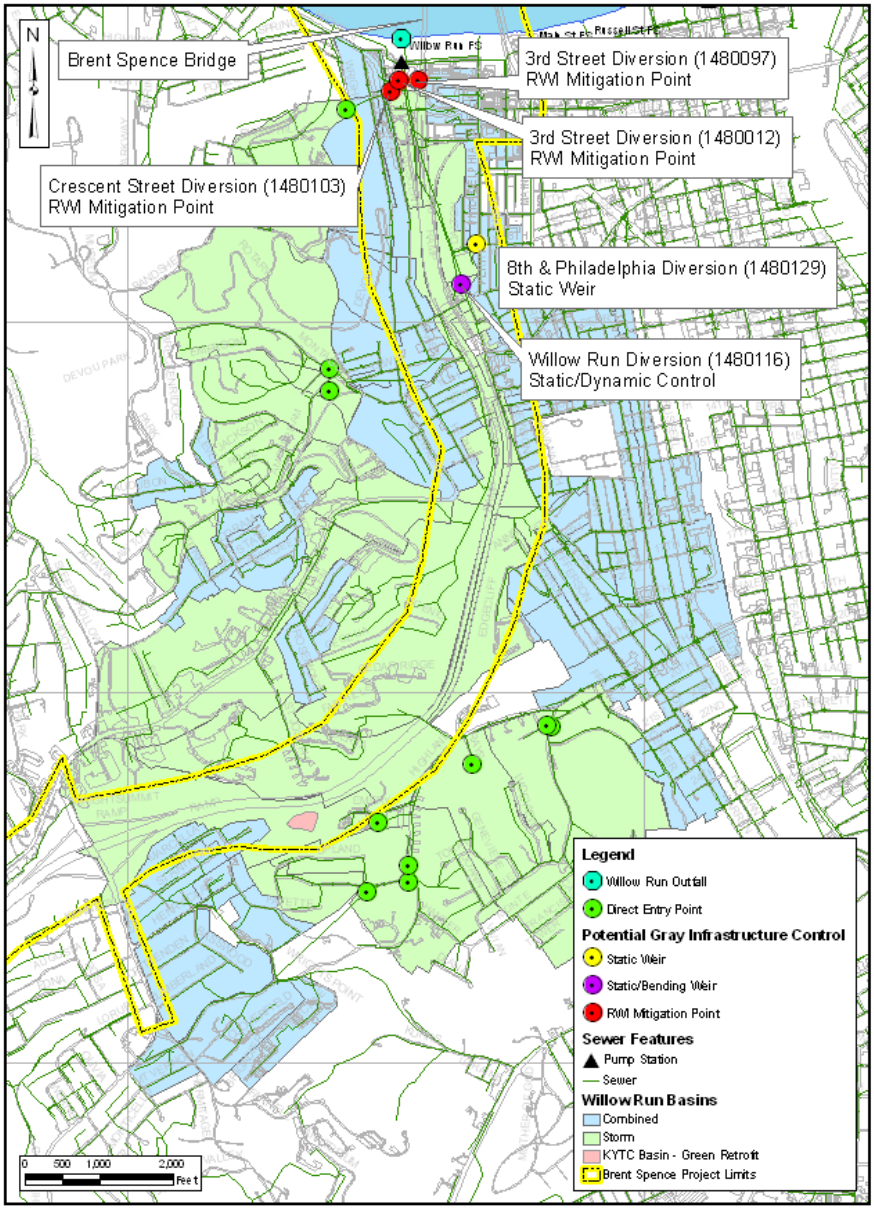
While the Brent Spence Bridge project could increase CSO discharges with more highway runoff, the project also provides partnering opportunities for SD1 and KYTC to reduce overflows through coordination and cost-sharing. Specific decisions have not yet been made; however, preliminary conversations with KYTC suggest that runoff from the Brent Spence Bridge, its approaches, and the highway expansion may be addressed through a dedicated storm water system. The potential for a dedicated storm water system offers SD1 a significant opportunity to cost-effectively redirect the open channel storm flow away from the combined sewer system. In addition, the dedicated storm water system offers the opportunity for integration with a number of green infrastructure features, from upstream ravine features to storm water treatment wetlands at the downstream end.

Given the impacts and opportunities provided by the Brent Spence Bridge project, SD1 will emphasize pursuit of short-term improvements for the proposed Five-year Improvement Program that will complement/benefit any potential long-term directions for the Willow Run Priority Area in future Watershed Plans. SD1 will also pursue coordination and cost-sharing opportunities available through the Brent Spence Bridge project with KYTC to lay the foundation for cost-effective, long-term overflow solutions for Willow Run in subsequent plan cycles. The following sections discuss the details of SD1's proposed Five-year Improvement Program for the Willow Run Priority Area.

Potential Control Alternatives

Figure 7.70 shows the locations for several potential control alternatives evaluated for the Willow Run Priority Area. Gray infrastructure alternatives include solids and floatables control, River Water Intrusion (RWI) mitigation, and dynamic controls for inline storage at the Willow Run diversion. Figure 7.68 also overlays the currently-defined project limits for the Brent Spence Bridge project with the Willow Run sewer system. Green infrastructure alternatives include retrofit of KYTC drainage basins, a constructed wetland, sewer separation projects, and ravine treatments along the I-71/I-75 highway corridor. The constructed wetland could likely be located in Goebel Park, providing treatment for and then discharging storm water runoff to the potential Brent Spence Bridge dedicated storm water system.

Figure 7.70 Willow Run Priority Area – Potential Controls



Evaluation of Alternatives

Gray Infrastructure

Table 7.33 summarizes the gray infrastructure alternatives "menu" developed for the Willow Run Priority Area for potential inclusion in SD1's Five-year Improvement Program. Goals for these alternatives include reducing the volume and activity of CSO discharges and maximizing capacity in the existing sewer system.

Table 7.33 Willow Run Priority Area – Potential Control Alternatives Summary

Goal	Alternative Summary
NMC – Overflow Reduction	Install 3-feet high weir for solids and floatables control at the 8th and Philadelphia diversion
	Increase weir height by ~2 feet at Willow Run diversion
NMC - Maximizing In-System Flow and Capacity	Install rubber duckbill style check valves at three Willow Run diversions to mitigate RWI Install multiple rubber duckbill style check valves or sluice gates at the Willow Run diversion to mitigate RWI
NMC - Maximizing In-System Flow and Capacity	Install bar racks on 10 direct entry points where open storm channels discharge into sewer system
Overflow Reduction/ Maximizing In-System Flow and Capacity	Install dynamic controls in new chamber at Willow Run diversion for inline storage

Static Weirs

As part of NMC compliance efforts, discussed previously in Section 7.2.2, SD1 conducted field investigations and performed hydraulic modeling for potential static weir locations at the 8th and Philadelphia and Willow Run diversions. These analyses evaluated potential overflow reductions from increasing weir height without creating an unacceptable risk of basement or surface flooding.

For these locations, flooding risk was minimized by maintaining a minimum of eight feet of freeboard in diversion manholes and surcharged pipes under four design storm/river stage combinations:

- 25-year 30-min design storm with no river influence;
- 25-year, 1-hour design storm with no river influence;
- 2-year, 30-min design storm with the Ohio River set at 40-ft stage; and
- 2-year,1-hour design storm with the Ohio River set at 40-ft stage.

For locations with less than eight feet of available freeboard under current conditions, the recommended static weir height increases do not cause surface flooding at the diversion manholes and do not exacerbate existing hydraulic gradelines under the four design storm/river stage combinations.

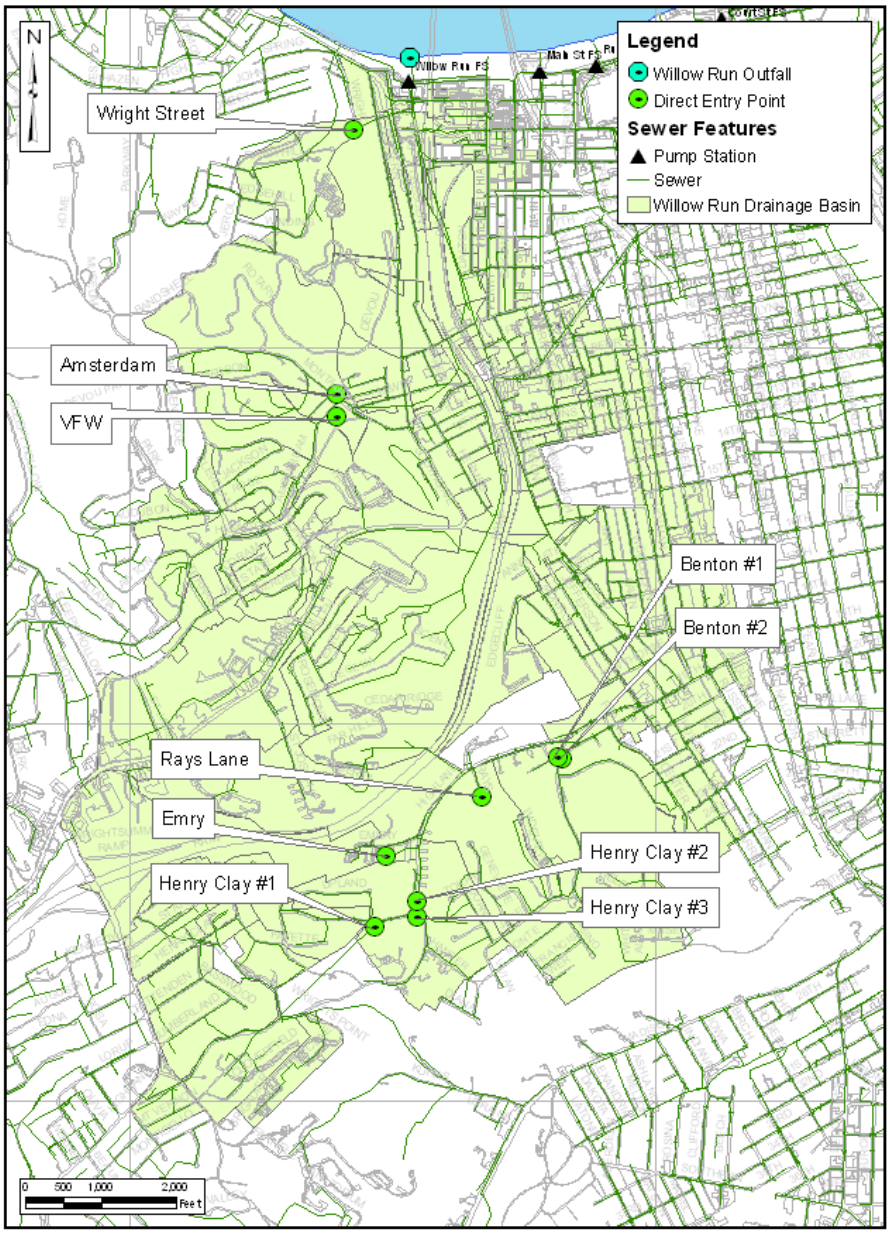
Rubber Duckbill Style Check Valves for RWI Mitigation

As discussed in Section 7.3.1, installation of rubber duckbill style check valves to minimize river water intrusion and maximize in-system capacity for wet weather flows was also assessed at the four Willow Run diversions with overflow bypass elevations below an Ohio River stage of 47 feet. This elevation was selected because existing Army Corps of Engineers flood control gates isolate the Willow Run outfall above river stages of 47 feet. While a single installation is infeasible at the Willow Run diversion with its 10-foot wide outfall pipe, single rubber duckbill style check valves were recommended for Crescent St, 3rd St at I-75, and 3rd St at Liquor Store. Multiple rubber duckbill style check valves, sluice gates, or other technology will be installed for RWI mitigation at the Willow Run diversion.

Direct Entry Point Bar Racks

Installation of bar racks was considered at ten direct entry points where open storm channels discharge into the Willow Run sewer system. Shown on Figure 7.71, most of these direct entry points are open pipes that enable rocks and debris to enter into the combined sewer pipes. SD1 plans to improve these direct entry points by constructing a custom bar rack facility at each location to prevent debris from entering the sewers. These bar rack openings would reduce the influx of rocks and debris into the sewer system, thereby minimizing the potential for restricted system capacity. The bar rack design will also provide an overflow into the CSS should the bar racks become blinded.

Figure 7.71 Willow Run Direct Entry Point Locations



In general, bar rack solutions were chosen based on site conditions for each direct entry point location. Table 7.34 lists each direct entry point and the dimensions of its associated discharge location. As part of the evaluation, the hydraulic performance of each location was also assessed to determine whether any nearby buildings would be at risk for flooding when the bar rack was blinded.

Table 7.34 Willow Run Direct Entry Points

Direct Entry Point	Inflow Pipe Size
Amsterdam	60”
Benton #1	18”
Benton #2	54”
Emry	24”
Henry Clay #1	18”
Henry Clay #2	30”
Henry Clay #3	30”
Rays Lane	24”
VFW	65”H x58.5” W
Wright Street	30”

Willow Run Diversion - Dynamic Controls for Inline Storage

SD1 examined the potential for overflow reductions at the Willow Run diversion using dynamic controls to maximize inline storage of wet weather flows. During small rainfall events, when the sewer system has excess capacity, dynamic regulator controls are typically set at their maximum height, thereby increasing wet weather storage and minimizing overflow volumes. During large events, the dynamic control lowers the overflow weir to its minimum height reducing the risk of upstream basement or surface flooding.

Basement and surface flooding upstream of the Willow Run diversion under current conditions were assessed for the four design storm/river combinations detailed previously (under the static weirs discussion). 2008 system-wide model results showed that flooding and surcharging were most extensive for the 25-year 30-minute design storm scenario. Since the existing Willow Run diversion and its upstream sewer system show model-calculated surface flooding and less than eight feet of available freeboard under peak conditions for the 25-year 30-minute design storm, dynamic controls were developed to prevent flooding to ground at the diversion and to not exacerbate upstream hydraulic gradelines during the five-year 30-minute design storm.

With the identified dynamic control settings, typical year simulations with SD1’s 2008 system-wide hydraulic model showed local overflow reductions of 146 MG at the Willow Run CSO and system-wide overflow reductions of 53 MG (assuming installation of improvements only at Willow Run, i.e., no other inline storage facilities) relative to current conditions. System-wide overflow volume reductions are lower due to dewatering impacts; with increased flows to downstream interceptors from dewatering

of the volume stored behind the dynamic control, increases in overflow volume and activity at downstream outfalls are calculated to occur. For consistency with previous results in the NMC Compliance Report, these overflow reduction results do not account for system operation under high-river level operating rules (restricting the Bromley PS to one small pump under high river conditions, Ohio River stage 41 feet and above).

Table 7.35 provides details on the local and system-wide benefits of the Willow Run dynamic controls relative to SD1's system-wide NMC improvements program (discussed in Section 7.2.1). Relative to the existing system as represented by the 2008 hydraulic model, the NMC improvements program reduces system-wide CSO volumes by 379 MG during the typical year. Installation of dynamic controls at Willow Run reduces local overflow volumes by an additional 92 MG, and reduces system-wide overflow volumes by an additional 63 MG, for a total 442 MG overflow reduction.

Table 7.35 Willow Run Dynamic Controls Benefits Summary

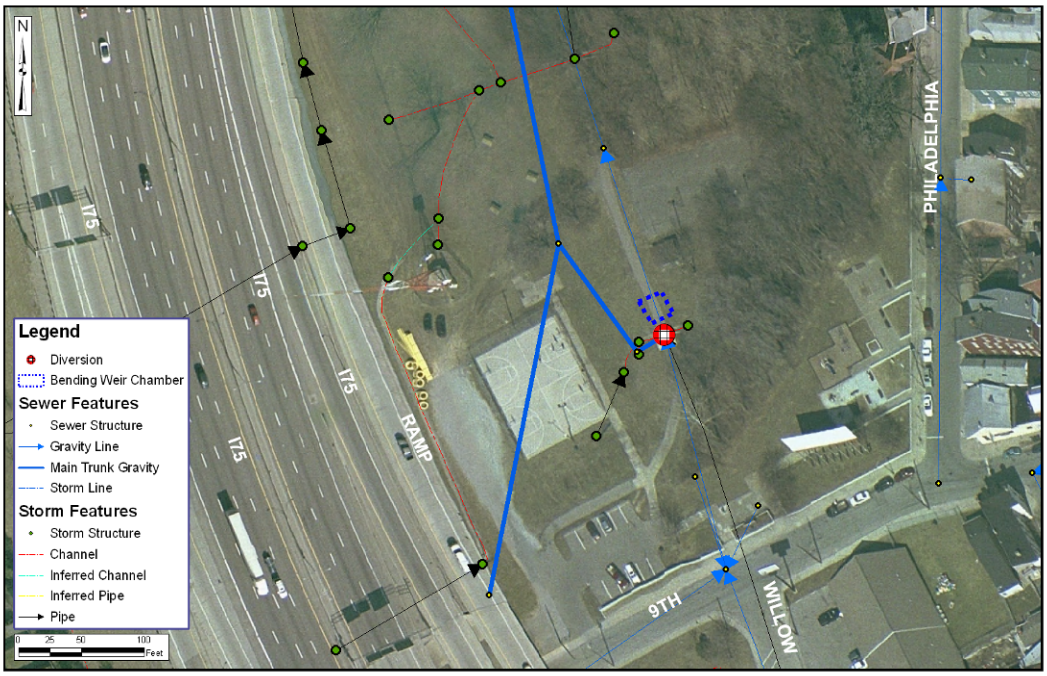
CSO Outfall ID	CSO Name	System-Wide NMC Improvements	Add Willow Run Dynamic Controls[1]	Overflow Volume Difference (MG)
		Typical Year Overflow Volume (MG)	Typical Year Overflow Volume (MG)	
1480187	Willow Run	548	456	-92
All Other CSOs		946	975	29
Total CSO Volume		1494	1431	-63

Note:

1. The presented results were generated by the hydraulic model assuming implementation of river water intrusion mitigation (up to 47 feet), the static weir inline storage program, and Bromley PS wet well modifications.

Figure 7.70 shows the proposed location for the dynamic control installation in a new chamber at the Willow Run diversion at the south end of Goebel Park. Configured to discharge to the existing 10-foot outfall pipe, the square chamber facility will also include space for the multiple rubber duckbill style check valves or sluice gates for mitigating river water intrusion up to an Ohio River stage of 47 feet. Total capital costs for the installation are projected at $588,000 in 2009 dollars. Preliminary conversations with KYTC also suggest no conflict between the footprint for the dynamic controls facility, and the construction limits for the Brent Spence Bridge upgrade project. As of February 13, 2009, KYTC expects construction limits to extend to the edge of the basketball courts shown on Figure 7.72.

Figure 7.72 Proposed Willow Run Dynamic Control Facility Location



Evaluation of Alternatives

Green Infrastructure

One of the most significant outcomes of the green evaluations conducted to date was the identification of the I-71/I-75 corridor from Kyles Lane north to the Ohio River, as an area with multiple, highly visible green infrastructure opportunities. SD1 quickly realized the opportunity to create a green infrastructure concept plan along this major highway corridor that would not only benefit the largest CSO in the combined system, but would also provide great partnership opportunities. Key components of this I-71/I-75 Corridor Green Infrastructure Concept Plan are discussed below.

Goebel Park

Green infrastructure can transform Goebel Park into 'Kentucky's Green Gateway'. A proposed wetland park can help remove storm water runoff from the combined sewer system, improve water quality, and create a valuable recreational amenity for the entire region. Most significant was the commitment from KYTC to work with SD1 to explore the incorporation of green components within the existing right-of-way within the context of the upcoming Brent Spence Bridge project.

While this significant transportation project is still in the planning phase, early coordination between SD1 and KYTC has resulted in several significant opportunities to integrate project goals and objectives benefiting each agency. For example, preliminary conversations have shown that KYTC is considering construction of a dedicated storm water system to convey highway runoff directly to the Ohio River. If SD1 redirected additional runoff from the CSS to a new storm water system, potential overflow

reductions at the Willow Run CSO could be significant. SD1 and KYTC are also evaluating the potential to utilize portions of low-lying areas of Covington's Goebel Park for green infrastructure that could treat the runoff prior to discharging to the Ohio River. The combination of these alternatives would reduce runoff to the CSS, improve the quality of the runoff to the river and provide the City of Covington with a community amenity at its gateway.

KYTC Basin – Green Retrofit

Detention basins located in the interstate corridor provide highly-visible opportunities for integrating green infrastructure. Retrofitting existing overflow structures can help capture and infiltrate storm water, ultimately reducing the volume that reaches the combined sewer system. Integrating natural plant species and filtering sediment will help improve the quality of water that is discharged from these basins to the Ohio River.

There are four KYTC-owned dry detention basins along this stretch of I-71 and I-75. KYTC has indicated that they are open to evaluating SD1 plans to retrofit these facilities in a manner that would reduce the volume of runoff discharged to the SD1 CSS. While three of these basins may be impacted by the proposed roadway expansions as part of the Brent Spence Bridge project, one two-acre basin near the top of the watershed will not be affected by any of the proposed alignments currently being evaluated.

Runoff from a drainage area of approximately 110 acres drains to this existing detention basin located along the east side of I-71/I-75 in Covington. The existing detention basin includes an outlet control structure and piping system that ultimately discharges storm water to the SD1 combined sewer system. It is estimated that 25 million gallons of runoff enter the CSS and eventually flows to the Willow Run CSO from this facility on an annual basis. There is little to no detention of smaller more frequent storm events. Therefore, in a "typical" year, this basin provides very little benefit to the functioning of the CSS. Figure 7.73 shows the basin location and the drainage area to the basin.

Figure 7.73 KYTC Regional Bioretention Facility

SD1 plans to retrofit the existing basin with a 1.5 acre bioretention system to improve water quality and reduce the volume of runoff entering the CSS. The facility will include a layered system of gravel and engineered soil with a densely planted surface of native plants.

Preliminary modeling of the new facility indicates that for a three-month design storm, 750,000 gallons of storm water can be reduced from the system. This represents an estimated 80 percent reduction from current conditions.

It has been estimated that a storage tank to capture and store this equivalent volume would cost approximately $3,750,000. The estimated cost to construct the bioretention facility is $1,500,000. After construction, SD1 will monitor the volume of runoff entering and leaving the bioretention facility to determine the overall effectiveness of the system.

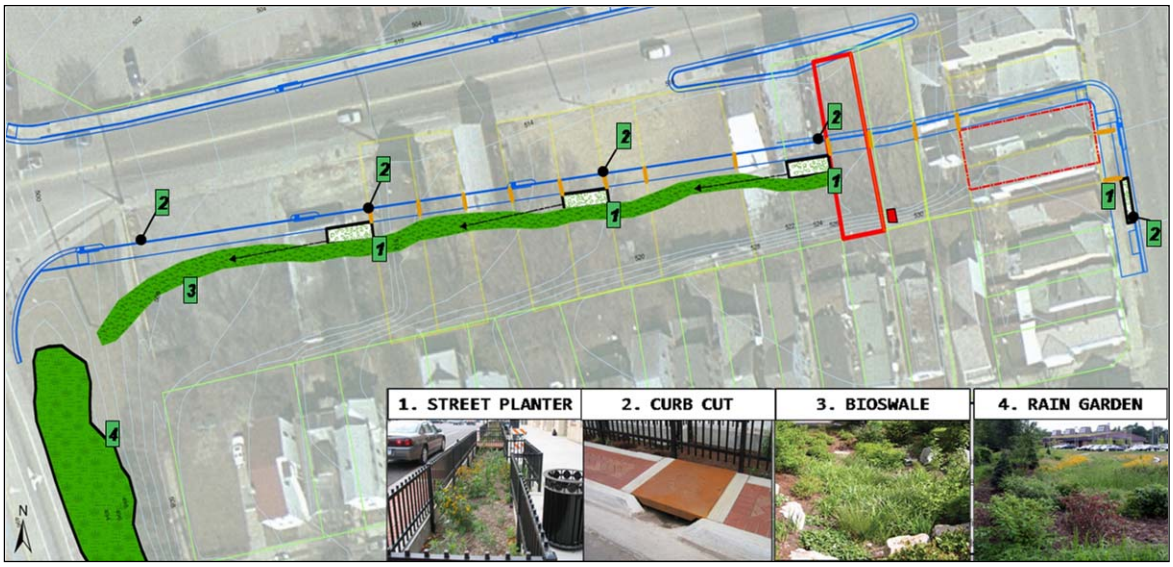
12th Street – Green Street

The City of Covington and KYTC have been developing plans for a major road expansion of the 12th Street corridor for almost eight years. Expansion of the right-of-way required the purchase, relocation and demolition of numerous homes, many of which had been deemed to have historical significance. One of the conditions of this project was that portions of approximately eight parcels of land immediately adjacent to the right-of-way be permanently preserved as an interpretive park to celebrate the history of this area.

SD1, the City of Covington, KYTC and the State Historic Preservation Office worked closely to evaluate the potential to incorporate green infrastructure elements into this road widening plan. The result has been an innovative design that incorporates roadside planters and a bioswale that collectively reduce the volume of runoff entering

the CSS from this new roadway. Additionally, these functional storm water controls were incorporated into the interpretive park elements that recognize the historical significance of this neighborhood. Figure 7.74 shows the green street location.

Figure 7.74 12th Street Green Street



St. Elizabeth Hospital

A new eight-acre hospital facility for St. Elizabeth's is being constructed on a formerly undeveloped parcel of land in Covington. This facility is located immediately adjacent to I-71/I-75 on the east side of the highway at the base of what is locally known as the "cut in the hill". SD1 realized the benefits of partnering with St. Elizabeth to incorporate green infrastructure into the site design. As a result of this partnership, potential retrofit of a regional KYTC detention basin into a large rain garden was identified on St. Elizabeth's campus. The large rain garden system provides for the control of runoff from the site and an additional 30 acres of off-site drainage. Construction of this facility began in 2008, and it is currently operational. SD1 is performing post-construction monitoring to determine the effectiveness of the regional facility.

Corridor Reforestation

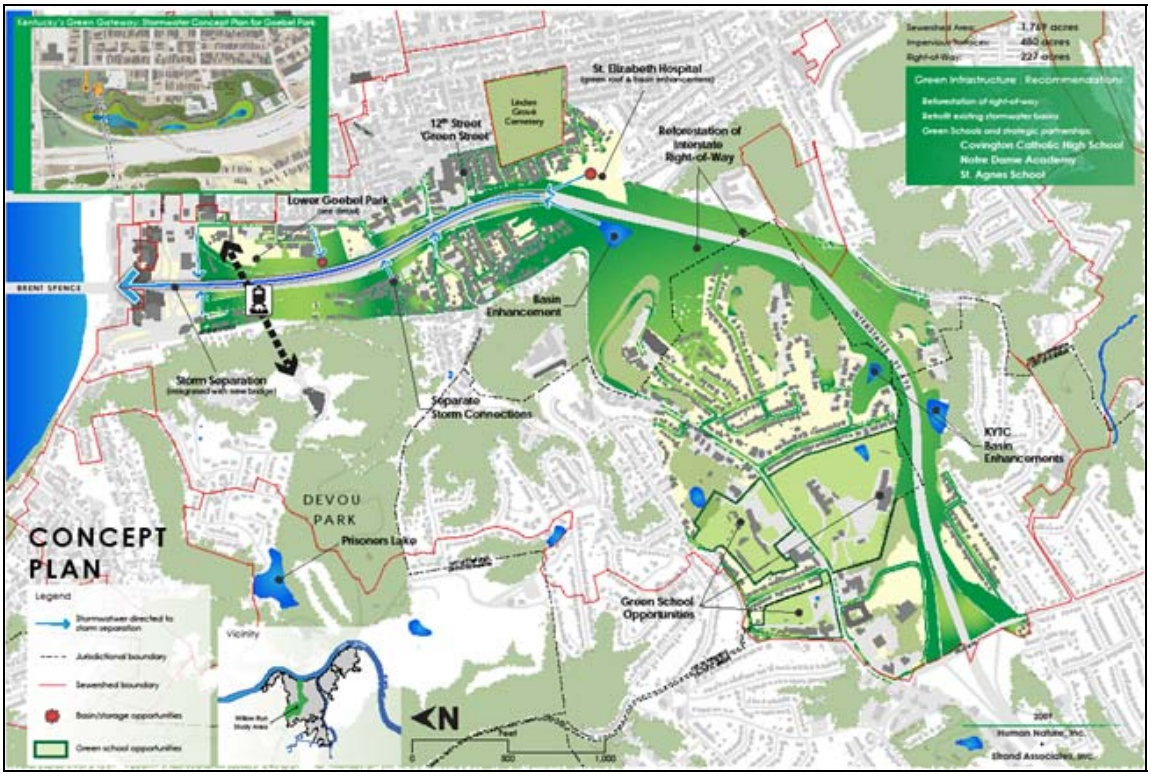
There are 227 acres of right-of-way in the I-71/I-75 corridor from Kyles Lane north to the Ohio River, which discharge to the Willow Run CSO. Adaptive reforestation techniques along interstate right-of-way will help capture and infiltrate storm water, while creating a unique and innovative green highway corridor through Northern Kentucky.

The series of vegetated berms would include bioretention features and trees. The berms would be strategically constructed along specific contours to intercept runoff from the upstream drainage area. The existing soil would be augmented with more permeable soil to promote better infiltration. Trees would be incorporated into the berm system to promote interception, evapotranspiration and infiltration. The goal of this innovative system is to reduce the amount of runoff that enters the combined sewer system while providing an aesthetic amenity to the community.

Strategic Partnership

Engaging public and institutional agencies helps create green infrastructure programs that have the momentum to survive future changes in government and program priorities. Collaboration with local stakeholders, such as students and teachers, should be an integral component of the green infrastructure strategy. There are 241 acres of public and semi-public properties located in the Willow Run Study Area. Figure 7.75 show the combination of all of the components of the green infrastructure plan for the I-71/ I-75 corridor.

Figure 7.75 I-71/I-75 Corridor Green Infrastructure Concept Plan



Conclusions

Based upon the gray and green infrastructure alternatives evaluations, Table 7.36 summarizes the recommended projects for inclusion in SD1's Five-year Improvement Program to address overflows in the Willow Run Priority Area. In combination, these short-term improvement projects will reduce CSO discharge volumes and activations and will complement the long-term program directions. In the short-term, this flexibility will save SD1 money by not investing in infrastructure controls with limited benefit, and will allow SD1 the flexibility to develop solutions that take full advantage of coordination and cost-sharing opportunities with the Brent Spence Bridge upgrade project.

Table 7.36 Willow Run Priority Area - Recommended Five-Year Projects

Project Description	Capital Cost in 2009 Dollars ($ Millions)	Site-Specific Benefits
Static Weir at 8th and Philadelphia Diversion	$0.01	Reduces local CSO discharges at outfall by approximately 70 MG during typical year (assuming no other static weir inline storage facilities and excluding high-level river influence). This project was completed as part of SD1's NMC program.
Static Weir at Willow Run Diversion	$0.008	
RWI - Rubber Duckbill Style Check Valves at Crescent St, 3rd St at I-75, and 3rd St at Liquor Store diversions	$0.09	Increases in-system wet weather volume and flow capacity
Willow Run Direct Entry Point Bar Racks	$0.06	Reduces lost system capacity and overflows due to blockages
Willow Run Dynamic Control	$1.0	Reduces system-wide CSO discharges by 60 MG during typical year (relative to system-wide NMC improvements program)
KYTC Basin Retrofit	$1.5	Reduces runoff by 0.75 MG for a 3-month design storm event

7.6.6 Summary of North Basin Projects

The recommended North Basin projects, costs, and benefits are shown in Table 7.37.

Table 7.37 North Basin Five-Year Projects

Project Name	Benefits	Cost in 2009 Dollars ($ Million)
Allen Fork PS Overflow Elimination	Eliminates pump station overflow and meets Consent Decree requirement	$6.7
Lakeside Park – Public Sewer Rehab and Private Source Removal	Improves public health; eliminates SSO, improve storm water quantity and quality	$5.0
Van Deren Sanitary Sewer Improvements	Eliminated/ reduced SSOs and illicit discharges. Controls I/I	Refer to "High-priority sewer projects" in Table 8.5
Avon Drive Sanitary Sewer Improvements	Eliminates SSOs	Refer to "Ongoing Sewer Rehabilitation / Repair projects" in Table 8.5
Willow Run Dynamic Control	CSO reduction using inline storage	$1.0
Willow Run Direct Entry Point Bar Racks	Reduce debris entry into system, maintain capacity and reduce blockages	$0.06
KYTC Basin – Green Infrastructure Retrofit	CSO reduction, informs future green infrastructure design	$1.5
Taylorsport PS Overflow Elimination	Eliminated pump station overflow and meets Consent Decree requirement	Completed
South Park PS Overflow Elimination	Eliminates pump station overflow and meets Consent Decree requirement	Refer to "Pump Station Backup Power" in Table 8.5
	Total	$14.3

7.7 West Basin Projects

Within the West Basin (Gunpowder Creek, Big Bone Creek, and Ohio River West), the majority of work within the Five year Improvement Program is in the construction of the Western Regional Conveyance System and Water Reclamation Facility, the details of which are described in Section 7.1, the Initial Watershed Projects. Additional projects within the West Basin are described in the following sections and include:

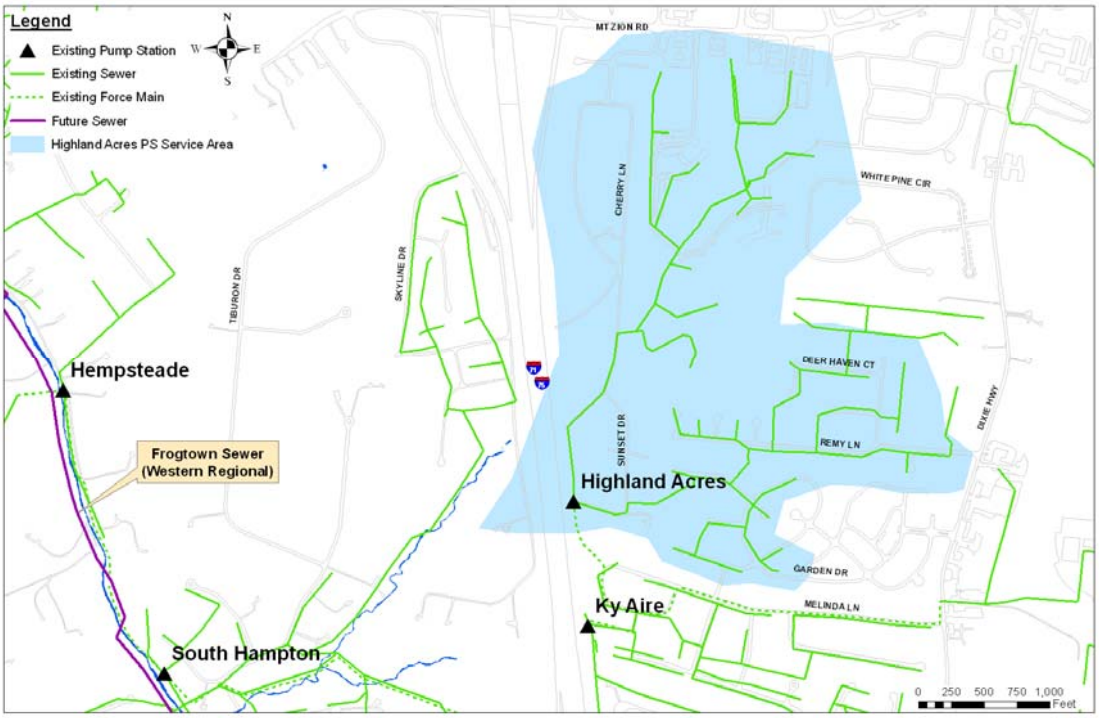
- Highland Acres PS overflow elimination,
- Kentucky Aire PS overflow elimination,
- South Hampton PS overflow elimination, and
- Union PS overflow elimination.

7.7.1 Highland Acres Pump Station Overflow Elimination

Background

Highland Acres Pump Station is a separate sanitary pump station in Boone County; it is located on an access road at the end of Sunset Drive, just east of I-71/I-75. The station receives flow from approximately 225 acres of tributary area and pumps to the Kentucky Aire Pump Station that eventually flows to the Lakeview system. Figure 7.76 shows the current service area. The pump station contains three pumps with a firm capacity of approximately 1.2 MGD and a wet weather peak capacity of approximately 1.5 MGD based on the results of the field testing. This pump station has a backup power generator.

Figure 7.76 Highland Acres Pump Station Service Area



During large wet weather events when the capacity of the pump station is exceeded, an overflow occurs into a small creek that is tributary to the South Fork Gunpowder Creek. SD1 has limited the potential for wet weather issues to occur at the pump station through proactive measures to reduce wet weather I/I. The hydraulic model predicts that overflows due to the pump station capacity limitations occur once in a typical year period, with a volume of less than 0.1 MG. According to SD1's Pump Station Overflow Elimination Plan, SD1 is scheduled to eliminate the overflow by December 31, 2010 (SD1, 2008c).

As shown in Figure 7.76, the pump station is located near the Western Regional improvements (and specifically the Frogtown sewer). Once the Western Regional WRF is on line in 2013, the flow from Highland Acres could be conveyed via gravity sewer to the proposed Frogtown Gravity Sewer, which flows to the Western Regional WRF. The Frogtown Sewer and new plant were both sized to handle peak flows from this region. Conveying flow from this area to the Western Regional system would reduce flows to the Lakeview sanitary system, which experiences capacity issues during wet weather events. However, because the deadline for eliminating the overflow from Highland Acres occurs earlier than the Western Regional improvements planned completion, several alternatives for controlling the overflow in the interim were evaluated.

Potential Control Alternatives

Three alternatives were considered at the Highland Acres Pump Station:

- Storage – inline versus tank,
- Pump Station upgrade, and
- Gravity sewer to Kentucky Aire.

In order to maximize SD1's investment, the most cost-effective option was determined to be the construction of a gravity sewer to the Kentucky Aire Pump Station in the near-term to meet the Consent Decree deadline of December 31, 2010. The downstream impact of conveying additional flow to the Kentucky Aire Pump Station is minimal, as the peak flows from the drainage areas do not always reach the pump station at the same time. Within the model simulation of the typical year period, the overflow volume at Kentucky Aire was essentially unchanged with the addition of the gravity sewer, due to the fact that the sewer provided some attenuation of peaks relative to the peak capacity of the pump station in some events. In a small number of events, the peak flow to Kentucky Aire was increased with the addition of a gravity sewer, but in some other events, the peak flow reaching Kentucky Aire was decreased due to the lack of a pump station.

When the Western Regional System is online in 2013, the flow from the Kentucky Aire system may then be conveyed via gravity to the Western Regional Frogtown sewer; a solution that will be discussed in further detail in the following section. Not only does eliminating both pump stations by gravity flow reduce the operation, maintenance, and energy costs associated with the pump stations, but this alternative also redirects flow that is currently being conveyed to the Lakeview system. A reduction in flow imposed upon the Lakeview system will benefit the SSOs within the Lakeview tributary system as well as the pump station.

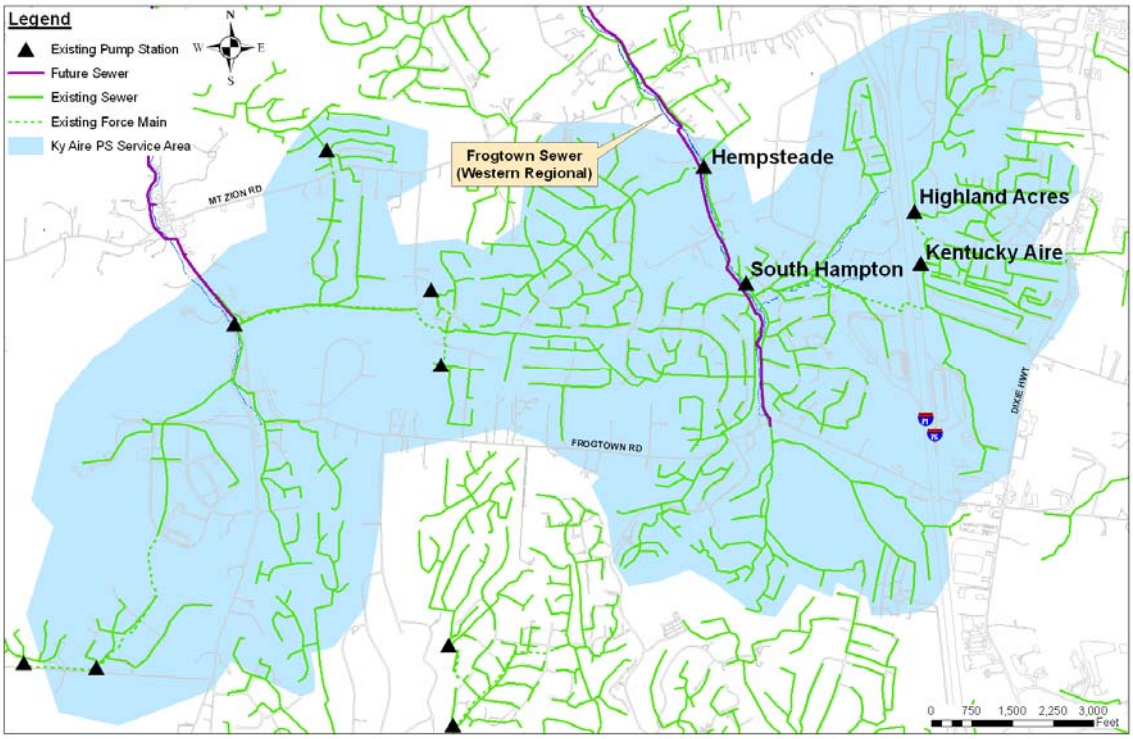
The new gravity sewer and elimination of the Highland Acres PS was completed ahead of the December 31, 2010 deadline specified in the approved Pump Station Overflow Elimination Plan.

7.7.2 Kentucky Aire Pump Station Overflow Elimination

Background

Kentucky Aire Pump Station is a separate sanitary pump station located in Boone County, at the end of Villa Drive, just east of I-71/I-75. The pump station receives flow from Highland Acres PS and South Hampton PS in addition to its gravity service area and conveys flow to the Lakeview sanitary system. The Kentucky Aire service area is shown in Figure 7.77. The pump station contains three pumps with a current firm capacity of approximately 2.4 MGD and wet weather peak capacity of approximately 3.0 MGD based on the results of field testing. A backup power generator was installed in 2008 along with upgrades to the valve vault and pump discharge piping.

Figure 7.77 Kentucky Aire Pump Station Service Area



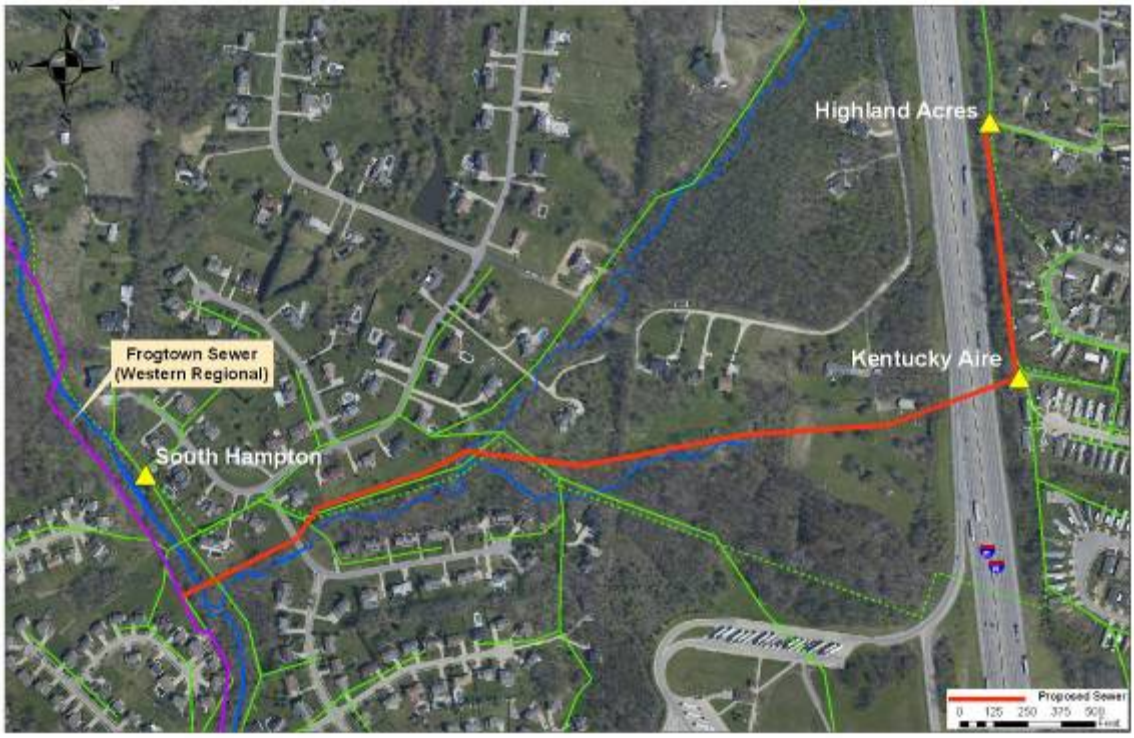
During large wet weather events, when the capacity of the pump station is exceeded, the pump station overflows into a small creek that is tributary to the South Fork Gunpowder Creek. The majority of the wet weather flow to the pump station comes from the Highland Acres and South Hampton PSs as opposed to its own drainage area. The hydraulic modeling predicts that the overflow due to the pump station capacity limitations activates eight times in a typical year period, with a volume of 1.1 MG.

In the approved Pump Station Overflow Elimination Plan, submitted to the EPA on September 14, 2007, SD1 described a number of alternatives that would be analyzed to identify an ultimate solution for the overflow at the Kentucky Aire Pump Station by the December 31, 2015 deadline specified in the Consent Decree. As part of the Watershed Plans, SD1 reviewed available alternatives for Kentucky Aire and selected construction of a new gravity sewer to the proposed Frogtown Gravity Sewer as the proposed alternative.

Once the Western Regional WRF is online in 2013, the flow from the Kentucky Aire PS will be conveyed via a gravity sewer to the new Frogtown Gravity Sewer, which flows to the Western Regional WRF. The Frogtown Sewer and new plant were both sized to handle peak flows from this region. Conveying flow from this area to the Western Regional system will reduce flows to the Lakeview sanitary system, which experiences capacity issues during wet weather events. Not only is there a benefit to the Lakeview system, but implementing the gravity conveyance results in energy cost and operation and maintenance savings to SD1.

Potential layouts for the proposed gravity sewers from Highland Acres and Kentucky Aire PSs are shown in Figure 7.78.

Figure 7.78 Proposed Kentucky Aire and Highland Acres Gravity Sewers



Conclusions

After the South Hampton PS is redirected to the Frogtown sewer as part of the Western Regional improvements, a gravity sewer from the Kentucky Aire PS will eliminate any remaining overflows at the pump station. The alignment of the gravity sewer will require trenchless construction under Interstate 75. After the highway is cleared, the remaining alignment may be constructed via traditional open-cut methods along an existing waterway; however, this alignment will require acquisition of property easements. The estimated cost to construct the proposed sewer is $3.31M. Once this project is complete and the new Western Regional System and WRF are in service (scheduled to be completed in 2013), the Kentucky Aire Pump Station and overflow will be eliminated. SD1 is currently on schedule to eliminate the overflow by March 31, 2013 as stated in the approved Pump Station Overflow Elimination Plan.

7.7.3 South Hampton Pump Station Overflow Elimination

The elimination of the South Hampton Pump Station and overflow through gravity sewer construction, as identified in the Pump Station Overflow Elimination, is the planned overflow elimination solution for this PS. The new Frogtown sewer will be constructed to convey peak dry and wet weather flows under future build-out conditions to the new Western Regional WRF. Following completion of the Western Regional sewer conveyance system and WRF, the South Hampton Pump Station service area will be able to drain through this new sewer system. Once the new Western Regional

Collection System and WRF are in service (scheduled for 2013), a connection to the new Frogtown sewer will be made to eliminate the South Hampton PS and overflow and the existing tributary sewers will be connected to the new Frogtown sewer. Design of the Frogtown sewer is complete and bids were opened in December 2010. Construction is anticipated to begin in early 2011. This project is currently on schedule to be completed by the March 31, 2013 date approved in the Pump Station Overflow Elimination Plan, well ahead of the Consent Decree deadline of December 31, 2015.

7.7.4 Union Pump Station Overflow Elimination

The elimination of the Union Pump Station and overflow through gravity sewer construction, as identified in the Pump Station Overflow Elimination Plan, is the planned overflow elimination solution for this station. The new 36-inch Union sewer will convey peak dry and wet weather flows under future build-out conditions to the new Western Regional WRF. Following completion of the Western Regional trunk sewer conveyance system and WRF, the Union Pump Station service area will be able to drain through this new sewer system. Once the new Western Regional Collection System and WRF are in service (scheduled for 2013), a connection to the new Union sewer will be made to eliminate the Union PS and overflow and the existing tributary sewers will be connected to the new Union sewer. Construction of the Union sewer began in 2006 and is complete. This project is currently on schedule to be completed by the March 31, 2013 date approved in the Pump Station Overflow Elimination Plan, well ahead of the Consent Decree deadline of December 31, 2015.

7.7.5 Summary of West Basin Projects

Table 7.38 summarizes the recommended projects, costs, and benefits for the West Basin.

Table 7.38 West Basin Five-Year Projects

Project Name	Benefits	Cost in 2009 Dollars ($Million)
Highland Acres PS Removal	SSO elimination	$1.5
Kentucky Aire PS Removal	SSO elimination	$3.3
South Hampton PS Removal	SSO elimination	Refer to Initial Watershed Projects Frogtown Interceptor Sewer in Table 7.2
Union PS Removal	SSO elimination	Refer to Initial Watershed Projects Union Sewer (North and South) in Table 7.2
	Total	$4.8

7.8 Summary of Five-year Improvement Program

The projects in the Five-year Improvement Program are the logical first steps in lowering pollutant levels, improving water quality and public health, and controlling overflows in Northern Kentucky. SD1 used a prioritization process for project selection

to align with input from the Watershed Community Council, other stakeholders, and results from a survey of community values (described in Section 6.1). The application of this process confirmed that Initial Watershed Projects listed in the Consent Decree are a priority and identified several integrated solution opportunities. The process also identified system-wide controls and specific basin projects, including several demonstration projects. These projects formed the Five-year Improvement Program. Solutions for future plans will incorporate information gained from the implementation of projects during the first Five-year Improvement Program.

The total cost and schedule with which controls are implemented cannot be fully defined. As explained in Section 4, SD1 used a very optimistic rate adjustment scenario to establish the maximum funding likely to be available for the first Five-year Improvement Program. Therefore, in order to implement the improvements proposed in the program, SD1 must be able to obtain annual rate increases of 15 percent each year for five years, from 2010 – 2014. The 15 percent rate increases for 2010 and 2011 have been approved, but it is important to note that the required increases for 2012, 2013, and 2014 are not guaranteed and will be difficult given the impact of the ongoing economic crisis on Northern Kentucky. However, through the five-year cycles, SD1 can measure progress and ensure that limited rate payer funds are invested consistent with community values and regulatory mandates.

It is important to note that SD1 had to make difficult decisions on which projects to include in the program, because not all candidate projects could be funded. Every candidate project, even some considered priorities under the Consent Decree, was carefully reviewed in terms of the primary goals of protecting human health, improving water quality and/or maintaining current assets. With the maximum cost of the Five-year Improvement Program being a limiting control factor, even with an optimistic funding ceiling, relative benefit became the key evaluation criterion, and certain projects worthy at the local scale had to be sacrificed when assembling the system-wide program. In some cases, phasing was used to incorporate initial high-impact stages of a project in the first Five-year Improvement Program, with the potential for additional phases in later cycles presuming that additional funding becomes available. Further, it is important to note that candidate projects not selected for the first Five-year Improvement Program become immediate candidates for the next improvement cycle, again on the presumption that additional funding will be available.

In order to have a consistent base to compare the cost-benefit of the programs and project identified as part of the watershed planning effort, all costs presented in Section 7 are based on current (2009) dollars. Projects and programs selected to be carried forward into the first Five-year Improvement Program were then put into a schedule and capital costs were escalated for inflation. Depending upon the timing of the project, the costs presented in Section 8 reflect future dollars that may differ from the costs presented in Section 7.

The evaluation and selection process led to a comprehensive Five-year Improvement Program that represents an integrated combination of traditional gray infrastructure, green infrastructure, and watershed controls. As shown in Figure 7.79, the program spans each of the four Consent Decree basins, and includes the Initial Watershed Projects, System-wide Projects, and Basin Projects selected based on the criteria

presented previously. A complete listing of projects by basin can be found in Tables 7.29, 7.30, 7.37 and 7.38. Four of these projects are not shown on Figure 7.79. These are: 1) Harrison Harbor PS Overflow Elimination, 2) Donnermeyer/Covert Run Improvements, Newport Pavilion Improvements, Bellevue Relief Sewer, and Wilson/Waterworks Rd. Improvements, 3) Willow Run Direct Entry Point Bar Racks, and 4) Taylorsport PS Overflow Elimination.

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Figure 7.79 SD1's Five-year Improvement Program

Note: A complete listing of projects can be found in Tables 7.29; 7.30, 7.37 and 7.38.

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Section 8
Implementation Process

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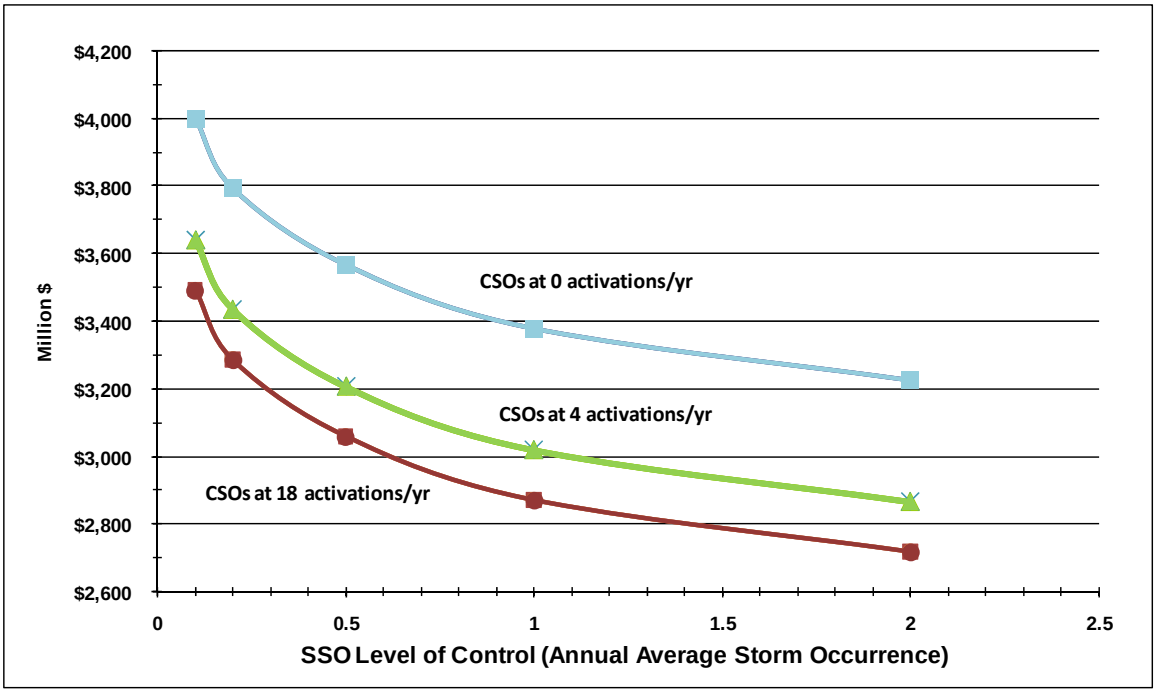
SECTION 8. IMPLEMENTATION PROCESS

This section summarizes the implementation of SD1's plan to reduce CSOs and eliminate SSOs by December 31, 2025. It provides details on the projects and programs to be implemented over the first five-year cycle, the total cost of the projects and programs, the expected benefits, and an implementation schedule. This section also discusses SD1's plan for post construction monitoring activities, identifies schedule adjustments, and future watershed planning cycles, to comply with the Consent Decree.

8.1 SD1's Plan to Reduce CSOs and Control SSOs

As part of the June 2009 Watershed Plan submittal, SD1 presented an analysis of a suite of full system gray and integrated solutions that addressed all sewer overflows, as required by the Consent Decree. This analysis identified several types of solutions and considered combinations of options at varying levels of control. Overall, this bounding analysis showed that the various combinations of controls would cost SD1 between $2.7 and $4.0 billion (2009 dollars) (Figure 8.1). This cost exceeded EPA's affordability standards and fell short of fully achieving water quality standards in receiving waters due to the presence of pollution sources other than CSOs and SSOs. Figure 8.1 Projected Full Program Costs for the Traditional Plan Over Range of Control Levels (Current 2009$)

Figure 8.1 Projected Full Program Costs for the Traditional Plan Over Range of Control Levels (Current 2009$)



Based on the conclusions of the bounding analysis, SD1 did not identify a preferred plan for 2025; rather, SD1 developed a detailed plan and schedule of projects to implement as part of the first Five-year Improvement Program. These five-year projects include a combination of gray, green, watershed, and required projects that addressed required projects listed in the consent decree, projects with significant public health concerns, opportunities for significant reduction in overflow volume, and demonstration projects that will be used to inform future Watershed Plans. Collectively, these projects are expected to provide a 45 percent reduction in typical year SSO volume and a 26 percent reduction in typical year CSO volume. EPA's feedback on the June 2009 plan indicated general support for the Five-year Improvement Program but required more detail on an Integrated Plan for 2025.

Since June 2009, SD1 has developed the Integrated Plan for 2025 (Table 8.1). As presented in this report, the Integrated Plan for 2025 was developed in accordance with the prioritization factors used to identify the projects that comprise the first Five-year Improvement Program and put a priority on projects that improve water quality, address public health concerns, and integrate green and gray solutions.

The Integrated Plan for 2025 includes the following benefits:

- Elimination of SSOs to a two-year level of service;
- A CSO level of control that meets the Presumptive Approach under the CSO Policy (greater than 85 percent capture). Water quality modeling shows that if all other sources were controlled, this level of control would also ensure remaining CSO discharges would meet water quality requirements for fecal coliform bacteria;
- Greater water quality benefits than the traditional plan in terms of reductions in fecal coliform bacteria levels. These benefits include greater number of days when fecal coliform levels are less than 400 cfu/100mL, reduction in total nitrogen and total phosphorus loads from the study area, increased number of stream miles improved, and improved ecological and human health conditions; and,
- Prevents additional degradation of waterways in the future by requiring pollutant control with policies and regulations.

The Integrated Plan for 2025 includes a combination of green and gray projects in the combined sewer area and gray and watershed projects in the separate areas to reduce CSOs, controls SSOs, and improve water quality. The total cost of these improvements to comply with the Consent Decree totals $1.26 billion. However, SD1 must also incur additional costs to maintain an appropriate level of service to the ratepayers (Table 8.2). These costs can be grouped into the following categories, described below:

- **Committed Projects for Asset Management:** Costs that reflect SD1's obligation to maintain current infrastructure, and include the cost to fix failing pipes, maximize existing dry and wet weather capacity, prevent loss of service and basement backups, and minimize wet weather overflows.

Table 8.1 Components and Cost of the Integrated Plan for 2025, Cost of Compliance with the Consent Decree

Categories of Projects	Capital Cost (Current 2009 $ M)
System-wide and Basin Projects in Five-Year Improvement Program (including River Water Intrusion)	$103
SSO Control – Source Reduction Projects	$248
SSO Control – Gray SSO Projects to meet 2-yr LOS	$215
SUBTOTAL – SSO Control	$463
CSO Control – Green Tier 1 Projects in CSS Area	$136
CSO Control – Green Programs in CSS Area	$9.2
CSO Control – Gray CSO Projects to meet targeted LOC	$344
SUBTOTAL – CSO Control	$489
Watershed – SIP Decentralized Projects	$12
Watershed – Stormwater BMPs in RDII Basins	$187
Watershed – Green Programs outside CSS	$1.8
SUBTOTAL – Watershed and Programmatic Projects	$201
TOTAL Consent Decree Costs	$1,260

- **Public Structural Rehabilitation**: Rehabilitation of public sewers to improve the reliability and extend the remaining useful life. This line item accounts for the sewers that are not addressed by gray SSO projects.

- **Facility Planning Projects:** Project and costs associated with the 2030 planning horizon that are not associated with current SSOs. These projects provide the trunk sewers and pump stations necessary to meet the demand of service area growth and not create new SSOs.

- **Initial Watershed Projects:** Improvements to SD1's sewer collection and treatment system that are listed in Exhibit D of the Consent Decree. These projects emphasize the fact that SD1's watershed planning process is not a new initiative, but rather the continuation of a wet weather control program that has been in place for many years.

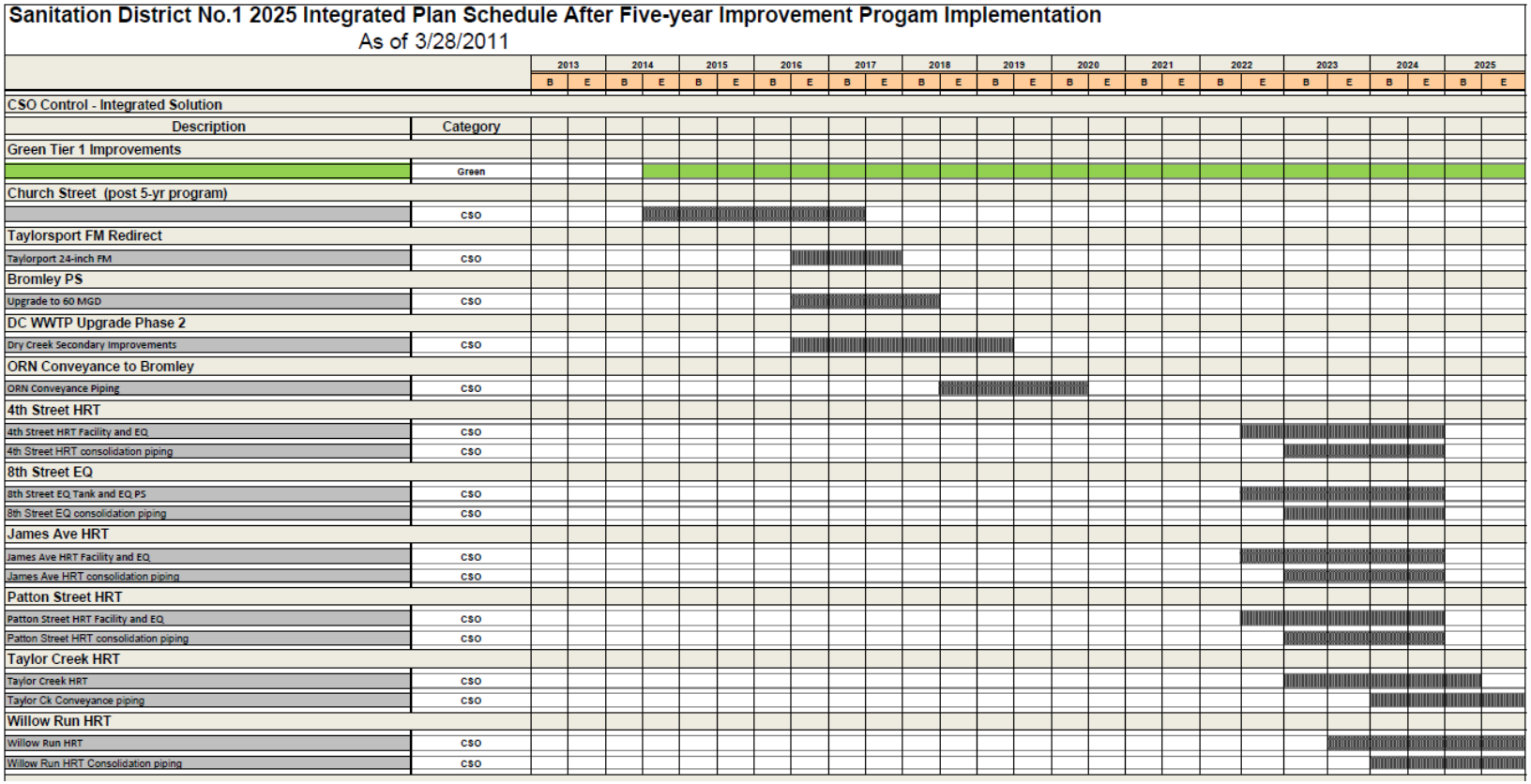
- **Anticipated Future Effluent Limits Projects:** The cost of future wastewater effluent limits changes for nitrogen and phosphorus. Due to the time span of the Consent Decree and the potential for these regulations to be imposed on SD1, the costs of these upgrades were included in the total cost used for the affordability analysis

Table 8.2 Components and Costs of the Integrated Plan, Cost of Compliance with the Consent Decree and Committed Project Costs (Affordability)

Categories of Projects	Capital Cost (Current 2009 $ M)
Consent Decree Costs	$1,260
Committed Projects for Asset Management	$252
Public Structural Rehabilitation	$197
Facility Planning Projects	$254
Initial Watershed Projects	$241
Anticipated Future Effluent Limits Projects	$229
Full Program Costs	$2,430

Figure 8.2 shows a schedule for all of the projects included in the Integrated Solution for 2025 and as presented in Section 3, the Integrated Plan for 2025 is expected to accomplish significant reductions in CSO volume and control of SSOs and provide water quality benefit greater than the traditional plan for every waterway (Table 8.3) and at an overall lower cost (Figure 8.3). However, as described in Section 4, the cost of this plan does not meet EPA standards for affordability.

Figure 8.2 Schedule of Projects for Integrated Plan for 2025



* Note: Refer to figure 8.2a for details.

Figure 8.2 Schedule of Projects for Integrated Plan for 2025 (Continued)

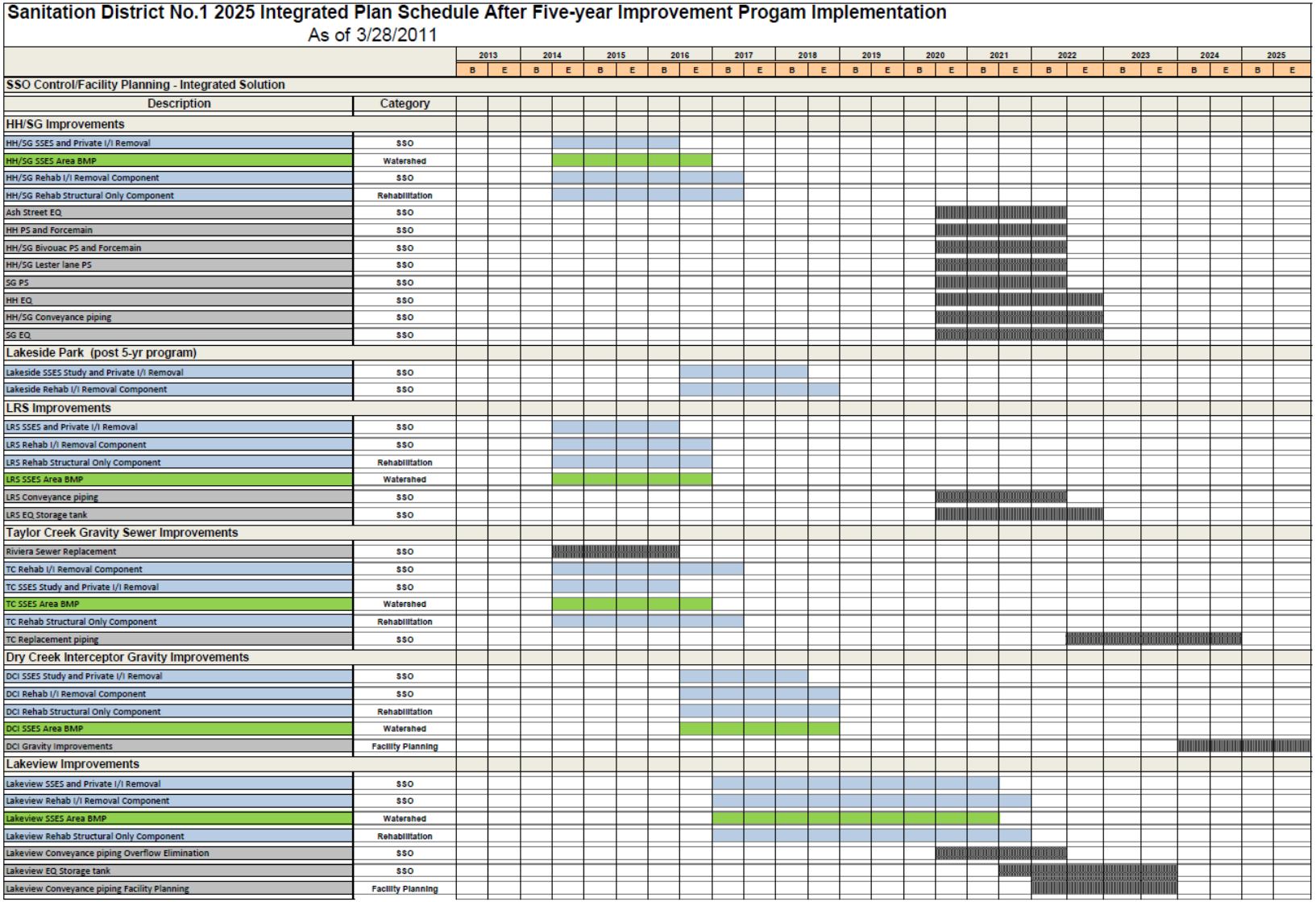


Figure 8.2 Schedule of Projects for Integrated Plan for 2025 (Continued)

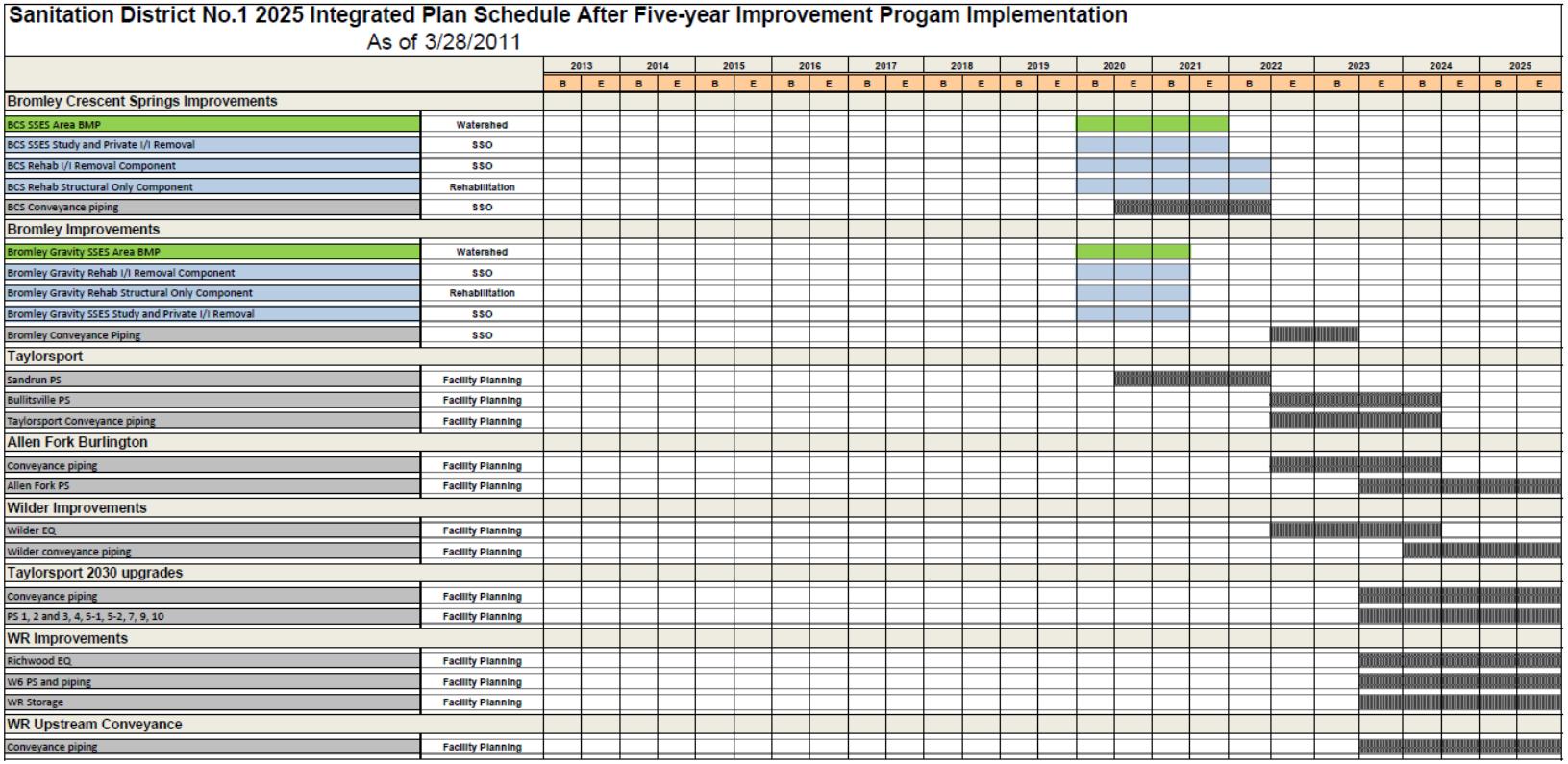


Figure 8.2a Schedule of Projects for Integrated Plan for 2025

Project Location	Project Description	Subbasin Map	CSO ID	Pipe (Ft)	Number of Priority Disconnects (downspouts)	WQ Features	Project Duration	Fiscal Start Year	2014 Jan-14 5.0	FY Jul-14 5.5	2015 Jan-15 6.0	FY Jul-15 6.5	2016 Jan-16 7.0	FY Jul-16 7.5	2017 Jan-17 8.0	FY Jul-17 8.5	2018 Jan-18 9.0	FY Jul-18 9.5	2019 Jan-19 10.0	FY Jul-19 10.5	2020 Jan-20 11.0	FY Jul-20 11.5	2021 Jan-21 12.0	FY Jul-21 12.5	2022 Jan-22 13.0	FY Jul-22 13.5	2023 Jan-23 14.0	FY Jul-23 14.5	2024 Jan-24 15.0	FY Jul-24 15.5	2025 Jan-25 16.0
11th Street and Prospect Street	Strategic separation and downspout disconnection offloaded from the combined system with water quality treatment.	Covington North	1420147	1,600	25	1	2.5	2015																							
Scott Street and 6th Street	Detention and volume control discharging back to the combined system.	Covington North	1420142	1,100	2	1	1.5	2015																							
Greenup Street and Eastern Avenue	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale.	Covington South	910068	100	5		1.5	2015																							
Eastern Avenue and Levassor Avenue (Holmes High School)	Strategic separation and downspout disconnection offloaded from the combined system.	Covington South	910068	1,000	1325		1.5	2015																							
6th Street and Columbia Street	Downspout disconnection directed toward a water quality feature that will be offloaded from the combined system through a proposed separate storm sewer as part of another project.	Newport	790086		3	1	1.5	2015																							
Truman Lane and Lincoln Road	Enhance existing detention discharging to existing swale for water quality treatment.	Covert Run	WQ Only			1	1.5	2015																							
Riviera Drive and Dave Cowen Drive	Enhance existing park with site BMP for water quality treatment.	Covert Run	WQ Only			1	1.5	2015																							
Riviera Drive and Donniemeyer Boulevard	Enhance existing parking lots with a site BMP for water quality treatment.	Covert Run	WQ Only			1	1.5	2015																							
Riviera Drive and Landmark Drive	Enhance existing swale to provide water quality treatment for storm water runoff	Covert Run	WQ Only			1	1.5	2015																							
Southern Avenue and Glenn Avenue	Strategic separation and downspout disconnection offloaded from the combined system with water quality treatment.	Latonia	870079	1,000	172	1	2.0	2015																							
33rd Street and Church Street	Strategic separation and downspout disconnection offloaded from the combined system with water quality treatment.	Latonia	880081	2,200	126	2	2.5	2015																							
James Avenue	Strategic separation and downspout disconnection offloaded from the combined system with a series of water quality treatment facilities.	Latonia	910065	7,900	883	8	8.0	2015																							
Maryland Avenue and 18th Street	Strategic separation and downspout disconnection offloaded from the combined system with water quality treatment and potential infiltration.	Covington South	930105	1,400	131	1	2.0	2015																							
Madison Avenue and Byrd Aly	Strategic separation and downspout disconnection offloaded from the combined system with water quality treatment.	Covington North	980081	5,300	247	2	4.0	2015																							
Chesapeake Street and 13th Street	Downspout disconnection to an infiltration opportunity that will overflow back to the combined system when needed.	Covington North	980081	400	122	1	4.0	2015																							
9th Street and Prospect Street	Strategic separation to a water quality feature that will be offloaded from the combined system.	Covington North	1420145	300		1	1.5	2015																							
Park Avenue and Dave Cowen Drive	Strategic separation and downspout disconnection to a water quality feature that will be offloaded from the combined system.	Newport	640090	500	15	1	1.5	2015																							
Patchen Avenue and Fairfield Avenue	Strategic separation and downspout disconnection that will be offloaded from the combined system and discharged to the Ohio River.	Covert Run	620075	500	22		1.5	2015																							
Columbia Street and 5th Street	Strategic separation and downspout disconnection with some water quality treatment that will be offloaded from the combined system. Includes significant opportunity to coordinated with the proposed Ovation redevelopment project.	Newport	790084	3,000	4	1	2.0	2015																							
Taylor Avenue and Eden Avenue	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale.	Covert Run	610071	45	22		3.5	2015																							
Center Street and Lafayette Avenue	Site BMPs on a City of Bellevue school property that will detain and reduce the amount of storm water runoff entering the combined system.	Covert Run	610071			1	3.5	2015																							
Division Street and Church Aly	Site BMPs to retrofit an existing parking lot that will detain and reduce the amount of storm water runoff entering the combined system.	Covert Run	610071			1	3.5	2015																							
Poplar Street and Williamson Aly	Site BMPs to retrofit an existing parking lot that will detain and reduce the amount of storm water runoff entering the combined system.	Covert Run	610071			1	3.5	2015																							
Church Aly and Poplar Street	Site BMPs and downspout disconnection that will detain and reduce the amount of storm water runoff entering the combined system.	Covert Run	610071		30	1	3.5	2015																							
Washington Avenue and Fairfield Avenue	Street bumpouts that will detain and reduce the amount of street runoff entering the combined system.	Covert Run	610071			1	3.5	2015																							
Oldham Street and Victoria Street	Strategic separation and offloading of existing storm sewer from the combined system that will discharge to an existing swale.	Ludlow	1710116	1,100	2		1.5	2015																							
Ringgold Street and Somerset Street	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale.	Ludlow	1710116	100	5		1.5	2015																							
River Road and Short Street	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale.	Pleasant Run	1730263	400	11		1.5	2015																							
Helen Street and Elm Street	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale.	Ludlow	1720109	800	62		2.0	2015																							
Lake Street and Laurel Street	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale that will be enhanced to provide treatment.	Ludlow	1720109	200	50	1	2.0	2015																							
Deverill Street and Adela Avenue	Downspout disconnection and offloading of existing separate storm from the combined system that will discharge to an existing swale.	Ludlow	1720109	200	25		2.0	2015																							
Stokesay Street and Adela Avenue	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale.	Ludlow	1720109	50	14		2.0	2015																							
Sandbank Road and Adela Avenue	Offloading of additional area to an existing separate storm network	Ludlow	1720109	200	0		2.0	2015																							
Highway Avenue and Montclair Avenue	Capture of hillside runoff, strategic separation, and downspout disconnection that will be offloaded from the combined system with some water quality treatment.	Devou	1500131	5,100	240	1	3.5	2015																							

Figure 8.2a Schedule of Projects for Integrated Plan for 2025 (Continued)

Project Location	Project Description	Subbasin Map	CSO ID	Pipe (Ft)	Number of Priority Disconnects (downspouts)	WQ Features	Project Duration	Fiscal Start Year	2014 Jan-14 5.0	FY Jul-14 5.5	2015 Jan-15 6.0	FY Jul-15 6.5	2016 Jan-16 7.0	FY Jul-16 7.5	2017 Jan-17 8.0	FY Jul-17 8.5	2018 Jan-18 9.0	FY Jul-18 9.5	2019 Jan-19 10.0	FY Jul-19 10.5	2020 Jan-20 11.0	FY Jul-20 11.5	2021 Jan-21 12.0	FY Jul-21 12.5	2022 Jan-22 13.0	FY Jul-22 13.5	2023 Jan-23 14.0	FY Jul-23 14.5	2024 Jan-24 15.0	FY Jul-24 15.5	2025 Jan-25 16.0
Baltimore Avenue and Michigan Avenue	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale within a golf course.	Latonia	1880091	1,800	121		1.5	2015																							
Oliver Avenue and Oakland Avenue	Strategic separation and downspout disconnection offloaded from the combined system to a water quality feature included with another project.	Covington North	960064	600	134		1.5	2015																							
Linden Grove Cemetery	Enhancement to an existing retention pond to delay discharge back to the combined system.	Willow Run	930104			1	2.5	2016																							
Kellogg Street and 16th Street	Downspout disconnection to an infiltration opportunity that will overflow back to the combined system when needed.	Covington South	930104		3	1	2.5	2016																							
Madison Avenue and 17th Street	Downspout disconnection to an infiltration opportunity that will overflow back to the combined system when needed.	Covington South	930104			1	2.5	2016																							
10th Street and Prospect Street	Strategic separation to a water quality feature that will be offloaded from the combined system.	Covington North	1420146	500		1	1.5	2016																							
Greenup Street and 8th Street	Strategic separation and downspout disconnection to multiple water quality features that will be offloaded from the combined system.	Covington North	1420144	1,700	79	3	3.0	2016																							
Mary Ingles Highway and Dodd Drive	Bioretention feature to capture and treat storm water runoff prior to discharge to the Ohio River.	Covert Run	WQ Only		38	1	3.5	2016																							
Vine Street and 9th Avenue (Dayton High School Football Field)	Capturing of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded with water quality treatment to the Ohio River.	Covert Run	570089	2,900	332	1	2.0	2016																							
Frank Benke Way and Ward Avenue	Strategic separation and downspout disconnection offloaded from the combined system to a water quality feature in Bellevue Beach Park.	Covert Run	600097	1,800	174	1	1.5	2017																							
Foote Avenue and Fairfield Avenue	Street bumpouts that will detain and reduce the amount of street runoff entering the combined system.	Covert Run	600094			1	1.5	2017																							
Taylor Avenue and Fairfield Avenue	Street bumpouts that will detain and reduce the amount of street runoff entering the combined system.	Covert Run	620077			1	1.5	2017																							
3rd Street and Saratoga Street	Offloading of roof runoff to site BMPs.	Newport	770096			1	4.0	2017																							
Saratoga Street and 3rd Street	Enhance existing parking lot with a site BMP for water quality treatment.	Newport	770096			1	4.0	2017																							
Monmouth Street and 4th Street	Coordination with redevelopment opportunities and downspout disconnection that will be offloaded from the combined system.	Newport	770096		74	1	4.0	2017																							
Main Street and 7th Avenue	Capturing of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded to the Ohio River with strategic separation.	Covert Run	570090	6,400	368		5.0	2017																							
5th Avenue and Clay Street	Downspout disconnection to an infiltration opportunity that will overflow back to the combined system when needed.	Covert Run	570090		40	1	5.0	2017																							
Providence Way and 4th Street	Strategic separation to a water quality feature that will be offloaded from the combined system to an existing swale for treatment.	Covert Run	650090	600	385		4.0	2019																							
Bonnie Leslie Avenue and Wilson Road	Strategic separation to a water quality feature that will be offloaded from the combined system to an existing swale for treatment.	Covert Run	650090	3,600	1117		4.0	2019																							
Covert Run Pike and O'Fallon Avenue	Strategic separation and downspout disconnection that will be offloaded from the combined system to an existing swale for treatment.	Covert Run	650090	100	9		4.0	2019																							
Berry Avenue and Donniemeyer Boulevard	Strategic separation and downspout disconnection that will be offloaded from the combined system to Covert Run.	Covert Run	650090	400	133		4.0	2019																							
Taylor Avenue and Grandview Avenue	Strategic separation and downspout disconnection that will be offloaded from the combined system to an existing separate storm network.	Covert Run	650090	900	157		4.0	2019																							
Carneal Street and Hay Street	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale connected to the Ohio River.	Ludlow	1710121	100	23		1.5	2021																							
Traverse Street and Elm Avenue	Capturing of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded to the Ohio River with strategic separation.	Ludlow	1710124	1,000	37		1.5	2021																							
John Street and Wilson Street	Capture of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded to the Ohio River through a series of water quality treatment features and strategic separation and downspout disconnection.	Devou	1490132	4,900	317	2	4.0	2019																							
Highway Avenue and Swain Ct	Capturing of existing separate storm prior to entering the combined system that will be offloaded to the Ohio River with strategic separation.	Devou	1490132	100			4.0	2019																							

Figure 8.2a Schedule of Projects for Integrated Plan for 2025 (Continued)

Project Location	Project Description	Subbasin Map	CSO ID	Pipe (Ft)	Number of Priority Disconnects (downspouts)	WQ Features	Project Duration	Fiscal Start Year	2014	FY	2015	FY	2016	FY	2017	FY	2018	FY	2019	FY	2020	FY	2021	FY	2022	FY	2023	FY	2024	FY	2025
									Jan-14	Jul-14	Jan-15	Jul-15	Jan-16	Jul-16	Jan-17	Jul-17	Jan-18	Jul-18	Jan-19	Jul-19	Jan-20	Jul-20	Jan-21	Jul-21	Jan-22	Jul-22	Jan-23	Jul-23	Jan-24	Jul-24	Jan-25
									5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0
Pike Street and Steve Tanner Street	Capturing of existing separate storm, downspout disconnection and strategic separation that will be offloaded to the Ohio River through a water quality feature.	Pleasant Run	1730259	1,600	54	1	2.0	2021																							
Moore Street and Steve Tanner Street	Strategic separation and downspout disconnection offloaded from the combined system to an existing storm system connected to Pleasant Run.	Pleasant Run	1730259	-	11		2.0	2021																							
Main Street and Moore Street	Strategic separation and downspout disconnection offloaded from the combined system to Pleasant Run.	Pleasant Run	1730259	100	8		2.0	2021																							
Main Street and Kenton Street	Strategic separation and downspout disconnection offloaded from the combined system to Pleasant Run.	Pleasant Run	1730259	100	44		2.0	2021																							
Pleasant Street and Boone Street	Strategic separation and downspout disconnection offloaded from the combined system to Pleasant Run.	Pleasant Run	1730259	800	1		2.0	2021																							
Western Avenue and Highway Avenue	Capture of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded to the Ohio River through strategic separation.	Willow Run	1480187	4,600	72		8.0	2018																							
Montague Road and Lewis Street	Capture of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded to the Ohio River through a series of water quality treatment features and strategic separation and downspout disconnection.	Willow Run	1480187	3,000	1025	3	8.0	2018																							
12th Street and Interstate 71/75	Capture of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded to the Ohio River through a series of water quality treatment features and strategic separation and downspout disconnection. This project requires significant coordination with KYTC and the Brent Spence Bridge Project for partnership on the separate storm sewer down I-71/75.	Willow Run	1480187	15,500	727	9	8.0	2018																							
Highland Pike and Euclid Avenue	Capture of existing separate storm and hillside runoff prior to entering the combined system that will be offloaded to the Ohio River through a series of water quality treatment features and strategic separation and downspout disconnection. This project connects to the I-71/75 storm sewer proposed as part of the Brent Spence Bridge Project.	Willow Run	1480187	13,600	1556	6	8.0	2018																							
Crescent Avenue and 4th Street	Capture of existing separate storm prior to entering the combined system that will be offloaded with water quality treatment to the storm sewer along I-71/75 proposed as part of the Brent Spence Bridge Project.	Willow Run	1480187	300	30	1	8.0	2018																							
12th Street and Jillian's Way	Capture of existing separate storm and the 12th Street Green Street prior to entering the combined system that will be offloaded to the storm sewer along I-71/75 proposed as part of the Brent Spence Bridge Project.	Willow Run	1480187	1,300	187	1	8.0	2018																							
Highland Pike and Bluegrass Drive	Downspout disconnection to existing ravines.	Willow Run	1480187		650		8.0	2018																							
York Street and Pike Street	Enhance existing parking lot with a site BMP for water quality treatment and detention of runoff to the combined system.	Willow Run	1480187			1	8.0	2018																							
Russell Street and 17th Street	Downspout disconnection to a system of infiltration opportunities that will overflow back to the combined system when needed.	Willow Run	1480187	1,900	228	3	8.0	2018																							
3rd Street and Bakewell Street	Strategic separation and redevelopment coordination that will be offloaded with water quality treatment to the storm sewer along I-71/75 proposed as part of the Brent Spence Bridge Project. This project requires significant coordination with the City of Covington as redevelopment occurs in the area.	Covington North	1470093	2,100	5	1	5.0	2021																							
Huntington Avenue and 47th Avenue	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale connected to Banklick Creek.	Latonia	1870194	900	73		1.5	2022																							
Decoursey Avenue and 46th Street	Strategic separation and downspout disconnection offloaded from the combined system to an existing swale connected to Banklick Creek.	Latonia	1870193	2,100	71		1.5	2024																							

***Definitions:**
Baseline Volume: CSO volume remaining after all SSES projects are complete and first five-year program implemented
Tier 1 Volume: CSO volume remaining after Tier 1 project is implemented
Difference in Volume: CSO volume removed by Tier 1 project
Baseline Activation: Number of CSO activations remaining after all SSES projects are complete and first five-year program implemented
Tier 1 Activations: Number of CSO activations remaining after Tier 1 project is implemented
Difference in Activations: Number of CSO activations removed by Tier 1 project

Project Ranking Assumptions
Basin meets water quality level of control
Watershed ranking - Licking River, Ohio River East, Ohio River North, Taylor, Banklick
Cost per gallon benefit
Projects relying on the I-75 corridor have been moved to last

Willow Run projects and anything related to the I-75 corridor has been moved to the bottom
Jacob Price CSO basin project has been moved to the top

Figure 8.3 Projected Full Program Costs for the Traditional Plan Over Range of Control Levels and Expected Cost of Integrated Plan for 2025 (Current 2009$)

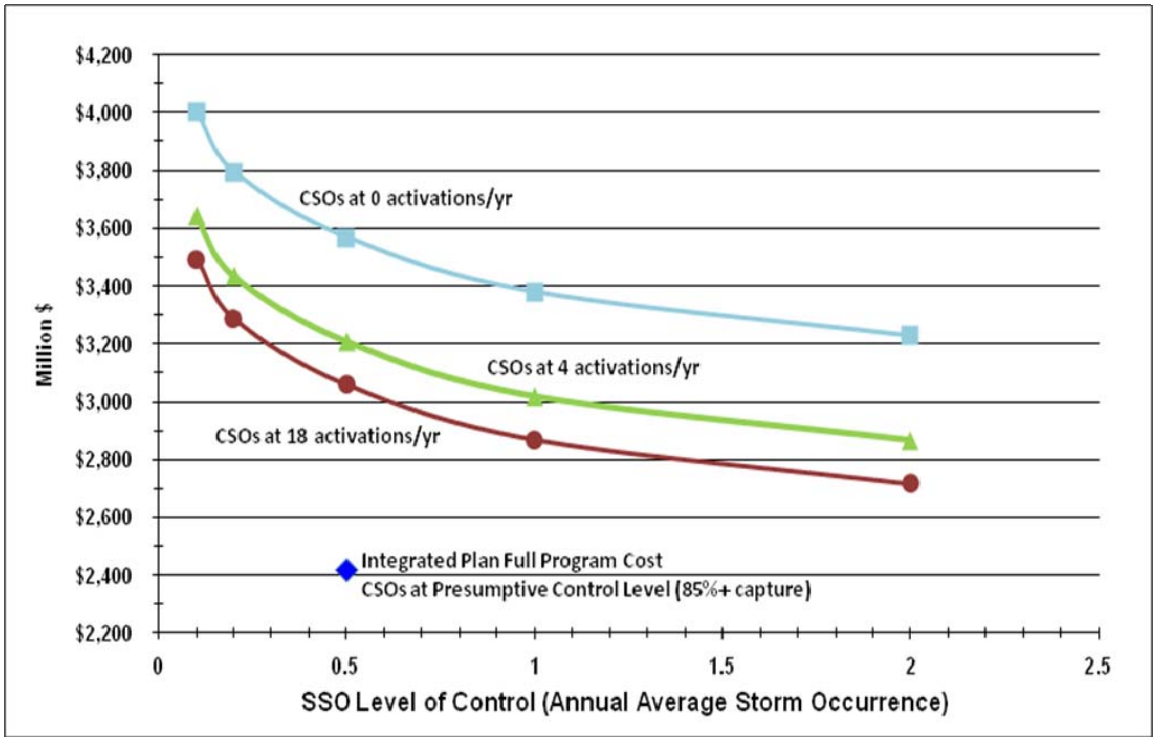


Table 8.3 Summary of Water Quality Benefits of SD1's Integrated Plan for 2025

Waterway	Number of Days in Recreation Season Less Than 400 cfu/100 ml (Count of Days)			Recreation Season Geometric Mean Fecal Coliform Density (cfu/100 ml)			Stream Miles Improved by Control Measures	
	Baseline (No Control)	Traditional Plan	Integrated Plan	Baseline (No Control)	Traditional Plan	Integrated Plan	Traditional Plan	Integrated Plan
Banklick Creek	67	84	108	1,080	556	310	1	19.1
Licking River	111	121	122	136	105	96	4.8	9.2
Taylor Creek	5.5	5.5	6.3	2,628	2,572	2,224	0.2	2.5
Ohio River	150	157	156	14	6	7	54.4	73.0
Fourmile Creek	102	109	110	446	323	305	2.1	9.5
Pleasant Run Creek	92	92	94	387	385	364	0.7	3.4
Twelvemile Creek	103	103	104	329	329	315	0	10.4
Threemile Creek	77	79	81	517	492	464	0	4.3
Dry Creek	83	88	90	514	426	402	0	7
Elijahs Creek	118	118	119	250	250	245	0	4
Sand Run	83	83	84	488	484	467	0	5.8

Notes:

1. Model results are shown for the 2030 future complete build-out condition.
2. Results for the CSO waterways (Banklick Creek, Licking River, Taylor Creek) are averaged from model segments comprising the CSO receiving portion of the waterway. Results for the Ohio River are provided at river mile 471.3, just downstream of the Willow Run CSO and corresponds to the location where the largest CSO impact on the Ohio River occurs. Results for the remaining waterways are provided at the mouth of the waterway. Results are not shown for Big Bone Creek, Gunpowder Creek or Woolper Creek because the models representing these areas are still being constructed and verified.
3. There are 184 days in the Recreation Season (May 1 through October 31, inclusive).
4. The Ohio River model simulations did not include loads from upstream or Ohio-side sources.

While the Integrated Plan for 2025 provides a guide from which SD1 will base future plans, near-term action is based on the projects slated for the first Five-year Improvement Program. In both the 2009 submittal and this update, SD1 provided detail on the projects and investment that will be made as part of the first Five-year Improvement Program. SD1 remains committed to making this investment and has begun to implement many of these projects.

8.2 First Watershed Plan Implementation

SD1 has been committed to implementing the projects in the first Five-year Improvement Program and has proceeded in accordance with the schedule presented in the June 2009 Watershed Plans. These projects and programs can be organized into three categories – (1) Initial Watershed Projects, (2) Committed Projects, and (3) Five-year System-wide Projects and Basin Projects:

Initial Watershed Projects represent improvements to SD1's sewer collection and treatment system that are listed in Exhibit D of the Consent Decree. These projects emphasize the fact that SD1's watershed planning process is not a new

initiative, but rather the continuation of a wet weather control program that has been in place for many years. Projects like the Western Regional System have been part of SD1's long-term vision since the mid-1990's to protect human health and improve water quality through proven infrastructure controls. SD1 has estimated expenditures of approximately $158 million from inception to the end of fiscal year 2009 for the Initial Watershed Projects and has $257 million budgeted to complete that work over the next 5 years.

Committed Projects are focused on the rehabilitation and maintenance of assets SD1 currently owns. Investment in these assets is critical to fix failing pipes, maximize existing dry and wet weather capacity, prevent loss of service and basement backups, and minimize wet weather overflows. In addition, this investment represents preventative maintenance activities that will enable SD1 to avoid failures (such as new SSOs) that are very costly to fix and could pose a threat to public health and the environment.

Five-year System-wide Projects and Basin Projects are designed to address public health concerns and improve water quality. In general, these projects were identified by applying criteria generated with input from SD1 ratepayers and stakeholders.

For the first Five-year Improvement Program, the impact of and ability to obtain rate increases becomes the control on the extent of proposed projects. Future economic realities may require a realignment of priorities which may affect the ability to fund the current proposed Five-year Improvement Program. If this occurs, the plan will need to be modified to reflect the changed regional priorities and SD1 ratepayers' ability to pay.

The affordability and funding issues have impacted many of the decisions that led to the Five-year Improvement Program. Since the availability of funds for the five-year program was a limiting factor, an assessment of the relative benefit of individual projects became essential in selecting projects and programs. In some cases, projects with only a local benefit had to be sacrificed when assembling the system-wide program. In some cases, phasing was used to incorporate initial high-impact stages of a project in the first Five-year Improvement Program, with the potential for additional phases in later cycles presuming that additional funding becomes available. It is important to note that candidate projects that were not selected for the first Five-year Improvement Program are not eliminated; rather they become candidates for the next detailed five-year plan for the next updated Watershed Plan submittal. SD1 is confident that the Five-year Improvement Program, across all four watershed basins, properly balances the wet weather priorities of the Consent Decree and objectives of the Northern Kentucky region with the maximum affordable funding available as outlined in Section 4.

Sections 8.2.1 through 8.2.5 summarize the projects included in the Five-year Improvement Program, their anticipated benefits, and schedule for implementation. SD1's requested schedule adjustments to the Consent Decree are summarized in Section 8.5.

8.2.1 Summary of Five-year Improvement Program: Initial Watershed Projects

The first five years of SD1's watershed improvement program include Initial Watershed Projects that were listed in Appendix D of the Consent Decree. Many of these projects have already been completed and several large projects are currently underway. Section 7 describes these projects and their benefits in detail. Table 8.4 provides a listing of these Initial Watershed Projects, their cost (in future and spent dollars), and a brief description of the benefit they have or will provide to SD1's wastewater collection and treatment system.

Table 8.4 Initial Watershed Project Summary

Project Name	Cost ($ Millions) (future and spent dollars)	Benefits
Western Regional System Related Projects ($301 million)		
Western Regional Water Reclamation Facility	$89.3	Provides additional dry weather treatment capacity at Dry Creek WWTP; CSO reduction; Eliminates and reduces SSO-Pump Stations; Eliminates and reduces SSOs;
Western Regional Conveyance System to Western Regional WRF (WR Tunnel)	$141.3	
Western Regional - Sunnybrook Sewer	$7.5	
Western Regional – Frogtown Interceptor Sewer	$6.6	
Western Regional – South Fork Gunpowder Sewer and Rosetta Sewer	$19.5	
Western Regional – Narrows Road Diversion Pump Station (PS)	$11.6	
Western Regional – KYTC Turkeyfoot Road Forcemain	$1.0	
Western Regional – Union Sewer (North and South)	$6.9	
Western Regional – Gunpowder Interceptor Sewer	$14.0	
Western Regional – Turkeyfoot Industrial Road Forcemain	$3.3	
Western Regional – Richwood Sewer and Forcemain	-	Refer to Section 8.3
Eastern Regional System Related Projects ($77.1 million)		
Eastern Regional Water Reclamation Facility	$41.7	Results in elimination of 8 MG of overflow volume in a typical year and provides additional dry and wet weather treatment capacity for Eastern Regional system
Eastern Regional – Contract 1- Pond Creek Forcemain and Gravity Sewer	$5.7	
Eastern Regional – Contract 2- Kahn's Gravity Sewer and Gravity Sewer to the Pond Creek PS	$4.3	
Eastern Regional Contract 3 – Riley Forcemain and Gravity Sewer	$5.7	
Eastern Regional Contract 4 – Alex-Licking Gravity Sewer & Forcemain to Contract 1	$3.9	
Eastern Regional Contract 5 – Sunset Forcemain and Gravity Sewer	$0.5	
Eastern Regional Contract 6 – Pond Creek PS	$4.1	
Eastern Regional Contract 7 – Riley Road #2 PS	$7.1	
Eastern Regional Contract 8A – Alex-Licking Pump Station	$2.3	
Eastern Regional Contract 8B – Sunset Pump Station Relocation	$1.8	

Project Name	Cost ($ Millions) (future and spent dollars)	Benefits
North Basin Initial Watershed Projects ($9.8 million)		
Strawberry PS Elimination	$0.2	Eliminate aging pump station
Beechwood Outfall Sewer Replacement	$2.3	Eliminate wet weather local capacity issue and replace aging infrastructure
Allen Fork Collection System – Phase I Improvements	$7.3	Improve dry and wet weather capacity of Allen Fork PS system
East Basin Initial Watershed Projects ($1.9 million)		
US 27 at Summit Assessment	$0.4	Connect failing septic systems to SD1 system
Parkside PS Relocation	$0.9	Replace aging pump station with more efficient pump station. Costs were shared with KYTC as part of their road widening project.
Highland Heights PS Study	$0.3	Study to examine alternatives for overflows in Highland Heights and Sliver Grove
Wilson/Waterworks Road Relief Sewer Study	$0.04	Study to examine alternatives for eliminating local capacity issues and overflows in Taylor Creek watershed
Pinehill/Skyview Terrace Sewer	$0.3	Sewer to address local wet weather capacity issue
West Basin Initial Watershed Projects ($1.5 million)		
American Sign PS Rehabilitation	$0.5	Replace existing pump station, eliminate local overflow and increase capacity
Duncan Drive Assessment Project	$1.0	Connect failing septic systems to SD1 system
Central Basin Initial Watershed Projects ($11.1 million)		
Banklick PS Screening Facility	$1.2	Improve combined sewer pump station operation and reduce upstream overflows
Stevenson Road Relief Sewer Project Phase II	$2.1	Eliminate local capacity restriction and reduce SSOs
Latonia Combined Sewer Separation	$2.6	Reduce CSO volume and eliminate local basement backups
Licking River Sewer Crossing Study	$0.2	Examine alternatives for reducing and eliminating largest SD1 SSO
McMillan PS Removal	$0.7	Construct gravity sewer to eliminate failing pump station and forcemain
Meyer Road PS Rehabilitation	$0.3	Replace aging pump station
Macke PS Rehabilitation	$0.4	Replace aging pump station with constructed bypass
Richwood PS Improvements	$0.3	Improve pump station operation and reduce odors
Patton Street Sewer Study	$0.2	Examine alternatives to reduce CSO volume
South Hills Outfall	$3.1	Eliminate CSO and reduce flows to Lakeview PS SSO

Project Name	Cost ($ Millions) (future and spent dollars)	Benefits
Multiple Basins Initial Watershed Projects ($13 million)		
Grit Chamber Projects	$3.8	Improve operation and effectiveness of combined interceptor system
Fort Wright Illicit Discharge Removal	$1.5	Find and eliminate illicit connections
Fort Wright Sanitary Sewer Rehabilitation	$1.7	Rehab existing sewers to reduce I/I and downstream SSOs
Fort Wright Outfall Sewer- Phase II	$1.0	Sewer to address local wet weather capacity issue
Dry Creek Treatment Plant – Grit Removal Modifications	$2.7	Improve operation and efficiency of Dry Creek WWTP
Large Diameter Sewer Assessment Program – Phase III	$0.5	Identify priority repairs and rehabilitation for most critical large diameter sewers
Brookwood Subdivision Sewer System Evaluation Survey (SSES) Study	$0.1	Identify I/I sources upstream of Lakeview PS to reduce SSO volume
Southern Kenton Drainage Study	$0.2	Refine model to examine alternatives to address SSOs in Lakeview PS basin
Wilson Road Sewer Assessment Project	$0.1	Connect failing septic systems to SD1 system
Apple Drive Outfall Sewer	$0.5	Sewer to eliminate failing treatment plant and address local wet weather capacity issue
Bluegrass Swim Club Sewer Separation	$0.9	Reduce wet weather I/I into SD1 system
TOTAL	$415.4	

8.2.2 Summary of Five-year Improvement Program: Committed Projects

In addition to funding projects necessary to comply with the Consent Decree, SD1 has an obligation to maintain current infrastructure. These projects are focused on the rehabilitation and maintenance of assets SD1 currently owns. Investment in these assets is critical to fix failing pipes, maximize existing dry and wet weather capacity, prevent loss of service and basement backups, and minimize wet weather overflows. These projects include high priority sewer repairs and replacements, a number of Consent Decree required programs, improvements at pump stations and treatment facilities, and capital purchases (Table 8.5).

Table 8.5 Five-Year Improvement Program: Committed Projects

Project Name	2010-2014 Budget ($ Millions)	Benefit
High-priority Sewer Projects	$10.1	Critical sewer rehabilitation / replacement projects; Projects include Van Deren, Highland Pike, Wayman's Branch
Nine Minimum Control Program	$3.7	Element of Nine Minimum Controls Program, Consent Decree requirement
River's Edge Inline Storage and Solids & Floatables Project	$2.1	Upsizing of 8,000 feet of Ohio River Interceptor as part of a new development to provide inline storage and solids & floatables control for 2 CSOs; CSO reduction
Capacity Management Operation Maintenance Program	$7.3	Consent Decree requirement; Projects include Pump Station Back-up Power, South Park Industrial PS Overflow Elimination and CSAP
Consent Decree Planning, Implementation, Management	$12.2	Necessary to ensure effective implementation of overall Consent Decree program
Improvements at Dry Creek Wastewater Treatment Plant	$28.8	System maintenance, increased treatment capacity
Pump Station Projects	$14.9	Pump station asset management and elimination
Ongoing Sewer Rehabilitation / Repair projects	$47.2	Rehabilitation / replacement based on CSAP and Cities opportunities; Identified projects include Crestview PS Overflow Elimination, South Hampton PS Overflow Elimination, Union PS Overflow Elimination, Bellevue Replacement Sewer, Avon Drive Sewer
Storm Sewer Rehabilitation / Repair	$11.0	Storm water asset management
Capital Purchases (vehicles, construction equipment, etc.)	$6.6	Equipment
Total	$143.8	

8.2.3 Summary of Five-year Improvement Program: System-wide and Basin Projects

Table 8.6 provides a listing for the System-wide Projects and the Basin Projects that are included in the Five-year Improvement Program. These projects were selected based on criteria important to both SD1 and local stakeholders:

- Reduction of sanitary sewage entering waterways,
- Public health benefit,
- Reduction of storm water runoff pollutants,
- Cost effectiveness,
- Eco-friendliness, and
- Criticality of aging infrastructure.

SD1 was guided by these criteria in evaluating and selecting system-wide and basin projects. Reduction of sanitary sewage entering waterways and public health benefit led SD1 to target SSOs that discharge in areas with a high potential for public contact; while many of these are small volume overflows, their public health risk made them a priority. Reduction in storm water runoff pollutants, cost effectiveness, and eco-

friendliness led SD1 to include a range of green and watershed controls; these innovative techniques have the potential to provide cost-effective control of many different source types. Finally, criticality of aging infrastructure supported inclusion of system-wide controls such as I/I source detection; these programs are directly aligned with SD1's institutional goal of maintaining existing infrastructure assets. It is important to note that the costs presented in Table 8.6 differ from the costs presented in Section 7 as costs in Section 8 represent future dollars. As projects were sequenced, costs were escalated for work scheduled for later years to account for inflation.

Table 8.6 Five-Year Improvement Program: System-wide and Basin Projects

Project Name	2010-2014 Budget in Future Dollars ($ Millions)	Benefit
System-wide		
River Water Intrusion Mitigation	$5.0	Reduces the inflow of river water into combined sewer system thereby increasing the conveyance capacity of the combined sewer system under high river elevations
Priority Inflow and Infiltration Source Identification & Removal Program	$6.0	Reduction and potential elimination of SSOs resulting from public and private source I/I removal. This work is in addition to and coordinated with the committed ongoing sewer rehab/replacement work listed in Table 8.5. Includes work in Lakeview, Licking River, and Taylor Creek areas.
Green Programs (DRIP, GrIPP)	$2.0	Source runoff control, CSO reduction, and pollutant load reduction from both CSO control and runoff
Demonstration Projects (pilot projects, innovative technology testing)	$4.6	Source runoff control, CSO reduction, and pollutant load reduction from both CSO control and runoff. Performance data to inform future Watershed Plans
Dry Creek WTP Headworks Project	$19.1	Increases the primary and disinfection capacity to 93 MGD
System-wide Project Total	$36.7	
Central Basin		
Lakeview Pump Station Pump Replacement	$5.4	Increase capacity and reliability of Lakeview Pump Station
Lakeview I/I Source Identification & Removal	Refer to "Priority I&I Source Identification and Removal" line item above	Refer to "Priority I&I Source Identification and Removal" line item above
Church Street (gray, green, and watershed controls)	$3.8	Phased approach to reduce CSO volume; water quality and community improvements
Vernon Lane – Public & Private Source I/I Reduction	$3.8	Improves public health; SSO elimination, improvements to storm water quantity and quality,

Project Name	2010-2014 Budget in Future Dollars ($ Millions)	Benefit
Watershed Controls Pilot Projects – Regional and decentralized controls	$3.6	Improve dry and wet weather water quality and stream conditions; Reduce public health risk; Pilot projects that will provide performance data to inform future plans
Alex Licking PS Overflow Elimination	Complete, Refer to Table 8.1	SSO elimination; Initial Watershed Project
Sunset PS Overflow Elimination	Refer to Table 8.1	SSO elimination; Initial Watershed Project
Licking River Siphon I/I Source Identification & Removal	Refer to "Priority I&I Source Identification and Removal" line item above	Refer to "Priority I&I Source Identification and Removal" line item above
Ripple Creek PS Removal	$0.9	Eliminates pump station overflow and meets Consent Decree requirement
Central Basin Project Total	$17.5	
East Basin		
Ash Street PS and Forcemain	$19.7	CSO elimination; SSO reduction, improves public health, addresses sensitive area
Harrison Harbor PS Overflow Elimination	Complete	Eliminates pump station overflow and meets Consent Decree requirement
Riley Road No. 1 PS Overflow Elimination	Complete	Eliminates pump station overflow and meets Consent Decree requirement
Crestview PS Overflow Elimination	Refer to "Ongoing Sewer Rehabilitation / Repair projects" in Table 8.5	Eliminates pump station overflow and meets Consent Decree requirement
Taylor Creek I/I Source Identification & Removal	Refer to "Priority I&I Source Identification and Removal" line item above	Refer to "Priority I&I Source Identification and Removal" line item above
Donnemeyer Improvements, Newport Pavilion Improvements, Bellevue Relief Sewer, Wilson/Waterworks Road	Completed	Reduces basement flooding risk and provides conveyance capacity for future improvements in Taylor Creek; SSO elimination
Bellevue Trunk Sewer Replacement	Refer to "Ongoing Sewer Rehabilitation / Repair projects" in Table 8.5	Replaces existing sewer to provide wet weather conveyance capacity; CSO elimination
East Basin Project Total	$19.7	
North Basin		
Allen Fork PS Overflow Elimination	$8.3	Eliminates pump station overflow and meets Consent Decree requirement
Lakeside Park – Public Sewer Rehab and Private Source Removal	$5.8	Improves public health; SSO elimination, improvements to storm water quantity and quality,
Van Deren Sanitary Sewer Improvements	Refer to "High-priority sewer projects" in Table 8.5	Eliminated/ reduced SSOs and illicit discharges. Controls I/I
Avon Drive Sanitary Sewer Improvements	Refer to "Ongoing Sewer Rehabilitation / Repair projects" in Table 8.5	Eliminates SSOs
Willow Run Dynamic Control	$1.3	CSO reduction using in-line storage
Willow Run Direct Entry Point Bar Racks	$0.06	Reduce debris entry into system, maintain capacity and reduce blockages
KYTC Basin – Green Infrastructure Retrofit	$1.5	CSO reduction, informs future green infrastructure design
Taylorsport PS Overflow Elimination	Completed	Eliminated pump station overflow and meets Consent Decree requirement

Project Name	2010-2014 Budget in Future Dollars ($ Millions)	Benefit
Southpark PS Overflow Elimination	Refer to "Pump Station Backup Power" in Table 8.2	Eliminates pump station overflow and meets Consent Decree requirement
North Basin Project Total	$17.0	
West Basin		
Highland Acres PS Removal	$1.65	Eliminates pump station overflow and meets Consent Decree requirement
Kentucky Aire PS Removal	$4.0	Eliminates pump station overflow and meets Consent Decree requirement
South Hampton PS Removal	Refer to "Ongoing Sewer Rehabilitation / Repair projects" in Table 8.5	Eliminates pump station overflow and meets Consent Decree requirement
Union PS Removal	Refer to "Ongoing Sewer Rehabilitation / Repair projects" in Table 8.5	Eliminates pump station overflow and meets Consent Decree requirement
West Basin Project Total	$5.7	
Five-Year Improvement Program: System-wide and Basin Projects Total [1]	$96.5	

Note: [1]The System-wide and Basin Projects budget total from Table 8.1 Components and Cost of the Integrated Plan for 2025 of $103 Million differs from the budget total in Table 8.6 of $96.5 Million. The $103 Million includes the full river water intrusion (RWI) costs outside the five-year window, and is based on the current costs to date (FY-2010 audited actual and FY-2011 to FY-2014 budget with a 3% deflation rate to 2009 dollars) used in the Financial Capacity Assessment.

As presented in the tables above, the benefit of these basin projects will collectively address public health issues, improve water quality, reduce CSOs and SSOs, and improve the reliability of the sewer system. In addition, several of these projects will be used to evaluate the benefit of integrated green, gray, and watershed solutions that are necessary components of the Integrated Plan for 2025. Many of these projects will include a performance monitoring program (Section 8.3). This information will enable SD1 to determine general effectiveness of different approaches and technologies, and will inform the prioritization of projects for subsequent Watershed Plans.

8.2.4 Summary of Five-year Improvement Program: Benefits

The cumulative impact of the Initial Watershed Projects, Committed Projects, and System-wide and Basin projects provides a substantial benefit to the SD1 system, as summarized below.

Increased Treatment Capacity

Upon the completion of the Western Regional Water Reclamation Facility, SD1 will have increased its sustained system-wide wet weather treatment capacity from 75 MGD to 117 MGD, an increase of 56 percent.

SSO/CSO Reduction

With the planned improvement program, SD1 is committed to implementing programs in the Five-year Improvement Program that will reduce overflows that have the most significant potential impacts on public health. Table 8.7 summarizes the modeled

annual reduction for a typical year in CSO and SSO volume after the Five-year Improvement Program is completed.

Table 8.7 Projected System-wide Typical Year CSO/SSO Reduction

Scenario	System-wide SSO Volume (MG)	System-wide CSO Volume (MG)
Current Condition	242.1 MG	1,872.8 MG
Implementation of Five-Year Improvement Program	134.3 MG[1]	1,375.4 MG[1]
Total Reduction	107.8 MG (45%)	497.4 MG (26%)

Note: [1]Includes benefits of River Water Intrusion Mitigation, Lakeside Park Sewer Rehab, and Church Street projects begun in Five-year Improvement Program that will extend beyond the first five-year period.

Hydraulic model results for the typical year also show that after the first Five-year Improvement Program is completed, a volume reduction will be observed at 46 of 97 CSO outfall locations (47%) and 29 of 126 confirmed SSO locations[1] (23%) (Tables 8.8 and 8.9).

Table 8.8. Summary of Remaining Overflow Volume (by CSO) Following Five-year Improvement Program

MH ID	Basin	Watershed	Remaining Overflow Volume Following Five-Year Improvement Program (MG)
0010228	East	Ohio River East	0.0
0010220	East	Fourmile Creek	0.0
1840130	Central	Banklick Creek	1.1
1510245	Central	Banklick Creek	0.0
1510133	Central	Licking River	0.0
0910066	Central	Licking River	0.0
1310100	Central	Licking River	0.0
1310106	Central	Licking River	0.0
1320112	North	Ohio River North	0.0
1380146	North	Ohio River North	0.0
1380132	North	Ohio River North	0.3
0730129	Central	Licking River	1.9
0840112	Central	Licking River	3.6
0690059	East	Taylor Creek	0.0
1730262	North	Pleasant Run Creek	0.0
0840111	Central	Licking River	0.1
1730261	North	Ohio River North	0.0
1440207	Central	Licking River	0.0

[1] The number of confirmed SSO points is subject to change based on ongoing field investigations and hydraulic modeling of the collection system. The number quoted above was current as of the writing of the original Watershed Plans submitted June 30, 2009. This number is updated annually in the April Quarterly Report to KDOW and EPA.

MH ID	Basin	Watershed	Remaining Overflow Volume Following Five-Year Improvement Program (MG)
1480185	North	Ohio River North	1.9
0650054	East	Taylor Creek	0.0
0660085	East	Taylor Creek	0.0
0650098	East	Taylor Creek	12.6
0650008	East	Taylor Creek	0.0
0540009	East	Taylor Creek	1.0
0540044	East	Taylor Creek	0.4
0550134	East	Taylor Creek	0.0
0360079	East	Ohio River East	0.2
0600104	East	Ohio River East	0.0
0600096	East	Ohio River East	0.1
1870194	Central	Banklick Creek	0.2
1870193	Central	Banklick Creek	1.3
1850158	Central	Banklick Creek	9.7
1880090	Central	Licking River	2.2
1880091	Central	Licking River	2.6
0870079	Central	Licking River	29.4
0870078	Central	Licking River	0.5
0880081	Central	Licking River	0.8
0880082	Central	Licking River	24.9
0910065	Central	Licking River	128.2
0030031	East	Ohio River East	0.0
0910068	Central	Licking River	50.5
0930102	Central	Licking River	0.0
0930103	Central	Licking River	0.1
0930105	Central	Licking River	29.0
1350155	North	Ohio River North	0.1
0930104	Central	Licking River	0.1
0930106	Central	Licking River	0.0
0200069	East	Ohio River East	0.9
0960063	Central	Licking River	1.9
0340051	East	Ohio River East	0.0
0960064	Central	Licking River	0.0
0980081	Central	Licking River	56.8
0980080	Central	Licking River	0.0
0840116	Central	Licking River	7.1
0980073	Central	Licking River	0.2
1420147	Central	Licking River	0.2
1420146	Central	Licking River	0.0
1420145	Central	Licking River	2.1
1420144	Central	Licking River	0.0
1730263	North	Ohio River North	2.2
1420142	Central	Licking River	69.5
1730259	North	Pleasant Run Creek	2.3
1420141	Central	Licking River	0.7

MH ID	Basin	Watershed	Remaining Overflow Volume Following Five-Year Improvement Program (MG)
0340050	East	Ohio River East	0.5
1720109	North	Ohio River North	15.4
0790086	Central	Licking River	69.5
1480187	North	Ohio River North	449.0
1470089	North	Ohio River North	0.7
1470093	North	Ohio River North	75.4
1440209	North	Ohio River North	92.4
1440212	North	Ohio River North	0.0
1490132	North	Ohio River North	1.7
1440204	North	Ohio River North	0.0
1440205	North	Ohio River North	0.5
1440206	North	Ohio River North	2.1
1490172	North	Ohio River North	0.0
1710116	North	Ohio River North	12.7
0650100	East	Taylor Creek	0.1
0790084	East	Ohio River East	13.7
1500131	North	Ohio River North	9.1
1710114	North	Ohio River North	0.4
1710119	North	Ohio River North	5.0
0770096	East	Ohio River East	2.3
1710121	North	Ohio River North	2.3
1710124	North	Ohio River North	3.7
0330100	East	Ohio River East	0.0
0640090	East	Ohio River East	112.6
0630061	East	Ohio River East	1.9
0650090	East	Ohio River East	3.9
0620075	East	Ohio River East	9.7
0620077	East	Ohio River East	0.3
0610071	East	Ohio River East	14.0
0610072	East	Ohio River East	1.0
0600094	East	Ohio River East	1.6
0600097	East	Ohio River East	4.4
0570089	East	Ohio River East	21.3
0570090	East	Ohio River East	1.5
		TOTAL	**1375.4**

Table 8.9. Summary of Remaining Overflow Volume (by SSO) Following Five-year Improvement Program

MH ID	Basin	Watershed	Remaining Overflow Volume Following Five-Year Improvement Program (MG)	Status Following Five-Year Improvement Program
0020014	Fourmile Creek	East	0.00	Eliminated
0050022	Ohio River East	East	0.36	
0060001	Ohio River East	East	0.34	
0060002	Ohio River East	East	0.03	
0300008	Ohio River East	East	0.01	
0410010	Taylor Creek	East	0.23	
0410011	Taylor Creek	East	0.00	
0410019	Taylor Creek	East	0.28	
0410036	Taylor Creek	East	0.00	Eliminated
0410068	Taylor Creek	East	0.02	
0440074	Taylor Creek	East	0.01	
0530083	Taylor Creek	East	1.42	
2150050	Fourmile Creek	East	0.00	
0090009	Threemile Creek	Central	0.00	
0100001	Threemile Creek	Central	0.00	
0100002	Threemile Creek	Central	0.70	
0110010	Threemile Creek	Central	0.63	
0150023	Threemile Creek	Central	0.00	
0150058	Threemile Creek	Central	1.90	
0150063	Threemile Creek	Central	0.00	
0150064	Threemile Creek	Central	0.00	
0150065	Threemile Creek	Central	0.22	
0150069	Threemile Creek	Central	0.00	
0150351	Threemile Creek	Central	0.00	
0150356	Threemile Creek	Central	0.00	
0860001	Licking River	Central	46.14	
0860003	Licking River	Central	0.00	
0860016	Threemile Creek	Central	0.00	
1040060	Banklick Creek	Central	0.00	Eliminated
1090069	Banklick Creek	Central	0.00	
1110025	Banklick Creek	Central	0.21	
1110067	Banklick Creek	Central	0.45	
1110161	Banklick Creek	Central	0.15	
1110294	Banklick Creek	Central	0.00	
1570100	Banklick Creek	Central	0.20	
1760047	Banklick Creek	Central	0.00	
1760048	Banklick Creek	Central	0.00	
1860108	Banklick Creek	Central	0.00	
1870013	Banklick Creek	Central	0.00	

MH ID	Basin	Watershed	Remaining Overflow Volume Following Five-Year Improvement Program (MG)	Status Following Five-Year Improvement Program
1920163	Licking River	Central	0.00	
1950199	Banklick Creek	Central	0.00	
1960012	Banklick Creek	Central	0.00	
2030097	Banklick Creek	Central	0.00	
2090001	Banklick Creek	Central	0.00	
2090026	Banklick Creek	Central	0.00	
2110002	Banklick Creek	Central	1.05	
2120001	Banklick Creek	Central	0.15	
2120002	Banklick Creek	Central	0.00	
2120041	Banklick Creek	Central	0.08	
2160036	Banklick Creek	Central	0.00	
2280010	Banklick Creek	Central	0.00	
2280011	Banklick Creek	Central	0.05	
2280012	Banklick Creek	Central	0.00	
2300123	Banklick Creek	Central	2.29	
1160004	Dry Creek	North	0.00	
1190007	Dry Creek	North	0.00	
1220029	Dry Creek	North	0.00	
1240008	Dry Creek	North	0.68	
1280008	Dry Creek	North	0.00	
1590006	Dry Creek	North	0.00	
1600005	Dry Creek	North	0.00	
1600009	Dry Creek	North	0.00	Eliminated
1600029	Dry Creek	North	0.00	
1600049	Dry Creek	North	0.00	
1600050	Dry Creek	North	0.00	Eliminated
1600059	Dry Creek	North	0.00	
1600110	Dry Creek	North	0.00	
1610102	Dry Creek	North	0.00	
1610114	Dry Creek	North	0.00	
1610115	Dry Creek	North	0.00	
1630012	Dry Creek	North	0.00	
1820014	Dry Creek	North	0.00	
1830017	Dry Creek	North	0.00	
1830020	Dry Creek	North	0.00	
1830067	Dry Creek	North	0.00	
1890001	Dry Creek	North	0.00	
1890010	Dry Creek	North	0.00	
1890011	Dry Creek	North	0.00	
2130022	Dry Creek	North	0.02	
1560016	Pleasant Run	North	0.00	
1560019	Pleasant Run	North	0.00	

MH ID	Basin	Watershed	Remaining Overflow Volume Following Five-Year Improvement Program (MG)	Status Following Five-Year Improvement Program
1560074	Pleasant Run	North	0.00	
1600113	Pleasant Run	North	0.00	
1620001	Pleasant Run	North	0.00	
1680001	Pleasant Run	North	0.69	
1690043	Pleasant Run	North	0.00	
1700025	Pleasant Run	North	0.00	
1730104	Pleasant Run	North	0.01	
1730110	Pleasant Run	North	0.00	
2290001	Pleasant Run	North	0.02	
2390002	Woolper Creek	North	0.00	
2390006	Woolper Creek	North	0.00	
2390008	Woolper Creek	North	0.00	
2390762	Woolper Creek	North	0.00	Eliminated
2380001	Gunpowder Creek	West	0.00	Eliminated
Eastern Regional			0.00	
2010PS1 (Keavy Rd PS)	Licking River	Central	0.00	
2010PS2 (Meadow Lane PS)	Licking River	Central	0.00	
2010PS3 (Ridgeway PS)	Licking River	Central	0.00	
2010PS4 (Mafred PS)	Licking River	Central	0.00	
2020PS2 (Meadow Hill PS)	Banklick Creek	Central	0.00	
2020PS7 (Twin Lakes PS)	Licking River	Central	0.00	
2200PS1 (Alex-Licking PS)	Licking River	Central	0.00	Eliminated
2450PS2 (Sunset PS)	Licking River	Central	0.00	Eliminated
1900PS3 (Ripple Creek PS)	Licking River	Central	0.00	Eliminated
Lakeview PS	Banklick Creek	Central	1.15	
0010PS5 - Harrison Harbor (Anderson)	Ohio River East	East	0.00	
0020PS1 - Silver Grove	Fourmile Creek	East	0.00	
0050PS1 - Highland Heights	Ohio River East	East	16.31	
1920PS3 - Winters Ln No. 2	Ohio River East	East	0.00	
2150PS1 - Crestview	Fourmile Creek	East	0.00	
2210PS2 - Enzweiller	Fourmile Creek	East	0.00	
2230PS3 - Riley Rd	Fourmile Creek	East	0.00	Eliminated

MH ID	Basin	Watershed	Remaining Overflow Volume Following Five-Year Improvement Program (MG)	Status Following Five-Year Improvement Program
2360PS1 (Taylorsport PS)	Elijahs Creek	North	0.00	
2360PS2 (Cardinal Cove PS	Elijahs Creek	North	0.00	
2360PS3 (South Park Industrial PS)	Elijahs Creek	North	0.00	
2370PS1 (Bullitsville PS)	Woolper Creek	North	0.00	
2390PS1 (Allen Fork PS)	Woolper Creek	North	0.00	
2280PS2 (Ky Aire PS)	Gunpowder Creek	West	0.00	Eliminated
2420PS6 (South Hampton PS)	Gunpowder Creek	West	0.00	Eliminated
2280PS1 | (Highland Acres PS	Gunpowder Creek	West	0.00	Eliminated
2420PS3 (Union PS)	Gunpowder Creek	West	0.00	Eliminated
1030PS1 (Gammon Calmet PS)	Gunpowder Creek	West	0.00	Eliminated
2380PS1 (Gunpowder PS)	Gunpowder Creek	West	0.00	Eliminated
1030PS2 (Levi PS)	Gunpowder Creek	West	0.00	
2320PS3 (Richwood PS)	Big Bone Lick	West	0.00	
		TOTAL	**77.9 MG[1]**	

Note: [1] Total overflow volume from Exhibit A SSO locations only. Volume from these overflows plus other potential overflow locations is predicted to be 134.3 MG. This value has been used in this document for summary purposes.

The breakdown of this reduction is shown in Table 8.10 based on the projects selected in the Five-year Improvement Program.

Table 8.10. Benefits of Five-year Improvement Program

Projects	Projected CSO/SSO Reduction[1]
Van Deren Sanitary Sewer Improvements	0.4 MG SSO
Avon Drive Sanitary Sewer Improvements	
Lakeside Park – Public Sewer Rehabilitation and Private Source Removal	
Western Regional Initial Watershed Projects	59.7 MG SSO
Highland Acres Pump Station Removal	
Kentucky Aire Pump Station Removal	
Allen Fork PS Overflow Elimination	
River Water Intrusion Mitigation – up to 47 feet	281 MG CSO 7.5 MG SSO
Eastern Regional Initial Watershed Projects	8 MG SSO
Church Street – Full system plan (downspout disconnect, storm inlet disconnection, sewer rehabilitation, wetland, new storm outlet)	35 MG CSO
Vernon Lane – Public & Private Source I/I Removal	3.8 MG SSO
Ash St PS and Forcemain	21.6 MG SSO 2.4 MG CSO
Ripple Creek PS Removal	0.3 MG SSO
River's Edge Inline Storage and Solids and Floatables Project	166.8 MG CSO 6.5 MG SSO
Wildcat Run Relief Sewer Improvements	
Newport Pavilion Improvements	
Donnermeyer Improvements	
Updated Bromley PS Operation Levels	
Nine Minimum Controls Static Weirs	
Willow Run Direct Entry Point Bar Racks	
Willow Run Dynamic Control	
DRIP and GrIPP in the Combined System	1 MG CSO
Green Demonstration Projects (KYTC Bioretention Facility, Terraced Reforestation, St. Elizabeth's Rain Garden, 12th Street Green Street)	11.2 MG CSO

Note: [1] SSO values presented include all confirmed SSO locations and model predicted volumes from other potential overflows

Table 8.11 summarizes the predicted volume balance in the combined system in the typical year after implementation of the Five-year Improvement Program. The volumes shown were taken from the hydraulic model which simulated the conditions at the end of the first five-years of implementation. The model predicts there will be approximately 1,376 MG/yr of untreated CSO at the end of the Five-year Improvement Program. The sustained secondary treatment capacity of Dry Creek WWTP will remain at 55 MGD.

Table 8.11. Model Predicted Volume After Five-year Program Implementation

Category	Typical Year Annual Volume (MG)
Total flow entering combined system[1]	8,093
Storm water entering combined system	2,819
Combined system flow receiving full secondary treatment	6,717
Untreated CSO	1,376
Flow at Dry Creek WWTP bypassing secondary	187

Note: [1]This includes flow to Bromley PS, and untreated CSO.

The table below shows that the Five-year Improvement Program is estimated to increase capture to 69.9% of combined flow, based upon modeled volumes in the typical year simulation.

Table 8.12. Percent Capture Calculation After Five-year Program Implementation

Category	Typical Year Annual Volume (MG)
Storm water entering combined system	2,819
Sanitary flow during wet weather	1,758
Total Combined Flow (TCF)	4,577
Untreated CSO (CSO)	1,376
Percent Capture [(TCF)-(CSO)]/(TCF)	69.9%

8.2.5 Summary of Five-year Improvement Program: Schedule

To accomplish these selected projects within the five-year timeline, SD1 developed a schedule for implementation that balanced the projects contained within this first five-year plan with the need for performance monitoring of certain projects to inform and support the next updated Watershed Plan submittal. The implementation schedule for Initial Watershed Projects and the projects in the Five-year Improvement Program are presented in Table 8.13 and Table 8.14

The implementation schedule shows a sequence of work that aligns with the key factors described below:

- **Financial Capability and Cash Flow:** Sequencing of work to fit within SD1's affordable capital budget.

- **Consent Decree Deadlines:** Impacts the timing of several Pump Station Overflow Elimination (PSOE) projects. Several stations with 2010 and 2013 deadlines needed to be started earlier in the schedule so the overflows associated with those pump stations will be eliminated by their scheduled deadline.
- **Demonstration Projects:** Design and construct green and watershed demonstration projects or integrated control projects so that sufficient time remains to collect meaningful post-construction monitoring data to inform and support future plans.
- **Public Health Priorities:** Attempt to prioritize projects that will have the greatest public health benefits.

SD1 balanced these key factors in developing the schedule. As noted above and in Section 4, the projects and their timing are ultimately linked to SD1's ability to obtain rate increases.

Table 8.13 depicts the schedule for the Initial Watershed Projects, and Table 8.14 shows the schedule for the System-wide and Basin projects. The start dates and completion dates are estimated to occur within the calendar year shown below. The Initial Watershed Projects listed in Table 8.4 that have already been completed are not included in the schedules below.

Table 8.13 Schedule for the Initial Watershed Projects

Project Location	Project Name	2009	2010	2011	2012	2013	2014	>2014
Initial Watershed	Western Regional Water Reclamation Facility							
Initial Watershed	Western Regional Conveyance System to Western Regional WRF (WR Tunnel)							
Initial Watershed	Western Regional – Sunnybrook Sewer							
Initial Watershed	Western Regional – Frogtown Interceptor Sewer							
Initial Watershed	Western Regional – South Fork Gunpowder and Rosetta Sewers							
Initial Watershed	Western Regional – Narrows Road Diversion Pump Station							
Initial Watershed	Western Regional – Union Sewer (North and South)	Complete						
Initial Watershed	Western Regional – Gunpowder Interceptor Sewer							
Initial Watershed	Western Regional – Turkeyfoot Industrial Road Forcemain							
Initial Watershed	Western Regional – Richwood Sewer and Forcemain	See Section 8.3						
Initial Watershed	Eastern Regional - Contract 5B-- Sunset Gravity Sewer Installation[1]							
Initial Watershed	Eastern Regional - Contract 8B-- Sunset Pump Station Relocation[1]							

Note: [1] See section 8.3 below for how this project scope has been adjusted.

Table 8.14 Schedule for the System-wide and Basin Projects[1]

Project Location	Project Name	2009	2010	2011	2012	2013	2014	>2014
System-wide	River Water Intrusion Mitigation							
System-wide	Priority Inflow and Infiltration Source Identification & Removal Program							
System-wide	Green Programs (DRIP, GrIPP)							
System-wide	Demonstration Projects (pilot projects, innovative technology testing)							
Central	Lakeview PS Pump Replacement							
Central	Church Street (gray, green, and watershed controls)							
Central	Vernon Lane – Public & Private Source I/I Removal							
Central	Watershed Controls Pilot Projects – Regional and decentralized controls							
Central	Ripple Creek PS Removal							
East	Ash Street PS and Forcemain							
East	Crestview Pump Station Overflow Elimination							
East	Rivera Drive Sewer							
North	Allen Fork PS Overflow Elimination							
North	Lakeside Park – Public Sewer Rehab and Private Source Removal							
North	Van Deren Sanitary Sewer Improvements							
North	Avon Drive Sanitary Sewer Improvements							
North	Willow Run Dynamic Control Facility							
North	Willow Run Direct Entry Point Bar Racks							
North	KYTC Basin - Green Infrastructure Retrofit							
North	South Park PS Overflow Elimination							
West	Highland Acres PS Removal							
West	Kentucky Aire PS Removal							
West	South Hampton PS Removal							
West	Union PS Removal							

Note: [1]Project will commence within the calendar year identified and likewise be completed prior to December 31st of the calendar year identified for completion.

8.3 Schedule Adjustments

Through the characterization and planning work, SD1 has identified three Initial Watershed Projects or Pump Station Overflow Elimination Projects that will not meet the dates stipulated in the appendices of the Consent Decree, or the subsequent approved Pump Station Overflow Elimination Plan (PSOEP). These projects are:

Lakeview Pump Station: As discussed in Section 7.4.7, with the replacement of the Lakeview pumps and diversion of a portion of SD1's service area to the Western Regional System, the typical year overflow volume at the Lakeview PS bypass will be reduced by nearly 98 percent from the volumes recorded when SD1 entered into the Consent Decree (41 MG to 1 MG, in a typical year). Rather than construct a large tank or high-rate treatment unit to capture or treat the remaining 1 MG of overflow that is predicted to occur in a typical year, SD1's watershed-based planning process has identified an innovative approach to watershed pollution reduction that employs a combination of traditional gray solutions, watershed controls, and regional green infrastructure components to maximize the benefits achieved. The proposed solution is discussed in more detail in Section 7.4.7. SD1 is proposing that the solution to address the overflow at Lakeview be focused on the larger issues within the Banklick watershed. The proposed solution includes six components:

- Increase in the pump station capacity and reliability to 22.5 MGD through the planned pumps replacement project;
- Redirect a portion of the Lakeview tributary area to the new Western Regional System and reduce the annual predicted overflow at Lakeview in a typical year by 91 percent to 1 MG;
- Conduct SSES investigations and targeted, cost-effective, I/I removal in the area remaining tributary to Lakeview to reduce extraneous wet weather flows;
- Implement a Source Identification Program to detect other sources of pollution (dry and wet weather-related sources) identified by monitoring and modeling efforts; and,
- Construct a wetland system along Banklick Creek and other decentralized watershed controls to reduce bacteria levels and improve overall water quality in the downstream system.

This proposed solution represents an opportunity for SD1, EPA, KDOW, and the Northern Kentucky community to implement holistic and cost-effective solutions that go beyond traditional point source control, are consistent with the goals of the Clean Water Act, and provide the community with greater tangible benefits than a more costly investment to contain or treat the remaining 1 MG discharge from the Lakeview bypass. In addition, by delaying further action to eliminate the remaining 1 MG of overflow at Lakeview, SD1 will be able to reallocate approximately $20 million to the Ash Street PS and Forcemain project located in Silver Grove, which will provide approximately 38 MG of overflow reduction in a part of the system where the overflow has much greater potential to significantly and directly impact public health.

Therefore, the Watershed Plans provide for a delay in the December 31, 2013 Consent Decree deadline to eliminate the bypass at the Lakeview PS. SD1 will monitor the effectiveness of the proposed controls and evaluate the plan for final overflow elimination at Lakeview in future watershed plans under an agreed upon level of service.

Richwood Pump Station: The upgrade of Richwood PS and the construction of a new forcemain to redirect flows to the Western Regional System was originally included in the Initial Watershed Projects due to the PS's potential lack of dry and wet weather

capacity and its perceived reduction in overflow volume in the Lakeview system. Based on flow monitoring conducted in 2007 and 2008 as part of the hydraulic model calibration and validation and subsequent hydraulic modeling, SD1 has found that the Richwood PS does not bypass during wet weather and has sufficient capacity to convey all dry and wet weather flows. In addition, redirecting the flows from the Richwood PS to the Western Regional system did not significantly reduce overflows downstream in the Lakeview system. The potential future need to construct this project will be based on monitoring the existing upstream and downstream sewer system after the Western Regional WRF is in operation. The timing of the upgrade and redirection of the Richwood PS to the Western Regional System will be evaluated based on monitoring the available capacity of the PS and the downstream Lakeview sewer system. Richwood PS will receive a backup power solution as well to eliminate any overflows due to power outages.

SD1 will include an evaluation of the capacity of the Richwood PS and a schedule for addressing overflows in the next watershed plan update.

Sunset Pump Station: The original plan in the Pump Station Overflow Elimination Plan for the Sunset PS was to replace the current pump station with a new 0.77 MGD pump station at the existing site. Since the original plan was developed, however, a private developer has proposed to partner with SD1 to construct a new pump station farther north to serve a new development as well as the existing Sunset PS area. This revised approach was described in the Addendum to the Pump Station Overflow Elimination Plan dated November 11, 2007. The new pump station (Arcadia PS) will eliminate the Sunset PS and overflow and will have a firm capacity of 1.3 MGD to provide capacity to convey peak dry and wet weather flows for current and future conditions. The new Arcadia PS will discharge to a gravity sewer tributary to the new Alex-Licking PS. The new Arcadia PS and associated gravity sewer and forcemain is currently under design. The original schedule provided in the PS Overflow Elimination Plan stated construction would be complete by spring of 2009. Due to the significant economic downturn and the slow-down in the housing and lending markets, SD1's partnership with the developer to construct the new PS has been delayed. At this point in time, it is optimistic that SD1's partnership will be restored in order to complete the new PS construction. In the meantime, an interim solution has been implemented that provided the required capacity in the near term to eliminate the overflow. The solution was to construct a new eight-inch force main and install new discharge piping in the existing pump station to allow the existing pumps to provide the necessary capacity in order to eliminate overflows. A new back-up diesel-driven pump was also provided to be used during power outages. This project was completed ahead of the Consent Decree deadline of December 31, 2010.

8.4 Monitoring Program

U.S. EPA requires that CSO communities monitor their progress in reducing CSOs during and after LTCP implementation. "Monitoring during LTCP implementation should include data collection to measure the overall effects of the program on water quality and to determine the effectiveness of CSO controls…A monitoring plan to assess water

quality conditions during and after program implementation will allow evaluation of the improvements through comparison to baseline conditions" (EPA, 1995b). This section describes how SD1 plans to monitor the implementation and effectiveness of the Integrated Plan for 2025 to meet the goals and the requirements of the Clean Water Act.

SD1 has made a significant investment since 1996 to characterize the combined and sanitary sewer systems, as well as the local rivers, streams and watersheds. SD1 has also expanded the scope of characterization efforts to encompass other watershed information such as physical and natural features, land use, and inventory of possible pollutant sources and associated pollutant loads (Section 2).

SD1 will continue to build upon this investment with a monitoring program to support several needs:

- Update characterization of the infrastructure and watersheds;
- Quarterly and annual reporting of wet weather CSO and SSO activations; and
- Monitor performance of constructed controls.

Although the Integrated Plan is expected to improve water quality, the Plan is not expected to enable all of the major tributaries in the 16 watersheds to fully attain the recreational use. Sources outside of SD1's jurisdiction will remain as major contributors to bacteria impairments in these waterbodies.

This ongoing monitoring is important to be aware of the current performance of the system, provide valuable and useful data for the update of hydraulic and water quality models, and understand the impacts of different control projects (reduction in CSOs and elimination of SSOs).

SD1's plan includes monitoring programs specific to project performance, the sanitary sewer collection system and watershed monitoring. Each of these components of the plan is described in the following sections.

8.4.1 Description of Project Performance Monitoring Program

Performance monitoring plans will be included in the detailed design for projects in the Five-year Improvement Program, as appropriate, and will continue through the full implementation of the Watershed Plans. Performance monitoring is necessary to evaluate specific watershed, green and integrated infrastructure control projects, test the effectiveness of phased controls (and aid in decisions about additional levels of control), and inform decisions about cost-effective projects in future control planning cycles. Because site-specific and cost data on these controls are needed for Northern Kentucky, performance monitoring may also be necessary to test the effectiveness of green infrastructure or watershed controls before decisions are made about implementation at other sites, or to inform the overall potential of these controls to improve water quality.

Performance evaluations will be based on the specific project being monitored and may include quantifying volume or load reductions, peak flow attenuation, or other volume and pollutant measures. The data will be used to update model assumptions regarding volume and/or load reductions, as well as cost assumptions for controls considered in future planning cycles. Performance monitoring data will be included in SD1's databases and used to modify SD1 tools, as appropriate.

Sampling plans will be developed for each control project so that monitoring may be tailored to meet specific objectives of measuring the control's performance. Example elements of a project-based performance monitoring plan to evaluate the effectiveness of the control against the expected performance include:

- Event-based influent and effluent monitoring (flow and/or water quality) of the control itself;
- Flow monitoring of the sewer system upstream and downstream of specific control project;
- Event-based watershed monitoring of waterbodies upstream and downstream of specific control project;
- Hydraulic and water quality model evaluations; and
- Operation and maintenance tracking associated with the control (e.g. sediment accumulation in basins, etc.).

Performance monitoring is planned for all projects implemented in the first Five Year Plan in order to assess effectiveness and confirm model predicted results.

Green Infrastructure Performance Monitoring

Green infrastructure performance monitoring will be a critical element in the early stages of SD1's overflow control strategy, and will ultimately shape the level and extent of specific strategies, as well as the overall role that green infrastructure will play in achieving SD1's water quality improvement goals for Northern Kentucky. The primary objectives of this monitoring are to measure and document specific project and/or BMP performance and to compare this data to modeled projections. This data may also prove useful in identifying the key design parameters that impact overall performance which will then allow for better and more cost effective designs moving forward.

Monitoring efforts will be designed to determine the performance of both individual BMPs as well as the benefits of program elements such as downspout disconnection.

The monitoring will be designed to generate the data necessary to verify the performance assumptions that SD1 has incorporated into the watershed plans. For example, in instances where SD1 has estimated a percent reduction in runoff volume through implementation of an infiltration feature, SD1 will conduct influent and effluent sampling of similarly designed features at various locations throughout the study area. The data produced from this sampling effort will aid in verifying that assumed infiltration rates are reasonable and sustainable across the study area. The results from this monitoring will allow SD1 to adjust modeled infiltration rates based on local data for future watershed plans. This same approach will also be employed for water quality

based BMPs, where the focus will be on verifying that modeled pollutant load reductions are realistic, for a range of BMP types. The results of this BMP specific monitoring will help SD1 evaluate the effectiveness of the green features included in CSO reduction projects, as well as green features constructed through project partnerships (GrIPP).

The proposed DRIP program focuses on disconnecting storm water runoff from the sewer systems through residential downspout disconnection. Due to factors affecting overall performance (lot size, participation rates, proximity to adjacent buildings), monitoring the benefits of this program will be more challenging and will likely produce results that are quite variable. A component of DRIP includes targeted downspout disconnection within the combined sewer system. The current plan includes runoff reduction estimates based on the assumption that 25 percent of non-priority area downspouts within the combined sewer system area can be removed. Representative pilot areas will be identified for pre and post- disconnect monitoring. It will be important to generate data on the percentage of homes/downspouts that may realistically be disconnected within the life of the Consent Decree; monitoring residential willingness and participation rates will also be of extreme importance in determining the success of the program. Once the pilot programs have been completed, disconnection assumptions will be re-evaluated and adjusted as necessary.

The results of this monitoring will determine the effectiveness of green controls (BMPs) in the region. This information will help guide the selection of future projects/BMPs needed to achieve desired volume or pollutant load reductions for CSO control and water quality improvements. Critical data will include:

- Infiltration rates,
- Pollutant load reductions,
- Peak flow reductions,
- BMP/drainage area ratios,
- Maintenance issues, and
- Performance over time.

The monitoring will consist of both short term and long term monitoring schedules. Select representative controls will be monitored for extended periods of time, ranging from one year to multiple years. This type of monitoring will address questions relating to seasonal variation and long term performance. Additionally, short term monitoring (three to six months) will be performed on a larger number of sites, which will provide information on a wide array of practices over a large geographic area. All monitoring data will be evaluated to determine trends in the performance of various green infrastructure BMPs.

Results from the green infrastructure performance monitoring will be used to right-size the gray infrastructure components required to achieve the desired level of control in the Integrated Solution for 2025.

8.4.2 Description of the Collection System Monitoring Program

Monitoring to Update Characterization of the Infrastructure

Additional monitoring to update and improve the characterization of the infrastructure is inherent in an adaptive management process. SD1's collection system monitoring program will include: 1) continued collection of data at key locations, 2) targeted monitoring to update computer models, and 3) collection of data at previously unmonitored locations.

The hydraulic model will need to be periodically updated and refined to reflect changes in SD1's sewer system. Changes in impervious areas, elimination of overflows, RDII reduction programs, pump station modifications, etc. may also require monitoring and model updates to assess their impact. A more detailed design model of a specific area may be desired for future alternatives analysis and sizing of planned CSO and SSO controls. To update the models, temporary and longer-term flow monitors will be deployed to collect data to support re-calibration. Flow monitoring is currently being used in this manner to support the SSO investigation, verification, and cleanup program and to assess effectiveness of current projects, such as the Lakeside Park, Van Deren project. SD1's ongoing flow monitoring program was described in the annual CMOM report dated December 17, 2010

Quarterly and Annual Reporting of Wet Weather CSO and SSO Activations

Flow monitors and rain gauges will continue to be operated at key locations within the combined and separate sanitary sewer systems. Given the size of SD1's sewer system, it is not practical or cost-effective to monitor every location. SD1 will continue to use the calibrated hydraulic model for generating quarterly and annual wet weather CSO and recurring SSO activation statistics and to track progress in reducing CSO and SSO discharges.

As part of the ongoing characterization effort, SD1 will continually update the model with new information from field inspections and, when necessary, verify that the model is still calibrated for its intended use.

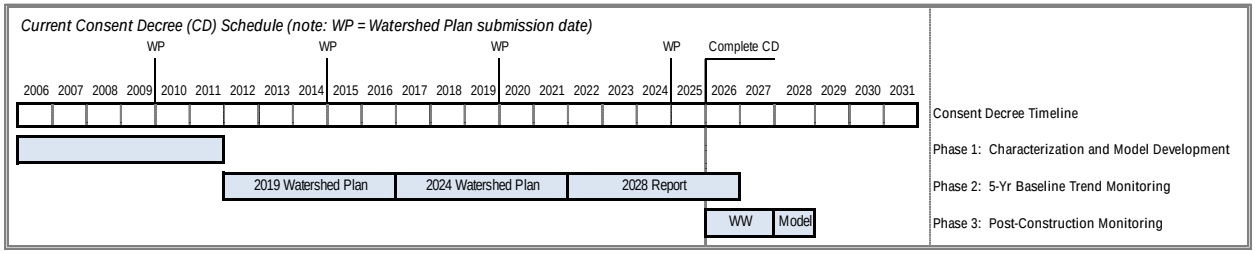
8.4.3 Description of the Watershed Monitoring Program

Monitoring is a key component in ensuring that the Watershed Plans are successfully implemented and that SD1's investment in source controls is cost-effective. Because SD1 is pursuing an Integrated Plan that includes green infrastructure and watershed controls in addition to traditional gray infrastructure controls, monitoring is needed throughout the 16 watersheds to measure the success of the Watershed Plans. The Watershed Monitoring Program (WMP) has been developed as one element of SD1's overall monitoring strategy. The WMP consists of three phases, which includes collecting data to: 1) initially characterize the waterbodies, 2) to capture changes in the waterbody conditions, and 3) post-construction monitoring to assess improvements in overall water quality, biology and habitat after the Watershed Plans are implemented. The phases of the WMP are:

- Baseline Monitoring Characterization and Model Development (2006-2011),
- Baseline Trend Monitoring (2012-2026), and
- Post-Construction Monitoring (2026-2028).

The phases of the WMP reflect the expected timing of activities needed to implement the Watershed Plans, to inform the five-year planning cycles of the Consent Decree, and to conform with the post-construction monitoring requirements of the CSO Policy. A timeline for each phase of the WMP is illustrated in Figure 8.4.

Figure 8.4 Watershed Monitoring Program Schedule by Phase



SD1 also plans to maintain the network of continuous flow and water quality multiprobe sondes that are operated in conjunction with the USGS throughout the duration of Consent Decree timeframe. In addition, SD1 intends to maintain contact with numerous providers of watershed and water quality data that have been identified as part of the watershed planning effort. As new or updated information and data are obtained from these agencies, SD1's databases and GIS layers will be updated (most likely on an annual basis).

Phase 1: Baseline Monitoring Characterization and Model Development

The first phase of the WMP was initiated in 2006 and will continue through 2011. This phase of the WMP is designed to address three purposes: 1) characterize current conditions in the 16 watersheds associated with the Consent Decree; 2) provide datasets for calibrating the detailed water quality models; 3) generate data to inform the Stream Condition Index and the Source Identification Program. This phase of the monitoring program was also described in Section 2.1.1 as part of the Watershed Characterization section. The components of this program include water quality, biological and habitat assessments, as well as hydromodification surveying.

The water quality component includes routine monitoring during base flow (dry weather) and event-based (discrete wet weather) conditions. Base flow sampling is conducted once per year at approximately 75 sites, unless conditions prevent sampling (e.g. creek is dry, accessibility to site changes). The goal of this sampling component is to have at least four base flow measurements at each site by the end of this phase of the program.

Up to three wet weather events are being sampled in all of the major tributaries, as well as the Ohio River[2]. Approximately eight samples are collected over a 48- to 72-hour

[2] Twelvemile Creek and the Ohio River between river miles 460 and 490 are only being monitored for two wet weather events because conditions changed (e.g. Eastern Regional Water Reclamation Plant coming on line in

period at each location in the tributary watersheds. Dry weather and wet weather samples collected at these locations are analyzed for bacteria (fecal coliform, *E. coli*), nutrients (total phosphorus, ortho-phosphate, total ammonia, nitrate-nitrite, total Kjeldahl nitrogen), solids (total suspended solids), and carbonaceous biochemical oxygen demand (5-day). In selected watersheds (Threemile Creek, Taylor Creek, Dry Creek, Pleasant Run, Gunpowder Creek and the four most downstream sites in Banklick Creek), metals and hardness are also collected. Wet weather samples are collected approximately every 24 hours in the Ohio River. Dry weather and wet weather samples collected in the Ohio River are analyzed for fecal coliform and *E. coli*.

Biological and habitat assessments are conducted by study basin (e.g. East, Central, North, West) with one basin per year being assessed. By the end of this phase of the program, all sites will have been assessed at least once. The major tributaries within each basin are assessed at multiple sites. Sites located in watersheds greater than five square miles are assessed for habitat quality, along with fish and macroinvertebrate communities, while only habitat and macroinvertebrates are assessed in those less than five square miles. This program also includes four least impacted monitoring sites (Double Lick Creek, Middle Creek, Garrison Creek, and Second Creek) in order to establish "best attainable" conditions for Northern Kentucky streams. These "best attainable" conditions will serve as a benchmark for biological communities and a point of comparison for other streams.

Hydromodification surveys are conducted at more than 20 sites across the study basin area. These include annually (up to three years) repeated level-tape surveys of the longitudinal profile and a representative riffle cross section, along with a 100-particle pebble count. Standard fluvial geomorphic variables were measured (e.g. bankfull top width, bank height and angle, etc.) and annual rates of geomorphic change were quantified across several metrics (e.g. longitudinal headcutting, change in channel depth, etc.). These results are used by SD1 to characterize the stability and degree of modification to a given stream sampling site.

The bulk of monitoring in this phase of the program was conducted between 2006 and 2010. The year 2011 is being used as a "catch-up" year, so that the goals of each component of this phase of the monitoring program can be achieved. In 2011, SD1 will revisit sites where biological and habitat assessments could not be conducted during the initial site visit, conduct base flow water quality sampling at locations with less than four observations, conduct three base flow surveys in the lower Ohio River (below river mile 490) and complete the event-based monitoring (one event in Gunpowder, Big Bone and Woolper and three events in the lower Ohio River).

Phase 2: Baseline Trend Monitoring

This phase of the WMP will be coordinated with the five-year planning cycles of the Watershed Plan and will consist of coordinated biological, habitat and base flow water

Twelvemile Creek) or because there is additional wet weather survey data to supplement SD1's monitoring (e.g. ORSANCO conducted five wet weather sampling events in this portion of the Ohio River as part of the Cincinnati/Northern Kentucky Wet Weather Demonstration Project).

quality monitoring. Monitoring will be conducted by basin with one basin per year being sampled over a four year period. The fifth year will be used as a "catch up" year similar to the sampling in Phase 1 in 2011. Samples will be collected at the same locations as Phase 1 monitoring sites.

The purpose of this phase of monitoring is to update SD1's understanding of baseline conditions for the detailed water quality models, update analytical tools (e.g. the Stream Condition Index and Watershed Assessment Tool) to reflect improvements resulting from control projects, identify trends in biological, habitat and water quality conditions in each watershed, and to serve as a basis for determining whether a use change is appropriate in waterbodies with persistent sources.

If appropriate, wet weather sampling may be conducted in this phase as conditions warrant. An example of conditions that may trigger wet weather sampling may be sampling in a watershed where a significant amount of new development has occurred so understanding the impact of runoff from this area would be instructive and valuable.

Phase 3: Post-Construction Monitoring

After the full implementation of the Watershed Plans, SD1 will initiate the last phase of the WMP, Post-Construction Monitoring. The purpose of this monitoring is to: 1) comply with USEPA CSO Policy requirements for post-construction monitoring, 2) verify that the Watershed Plans achieve expected water quality benefits, and 3) to characterize the potential duration and extent of change in water quality standards or uses that may be needed after the Plans are implemented. The monitoring strategy is focused on evaluating the benefits associated with the performance of the controls implemented for the Watershed Plans and to provide a post-construction dataset to use in updating the calibration of the detailed water quality models. SD1 will use the monitoring data and water quality models to determine how often the waterbodies attain the designated uses over the typical five-year period. The sampling portion of this plan may span a two-year period as shown in Figure 8.2, while the modeling updates and application are expected to be completed approximately three years after the Watershed Plans are implemented.

Sampling will be conducted as a single coordinated wet weather sampling across basins (16 major watersheds) at a subset of the Phase 1 monitoring locations. The subset of sampling locations will be determined based on proximity to controls, representation in the detailed models, and accessibility. The wet weather sampling frequency will mimic the wet weather sampling design used in Phase 1 (and described in Section 2.1.1). These data will be used to confirm and/or update the calibrations of the detailed water quality models. The sampling and model calibrations are anticipated to occur over a two year period. Like all computer models, the detailed water quality models inevitably carry some inherent variability, and calibration relies on reproducing the magnitude and timing of instream concentrations.

Once the detailed water quality models are updated, they will be applied for the typical five-year period to demonstrate that performance objectives and Watershed Plan benefits are being achieved in the waterbodies. The bacteria reduction evaluation

metrics shown in Table 3.1 will be used as performance objectives and will be based on a comparison to the baseline condition presented in Section 2.

8.5 Public Participation

SD1 is committed to continuing public participation and outreach during the design, construction and implementation of the Five-year Improvement Program to continue to inform the public and build support for future updates to the Watershed Plans and ongoing financing of the program.

The watershed-based approach and emphasis on green infrastructure will require significant public involvement to help identify and implement solutions that address the issues facing Northern Kentucky's rivers and streams. In addition, green programs, such as downspout disconnection, rain barrel, and rain garden programs, will require active participation and engagement of area residents.

The watershed-based approach also mandates that the success, priorities, and programs be reevaluated, and updated Watershed Plans be developed after five years. Throughout the five-year updates of the Watershed Plans, SD1 anticipates continuing outreach to the community through advisory groups, educational activities, community meetings, online and through the media to help solicit input and feedback and build support for the Watershed Plans.

8.5.1 Support Partners

As discussed in the Watershed Characterization Reports, public interest and watershed group activities is rated moderate to high for several of the watersheds. These groups and public activities complement SD1's watershed approach, since some may be able to extend to localities or sources typically beyond SD1's authority. Activities by these groups can include improvement projects, monitoring, assessments, and planning. SD1 will continue to support these partners by providing characterization information and assistance with grant applications as appropriate. Specifically, SD1 can assist these partners in identifying monitoring locations and appropriate field and laboratory techniques. In some instances, coordinating with these partners may identify common monitoring strategies which will minimize duplication of efforts.

8.6 First Watershed Plan Implementation Summary

As described earlier in this Section and in earlier sections of this report, SD1 has identified projects to be implemented in the first five years that will comply with the Consent Decree, address significant public health concerns, and provide SD1 with the ability to test innovative solutions to inform and support future plans. The projects represented in the first Five-year Improvement Program are on the cusp of affordability for SD1's ratepayers. The projects are summarized below:

- **Completion of Initial Watershed Projects***:* These projects, stipulated in the Consent Decree, will improve the performance of the separate and combined

sewer systems and play a significant role in reducing the activation of the Lakeview PS bypass. In addition, these Initial Watershed Projects will provide needed capacity to support current and future wastewater demands in the eastern and western ends of the service area.

- **Address known, significant public health concerns:** The Ash Street PS project, Vernon Lane rehabilitation project, and the Lakeside Park rehabilitation project will address long-standing overflows that pose a significant risk to public health.

- **Ability to assess the performance of green and watershed controls:** A variety of green infrastructure and watershed projects are included in the initial watershed plan, and a primary goal is to determine the effectiveness at removing or reducing the concentration of pollutants and improving water quality. In addition, piloting these projects in the first five years is necessary to determine the implementability and cost effectiveness of these controls for future Watershed Plans. The evaluations will address state and federal regulations, community ordinances, public involvement, and cost-effectiveness.

8.7 Future Watershed Planning Cycles

This updated Watershed Plan has identified an Integrated Plan for 2025 that provides a path forward in addressing CSOs and eliminating SSOs. SD1 plans to continue to implement the integrated projects in accordance with the prioritization effort described in Section 6. However, the combination of controls to address these prioritized needs may change once SD1 has the opportunity to review post-construction performance data and as system characterization efforts provide additional information on the extent of problems that remain across the service area. SD1's financial capability and the economic climate will also be critical factors assessed in developing subsequent plans.

8.7.1 Process for Updating Watershed Plans

The Watershed Plans contain an Integrated Plan for 2025 and a detailed Five-year Improvement Program, as required by the Consent Decree. The plans also describe SD1's watershed management program, which consists of an iterative program of characterization, monitoring, modeling, and ranking of challenges and solutions. SD1 will submit updates to these plans to the Cabinet and EPA for approval every five years, as required by the Consent Decree.

SD1's watershed management program is based on targeting resources on the most cost-effective controls first, while assessing the feasibility and benefits of controlling other sources through green, gray and watershed approaches. This allows SD1 to test the effectiveness of new technologies, such as green infrastructure, for incorporation into the next cycle of watershed planning. As SD1 implements the controls identified in this first set of plans, additional information will be collected to assess effectiveness, fill data gaps, refine the watershed management program, and refine the additional controls proposed in the next set of plans.

A comprehensive program of monitoring stream water quality, habitat and biological assessments, demonstration of project performance, and flow monitoring for areas with excessive sewer flows will help to identify additional problem areas and track improvements to the system. Data collected through the regional monitoring efforts will support the selection of goals and the prioritization process for gray, green and watershed controls in the next set of plans. Data collection from pilot projects will include pre- and post-monitoring to provide performance information for specific technologies to better inform and support future plans and design processes.

As with the current Watershed Plans, public input and participation will continue to shape goals and assist in the prioritization of the projects for updated Watershed Plans. In future years, public input and priorities may have an increasing role, as the Initial Watershed Projects are completed and additional resources are available for project selection. Also in subsequent plans, system improvements and post-construction monitoring will provide greater understanding of remaining pollutant source reduction needs in comparison to water quality standards for public consideration.

SD1's update process will also include the modification of any CSO operational plans to account for any long-term combined sewer system controls. This includes operational changes for existing infrastructure, such as pump station and wastewater treatment plants, as well as the required operation and maintenance of any new proposed projects such as inline storage structures and SD1 owned retention basins.

8.8 Conclusions

In this plan, SD1 is making a commitment to spend approximately $459 million on projects identified in the Five-year Improvement Program. These projects will improve reliability of the system, eliminate overflows, provide service to developing areas, improve water quality, and address priority public health concerns. Model results show that after this investment, typical year CSO volume is predicted to be reduced by 26 percent from current conditions and typical year SSO volumes will be reduced by 45 percent. These reductions result in an improvement in water quality and address significant public health concerns in areas such as Lakeside Park and Silver Grove. The Five-year Improvement Program represents a positive investment of ratepayer money across SD1's service area.

Beyond the first five years, the Integrated Plan provides for evaluation of a watershed-based approach to design projects consistent with the approach set out herein to direct funds to those projects that provide the most meaningful benefit to water quality and public health. This approach is expected to yield a greater benefit at a lower cost than traditional gray infrastructure solutions. This approach will also result in additional community benefits that cannot be achieved through gray-only solutions.

The iterative structure of SD1's Watershed Plans allows time to investigate new technologies and adjust the approach to lessons learned. This approach:

- Recognizes other pollutant sources and their relative impacts and puts CSOs and SSOs into context with the other pollutant sources;

- Provides a process to address highest regional priorities first;
- Opens the door to address more varied sources of pollution;
- Uses an integrated approach of controls that will address both dry and wet weather-related sources of pollution and lead to a greater improvement in water quality and public health at lower costs to ratepayers;
- Directs funds to projects that provide the greatest benefits; and
- Can achieve the ultimate goals of the Consent Decree with respect to CSO and SSO discharges.

Solutions for future plans will be developed using information gained from the implementation of projects during the first five years.

SD1's Watershed Plans are focused on prioritizing the projects that maximize the return on investment, protect public health, and improve water quality. By embracing green infrastructure, SD1 will "keep rainwater out of the sewer system to reduce sewer overflows and to reduce the amount of untreated storm water discharging to surface waters" (EPA, 2007). This approach also allows SD1 to compare gray-only controls against integrated sets of gray, green, and watershed solutions and predict the estimated cost savings and greater net water quality benefit of the integrated solutions. The approach allows SD1 to "learn by doing" and allows the information gained on project effectiveness to be factored into the next round of decision-making and project selection.

As a pioneer in this approach to Consent Decree implementation, SD1 will need to work closely with the regulatory agencies and local stakeholders to coordinate and maintain considerable flexibility throughout the duration of the Consent Decree. For example, this could mean that, in certain situations, it is sensible to accept a lower level of overflow control than traditional programs, in exchange for greater improvement in water quality through investments in a combination of controls that address other pollution sources, such as runoff and dry weather sources. This offset or delay concept is specifically recognized in the Consent Decree. Likewise, SD1 may find that directing resources toward other sources of pollution provides a more substantial improvement in water quality. The planning of such projects will require assurances by SD1 that the projects will be implemented as well as the willingness of regulators to accept offsets or delays in typical overflow controls.

As presented in Section 4, the Integrated Plan for 2025 is more cost-effective than the traditional gray approach, but still exceeds SD1's financial capability as recognized by the regulators. The parties will need to determine the appropriate relief to the December 31, 2025 deadline in the Consent Decree. The issue of the form of the relief from the deadline is beyond the scope of this plan, but could include use attainability analyses, point source specific variances, deadline extensions, or affordability adjustments in five-year plan updates. Nevertheless, through the five-year cycles, SD1 will measure progress and ensure that limited ratepayer funds are directed into control programs that meet regulatory mandates, maximize improvements in water quality and public health, and meet the expectations of the public.

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Section 9
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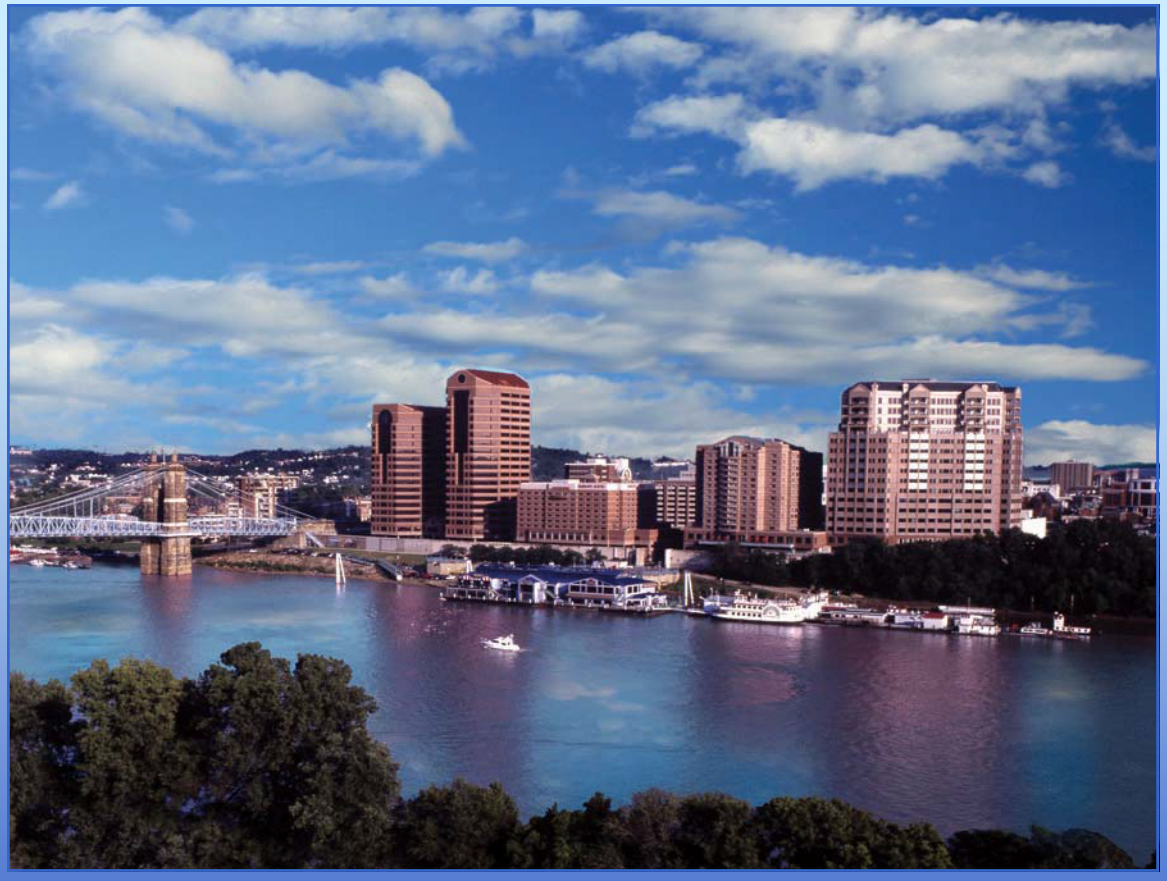
APPENDICES

Watershed Plans for Northern Kentucky

Sanitation District No. 1
March 14, 2014



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Appendix 1-A

Consent Decree, Paragraphs 39 and 40

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Consent Decree, Paragraphs 39 and 40

39. The District shall prepare and submit to the Cabinet/EPA for review and joint approval a Framework for Development of Watershed Plans, a Watershed Plan for each of the four (4) watersheds that comprise the District's service area as identified on the maps attached hereto as ***Exhibit F***, and Updated Watershed Plans within the time frames and as more particularly set forth in subparagraphs (a), (b), and (c) below. Each Watershed Plan shall include components for a LTCP and a Sanitary Sewer Overflow Plan ("SSOP"). The District shall develop these Watershed Plans for the purpose of the reduction and control of discharges from CSO Outfalls consistent with the CSO Control Policy, the elimination of SSOs and Unpermitted Discharges in the Sewer System, and the improvement of water quality in the receiving waters. In preparing these Watershed Plans, the District shall implement a prioritization scheme for remedial measures based upon such factors as environmental impact, public risk, regulatory requirements, the degree of water quality improvement expected to be achieved, public input, and cost effectiveness. The District shall prepare conventional, innovative or alternative designs as part of each Watershed Plan, including but not limited to: sewer rehabilitation, sewer replacement, sewer separation, relief sewers, above ground or below ground storage, high rate secondary treatment, illicit connection removal, remote wet weather secondary treatment facilities, and other appropriate alternatives. Designs shall be based on sound engineering judgment and shall be in accordance with generally accepted engineering design criteria and may include interim remedial measures to reduce pollutant loading and improve water quality in the short term while alternatives for final remedial measures are being developed, evaluated and implemented. In addition, the District may develop the LTCP component of the Watershed Plans in conjunction with a watershed based approach providing for the evaluation of water pollution control needs on a watershed management basis and the coordination of CSO control efforts with other permitted point sources and nonpoint source control activities. This watershed based approach may allow for a demonstration of attainment of water quality standards by the District's CSOs considering natural background conditions and pollution sources other than CSOs through any total maximum daily loads ("TMDLs") developed by the Cabinet.

(a) **Framework for Developing the Watershed Plans.** Within twelve months of entry of this Consent Decree, the District shall submit to the Cabinet/EPA for review and joint approval a Framework for developing the Watershed Plans.

(1) The Framework shall describe the manner in which the District plans to undertake the development of the LTCP component of the Watershed Plans, including, at a minimum, the following elements:

(A) An evaluation, if appropriate, of water pollution control needs on a watershed management basis and the coordination of CSO control efforts with other permitted point sources and nonpoint source

control activities; this watershed based approach shall allow for a demonstration that the District's CSOs comply with water quality standards considering natural background conditions and those pollution sources other than CSOs and shall take into consideration only those TMDLs expected to be finalized by the Cabinet prior to September 1,2008;

(B) Characterization, monitoring, modeling activities, and design parameters as the basis for selection and design of effective CSO controls (including controls to address those discharges resulting from the District's compliance with the requirements of the United States Army Corps of Engineers' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);

(C) A public participation process that actively involves the affected public in the decision-making to select long-term CSO controls consistent with provisions of Paragraph 40 below;

(D) Consideration of sensitive areas as a high priority for controlling overflows, including drinking water intakes;

(E) Evaluation of alternatives that will enable the District, in consultation with the Cabinet, EPA, and the public, to select CSO controls that will meet the requirements of the CWA;

(F) Cost/performance considerations to demonstrate the relationships among a comprehensive set of reasonable control alternatives;

(G) Operational plan revisions to include agreed-upon long-term CSO controls; and

(H) Maximization of treatment at the District's DCWWTP for wet weather flows.

(2) The Framework shall describe the manner in which the District plans to prioritize, pursuant to the SSOP component of the Watershed Plans, the elimination of SSOs and Unpermitted Discharges at locations other than those already identified on ***Exhibit E*** and addressed pursuant to the Pump Station Plan, and shall include schedules for the evaluation of WWTP peak flow treatment capacity for WWTPs that have experienced a prohibited bypass (as defined in 401 KAR 5:065**,** Section 1(13)(c)) within three (3) years before the date of entry of this Consent Decree and for any WWTP that will receive additional flow based on any SSOP project.

(3) If the District plans to identify and incorporate other permitted point sources and nonpoint sources contributing to water quality impairment into the Watershed Plans, the Framework shall describe the manner in which the District plans to identify and incorporate such other permitted point sources and nonpoint sources and, where appropriate, how the District intends to insure that necessary controls are implemented at these sources.

(b) **Watershed Plans.** By December 31, 2008, the District shall submit a Watershed Plan for each of the four (4) Watersheds, which shall include components for a LTCP and a SSOP, to the Cabinet/EPA for review and joint approval. The LTCP component of the Watershed Plans shall conform to the CSO Control Policy, and, in developing the LTCP component, the District shall use as guidance EPA's "Guidance for Long-Term Control Plan," EPA 832-B- 95- 002, September 1995. The SSOP component of the Watershed Plans shall specify remedial measures to eliminate SSOs and Unpermitted Discharges at locations other than those already identified on ***Exhibit E*** and addressed pursuant to the Pump Station Plan. The Watershed Plans shall include expeditious and prioritized schedules, deadlines and timetables for remedial measures that will bring the District's CSOs into full compliance with the water quality standards criteria listed for the CSO demonstrative approach or the presumptive approach, and that will eliminate SSOs and Unpermitted Discharges, as soon as practicable based on sound engineering judgment but in no event later than December 31, 2025. The Watershed Plans shall provide more detail for all remedial measures to be implemented in the first five (5) years after approval.

(1) The LTCP component of each Watershed Plan shall meet the following goals:

(A) Ensure that if CSOs occur, they are only as a result of wet weather (this goal shall include addressing those discharges resulting from the District's compliance with the requirements of the united States Army Corps of Engineers' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);

(B) Bring all wet weather CSO discharge points into compliance with the technology-based and water quality-based requirements of the CWA; and

(C) Minimize the impacts of CSOs on water quality, aquatic biota, and human health.

(2) The LTCP component of each Watershed Plan shall include, at a minimum, the following elements:

(A) The results of any evaluation of water pollution control needs on a watershed management basis and the coordination of CSO control efforts with other permitted point sources and nonpoint source control activities and a demonstration that the District's CSOs comply with water quality standards considering natural background conditions and pollution sources other than CSOs through those TMDLs finalized by the Cabinet prior to September 1, 2008;

(B) The results of characterization, monitoring, modeling activities, and the application of design parameters as the basis for selection and design of effective CSO controls (including controls to address those discharges resulting from the District's compliance with the requirements of the United States Army Corps of Engineers' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);

(C) The results of an evaluation of peak flow treatment capacity for the DCWWTP and any WWTP that will receive additional flow based on any LTCP project. In preparing such an evaluation, the District shall use as guidance the EPA publications "Improving POTW Performance Using the Composite Correction Approach," EPA CERI, October 1984, and "Retrofitting POTWs," EPA CERI, July 1989;

(D) A report on the public participation process;

(E) Identification of how the LTCP addresses sensitive areas, including drinking water intakes, as a high priority for controlling overflows;

(F) A report on the cost analyses of the alternatives considered, including a financial capability assessment based upon EPA's "Combined Sewer Overflows Guidance for Financial Capability Assessment and Schedule Development," EPA 832-B-97-004, February 1997, taking into account the economic capability of the communities the District serves;

(G) Operational plan revisions to include agreed-upon long-term CSO controls;

(H) Maximization of treatment at the District's existing WWTPs for wet weather flows;

(I) Identification of, and an implementation schedule for, the selected CSO controls; and

(J) A post-construction compliance monitoring program adequate to ascertain the effectiveness of CSO controls and to verify compliance of the District's CSOs with water quality-based CWA requirements.

(3) The SSOP component of each Watershed Plan shall include, at a minimum, the following elements:

(A) The results of an evaluation of WWTP peak flow treatment capacity for WWTPs that have experienced a prohibited bypass (as defined in 401 KAR 5:065, Section 1(13)(c)) within three (3) years before the date of entry of this Consent Decree and for any WWTP that will receive additional flow based on any SSOP project. In preparing such evaluation, the District shall use as guidance the EPA publications "Improving POTW Performance Using the Composite Correction Approach," EPA CERI, October 1984, and "Retrofitting POTWs," EPA CERI, July 1989.

(B) A map that shows the location of all known SSOs and Unpermitted Discharges. The map shall include the areas and sewer lines that serve as tributary to each SSO and Unpermitted Discharge. Smaller maps of individual tributary areas also may be included to show the lines involved in more detail.

(C) A description of each SSO and Unpermitted Discharge location that includes:

(i) The frequency of the event;

(ii) The annual volume of the event;

(iii) A description of the location of the event, *e.g.,* manhole, etc.;

(iv) The receiving stream;

(v) The immediate area and downstream land use, including the potential for public health concerns;

(vi) A description of any studies to investigate the event that were conducted within five (5) years of plan submission, that are being conducted at the time of plan submission, or that is proposed for the future; and

(vii) A description of any rehabilitation or construction work that was conducted within five (5) years of plan submission, that is being conducted at the time of plan submission, or that is proposed for the future to remediate or eliminate the SSO or Unpermitted Discharge.

(D) A prioritization of the SSO and Unpermitted Discharge locations identified above, based primarily on the frequency, volume and impact on the receiving stream and upon public health, and in coordination with any remedial activity performed pursuant to the CMOM Programs and any other component of a Watershed Plan and an evaluation of water pollution needs on a watershed management basis. Based upon this prioritization, the District shall develop remedial measures and expeditious schedules for design, initiation of construction and completion of construction.

(E) A plan to involve stakeholders in the planning, prioritization and selection of projects consistent with provisions of Paragraph 40 below.

(4) If Watershed Plans identify any permitted point sources or nonpoint sources, other than CSOs and SSOs, that are contributing to water quality impairment, the Watershed Plans shall also identify planned control measures, if any, that the District plans to utilize and shall provide implementation schedules for these controls. If a control on these other sources of pollution is to be implemented to offset the level of CSO controls or to delay the elimination of an SSO or Unpermitted Discharge, other than through a final TMDL developed by the Cabinet, the Watershed Plan shall identify the means by which the District intends to insure that the control is implemented.

(c) **Updated Watershed Plans.** At least ninety days prior to the five (5) year anniversary of approval of each Watershed Plan, the District shall submit an Updated Watershed Plan to the Cabinet/EPA for review and joint approval. Existing Watershed Plans shall continue in effect until the Cabinet/EPA approves an updated plan. The District shall have the right to submit an Updated Watershed Plan to the Cabinet/EPA for review and joint approval at any time. Updated Watershed Plans shall be based upon the Framework for developing the Watershed Plans, as set forth in Paragraph 39(a) above, and shall take into consideration any TMDLs finalized by the Cabinet three (3) months prior to the update. The Updated Watershed Plans shall provide more detail for all remedial measures to be implemented over the successive five (5) year period based upon the approved schedule in the initial Watershed Plan or any revised scheduled approved by the Cabinet/EPA.

40. **Public Participation.** In the required public participation process to be developed in the Framework and the SSOPs, the District shall include procedures to advertise, convene a public meeting, and accept public comment on the development of each Watershed Plan, in accordance with the publication procedures of KRS Chapter 424, as follows:

(a) Within twelve months of entry of this Consent Decree, to obtain public input on the Watershed Plan process and potential consideration of projects; and

(b) Following development of a draft Watershed Plan or draft Updated Watershed Plan, but prior to submittal of a proposed Watershed Plan or Updated Watershed Plan to the Cabinet/EPA for approval, to obtain public input on such draft plans.

The District shall also hold informal workshops and other informational meetings to solicit input from the public and the Cabinet/EPA in the decision-making process. The number and format of such informal workshops and meetings shall be left to the District's discretion. The District may, in its discretion, also form interest groups for each Watershed that may include members of the public, businesses, and/or governmental agencies that will be kept advised of progress on Watershed Plans through annual meetings.

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Appendix 1-B

Consent Decree Requirements Mapped to Watershed Plans

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Appendix 1-B
Consent Decree Requirements Mapped to Watershed Plans

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV. D. 39 A Watershed Plan for each of the four (4) watersheds…Each Watershed Plan shall include components for a LTCP and a Sanitary Sewer Overflow Plan ("SSOP"). The District shall develop these Watershed Plans for the purpose of the reduction and control of discharges from CSO Outfalls consistent with the CSO Control Policy, the elimination of SSOs and Unpermitted Discharges in the Sewer System, and the improvement of water quality in the receiving waters.	Section 7. Five-Year Improvement Program Appendix 3-A. Full System Bounding Analysis Section 3. Integrated Plan for 2025	SD1's Five-year Improvement Program consists of Initial Watershed Projects, Committed Projects, and System-wide Projects and Basin Projects for each of the four basins (Section 7). This program is based on the findings of the Full System Bounding Analysis (Appendix 3-A), which evaluated gray, green and watershed controls (and combinations thereof) to assess the relative water quality benefits of different levels of control. The Full System Bounding Analysis was developed to provide the reasonable range of alternatives required by the LTCP, but also provides information on the extent, costs, and benefits of various regional solutions to support the watershed-based decision-making applied in the development of the Five-year Improvement Program. The results of the Full System Bounding Analysis also supported the selection of the Integrated Plan for 2025 (Section 3) which is the preferred Integrated Plan that addresses the 2025 compliance objectives, but exceeds EPA affordability standards. The Integrated Plan was found to be the most cost-effective and environmentally sound plan for eliminating SSOs and controlling CSOs to meet water quality based requirements by 2025, but it cannot be completed by 2025 due to its costs. The parties will need to determine the best approach for addressing this affordability constraint through deadline extensions or other CSO Control Policy options. Unpermitted discharges are point source discharges which are not covered in a permit. In the SD1 service area, this would be limited to SSOs and any non-permitted CSOs. SD1's approach has been to treat any known point source discharge from the sanitary sewer system as an SSO (this includes pump station bypasses) and any known wet weather discharge from the combined sewer system as a CSO (either permitted or to-be-permitted), thereby eliminating the need for the term 'Unpermitted Discharge'.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39 District shall implement a prioritization scheme for remedial measures based upon such factors as environmental impact, public risk, regulatory requirements, the degree of water quality improvement expected to be achieved, public input, and cost-effectiveness.	Appendix 3-A. Full System Bounding Analysis Section 6. Prioritization	SD1 identified metrics for evaluating controls (Table 1 of Appendix 3-A) and conducted a public survey to assess the community's values and priorities (Section 5.1.3). These results were used to establish regional priorities and inform the identification of Priority Areas so that projects could be developed for the first Five-year Improvement Program. Criteria for identifying Priority Areas (developed by aligning watershed goals with results of stakeholder input) included: Public Health Risk Areas, Consent Decree Exhibit E Pump Stations, Watershed Control Opportunities, Green Opportunities, Integration (gray/green/watershed) Opportunities, and High Volume CSOs and SSOs.
IV.D.39 The District shall prepare conventional, innovative or alternative designs as part of each Watershed Plan, including but not limited to: sewer rehabilitation, sewer replacement, sewer separation, relief sewers, above ground or below ground storage, high rate secondary treatment, illicit connection removal, remote wet weather secondary treatment facilities, and other appropriate alternatives. Designs shall be based on sound engineering judgment… and may include interim remedial measures to reduce pollutant loadings and improve water quality in the short term while alternatives for final remedial measures are being developed, evaluated and implemented.	Section 7.1 Initial Watershed Projects Section 7.2 Committed Projects Section 7.3 System-wide Projects Sections 7.4 to 7.7 Basin Projects Appendix 3-B Green Opportunities Analysis Appendix 3-C Watershed Control Opportunities Analysis	Section 7 provides the details of the specific projects identified for the first Five-year Improvement Program. These include the Initial Watershed Projects, Committed Projects, and System-wide Projects and Basin Projects for each of the four Consent Decree watersheds. Projects selected include new conveyance and treatment systems, pump station improvement/eliminations, sewer repair/replacement/rehabilitation, sewer separation and illicit connection removal, reduction of river water intrusion, and private source inflow/infiltration reduction. In addition to the traditional gray solutions, SD1 has chosen to emphasize green infrastructure (Appendix 3-B) and watershed controls (Appendix 3-C) in the Watershed Plans to assess the effectiveness of the controls in reducing overflow volumes and improving water quality. Green programs include DRIP (residential downspout disconnection, rain barrel and rain garden incentives), GrIPP (non-residential project partnership incentives) and technical support for urban reforestation and riparian buffers. Watershed programs include large-scale regional controls (constructed wetlands and retention basins) and smaller decentralized controls (storm water wetlands, bioretention/biofiltration basins, and enhanced retention basins) within SSES areas as well as within other areas of the separate sewer system. For the Five-year Improvement Program, SD1 has obligations both to the Committed Projects (ongoing asset management) as well as the completion of the Initial Watershed Projects, which represent a spending commitment of $396 Million over the next five years. SD1's objective is to fund the completion of the Initial Watershed Projects, continue working on the Committed Projects, and begin the implementation of System-wide and Basin Projects identified for Priority Areas.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39 The District may develop the LTCP component in conjunction with a watershed based approach providing for the evaluation of water pollution control needs on a watershed management basis and the coordination of CSO control efforts with other permitted point sources and nonpoint source control activities. This watershed based approach may allow for a demonstration of attainment of water quality standards by the District's CSOs considering natural background conditions and pollution sources other than CSOs through any…TMDLs…developed by the Cabinet.	Appendix 3-A, Section 3: Water Quality Evaluation and Sensitivity Analysis Section 3 Integrated Plan for 2025	As part of the Full System Bounding Analysis, SD1 evaluated the potential water quality benefits from the gray-only overflow solution and assessed if addressing other point and nonpoint sources (with a combination of gray, green and watershed controls) are more cost-effective and provide greater benefit in improving water quality. The analysis showed that the integrated solution concepts provided greater improvements in water quality over more stream miles and can be more cost-effective as compared to gray infrastructure solution concepts. The water quality models indicate that a program based on a combination of gray controls at a lower level of overflow reduction with a moderate implementation of green and watershed controls yields greater overall benefits than a higher level of gray-only overflow controls. The green and watershed controls also provide additional community benefits. The Integrated Plan was found to be the most cost-effective and environmentally sound plan for eliminating SSOs and controlling CSOs to meet water quality based requirements by 2025, but it cannot be completed by 2025 due to its costs. The parties will need to determine the best approach for addressing this affordability constraint through deadline extensions or other CSO Control Policy options. Note: Only 2 TMDLs have been approved in the study area (Elijahs & Gunpowder glycol TMDLs in 1998) and no CSOs are located in those watersheds.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b) Include expeditious and prioritized schedules, deadlines and timetables for remedial measures that will bring the District's CSOs into full compliance with the water quality standards criteria listed for the CSO demonstrative approach or the presumptive approach, and that will eliminate SSOs and Unpermitted Discharges, as soon as practicable based on sound engineering judgment but in no event later than December 31, 2025. The Watershed Plans shall provide more detail for all remedial measures to be implemented in the first five (5) years after approval.	Section 7. Five-year Improvement Program Sections 8.2.1 - 8.2.5 Summary of Five-year Improvement Program Projects, Costs, Benefits, and Schedule Section 4.5.1 Projection of Potential Full Program Costs Section 3. Integrated Plan for 2025	The detailed project summaries are included in the basin sections (Sections 7.4 to 7.7) and summarized in Section 7.8. The estimated costs, benefits, and schedules for the projects are provided in Section 8. Specific schedules are provided for projects in the Five-year Improvement Program, and a preliminary schedule is provided for the Integrated Plan for 2025. The Full System Bounding Analysis presented in Appendix 3-A provides the basis to assess the costs and benefits associated with a full gray infrastructure solution concept. The estimated cost of the overflow control component of the gray solution concept varied from $1.9 Billion to $3.2 Billion in 2009 dollars, depending on the level of overflow reduction, while the full program cost of a 2025 solution varied from $2.7 Billion to $4.0 Billion in 2009 dollars (June 2009 submittal). The economic analysis of this scenario indicated that this program would be unaffordable by EPA standards. For the March 2011 update, SD1 conducted an analysis of the Integrated Plan for 2025 to determine the cost-effectiveness and implementability of a gray, green, and watershed full system solution. The estimated cost for the Integrated Plan to achieve the compliance objectives of the Consent Decree is $1.26 Billion in 2009 dollars. The estimated full program cost of the Integrated Plan for 2025 is $2.4 Billion in 2009 dollars Section 4 and Section 8). SD1 has focused on the watershed-based approach for the first Five-year Improvement Program to realize the maximum benefits for the money spent. SD1 was unable to demonstrate that water quality standards could be achieved by 2025 even if all CSOs were eliminated and a five-year level of service was provided for SSOs. SD1, therefore, identified a preferred Integrated Plan that addresses the 2025 compliance objectives, but exceeds EPA affordability standards.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(1)(A) Ensure that if CSOs occur, they are only as a result of wet weather (this goal shall include addressing those discharges resulting from the District's compliance with the requirements of the United States Army Corps of Engineers' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988)	Section 1.7.1 Compliance with the CSO Control Policy Section 7.2 Committed Projects Section 7.3.1 River Water Intrusion Mitigation	Section 1.7.1 describes SD1's prevention-based approach for ensuring that CSOs are only a result of wet weather conditions. The Five-year Improvement Program includes a Continuous Sewer Assessment Program and the Targeted Sewer Cleaning Program (Section 7.2), which efficiently identifies and targets cleaning activities where they can have the most benefit, thereby decreasing blockages and maintaining designed conveyance capacity. Additionally, implementation of the Nine Minimum Controls (NMC) Solids and Floatables Control Program further reduces potential dry weather overflows through catch basin and diversion structure modification. To address the Army Corps of Engineers (USACE) Flood Protection System, SD1 has conducted a detailed river water intrusion mitigation feasibility analysis. Since portions of the combined sewer system are below both normal and elevated Ohio River levels, the activation of the USACE Flood Protection System is often due to wet weather conditions elsewhere that raise the Ohio River level, and rarely by local rainfall. The goal of this analysis was to fully understand the effects that the USACE's Flood Protection System has on SD1's sewer system and to identify measures to prevent river water from entering the combined sewer system. The study showed that the USACE's Flood Protection System impacts operations of the combined sewer system. Projects were identified to reduce river water intrusion into the sewer system and reduce CSO volumes by approximately 230 million gallons annually.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(1)(B) Bring all wet weather CSO discharge points into compliance with the technology-based and water quality-based requirements of the CWA	Section 1.7.1 Compliance with the CSO Control Policy Section 7.2 Committed Projects Section 7.3 System-wide Projects Appendix 3-A Full System Bounding Analysis Section 3 Integrated Plan for 2025	Section 1.7.1 describes SD1's approach for compliance with the technology-based and water-quality based requirements of the Clean Water Act. Technology-based requirements are documented in SD1's NMC Program, which was submitted on March 12, 2008 and approved on July 6, 2008. NMC Program components are integrated into the Committed and System-wide Projects, in projects and programs such as the Bromley Wet Well Optimization, In-line Storage, Solids and Floatables, Continuous Sewer Assessment, and Targeted Sewer Cleaning. The water quality-based requirement aligns with SD1's watershed-based approach outlined in the Consent Decree. Ultimately, the water quality based CSO controls will be addressed through the implementation of the Integrated Plan for 2025 in five-year increments. While the Integrated Plan for 2025 was found to be the most cost-effective and environmentally sound plan for eliminating SSOs and controlling CSOs to meet water quality based requirements by 2025, it cannot be completed by 2025 due to its costs. The parties will need to determine the best approach for addressing this affordability constraint through deadline extensions or other CSO Control Policy options.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(1)(C) Minimize the impacts of CSOs on water quality, aquatic biota, and human health	Section 2.1.1 Watershed Characterization Section 2.2.6 Summary of Current Water Quality Impacts Section 2.3.4 Future Conditions – Projections in the Combined Sewer Service Area Section 6 Prioritization Section 3 Integrated Plan for 2025 Section 7. Five-Year Improvement Program	SD1's watershed-based approach to improving water quality is based on the fact that sewer overflows are not the sole source of impairment for Northern Kentucky's streams and rivers. SD1's approach involves a more thorough characterization of the waterways, their water quality, and their response to not just overflows, but also other sources of pollution. Characterization activities included instream water quality, biological and habitat monitoring, outfall sampling, flow monitoring, sewer system modeling, and watershed and water quality modeling. The data and models were used to understand current conditions and sensitive areas, as well as future conditions within each of the area's sixteen watersheds. SD1's characterization also included a prioritization process which evaluated criteria such as Public Health Risk to identify Priority Areas (Section 6). The evaluation of green infrastructure (Section 3), using detailed watershed, infrastructure and water quality models, allowed SD1 to evaluate the potential benefits of gray, green and watershed controls to maximize overall improvements to water quality, aquatic biota, and human health. This comprehensive process resulted in a Five-year Improvement Program that cost-effectively minimizes the impacts of overflows (including CSOs) and other pollution sources.
IV.D.39(b)(2)(A) The results of any evaluation of water pollution control needs on a watershed management basis and the coordination of CSO control efforts with other permitted point sources and nonpoint source control activities and a demonstration that the Districts' CSOs comply with water quality standards considering natural background conditions and pollution sources other than CSOs through those TMDLs finalized by the Cabinet prior to September 1, 2008.	Appendix 3-A, Section 3: Water Quality Evaluation and Sensitivity Analysis	SD1's Full System Bounding Analysis estimated the benefits of gray infrastructure solution concepts at various levels of overflow control and compared the results with the water quality benefits of integrated solution concepts using the evaluation metrics identified in Table 1 of Appendix 3-A. The analysis showed: 1) the lowest level of overflow control considered along with moderate watershed controls yields similar water quality improvements as controlling CSO and SSO alone at a higher level, and 2) benefits from integrated solutions occur along more stream miles and address sources (such as dry weather sources) that gray-only controls cannot. These results show that use of green and watershed controls can be a more effective approach to improving water quality than using gray-only controls. Depending on the level of control, the use of green and watershed controls can also be more cost-effective than using gray-only controls alone. Note: Only 2 TMDLs have been approved in the study area (Elijahs & Gunpowder glycol TMDLs in 1998) and no CSOs are located in those watersheds.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(2)(B) The results of characterization, monitoring, modeling activities, and the application of design parameters as the basis for selection and design of effective CSO controls	Section 2.1.2 Gray Infrastructure Characterization Section 2.1.1 Watershed Characterization Appendices 2-A through 2-D Section 3. Integrated Plan for 2025 Section 7. Five-Year Improvement Program	SD1's characterization, monitoring and modeling activities are described in Section 2 with additional detail provided in Appendices 2-A through 2-D. SD1's infrastructure characterization included rainfall and flow monitoring, water quality sampling of priority CSO, SSO, and storm water outfall locations, and updated hydraulic modeling to characterize and document the performance of the SD1 infrastructure. Detailed overflow characteristics for each basin can be found in Appendix 2-C. SD1 selected 1970 as the most typical rainfall year for the design and sizing of controls (Section 2.1.2). For the water quality models, it was found that no single year provided a representative period for both rainfall and stream conditions. Instead, a five-year period (1992-1996) was selected for the instream conditions (Section 2.1.1). Modeling tools were used to evaluate a range of gray, green and watershed controls (Section 3) and optimize the selection of controls for the Five-year Improvement Program.
IV.D.39(b)(2)(C) The results of an evaluation of peak flow treatment capacity for the DCWWTP and any WWTP that will receive additional flow based on any LTCP project.	Section 2.4 Dry Creek WWTP Plant Capacity Study Appendix 7-A No Feasible Alternatives Analysis	The overall capacity of the Dry Creek WWTP was originally assessed and documented in SD1's NMC Compliance Report. Projections showed that the peak sustained primary/disinfection treatment capacity at Dry Creek WWTP is limited to 75 MGD and the peak sustained secondary treatment capacity is 55.5 MGD. There were no cost-effective, NMC-based alternatives for increasing treatment capacity at Dry Creek. In the development of the Watershed Plans, a more rigorous analysis was conducted which identified larger-scope and higher cost projects for increasing capacity at the Dry Creek WWTP. The analyses in Section 2.4 and Appendix 7-A identified improvements required to the Dry Creek WWTP to increase secondary treatment peak wet weather capacity to 100 MGD, 130 MGD, and 160 MGD. The analysis showed that there is no feasible alternative to increase the secondary peak wet weather treatment capacity of the plant above 100 MGD.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(2)(D) A report on the public participation process	Section 5. Public Participation	SD1's public participation program helped to educate the public, make sure the Watershed Plans reflected community values, and provided valuable input on both the Framework and the draft Watershed Plans. Public Participation included the Watershed Community Council, Community Values Survey, a Watershed Summit, Innovative Storm Water (Green Infrastructure) Design Workshop, and coordination with regulators, industry experts, and local agencies/municipalities.
IV.D.39(b)(2)(E) Identification of how the LTCP addresses sensitive areas, including drinking water intakes, as a high priority for controlling overflows	Section 2.2.1 Overview of Current Conditions Section 6. Prioritization	SD1 evaluated sensitive areas for all sixteen watersheds as part of the watershed characterization process. The types of sensitive areas included primary contact waters, threatened and/or endangered species, public drinking water intakes, and source water protection areas. Primary contact recreation use designations are ubiquitous throughout Kentucky, and applied to all watersheds within the study area. Threatened and/or endangered species were present in five of the combined sewer watersheds, but were all located upstream of the CSOs. Source water protection areas were applicable in four of the watersheds (Table 2.15). These are the Licking River watershed downstream of Banklick Creek, Banklick Creek watershed, Fourmile Creek watershed, and Ohio River East watershed north of the Highland Heights Pump station. The sensitive area information was one of the factors used in the identification of Priority Areas for the Five-year Improvement Program. Priority Areas with sensitive areas included: Silver Grove (Fourmile), Highland Heights (Ohio River East), and Church Street (Banklick/Licking).
IV.D.39(b)(2)(F) A report on the cost analyses of the alternatives considered, including a financial capability assessment based upon EPA's "Combined Sewer Overflows Guidance for Financial Capability…" taking into account the economic capability of the communities the District serves	Section 4. Economic Characterization	The economic characterization section presents two different analyses that were conducted to estimate the financial impacts to Northern Kentucky ratepayers. The first looks at the overall affordability of the Integrated Plan for 2025 according to EPA's financial capability guidance. The second examines the impacts of potential rate increases needed to fund the initial Five-year Improvement Program. Also discussed are the unprecedented challenges to both the national economy and the economy of Northern Kentucky, the full implications of which are unknown, but may impact SD1's ability to raise the necessary funds during the implementation schedule for the Consent Decree.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(2)(G) Operational plan revisions to include agreed-upon long-term CSO controls	Section 8.7.1 Process for Updating Watershed Plans	Operational plans will be updated as necessary to account for any long-term CSO controls.
IV.D.39(b)(2)(H) Maximization of treatment at the District's existing WWTPs for wet weather flows	Section 2.4 Dry Creek WWTP Plant Capacity Study Section 7.1.1 Western Regional System Section 7.2.6 Improvements at Dry Creek Wastewater Treatment Plant Appendix 7-A No Feasible Alternatives Analysis	The overall capacity of the Dry Creek WWTP was originally assessed and documented in SD1's NMC Compliance Report, which determined that there were no low-cost solutions to increase treatment capacity. However, opportunities for increasing conveyance to the WWTP were identified by lowering the wet well settings at the Bromley PS which conveys all of the combined flow to the Dry Creek WWTP. The ability to treat this additional flow is limited by the previously stated treatment capacities. In the development of the Watershed Plans, a more rigorous analysis was conducted. The analysis identified larger-scope and higher cost projects for increasing capacity at the Dry Creek WWTP to maximize the feasible treatment capacity. The analyses in Section 2.4 and Appendix 7-A identified improvements required to the Dry Creek WWTP to increase secondary treatment peak wet weather capacity to 100 MGD, 130 MGD, and 160 MGD. The analysis showed that there is no feasible alternative to increase the secondary peak wet weather treatment capacity of the plant above 100 MGD. The Five-year Improvement Program includes the new Dry Creek headworks facility sized for 100 MGD capacity to provide a total of 175 MGD capacity combined with the existing headworks; this project will increase peak wet weather primary/disinfection capacity to 93 MGD. Also included in the Five-year Improvement Program is the Western Regional Water Reclamation Facility which will remove base flow and allow for increased peak wet weather capacity from the Bromley system. The secondary improvements, which are included in the Integrated Plan, will increase the peak wet weather primary/disinfection treatment capacity to 160 MGD and the peak wet weather secondary treatment capacity to 100 MGD. Average dry weather flow capacity will not be affected.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(2)(I) Identification of, and an implementation schedule for, the selected CSO controls	Section 8.2.5 Summary of Five-year Improvement Program: Schedule	To accomplish and afford the selected projects within the five-year timeline, SD1 developed a schedule for implementation that aligns with key factors such as financial capability and cash flow, Consent Decree deadlines, pilot projects, and public health priorities (Table 8.8 and 8.9).
IV.D.39(b)(2)(J) A post-construction compliance monitoring program adequate to ascertain the effectiveness of CSO controls and to verify compliance of the District's CSOs with water quality-based CWA requirements.	Section 8.4 Monitoring Program	SD1's monitoring plan includes monitoring programs specific to project performance monitoring (including green infrastructure), the sanitary sewer collection system monitoring and watershed monitoring. The intent of this monitoring is to determine the effectiveness of CSO and SSO controls and measure the effects of the Five-year Improvement Program on water quality. SD1 will also continue ongoing monitoring programs to update characterization of the sewer systems, streams, and watersheds using rainfall data, flow monitoring, instream continuous monitoring stations, and biological/habitat monitoring. CSO and SSO activations will be tracked using rainfall and flow monitoring data to update the sewer system model. Lastly, performance monitoring will be included in detailed engineering designs, as appropriate, for selected projects in the Five-year Improvement Program to test effectiveness of phased controls and aid in decisions about additional levels of control. Performance monitoring may also be needed to provide site-specific and cost data on green infrastructure controls.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(3)(A) The results of an evaluation of WWTP peak flow treatment capacity for WWTPs that have experiences a prohibited bypass (as defined….) within three (3) years before the date of entry of this Consent Decree and for any WWTP that will receive additional flow based on any SSOP project.	Section 2.4 Dry Creek WWTP Plant Capacity Study Appendix 7-A No Feasible Alternatives Analysis	The overall capacity of the Dry Creek WWTP was originally assessed and documented in SD1's NMC Compliance Report. Projections showed that the peak sustained primary/disinfection treatment capacity at Dry Creek WWTP is limited to 75 MGD, and the peak sustained secondary treatment capacity is 55.5 MGD. There were no cost-effective, NMC based, alternatives for increasing treatment capacity at Dry Creek. In the development of the Watershed Plans, a more rigorous analysis was conducted which identified larger-scope and higher cost projects for increasing capacity at the Dry Creek WWTP. The analyses in Section 2.4 and Appendix 7-A identified improvements required to the Dry Creek WWTP to increase secondary treatment peak wet weather capacity to 100 MGD, 130 MGD, and 160 MGD. The analysis showed that there is no feasible alternative to increase the secondary peak wet weather treatment capacity of the plant above 100 MGD. The Five-year Improvement Program includes the new Dry Creek headworks facility sized for 100 MGD capacity to provide a total of 175 MGD capacity when combined with the existing headworks; this project will increase peak wet weather primary/disinfection capacity to 93 MGD. Also included in the Five-year Improvement Program is the Western Regional Water Reclamation Facility which will remove base flow and allow for increased peak wet weather capacity from the Bromley system. The secondary improvements, which are included in the Integrated Plan for 2025, will increase the peak wet weather primary/disinfection treatment capacity to 160 MGD and the peak wet weather secondary treatment capacity to 100 MGD. Average dry weather flow capacity will not be affected.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(3)(B) A map that shows the location of all known SSOs and Unpermitted Discharges. The map shall include the areas and sewer lines that serve as tributary to each SSO and Unpermitted Discharge. Smaller maps of individual tributary areas also may be included to show the lines involved in more detail.	Appendix 2-C	Overflow location maps are provided in Appendix 2-C along with accompanying lists of individual overflow characteristics. Additionally, a GIS geodatabase containing SD1's sewers, SSOs. CSOs, road centerline and parcel data was provided to EPA and the Cabinet during the preparation of the Integrated Plan for 2025. Unpermitted discharges are point source discharges which are not covered in a permit. In the SD1 service area, this would be limited to SSOs and any non-permitted CSOs. SD1's approach has been to treat any known point source discharge from the sanitary sewer system as an SSO (this includes pump station bypasses) and any known wet weather discharge from the combined sewer system as a CSO (either permitted or to-be-permitted), thereby eliminating the need for the term 'Unpermitted Discharge'.
IV.D.39(b)(3)(C) A description of each SSO and Unpermitted Discharge location that includes: frequency of event; annual volume of event; description of location of event; receiving stream; immediate area and downstream land use, including public health concerns; a description of any investigative studies conducted within five (5) years of plan submission; a description of any rehabilitation or construction work that was conducted within five years of plan submission, or that is proposed for the future to remediate or eliminate the SSO or Unpermitted Discharge.	Appendix 2-C	A description of each SSO and related information is provided by basin in Appendix 2-C.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(3)(D) A prioritization of the SSO and Unpermitted Discharge locations identified above, based primarily on the frequency, volume and impact on the receiving stream and upon public health, and in coordination with any remedial activity performed pursuant to the CMOM Programs and any other component of a Watershed Plan and an evaluation of water pollution needs on a watershed management basis. Based upon this prioritization, the District shall develop remedial measures and expeditious schedules for design, initiation of construction and completion of construction.	Section 3. Integrated Plan for 2025 Section 5.1 Public Involvement During Development of Watershed Plans Section 6. Prioritization Section 7. Five-Year Improvement Program Section 8. Summary of Integrated 2025 Plan Schedule	SD1 identified metrics for evaluating controls (Appendix 3-A, Table 1) and conducted a public survey to assess the community's values and priorities (Section 5.1.3). These results were used to identify Priority Areas, so that projects could be developed for the first Five-year Improvement Program. Criteria for identifying Priority Areas (developed by aligning watershed goals with results of stakeholder input) included: Public Health Risk Areas, Consent Decree Exhibit E Pump Stations, Watershed Control Opportunities, Green Opportunities, Integration (gray/green/watershed) Opportunities, and High Volume CSOs and SSOs (Section 6). Consistent with Section 2.9 of SD1's approved Watershed Framework, the selection of SSO controls and implementation schedules were prioritized in conjunction with other CSO controls, green controls, watershed controls, and the projected water quality benefits for all identified projects. The highest priority areas were included in the first Five-year Improvement Program along with the associated controls and implementation schedules. All SSOs have been evaluated and prioritized with the Integrated Plan for 2025 (Section 3, Section 6). A preliminary schedule for implementing the Integrated Plan for 2025 was also included (Section 8).
IV.D.39(b)(3)(E) A plan to involve stakeholders in the planning, prioritization and selection of projects consistent with provisions of paragraph 40 below.	Section 5. Public Participation	SD1's public participation program helped to educate the public, ensure that the Watershed Plans reflected community values, and provided valuable input on both the Framework and the draft Watershed Plans. Public Participation included the Watershed Community Council, Community Values Survey, a Watershed Summit, Innovative Storm Water (Green Infrastructure) Design Workshop, and coordination with regulators, industry experts, and local agencies/municipalities.

Consent Decree Paragraph	Section(s)	Watershed Plan Summary
IV.D.39(b)(4) If Watershed Plans identify any permitted point sources or nonpoint sources, other than CSOs and SSOs, that are contributing to water quality impairment, the Watershed Plans shall also identify planned control measures… and provide implementation schedules for these controls… to offset the level of CSO controls or to delay the elimination of an SSO…if other than through a final TMDL…identify the means…intends to insure that the control is implemented.	Section 3 Integrated Plan for 2025 Section 7.4.7 Lakeview Priority Area Section 8.4 Schedule Adjustments Section 8: Implementation Schedule for Five-year Improvement Program and Integrated Plan for 2025	SD1's Full System Bounding Analysis (Appendix 3-A) estimated the benefits of gray infrastructure solution concepts at various levels of overflow control and compared the results with the water quality benefits of integrated solutions concepts using the evaluation metrics identified in Appendix 3-A, Table 1. The analysis showed: 1) the lowest level of overflow control considered along with moderate watershed controls yields similar water quality improvements as controlling CSO and SSO alone at a higher level, and 2) benefits from integrated solutions occur along more stream miles and address sources (such as dry weather sources) that gray-only solutions cannot. These results show that use of green and watershed controls can be a more effective approach to improving water quality than using gray-only controls. Depending on the level of control, the use of green and watershed controls can also be more cost-effective than using gray-only controls alone. Based on these findings, the Integrated Plan for 2025 (Section 3) and the Five-year Improvement Program were developed. Both the Integrated Plan for 2025 and the Five-year Improvement Program include a combination of gray, green and watershed controls, which was found to be the most cost-effective in improving water quality. SD1's evaluation of green and watershed controls identified the most effective control types for inclusion and evaluation as part of the Five-year Improvement Program. Information gathered on the implementability, cost effectiveness and water quality benefit of these controls will be used in the development of green and watershed controls for future improvement cycles. SD1 has identified three projects where schedule adjustments would enable SD1 to pursue alternative green and watershed-based controls, leverage a public-partnership opportunity, or to reassess the necessity of a project (Section 8.4). The Lakeview Priority Area (Section 7.4.7) is one location where further investment in overflow control is not cost-effective and SD1 instead identified green and watershed-based controls to more effectively improve water quality.

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Appendix 2-A

Watershed Characterization Summary Report

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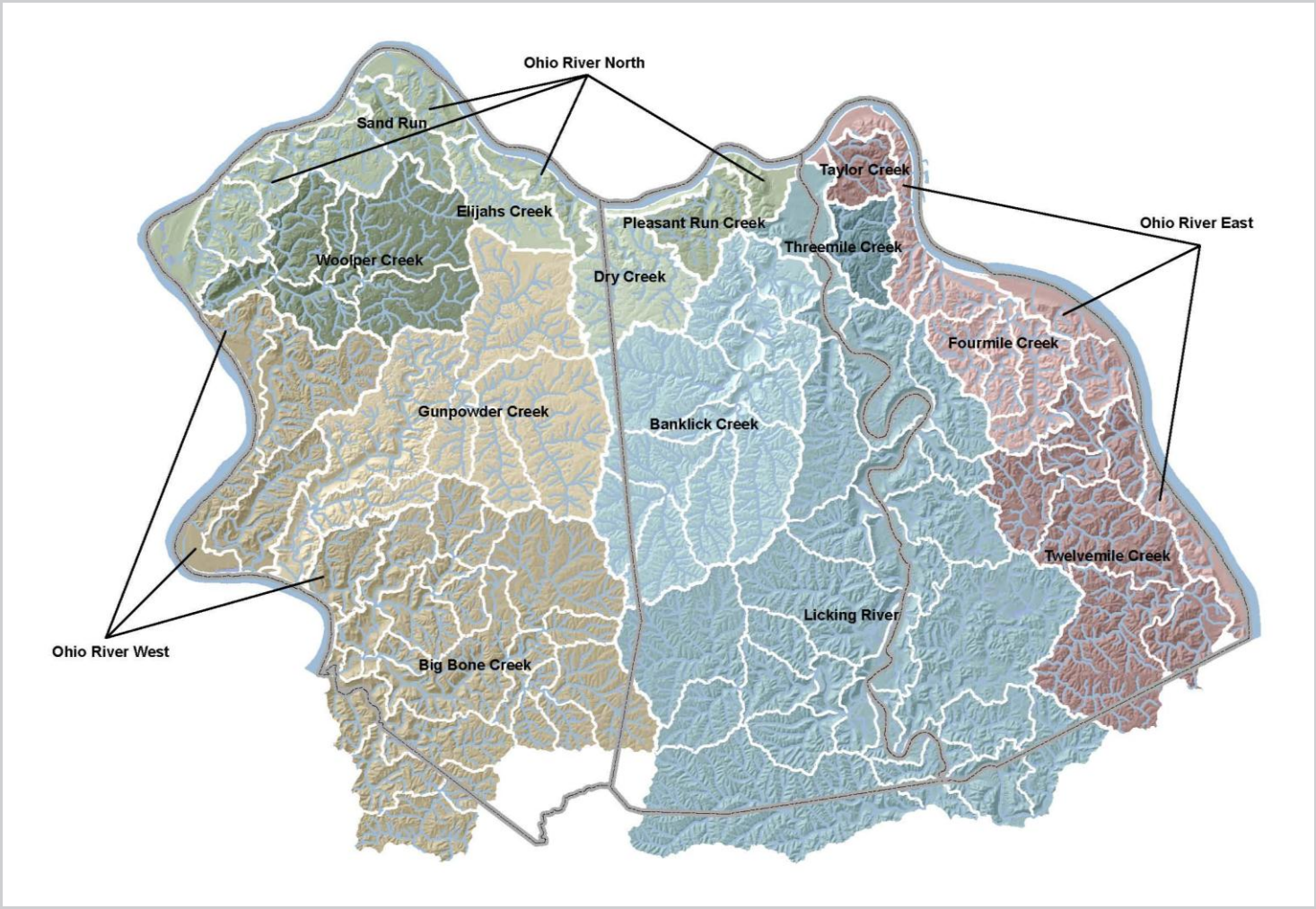

Northern Kentucky Watersheds – A Summary

Prepared for: **Sanitation District No. 1 of Northern Kentucky**

June 2009

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Ann Arbor, Michigan
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List of Definitions

Basins: The four watershed study basins (East, Central, North and West) defined as watersheds in the Consent Decree.

Study area watersheds: The sixteen watersheds encompassing the jurisdictional area of Sanitation District No. 1 (SD1) in Boone, Campbell and Kenton Counties, which are located within the four basins described in the Consent Decree.

Watershed: A defined area of land that drains into a particular body of water, such as a stream, river, lake, or ocean. Watersheds come in all shapes and sizes and can cross city, state and even national borders. A healthy watershed provides habitats for plants, aquatic life, and animals as well as high-quality water for human use.

Runoff: Storm water runoff is generated when precipitation from rainfall or snowmelt events flow over the land transporting pollutants untreated into water bodies instead of infiltrating into the ground. As the runoff flows over agriculture lands, residential and commercial lawns, construction sites or impervious surfaces (roads, driveways, parking lots, and building rooftops), it accumulates chemicals, bacteria, sediment or other pollutants that can adversely affect water quality.

Combined sewer system: A combined sewer system is a wastewater sewer system that is specifically designed to collect and convey sanitary wastewater (domestic sewage from homes as well as industrial and commercial wastewater) and storm water through a single pipe. During normal dry weather conditions, sanitary wastes collected in the combined sewer system are conveyed to a wastewater treatment plant.

Combined sewer overflow: During rain events or snowmelt, combined sewer systems are designed to overflow when the sewer system capacity is exceeded, resulting in a combined sewer overflow (CSO) that discharges directly to surface waters such as rivers, streams, estuaries, and coastal waters.

Sanitary sewer system: A separate sanitary sewer system is a wastewater sewer system, owned by a state or municipality that is specifically designed to collect and convey only sanitary wastewater (domestic sewage from homes as well as industrial and commercial wastewater). In such systems, storm water is conveyed through a separate set of pipes. These systems are not designed to collect large amounts of storm water runoff from precipitation events.

Sanitary sewer overflow: A sanitary sewer overflow (SSO) can occur when sewer system capacity is exceeded due to wet weather, when normal dry weather flow is blocked for any of several reasons, or when mechanical failures prevent the system from proper operation.

Additional information on CSOs, SSOs and watersheds is available at:
http://www.sd1.org

Background

Sanitation District No. 1 (SD1) is responsible for the collection and treatment of wastewater and regional storm water management in Northern Kentucky and serves over 30 communities in Boone, Campbell, and Kenton Counties. SD1 has negotiated a Consent Decree to address sanitary sewer overflows (SSOs) and combined sewer overflows (CSOs) to improve stream water quality. Specific solutions to achieve this goal are being described in Watershed Plans, which will be updated every five years through 2025. The first Watershed Plans will be submitted to the United States Environmental Protection Agency (EPA) and the Kentucky Division of Water (KDOW) by June 30, 2009.

The Consent Decree describes four study basins (East, Central, North and West), which encompass the area's sixteen watersheds (Figure 1). This summary report describes SD1's efforts to characterize and improve conditions within this 592 square mile area, and provides an overview of study area features. The unique characteristics of each of the study area watersheds are highlighted in individual fact sheets (Appendix A). These characteristics will be considered in prioritizing watersheds, identifying specific sources for improvement, and identifying data gaps to be addressed in subsequent updates to the Watershed Plans. Additional details can be found in the sixteen Watershed Characterization Reports which are available at http://www.sd1.org.

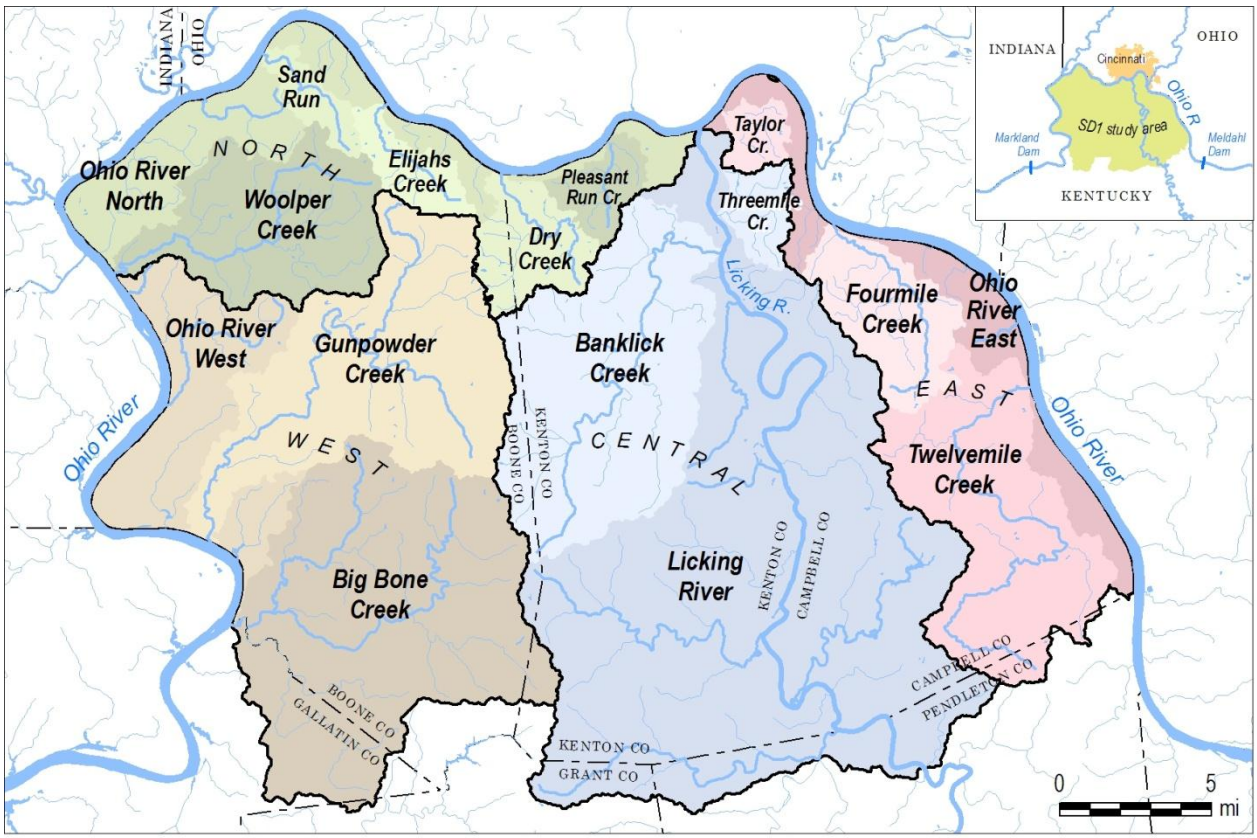


Figure 1. Study Area Map

SD1 Characterization and Improvement Efforts

This section provides a summary of SD1 activities to characterize and improve water quality in Northern Kentucky streams.

SD1 Data Collection and Modeling

SD1 has undertaken a substantial effort to obtain, compile and generate information and data describing the study area watersheds. Information on streams, watersheds, sampling locations, soils, hydrology, current and predicted future land cover, infrastructure, permitted dischargers, likely septic locations, livestock and improvement projects has been obtained in geographic information system (GIS) format and checked for accuracy. Water quality, habitat, biological, flow, and climatic data have also been obtained, reviewed and compiled in a database, which will be continuously updated as new information becomes available. SD1 now serves as a clearinghouse for Northern Kentucky watershed data, helping to provide easy access to the best available information for watershed characterization and the development of Watershed Plans.

In 2006, SD1 initiated a comprehensive program to gather updated stream data by conducting monitoring at multiple locations in each of the watersheds. This program is ongoing and includes aquatic habitat and biological assessments, wet and dry weather stream water quality sampling, and measurement of instream flow. SD1 also participates in funding thirteen continuous monitoring stations throughout the study area in cooperation with the United States Geological Survey (USGS). These stations provide flow and water quality measurements at 15-minute intervals. In 2007, SD1 initiated outfall sampling to better characterize water quality and loadings from combined sewer overflows (CSOs), sanitary sewer overflows (SSOs) and storm water runoff.

SD1 reviews all monitoring data prior to inclusion in a database. Data are subsequently analyzed to characterize stream conditions and identify potential pollutant sources. SD1 intends to continue the monitoring program over time to identify trends in water quality and provide feedback on the effectiveness of pollutant controls and other actions to improve water quality.

SD1 has developed of a suite of computer models to simulate the flow in the separate sanitary and combined sewer systems to quantify the amount of SSOs and CSOs. SD1 has also developed computer models to integrate watershed and water quality data and provide a way to link sources and water quality impacts. These models can be applied to identify current stressors and important sources. They can also be applied to forecast water quality conditions in response to different "what if" pollutant control scenarios. A Watershed Assessment Tool (WAT!) has been developed for the entire study area, to simulate the potential for different sources to generate bacteria loads. More detailed watershed and water quality models have been developed for Banklick Creek, Taylor Creek, the Lower Licking River and the Ohio River. These detailed models calculate water quality changes in response to new development, watershed controls and sanitary sewer controls.

Other SD1 Activities

SD1 is continually working to improve the capacity of the sanitary and storm water sewer systems, to upgrade aging infrastructure and to respond to growing demands for more wastewater treatment and storm water management. In 2007, SD1 began operating the Eastern Regional Water Reclamation Facility in Campbell County and will soon begin construction of the Western Regional Water Reclamation Facility in Boone County to provide additional capacity and treatment in the western portion of the study area. These two projects along with upgrades to SD1's Dry Creek Wastewater Treatment Plant and many other projects that are well underway will reduce or eliminate sewer overflows and eliminate smaller treatment plants and failing septic systems.

Watershed Characterization

SD1 has compiled data to better understand the condition of the streams and to characterize pollutant sources and stressors. Stream assessment included examination of:

- Hydrology, which indicates how quickly a stream responds to rain events.
- Water quality, which provides an indication of whether the stream quality is meeting standards set by the State to protect aquatic life, swimming or other designated uses.
- Aquatic habitat, which indicates whether a stream can support diverse aquatic communities, independent of stream quality.
- Aquatic biology, which integrates the effects of water quality, flow and habitat over time. The presence and abundance of different species provides a reflection of stream health.

Source assessment involved examination of:

- Geology and soil, which indicate erodibility and infiltration.
- Land cover and impervious surfaces, which influence the amount of rainfall that is converted to runoff and predict the type and amount of pollutants generated.
- Point sources, which provide information on discharges from facilities which have permits from the State such as wastewater treatment plants and CSOs.
- Nonpoint sources, which provide information on other pollutant sources such as storm water runoff, livestock, wildlife and septic systems.

The results of this characterization effort are described in detail in sixteen individual Watershed Characterization Reports. A more general characterization of the entire study area is presented in the following section.

Study Area Overview

This section briefly describes land cover characteristics, current stream conditions and sources for the study area. An assessment of the potential water quality impact of each watershed is also provided. This information is considered, in combination with other watershed characteristics, when prioritizing watersheds and sources for improvement.

Land Cover Characteristics

The land cover in a watershed is an important characteristic because it affects the amount and quality of runoff. Figure 2 contrasts two study area streams that drain watersheds with different levels of development. Double Lick Creek in the Woolper Creek watershed drains a primarily undeveloped watershed, and has been identified as an exceptional water by the State. Fourmile Creek, in contrast, drains a more highly developed watershed and is identified on State's 303(d) list as being impaired.

Figure 2. Double Lick Creek (left) and Fourmile Creek (right)

Current (2007) land cover within the study area is shown in Figure 3. Developed areas currently comprise approximately 29% of the study area and the percent imperviousness is roughly 6.5%. Future land cover was developed by modifying the 2007 land cover to reflect potential future conditions (roughly 2030). In the future, 39% of the study area is predicted to be developed and the percent imperviousness is anticipated to increase to 9.3%. Growth is anticipated primarily within the boundary indicated on Figure 4 (predicted extent of future development). New development can increase storm water runoff and pollutant loads, and introduce additional challenges for protecting and improving stream condition.

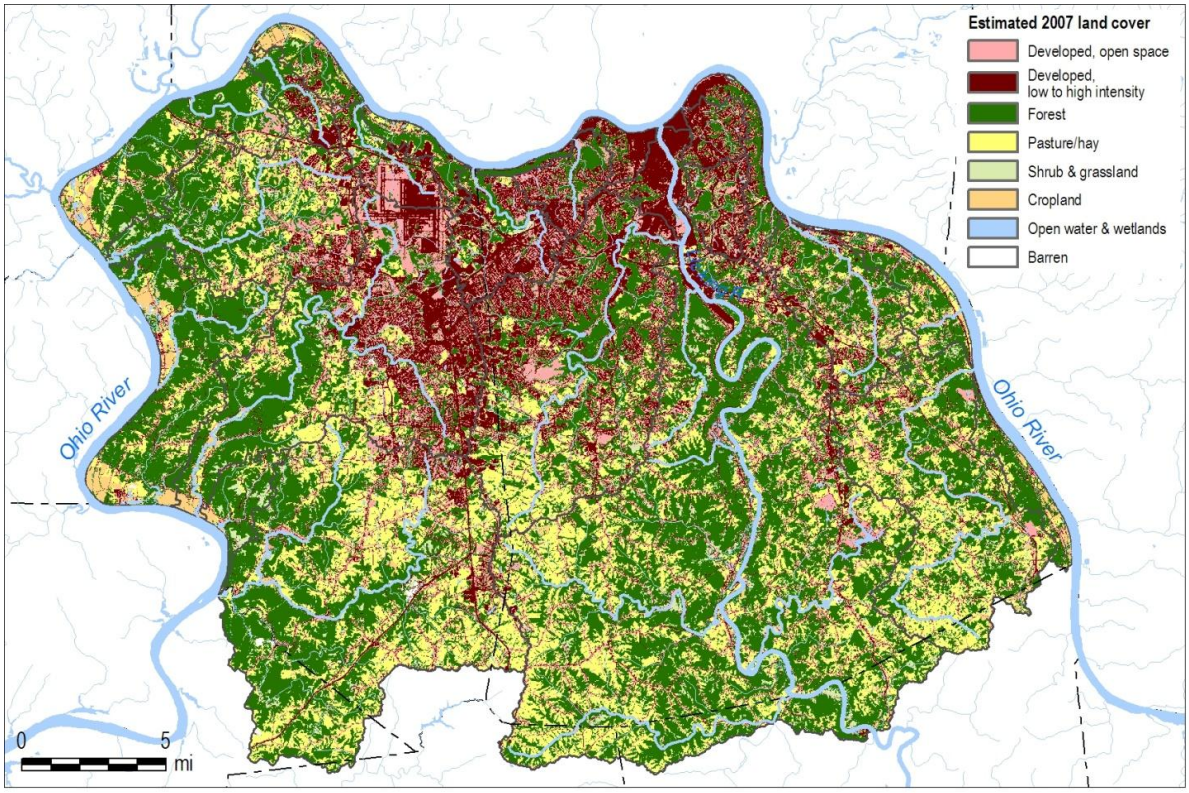


Figure 3. Current (2007) Land Cover

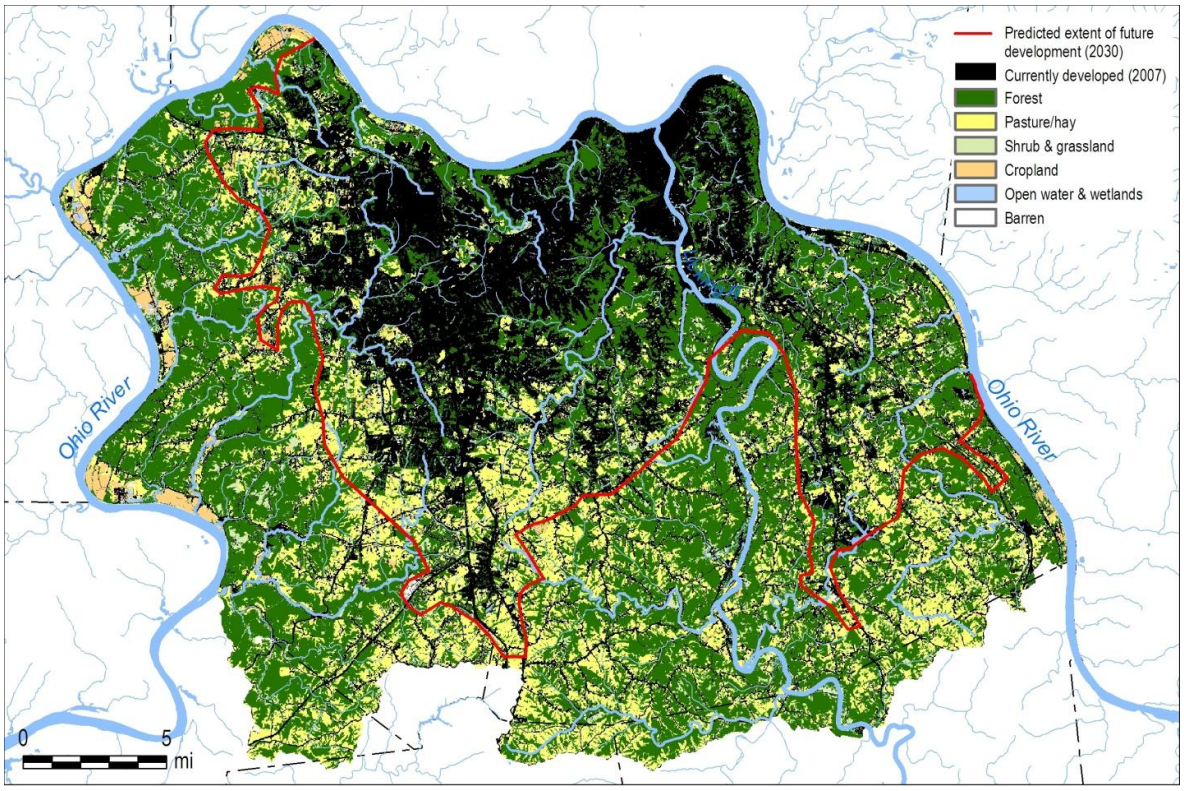


Figure 4. Predicted Extent of Future (2030) Development

Current Conditions and Sources

Current conditions have been assessed using habitat, biological and water quality data. Aquatic habitat and biological assessments reflect highly variable conditions both within and between watersheds. Typical water quality problems include elevated bacteria (fecal coliform and/or *E. coli*) densities, low dissolved oxygen and some violations of pH and metals.

Pollutant sources in the study area include CSOs, SSOs, other KPDES[1]-permitted discharges, storm water runoff and septic systems[2]. The distribution of these sources in the study area is shown on Figures 5 and 6, along with the boundaries for the sanitary (wastewater) sewer and storm water service area. Florence and Walton are shown separately, because these communities are responsible for their own wastewater and storm water.

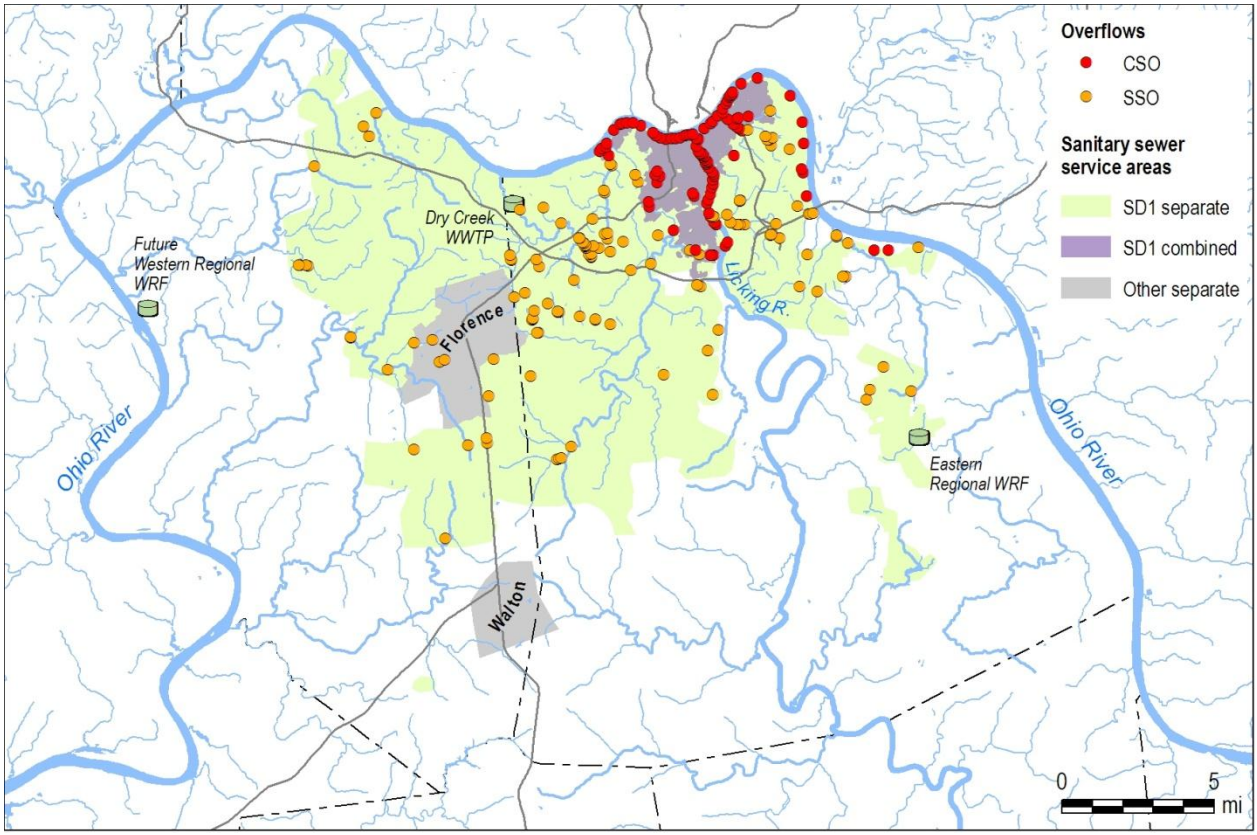


Figure 5. Sewer Overflows and Sanitary Service Area

[1] KPDES stands for Kentucky Pollutant Discharge Elimination System. Any point source that discharges to a Kentucky stream must have a permit from the State to ensure that the discharge will not adversely impact stream water quality.

[2] Septic information was not available at the time of this report for the southern-most extent of the study area (Pendleton, Grant or Gallatin Counties).

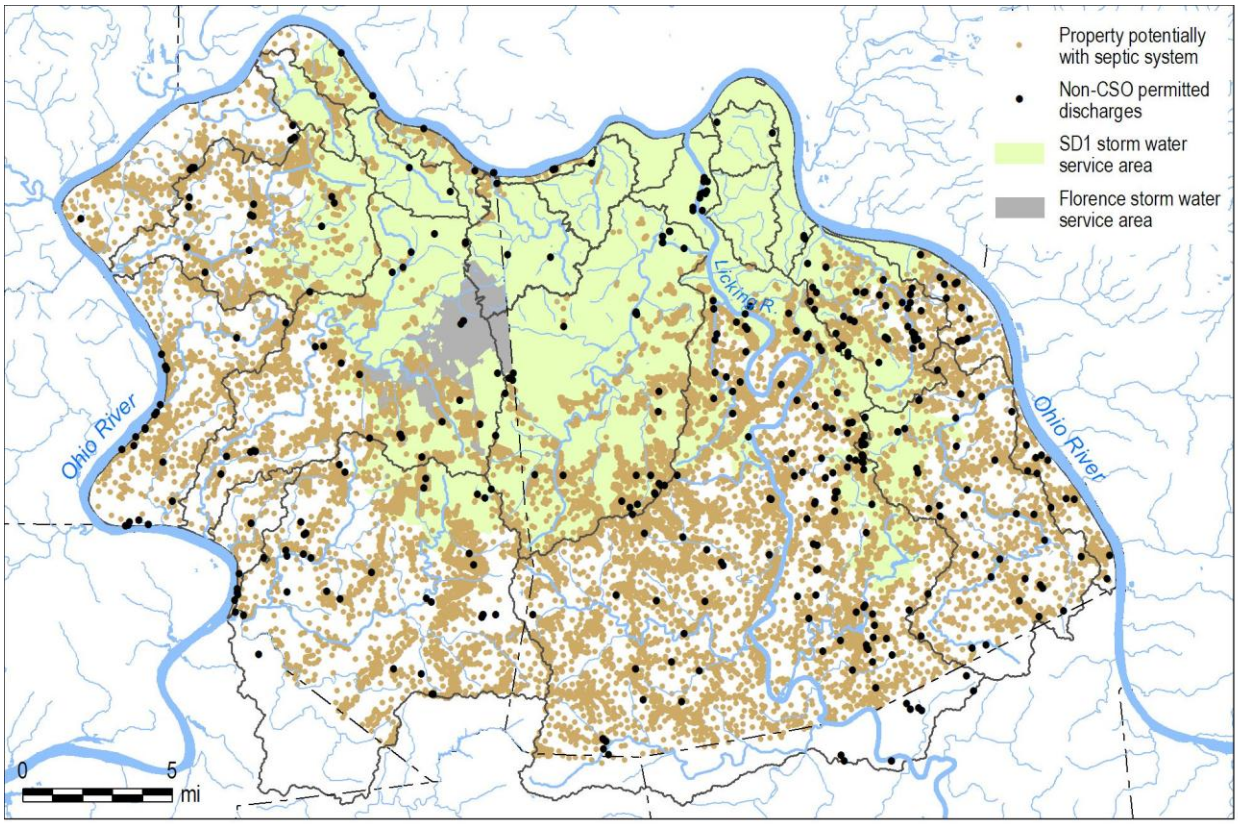


Figure 6. Other Permitted Discharges, Properties Potentially Served by Septic, and Storm Water Service Area

The potential for these sources to generate fecal coliform bacteria loads over a year-round period has been assessed using WAT!. These WAT! results also incorporate predicted sewer overflow volumes from infrastructure model simulations.[3]

The pie charts shown in Figure 7 are sized to reflect the potential for each watershed to generate fecal coliform bacteria, for year-round conditions, relative to the other study area watersheds. A larger pie chart indicates that a watershed has a higher potential to generate bacteria loads. The pie slices reflect the loading potential by source. In most watersheds, storm water runoff (e.g., runoff from agricultural, developed and forested lands) is the source with the highest potential to generate bacteria.

[3] The results presented were generated by models based on SD1's current understanding of the sewer system infrastructure. These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the sewer system, and may differ from actual measured field conditions. All models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. Since publication of the Watershed Characterization reports in January 2009, WAT! has been updated to reflect refinements in the Banklick Creek and Taylor Creek models. WAT! will continue to be updated based on additional monitoring and modeling of pollution sources within the watersheds.

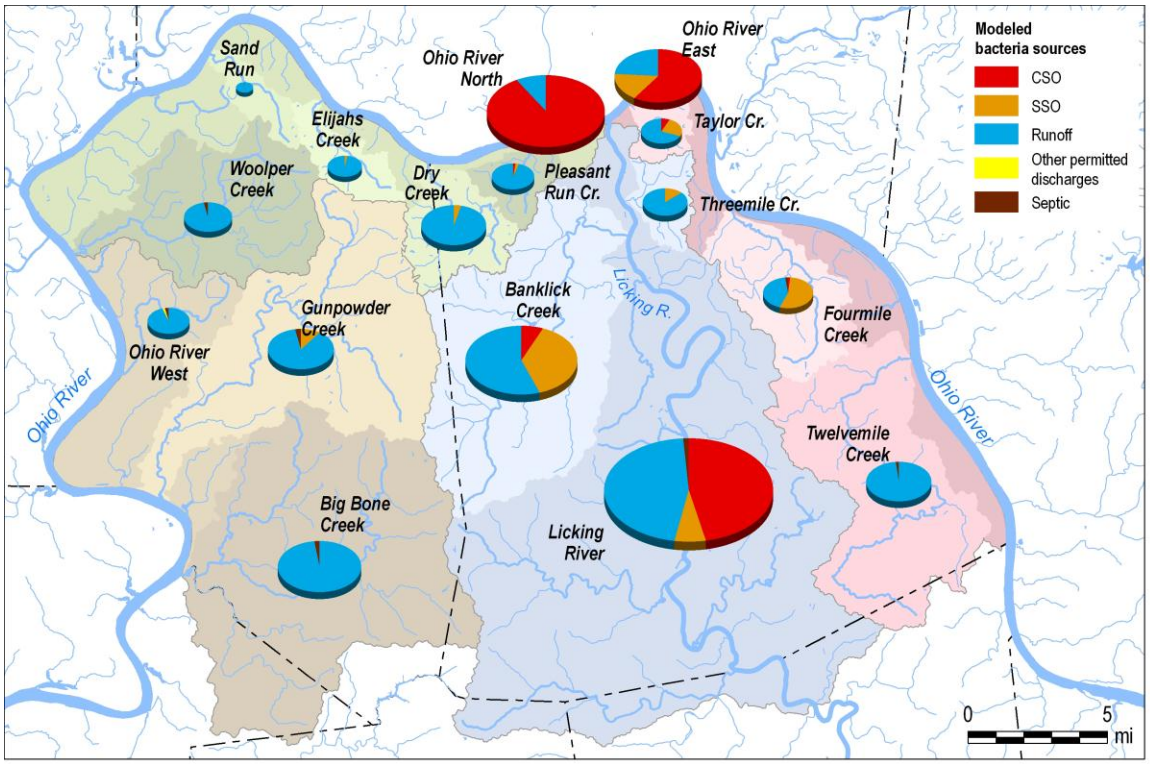


Figure 7. WAT! Loading Potential Results for Fecal Coliform

The Licking River pie chart does not include results from sources outside the study area or from Banklick Creek and Threemile Creek, which are presented separately.

Assessment of Potential Water Quality Impact

WAT! can also be applied to assess the potential that each watershed has to impact water quality. This potential impact can be calculated in WAT!, by normalizing the bacteria loading potential of each watershed by the watershed's drainage area (e.g., by dividing the loading potential shown in Figure 7, by the area of each watershed). The area-normalized results for each watershed can then be ranked for year-round or dry weather conditions to inform prioritization of pollutant source investigations and controls.

Figure 8 shows the area-normalized results for each watershed, where the size of each pie reflects what can be viewed as loading potential per acre. For example, both the larger rural Ohio River West watershed (with a 33.0 square mile drainage area) and much smaller, urban Pleasant Run Creek watershed (with a 6.5 square mile drainage area) have similar bacteria loading potentials, as shown in Figure 7. When normalized by watershed area, as shown in Figure 8, it can be seen that, on average, land in the Pleasant Run Creek watershed has a higher bacteria loading potential than land in the Ohio River West watershed.

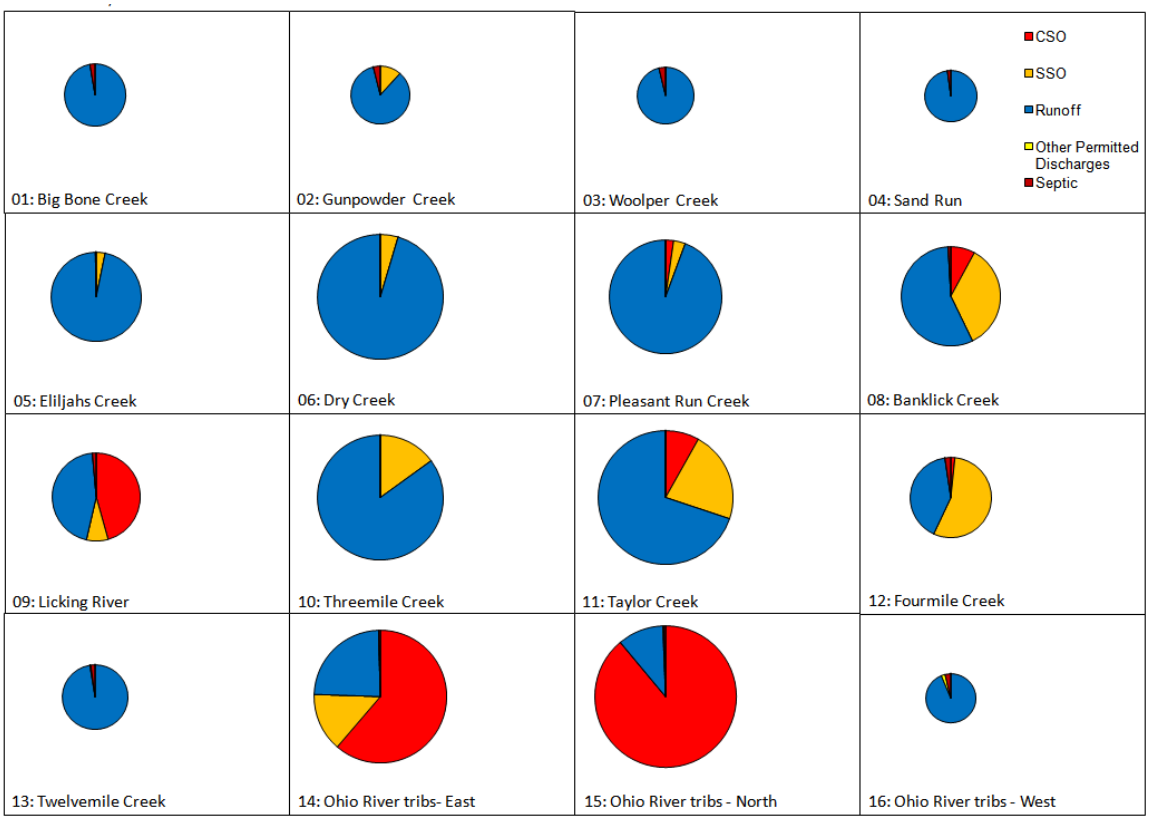


Figure 8. WAT! Area-Normalized Results Indicating Fecal Coliform Impact

Table 1 shows the rankings for the sixteen watersheds based on their respective area-normalized results, for both year-round and dry weather conditions. Dry weather conditions were assessed separately because bacteria can adversely affect recreational use of the streams and people may be more likely to use the streams when flow conditions are not affected by runoff. A ranking of 1 reflects a larger potential to impact instream water quality and a ranking of 16 reflects a lower potential to impact water quality. As discussed previously, even though the Ohio River West and Pleasant Run Creek watersheds have similar bacteria loading potentials, their watershed rankings based on potential impact (area-normalized results) are quite different.

Table 1. WAT! Watershed Rankings Based on Area-Normalized Results for Bacteria

Watershed	Rank, year-round fecal coliform results	Rank, dry weather fecal coliform results
Banklick Creek	7	9
Big Bone Creek	12	8
Dry Creek	5	12
Elijahs Creek	8	13
Fourmile Creek	10	1
Gunpowder Creek	13	3
Licking River	9	7
Ohio River East	3	10
Ohio River North	1	4
Ohio River West	16	2
Pleasant Run Creek	6	14
Sand Run	15	11
Taylor Creek	2	16
Threemile Creek	4	15
Twelvemile Creek	11	6
Woolper Creek	14	5

The WAT! rankings support the prioritization of watersheds and sources for improvement, and aid in the identification of data gaps. The Taylor Creek watershed provides an example of this. Taylor Creek has the lowest WAT! ranking within the study area during dry weather conditions (16th of 16). However, the recent bacteria monitoring results show that Taylor Creek has the highest bacteria levels of all watersheds during dry weather conditions. Because WAT! considers all known bacteria sources in calculating rankings, it is likely that additional dry weather sources (e.g., illicit connections or failing infrastructure) exist in this watershed. Therefore, additional field investigation and updates of the WAT! are recommended to identify the sources and their relative contribution to bacteria during dry weather conditions.

The watershed characterization work completed to date supports a detailed assessment of potential water quality impact, and a solid, baseline understanding of the study area watersheds, including important features and stream condition using the best available information. A summary of unique watershed characteristics is provided in Appendix A, and additional information can be found in the individual Watershed Characterization Reports.

Appendix A. Fact Sheets

This appendix contains individual fact sheets that are specific to the study area watersheds (Figure A-1). The fact sheets provide an overview of the study area watersheds, condensed from the more detailed Watershed Characterization Reports[4,5]. Each fact sheet consists of a table of key watershed features and a map showing identified sources within the watershed. The fact sheets primarily describe current watershed conditions and sources, but also include predicted future land cover and percent imperviousness for roughly 2030 conditions. A key to understanding the information described in the fact sheet tables is presented in Table A-1.

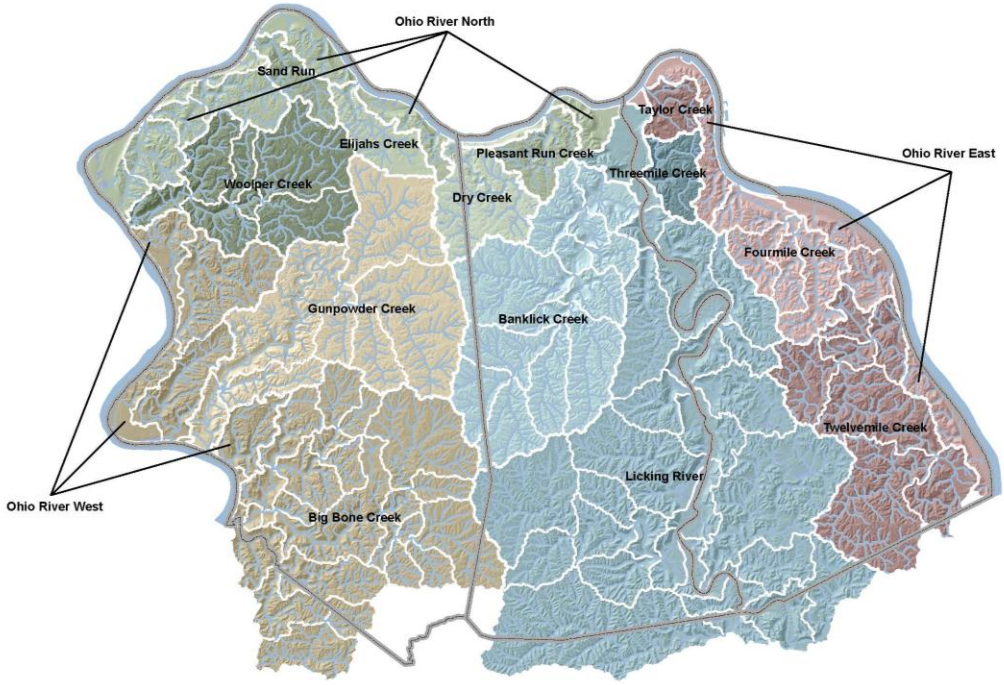


Figure A-1. Watershed Map

Available fact sheets include:

Ohio River - Mainstem	Elijahs Creek	Sand Run
Ohio River - Small Tributaries	Fourmile Creek	Taylor Creek
Banklick Creek	Gunpowder Creek	Threemile Creek
Big Bone Creek	Licking River	Twelvemile Creek
Dry Creek	Pleasant Run Creek	Woolper Creek

[4] A single fact sheet describes the small tributaries to the Ohio River, which are located within the Ohio East, Ohio North and Ohio West watersheds. A fact sheet has also been developed for the Ohio River; however, the format is modified slightly because Ohio River itself is not characterized in a separate report by SD1. Readers are encouraged to review ORSANCO's report on the Ohio River (ORSANCO, 2008).

[5] Since publication of the Watershed Characterization Reports, WAT! has been updated to reflect refinements in the Banklick Creek and Taylor Creek models.

Table A-1. Key to the Fact Sheets

Overview	Text describing unique watershed characteristics that are not covered below.
Drainage Area	The size of the watershed in square miles
Special Stream Designations	Waterbodies identified by the State as being exceptional waters, reference reach streams or Outstanding State Resource Waters.
Aquatic-dependent State or Federally Threatened or Endangered Species	Federally threatened and/or endangered species that inhabit aquatic environments or riparian areas.
Dominant Land Cover	Pie charts showing the percent of the watershed that has been developed, forested (forest and shrub) and agricultural (pasture, hay and cropland) land cover under current (2007) and predicted future (2030) conditions. To simplify presentation, barren lands and water which are generally negligible, are excluded from the pie charts. More detailed information is found in SD1's Watershed Characterization Reports.
Percent Impervious Area	Percent of the watershed that is covered by impervious surfaces (e.g., roads, driveways, roofs) under current and predicted future conditions.
Sewer Overflows	The number of combined sewer overflows (CSOs) and sanitary sewer overflows (SSOs) in the watershed[6]. CSOs include those that are permitted and those that SD1 has (or will) identify for Kentucky Pollutant Discharge Elimination System (KPDES) permitting.
Other KPDES Discharges	The number of other KPDES-permitted outfalls (unique from CSOs). Some facilities have more than one permitted outfall.
State Impaired Waters	Every two years the State produces a report that documents whether Kentucky lakes and streams are able to support their designated uses (e.g., recreation, aquatic life support, drinking water). Waters unable to support these uses are identified on the Kentucky Division of Water 303(d) list of impaired waterbodies. This entry describes the impaired waterbodies, if any, in a watershed, based on the 2008 303(d) list.
TMDL Status	Describes whether a Total Maximum Daily Load (TMDL) is currently planned for the State impaired waters.
Recent Assessments	
Habitat	A general statement of habitat quality based on the most recent available data. Habitat is assessed based on whether it can support fully functioning or diverse aquatic communities. Results range from not supporting to fully supporting. A different habitat index was used for the larger Licking River, and results can range from very poor to excellent using this index.
Biological	A general statement of biological conditions based on the most recent macroinvertebrate, fish and/or diatom data. Biological data are assessed using standardized protocols that compile community attributes such as taxa richness and pollution tolerance/intolerance. Results range from very poor to excellent.
Water Quality	A general statement describing water quality measurements that violated applicable State water quality criteria, based on the most recent available data. If only a single violation was observed, the violation is not noted in this report. However, all recent violations are described in the Watershed Characterization Reports, and additional sampling will be conducted to further characterize water quality. Recent data are defined as those collected between 2006 and 2008. Bacteria densities are noted as being elevated if either fecal coliform is higher than 400 cfu/100 ml or if *E. coli* is higher than 240 cfu/100 ml. These instances are not identified as violations, because the minimum number of samples was not available within a 30-day period for direct comparison to the criteria.
WAT! Bacteria Loading Potential, By Source	Pie chart presenting the current annual modeled fecal coliform bacteria loading potential by source within the watershed. Source categories are: CSO, SSO, runoff, other KPDES-permitted discharges, and septic systems. These results are based on the WAT!

[6] SD1 is continuing to refine the characterization and assessment of the sanitary sewer system, and sources are subject to change.

The Ohio River

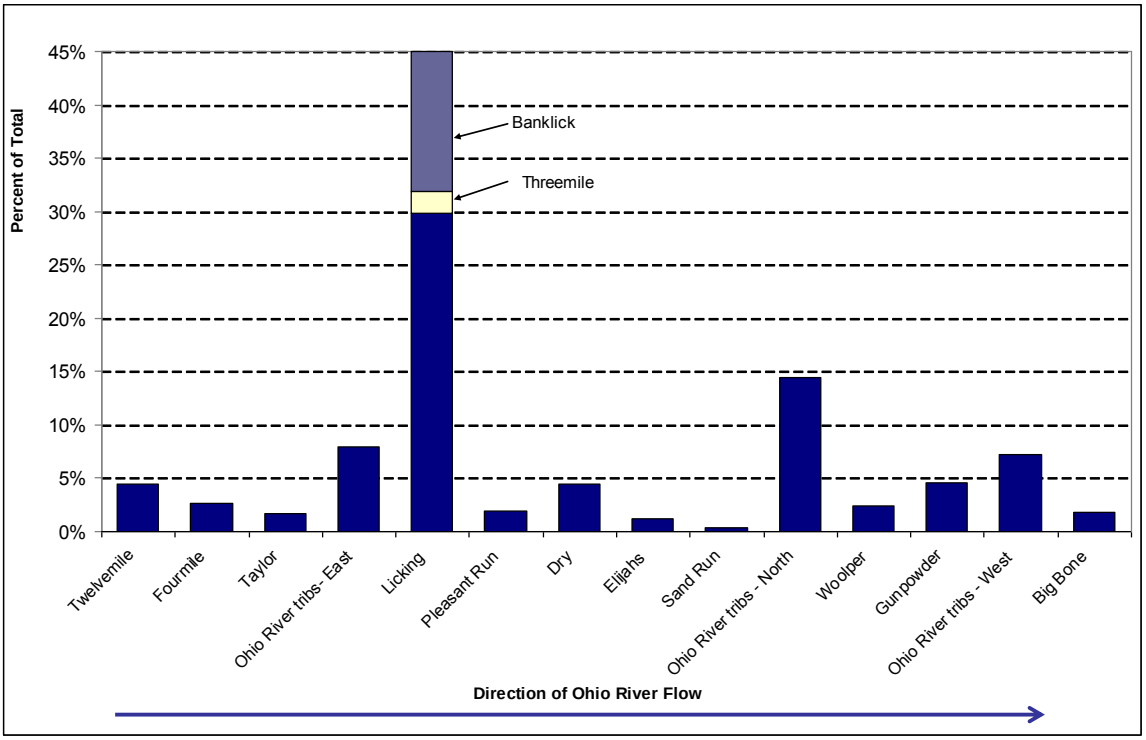
The Ohio River is almost 1,000 miles long and its watershed drains over 200,000 square miles and portions of fourteen states. The sixteen study area watersheds have an area of 592 square miles and comprise less than 0.3% of the Ohio River watershed.

SD1 Study Area Watersheds within the Ohio River Watershed

The portion of the Ohio River that bounds the study area is 72.8 miles long, and extends from the Pendleton/Campbell County line to the Boone/Gallatin County line. The Kentucky Division of Water (KDOW) has assessed this entire segment as impaired due to dioxin and polychlorinated biphenyls (PCBs). Thirty-seven miles of this segment are also identified as impaired due to elevated levels of fecal coliform bacteria, which is used as an indicator of pathogens. The Ohio River Valley Water Sanitation Commission (ORSANCO) is collecting data to support development of Total Maximum Daily Loads (TMDLs) for PCBs, dioxin and pathogens. Currently, a TMDL is being developed by a contractor to EPA Region 5 for *E. coli* bacteria (an indicator of pathogens) and is anticipated to be completed in 2010.

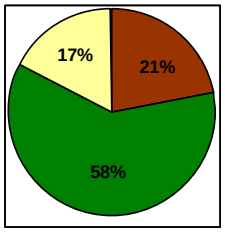
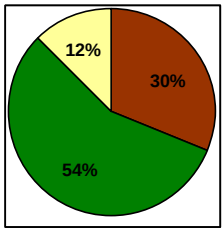
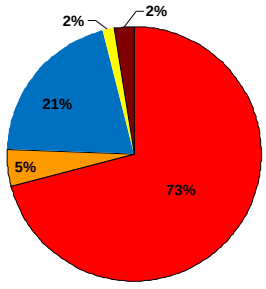
Source: SD1 and LTI

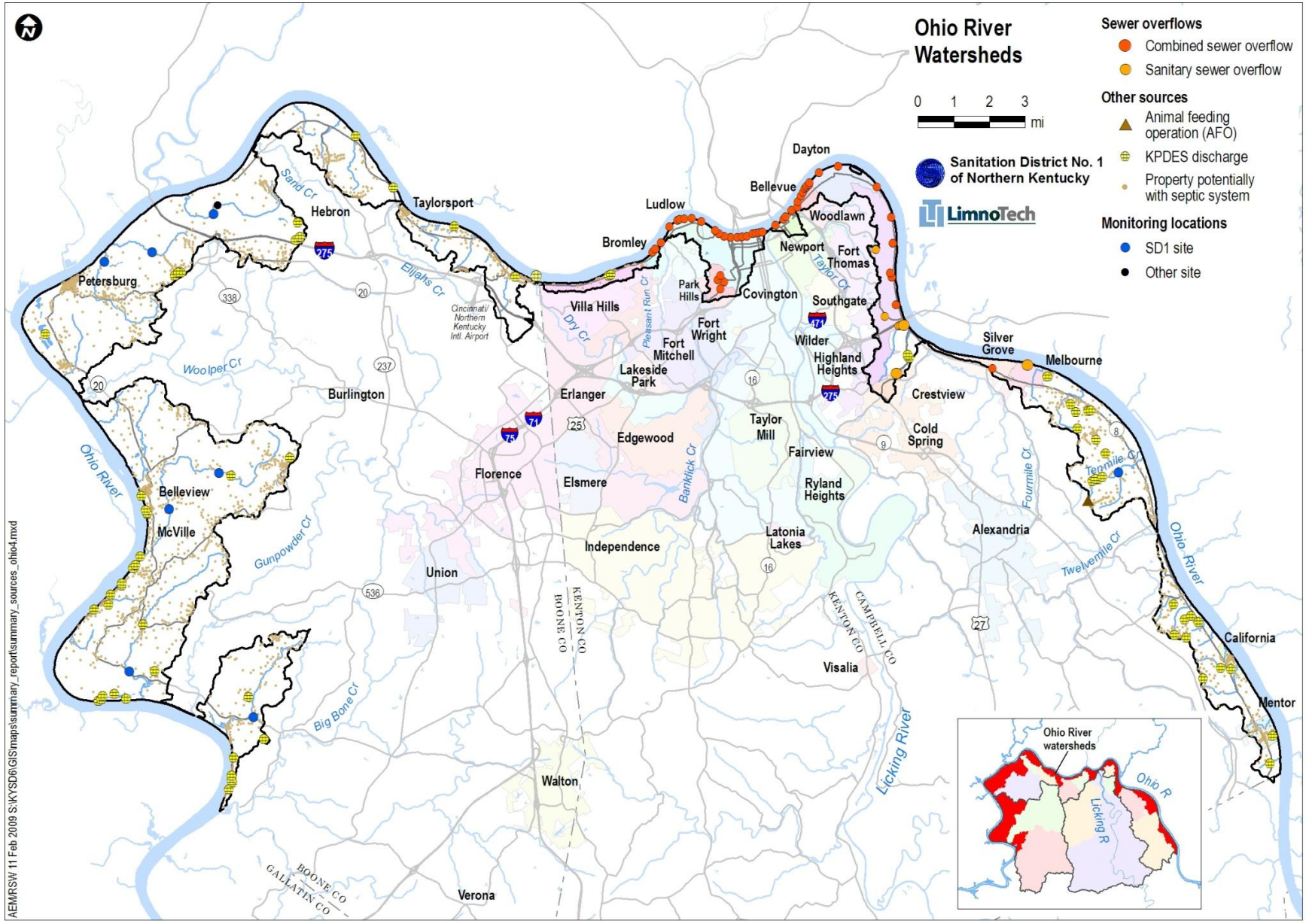
With the exception of two Licking River tributaries (Banklick Creek and Threemile Creek), the study area watersheds drain directly to the Ohio River. The relative potential of each watershed to generate fecal coliform bacteria has been predicted using WAT!. These results are plotted below, in the order (upstream to downstream) that these watersheds drain to the Ohio River. The portion of the Licking River watershed within SD1's study area is defined as the area draining to the Licking River between the mouth and River Mile 35.6.



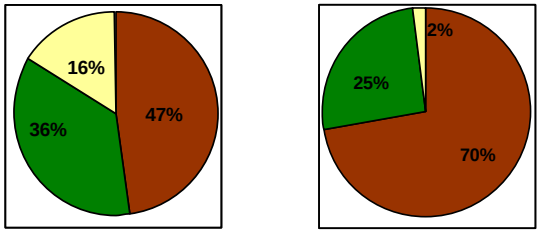
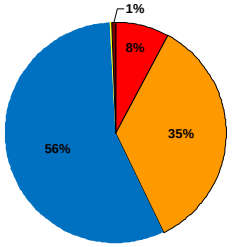
Relative WAT!-Predicted Bacteria Loading Potential for Study Area Watersheds

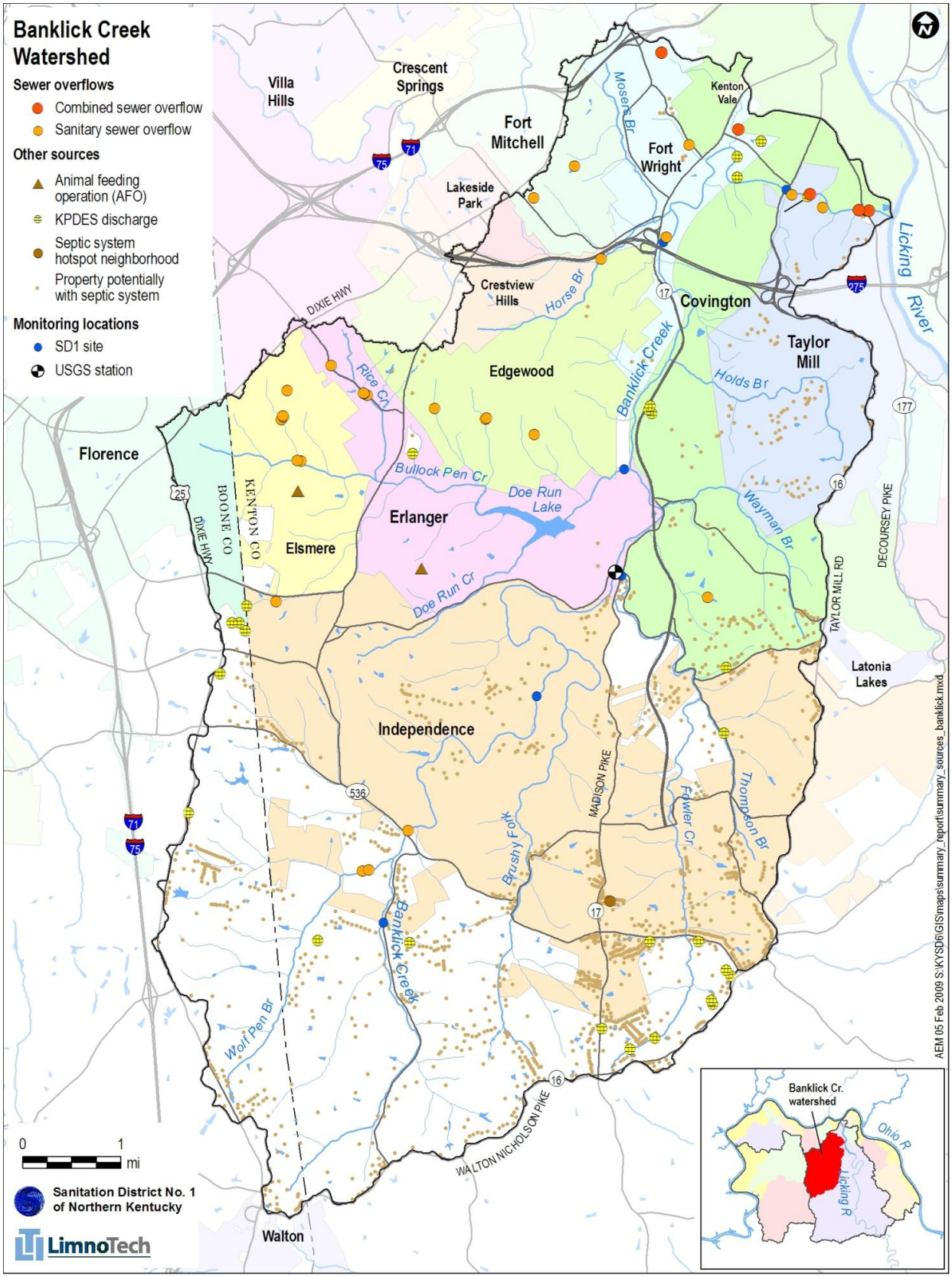
Small Ohio River Tributaries Fact Sheet

Overview	This area includes many small tributaries and direct drainage to the Ohio River. Development in this area is currently concentrated between Dayton and Bromley, but is expected to extend to the west and south in the future. SD1 will be constructing the Western Regional Water Reclamation Facility in the western portion of this watershed.
Drainage Area	85 square miles
Special Stream Designations	Garrison and Second Creek are exceptional waters and reference reach streams.
Aquatic-dependent State or Federally Threatened or Endangered Species	1 plant (running buffalo clover), 1 fish (lake sturgeon) and 2 mussels (pink mucket and sheepnose)
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current  5% Future  7%
Sewer Overflows	46 CSOs, 7 SSOs
Other KPDES Discharges	70 permitted outfalls
State Impaired Waters	1.1 miles of Tenmile Creek are identified as impaired due to nutrients and sedimentation.
TMDL Status	KDOW does not currently have plans to develop TMDLs for these watersheds.
Recent Assessments	
Habitat	Stream habitat was last assessed in three streams in 2003-2004 and reflects highly variable conditions ranging from not supporting to fully supporting of a diverse aquatic community at different sites.
Biological	Biological data were last assessed in four streams in 2003-2004 and reflects highly variable conditions ranging from poor to excellent.
Water Quality	Recent water quality data reveal elevated levels of bacteria during dry weather, as well as dissolved oxygen violations in several streams.
WAT! Bacteria Loading Potential, By Source CSO SSO Runoff Other KPDES dischargers Septic	Current Conditions, Watershed Contributions by Source 

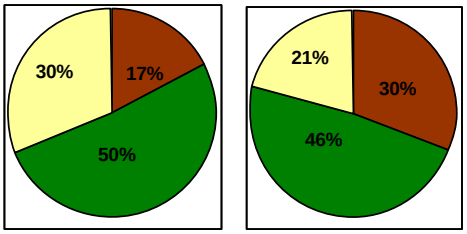
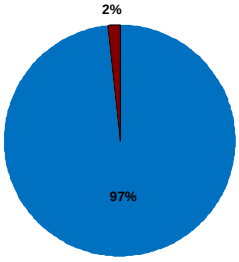

Ohio River Watersheds
Sewer overflows
Combined sewer overflow
Sanitary sewer overflow
Other sources
Animal feeding operation (AFO)
KPDES discharge
Property potentially with septic system
Monitoring locations
SD1 site
Other site
0 1 2 3 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Dayton
Bellevue
Ludlow
Bromley
Woodlawn
Newport
Fort Thomas
Taylor Cr
Park Hills
Covington
Southgate
Villa Hills
Dry Cr
Pleasant Run Cr
Fort Wright
Fort Mitchell
Lakeside Park
Wilder
Highland Heights
Silver Grove
Melbourne
Crestview
Cold Spring
Taylor Mill
Fairview
Ryland Heights
Alexandria
Latonia Lakes
Independence
Edgewood
Erlanger
Elsmere
Florence
Banklick Cr
Fourmile Cr
Tenmile Cr
Twelvemile Cr
Ohio River
Hebron
Taylorsport
Sand Cr
Elijahs Cr
Cincinnati/ Northern Kentucky Intl. Airport
Petersburg
Woolper Cr
Burlington
Belleview
McVille
Gunpowder Cr
Union
Big Bone Cr
Walton
Verona
Boone Co
Gallatin Co
Kenton Co
Boone Co
Campbell Co
Kenton Co
Visalia
Licking River
California
Mentor
Ohio River watersheds
Ohio R
Licking R
AEM/RSW 11 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_ohio4.mxd

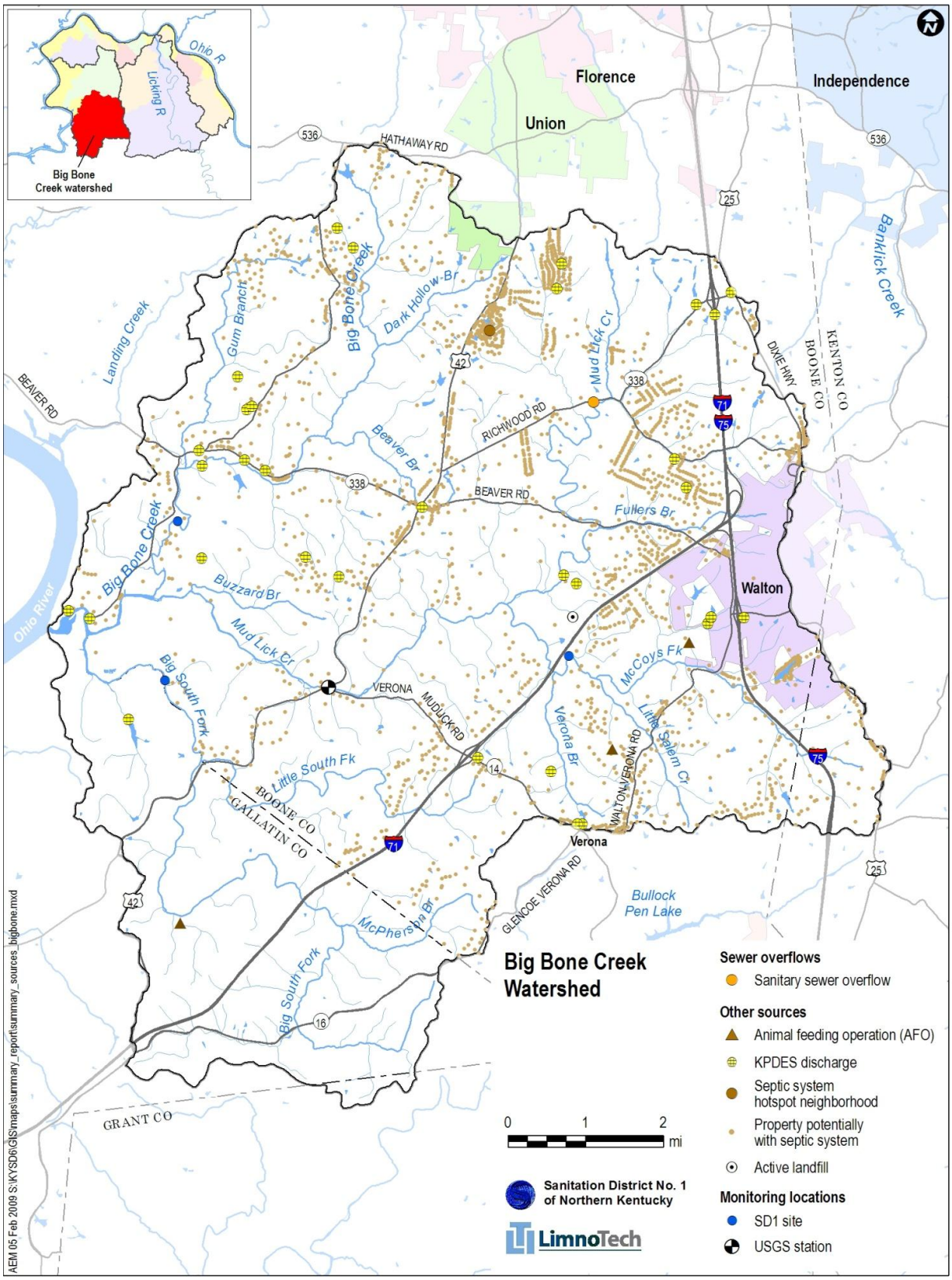
Banklick Creek Watershed Fact Sheet

Overview	The Banklick watershed, a tributary of the Licking River, is highly developed in the downstream portion and flooding is a recurring problem in this area. Farther upstream, the watershed is less developed. This portion of the watershed is rapidly developing and Banklick Creek is predicted to have the largest amount of new development of all the study area watersheds. The Banklick Creek Watershed Council is actively working to improve stream condition in this watershed.
Drainage Area	58.2 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	1 plant (running buffalo clover)
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current Future  11% 17%
Sewer Overflows	5 CSOs, 27 SSOs
Other KPDES Discharges	32 permitted outfalls
State Impaired Waters	The entire length of this creek is impaired due to fecal coliform bacteria, nutrients and organic enrichment. The lower 8.2 miles are also impaired due to sedimentation. Doe Run Lake is impaired due to low dissolved oxygen, nutrients and dissolved gas supersaturation.
TMDL Status	KDOW plans to complete TMDLs for the impaired waters in this watershed, although nutrient and organic enrichment TMDLs will not be initiated until nutrient targets are available.
Recent Assessments	
Habitat	Stream habitat was last assessed in 2001 with sites rated as either partially supporting or not supporting of a diverse aquatic community.
Biological	Biological data were last assessed in early 2000 (2001 – 2003) and reflects highly variable conditions, ranging from very poor to excellent.
Water Quality	Recent water quality data reveal elevated levels of bacteria in the tributaries and along the length of the mainstem, during both wet and dry conditions.
WAT! Bacteria Loading Potential, By Source CSO SSO Runoff Septic	Current Conditions, Watershed Contributions by Source 

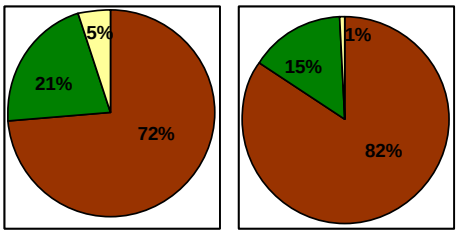
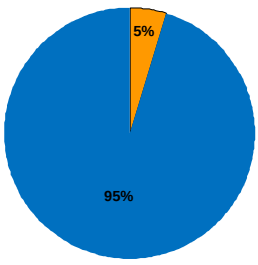

Banklick Creek Watershed
Sewer overflows
Combined sewer overflow
Sanitary sewer overflow
Other sources
Animal feeding operation (AFO)
KPDES discharge
Septic system hotspot neighborhood
Property potentially with septic system
Monitoring locations
SD1 site
USGS station
Villa Hills
Crescent Springs
Fort Mitchell
Kenton Vale
Fort Wright
Lakeside Park
Crestview Hills
Covington
Taylor Mill
Edgewood
Florence
Erlanger
Elsmere
Independence
Latonia Lakes
Walton
Mosers Br
Horse Br
Rice Cr
Bullock Pen Cr
Doe Run Lake
Doe Run Cr
Banklick Creek
Holds Br
Wayman Br
Brushy Fork
Fowler Cr
Thompson Br
Wolf Pen Br
Licking River
DIXIE HWY
BOONE CO
KENTON CO
TAYLOR MILL RD
DECOURSEY PIKE
MADISON PIKE
WALTON NICHOLSON PIKE
0 1 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Banklick Cr. watershed
Ohio R
Licking R
AEM 05 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_banklick.mxd

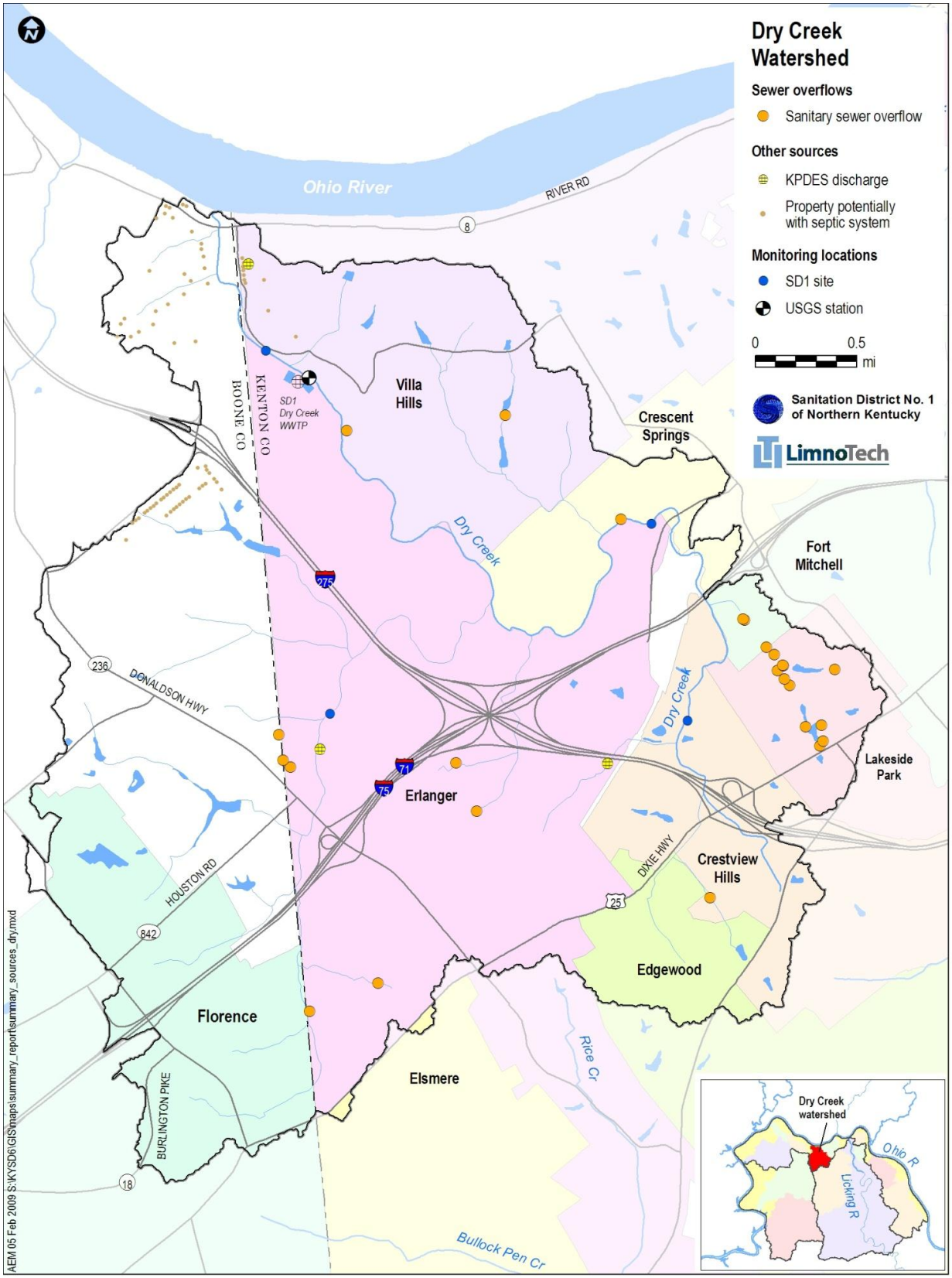
Big Bone Creek Watershed Fact Sheet

Overview	The Big Bone Creek watershed is the second largest in the study area and is predominantly rural in character. Existing development is concentrated primarily in the Mud Lick Creek subwatershed, where flooding has been reported. There is one drinking water intake in this watershed, within Big Bone Lick State Park.
Drainage Area	82.6 square miles
Special Stream Designations	Little South Fork is a candidate for exceptional water designation.
Aquatic-dependent State or Federally Threatened or Endangered Species	2 vascular plants (running buffalo clover and nodding rattlesnake-root)
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current / Future  3% 6%
Sewer Overflows	1 SSO
Other KPDES Discharges	35 permitted outfalls
State Impaired Waters	None
TMDL Status	Not applicable
Recent Assessments	
Habitat	Stream habitat was last assessed in 2004 in the mainstem and two tributaries, and was assessed as partially to fully supporting of a diverse aquatic community.
Biological	Biological data were last collected in 2003 - 2004 indicating good to excellent conditions at two mainstem sites.
Water Quality	Recent water quality data reveal elevated levels of bacteria in the mainstem and in a tributary.
WAT! Bacteria Loading Potential, By Source Runoff Septic	Current Conditions, Watershed Contributions by Source 

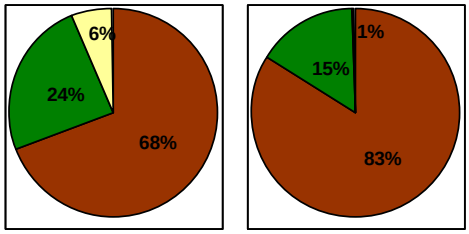
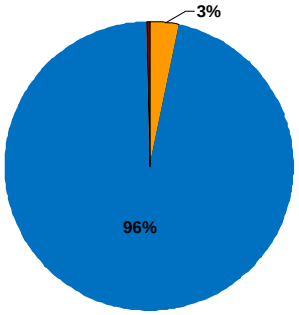

Ohio R
Licking R
Big Bone Creek watershed
Florence
Union
Independence
HATHAWAY RD
536
25
Banklick Creek
Landing Creek
Gum Branch
Big Bone Creek
Dark Hollow Br
Mud Lick Cr
DIXIE HWY
KENTON CO
BOONE CO
BEAVER RD
42
338
71
75
RICHWOOD RD
Beaver Br
BEAVER RD
Fullers Br
Big Bone Creek
Ohio River
Buzzard Br
Mud Lick Cr
Walton
McCoys Fk
Big South Fork
VERONA
MUDLICK RD
Verona Br
Little Salem Cr
WALTON-VERONA RD
14
Little South Fk
BOONE CO
GALLATIN CO
Verona
GLENCOE VERONA RD
Bullock Pen Lake
McPherson Br
Big South Fork
16
GRANT CO
Big Bone Creek Watershed
0 1 2 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Sewer overflows
Sanitary sewer overflow
Other sources
Animal feeding operation (AFO)
KPDES discharge
Septic system hotspot neighborhood
Property potentially with septic system
Active landfill
Monitoring locations
SD1 site
USGS station
AEM 05 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_bigbone.mxd

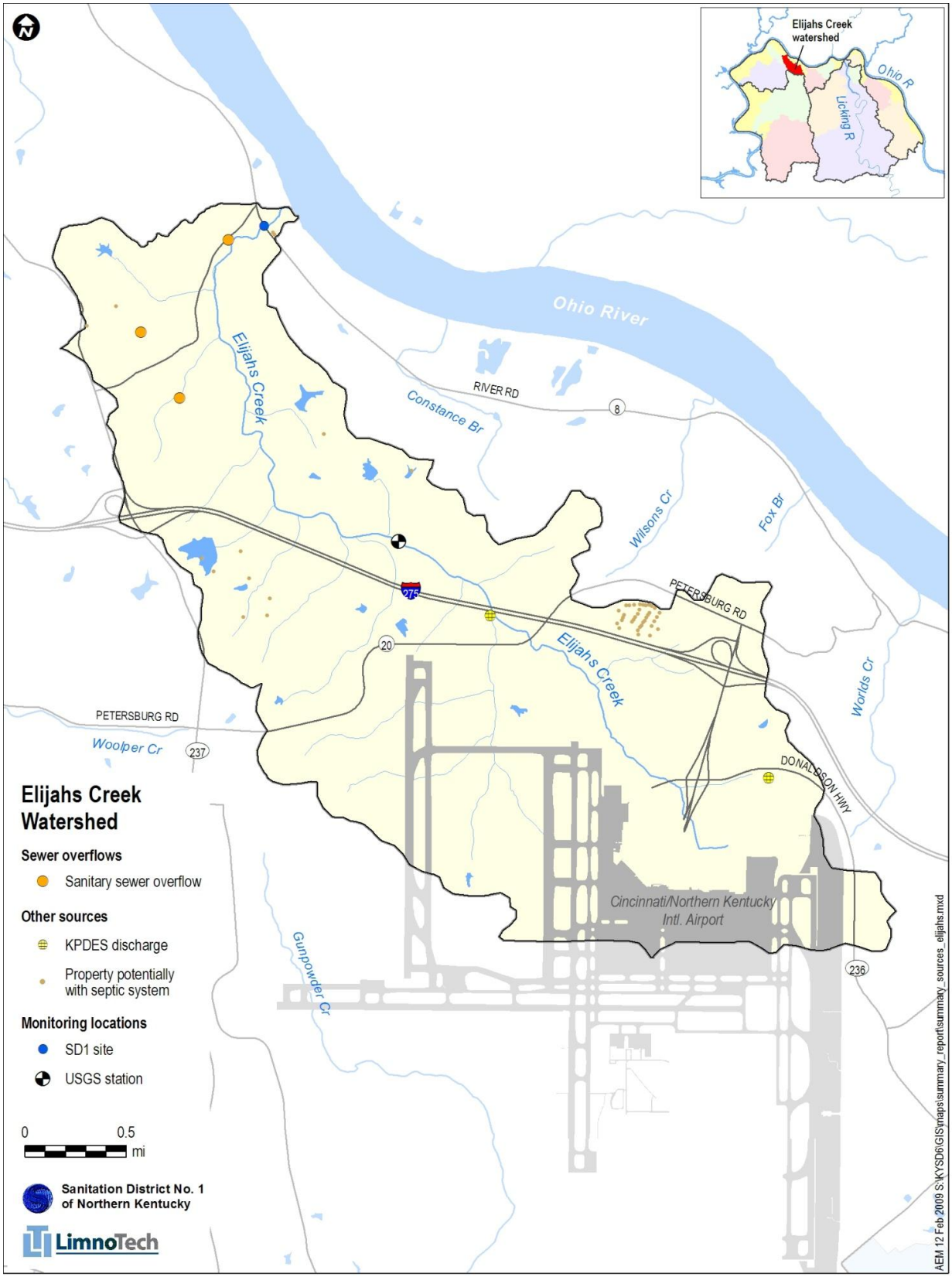
Dry Creek Watershed Fact Sheet

Overview	The small Dry Creek watershed is the second most highly developed watershed. A portion of this watershed lies within Florence, outside SD1's sanitary sewer and storm water service area. SD1's Dry Creek Wastewater Treatment Plant lies within the watershed. This facility receives and treats wastewater from many other watersheds, and discharges treated effluent directly to the Ohio River.
Drainage Area	12.4 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current Future  24% 28%
Sewer Overflows	25 SSOs
Other KPDES Discharges	4 permitted outfalls
State Impaired Waters	6.8 miles of Dry Creek are identified as impaired due to nutrients and organic enrichment.
TMDL Status	TMDL development has not yet been initiated. TMDLs for nutrients and organic enrichment will not be initiated until after nutrient criteria are promulgated by the State.
Recent Assessments	
Habitat	Stream habitat was last assessed in 2004 as not supporting of a diverse aquatic community at a mainstem site.
Biological	Biological data were last collected in 2004 indicating fair conditions at one mainstem site.
Water Quality	Recent water quality data reveal elevated levels of bacteria during dry weather in one tributary and at two mainstem sites.
WAT! Bacteria Loading Potential, By Source SSO Runoff	Current Conditions, Watershed Contributions by Source 

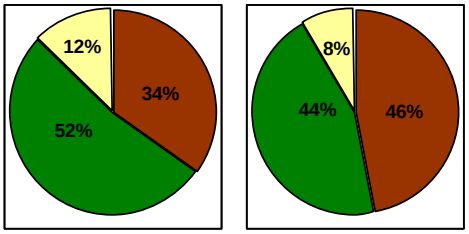
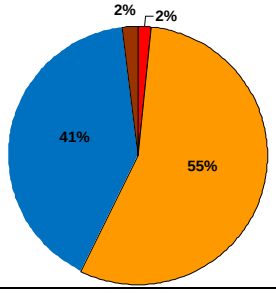

Dry Creek Watershed
Sewer overflows
Sanitary sewer overflow
Other sources
KPDES discharge
Property potentially with septic system
Monitoring locations
SD1 site
USGS station
0 0.5 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Ohio River
RIVER RD
8
BOONE CO
KENTON CO
SD1 Dry Creek WWTP
Villa Hills
Crescent Springs
Fort Mitchell
Dry Creek
275
236
DONALDSON HWY
71
75
Erlanger
Lakeside Park
Crestview Hills
DIXIE HWY
25
HOUSTON RD
842
Edgewood
Florence
Elsmere
Rice Cr
BURLINGTON PIKE
18
Bullock Pen Cr
Dry Creek watershed
Ohio R
Licking R
AEM 05 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_dry.mxd

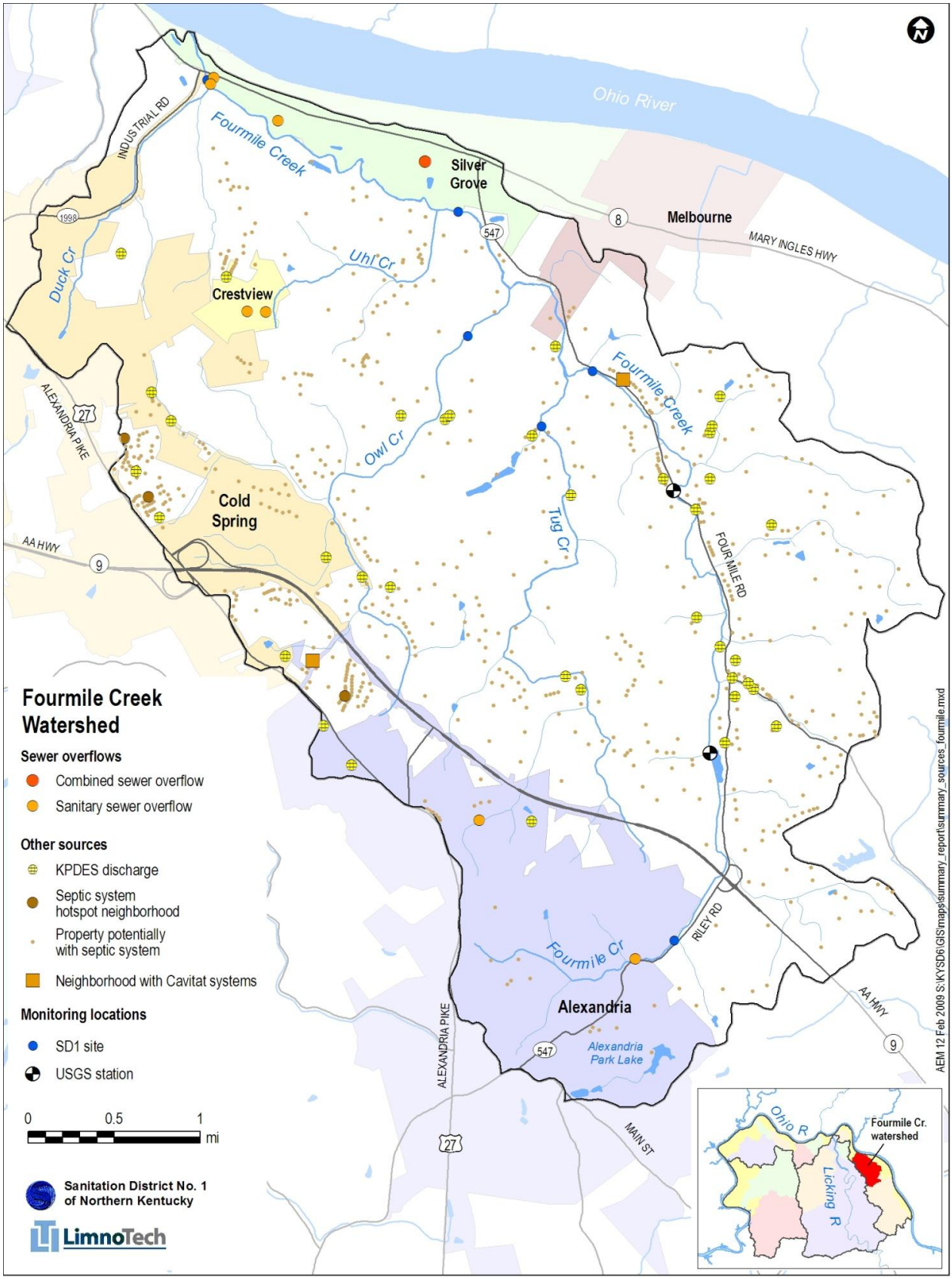
Elijahs Creek Watershed Fact Sheet

Overview	The small Elijahs Creek watershed is highly developed. The Cincinnati/Northern Kentucky International Airport is located at the headwaters of this creek and contributes to this watershed having the highest percent impervious cover within the study area.
Drainage Area	6.7 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current / Future  25% 31%
Sewer Overflows	3 SSOs
Other KPDES Discharges	2 permitted outfalls
State Impaired Waters	Elijahs Creek between RM 0.0 – 5.2 is identified as impaired due to ethylene glycol.
TMDL Status	A TMDL for ethylene glycol in Elijahs Creek was developed by KDOW in 1998 to address impacts from airport deicing fluid on the creek. Deicing fluid from the airport is now collected and reclaimed at a glycol recovery facility. The airport also has a storm water treatment plant, located in the adjacent Gunpowder Creek watershed.
Recent Assessments	
Habitat	Stream habitat was last assessed in 2004 as not supporting of a diverse aquatic community at two mainstem sites.
Biological	Biological data were last collected in 2004 indicating poor to very poor conditions at two mainstem sites.
Water Quality	Recent water quality data from two mainstem sites reveal generally good water quality during base flow conditions.
WAT! Bacteria Loading Potential, By Source SSO Runoff Septic	Current Conditions, Watershed Contributions by Source 

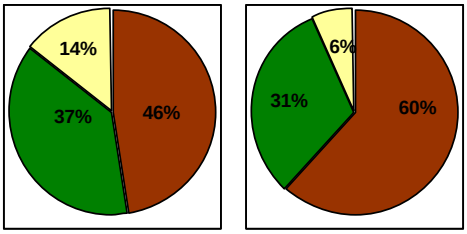
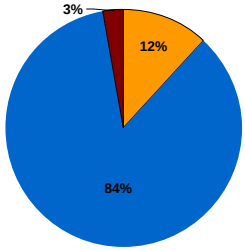

Elijahs Creek watershed
Ohio R
Licking R
Ohio River
Elijahs Creek
RIVER RD
8
Constance Br
Wilsons Cr
Fox Br
PETERSBURG RD
275
20
Elijahs Creek
Worlds Cr
PETERSBURG RD
Woolper Cr
237
DONALDSON HWY
Cincinnati/Northern Kentucky Intl. Airport
Gunpowder Cr
236
Elijahs Creek Watershed
Sewer overflows
Sanitary sewer overflow
Other sources
KPDES discharge
Property potentially with septic system
Monitoring locations
SD1 site
USGS station
0
0.5
mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
AEM 12 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_elijahs.mxd

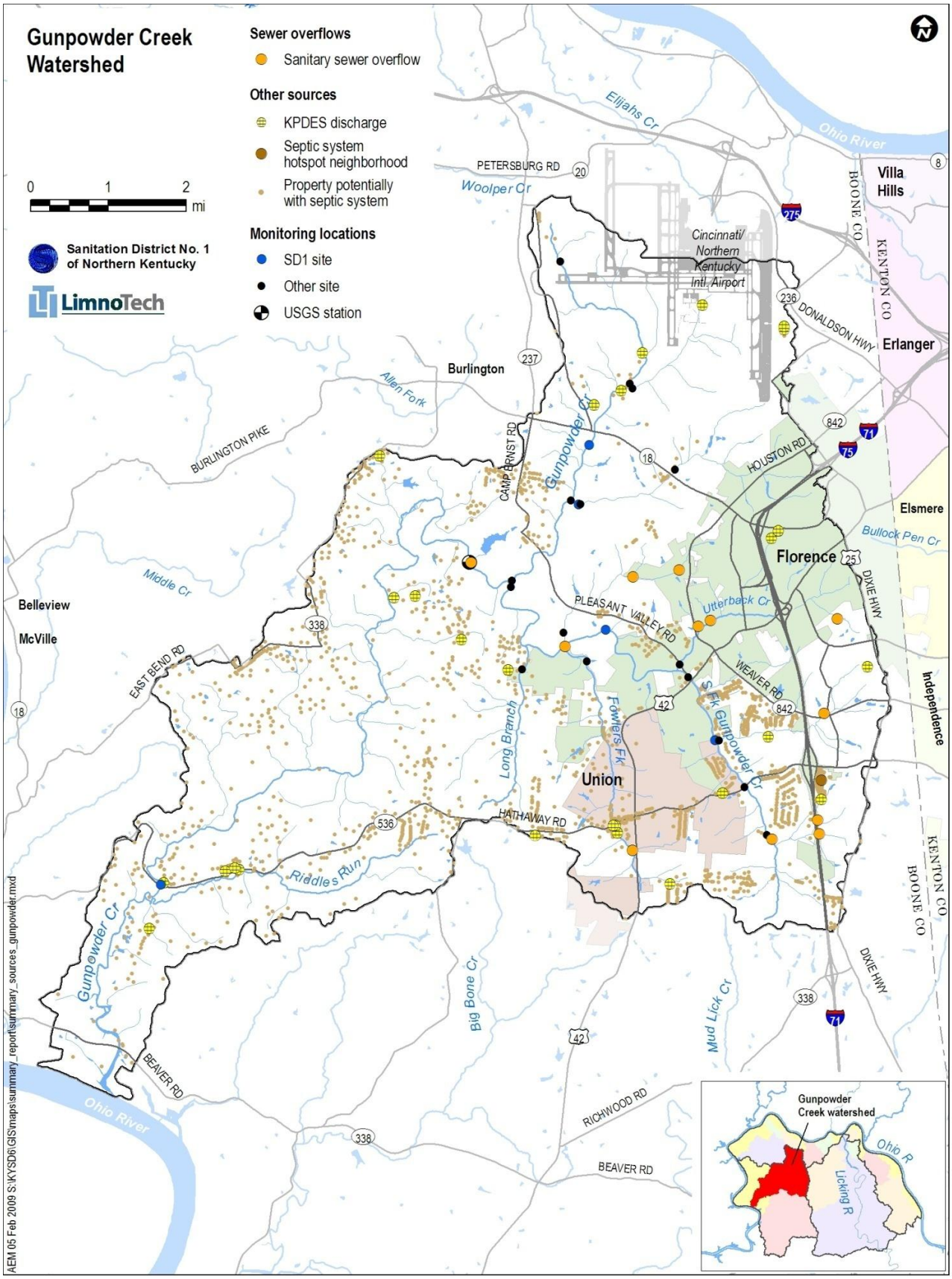
Fourmile Creek Watershed Fact Sheet

Overview	Fourmile Creek originates in Alexandria, Kentucky and drains a watershed with mixed land cover. Development is currently concentrated near the headwaters of Fourmile Creek and its tributaries. Locations with severe streambank erosion have been observed.
Drainage Area	17.8 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current / Future  6% 9%
Sewer Overflows	1 CSO, 7 SSOs
Other KPDES Discharges	37 permitted outfalls
State Impaired Waters	Fourmile Creek between RM 0.2 – 8.5 is identified as impaired due to fecal coliform bacteria. Alexandria Park Lake is identified as impaired due to mercury in fish tissue.
TMDL Status	TMDL development has not yet been initiated. Neither listed waterbody is identified as having a TMDL planned for the near future.
Recent Assessments	
Habitat	Stream habitat was last assessed in 2007 as not supporting of a diverse aquatic community at three mainstem locations and in two tributaries.
Biological	Biological data were last collected in 2007 indicating fair to good conditions in the mainstem and two tributaries.
Water Quality	Recent water quality data indicate frequent instances of elevated levels of bacteria along the mainstem and in two tributaries during wet weather and along the mainstem during dry weather. Violations of the dissolved oxygen criteria have been observed at two mainstem locations.
WAT! Bacteria Loading Potential, By Source CSO SSO Runoff Septic	Current Conditions, Watershed Contributions by Source 

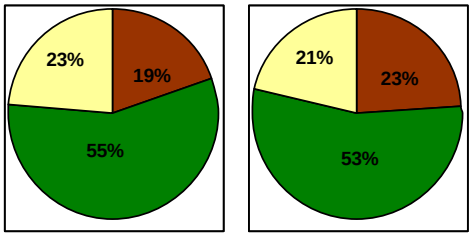
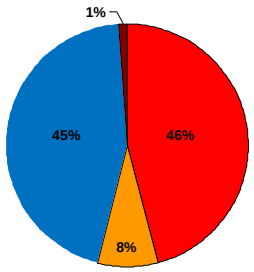

Ohio River
Fourmile Creek
Silver Grove
Melbourne
MARY INGLES HWY
INDUSTRIAL RD
1998
Duck Cr
Uhl Cr
Crestview
Fourmile Creek
ALEXANDRIA PIKE
27
Owl Cr
Cold Spring
Tug Cr
FOUR MILE RD
AA HWY
9
8
547
Fourmile Cr
RILEY RD
Alexandria
Alexandria Park Lake
ALEXANDRIA PIKE
MAIN ST
Fourmile Creek Watershed
Sewer overflows
Combined sewer overflow
Sanitary sewer overflow
Other sources
KPDES discharge
Septic system hotspot neighborhood
Property potentially with septic system
Neighborhood with Cavitat systems
Monitoring locations
SD1 site
USGS station
0 0.5 1 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Ohio R
Licking R
Fourmile Cr. watershed
AEM 12 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_fourmile.mxd

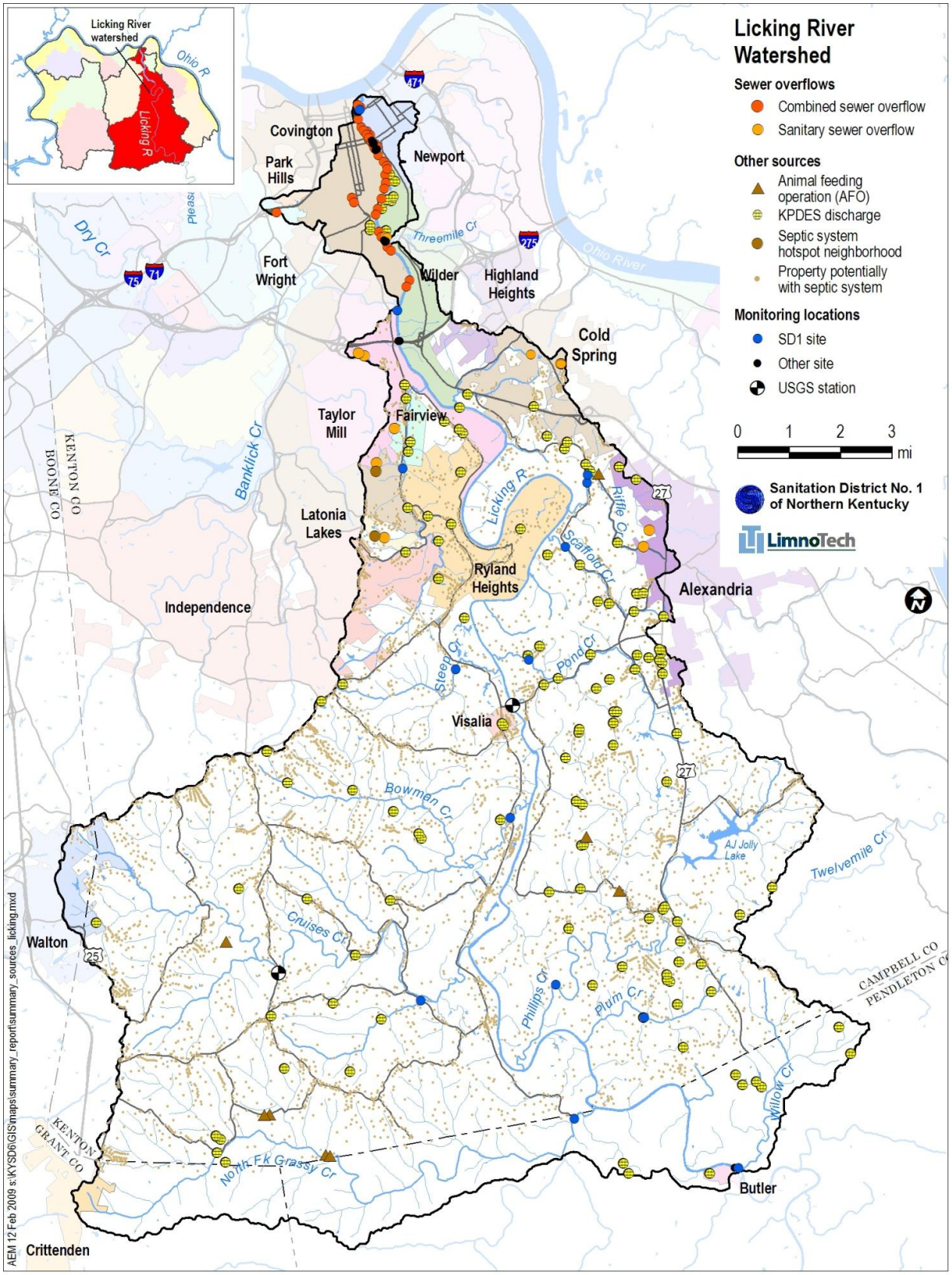
Gunpowder Creek Watershed Fact Sheet

Overview	Gunpowder Creek originates west of the Cincinnati/Northern Kentucky International Airport and the headwaters of this large watershed drain a highly developed area that includes the airport and portions of Florence, which is outside SD1's service area. Flooding has been reported near the headwaters and near the mouth. Erosion is also severe in some locations.
Drainage Area	58.2 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current Future  12% 16%
Sewer Overflows	13 SSOs (5 of these are in Florence)
Other KPDES Discharges	26 permitted outfalls
State Impaired Waters	South Fork Gunpowder Creek: Two segments are identified as impaired. One (2.7 miles) is listed due to fecal coliform and the other (2 miles) is listed for sedimentation, turbidity, nutrients and organic enrichment. Gunpowder Creek: Three segments are identified as impaired. One (2.7 miles) is listed due to an unknown pollutant, another (1.7 miles) is listed due to sedimentation, nutrients, organic enrichment and ethylene glycol, and a third (15 miles) is listed due to sedimentation.
TMDL Status	A TMDL for ethylene glycol in Gunpowder Creek was developed by KDOW in 1998 to address impacts from airport deicing fluid on the creek. Runoff from the airport is now treated by a storm water treatment plant that is located in this watershed. Deicing fluid is also collected and reclaimed at a glycol recovery facility (Elijahs Creek watershed). KDOW planned to initiate TMDLs for the 303(d)-listed segments in 2008. Sediment TMDLs will be developed once additional sediment data are collected, if needed. TMDLs for nutrients and organic enrichment will not be initiated until nutrient criteria are promulgated by the State.
Recent Assessments	
Habitat	Stream habitat was last assessed in 2004 as ranging from partially supporting to fully supporting of a diverse aquatic community in the mainstem and two tributaries.
Biological	Biological data were last collected in 2004 indicating highly variable conditions ranging from very poor to excellent in two tributaries and fair in the mainstem.
Water Quality	Recent water quality data indicate elevated levels of bacteria during wet and dry weather in two tributaries. No recent wet weather data were available for the mainstem.
WAT! Bacteria Loading Potential, By Source SSO Runoff Septic	Current Conditions, Watershed Contributions by Source 

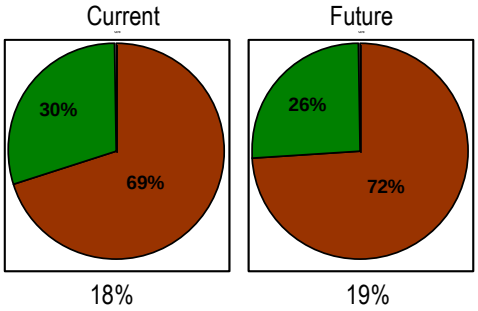
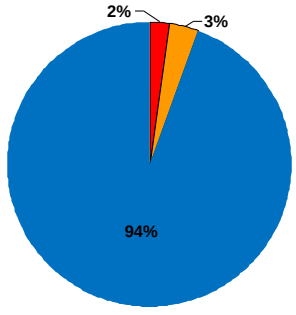

Gunpowder Creek Watershed
Sewer overflows
Sanitary sewer overflow
Other sources
KPDES discharge
Septic system hotspot neighborhood
Property potentially with septic system
Monitoring locations
SD1 site
Other site
USGS station
0 1 2 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Elijahs Cr
Ohio River
PETERSBURG RD
Woolper Cr
Villa Hills
BOONE CO
KENTON CO
Cincinnati/ Northern Kentucky Intl. Airport
DONALDSON HWY
Erlanger
Burlington
Allen Fork
BURLINGTON PIKE
CAMP ERNST RD
Gunpowder Cr
HOUSTON RD
Elsmere
Bullock Pen Cr
Florence
DIXIE HWY
Middle Cr
Belleview
McVille
PLEASANT VALLEY RD
Utterback Cr
WEAVER RD
EAST BEND RD
Fowlers Fk
S Fk Gunpowder Cr
Independence
Long Branch
Union
HATHAWAY RD
Riddles Run
Big Bone Cr
Mud Lick Cr
RICHWOOD RD
BEAVER RD
Gunpowder Creek watershed
Ohio R
Licking R
AEM 05 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_gunpowder.mxd

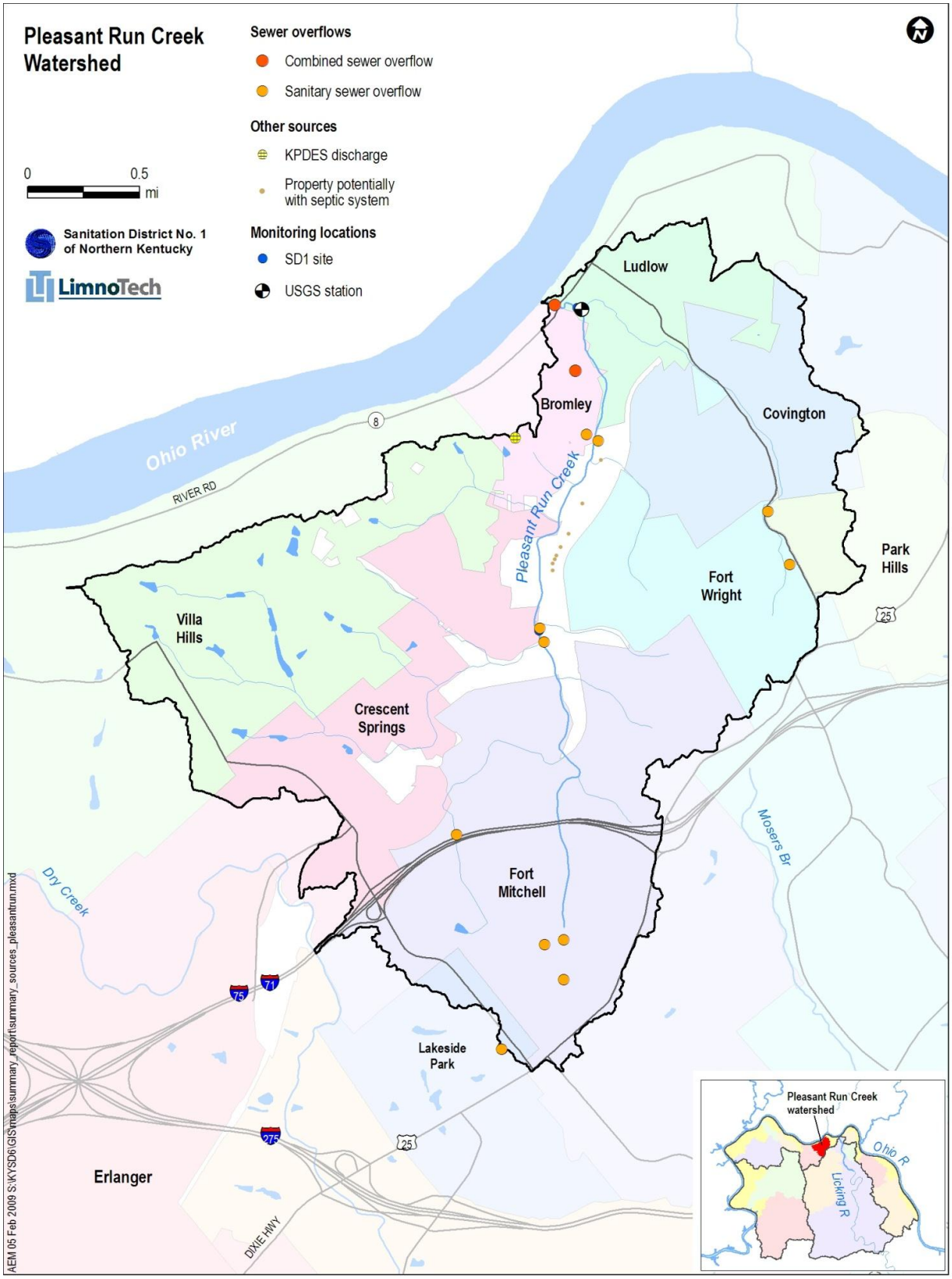
Licking River Watershed Fact Sheet

Overview	The entire Licking River watershed is approximately 3,600 squares miles and extends 300 river miles to Magoffin County, KY. For this study, the Licking River watershed is defined as the area between the mouth and river mile 35.6, excluding two tributaries, Banklick Creek and Threemile Creek, which are described in separate fact sheets. This watershed is highly developed between Wilder and its confluence with the Ohio River. Farther upstream, land use transitions to more rural uses, and forest and agriculture dominate. There are two public drinking water intakes from the Licking River that are located in this watershed.
Drainage Area	170 square miles
Special Stream Designations	Licking River RM 18.9 – 35.6 is an Outstanding State Resource Water. Bowman Creek and Sawyers Fork are candidates for exceptional water designation.
Aquatic-dependent State or Federally Threatened or Endangered Species	5 mussels (elktoe, fanshell, pink mucket, salamander and purple lilliput)
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current Future  3% 4%
Sewer Overflows	34 CSOs, 11 SSOs
Other KPDES Discharges	136 permitted outfalls
State Impaired Waters	Licking River: Three segments (19.5 miles total) identified as impaired due to fecal coliform. Phillips Creek: One segment (5.3 miles) identified as impaired due to fecal coliform.
TMDL Status	No TMDLs are planned at this time.
Recent Assessments	
Habitat	Stream habitat in the Licking River mainstem was last assessed in 1996 as fair to good conditions. Habitat was assessed in two tributaries from 2003 to 2005 as partially supporting to fully supporting of a diverse aquatic community.
Biological	Biological data collected in two tributaries from 2003 to 2005 indicated fair to excellent conditions.
Water Quality	Recent water quality data from nine mainstem locations and twelve tributaries indicates elevated levels of bacteria at 13 of the 21 samples locations. During dry weather, elevated bacteria levels were observed in the mainstem at several upstream and downstream locations and in eight of the 12 sampled tributaries. During wet weather, elevated bacteria levels were observed at two downstream mainstem locations. (Recent wet weather data were not available for the tributaries or upstream mainstem locations.)
WAT! Bacteria Loading Potential, By Source CSO SSO Runoff Septic	Current Conditions, Watershed Contributions by Source 

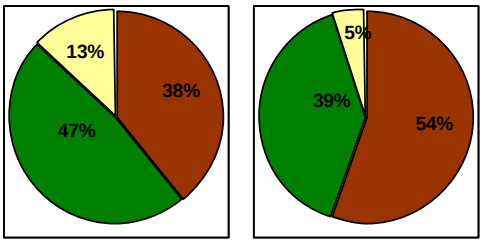
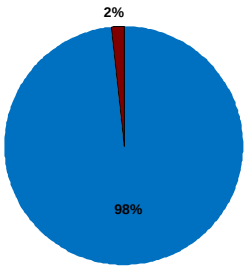

Licking River watershed
Ohio R
Licking R
Licking River Watershed
Sewer overflows
Combined sewer overflow
Sanitary sewer overflow
Other sources
Animal feeding operation (AFO)
KPDES discharge
Septic system hotspot neighborhood
Property potentially with septic system
Monitoring locations
SD1 site
Other site
USGS station
0 1 2 3 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Covington
Park Hills
Newport
Fort Wright
Wilder
Highland Heights
Cold Spring
Taylor Mill
Fairview
Latonia Lakes
Ryland Heights
Alexandria
Independence
Visalia
Walton
Crittenden
Butler
Dry Cr
Banklick Cr
Threemile Cr
Ohio River
Licking R
Scaffold Cr
Riffle Cr
Steep Cr
Pond Cr
Bowmen Cr
Cruises Cr
Phillips Cr
Plum Cr
Twelvemile Cr
AJ Jolly Lake
Willow Cr
North Fk Grassy Cr
KENTON CO
BOONE CO
GRANT CO
CAMPBELL CO
PENDLETON CO
AEM 12 Feb 2009 s:\KYSD6\GIS\maps\summary_report\summary_sources_licking.mxd

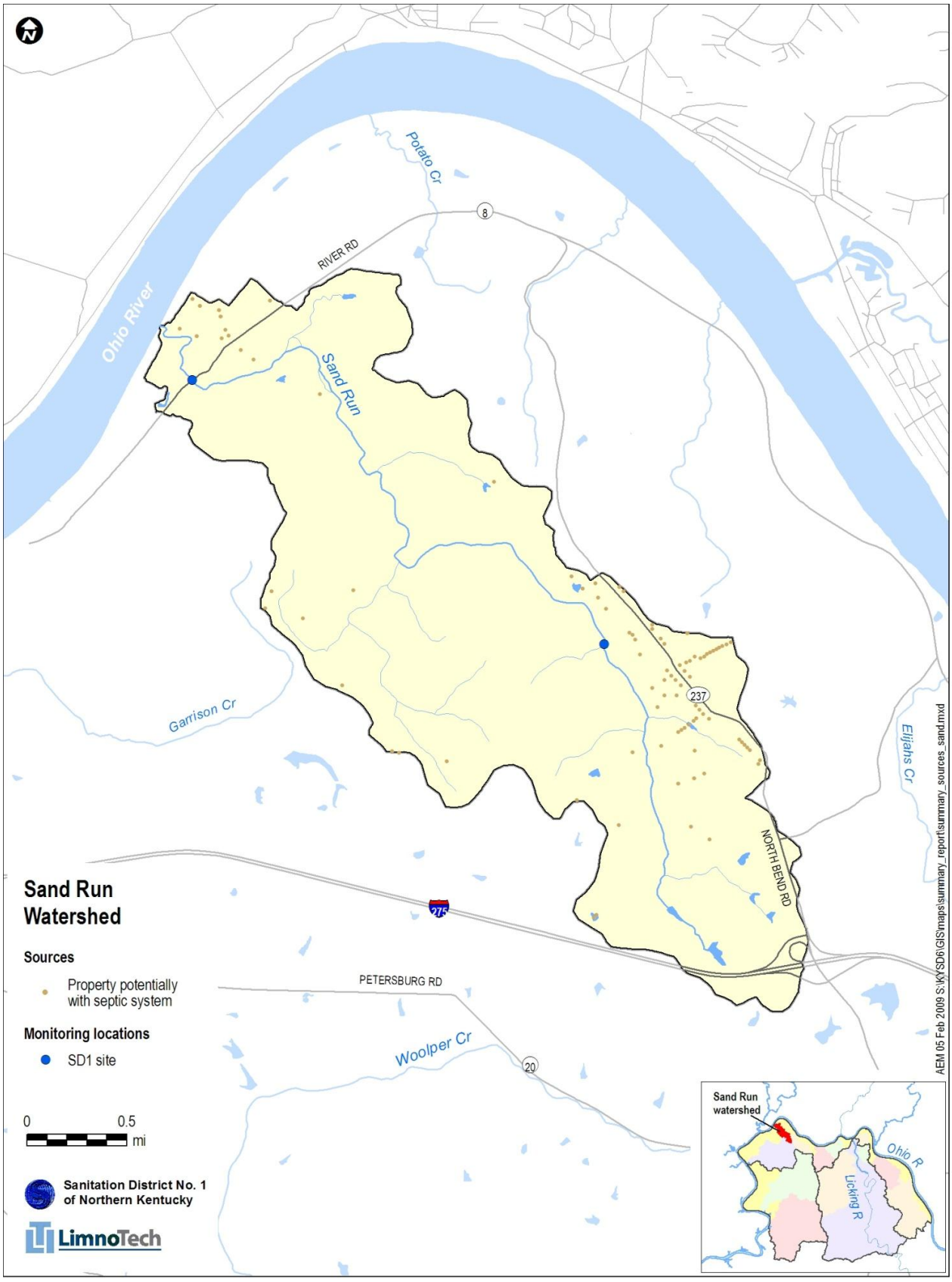
Pleasant Run Creek Watershed Fact Sheet

Overview	Pleasant Run Creek drains a small and very highly developed watershed. Much of the undeveloped land that remains is located within Devou Park, near the mouth of this creek.
Drainage Area	6.5 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	1 reptile (Kirtland's snake)
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	
Sewer Overflows	2 CSOs, 11 SSOs
Other KPDES Discharges	1 permitted outfall
State Impaired Waters	None
TMDL Status	Not applicable
Recent Assessments	
Habitat	Habitat was last assessed in 2004 as partially supporting of a diverse aquatic community at one mainstem site.
Biological	Biological data were last collected in 2004 indicating good conditions in one mainstem site.
Water Quality	Recent water quality data were collected at two mainstem locations during dry weather. At both locations, one in three samples reveals elevated levels of bacteria.
WAT! Bacteria Loading Potential, By Source CSO SSO Runoff	Current Conditions, Watershed Contributions by Source 

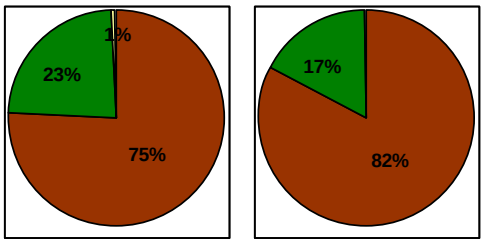
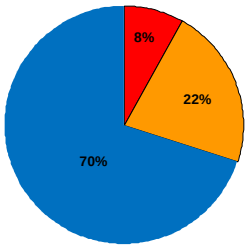

Pleasant Run Creek Watershed
Sewer overflows
Combined sewer overflow
Sanitary sewer overflow
Other sources
KPDES discharge
Property potentially with septic system
Monitoring locations
SD1 site
USGS station
0
0.5
mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Ludlow
Bromley
Covington
Park Hills
Fort Wright
Villa Hills
Crescent Springs
Fort Mitchell
Lakeside Park
Erlanger
Ohio River
RIVER RD
Pleasant Run Creek
Dry Creek
Mosers Br
DIXIE HWY
Pleasant Run Creek watershed
Ohio R
Licking R
AEM 05 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_pleasantrun.mxd

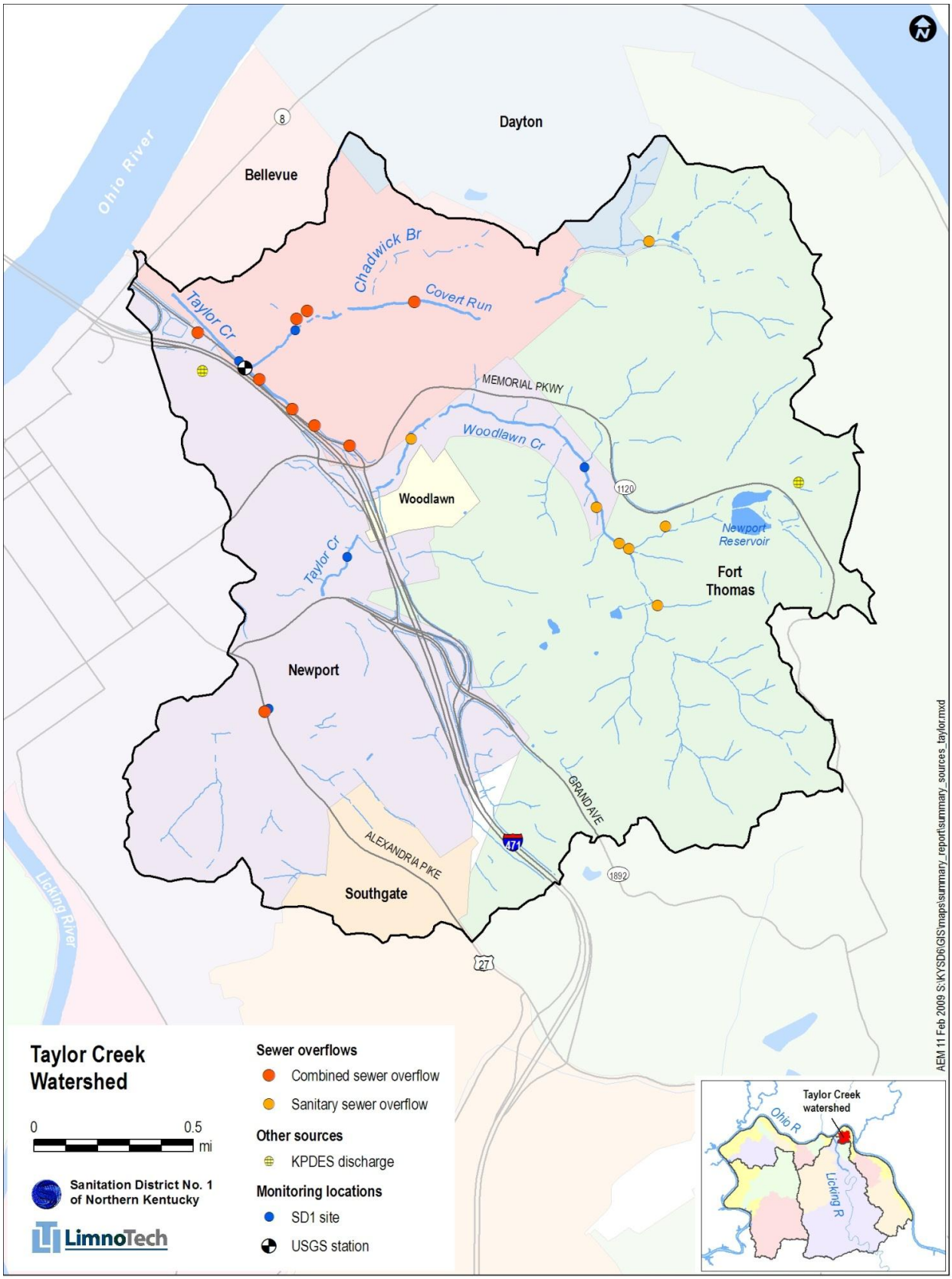
Sand Run Watershed Fact Sheet

Overview	Sand Run is a small watershed that recently has seen rapid development, especially near the headwaters. Flooding has become a problem more recently in this watershed, and although forested areas remain on the steep slopes adjacent to the creek, severe streambank erosion has been observed.
Drainage Area	5 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current / Future  12% 16%
Sewer Overflows	None
Other KPDES Discharges	None
State Impaired Waters	None
TMDL Status	Not applicable
Recent Assessments	
Habitat	Not available
Biological	Not available
Water Quality	Recent water quality data collected during dry weather at two mainstem locations reveal elevated levels of bacteria at both locations and dissolved oxygen violations at one location.
WAT! Bacteria Loading Potential, By Source Runoff Septic	Current Conditions, Watershed Contributions by Source 

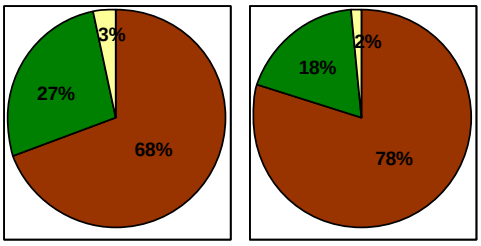
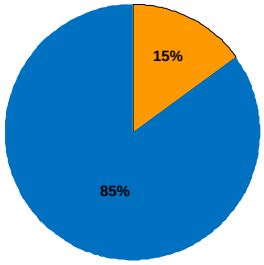

Potato Cr
8
RIVER RD
Ohio River
Sand Run
Garrison Cr
237
Elijahs Cr
NORTH BEND RD
275
PETERSBURG RD
Woolper Cr
20
Sand Run Watershed
Sources
Property potentially with septic system
Monitoring locations
SD1 site
0
0.5
mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Sand Run watershed
Ohio R
Licking R
AEM 05 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_sand.mxd

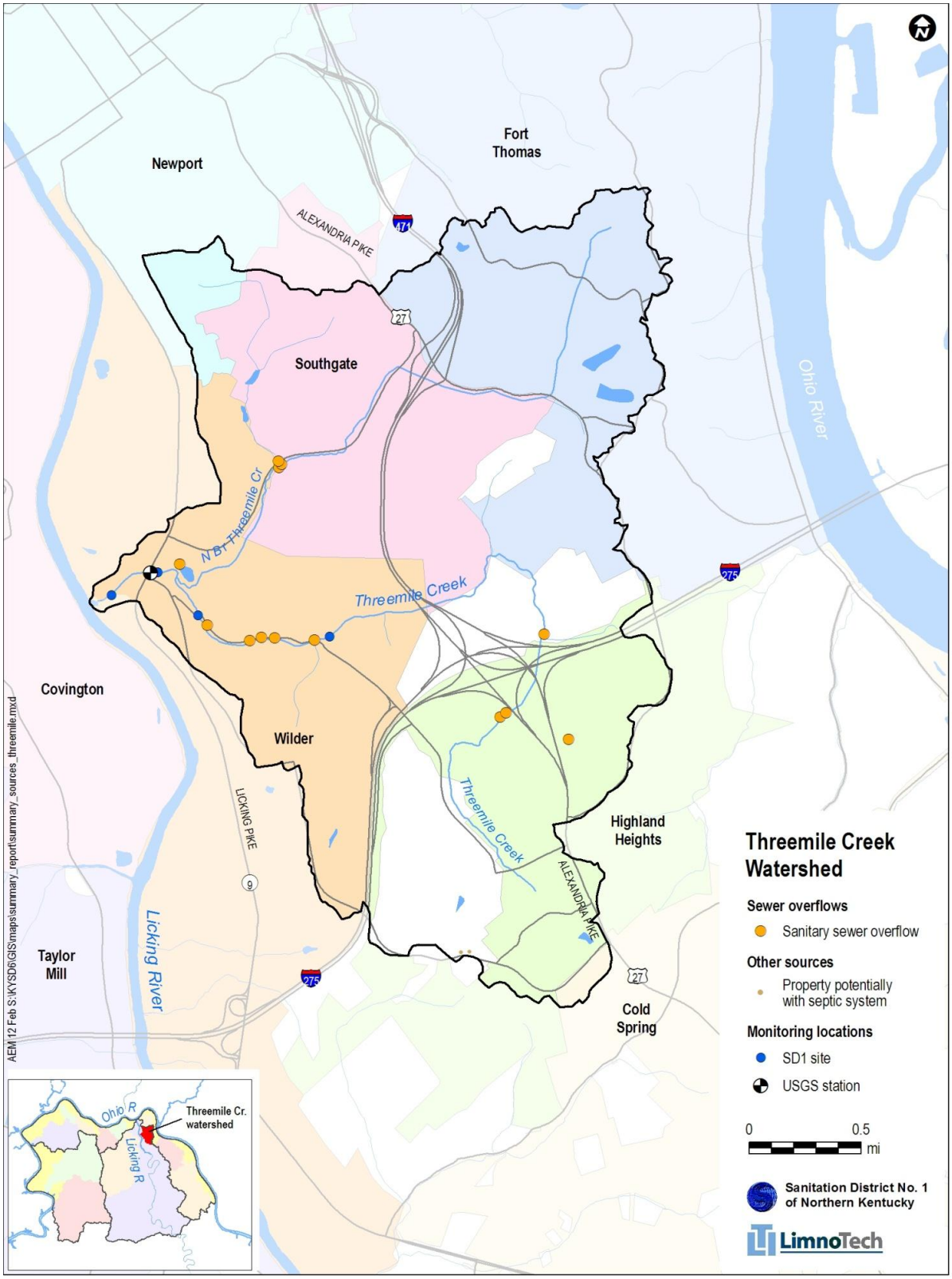
Taylor Creek Watershed Fact Sheet

Overview	Taylor Creek has the smallest and most highly developed watershed in the study area. Flooding has been a recurring problem in this watershed.
Drainage Area	4.2 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current Future  23% 25%
Sewer Overflows	9 CSOs, 7 SSOs
Other KPDES Discharges	2 permitted outfalls
State Impaired Waters	None
TMDL Status	Not applicable
Recent Assessments	
Habitat	Habitat was last assessed in 2007 at one mainstem and two tributary locations as not supporting of a diverse aquatic community.
Biological	Biological data were last collected in 2007 at one mainstem and two tributary locations indicating variable conditions ranging from very poor to fair.
Water Quality	Recent water quality data available for the mainstem and three tributaries indicate widespread occurrences of elevated levels of bacteria during wet and dry weather and violations of dissolved oxygen, copper, and zinc criteria during wet weather. Infrequent pH violations have also been observed.
WAT! Bacteria Loading Potential, By Source CSO SSO Runoff	Current Conditions, Watershed Contributions by Source 

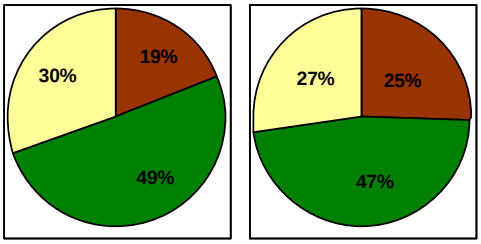
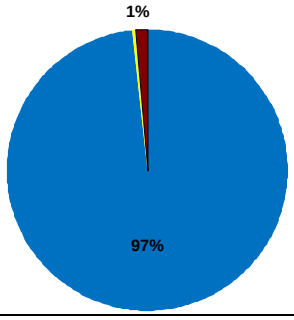

Dayton
Bellevue
Ohio River
Chadwick Br
Covert Run
Taylor Cr
MEMORIAL PKWY
Woodlawn Cr
Woodlawn
Taylor Cr
Newport Reservoir
Fort Thomas
Newport
GRAND AVE
ALEXANDRIA PIKE
Southgate
Licking River
Taylor Creek Watershed
0
0.5
mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
Sewer overflows
Combined sewer overflow
Sanitary sewer overflow
Other sources
KPDES discharge
Monitoring locations
SD1 site
USGS station
Taylor Creek watershed
Ohio R
Licking R
AEM 11 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_taylor.mxd

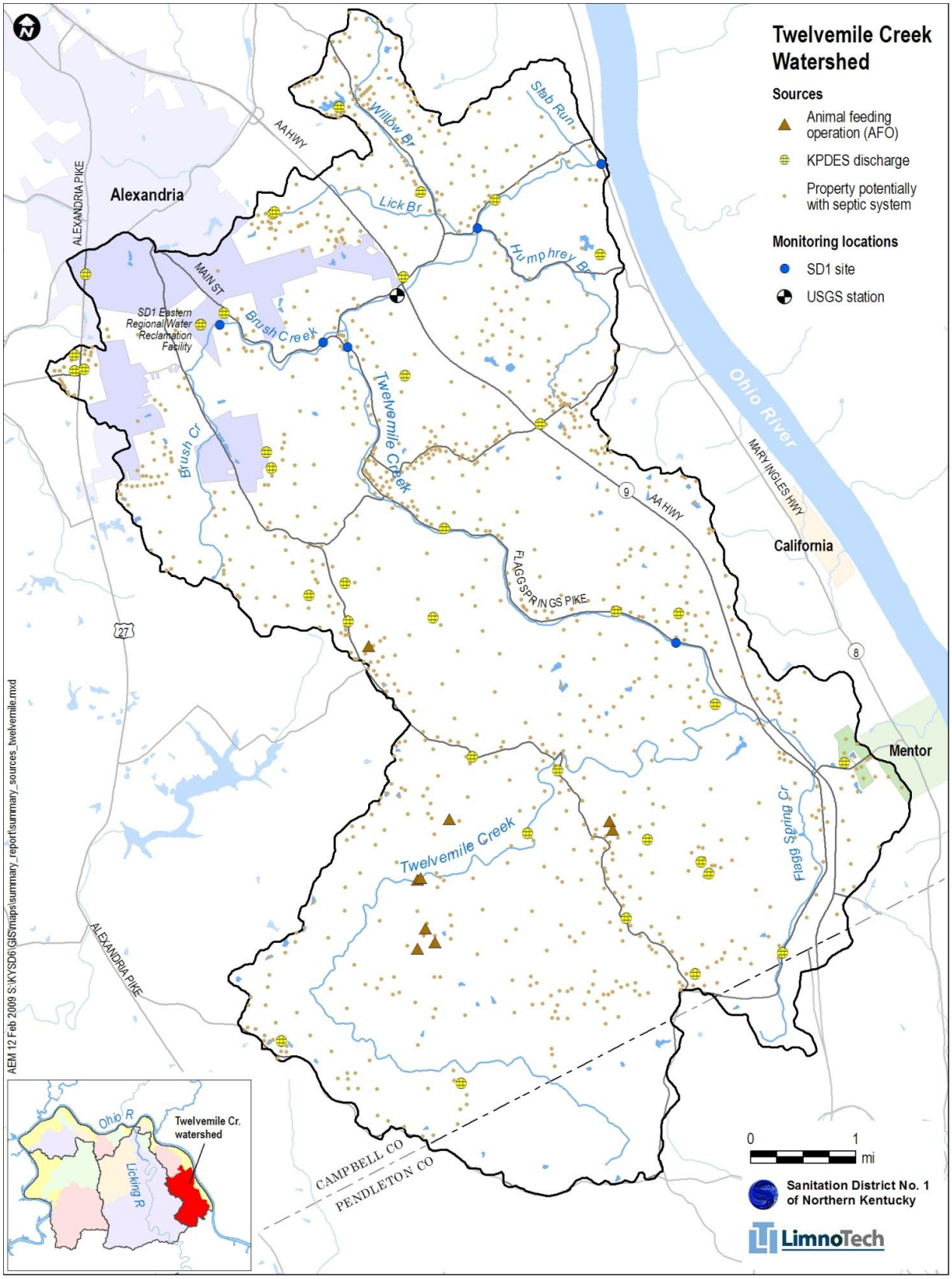
Threemile Creek Watershed Fact Sheet

Overview	Threemile Creek drains a small, highly developed watershed that is a tributary to the Licking River. The watershed is traversed by two major highways. Streambank erosion has been observed at several locations in this watershed.
Drainage Area	5.9 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current / Future  17% 19%
Sewer Overflows	13 SSOs
Other KPDES Discharges	None
State Impaired Waters	4.6 miles of Threemile Creek are identified as impaired due to nutrients, organic enrichment and fecal coliform bacteria.
TMDL Status	KDOW completed data collection in 2005, and may collect additional sediment data, if needed. Once data collection is complete, KDOW plans to develop the sediment TMDLs. TMDLs for nutrients and organic enrichment will not be initiated until after nutrient criteria are promulgated by the State.
Recent Assessments	
Habitat	Habitat assessed in 2004 in the mainstem and two tributaries indicates these locations are not supporting of a diverse aquatic community.
Biological	Biological data collected in 2004 in the mainstem and two tributaries indicate poor conditions.
Water Quality	Recent water quality data indicate elevated levels of bacteria in the mainstem and a tributary during dry weather conditions and in the mainstem during wet weather.
WAT! Bacteria Loading Potential, By Source SSO Runoff	Current Conditions, Watershed Contributions by Source 

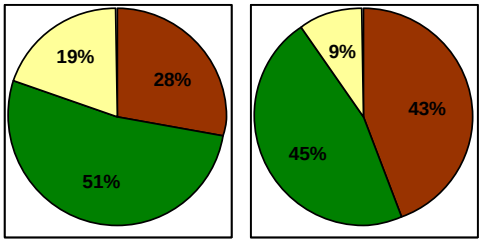
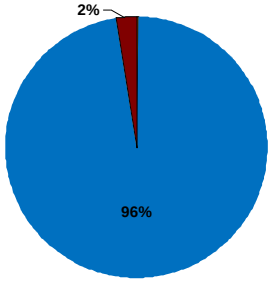

Newport
Fort Thomas
ALEXANDRIA PIKE
471
27
Southgate
Ohio River
NBT Threemile Cr
Threemile Creek
275
Covington
Wilder
LICKING PIKE
9
Threemile Creek
Highland Heights
ALEXANDRIA PIKE
Licking River
Taylor Mill
275
27
Cold Spring
AEM 12 Feb S:\KYSD6\GIS\maps\summary_report\summary_sources_threemile.mxd
Ohio R
Licking R
Threemile Cr. watershed
Threemile Creek Watershed
Sewer overflows
Sanitary sewer overflow
Other sources
Property potentially with septic system
Monitoring locations
SD1 site
USGS station
0
0.5
mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech

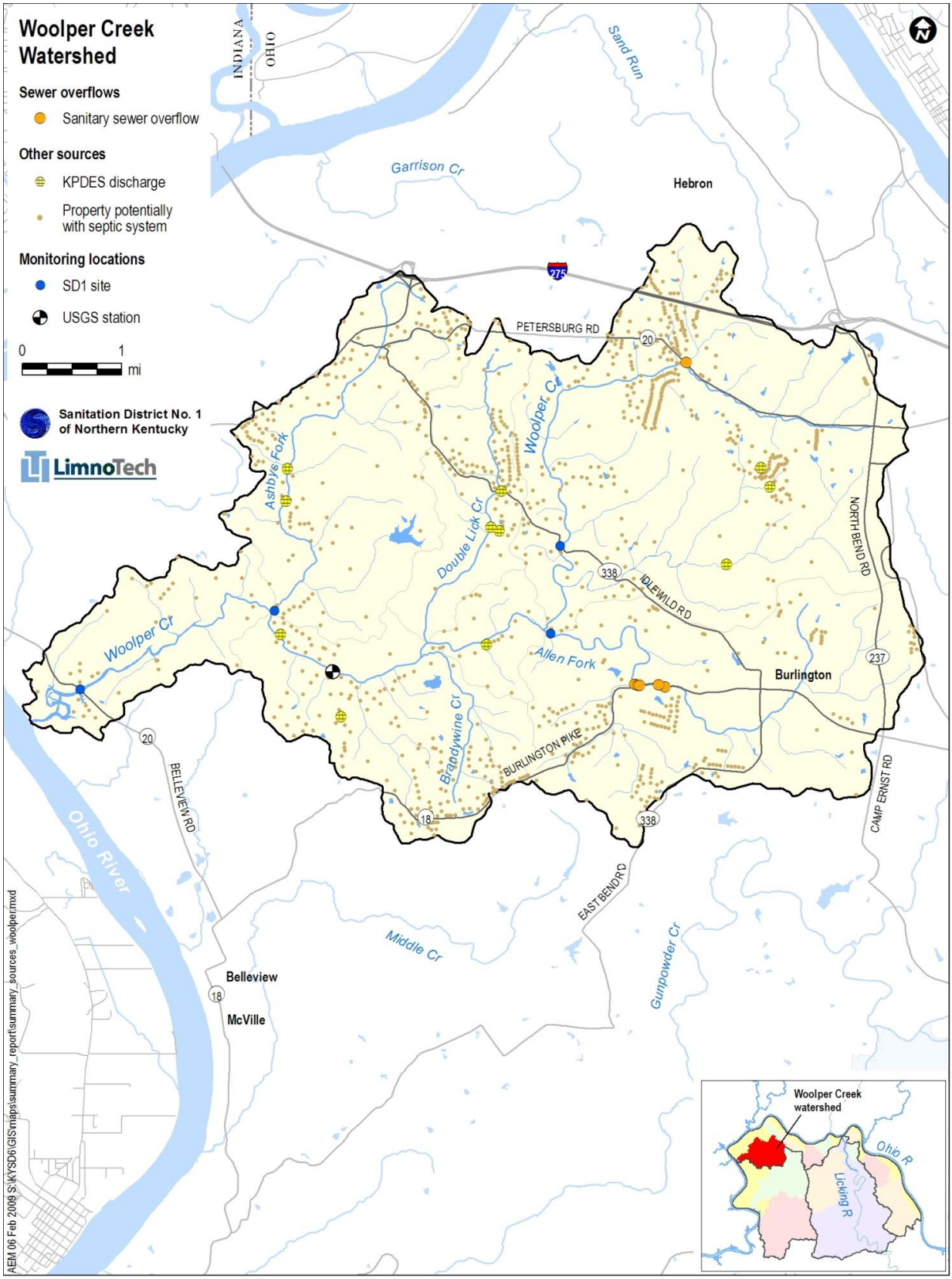
Twelvemile Creek Watershed Fact Sheet

Overview	The Twelvemile Creek watershed is primarily rural and has a higher concentration of livestock than other study area watersheds. Significant algal growth has been observed near the mouth of this creek in the past. SD1's Eastern Regional Water Reclamation Facility was recently activated in this watershed, replacing the older Alexandria Wastewater Treatment Plant.
Drainage Area	46.1 square miles
Special Stream Designations	None
Aquatic-dependent State or Federally Threatened or Endangered Species	None
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current / Future  3% 4%
Sewer Overflows	None
Other KPDES Discharges	38 permitted outfalls
State Impaired Waters	1.6 miles of Brush Creek are identified as impaired due to fecal coliform.
TMDL Status	TMDL development has not yet been initiated.
Recent Assessments	
Habitat	Habitat was last assessed in 2007 as ranging from partially supporting (at all mainstem locations) to not supporting (at two tributary sites) of a diverse aquatic community.
Biological	Biological data were last collected in 2007 on the mainstem and one tributary and indicate highly variable conditions ranging from poor to good.
Water Quality	Recent water quality data reveal frequent instances of elevated levels of bacteria in a tributary during dry and wet weather conditions, and in the mainstem during wet weather.
WAT! Bacteria Loading Potential, By Source Runoff Other KPDES dischargers Septic	Current Conditions, Watershed Contributions by Source 


Twelvemile Creek Watershed
Sources
Animal feeding operation (AFO)
KPDES discharge
Property potentially with septic system
Monitoring locations
SD1 site
USGS station
Alexandria
California
Mentor
Ohio River
Twelvemile Creek
Brush Creek
Brush Cr
Lick Br
Willow Br
Slab Run
Humphrey Br
Flagg Spring Cr
SD1 Eastern Regional Water Reclamation Facility
AA HWY
MAIN ST
ALEXANDRIA PIKE
FLAGG SPRINGS PIKE
MARYINGLES HWY
CAMPBELL CO
PENDLETON CO
Ohio R
Licking R
Twelvemile Cr. watershed
0
1
mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
AEM 12 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_twelvemile.mxd

Woolper Creek Watershed Fact Sheet

Overview	The Woolper Creek watershed is predominantly forested, with development currently concentrated near the headwaters of Woolper Creek and in the Allen Fork subwatershed. Problems with flooding have been reported in these areas. Portions of this watershed are developing rapidly, and the headwaters are predicted to become highly developed in the future.
Drainage Area	33 square miles
Special Stream Designations	Double Lick Creek is an exceptional water and reference reach stream.
Aquatic-dependent State or Federally Threatened or Endangered Species	1 plant (running buffalo clover)
Dominant Land Cover *(To simplify presentation, barren and water categories are excluded)* Developed Forest/shrub Agriculture Percent Impervious Area	Current / Future  5% 9%
Sewer Overflows	6 SSOs
Other KPDES Discharges	11 permitted outfalls
State Impaired Waters	Woolper Creek: Two segments (6.5 miles total) are identified as impaired due to fecal coliform. One 2.1 mile segment is also identified as impaired due to total suspended solids, nutrients, and organic enrichment. Allen Fork: One segment (2.6 miles) is identified as impaired due to sedimentation/siltation and nutrients/eutrophication.
TMDL Status	TMDLs are planned for Woolper Creek. KDOW has completed nutrient, organic enrichment and total suspended solids data collection, and may collect additional sediment data, if needed. Once data collection is complete, KDOW plans to develop the sediment TMDLs. TMDLs for nutrients and organic enrichment will not be initiated until after nutrient criteria are promulgated by the State.
Recent Assessments	
Habitat	Habitat was last assessed in 2004 on the mainstem and several tributaries as predominantly not supporting of a diverse aquatic community. Habitat in two of the tributaries was partially supporting and supporting but threatened.
Biological	Biological data were last collected in 2004 on the mainstem and several tributaries indicating predominantly poor conditions, with one tributary rated as good.
Water Quality	Recent water quality data from the mainstem and two tributaries revealed generally good water quality.
WAT! Bacteria Loading Potential, By Source SSO Runoff Septic	Current Conditions, Watershed Contributions by Source 


Woolper Creek Watershed
Sewer overflows
Sanitary sewer overflow
Other sources
KPDES discharge
Property potentially with septic system
Monitoring locations
SD1 site
USGS station
0 1 mi
Sanitation District No. 1 of Northern Kentucky
LimnoTech
INDIANA
OHIO
Sand Run
Garrison Cr
Hebron
PETERSBURG RD
Woolper Cr
Ashbys Fork
Double Lick Cr
NORTH BEND RD
IDLEWILD RD
Allen Fork
Burlington
Brandywine Cr
BURLINGTON PIKE
CAMP ERNST RD
BELLEVIEW RD
Ohio River
EAST BEND RD
Middle Cr
Gunpowder Cr
Belleview
McVille
Woolper Creek watershed
Ohio R
Licking R
AEM 06 Feb 2009 S:\KYSD6\GIS\maps\summary_report\summary_sources_woolper.mxd

Appendix B. List of References

Watershed Characterization Reports (http://www.sd1.org)

LimnoTech, 2009. Banklick Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Big Bone Creek Watershed Characterization Report, January 2009

LimnoTech, 2009. Dry Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Elijahs Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Fourmile Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Gunpowder Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Licking River Watershed Characterization Report, January 2009.

LimnoTech, 2009. Ohio River East Tributaries Watershed Characterization Report, January 2009.

LimnoTech, 2009. Ohio River North Tributaries Watershed Characterization Report, January 2009.

LimnoTech, 2009. Ohio River West Tributaries Watershed Characterization Report, January 2009.

LimnoTech, 2009. Pleasant Run Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Sand Run Watershed Characterization Report, January 2009.

LimnoTech, 2009. Taylor Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Threemile Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Twelvemile Creek Watershed Characterization Report, January 2009.

LimnoTech, 2009. Woolper Creek Watershed Characterization Report, January 2009.

Watershed Assessment Tool (WAT!) Documentation

LimnoTech, 2009. Watershed Assessment Tool – WAT! Model Documentation. June 23, 2009.

Other

Ohio River Valley Water Sanitation Commission (ORSANCO), 2008. Biennial Assessment of Ohio River Water Quality Conditions for Water Years 2006 and 2007. http://www.orsanco.org/rivinfo/pubs/305b/2008/2008305b.pdf

Websites on Related Topics

Designated uses: http://www.lrc.ky.gov/kar/401/010/026.htm

Surface water standards: http://www.lrc.ky.gov/kar/401/010/031.htm

Special use waters: http://www.water.ky.gov/sw/specialwaters/

Exceptional waters: http://www.lrc.ky.gov/kar/401/010/030.htm

KPDES-permitting: http://www.water.ky.gov/permitting/wastewaterpermitting/KPDES/

State 303(d) list of impaired waters: http://www.water.ky.gov/sw/tmdl/303d.htm

Total Maximum Daily Load (TMDL) Program: http://www.water.ky.gov/sw/tmdl/

Biological monitoring:
http://www.water.ky.gov/sw/swmonitor/monitoring/biologicalmonitoring/

Appendix 2-B

Water Quality Model Calibration

Index of Memoranda

Banklick Creek Watershed Model

- Banklick Creek HSPF Model Hydrology and Water Quality Calibration Update
- Banklick Creek HSPF Model: 2010 Dry Weather Load Update and Wet-Weather Corroboration

Ohio River/Licking/Banklick Creek Water Quality Model

- Development of an EFDC Hydrodynamic Model Grid of the Ohio River, Licking River, and Banklick Creek
- Hydraulic Calibration of the EFDC Model of the Ohio River, Licking River and Banklick Creek
- Lateral Mixing Calibration of the EFDC Model of the Ohio River, Licking River and Banklick Creek
- Development of Site-Specific Bacteria Loss Rate for Use in the EFDC Model of the Ohio River, Licking River and Banklick Creek
- Water Quality Calibration and Corroboration to Fecal Coliform in the EFDC Model of the Ohio River, Licking River and Banklick Creek
- Water Quality Corroboration of Fecal Coliform Calculations in the EFDC Model of the Ohio River and Major Kentucky Tributaries

Taylor Creek Watershed Model

- Taylor Creek SWMM Model Hydrology and Water Quality Calibration.

Lower Licking River Watershed Model

- Development of an HSPF Watershed Model of the Lower Licking River watershed

Ohio River Tributary Watershed Model

- Development of an HSPF Watershed Model of the Ohio River Tributaries

WAT!

- Watershed Assessment Tool WAT! Model Documentation

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LimnoTech
Water | Environment | Scientists | Engineers

DATE: November 24, 2008

MEMORANDUM

FROM: Tim Towey

TO: Jim Gibson (SD1), Mindy Scott (SD1)

CC: Carrie Turner (LimnoTech)

SUBJECT: Banklick Creek HSPF Model Hydrology and Water Quality Calibration Update

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Overview

The Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are an important contribution for watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) long-term control plan. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

A model of the Banklick Creek watershed using the Hydrologic Simulation Program in Fortran was originally developed in 2004 as part of a federal grant to develop and apply a Watershed Assessment Protocol (WAP) in order to understand water quality problems on a watershed basis (LimnoTech, 2004). The calibration of that model was updated to incorporate a more detailed land cover analysis; to evaluate dry-weather fecal coliform loads using a larger set of monitoring results; and to calibrate wet-weather loads incorporating recent literature values of storm water fecal coliform densities, output from an updated collection system model, SD1 outfall monitoring data, and a new set of wet-weather monitoring data collected in May 2008. This memorandum describes the updates to the Banklick model and presents a comparison of modeled versus measured values for flow, dry-weather fecal coliform density, and wet-weather fecal coliform density.

Calibration Approach

The following is a summary of the approach to calibrating the Banklick HSPF model:

- Step 1: Watershed characteristics and stream configuration
  - Land use updated using analysis completed in 2007, stream configuration maintained from original WAP configuration.
- Step 2: Hydrology
  - Hydrologic characteristics largely maintained from WAP configuration. Slight changes made due to land use update and a calibration with more emphasis on reproducing measured hourly, in addition to daily and monthly, flows.
  - Observed and predicted values were compared at both USGS/SD1 gage and using level sensor data from River Mile (RM 1.2).

501 Avis Drive
Ann Arbor, MI 48108
734-332-1200
Fax: 734-332-1212
www.limno.com

- Step 3: Dry weather fecal coliform loading
    - Constrained with existing info on dry weather sources, being cognizant of lack of specific information on these sources.
    - Evaluated long term (2002-2007) dry weather densities and compliance with water quality standards (WQS) at eight sites (six in Banklick, two in major tributaries (Bullock Pen and Fowler)).
    - Update resulted in lower dry weather loads than used in recent Banklick Pilot analysis.
- Step 4: Wet weather fecal coliform loading
    - Reproduced wet weather instream densities for multiple events spanning a range of conditions (three 2003 wet weather events, 2008 May wet weather event)
        - Used CSO and SSO volumes from calibrated IC model and applied densities based on SD1 monitoring data (note: model-predicted overflow locations (e.g. model-calculated overflows at manholes that have not been field verified) will be treated as SSOs).
        - Used SD1 monitoring data to constrain fecal coliform densities
        - Used storm water literature to constrain runoff site mean densities for land covers in watershed.
    - Conducted analysis to understand model sensitivity to CSO and SSO densities and presence of unverified SD1 infrastructure overflows.
- Step 5: *E. coli* simulation
    - Tested the models ability to reproduce instream E. coli densities, by using SD1 monitoring data for CSO and SSO E. coli densities

Watershed Characteristics and Stream Configuration

The land cover from the original Banklick model was refined using a number of newly available datasets:

- Aerial photography from 2006 from the National Resource Conservation Service;
- Open space land delineation obtained in 2007 from the Ohio-Kentucky-Indiana Council of Governments;
- Building footprints provided by SD1 in 2007;
- Pavement provided by SD1 in 2007; and
- Surface waters provided by SD1 in September 2006.

Although these datasets are more recent than the primary Banklick hydrology and wet-weather calibration period (2002-2003), LimnoTech felt that the improved quality and completeness of the land cover created with this data made it preferable to the previously used land cover information. A more complete description of the development of the land cover dataset will be part of the WAT! report materials.

The channel geometry was maintained from the model version used in the WAP Application report. The geometry was based on a US Army Corps of Engineers HEC-2 model of Banklick Creek and refined using field information gathered by XCG in 2003 (LimnoTech, 2004).

Hydrology Calibration

The hydrologic calibration of the model was re-evaluated using the new land cover classifications. Also, this calibration effort placed more emphasis on reproducing the distribution of hourly flow results than the original calibration presented in the WAP application report. In addition to the hourly results, the calibration was evaluated in terms of daily and monthly flow because there is guidance available for model performance in terms of these parameters (Donigian, 2002).

The model parameter that was adjusted as part of the calibration update was the slope (SLSUR in HSPF) of both pervious and the impervious lands. Increasing the slope improves the ability of the model to reproduce peak hourly flows, reduces the "trickle" of fecal coliform loading after storm events that impacts instream dry-weather densities, and is a better reflection of conditions in the Banklick watershed. A GIS evaluation of slopes in the Banklick Creek watershed showed the average slope in pervious areas is 0.16 and the average impervious slope is 0.08. These values were incorporated into the HSPF model.

Hydrologic model performance was evaluated by comparing flows predicted by the HSPF model to the measured flows at two locations: the jointly operated USGS/SD1 gage located at Highway 1829 (RM 8.0) and at Kentucky Hwy 16 (KY16 - RM 1.2), where a level sensor was installed as part of the SD1 Watershed Assessment (XCG, 2003). The predicted flows were compared to the USGS/SD1 gage for the period from January 1, 2001 to September 30, 2003. At RM 1.2, the predicted flows were compared to level sensor data for August 2003, a month of nearly complete data.

The USGS/SD1 gage is located just downstream of the confluence of Banklick and Fowler Creeks, therefore the modeled Banklick flow from just upstream of the confluence was summed with the modeled flow in Fowler Creek in order to make the comparison to measured flow. Figure 1 and Table 1 show the distribution of modeled and measured hourly flow values at the USGS/SD1 gage for the comparison period. Table 1 also shows the distribution of values when the comparison is limited to the May 1 – October 31 recreation season. These comparisons demonstrate that the model is reproducing the overall distribution of measured values at this location.

Figure 1. Distribution of Measured and Modeled Hourly Flows at USGS/SD1 Gage.

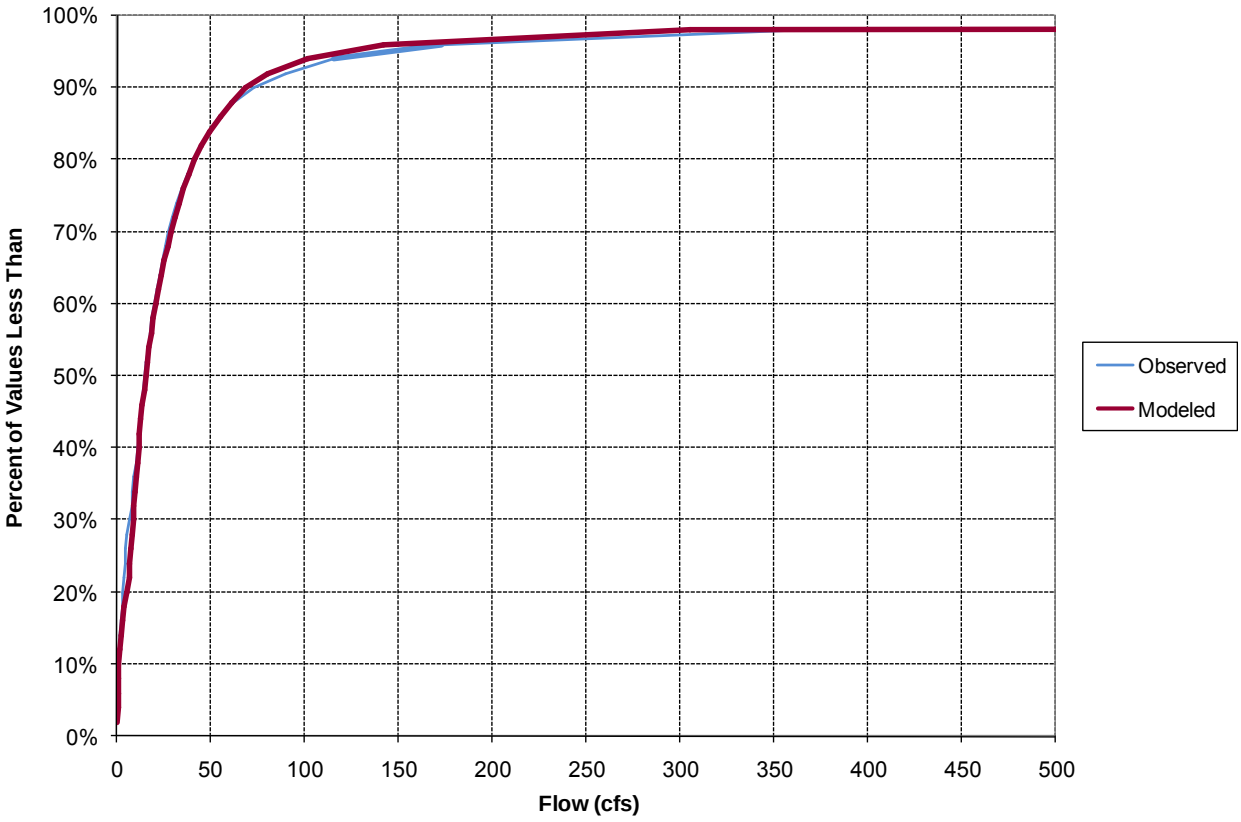


Table 1. Distribution of Measured and Modeled Hourly Flows at USGS/SD1 Gage.

	Full comparison period		Recreation season	
	Measured (cfs)	Modeled (cfs)	Measured (cfs)	Modeled (cfs)
Mean	48.2	47.2	37.3	42.2
Geometric Mean	10.9	12.5	5.1	6.8
5th %ile	0.2	0.4	0.1	0.3
25th %ile	4.4	7.1	1.7	1.7
50th %ile	14.7	15.2	6.2	8.9
75th %ile	32.9	34.3	20.3	24.6
95th %ile	137.6	117.3	106.6	100.9

In addition to hourly flows, the hydrologic calibration was also evaluated using HSPF-specific criteria suggested by Donigian (2002). He suggests using monthly or annual relative percent differences (RPDs) to evaluate how well the model is reproducing the central tendency of the data. He characterizes an RPD of <10% as "Very good." The RPD for the Banklick HSPF flow for the entire January 2002-September 2003 period is 2% and for the recreation season it is 13%.

To characterize the ability of the model to reproduce the timing of observed flow conditions, Donigian provides a range of R and R^2 values for monthly and daily flows. Figure 2 shows the criteria for model performance suggested by Donigian . Table 2 shows the performance of the Banklick HSPF model for both the full model period and using just the recreation season. For both daily and monthly flows, the Banklick model performance is "Good" for the full model period. The model performs slightly better during the recreation season when comparing monthly flow values and slightly worse when comparing daily values.

Figure 2. R and R^2 Values for the Evaluation of Model Performance from Donigian, 2002.

Table 2. R And R^2 Values for Banklick HSPF Model and Evaluation of Performance Using Donigian Criteria.

	R	R^2	Model Performance
Daily – Full model period	0.86	0.74	Good
Monthly – Full model period	0.91	0.82	Good
Daily – Recreation season	0.81	0.66	Fair
Monthly – Recreation season	0.95	0.90	Very Good

A similar evaluation was performed using the level sensor data obtained at River Mile 1.2. SD1 deployed level sensors in lower Banklick Creek at river mile 1.2 (KY16) and river mile 0.3 (KY177) during portions of 2002 and 2003 to characterize backwater influences from the Ohio River and Licking River. The primary purpose of this model-to data comparison was to evaluate the performance of the lower Banklick Creek portion of SD1's EFDC model. The dataset from August 2003 was used because this period was characterized by low flow in the Ohio River so backwater effects were limited to the meter at KY177, a wide range of flows from the upper portion of the Banklick Creek watershed, and a relatively complete dataset because both meters were operational through the first 25 days of the month. This dataset provides the best contrast between the level meters: the meter at KY16 (RM 1.2) reflects upstream flows while the meter at KY177 (RM 0.3) reflects Ohio River stage conditions. Figure 3 and Table 3 show the distribution of modeled and measured flows.

Figure 3. Distribution of Measured and Modeled Hourly Flows At KY16.

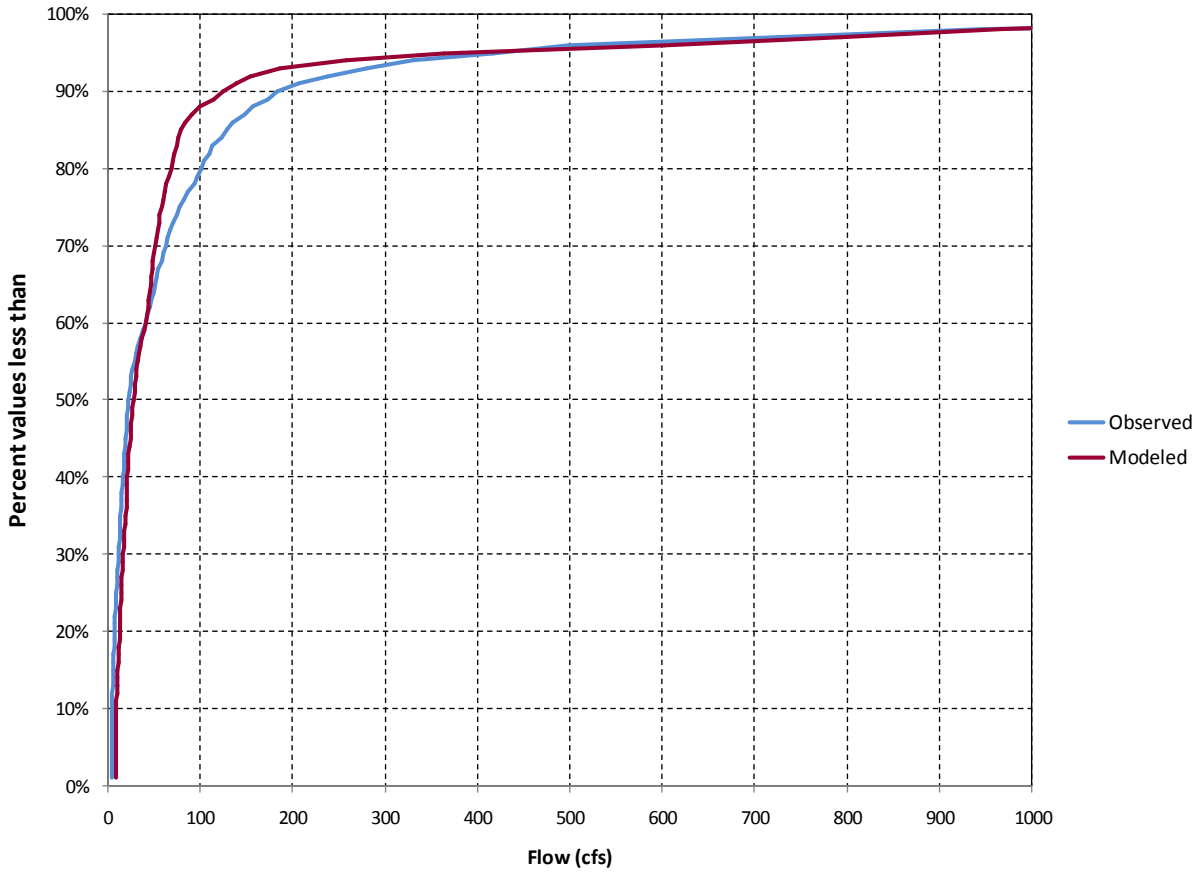


Table 3. R and R^2 Values for Banklick HSPF Model and Evaluation of Performance Using Donigian Criteria at KY16.

	Measured (cfs)	Modeled (cfs)
Mean	99.6	89.9
Geometric Mean	28.4	33.1
5th %ile	8.7	13.8
25th %ile	21.5	27.3
50th %ile	76.6	58.1
75th %ile	416.0	363.2
95th %ile	99.6	89.9

The RPD for the for the August 2003 period at RM 1.2 is -10%, and the daily R and R^2 values are 0.89 and 0.80 respectively, putting the model performance in the "Very Good" category using the Donigian criteria. The model reasonably reproduces measured values at Banklick Creek RM 1.2, downstream of its major tributaries.

Dry Weather Fecal Coliform Load Calibration

The dry-weather fecal coliform loading was determined to have a large impact on meeting water quality standards in the Banklick Pilot project. In that version of the Banklick model, dry weather loads were input as failing septic systems, KPDES permitted dischargers, and cattle in stream. Estimates were made about the location and magnitude of each of the sources, using information about land use, age of homes, and KPDES records. In an evaluation of modeled and measured instream fecal coliform densities using data from 2002-2007, it was determined that the dry-weather loads should be relocated and scaled back.

For the current version of the model, all dry-weather sources were input as a single load for any given subwatershed. A model to data comparison was used to determine the appropriate magnitude and location of the loads. An assessment of the sources contributing to the loads (e.g., septics, KPDES dischargers, cattle, wildlife) will be made outside of the model framework.

The loads were calibrated using recreation season (May 1 – October 31) geometric mean densities, percent of days complying with the single sample max criteria of 400 cfu/100 mL, and peak densities. In order to meet all of the criteria, the loads were input as oscillating loads. The oscillations varied smoothly over a period of approximately 5 days. Because small amounts of rainfall can impact instream fecal coliform densities in the model, the model to data comparison was restricted to days with only base flow (i.e., no storm flow) and having 0.01 inch or less of rainfall on that day or the day prior. Table 3 shows the numbers of measured fecal coliform densities available at eight locations (six along Banklick Creek, two in tributaries) in the 2002-2007 period that meet the dry-weather criteria.

Table 4. Location and Number of Instream Measurements used to Calibrate Dry-Weather Loads.

Stream	River Mile	Number of dry-weather samples
Banklick Creek	15.6	5
Banklick Creek	11.6	4
Banklick Creek	8.1	16
Banklick Creek	3.9	17
Banklick Creek[1]	1.2	14
Banklick Creek	0.5	17
Bullock Pen Creek	0.1	7
Fowler Creek	0.1	5

[1]One dry weather sample from River Mile 1.2 was identified as an outlier (26,000 cfu/100 mL) because of an isolated incident and was not included in the analysis.

Figures 4 through 6 show the measured and modeled recreation season geometric mean densities, single sample maximum compliance rates, and peak densities, respectively. Peak densities are compared using the maximum measured value and the 95th percentile modeled value. The maximum measured value at Banklick Creek RM 1.2 was 26,000 cfu/100 mL, and was considered an outlier; the value is not included in the analysis. Additionally, because only four measurements were available at RM 11.6, less consideration was given to meeting the seasonal geomean and WQS compliance values at that location.

Figure 4. Modeled and Measured Dry-Weather Recreation Season Geometric Mean Fecal Coliform Densities.

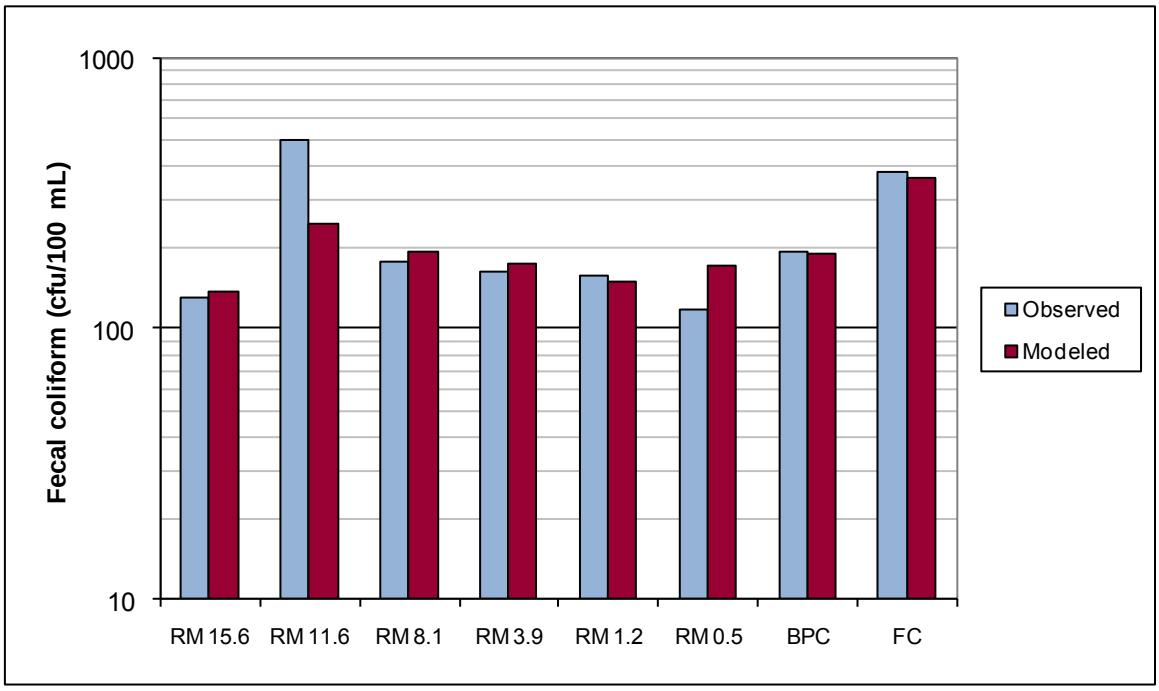


Figure 5. Modeled and Measured Dry-Weather Compliance with Single-Sample Maximum Criterion (400 cfu/100 ml).

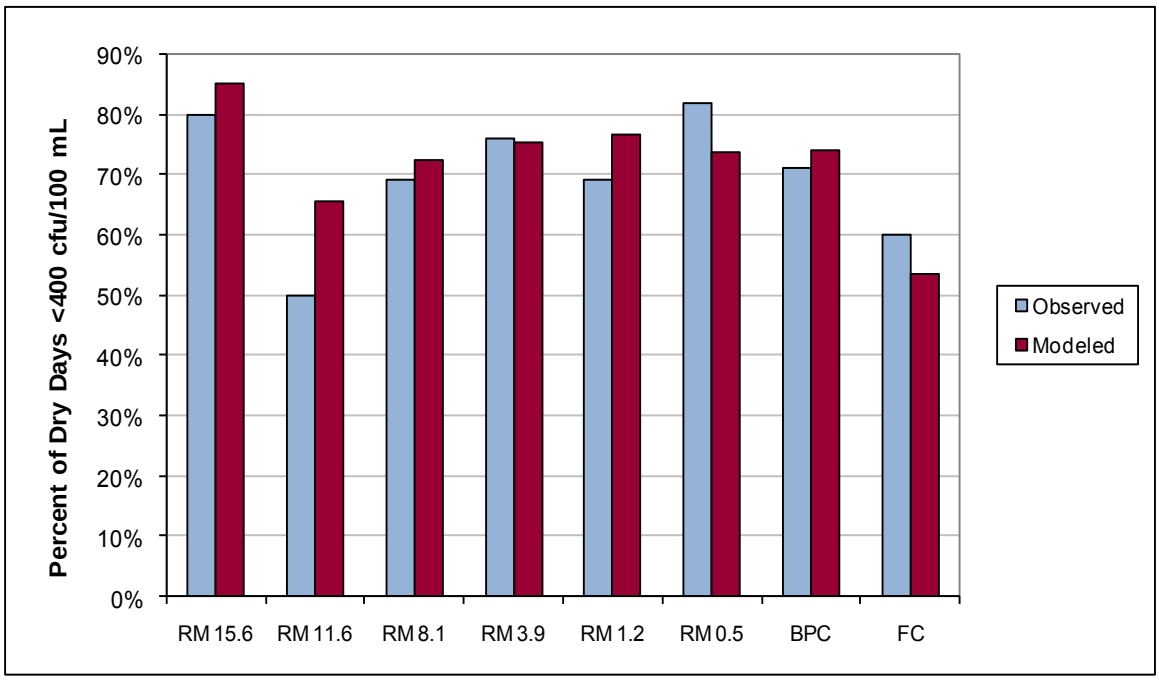
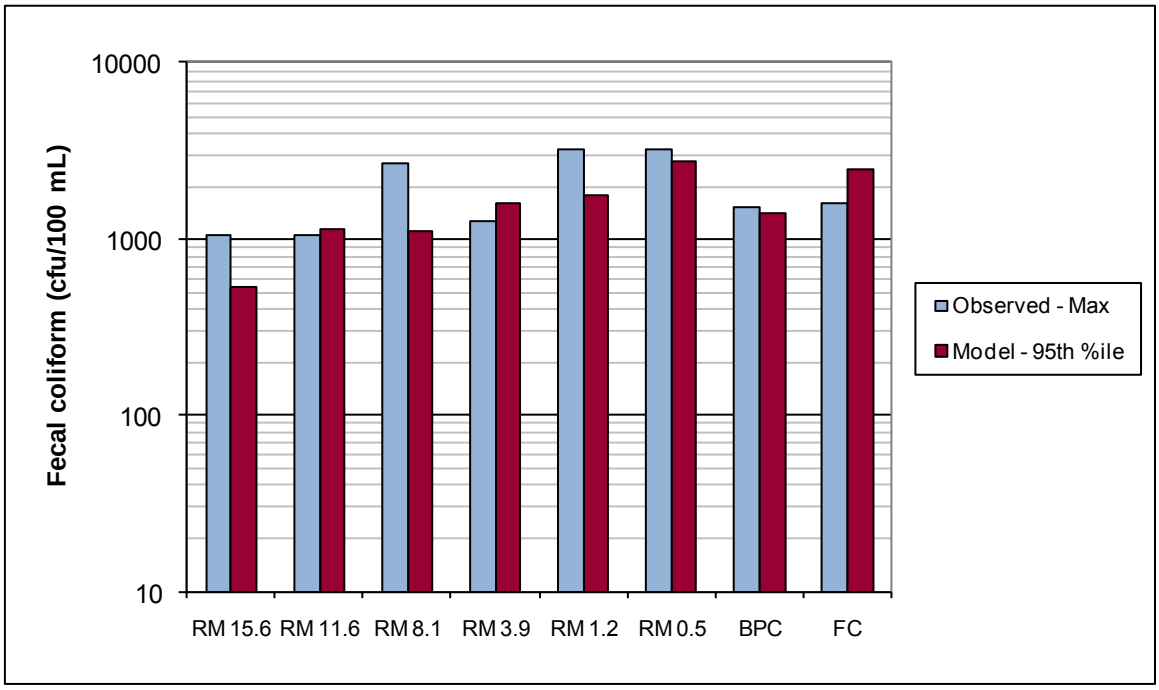


Figure 6. Modeled and Measured Peak Dry-Weather Fecal Coliform Densities.



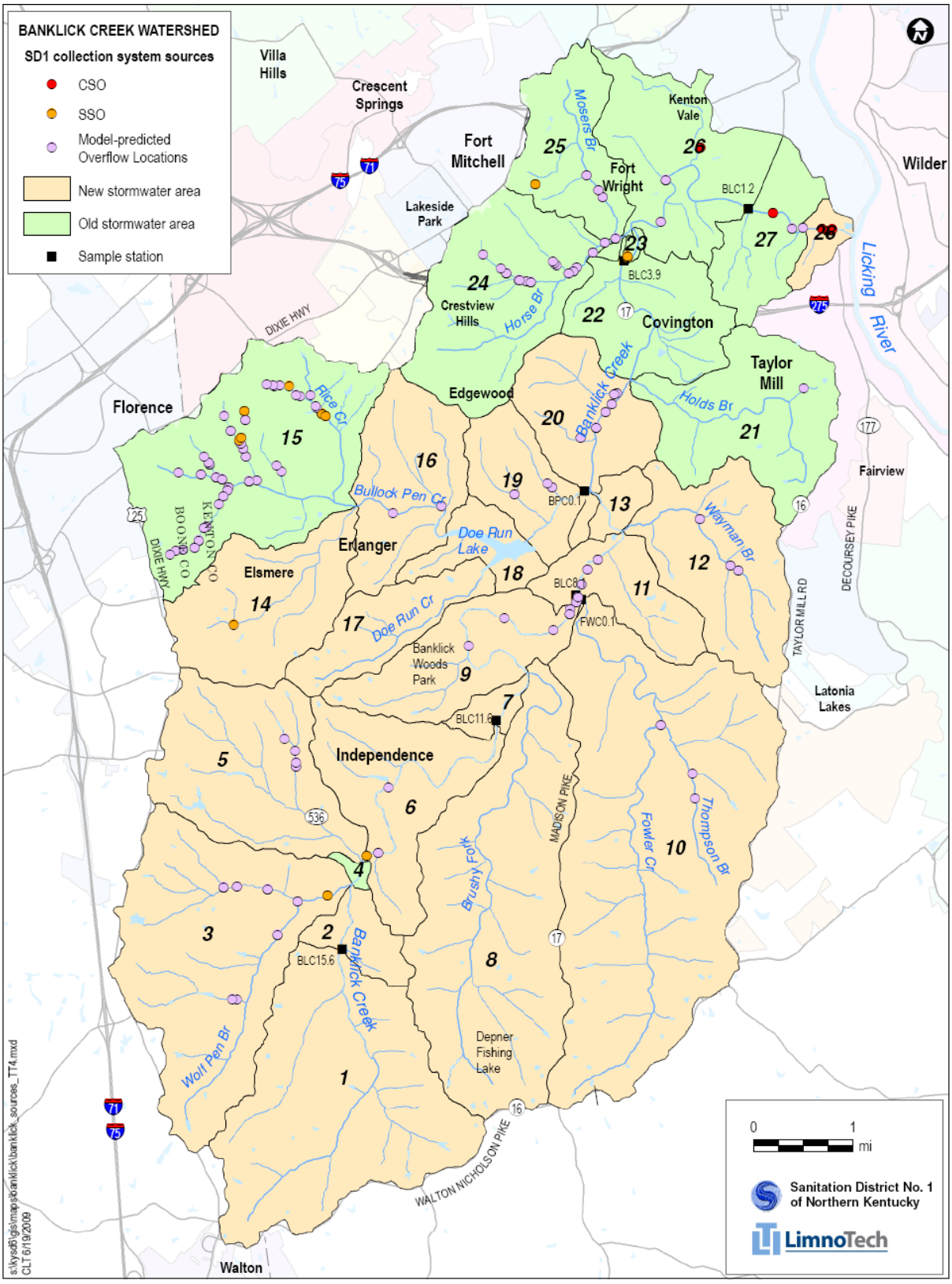
The charts show that the model reasonably reproduces both the central tendency and the elevated densities of instream dry-weather bacteria levels.

Wet Weather Fecal Coliform Calibration

Wet weather sources of fecal coliform bacteria include both runoff sources and sources from the SD1 collection system. In HSPF, the runoff source load is calculated based on a build-up and wash-off routine for each land use/land cover (LULC) type specified in the model. The SD1 infrastructure sources are input to the watershed model based on output from the collection system models. These sources include CSOs, SSOs, and model-predicted overflow locations. The loads from these sources are calculated by assigning a fecal coliform density to modeled overflows. SD1 outfall monitoring data was used to determine the appropriate density for these sources. For the model calibration, the geomean densities of measured fecal coliform density in CSOs (682,000 cfu/100 mL) and SSOs (1,870,000 cfu/100 mL) were used. Because the model-predicted overflow locations occur in the sanitary sewer areas, they were assigned the SSO density. Figure 7 shows the locations of the SD1 infrastructure sources in the Banklick Creek watershed.

Monitoring data was also used to constrain the modeled fecal coliform runoff density from developed areas. Monitoring of SD1 storm water outfalls suggested that fecal coliform densities vary based on the age of the developed area. Monitored storm water outfalls were roughly divided into two categories: those in older developments and those in newer developments. The geomean fecal coliform density from outfalls in older areas was 86,500 cfu/100 mL, while in the newer areas, the geomean density was 14,200 cfu/100 mL. This division in the storm water data was consistent with the instream data for Banklick Creek. An increase in fecal coliform densities was observed in downstream Banklick Creek in the vicinity of the older developed areas that other watershed and infrastructure sources did not fully account for. Therefore, the HSPF RCHRES (subwatersheds) were divided into old and new categories and the build-up wash off parameters for developed areas were adjusted to approximate the monitored densities.

Figure 7. Map of the Banklick Creek Watershed, Including SD1 Infrastructure Sources, Old and New Developed Areas, and Sampling Stations.



Data from the 2000 US Census was used to designate each HSPF RCHRES as "old" or "new." The census provides household construction data for individual block-groups. There are a total of 175 block groups that intersect the Banklick model domain. For each block-group, the number of households built in each decade is available. An area weighted average of households built before 1980 and after 1980 was calculated for each HSPF RCHRES. The RCHRES with a minimum of 25% developed area and at least 50% of dwellings built before 1980 were classified as old. The remaining RCHRES were classified as new. The 25% developed area and 50% pre-1980 figures correspond closely with the median values for Banklick Creek. Figure 7 shows a map of the HSPF RCHRES and their storm water age classification.

The geomean fecal coliform densities for both the old and new storm water areas are significantly higher than the medians found in the National Stormwater Quality Database (NSQD, 2005) for developed areas. In order to achieve flow-weighted averages that reasonably matched the SD1 monitoring data, the build-up parameters for each developed LULC were scaled up from parameters that produce the median densities found in the NSQD. The parameters were scaled by approximately a factor of five to match the new development storm water densities and a factor of about 30 to meet the old development storm water densities. Having constrained the infrastructure loads and the storm water loads, the build-up and wash-off parameters for the remaining LULC categories were then adjusted to reasonably reproduce the instream fecal coliform densities while staying within density ranges seen in the literature for the various LULCs.

Table 5 presents the flow-weighted site mean densities from each HSPF LULC category. It should be noted that the majority of the flow from developed areas comes from impervious lands which have relatively lower fecal coliform densities. This is why the pervious developed land categories have site mean densities substantially higher than the targeted densities described above.

Table 5. Site Mean Fecal Coliform Densities from Calibrated Banklick HSPF Model.

HSPF LULC category	Description	Flow-weighted site mean density (cfu/100 mL)	Literature density (cfu/100 mL)	Source
PER-1	New Storm: HDD - Comm/Indus	21,773	4,300	NSQD, 2005
PER-2	New Storm: HDD - Res	53,725	11,000	NSQD, 2005
PER-3	New Storm: MDD - Comm/Indus	25,213	5,000	NSQD, 2005
PER-4	New Storm: MDD - Res	42,489	8,300	NSQD, 2005
PER-5	New Storm: LDD - Comm/Indus	25,213	5,000	NSQD, 2005
PER-6	New Storm: LDD - Res	42,489	8,300	NSQD, 2005
PER-7	Developed Open Space	2,747	2,600	NSQD, 2005
PER-8	Cropland	65,040	67,000	CWP, 1999
PER-9	Forest	769	100-1,000	CWP, 1999
PER-10	Pasture/Grassland	91,628	120-1.3e6	CWP, 1999
PER-11	Barren	1,116		
PER-12	Failing septic	1.1E+06	10,000-1e8	CWP, 1999
PER-13	Old storm: HDD - Comm/Indus	133,928	4,300	NSQD, 2005
PER-14	Old storm: HDD - Res	341,805	11,000	NSQD, 2005
PER-15	Old storm: MDD - Comm/Indus	153,229	5,000	NSQD, 2005
PER-16	Old storm: MDD - Res	257,329	8,300	NSQD, 2005
PER-17	Old storm: LDD - Comm/Indus	153,229	5,000	NSQD, 2005
PER-18	Old storm: LDD - Res	257,329	8,300	NSQD, 2005
IMP-1	New storm: Impervious	5,199	1,100 (730 - 4,300)	NSQD, 2005
IMP-2	Old storm: Impervious	34,495	1,100 (730 - 4,300)	NSQD, 2005

PER – pervious land category; IMP – impervious land category; HDD- high density development; MDD – medium density development; LDD- low density development; Comm/Ind – Commercial/Industrial; Res – residential

The model was calibrated by comparing predicted and measured instream fecal coliform densities at six locations on Banklick Creek during four separate storm events – three events in the summer of 2003 and one event in May 2008. A seventh location, BLC 0.5, was also sampled during all of the wet-weather events. However this location can be impacted by backwaters from the Licking and Ohio Rivers, which are not included in the HSPF model. This location was included in the EFDC model domain. Additionally, BLC 1.2 was sampled in the May 2008 event; however, it is not broken out in the model to data comparisons, because it includes relatively few samples. However, figures and statistics that include all Banklick Locations do include this location. Additionally, a WinModel snapshot comparison of model to data at this location for the May 2008 event is available in Attachment A.

During each event, multiple samples were collected at each location. During the 2003 events, sample were approximately collected at event initiation, hour 3, hour 6, hour 9, hour 12, and hour 24. During the May 2008 event, sample collection distributed over a longer period. Samples were collected at approximately event initiation, hour 8, hour 16, hour 24, hour 36, hour 48, and hour 72.

Table 6 presents a statistical summary of the model to data comparison for the calibrated Banklick model for samples collected during wet-weather events at each location.. The table shows the observed and modeled geomeans, the observed and modeled compliance with the single sample maximum criteria of

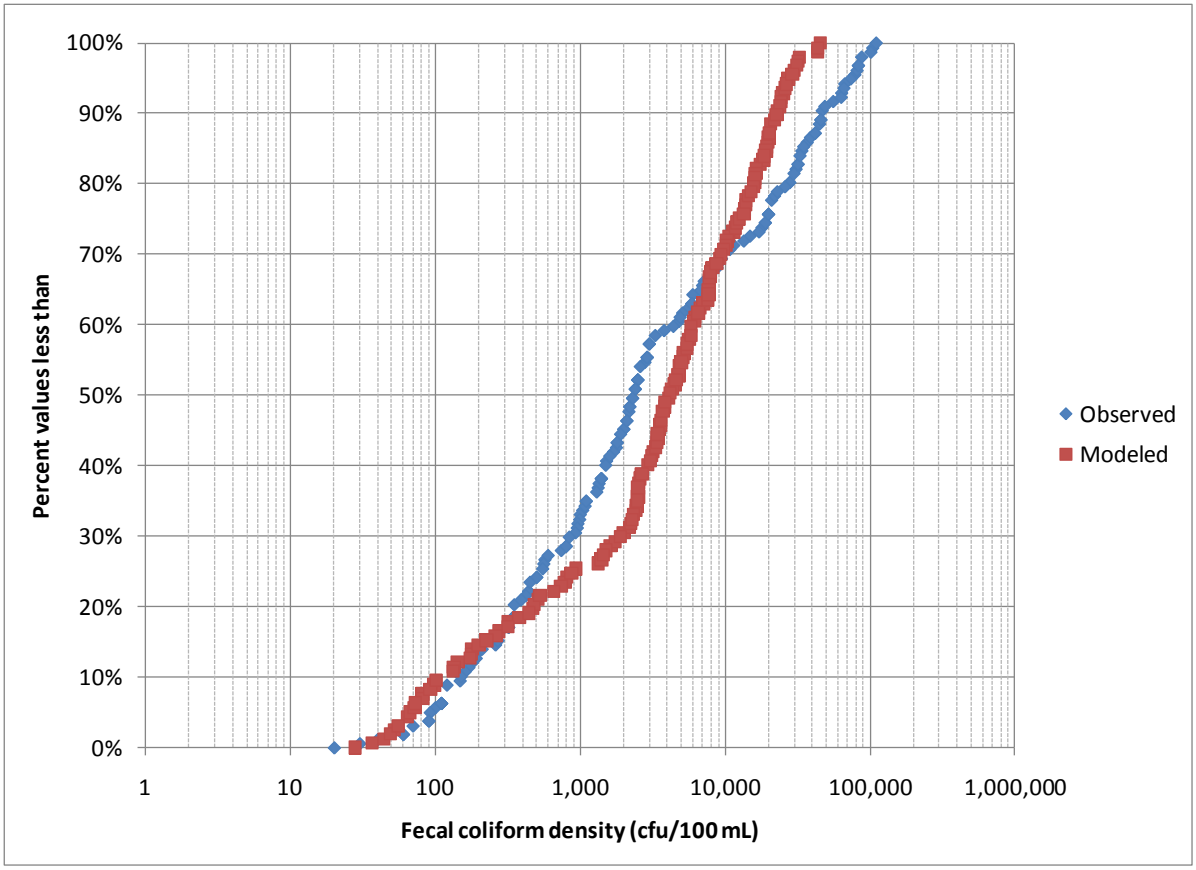
400 cfu/100 mL, and the mean relative and absolute percent differences of the natural-logarithm transformed modeled and observed values. Comparing observed and modeled geomeans allows for an evaluation of how well the model is reproducing the central tendency of the measured values. The observed and modeled geomeans are good matches in the main stem of Banklick Creek, however the model under-predicts densities in Fowler Creek and over-predicts densities in Bullock Pen Creek. Across all locations, the model reasonably reproduces the central tendency of the data. Additionally, the model produces compliance rates with the single-sample maximum similar to observed values. The mean RPD of the natural log transformed values is less than 10% at all locations except Bullock Pen Creek and the mean absolute percent difference is less than 30% at all locations.

Table 6. Summary Statistics Comparing Predicted and Instream Fecal Coliform Measurements for the Calibrated Model.

HSPF RCHRES outlet	Location	n	Observed geomean (cfu/100 mL)	Model geomean (cfu/100 mL)	% Observed compliance with SS Max	% Modeled compliance with SS Max	Mean relative % difference of ln values	Mean absolute % difference of ln values
1	BLC 15.6	25	2689	1945	20%	32%	0.6%	24.4%
6	BLC 11.6	25	2852	3089	24%	16%	5.9%	22.9%
9	BLC 8.1	25	2767	2472	24%	16%	5.0%	21.9%
22	BLC 3.9	25	4499	4501	15%	15%	5.1%	20.4%
10	Fowler Creek	25	3004	2151	19%	19%	0.4%	19.0%
19	Bullock Pen	24	1730	3395	25%	17%	14.4%	29.4%
All Locations		183	3314	3207	20%	18%	4.8%	23.1%

Figure 8 is the cumulative frequency distribution plot of the observed data at all sampling locations and the corresponding model outputs from the hour closest to when the samples were collected. Cumulative frequency distribution plots show the percent of values within the dataset that are less than each observed or simulated density. They are useful for comparing the range of observed and simulated densities and the relative frequencies at which the densities occur.

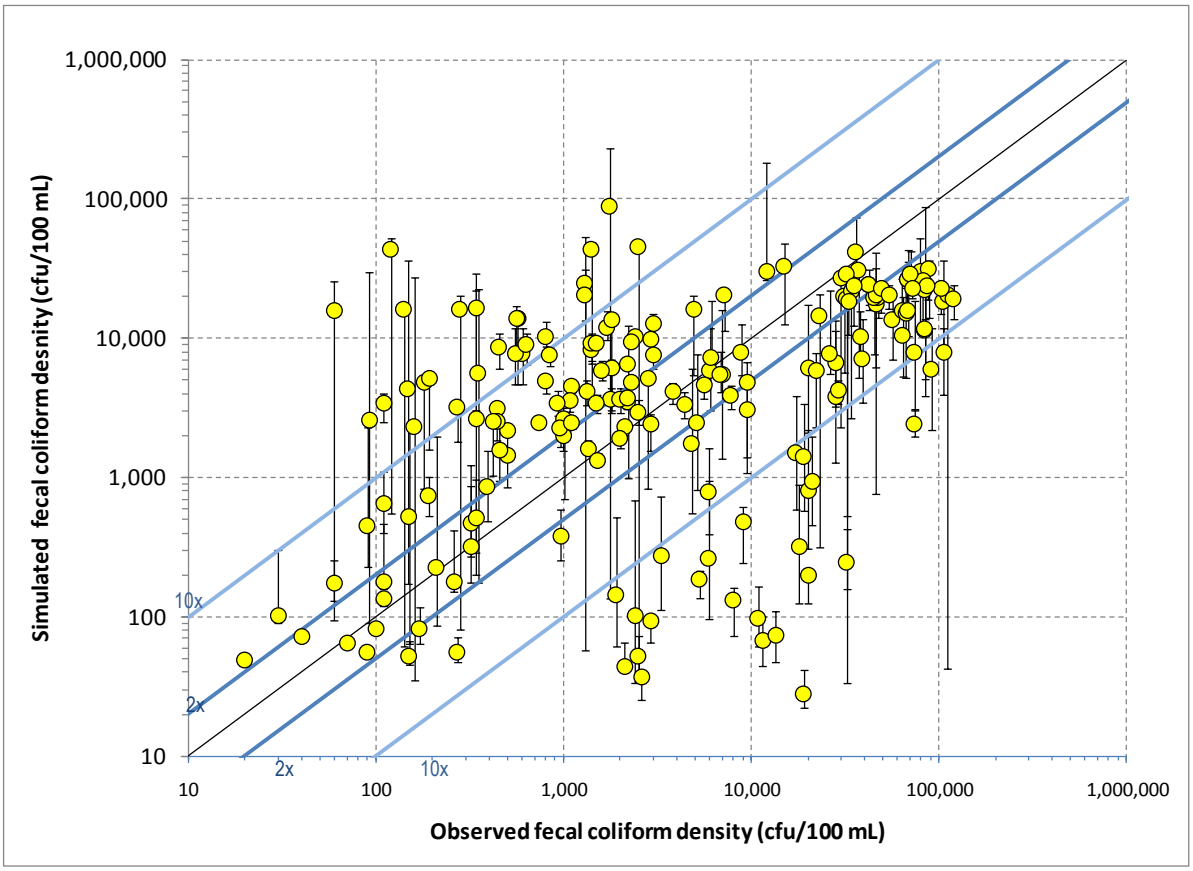
Figure 8. Cumulative Frequency Distribution of Modeled and Measured Wet-Weather Fecal Coliform Densities.



The cumulative frequency distribution plots of the model and the data match fairly well, indicating that the model is successfully reproducing the range of observed densities at the appropriate frequency. Cumulative frequency distribution plots at each location where a minimum of 20 samples were analyzed are included in Attachment A. These plots show the model is successfully reproducing the range of observed data at each location.

Figure 9 is a scatter plot or (one-to-one plot) of modeled and measured fecal coliform densities. Scatter Plots of model predictions versus data predictions show how well the model is reproducing the data for each measured value. Two sets of lines on the one-to-one plots form limits for acceptable model-to-date comparisons. Points on the scatter plot that fall within the lines labeled '2x' are considered excellent predictions because they roughly correspond to the sampling and analytical accuracy limits of the bacteria count. The wider band between the '10x' lines is a more liberal criteria for the model predictions; predictions that fall within these bands are accurate to one order of magnitude of the measured bacteria densities. The error bars around each point indicate the minimum and maximum modeled values for the three hours before and three hours after each sample collection time, showing the variability of fecal coliform densities over a short time period during wet-weather events.

Figure 9. Scatter Plot of Modeled and Measured Wet-Weather Fecal Coliform Densities.



The scatter plot shows that the majority of the modeled values are within an order of magnitude of observed values. In the cases in which the model over-predicts the observed values by more than an order of magnitude, the error bars show that the model produces values that better match the observed values within a few hour time-window. The cases where the model under-predicts the observed the observed values by more than an order of magnitude almost all occur 24-hours after the event initiation for two storm event. This could be related to the timing of the rainfall at different locations in the watershed.

Scatter plots for each location with at least 10 measured values, as well as snapshots of model-to-data comparisons from the WinModel framework for the May 2008 event, are available in Attachment A.

Model Wet Weather Sensitivity Analysis

Selection of model inputs can have a significant influence on water quality model predictions. Each of the model inputs has a degree of uncertainty associated with it. Two model features of particular interest are the densities associated with the infrastructure sources, and the impact of the overflows that have not been verified (model-predicted overflows).

Sensitivity to CSO and SSO Densities

To assess the sensitivity of the model results to the CSO and SSO densities, the model was run using the arithmetic means from the SD1 outfall monitoring program: 1,110,000 cfu/100 mL and 3,263,000 cfu/100 mL for CSOs and SSOs respectively. These values are over 50% greater than the geometric mean values

used for the calibration. The same set of summary statistics and charts as were presented for the model calibration are shown for this simulation in Table 7 and Figures 10 and 11 below.

Table 7. Summary Statistics Comparing Predicted and Instream Fecal Coliform Measurements for Model with the Collection System Source Densities Set to the Arithmetic Averages.

HSPF RCHRES	Location	n	Observed geomean (cfu/100 mL)	Model geomean (cfu/100 mL)	% Observed compliance with SS Max	% Modeled compliance with SS Max	Mean relative % difference of ln values	Mean absolute % difference of ln values
1	BLC 15.6	25	2689	1945	20%	32%	0.6%	24.4%
6	BLC 11.6	25	2852	3430	24%	16%	7.2%	23.5%
9	BLC 8.1	25	2767	2700	24%	16%	6.2%	22.6%
22	BLC 3.9	25	4499	4853	15%	15%	6.2%	21.0%
10	Fowler Creek	25	3004	2151	19%	19%	0.4%	19.0%
19	Bullock Pen	24	1730	3541	25%	17%	14.9%	29.5%
All RCHs		158	2668	2942	22%	19%	6.4%	23.4%

Figure 10. Cumulative Frequency Distribution of Modeled and Measured Wet-Weather Fecal Coliform Densities for Model with the Collection System Source Densities Set to the Arithmetic Averages.

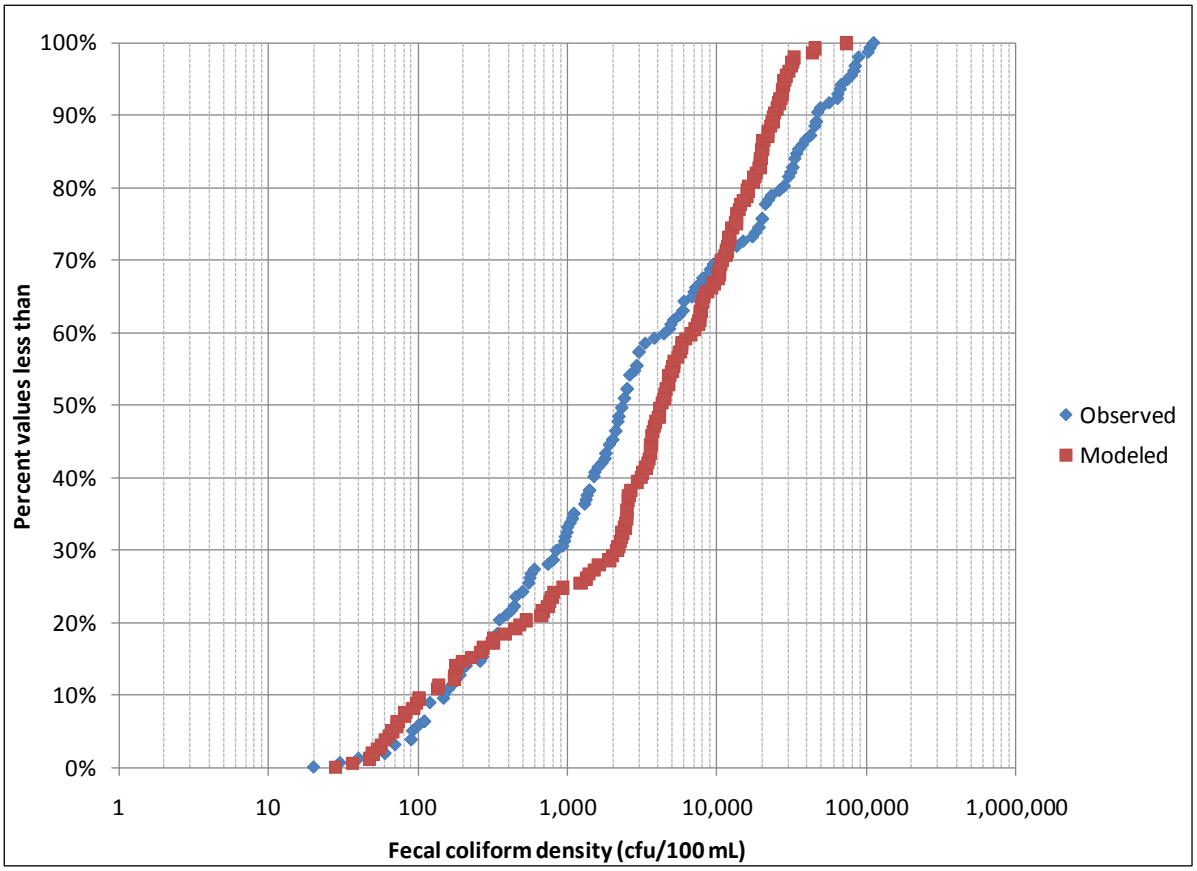
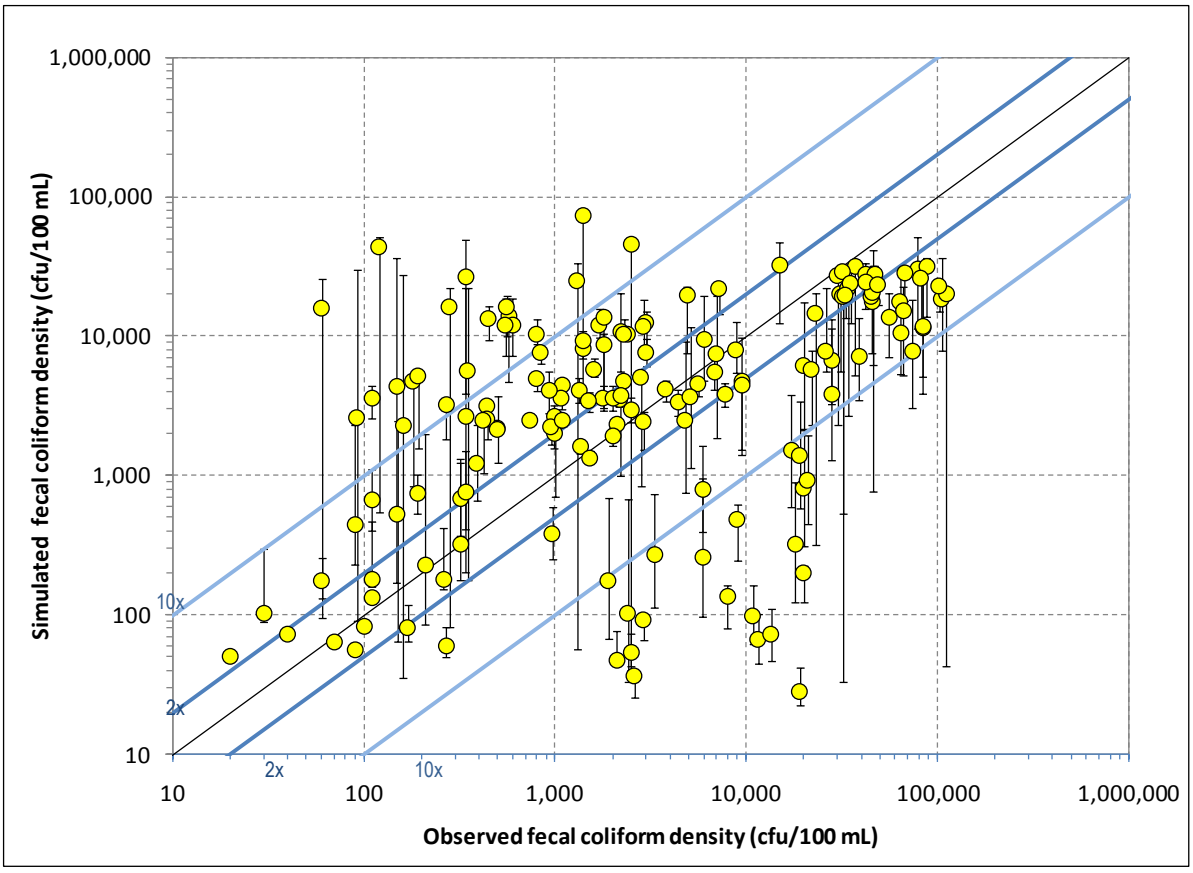


Figure 11. Scatter Plot of Modeled and Measured Wet-Weather Fecal Coliform Densities for Model with Collection System Densities Set to Arithmetic Averages.



The results show that the model still reasonably reproduces the measured data using higher CSO and SSO densities. While the modeled geomean is higher for the locations impacted by infrastructure sources (all but BLC 15.6), the use of the higher value does not dramatically affect the quality of the calibration. In fact, the model better reproduces the peak instream densities using these values. Notably, the simulated percent compliance with the single sample maximum criterion does not change using the higher densities for these sources.

Sensitivity to Model-Predicted Overflow Locations

Overflows occurring at model-predicted overflow locations have not been field verified, so it is important to understand how they are impacting the simulations of the Banklick system. The model sensitivity to the presence of these sources was evaluated by running the model without those components. The same set of summary statistics and charts as were presented for the model calibration are shown for this simulation in Table 8 and Figures 12 and 13 below.

Table 8. Summary Statistics Comparing Predicted and Instream Fecal Coliform Measurements for Model without Model-Predicted Overflow Locations.

HSPF RCHRES	Location	n	Observed geomean (cfu/100 mL)	Model geomean (cfu/100 mL)	% Observed compliance with SS Max	% Modeled compliance with SS Max	Mean relative % difference of ln values	Mean absolute % difference of ln values
1	BLC 15.6	25	2689	1945	20%	32%	0.6%	24.4%
6	BLC 11.6	25	2852	2369	24%	20%	2.5%	23.1%
9	BLC 8.1	25	2767	1999	24%	20%	1.9%	21.2%
22	BLC 3.9	25	4499	3766	15%	15%	2.5%	18.8%
10	Fowler Creek	25	3004	2151	19%	19%	0.4%	19.0%
19	Bullock Pen	24	1730	3142	25%	17%	13.4%	29.4%
All RCHs		158	2668	2440	22%	20%	3.8%	22.4%

Figure 12. Cumulative Frequency Distribution of Modeled and Measured Wet-Weather Fecal Coliform Densities for Model with no Model-Predicted Overflow Locations.

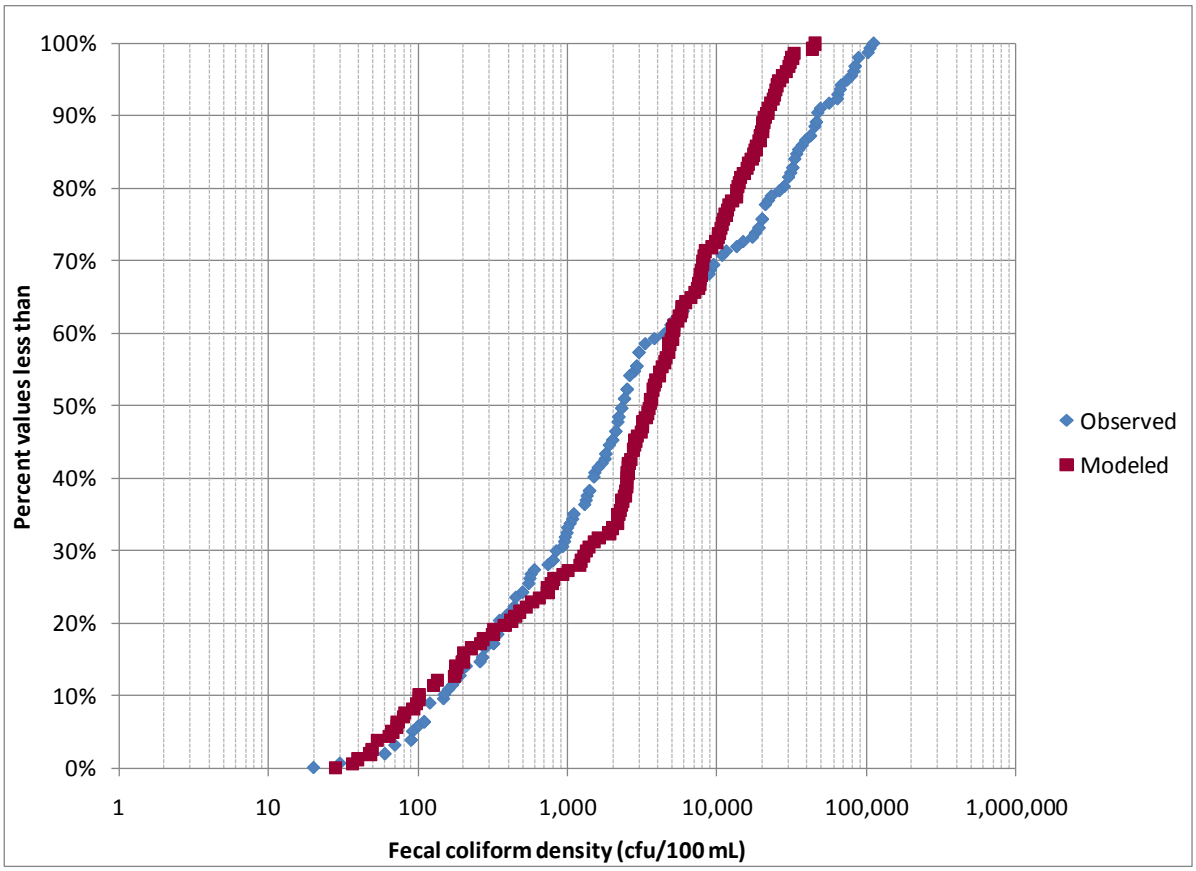
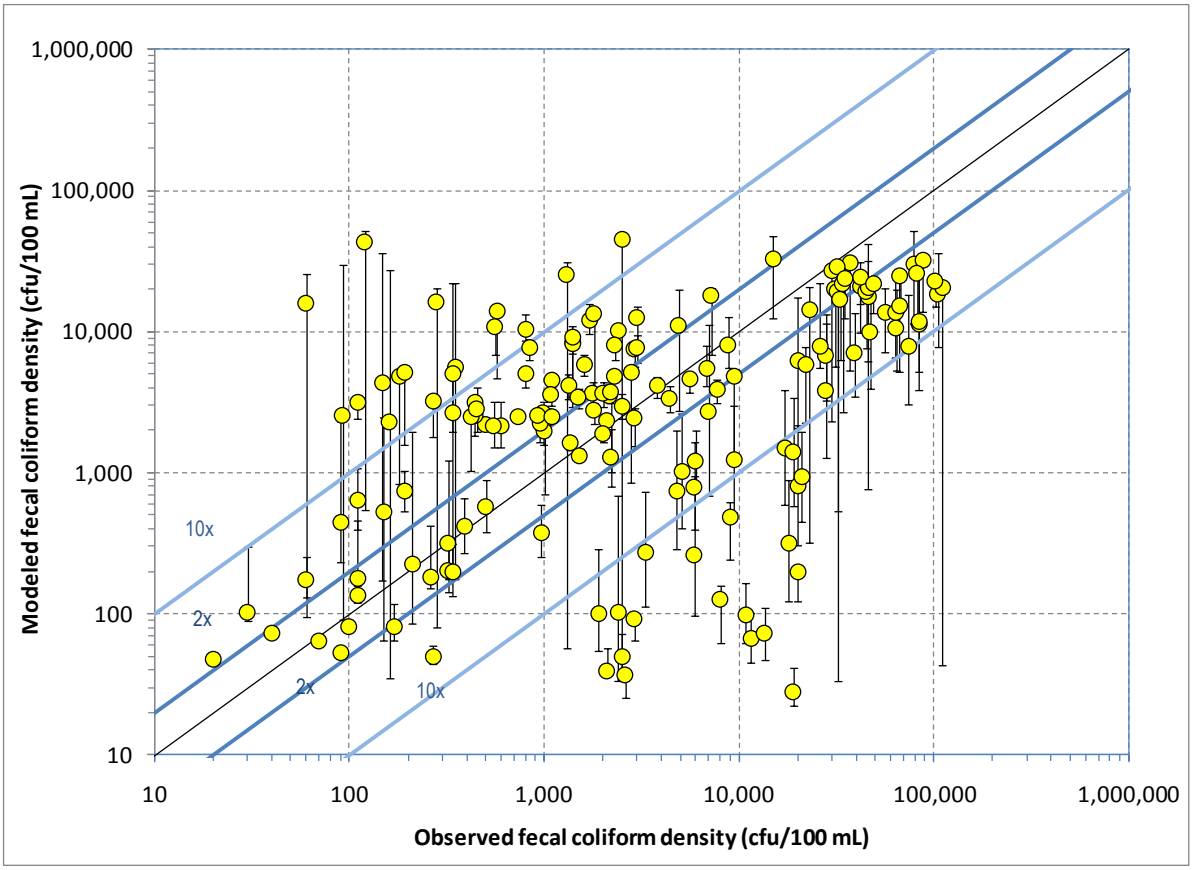


Figure 13. Scatter Plot of Modeled and Measured Wet-Weather Fecal Coliform Densities for Model with no Model-Predicted Overflow Locations.



The results suggest that the model reasonably reproduces the central tendency without these sources. However, the highest observed densities are under-predicted to a greater degree than they are in the calibrated model.

E. coli Simulation

The Banklick HSPF model was also run using the *E. coli* geometric mean densities from the SD1 infrastructure modeling (210,000 cfu/100 mL for CSOs and 705,000 cfu/100 mL for SSOs) to gage the models ability to reproduce instream *E. coli* densities. For this simulation, the build-up, wash-off parameters calibrated for fecal coliform densities were used. Table 9 and Figures 14 and 15 present the results of this simulation. It should be noted that the single-sample maximum for *E. coli* is 240 cfu/100 mL as opposed to 400 cfu/100 mL for fecal coliform.

Table 9. Summary Statistics Comparing Predicted and Instream *E. coli* Measurements for Model.

HSPF RCHRES	Location	n	Observed geomean (#/100 mL)	Model geomean (#/100 mL)	% Observed compliance with SS Max (240 #/100 mL)	% Modeled compliance with SS Max (240 #/100 mL)	Mean relative % difference of ln values	Mean absolute % difference of ln values
1	BLC 15.6	25	2138	1594	12%	20%	0.4%	26.2%
6	BLC 11.6	25	2177	2042	20%	16%	4.0%	22.5%
9	BLC 8.1	25	2130	1629	16%	16%	1.1%	19.8%
22	BLC 3.9	26	2991	1940	8%	15%	-1.6%	17.6%
10	Fowler Creek	26	2560	1439	12%	15%	-4.4%	16.8%
19	Bullock Pen	24	1214	1175	21%	25%	4.3%	25.9%
All RCHs		158	2038	1564	15%	18%	0.6%	20.9%

Figure 14. Distribution of Modeled and Measured Wet-Weather *E. coli* Densities.

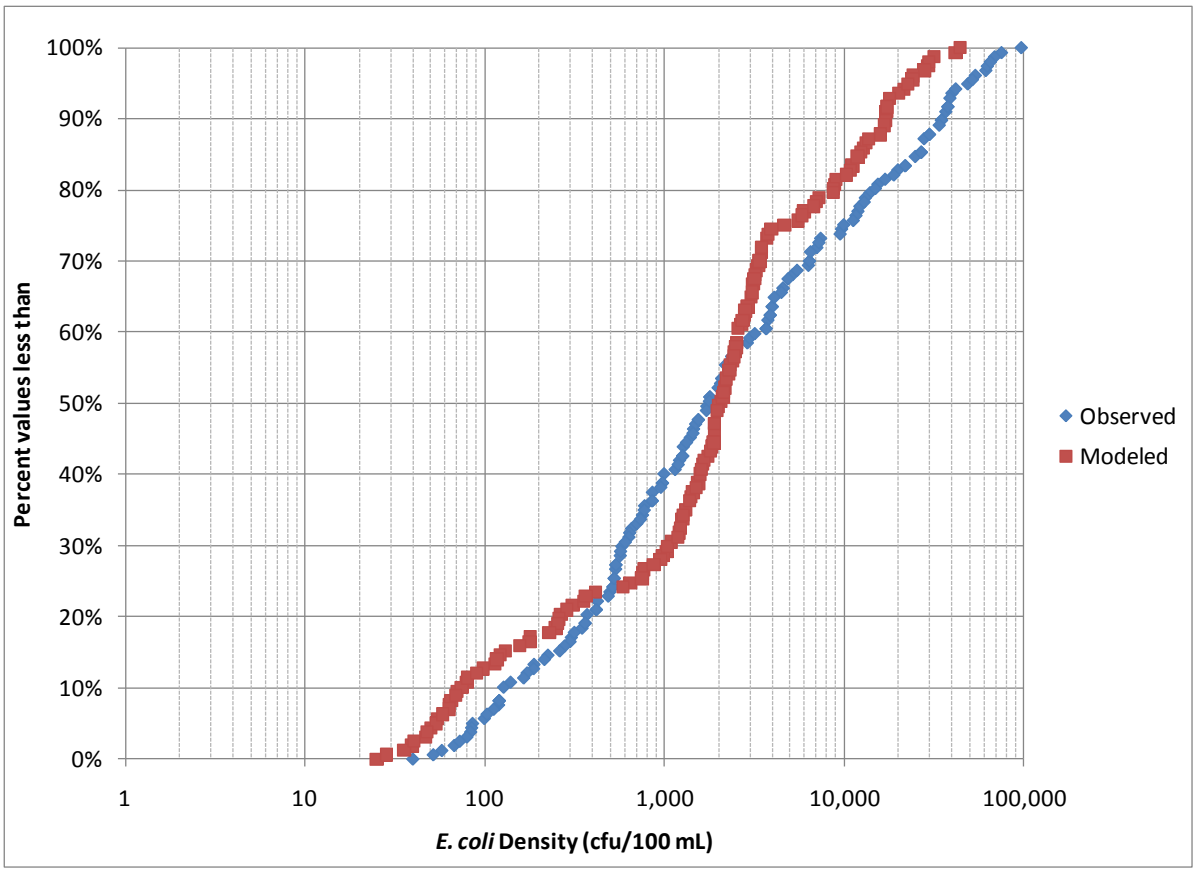
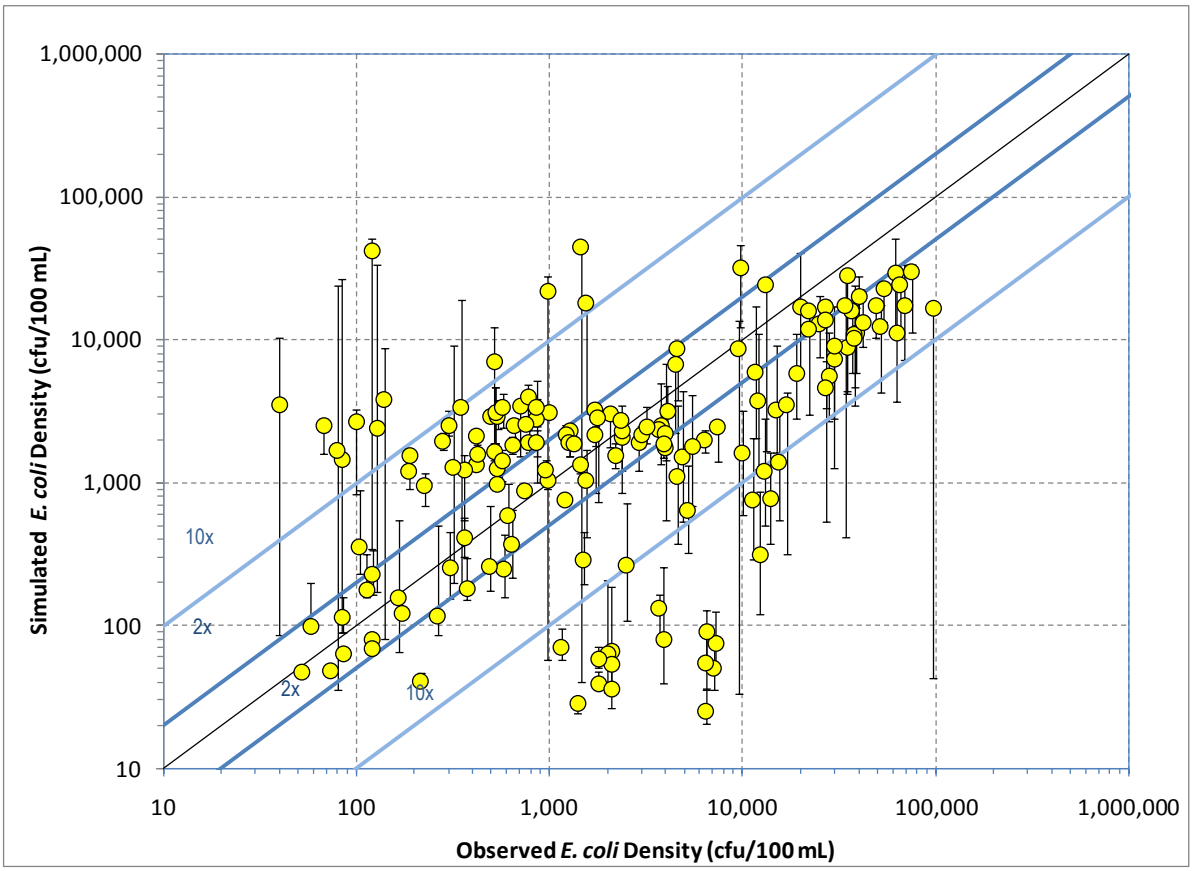


Figure 15. Modeled and Measured Wet-Weather *E. coli* Densities.



The model under-predicts measured *E. coli* densities using this configuration. This suggests that *E. coli* runoff loads would need to be greater than the calibrated fecal coliform loads to better match instream data.

Conclusions

The information from the Banklick Creek watershed modeling effort can be summarized as follows:

- The HSPF model provides a reasonable reproduction of flow and fecal coliform densities in Banklick Creek for a range of environmental conditions;
- The calibration suggests that the methods used for quantifying fecal coliform loading are providing reasonable estimates of point and nonpoint source bacteria loads;
- The water quality model will be a useful tool for quantifying potential benefits of various control scenarios considered for the LTCP.

The calibration to instream values indicates that it is capable of reproducing the timing and magnitude of most of the observed data. It is the best tool available for evaluating instream impacts from fecal coliform sources, including CSOs and SSOs, under a range of environmental conditions and control scenarios. The model is suitable for evaluating the water quality benefits of traditional infrastructure, green infrastructure, and watershed control alternatives in the Banklick Creek watershed.

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XCG Consults, Inc. 2003. Banklick Creek. Watershed Assessment. Summary of results for countinuous flow/level meters and continuous water quality datasonde. Prepared for Sanitation District Number 1 of Northern Kentucky. December, 2003.

FINAL

Attachment A

Location-specific figures for Banklick Creek HSPF Model Comparison

Figure 1. Distribution of modeled and measured values at Banklick Creek River Mile 15.6.

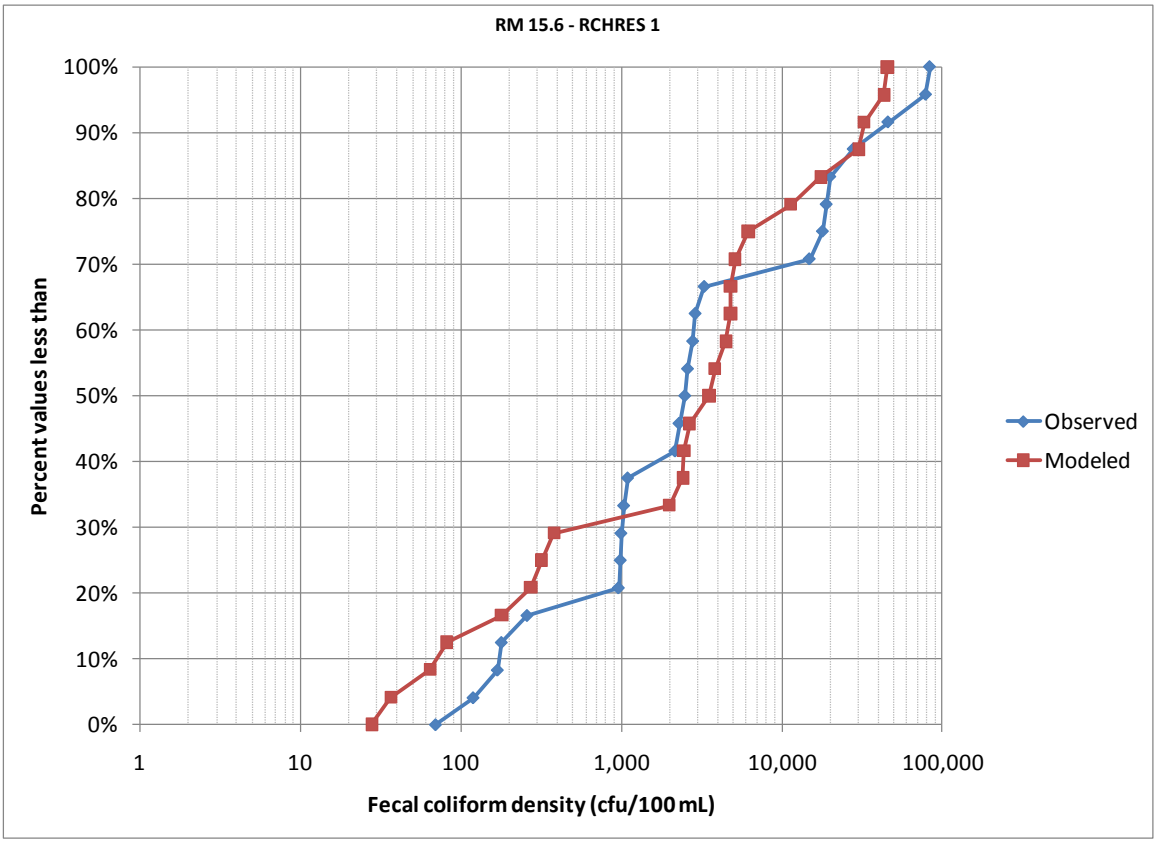


Figure 2. Distribution of modeled and measured values at Banklick Creek River Mile 11.6.

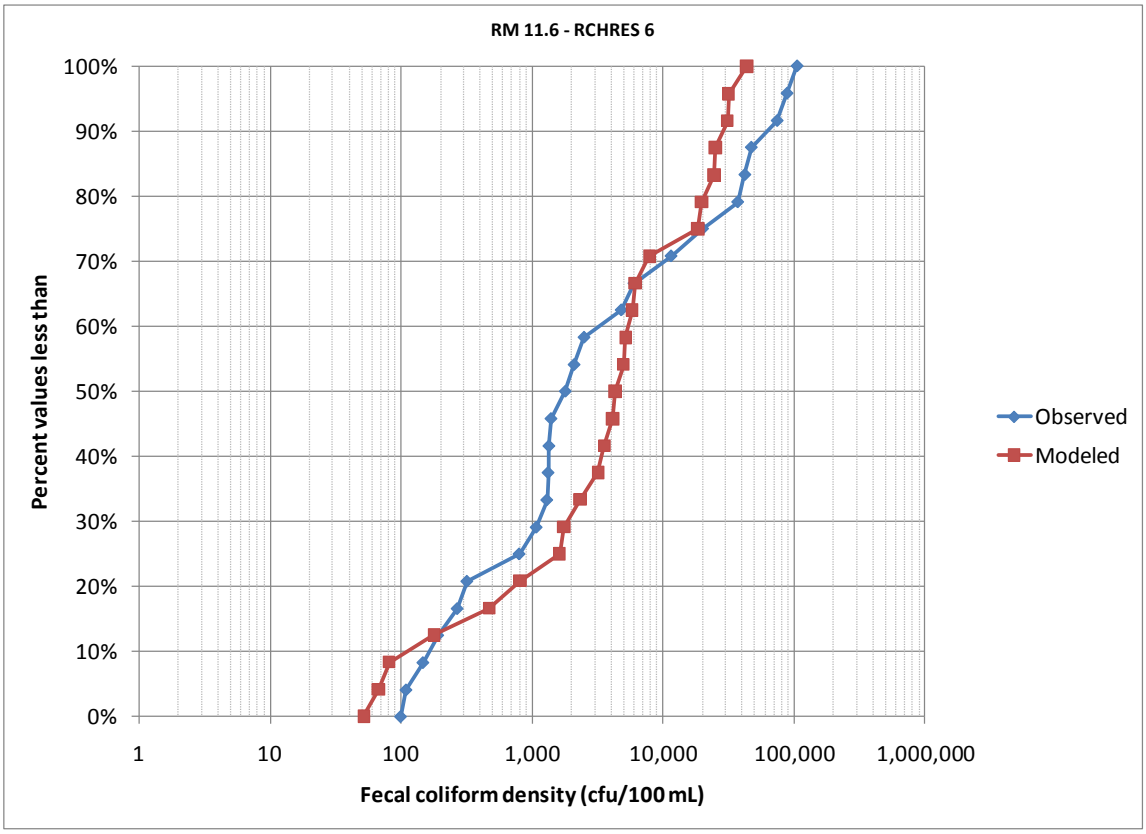


Figure 3. Distribution of modeled and measured values at Banklick Creek River Mile 8.1.

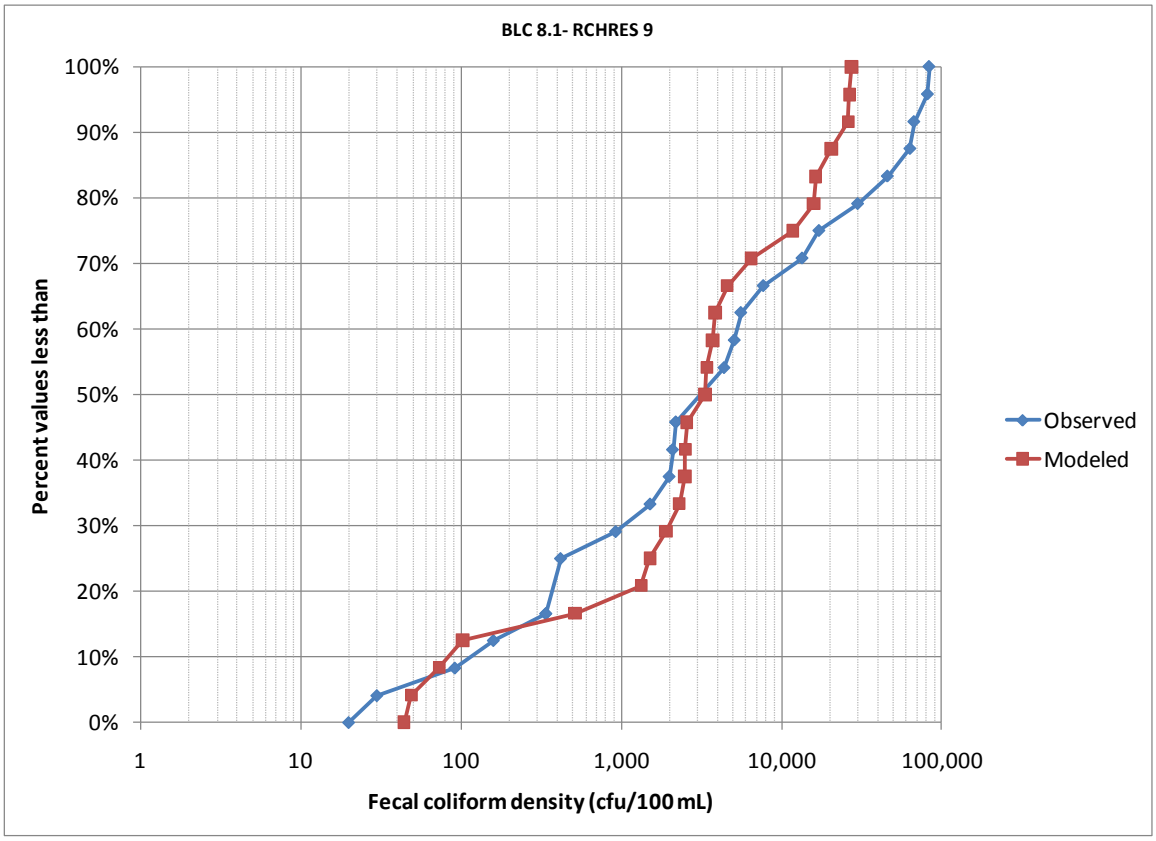


Figure 4. Distribution of modeled and measured values at Banklick Creek River Mile 3.9.

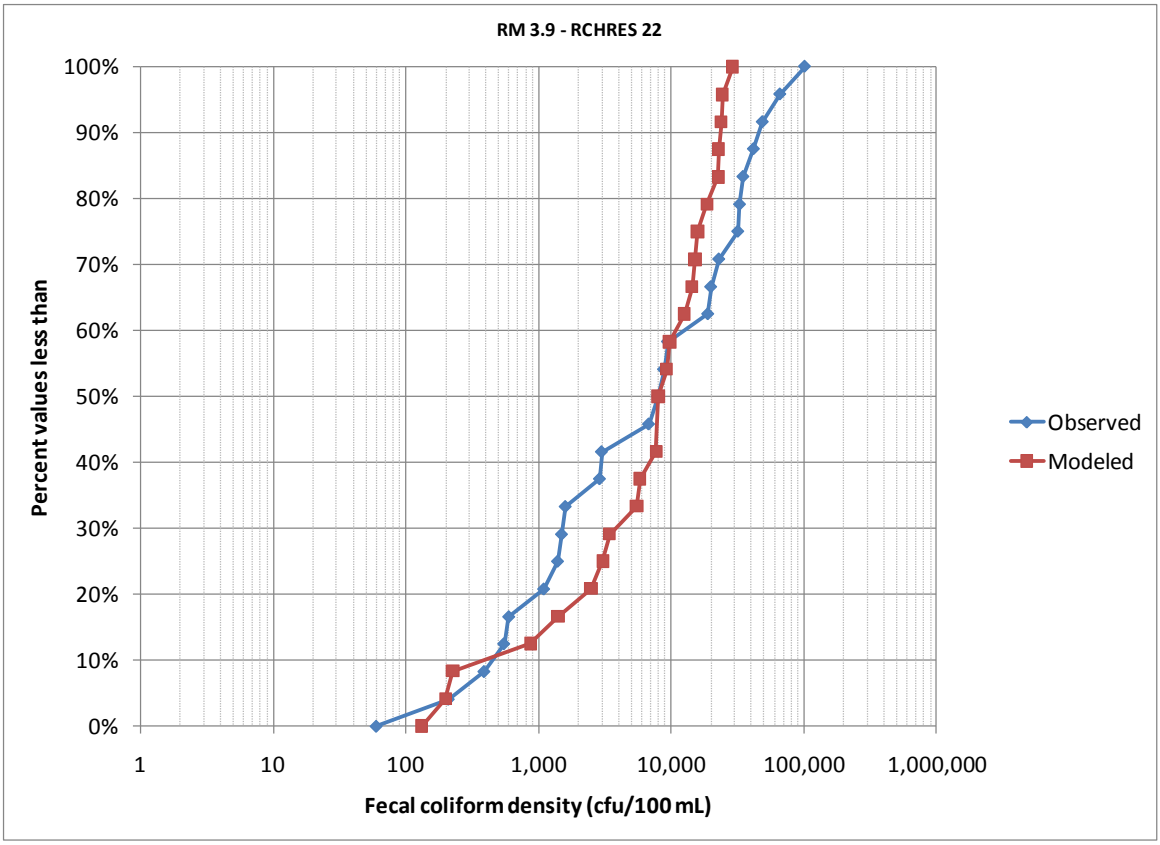


Figure 5. Distribution of modeled and measured values at outlet of Fowler Creek.

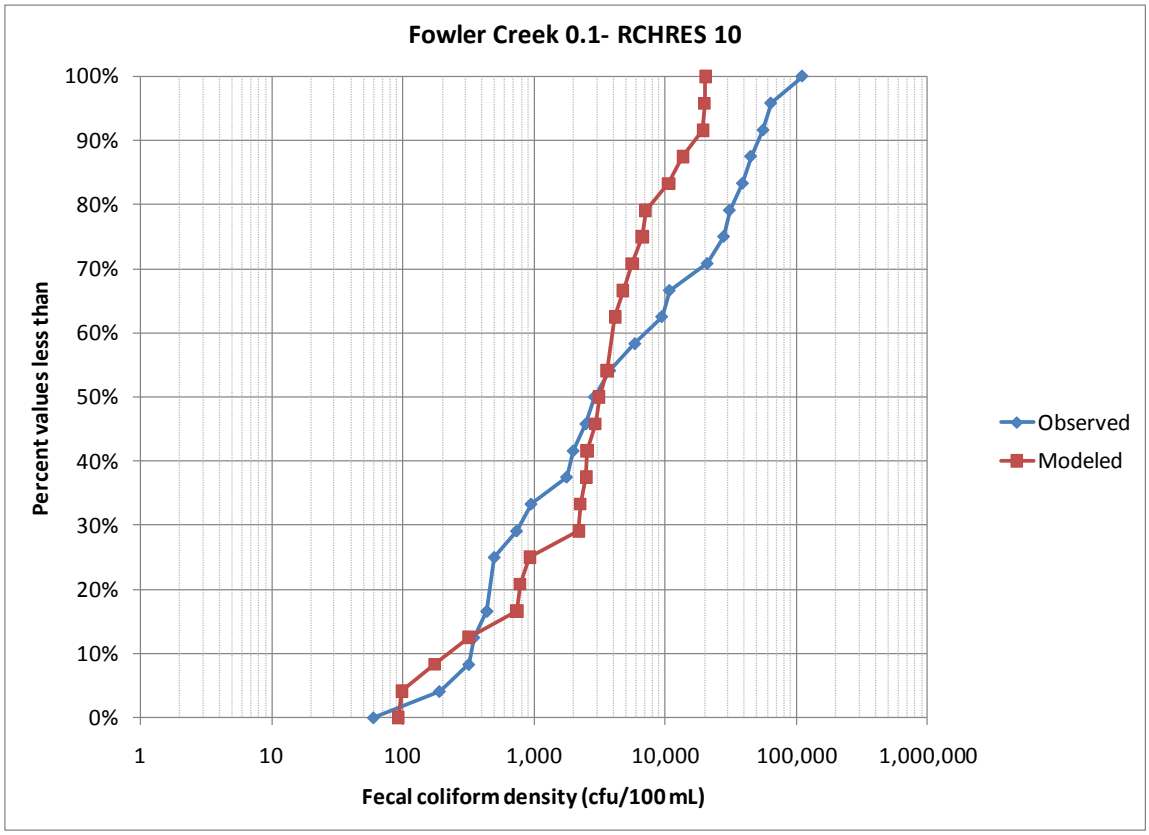


Figure 6. Distribution of modeled and measured values at outlet of Bullock Pen Creek.

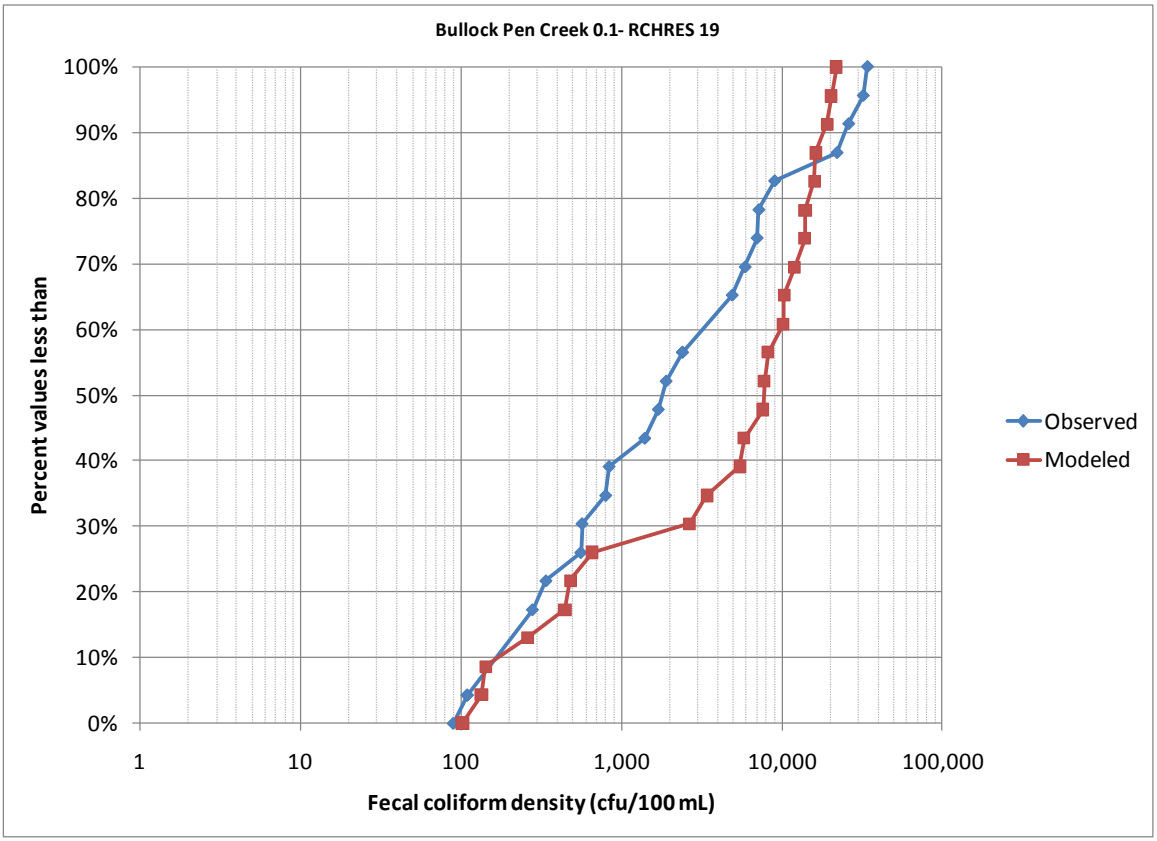


Figure 7. Scatter plot of modeled and measured values at Banklick Creek River Mile 15.6.

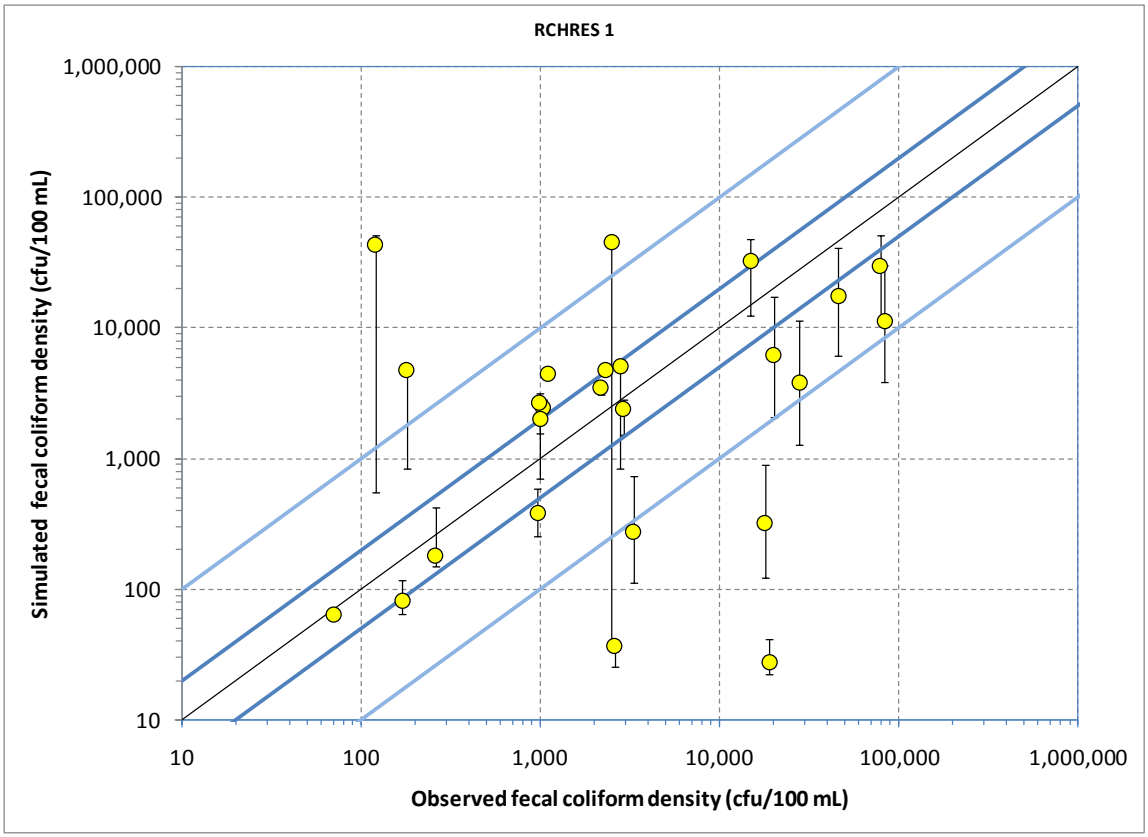


Figure 8. Scatter plot of modeled and measured values at Banklick Creek River Mile 11.6.

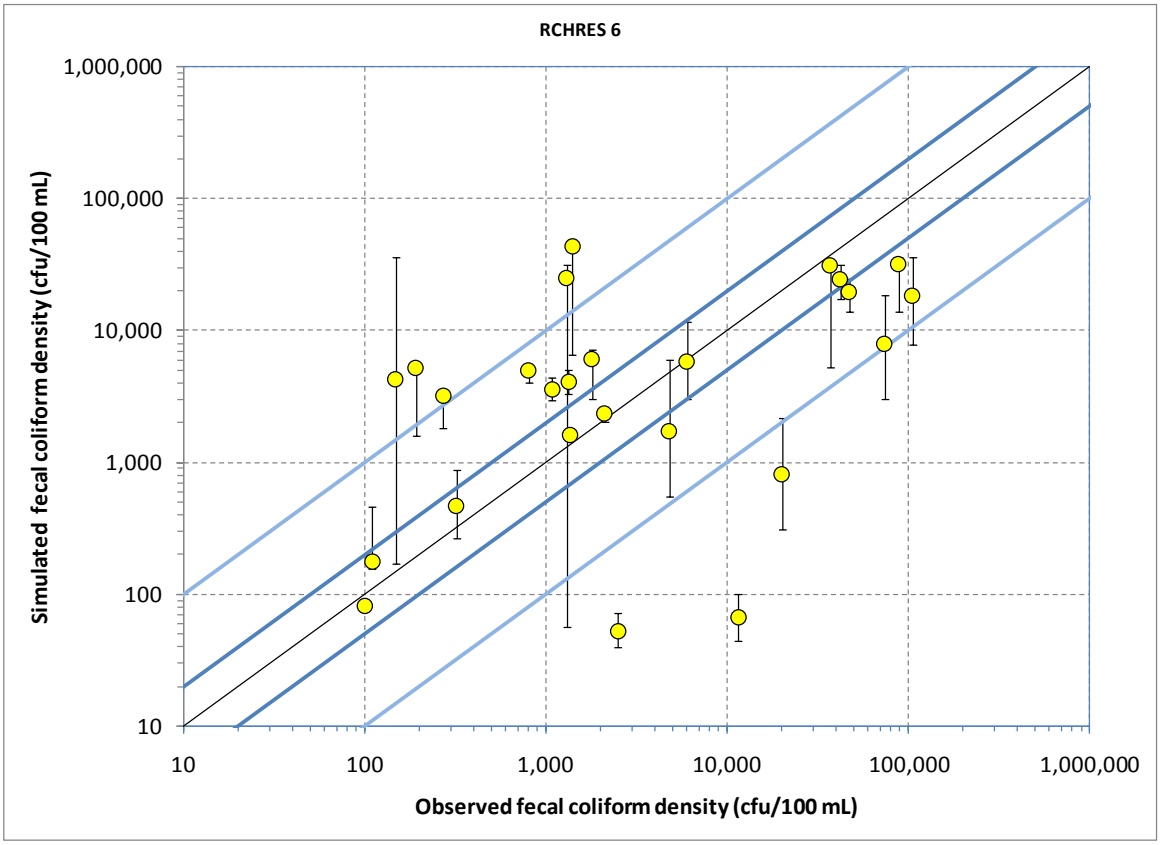


Figure 9. Scatter plot of modeled and measured values at Banklick Creek River Mile 8.1.

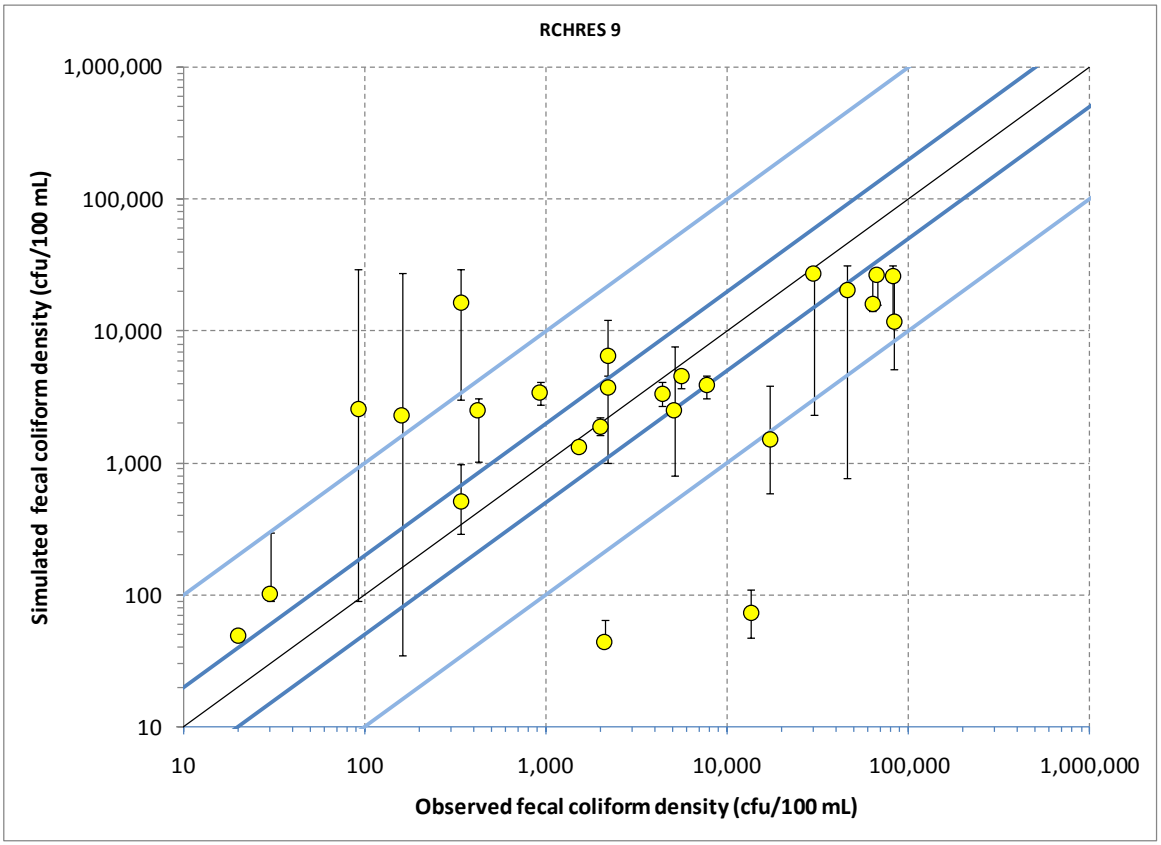


Figure 10. Scatter plot of modeled and measured values at Banklick Creek River Mile 3.9.

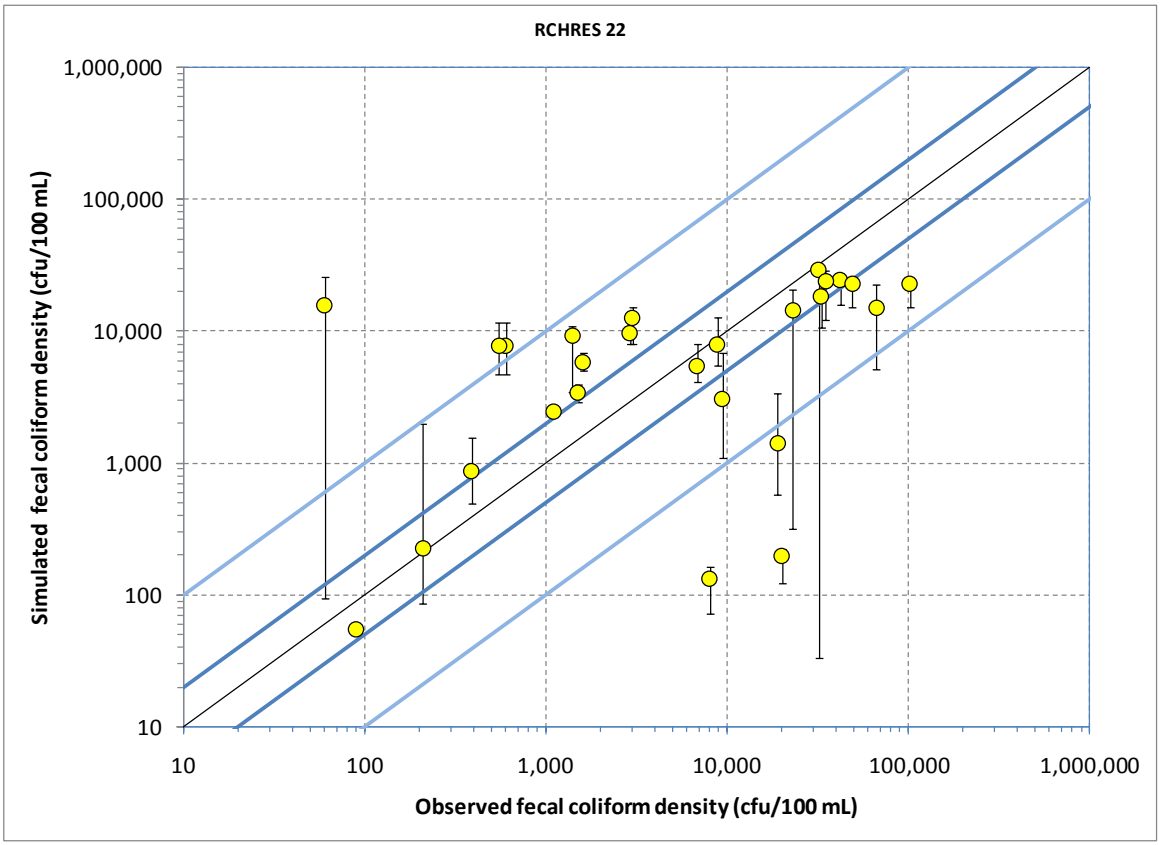


Figure 11. Scatter plot of modeled and measured values at outlet of Fowler Creek.

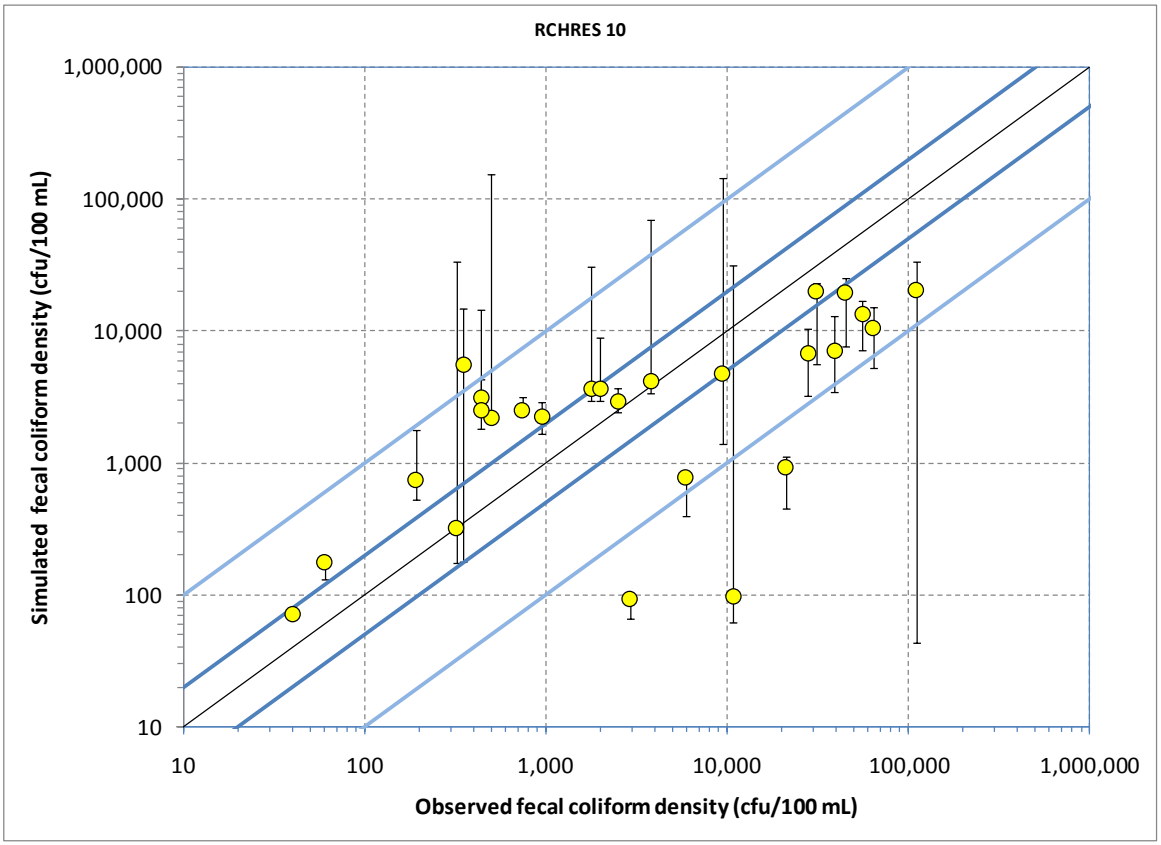


Figure 12. Scatter plot of modeled and measured values at outlet of Bullock Pen Creek.

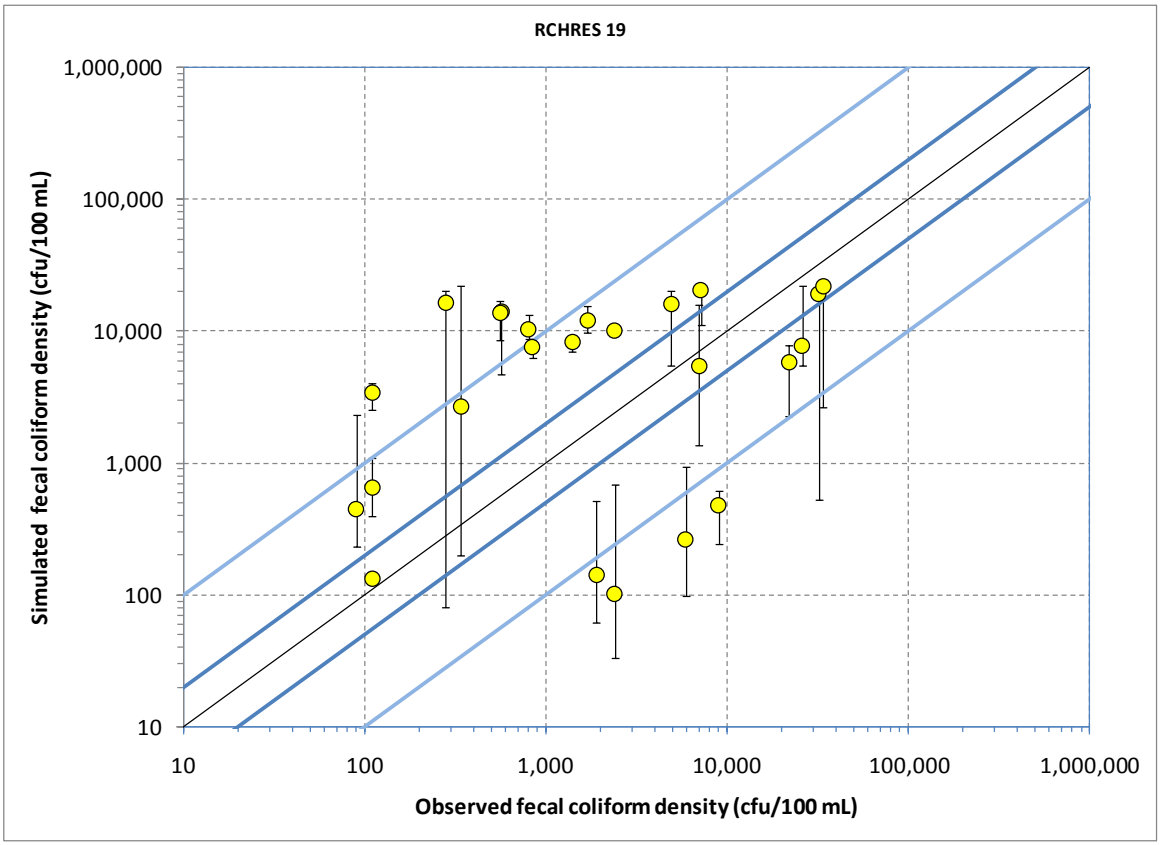


Figure 13. Model to data comparison for May 2008 at Banklick Creek River Mile 15.6.

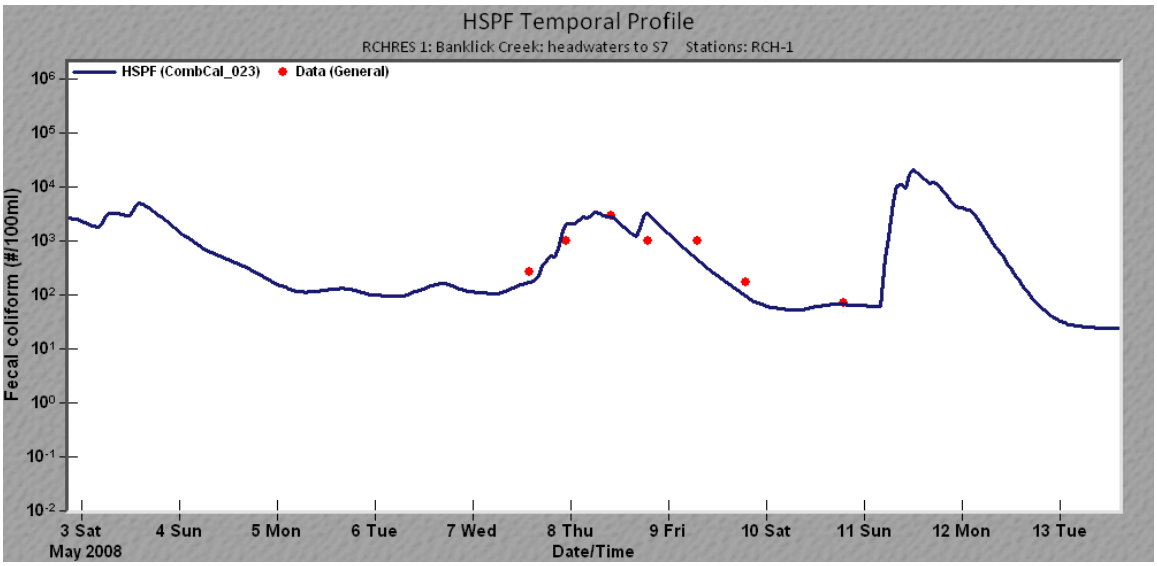


Figure 14. Model to data comparison for May 2008 at Banklick Creek River Mile 11.6.

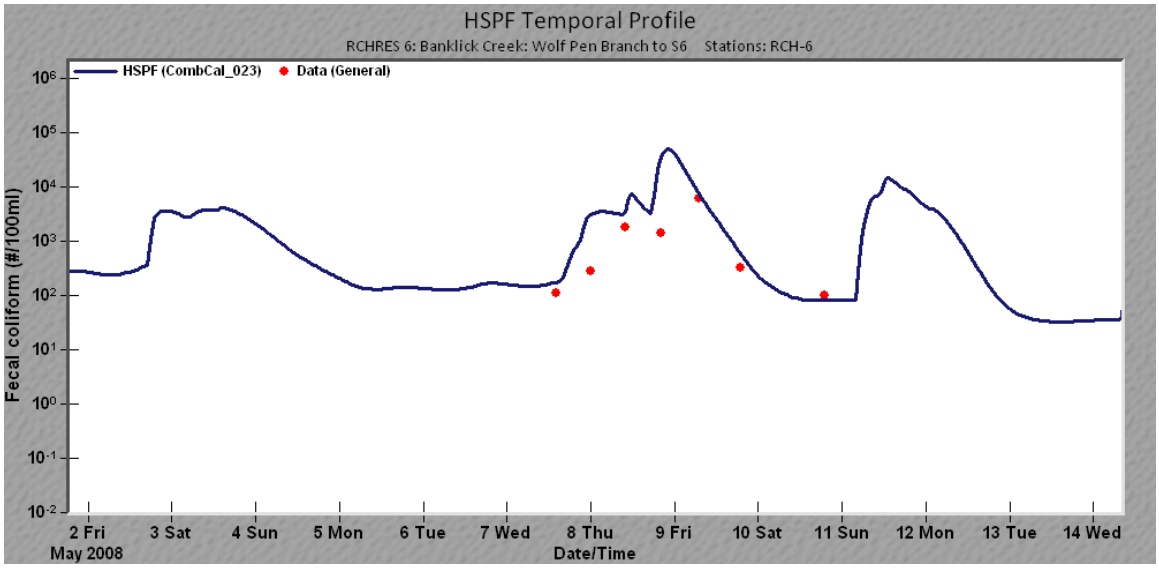


Figure 15. Model to data comparison for May 2008 at Banklick Creek River Mile 8.1.

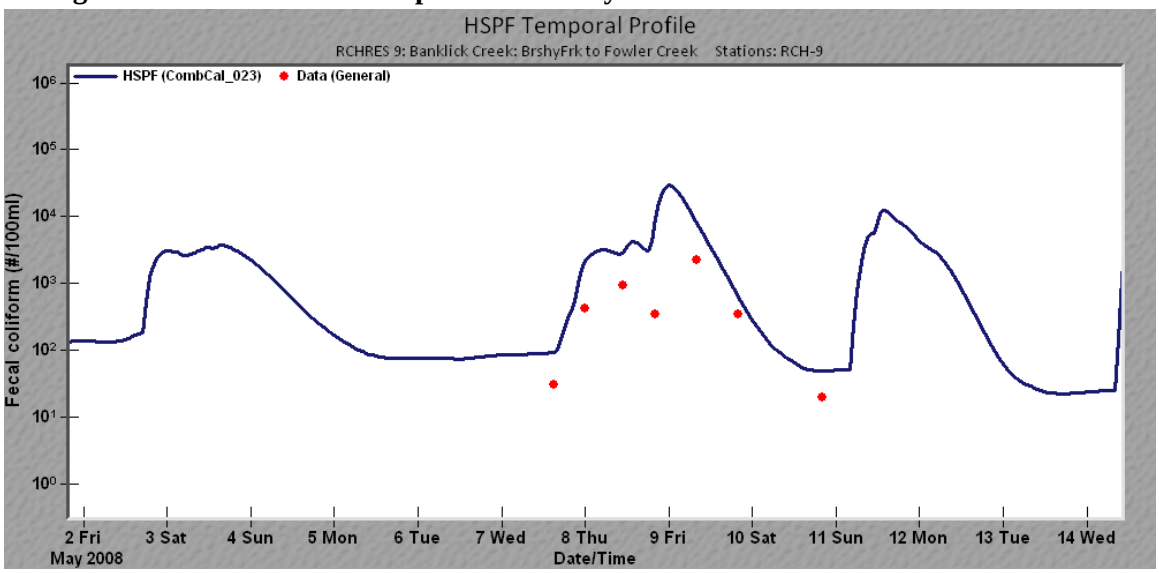


Figure 16. Model to data comparison for May 2008 at Banklick Creek River Mile 3.9.

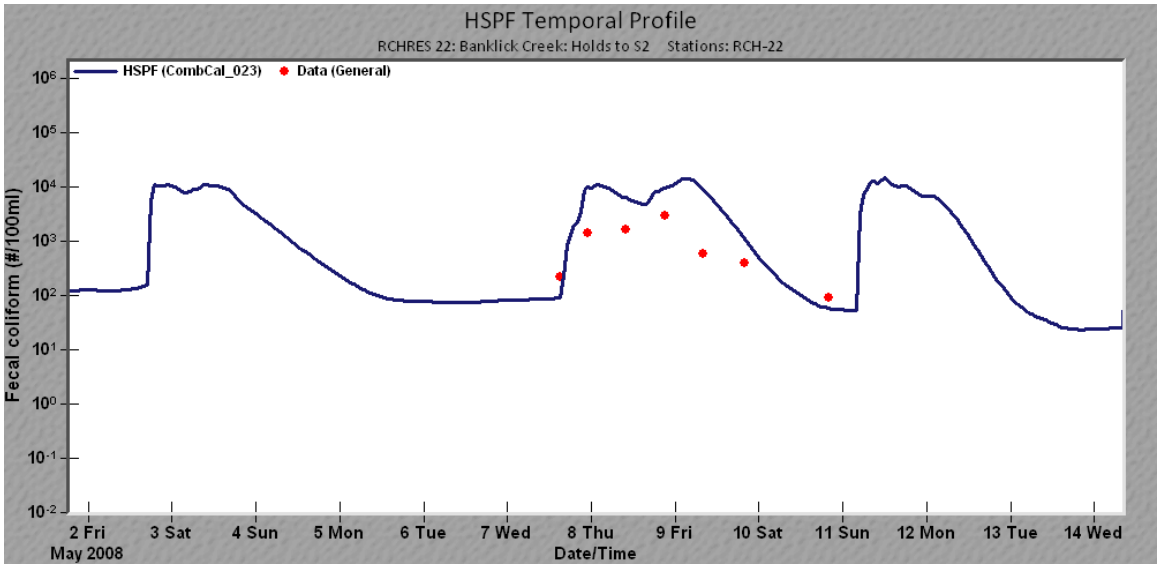
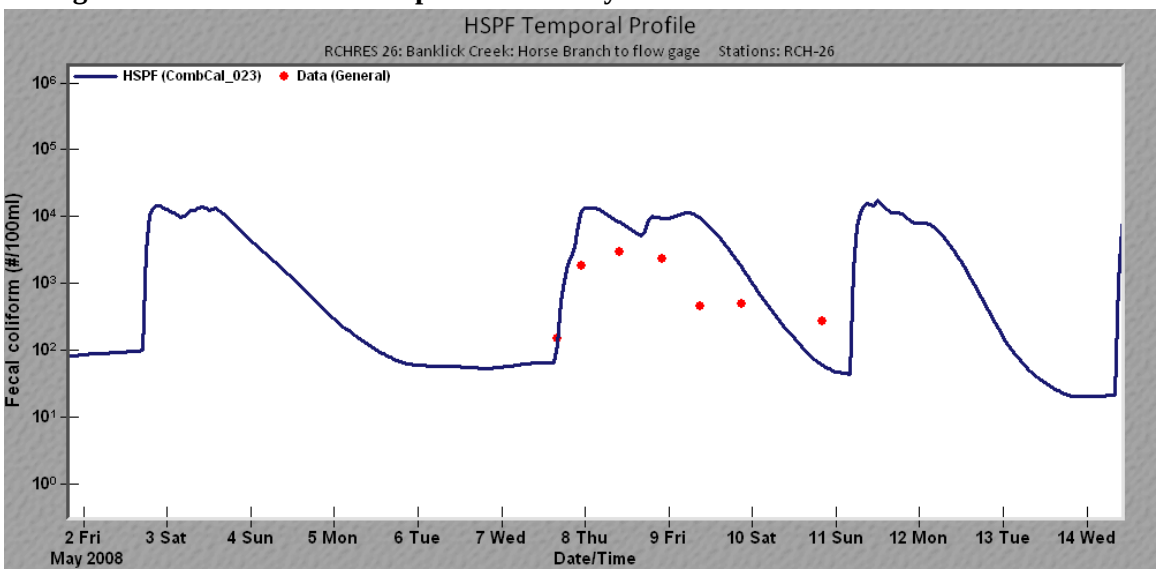


Figure 17. Model to data comparison for May 2008 at Banklick Creek River Mile 1.2.



LimnoTech
Water | Environment | Scientists | Engineers

DATE: October 26, 2010

MEMORANDUM

FROM: Stacey Burgtorf, Tim Towey, Carrie Turner

TO: Mindy Scott (SD1), Jim Gibson (SD1)

CC: Adrienne Nemura

SUBJECT: Banklick Creek HSPF Model: 2010 Dry Weather Load Update and Wet-Weather Corroboration

Overview

The Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are an important contribution for watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) long-term control plan. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

A model of the Banklick Creek watershed using the Hydrologic Simulation Program in Fortran was originally developed in 2004 as part of a federal grant to develop and apply a Watershed Assessment Protocol (WAP) in order to understand water quality problems on a watershed basis (LimnoTech, 2004). The calibration of that model was updated in 2008 to incorporate a more detailed land cover analysis; to evaluate dry-weather fecal coliform loads using a larger set of monitoring results; and to calibrate wet-weather loads incorporating recent literature values of storm water fecal coliform densities, output from an updated collection system model, SD1 outfall monitoring data, and a new set of wet-weather monitoring data collected in May 2008.

Additional sampling has been conducted since the calibration update. Dry-weather samples were collected in 2008 and 2009 (base flow surveys and pre/post-event wet weather samples), and three wet-weather periods were sampled in 2009. This memorandum describes an update to the Banklick Creek dry-weather loads based on the new monitoring results and presents a corroboration of the previous wet-weather calibration of the Banklick model using the new wet-weather monitoring data.

Dry Weather Fecal Coliform Update

Additional dry weather samples were collected in Banklick Creek in 2008 and 2009, following the calibration of the HSPF Banklick Model. Because some of the stations had relatively few samples in the 2002-2007, the additional data was incorporated to update the dry-weather loads. Table 1 presents a comparison of the data used in the 2008 dry-weather calibration and the updated values.

501 Avis Drive
Ann Arbor, MI 48108
734-332-1200
Fax: 734-332-1212
www.limno.com

Table 1. Comparison of the data used in the original dry-weather calibration (2002-2007) and the updated values (2002-2009).

Sampling Location[1]	2002-2007 Values				2002-2009 Values			
	n	Geometric mean (cfu/100 ml)	95th Percentile (cfu/100 ml)	Percent < 400 cfu/100 mL	n	Geometric mean (cfu/100 ml)	95th Percentile (cfu/100 ml)	Percent < 400 cfu/100 mL
BLC 15.6	5	130	870	80%	8	140	761	88%
BLC 11.6	4	497	991	50%	8	335	1,619	50%
BLC 8.1	16	178	1,794	69%	21	168	1,458	68%
BLC 3.9	17	164	1,074	76%	22	217	1,321	70%
BLC 1.2	14	157	2,164	69%	18	158	1,729	75%
BLC 0.5[2]	17	118	1,562	82%	21	156	1,094	79%
BPC	7	195	1,287	71%	10	177	1,166	80%
FC	5	382	1,574	60%	9	197	1,548	78%

Notes:
[1] Sampling Location naming convention is as follows:"BLC" refers to Banklick Creek and the number that follows is the river mile (distance from the confluence) of the location. "BPC" refers to Bullock Pen Creek and "FC" refers to Fowler Creek. Samples were collected only at river mile 0.1 in both of these creeks.
[2] The sampling location is actually at river mile 0.3 but the model output from the subwatershed at river mile 0.5 is used for comparison to these data. To be consistent with previous memoranda describing this model, the model subwatershed identifier is used.

As expected, the largest differences in fecal coliform levels between the previous and updated sets of monitoring results were for the locations that had relatively few samples. The largest difference in terms of central tendency of the data was at Fowler Creek.

Minor changes were made to the previously developed dry weather loads in the Banklick HSPF model to reflect the more extensive set of data (2002-2009). Figures 1 through 3 compare observed results with model results restricted to dry-weather days. The figures show the measured and modeled recreation season geometric mean densities, 95th percentile densities, and single sample maximum compliance rates, respectively.

Figure 1. Comparison of Observed and Modeled Recreation Season Geometric Means.

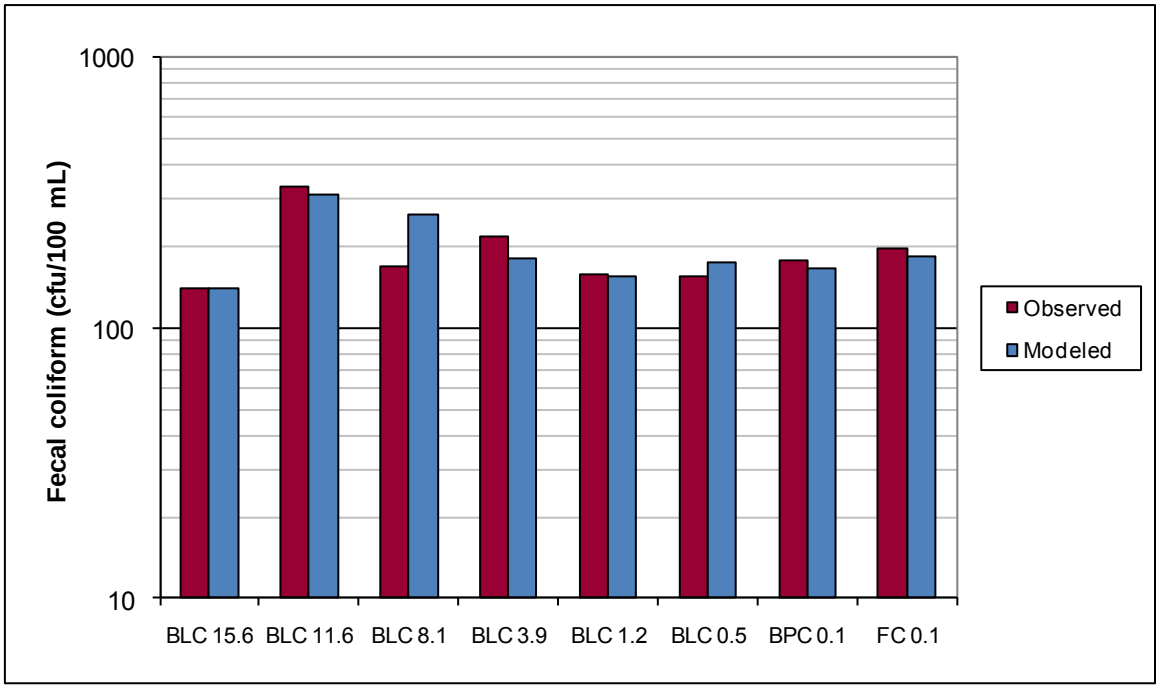


Figure 2. Comparison of Observed and Modeled Recreation Season 95th Percentile Densities.

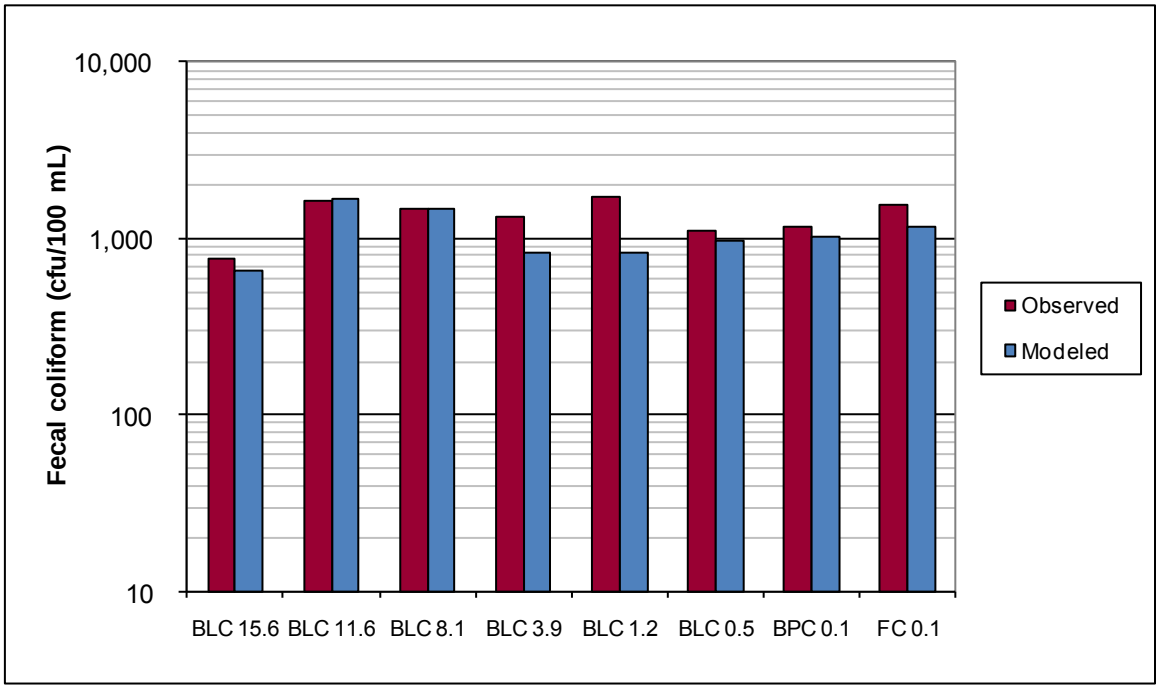
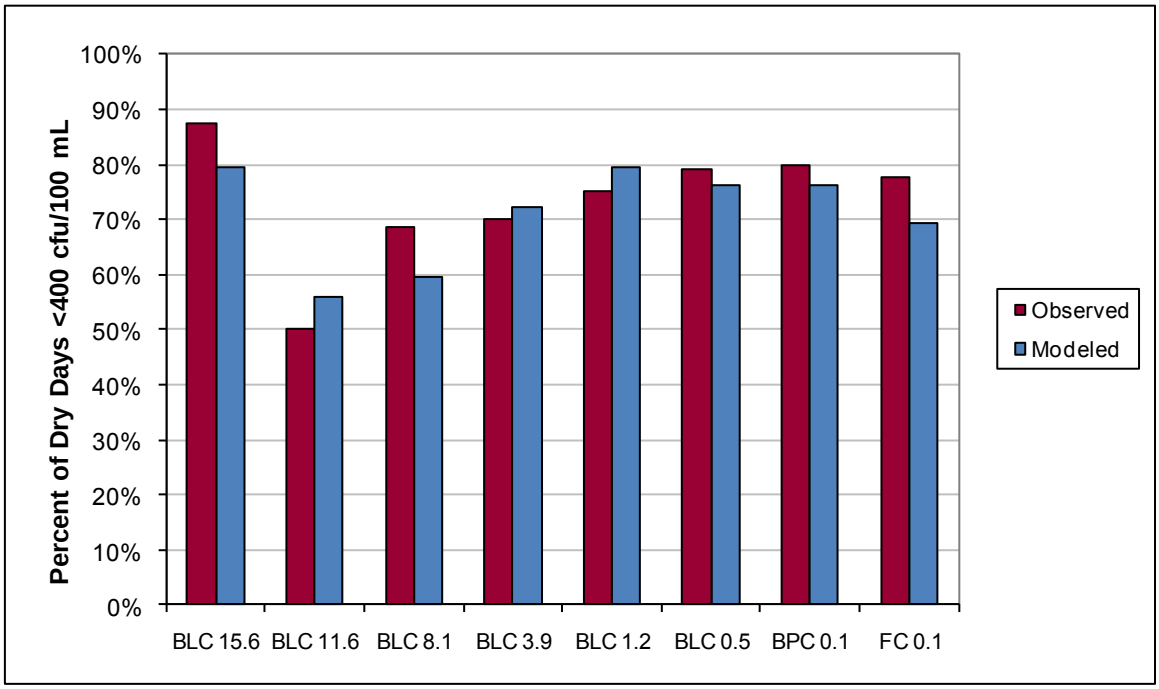


Figure 3. Comparison of Observed and Modeled Recreation Season Days With Fecal Coliform Levels Less Than 400 cfu/100 Ml.

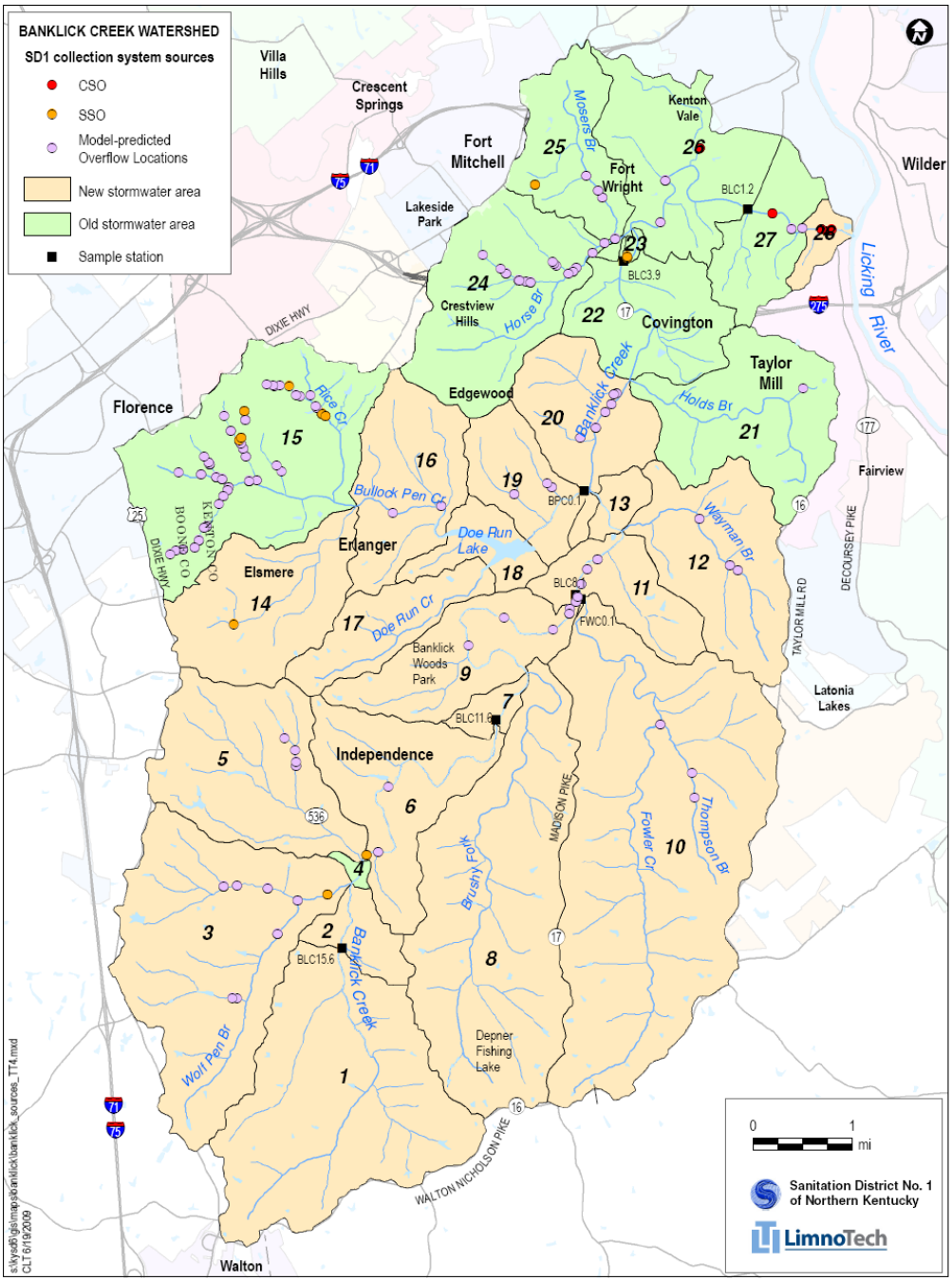


The updated dry-weather model loads reasonably reproduce the observed values for each of the dry weather calibration metrics.

Wet Weather Fecal Coliform Corroboration

Wet weather sources of fecal coliform bacteria include both runoff sources and sources from the SD1 collection system. In HSPF, the runoff source load is calculated based on a build-up and wash-off routine for each land use/land cover (LULC) type specified in the model. The SD1 infrastructure sources are input to the watershed model based on output from the collection system models. These sources include CSOs, SSOs, and model-predicted overflow points. Figure 4 (copied from LimnoTech 2008) shows the model configuration and location of SD1 sources.

Figure 4. Map of the Banklick Creek Watershed, Including SD1 Infrastructure Sources, Old and New Developed Areas, and Sampling Stations.



The model was calibrated to data from three wet weather surveys sampled in 2003 and one wet weather survey sampled in 2008 (LimnoTech 2008). The model calibration was then corroborated by comparing modeled and measured instream fecal coliform densities at four locations on Banklick Creek during three separate storm events that occurred during the summer and fall of 2009 (Table 2). The four sampling locations correspond to river miles 8.1, 3.9, 1.2, and 0.3 in Banklick Creek. During each event, multiple samples were collected at each location nominally at event initiation, then 2, 4, 6, 12, 24, 36 and 48 hours later (actual sample time interval varied by event and location).

Table 2. Rainfall, Flow and Fecal Coliform Characteristics for 2009 Wet Weather Events

Characteristic	Condition	Wet Weather Event 1 (07/22-25/09)	Wet Weather Event 2 (09/20-24/09)	Wet Weather Event 3 (10/08-13/09)
Rainfall[1]	Total rainfall (in)	1.16	1.28	4.62
	Storm duration (hrs)	24	20	22
	Max intensity (in/hr)	0.15	0.22	1.06

Note: Storm characteristics based on hourly rainfall data measured at the Cincinnati/Northern Kentucky International Airport (WMO ID = 72421), which were used as input in the model corroboration simulations.

The model was applied over the period comprising the three 2009 wet weather sampling events (July 2009 through October 2009). The model was applied with the same fecal coliform water quality settings (e.g. build-up rate, wash-off rate) used in the 2008 calibration update (LimnoTech 2008). Model results from this corroboration were evaluated using many of the same analyses used previously and are described below.

Figure 5 is the cumulative frequency distribution plot of the observed data at all sampling locations and the corresponding model outputs from the hour closest to when the samples were collected. Cumulative frequency distribution plots show the percent of values within the dataset that are less than each observed or simulated density. They are useful for comparing the range of observed and modeled densities and the relative frequencies at which the densities occur. The cumulative frequency distribution plot indicates that the model reproduces the range of observed densities at the appropriate frequency reasonably well.

Figure 5. Cumulative Frequency Distribution of Modeled and Measured Wet-Weather Fecal Coliform Densities.

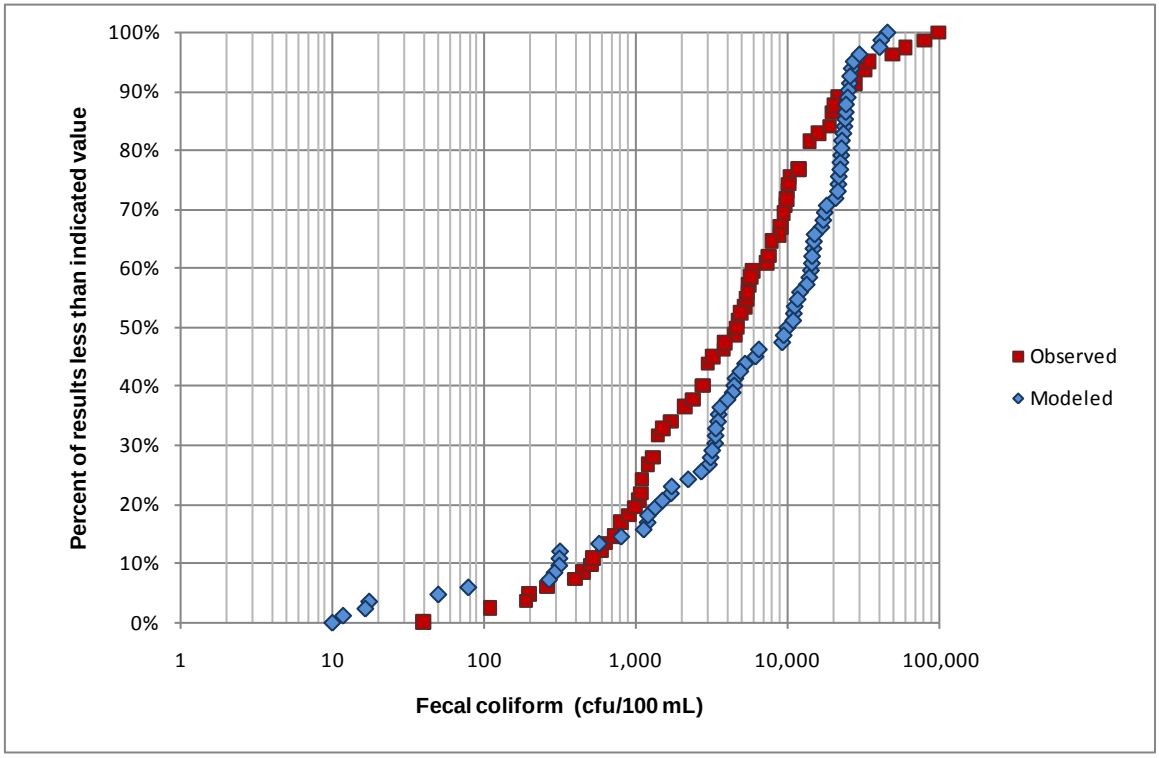
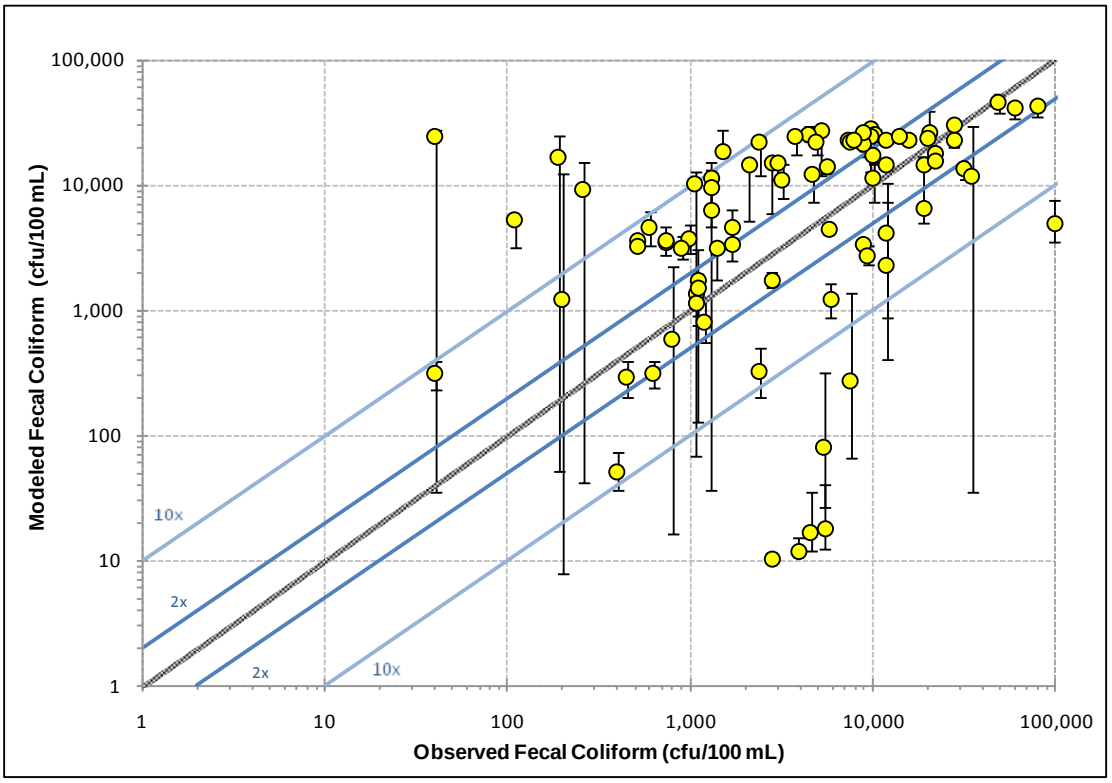


Figure 6 is a scatter plot or (one-to-one plot) of modeled and observed fecal coliform densities. Scatter plots of model predictions versus data predictions show how well the model is reproducing the data for each measured value. Two sets of lines on the one-to-one plots form limits for acceptable model-to-date comparisons. Points on the scatter plot that fall within the lines labeled '2x' are considered excellent predictions because they roughly correspond to the sampling and analytical accuracy limits of the bacteria count. The wider band between the '10x' lines is a more liberal criteria for the model predictions; predictions that fall within these bands are accurate to one order of magnitude of the measured bacteria densities. The error bars around each point indicate the minimum and maximum modeled values for the three hours before and three hours after each sample collection time, showing the variability of fecal coliform densities over a short time period during wet-weather events.

Figure 6. Scatter Plot of Modeled and Measured Wet-Weather Fecal Coliform Densities.

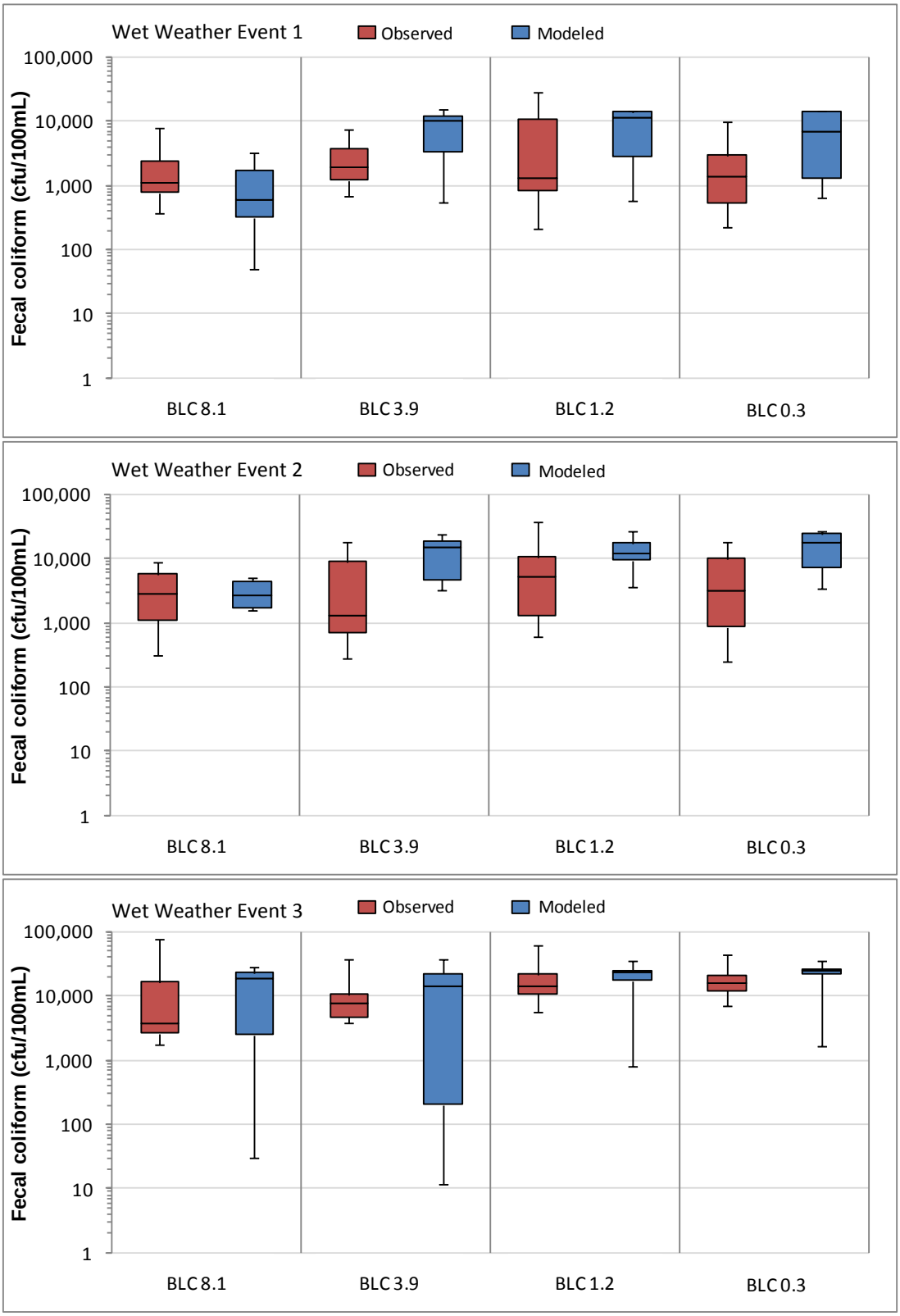


The scatter plot shows that the majority of the modeled values are within an order of magnitude of observed values. In the cases in which the model over-predicts the observed values by more than an order of magnitude, the error bars show that the model produces values that better match the observed values within a few hour time-window. All of the cases where the model under-predicts the observed values by more than an order of magnitude occur in the sampling rounds 24 hours after the event initiation for the third storm event (October 2009). This was observed at all four stations, indicating that the model simulated a more rapid recession of fecal coliform levels for that particular storm than the data captured.

Figure 7 depicts box-and-whisker plots of modeled and observed fecal coliform densities at all locations of Banklick Creek for the three wet weather events. These plots demonstrate whether the model is reproducing the observed results at upstream, mid-stream, and downstream locations on Banklick Creek for each event. Overall, the model reasonably reproduces the central tendency, with some overprediction.

Figure 8 includes temporal profiles, or pollutographs, of modeled and observed fecal coliform densities. The pollutographs show all three wet-weather events sampled in 2009. Overall, the model reproduces the temporal pattern of the data well, including peak densities and the timing and duration of wet weather event response instream.

Figure 7. Distributions of Observed and Modeled Fecal Coliform Densities Along Banklick Creek



Note: The line in the middle of the box represents the median, the box edges represent the 25th and 75th percentiles, and whiskers extend to the 5th and 95th percentiles.

Figure 8. Pollutographs of Modeled and Measured Wet-Weather Fecal Coliform Densities.

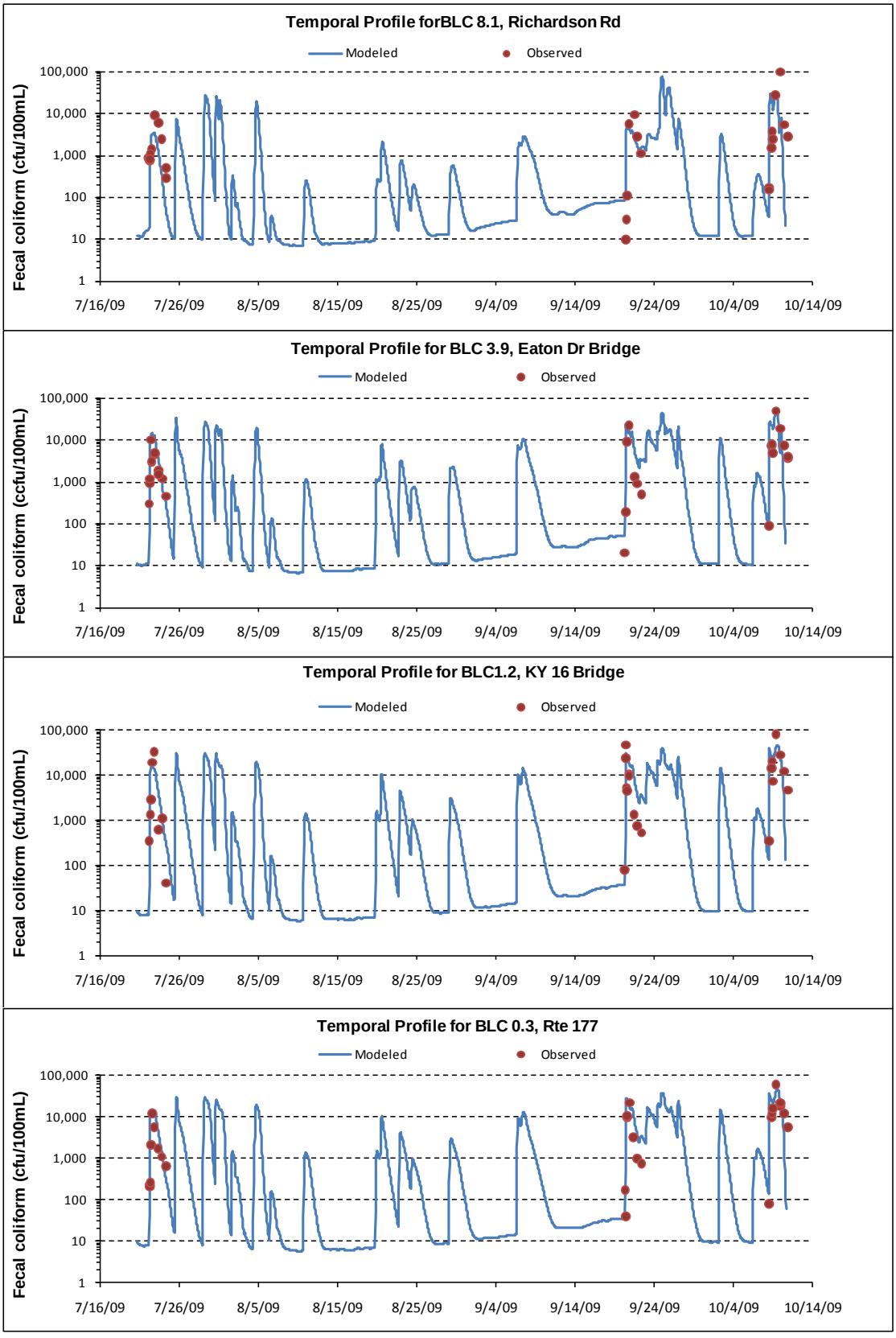


Table 3 compares the geometric means of observed and modeled fecal coliform densities, using information from all three wet weather events. For the 2009 data, the model tends to over-predict the central tendency of observed values in downstream reaches.

Table 3. Geometric Mean of Observed and Modeled Fecal Coliform

Sampling Station	Observed (cfu/100 ml)	Modeled (cfu/100 ml)
BLC 8.1	2480	1405
BLC 3.9	3255	4555
BLC 1.2	5325	7760
BLC 0.3	3846	7715

Note that the lower two sampling locations (BLC 1.2 and BLC 0.3) are also modeled with SD1's water quality EFDC model of lower Banklick Creek, lower Licking River and the Ohio River (LimnoTech 2009). Comparison of the outputs from each model indicate that the HSPF watershed model has tended to be the more conservative water quality model (e.g. predicting worse water quality impact) than the EFDC model, mainly because the EFDC model can simulate the effects of Ohio River and Licking River backwater on bacteria losses and transport in this lower portion of Banklick Creek. The results from this corroboration exercise of the HPSF watershed model suggest that this difference between models will persist as SD1 continues to apply the models to evaluate source control opportunities. Nevertheless, all models have inherent uncertainty and limitations in their ability reproduce all observed conditions so use of both models provides an envelope of water quality impacts that is more informative than use of either model alone.

Conclusions

The dry-weather inputs to the Banklick Creek model have been updated to reflect additional samples collected in 2008 and 2009. The model is reasonably reproducing the range of dry-weather fecal coliform levels in the updated dataset.

The corroboration of the HSPF model with the three wet-weather events sampled in 2009 confirms that the the Banklick model provides a reasonable reproduction of instream fecal coliform levels and is the best tool available for evaluating instream impacts from fecal coliform sources, including CSOs and SSOs, throughout the watershed under a range of environmental conditions and control scenarios.

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LimnoTech
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DATE: November 6, 2007

MEMORANDUM

FROM: Jeremy Grush

TO: Jim Gibson (SD1)

CC: Carrie Turner (LimnoTech)
SUBJECT: Development of an EFDC Hydrodynamic Model Grid of the Ohio River, Licking River, and Banklick Creek

Introduction

The Sanitation District No. 1 (SD1) and the Metropolitan Sewer District of Greater Cincinnati (MSD-GC) are collaborating to construct and calibrate an extended EFDC model of the Ohio River and its major tributaries. This work is being initiated by SD1 and will be conducted for the District by LimnoTech (LTI) building upon previous work by MSD-GC. In keeping with the common goal of addressing water quality issues through coordinated, watershed-based solutions, the intent of the two districts is to work cooperatively on the development of the model. The purpose of this memorandum is to describe the LimnoTech's development of a detailed model grid. The following is an outline of this memorandum:

- Model Overview
- Computational Domain
- Bathymetry and Roughness Characteristics

Model Overview

The extent of the two-dimensional EFDC hydrodynamic model of the Ohio River includes approximately 90 miles of the Ohio River. The downstream boundary of the model is located at Markland Dam near Warsaw, Kentucky (River Mile 532.7) and the upstream model extent on the Ohio River is at River Mile 443.4 near the county line between Campbell and Pendleton Counties, approximately 7 miles downstream of Meldahl Dam. Approximately 5.5 miles of the Licking River and 4.0 miles of Banklick Creek are also included in the model domain. Both of these tributaries are modeled from their mouths up to their respective intersection with the I-275 Interstate Highway Bridge. Figure 1 illustrates the model domain with an inset map of the Licking River and Banklick Creek portion of the model. MSD-GC and XCG plan to expand the model grid domain to include the major tributaries in Cincinnati, which include the Little Miami River and Mill Creek.

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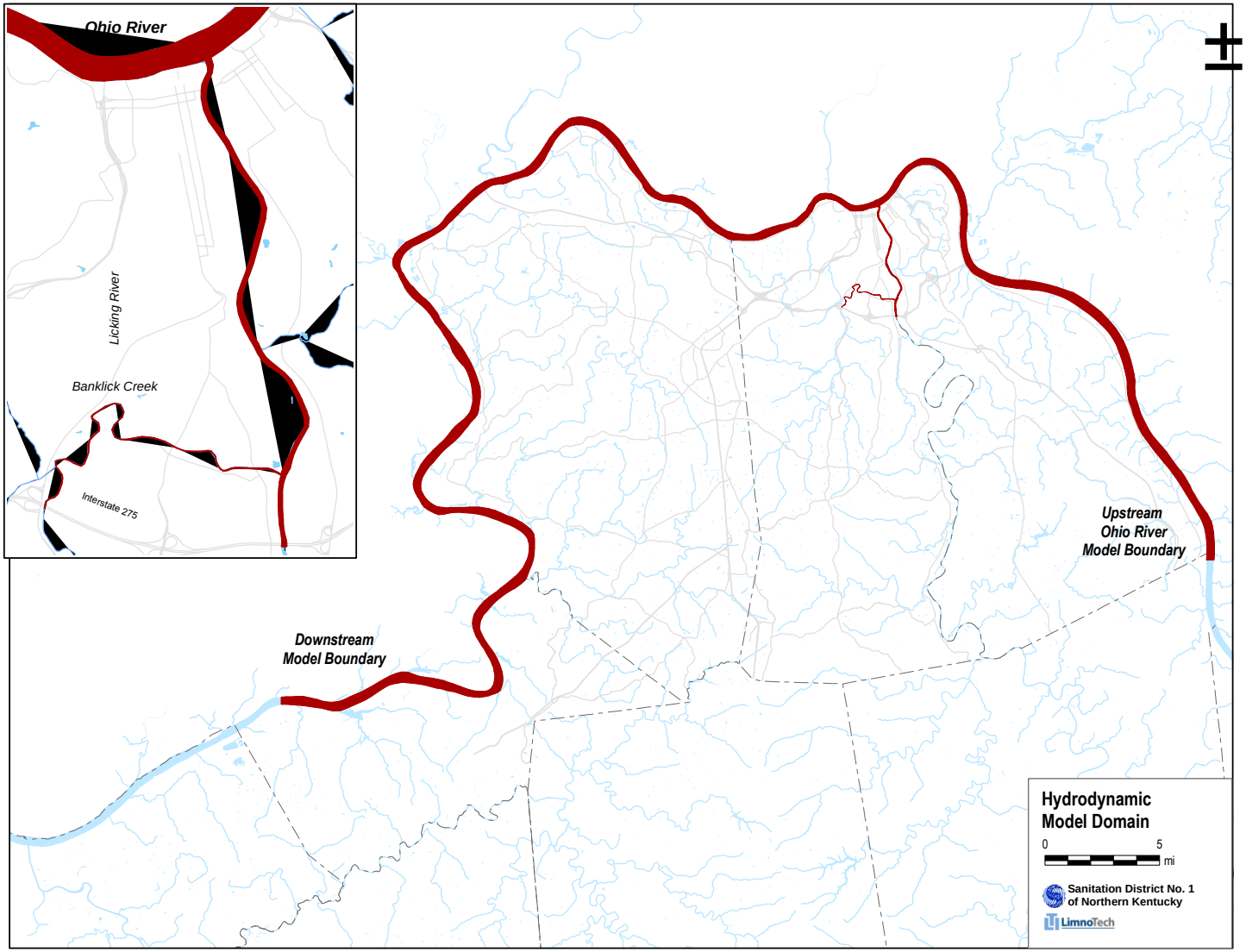

Figure 1: Hydrodynamic Model Domain

Water levels are controlled at the Markland Dam by the United States Army Corps of Engineers. The dam is typically operated to maintain the water surface elevation at a pool elevation of 455 feet, Ohio River Datum. The Licking River and Banklick Creek experience backwater when the stage is elevated on the Ohio River, but otherwise, hydrodynamic conditions in these tributaries are controlled by local meteorology and topography. For this reason, hydrodynamic conditions in Banklick Creek and the Licking River change substantially in nature during a wet weather event.

Computational Domain

The computational domain for this EFDC model was developed with the following goals:

- Consistency and collaboration with XCG in their modeling for the MSD-GC;
- Characterization of hydrodynamic conditions in the system;
- Allowance for the lateral mixing of constituents in the Licking and Ohio Rivers;
- Accommodation for important tributary and combined sewer overflow (CSO) loadings as input to the water quality model;
- Assurance of model stability by minimizing deviations from grid cell orthogonality;
- Maximization of grid dimensions to reduce model run-times.

The computational grid covering the Ohio River is modeled with five cells across the width of the channel. This degree of lateral resolution was chosen for consistency with previous modeling of the Ohio River (e.g. ORSANCO, XCG) while also recognizing that five cells provides sufficient resolution to describe lateral variability in hydrodynamic and water quality conditions. Model cells vary in length from approximately 30 meters to 600 meters.

Generally, the preliminary model grid is consistent with the XCG model grid (which spans river mile 460 to river mile 490), except for areas where more resolution was added to either improve grid orthogonality or to allow for tributary or CSO loadings. In particular, grid resolution was refined at the confluence of the following tributaries with the Ohio River: Licking River, Little Miami River, Great Miami River, Mill Creek, Taylor Creek, Dry Creek, and Twelvemile Creek. The preliminary grid between river mile 460 and river mile 490 was developed by aligning cell edges with grid cells from XCG's model grid. If finer resolution was needed to accommodate a tributary input or river bend, the preferred approach was to subdivide these grid cells. In this way, the preliminary grid is consistent with XCG's model grid. Grid cell indexing was offset by 50 cells to allow for the addition of the Ohio-side tributaries by XCG.

The Licking River was modeled with three cells across the channel width in order to account for potential lateral gradients in constituent concentrations and to accommodate source loadings from CSOs. Model cells vary in length from 25 meters to 230 meters. Banklick Creek is modeled with one cell across the channel. This grid was developed with the intention of modeling hydrodynamics as accurately as possible with reasonable grid resolution.

Seagrid, a MatLab-based grid development tool provided by the USGS, was used to develop the model grid. Seagrid and other grid processing tools were used to ensure grid orthogonality and also allow for efficient updates to the model grid. Because Seagrid will not allow less than six cells in the lateral direction, the grid was initially built with ten cells in the lateral direction and then "dissolved" in the lateral direction to five cells in the Ohio River. Grid dissolution was also performed on the Licking River and Banklick Creek in the longitudinal direction in order to limit the minimum timestep required for hydrodynamic simulation. The model grid was boundary-fitted to a detailed delineation of the Ohio River shoreline generated in GIS by the Sanitation District, and to an LTI-generated shoreline feature for Banklick Creek and the Licking River. Table 1 displays the number of grid cells per modeled reach.

Table 1: Number of Grid Cells per Reach

Reach	Number of Grid Cells
Ohio River	2,475
Ohio River – XCG model domain	1,094
Licking River	210
Banklick Creek	68

Figure 2 shows a subset of the model grid at the mouth of the Licking River and the mouth of Banklick Creek. This figure shows how the model grid resolution was increased at tributaries to accommodate their connections with the Ohio River and at bends in the river to improve grid orthogonality.

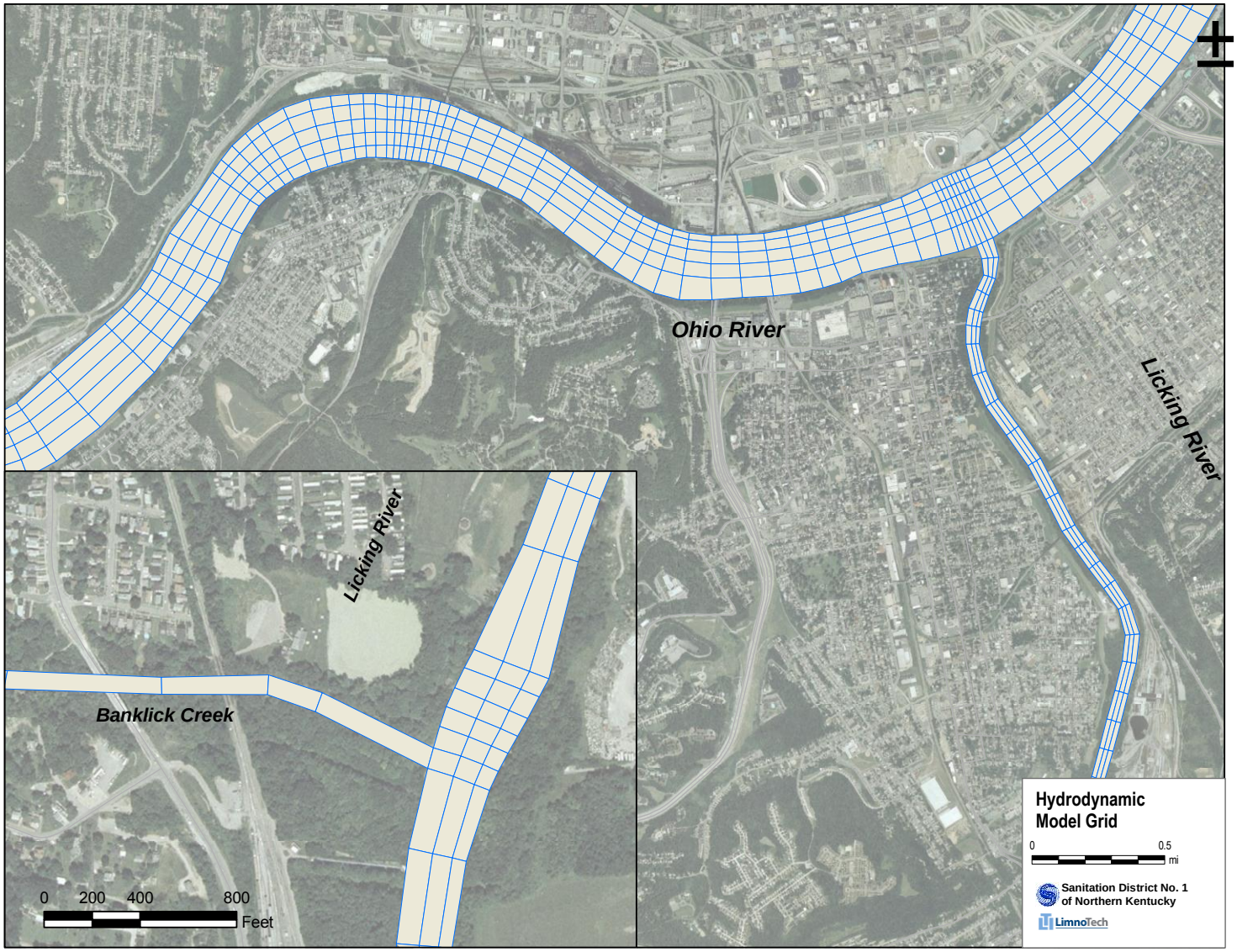

Figure 2: Hydrodynamic Model Grid

Model Bathymetry and Roughness Characteristics

Detailed bathymetric data was used to specify model bathymetry in the Ohio River, Licking River, and Banklick Creek. Bathymetric data for the Ohio River was obtained from two sources: detailed bathymetric surveys from the United States Geological Survey (USGS, 2006) and the United States Army Corps of Engineers (1997). Lateral transects at 500 foot intervals were obtained from the USACE and lateral transects at 800 foot intervals were obtained from the USGS study. The USACE dataset covered the entire Ohio River model extent and overlapped the USGS dataset. A visual comparison between elevations from both dataset showed close agreement. The USGS bathymetric dataset was used in regions of overlapping data because it was collected more recently. Figure 3 shows the extent and resolution of the two sets of bathymetric data that were used to develop model bathymetry for the Ohio River.

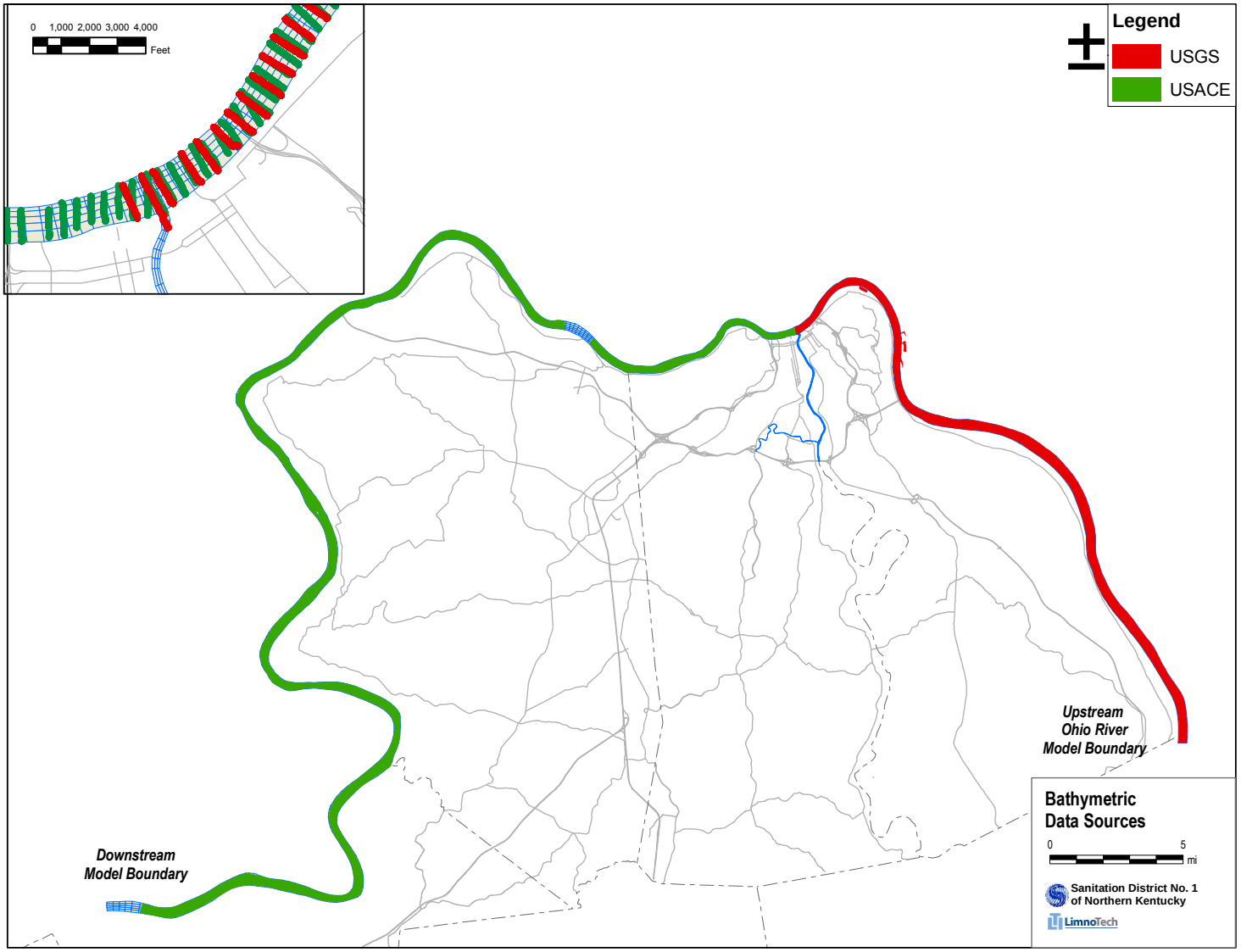

Figure 3: Bathymetric Data Sources

Interpolation of the Ohio River bathymetric data was required in order to have a continuous set of bathymetric data over the Ohio River. 'Geostatistical Analyst,' an ArcGIS extension, was used to perform the interpolation. This method was preferred to generating a triangular irregular network (TIN), because the TIN would not perform well between transects due to the spacing of bathymetric transects. A set of 'shoreline' points at elevation 455 feet (Ohio River Datum), was used in addition to the bathymetric transects as input to the geostatistical interpolation.

Ordinary Kriging was used as an interpolation method. The following list summarizes parameters that were used for the interpolation:

- Spherical semi-variogram model
- Zero nugget effect, recognizing that uncertainty in the data is minimal
- Semi-variogram was modeled with anisotropy due to the difference in spatial patterns in the longitudinal and lateral directions
- An ellipsoid was specified for the search neighborhood with the major axis occurring in the longitudinal direction

Prior to the interpolation, the model grid and bathymetric dataset were both 'straightened' in order to improve the interpolation. The straightening routine preserves geometry while projecting the grid so that no curvature exists. Grid straightening improves the geostatistical interpolation by forcing the axes of anisotropy to be predominantly in two directions. After the interpolation is performed, each grid cell receives an average value from the surface. The average elevation attribute of each straightened grid cell is then also attributed to the model cells in the real or curved grid.

Licking River bathymetry was adapted from a RMA-2V model that was developed by LTI for the Sanitation District in the mid-1990s. These bathymetric transects were again interpolated using the Geostatistical Analyst in ArcGIS. Bathymetric data for Banklick Creek was adapted from a HEC-2 model. Model bathymetry for Banklick Creek was selected from the thalweg of each HEC-2 transect. A third-order polynomial was fit through the thalweg elevations in order to generate a smoothed longitudinal profile. Abrupt changes in bottom elevation that would occur in the absence of this interpolation cause model instabilities during low flow conditions.

LTI collected detailed bathymetric data for the Licking River and Banklick Creek in late 2007. Bottom surface elevations were measured at between 10-20 points across each transect in the Licking River and between 5-10 points across each transect in Banklick Creek. Bathymetric transects were evaluated approximately every 0.5 miles in the Licking River between river mile 5.5 (near the I-275 bridge) and the mouth. Bathymetric transects were evaluated approximately every 0.25-0.50 miles in Banklick Creek between river mile 4.0 (near Eaton Dr) and the mouth. These data are the primary source of bathymetric data for the modeling of these tributaries.

Model roughness was initially set to one millimeter for all cells. Roughness height is assumed to be proportional to sediment grain size and is also related to bed forms. Bed roughness likely has minimal influence on hydrodynamics on the large, heavily flow-regulated Ohio River, but some adjustment to this parameter may be done during the hydraulic calibration.

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DATE: November 25, 2008

MEMORANDUM

FROM: Jeremy Grush
TO: Jim Gibson (SD1)
CC: Carrie Turner (LimnoTech), Mindy Scott (SD1)

SUBJECT: Hydraulic Calibration of the EFDC Model of the Ohio River, Licking River and Banklick Creek

Introduction

The Sanitation District No. 1 (SD1) and the Metropolitan Sewer District of Greater Cincinnati (MSD-GC) are collaborating to construct and calibrate an extended EFDC model of the Ohio River and its major tributaries. This work is being initiated by SD1 and will be conducted for SD1 by LimnoTech (LTI) building upon previous work conducted by XCG Consultants (XCG) for MSD-GC. In keeping with the common goal of addressing water quality issues through coordinated, watershed-based solutions, the intent of the two districts is to work cooperatively on the development of the model. The purpose of this memorandum is to describe LimnoTech's hydraulic calibration of this EFDC model. The following is an outline of this memorandum:

- Hydraulic Calibration Overview
- Available Data
- Model to Data Comparisons
- Model Uncertainty

Hydraulic Calibration Overview

The calibration strategy of the EFDC model was to accurately predict water levels (e.g. stage) and velocities observed in the Ohio River over a range of flow conditions. In particular, the model was calibrated to level data from base flow conditions up to approximately a 5-year flood event. Three datasets were available to compare model predictions to data for calibration:

- Water level (stage) data measured at Cincinnati, Ohio and estimated at the model's upstream boundary,
- Acoustic Doppler Current Profiler (ADCP) velocity data along the model's upper reach, and
- Water level (stage) data measured in Banklick Creek at river miles 0.3 and 1.2 during 2002 and 2003.

Calibration focused on predicting typical stage conditions as well as the timing of flow through the system. These two characteristics of flood flows are particularly important to accurately predict water quality conditions during wet weather events.

Model calibration to Ohio River data was achieved primarily by adjusting roughness until a suitable model-to-data fit was achieved for the water level data and ADCP data. A uniform roughness height of two millimeters was used to achieve the calibration. This roughness height is assumed to be proportional

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to roughness elements contacting the wetted perimeter of the river. It also reflects possible bedforms that cause resistance to flow. This roughness value is similar to values used to calibrate other large river models in the Midwest, such as the Upper Mississippi River (Hydrodynamic Model Development and Application for the Upper Mississippi River between I-694 and Ford Dam 2007) and upper Ohio River (Wheeling Use Attainability Analysis Demonstration Project Final Report, ORSANCO 2007)

No single value of roughness could reproduce the range of stage conditions observed at Cincinnati. The calibration sacrificed goodness of fit to high stage (and high flow) conditions to achieve a better calibration at lower flows that occur more frequently and are more representative of typical conditions that are often used in CSO control planning. The model to data fit of the ADCP data indicate that the model is well constrained with respect to predicting lateral variations in velocity, which is necessary for predicting the spatial variation of constituents during water quality simulations. The model's fit to both calibration targets (stage and velocity) suggest that model predictions of travel of time are reasonable, which will inform the downstream impact of source loads originating from SD1, MSD-GC and nonpoint sources in the Cincinnati/Northern Kentucky metropolitan area.

The Banklick Creek level data offers a second dataset for evaluating the hydraulic model performance for a system with very different characteristics than the Ohio River. Banklick Creek differs from the Ohio River in several ways: 1) size (average annual stream flow is 33 cfs in Banklick Creek and 45,600 cfs in the Ohio River); and 2) regulation (the Ohio River level is controlled by Markland Dam downstream and flow is controlled by Meldahl Dam upstream whereas only the most downstream mile on Banklick Creek level is affected by backwater effects from the Ohio River during typical flow conditions). Banklick Creek is simulated within the EFDC model using a one-dimensional configuration. The calibrated model reasonably predicted the Banklick Creek level data.

However, subsequent simulations over a wider range of flows indicated that the original channel geometry in Banklick Creek occasionally resulted in dry bed conditions at low flows. The channel geometry was adjusted or smoothed to maintain flow at all times at KY 177 (RM1.2) and the fit to the level data was reevaluated with the new geometry. Model to data comparison indicates that the model predicted elevations are lower than the data. However, the bottom surface elevation at KY 177 was set to a lower value as part of the geometry smoothing. Comparisons of velocities between the two geometries are similar, suggesting that hydraulic residence times and time of travel are consistent between the two geometries. Additional discussion is provided in the Model Results section of this memorandum.

Available Data

Ohio River

Hydrologic data from the United States Army Corps of Engineers (USACE) and the United States Geological Survey (USGS) provided a source for calibration comparisons. Hourly stage data from 1998 through 2007 were available at Cincinnati and at the Meldahl Dam tailwater (which is located approximately 7 miles upstream of the EFDC model upstream boundary). Data from the Cincinnati gauge was used directly, while an interpolation between the Cincinnati gauge and the Meldahl gauge provided an estimate of the hourly stage at the model's upstream boundary. The USGS collected velocity ADCP data in 2005 as part of a study that was intended to support future hydrodynamic modeling of the Ohio River. These two data sources were the principal datasets used in the hydraulic calibration.

Other datasets were used to specify the forcing functions at the model boundaries. The USACE maintains gauges above and below the Markland Dam control structure. The stage data from the gauge in the pool (above the dam control structure) were used as downstream forcing functions in the EFDC model. The

stage dataset is very detailed, offering an hourly record for use in the model. Model forcings that use measured data provide much more constraint of the model and its associated uncertainty than boundary inputs that are based on processed or estimated data.

Several data sources were used to develop the flow inputs at the model's upstream boundary, including the USACE and the USGS. The USACE stage-discharge rating curve was the primary data source for specifying flow in the Ohio River. The flow predicted by the USACE at Cincinnati, Ohio was adjusted by six hours to account for travel time between the model upstream boundary and the gauge in Cincinnati. Tributary inflow timing was also adjusted according to estimated travel time between gauges and the Ohio River. Additionally, the USACE rating curve was adjusted slightly to better represent high flow measurements made by the USGS. A linear function was fitted to the relationship between flow and stage above a stage of 460 feet (above the North American Vertical Datum of 1988 (NAVD88)).

Gauge data from the USGS were used to estimate tributary inflows from the Little Miami River, the Licking River and the Great Miami River. Estimated flows from the Licking River and the Little Miami River were subtracted from the Cincinnati gauge flow estimates because these Ohio River tributaries discharge between the model's upstream boundary and the Cincinnati gauge. The flows for these tributaries and for the Great Miami River were added as boundary conditions into the model at their respective locations along the Ohio River. USGS flow data at hourly increments were used to specify these boundary conditions. All data used to specify boundary conditions were reviewed and edited to eliminate any corrupt data.

The original data sources used for the stage datasets report water surface elevations in different vertical datum references, including Ohio River datum (used by USACE) and NGVD29 (used by USGS). All of the stage data were converted to a consistent vertical datum reference (NAVD88) for use in the EFDC model using published conversion methods.

Banklick Creek

SD1 was awarded a federal grant to develop and implement a watershed assessment protocol to identify impairments and sources of these impairments. The protocol was tested in Banklick Creek in 2002-2004. SD1 installed continuous level meters at two locations in Banklick Creek, at KY177 (river mile (RM) 0.3) to monitor backwater effects from the Ohio and Licking Rivers, and at KY16 (RM 1.2), which is close to the mouth but generally less affected by backwater. These meters were deployed in October and November 2002, then again from May 2003 through September 2003. The data from August 2003 were used to evaluate the model performance. This period was characterized by low flow in the Ohio River so backwater effects were limited to the meter at KY177, a wide range of flows from the upper portion of the Banklick Creek watershed, and a relatively complete dataset because both meters were operational through the first 25 days of the month. This dataset provides the best contrast between the level meters: the meter at KY16 (RM 1.2) reflects upstream flows while the meter at KY177 (RM 0.3) reflects Ohio River stage conditions.

Model to Data Comparisons

Level Data Comparisons – Ohio River

Level data comparisons were the primary measure of successful calibration. Long-term records of water levels at Cincinnati, Ohio (river mile 470.5) and at the Meldahl Dam tailwater (river mile 436.2) were obtained from the USACE. Water levels at these two gauges were interpolated in order to estimate water levels at the model's upstream boundary (river mile 443.4). According to model results, the water surface

slope is nearly linear between these two locations over all flow conditions, so a linear interpolation was assumed sufficient for estimating water levels at the model boundary.

The USACE rating curve at Cincinnati, Ohio appears to more closely fit the stage-discharge measurements between stages of 460 feet and 465 feet than measurements at higher stages, so calibration focused on the accurate prediction of these levels. Over 99% of the hourly stage measurements (from 1998-2007) are less than 465 feet. The following charts show model predictions of water surface elevation at Cincinnati, Ohio and at the model's upstream boundary under a variety of conditions on the Ohio River. Flow conditions during the simulation period ranged from 10,000 cfs to 400,000 cfs.

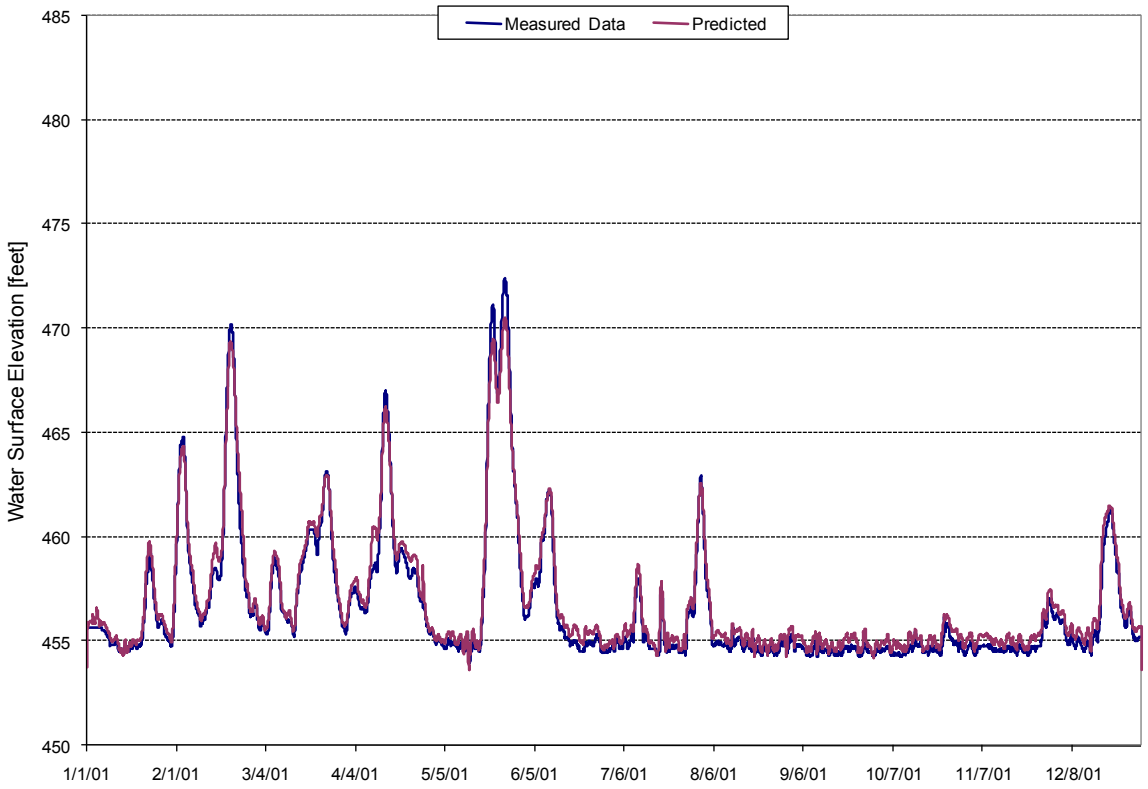


Figure 1: Model-to-Data Comparisons at Cincinnati, Ohio (RM 470.5)

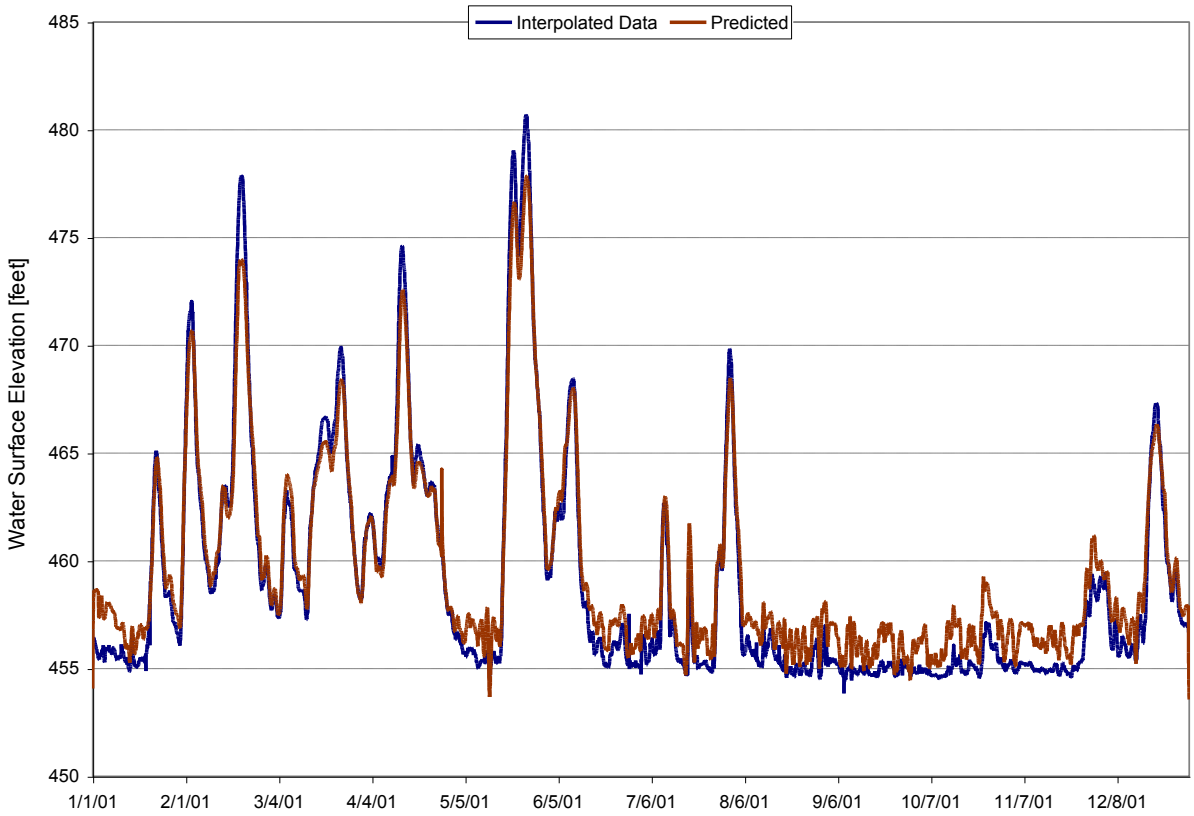


Figure 2: Model-to-Data Comparisons at the Upstream Boundary of the Model (RM 436.2)

Due to the length of this model, small changes in roughness cause observable differences in predicted water levels in the upstream reaches. The following figure illustrates the sensitivity of water levels at Cincinnati to model roughness by showing results from three simulations that use unique values of roughness.

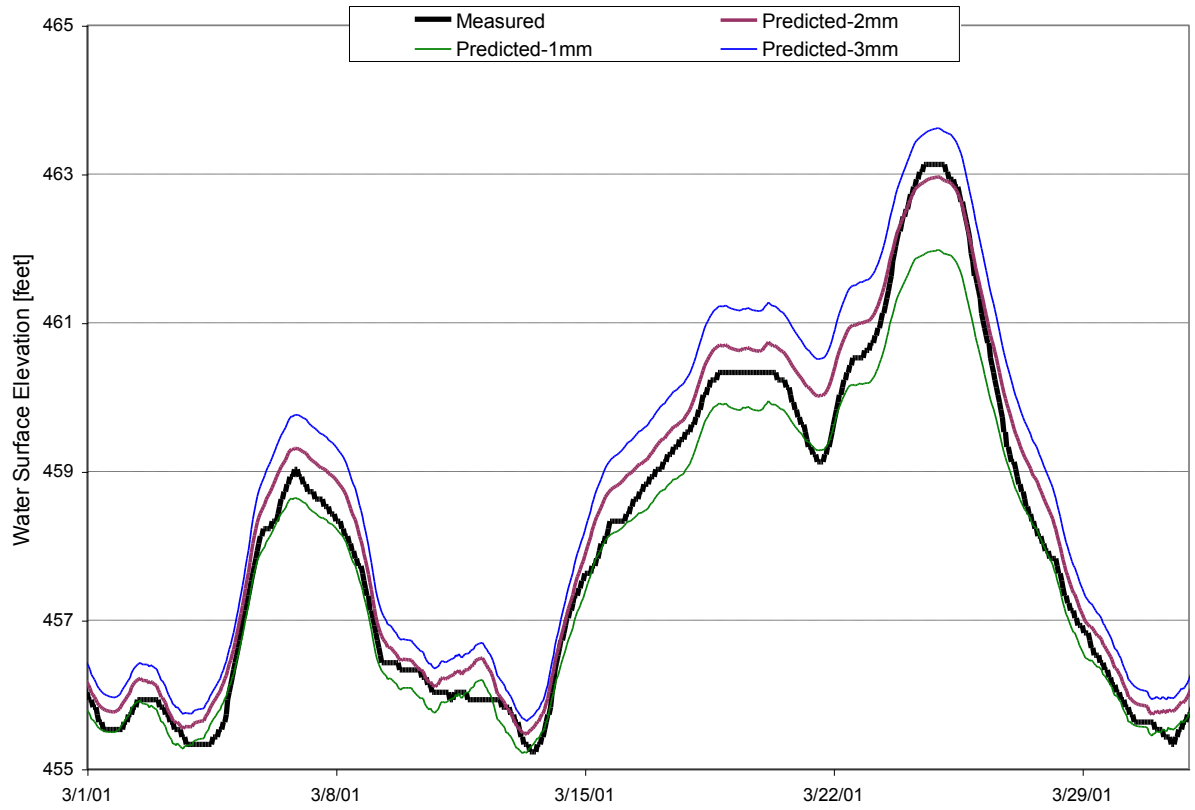


Figure 3: Model Sensitivity to Roughness Height at Cincinnati, Ohio

A roughness height of two millimeters was chosen because results show that peak stages are predicted most closely with this value of roughness. A smaller value of roughness produces better predictions of low-flow water levels, but this is likely due to the inexact prediction of discharge at low flows by the USACE rating curve. The rating curve based on Cincinnati data may be slightly inaccurate depending on conditions at Markland Dam. While the dam is operated to maintain a pool elevation of 455' (Ohio River Datum), the pool level fluctuates by about one foot. For this reason, a unique relationship between stage and discharge is not possible at lower flows, and discharge estimates may be inexact during low flow conditions. This explains some uncertainty in model predictions under low flow conditions.

Level Data Comparisons – Banklick Creek

Water level data at river mile 1.2 was used to assess the ability of the model to predict hydrodynamic conditions in Banklick Creek because water levels at RM 0.3 reflect Ohio River stage conditions, which are specified as a forcing function (e.g. boundary) in the model (see Figure 4).

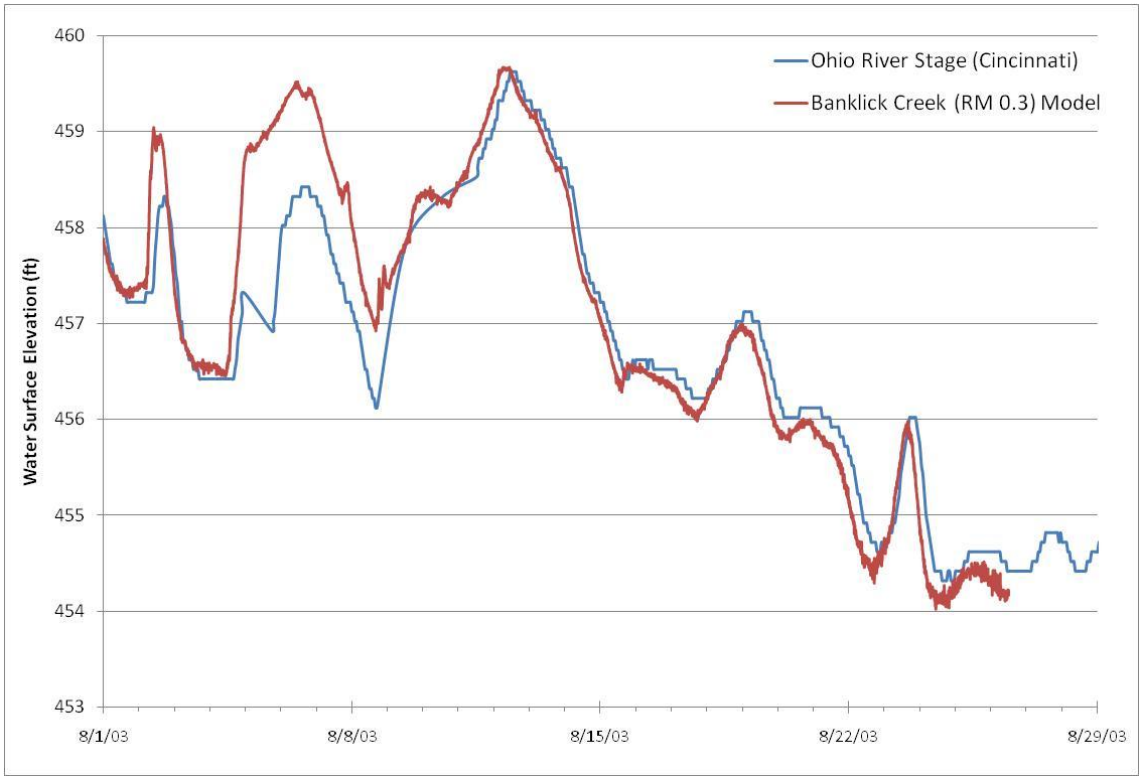


Figure 4: Model-to-data Comparison of Water Levels at Banklick Creek KY16 (RM 0.3) and Ohio River in Cincinnati.

Initially, the model geometry in Banklick Creek was estimated by linear interpolation between bathymetric cross-section measurements that LimnoTech made in 2007. A comparison of model-predicted water levels to measured water levels in Figure 5 shows that the model produces accurate predictions.

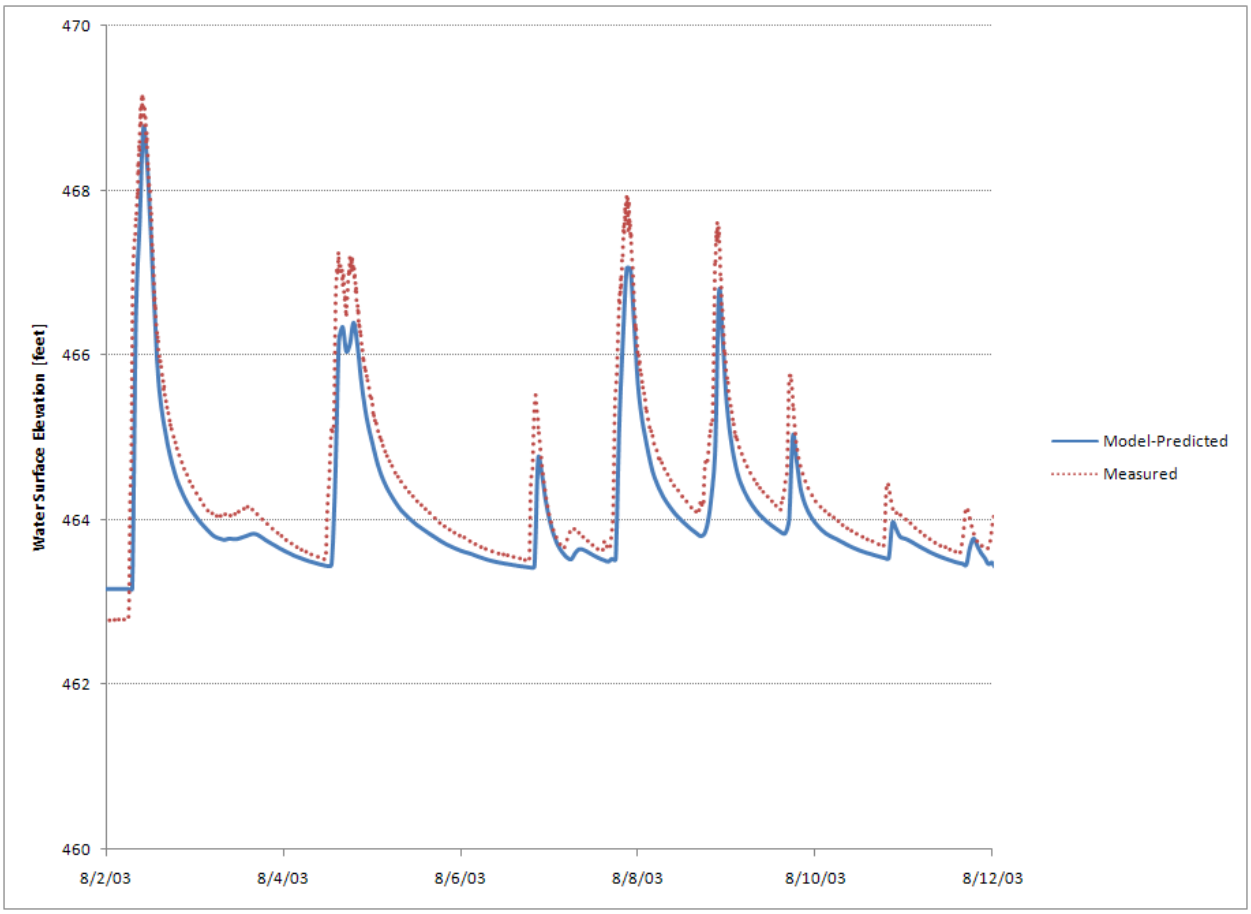


Figure 5: Model-to-data Comparison of Water Levels at Banklick Creek KY177 (RM 1.2) using Original Geometry

However, model stability was compromised by strictly interpolating cross-section measurements due to the coarseness of the model grid and the sometimes steep bed slope of Banklick Creek. In order to achieve model stability under low flow conditions, bed elevations were slightly modified. Figure 6 shows the strictly interpolated and the "smoothed" longitudinal average bed elevation profiles of Banklick Creek.

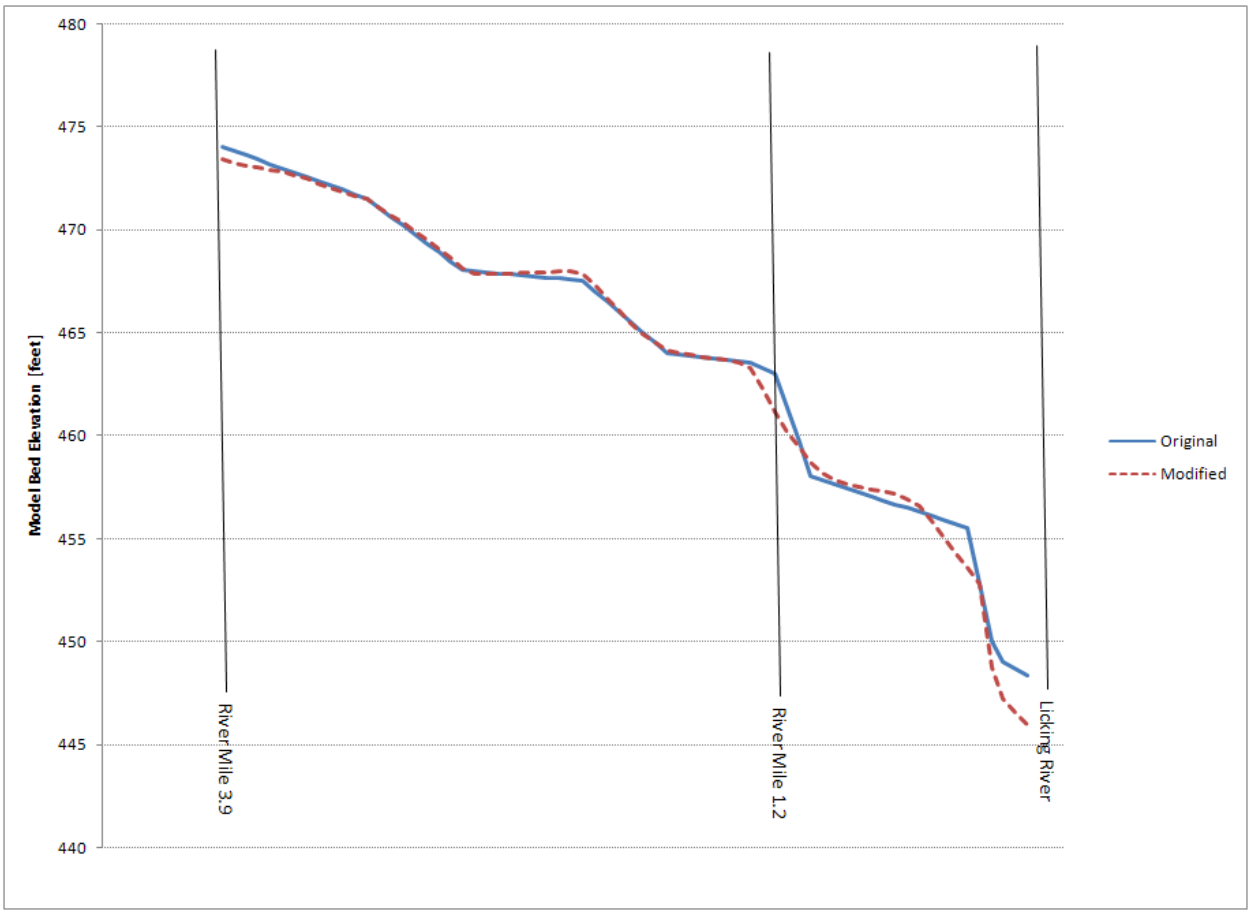


Figure 6: Comparison of Original Bed Elevation Profile to Modified Bed Elevation Profile on Banklick Creek

Model results using the modified bed elevations were compared to the August 2003 water level data. Results in Figure 7 show that the modified bed produces slightly lower water surface elevations compared to the data. This likely reflects the change is bottom surface elevation at this river mile (see Figure 6) as the difference in predicted water surface elevations in the two simulations are roughly equivalent to the difference in bottom surface elevations. Figure 8 shows a one-to-one comparison of velocities at river mile 1.2 between the original Banklick Creek geometry and the modified Banklick Creek geometry. The difference in velocity is nominal, suggesting little difference in travel and residence times and correspondingly little impact on predicted water quality concentrations.

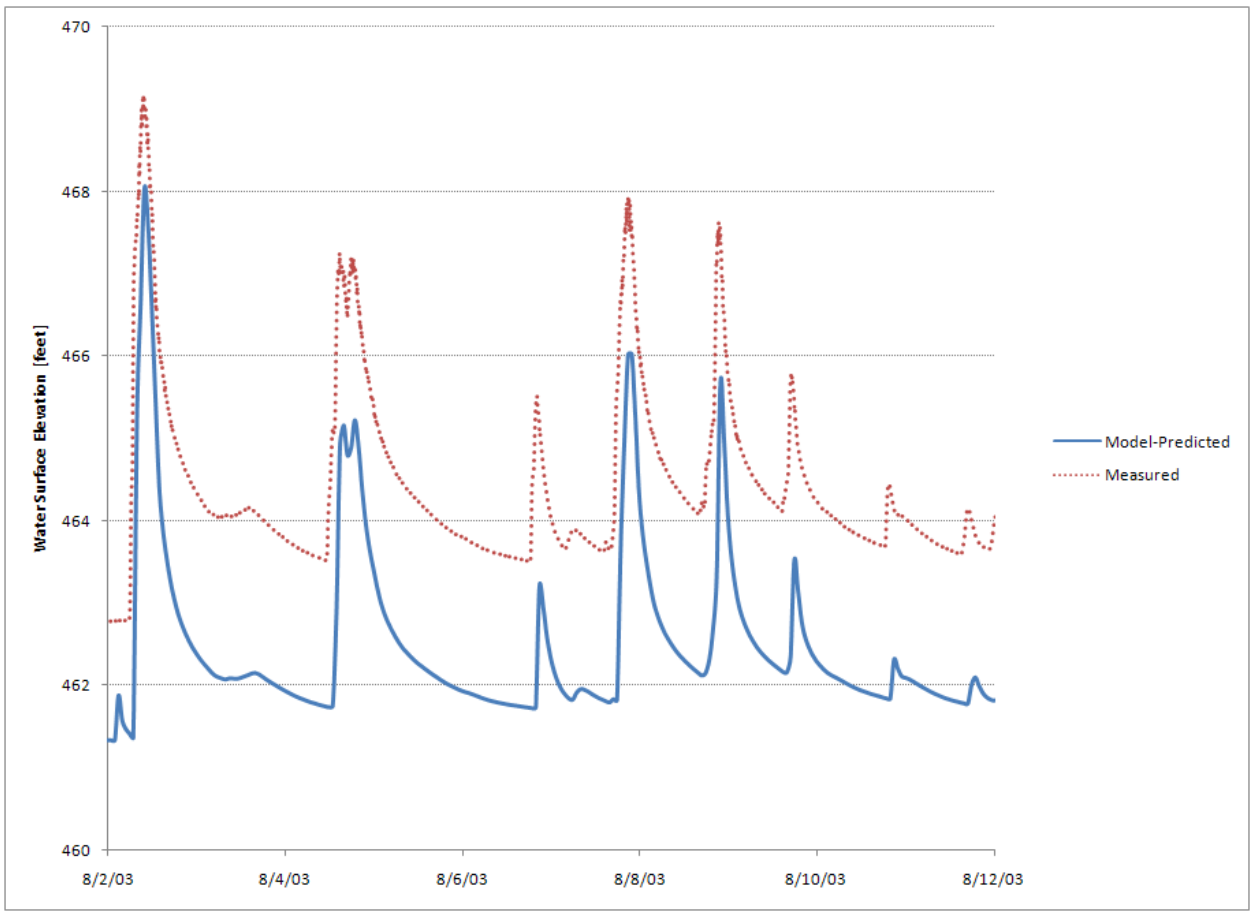


Figure 7: Model-to-data Comparison of Water Levels at Banklick Creek RM 1.2 using Modified Geometry

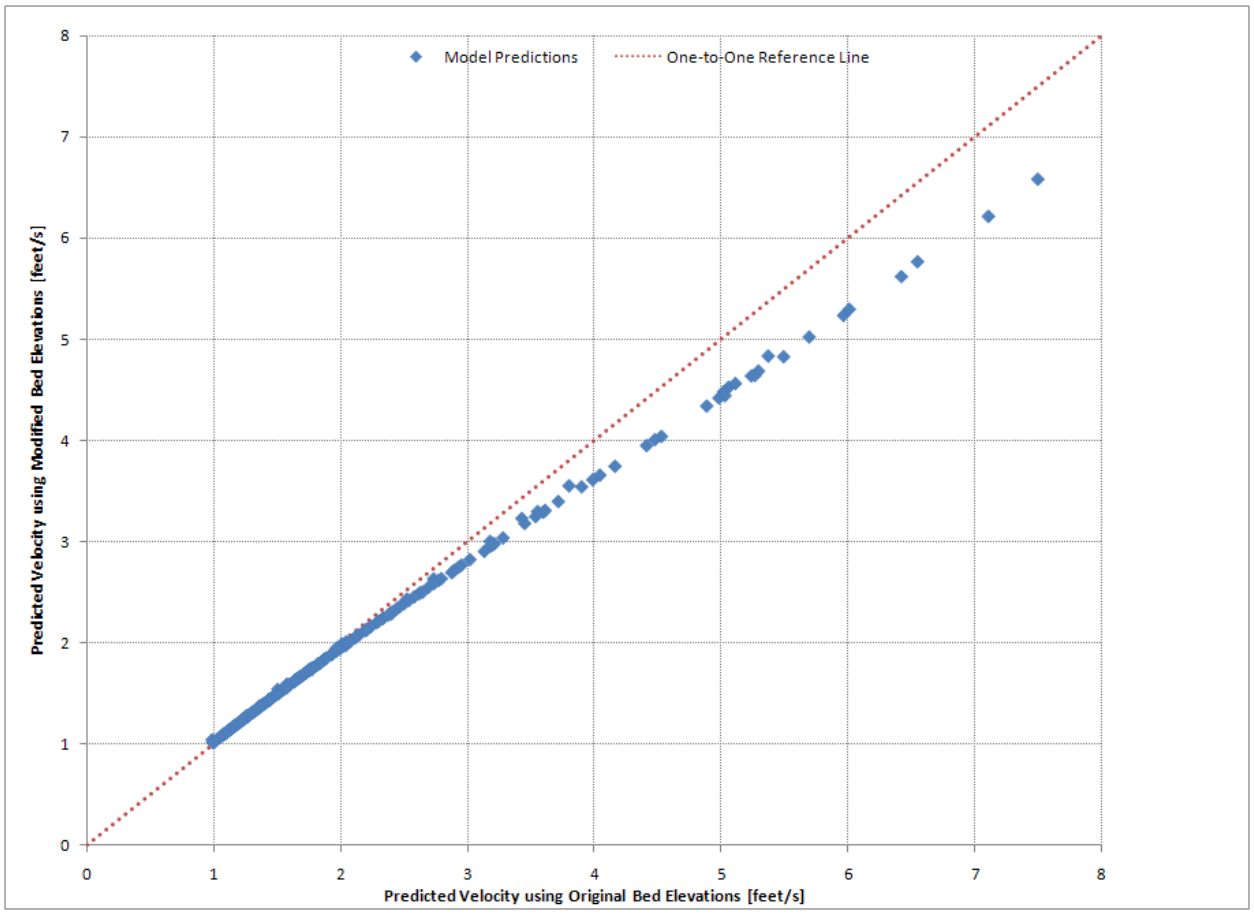


Figure 8: Comparison of Model Predicted Velocities using Original Geometry and Modified Geometry

To maintain model stability over the range of flows anticipated in planning scenarios, the modified geometry will be used to complete the calibration and apply the model for scenario planning.

Velocity Data Comparisons

Nineteen transects of Acoustic Doppler Current Profiler (ADCP) data, which measure water velocity, were used to evaluate model performance. Accurately predicting lateral variations in velocity is necessary for predicting the spatial variation of constituents during water quality simulations. The USGS collected ADCP data in August 2005 as part of a mixing study (USGS, 2007). Figure 9 shows the location of ADCP transects that were used to evaluate model performance.

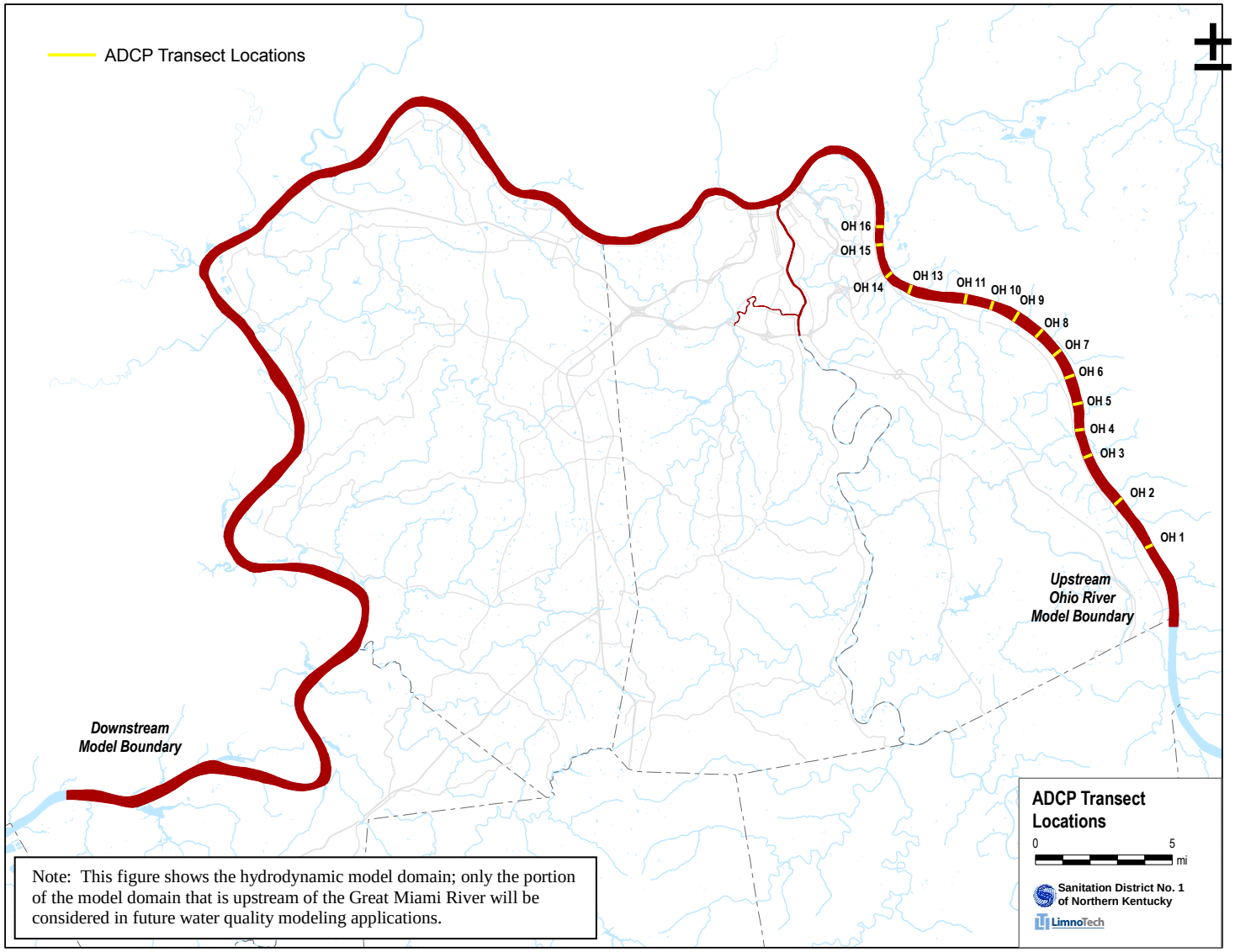
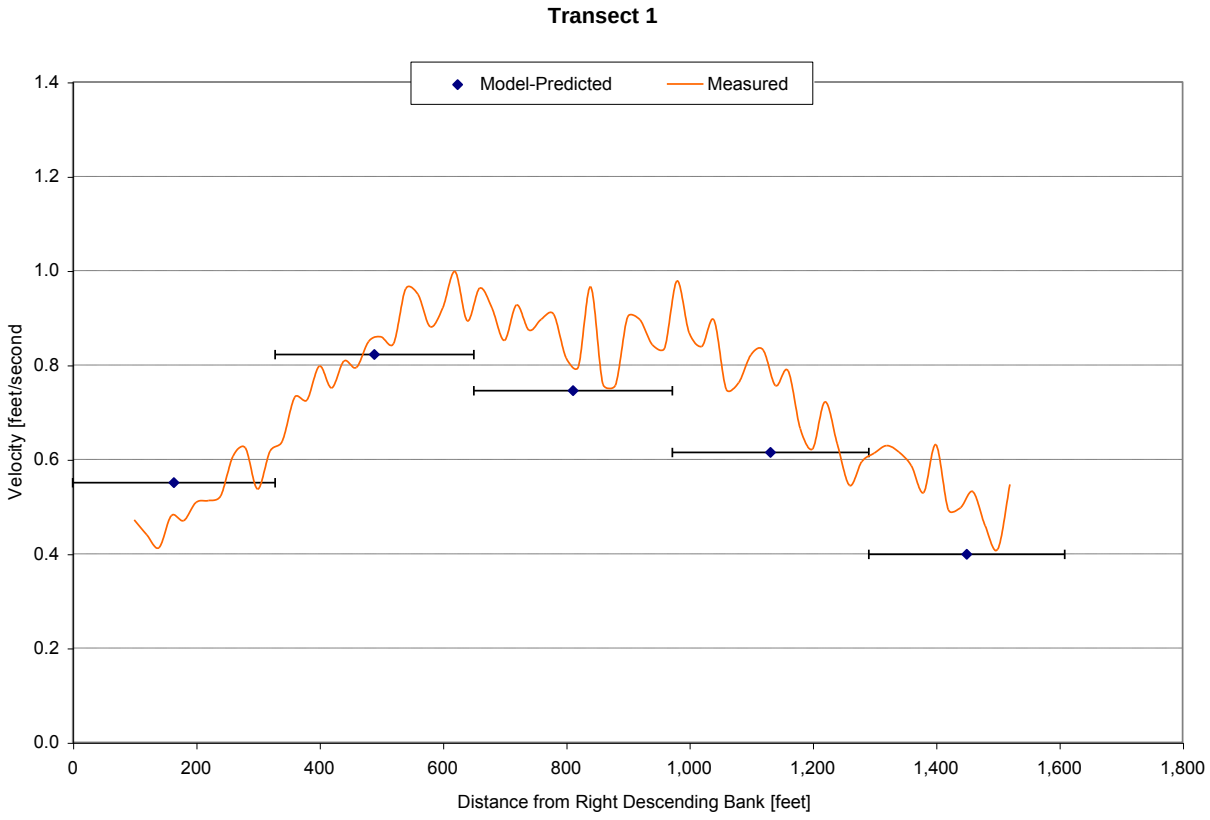


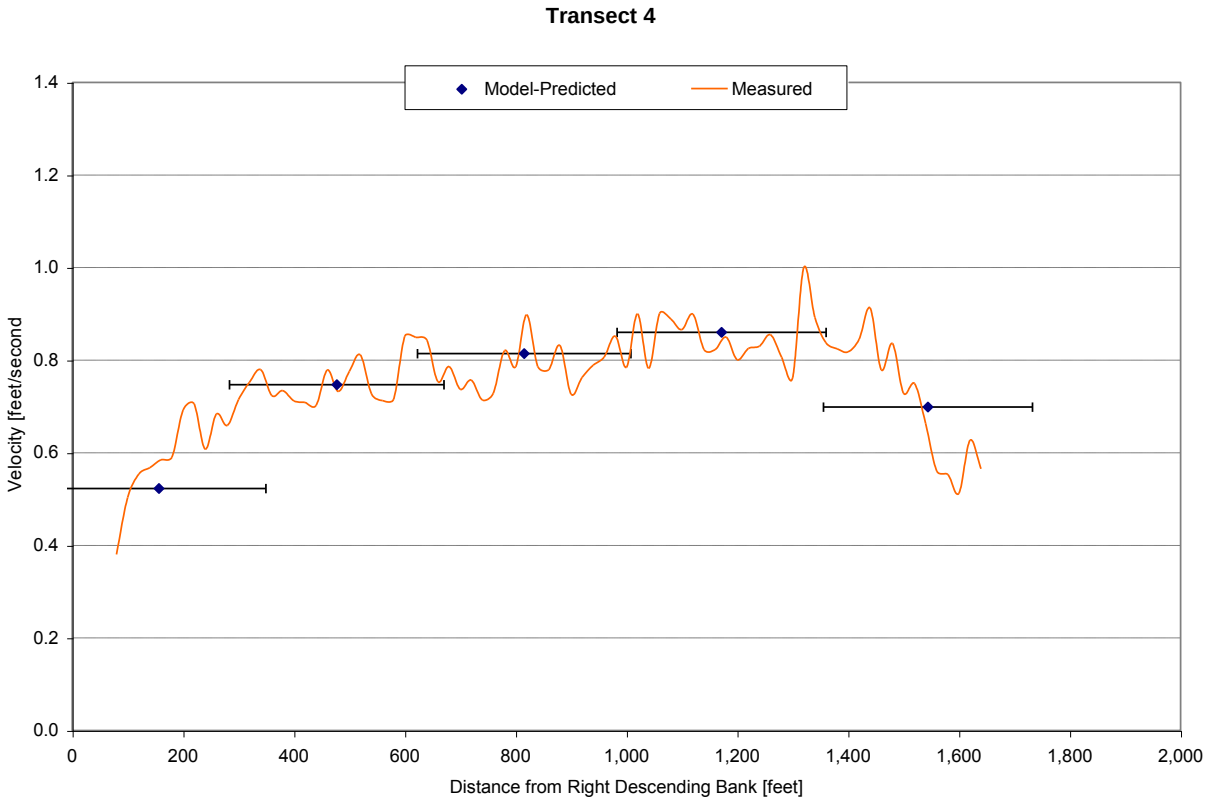
Figure 9: ADCP Transect Locations

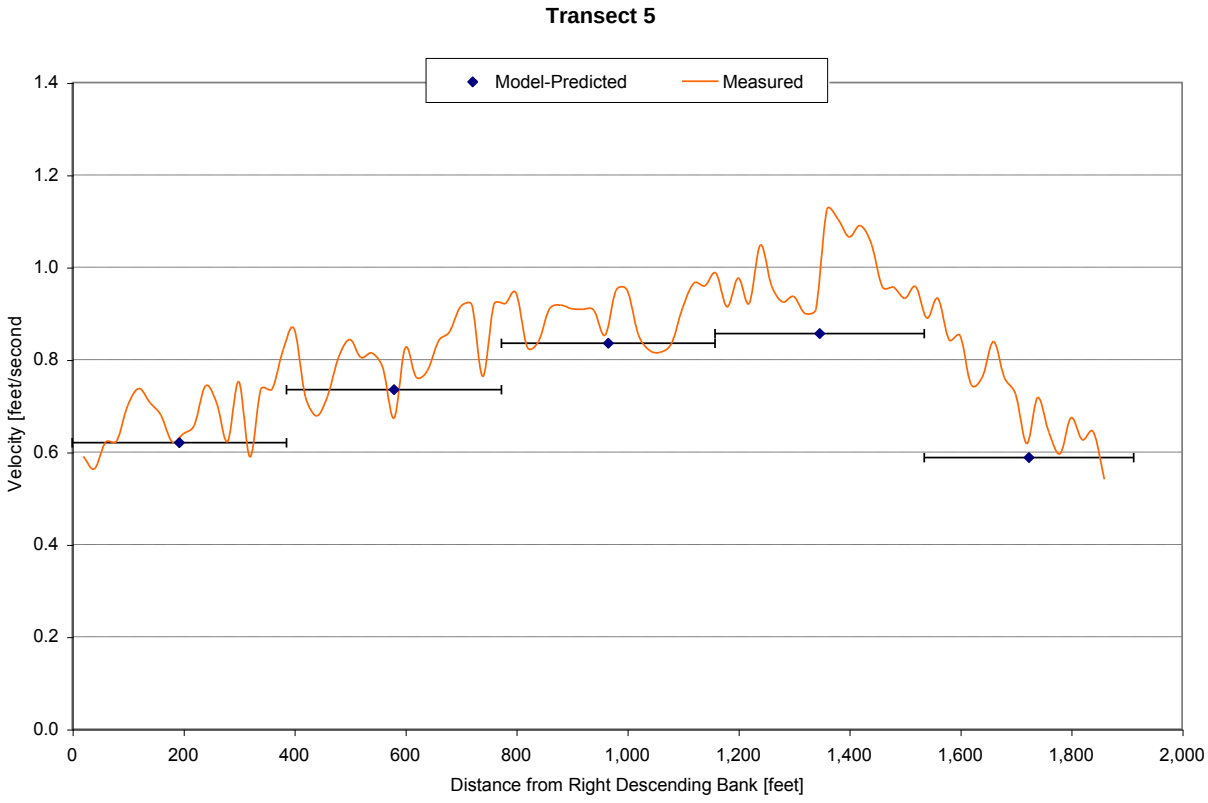
The ADCP data were processed so that appropriate comparisons could be made to model results. The two-dimensional EFDC model predicts depth-averaged values of velocity at each grid edge. The ADCP data were averaged over the depth of the water column for comparison. The ADCP measurement device measures velocity over the majority of the water column, but due to physical constraints, the device cannot measure velocities near the water surface, river bed, and near the river banks. Estimates of velocities in each of these zones were made to arrive at an accurate estimate of depth-averaged velocity and discharge at each location.

Model simulations were conducted so that model-predicted velocities could be compared to ADCP-measured velocities. The upstream flow boundary condition for these simulations was developed by calculating a flow rate from the ADCP data. The USACE rating curve was not used to estimate flow rate because the rating curve tends to be more uncertain at low flows, as noted previously (further discussion of this behavior is also provided in the "Model Uncertainty" section of this memorandum). Flow estimates are somewhat uncertain, likely biased low, because flow in the zones of each transect that cannot be measured were not accounted for in the calculation. Generally, the model will, therefore, tend to under-predict velocities compared to the ADCP data.

The following figures show several comparisons between model-predicted velocities and ADCP depth-averaged velocities. Transects were selected for comparison based on their location relative to key landside inputs, such as near the confluence of Twelvemile Creek. Horizontal bars at each EFDC model data point represent the width of the EFDC grid cell. An overall assessment of the model's performance indicates that the model performs well in reproducing the lateral velocity profiles.




Transect 4
Model-Predicted
Measured
Velocity [feet/second
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Distance from Right Descending Bank [feet]


Transect 5
Model-Predicted
Measured
Velocity [feet/second
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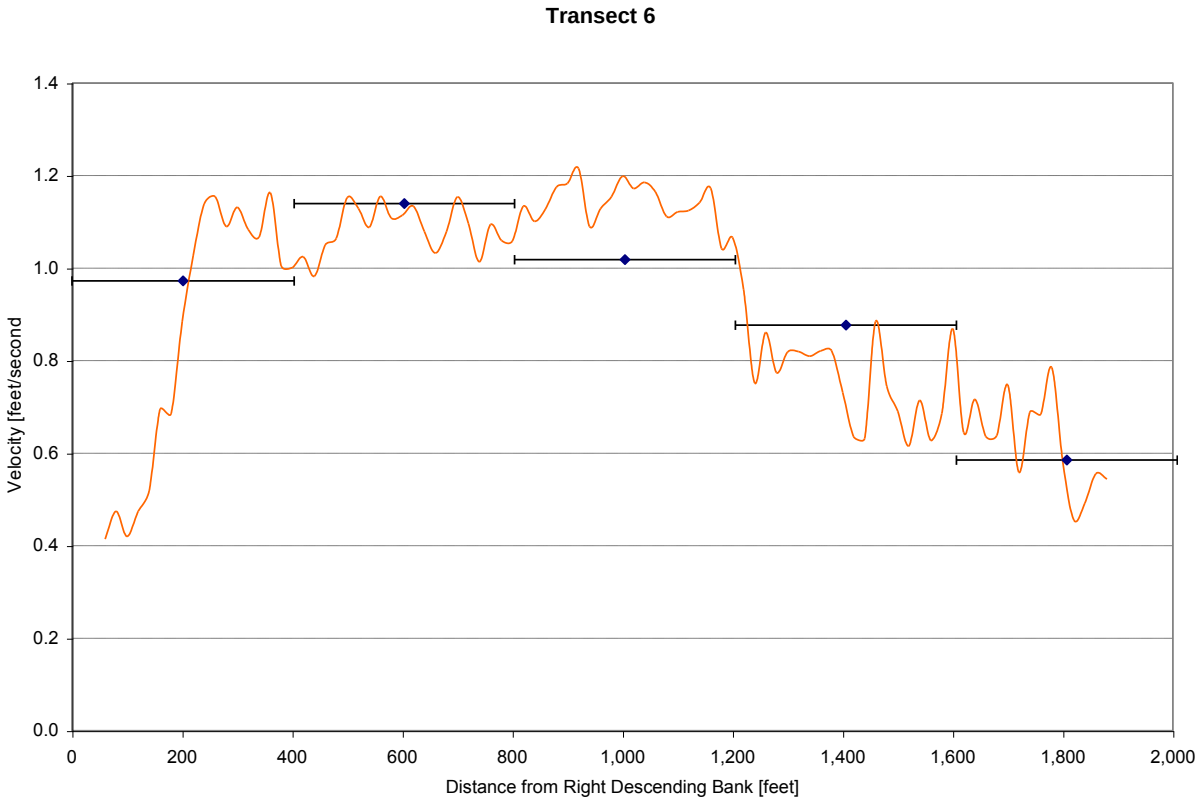
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
Distance from Right Descending Bank [feet]


Transect 6
Velocity [feet/second
Distance from Right Descending Bank [feet]
0.0
0.2
0.4
0.6
0.8
1.0
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400
600
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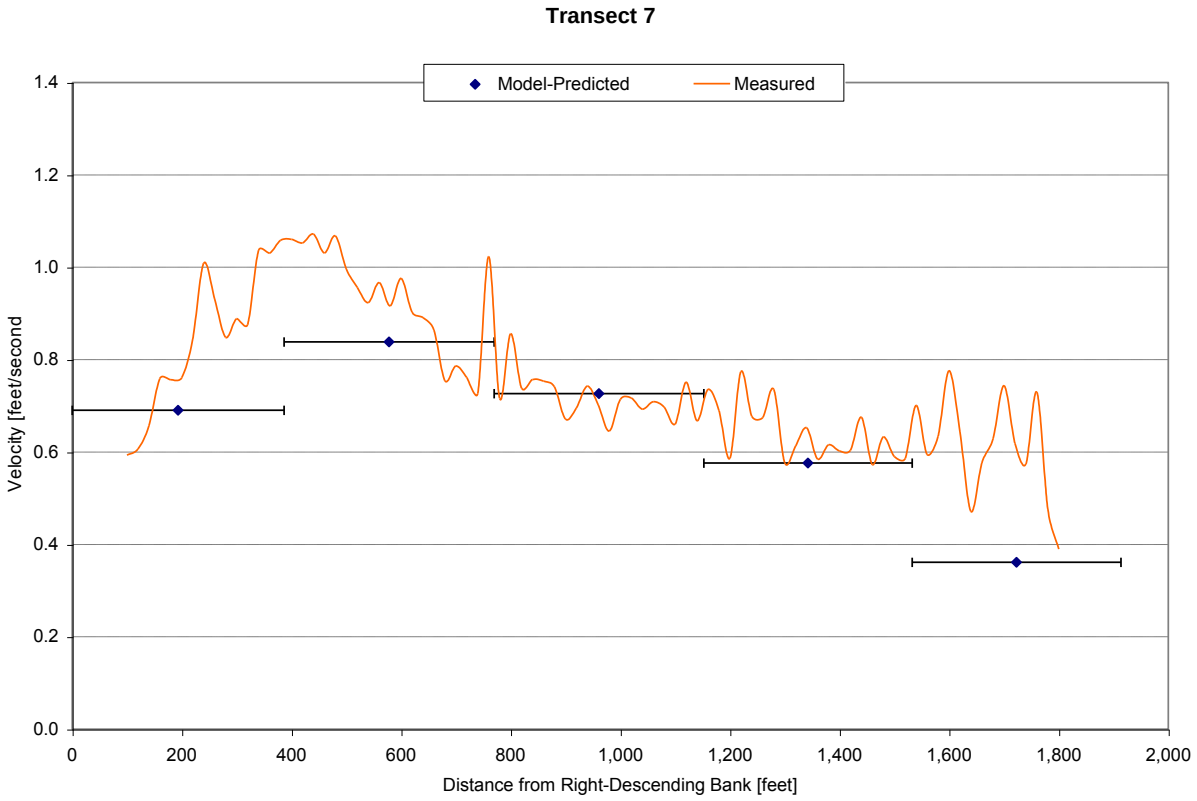
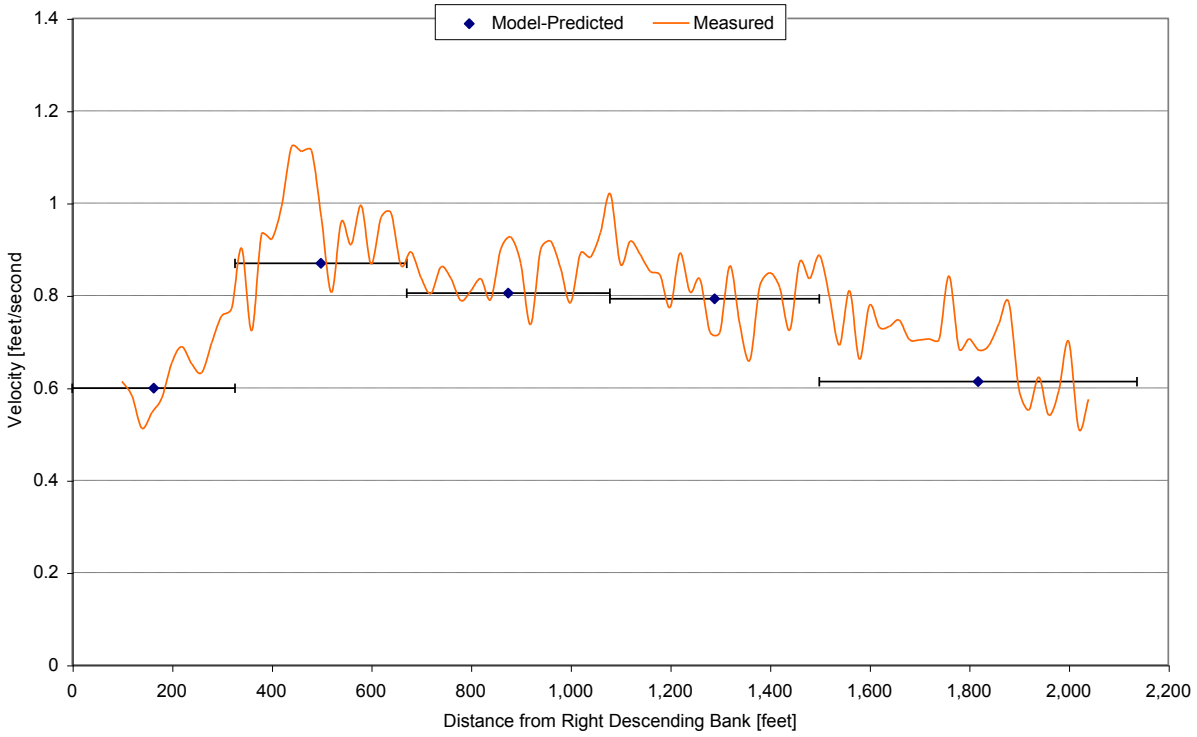
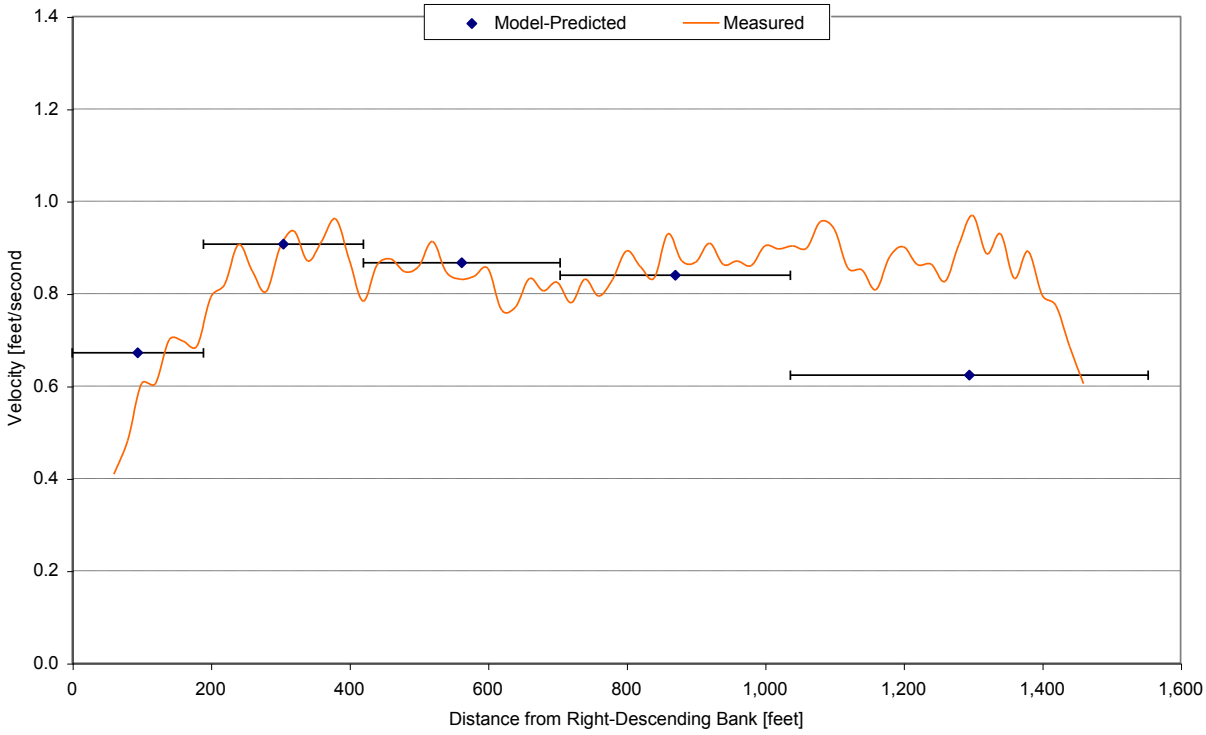
1,200
1,400
1,600
1,800
2,000

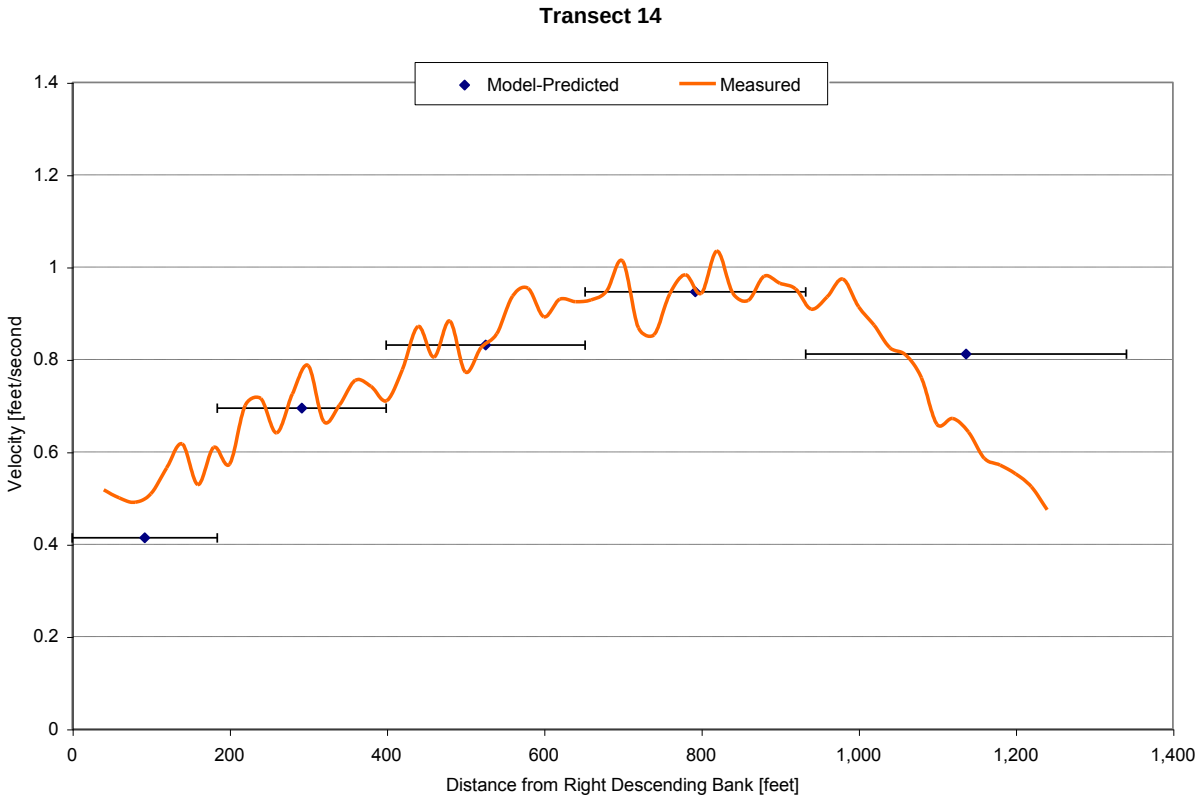

Transect 7
Model-Predicted
Measured
Velocity [feet/second
Distance from Right-Descending Bank [feet]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000

Transect 9



Transect 13





Figures 10 – 17: Velocity Model-to-Data Comparisons.

Model Uncertainty

The major source of uncertainty associated with this model is the USACE rating curve that was developed from USGS field measurements. Two causes for uncertainty exist despite the careful USGS measurements made to support this rating curve. First, the USACE rating curve assumes a unique relationship between stage and discharge under low flow conditions. The Markland Dam is operated to maintain a pool elevation of 455' (Ohio River Datum) during base flow conditions. However, the pool level at Cincinnati can fluctuate by about one foot at or with slight changes in this elevation at the dam. For this reason, a unique relationship between stage and discharge at Cincinnati is not possible at lower flows, and discharge estimates may be inexact during low flow conditions. This explains some uncertainty in model predictions under low flow conditions. Second, discharge measurements during high flow conditions may be uncertain due to the high velocity conditions. In the Ohio River, *average* velocities exceed six feet per second during high flow conditions. USGS measurements may under-predict discharge by incompletely measuring the velocity profile under high flow conditions. This condition was supported by the model sensitivity analysis and close inspection of the rating curve. Figure 18 shows USGS field measurements made at Cincinnati, the USACE rating curve, the modified rating curve used for the model (uses a simple linear regression similar to the rating curve developed by Papadakis (1994)), and a rating curve generated using steady flow simulations in EFDC.

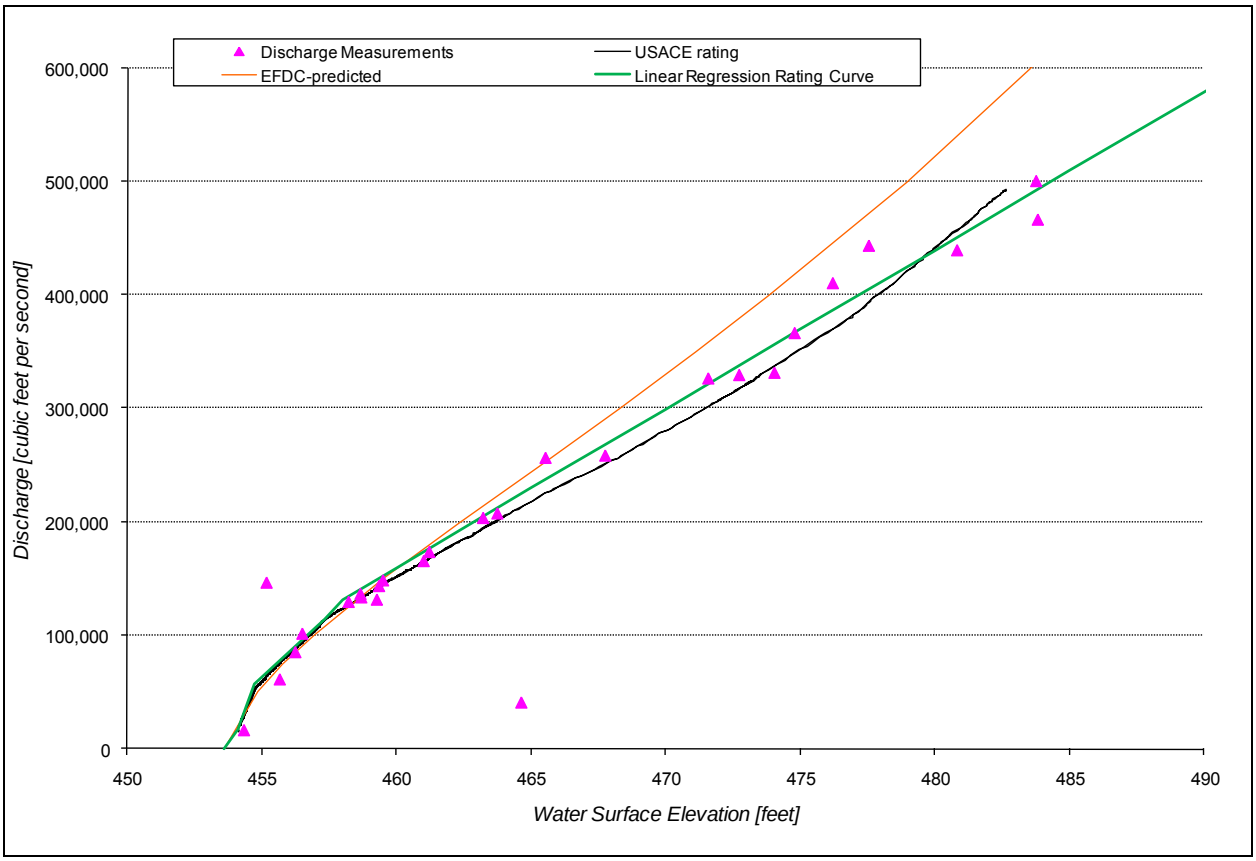


Figure 18: Rating Curve Comparison

A new rating curve was developed by running several EFDC steady flow simulations over a range of flows. This curve predicts discharge as a function of water surface elevation at the gauge in Cincinnati, Ohio. During low flows, when the relationship between stage and discharge is not unique due to dam operation, a relationship between the difference in stage between the Cincinnati gauge and Meldahl Dam tailwater elevation and the Ohio River discharge was used. Figure 18 compares the rating curve determined by EFDC to the rating curve used by the USACE. USGS measurements of discharge are also included on this plot for comparison. Generally, the EFDC-developed rating curve agrees well with USACE rating at intermediate flows, however, the relationships differ under low-flow and high-flow conditions.

As a second check of the ability of the USACE rating curve to predict discharge, the curve was used to predict discharge on days when ADCP measurements were taken. Nine ADCP measurements taken on 8/2/2005 by the USGS averaged approximately 30,000 cfs with a range of 28,000 to 32,000 cfs. The USACE reports a discharge of 50,000 cfs whereas the EFDC-predicted rating curve predicts a discharge of 29,000 cfs.

Other sources of model uncertainty are insignificant compared to uncertainty in discharge estimates. Model bathymetry was specified using a high quality and complete dataset resulting in high confidence in model geometry. Also, the downstream boundary condition at Markland Dam is specified using reliable stage data.

References

MWMO, 2007. Prepared by LimnoTech. Hydrodynamic Model Development and Application for the Upper Mississippi River between I-694 and Ford Dam. October, 2007

ORSANCO, 2007. Prepared by LimnoTech, Inc. Wheeling Use Attainability Demonstration Project – Final Report. September, 2007

Papadakis, C.N. 1994. Discharge and Stage Statistics of the Ohio River at Cincinnati. University of Cincinnati. September 1994.

USGS, 2007. G. F. Koltun, Chad J. Ostheimer, and Michael S. Griffin. Velocity, Bathymetry, and Transverse Mixing Characteristics of the Ohio River Upstream from Cincinnati, Ohio, October 2004—March 2006. USGS Open-File Report 2006-1159. Retrieved at: http://pubs.usgs.gov/of/2006/1159/report.html#1000352 on 9/26/2007

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LimnoTech
Water | Environment | Scientists | Engineers

DATE: November 25, 2008

MEMORANDUM

FROM: Jeremy Grush
TO: Jim Gibson (SD1)
CC: Carrie Turner (LimnoTech), Mindy Scott (SD1)
SUBJECT: Lateral Mixing Calibration of the EFDC Model of the Ohio River, Licking River and Banklick Creek

Introduction

The Sanitation District No. 1 (SD1) and the Metropolitan Sewer District of Greater Cincinnati (MSD-GC) are collaborating to construct and calibrate an extended EFDC model of the Ohio River and its major tributaries. Use of modeling tools is supported by EPA (EPA, 1999) for combined sewer overflow (CSO) long term control plans (LTCP). This work is being initiated by SD1 to meet the requirements of their Consent Decree, which requires that SD1's Watershed Plans include all elements of a LTCP. The work will be conducted for SD1 by LimnoTech (LTI) and builds upon previous work conducted by XCG Consultants (XCG) for MSD-GC. In keeping with the common goal of addressing water quality issues through coordinated, watershed-based solutions, the intent of the two districts is to work cooperatively on the development of the model. The purpose of this memorandum is to describe LimnoTech's lateral mixing calibration of this EFDC model. The following is an outline of this memorandum:

- Calibration Strategy and Major Findings
- Dye Survey Data
- Model to Data Comparisons
- Analysis of Model Performance

The two-dimensional EFDC model of the Ohio River, Licking River, and Banklick Creek was calibrated using two comprehensive dye studies conducted by the USGS in 2005 and confirmed using two dye studies conducted by ORSANCO in 1995. The model reasonably reproduces the lateral and longitudinal variations in dye concentrations due to a near-shore dye release. Differences between the observed concentrations and the model predicted concentrations are mostly likely due to the coarseness of the grid cells and initial dilution of the dye. The calibration of lateral mixing in the Ohio River led to four major findings:

1. The model accurately predicts the distance required to reach laterally well-mixed conditions;
2. The model reproduces the rate of lateral mixing in the downstream direction;
3. The model more accurately predicts the lateral and longitudinal profile of dye concentrations in areas where the model also accurately simulates the lateral velocity profile, especially near the river banks; and,
4. In areas near the dye release point where near-shore velocities are close to stagnant, the model underpredicts dye concentrations but downstream predictions suggest that the overall mass loading is consistent with the loading predicted by the data.

501 Avis Drive
Ann Arbor, MI 48108
734-332-1200
Fax: 734-332-1212
www.limno.com

Calibration Strategy and Major Findings

LimnoTech's calibration strategy for the Ohio River EFDC model is to independently calibrate physical processes of the system in a step-wise process where each step adds more complexity to the model representation of the study area. Important processes in the modeling of bacteria include hydrodynamic transport, lateral mixing, and the loss rate of bacteria. A previous memorandum outlined the calibration of hydrodynamic transport in the system and showed that the model accurately predicted water levels and velocities throughout the system (LimnoTech, 2008).

This memorandum details the lateral mixing calibration, which focuses on the accurate simulation of two dye studies that the United States Geological Survey (USGS) performed in 2005. The USGS released rhodamine dye from two locations – one near the Ohio bank of the Ohio River and one near the Kentucky bank of the Ohio River. Then they measured dye concentrations at several transects downstream from the dye release.

Because Rhodamine dye is a conservative tracer, it is useful for characterizing lateral mixing in the river. Concentration gradients observed in the data are the result of hydrodynamic advection and mixing only. Measurements of bacteria, on the other hand, reflect transport (advection and mixing) and losses from physical and chemical processes. In a forthcoming memorandum, calibration of the bacteria loss rates will be explained. Model calibration of these three processes provides the basis for the reliable prediction of bacteria fate and transport through the system. Therefore, in terms of modeling complexity, calibrating the lateral mixing using the dye survey data prior to calibrating to bacteria data is advantageous because the model does not require accounting for physical and chemical losses.

The remainder of this memorandum describes the available data, calibration results and conclusions.

Dye Survey Data Overview

The USGS performed a comprehensive mixing study on the Ohio River between river miles 446 and 464 that was designed for use in a two-dimensional hydrodynamic and water quality model of the Ohio River (USGS 2007). Two studies were actually conducted: one near the upstream end of the model domain (on 8/4/2005) and one farther downstream (on 8/2/2005). In both studies, dye was released at a constant flow rate near a bank of the Ohio River for a period of approximately eighteen hours. Beginning twelve hours after the initiation of the dye release, dye concentrations were measured at several transects downstream of the release point. Dye measurements were made at many lateral locations along each transect, and until complete vertical mixing was confirmed, also at multiple depths. Additionally, the USGS made Ohio River bathymetric and velocity measurements that supported the lateral mixing model calibration effort.

Figure 1 shows the dye release locations and the transects where the USGS measured dye concentrations and water velocity.

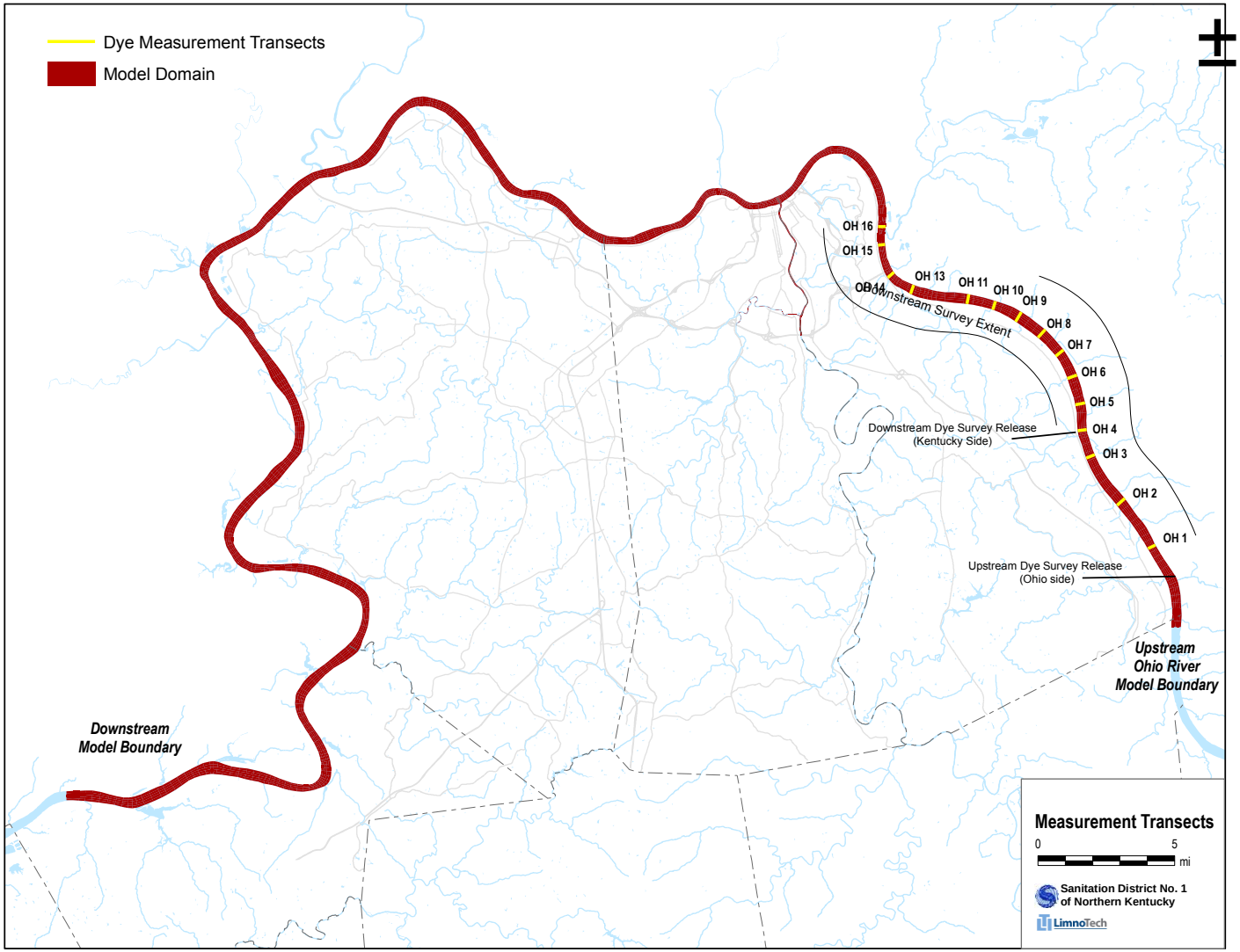

Figure 1: Dye Release and Measurement Locations

Model simulations were designed to reproduce the conditions that existed in the Ohio River during the dye studies. ADCP measurements were used to describe the Ohio River velocity and flow during each dye survey. Also, the description of the dye release and measurements timing were used to describe dye boundary conditions and to extract concentration profiles from the model at the appropriate times.

Additionally, two dye surveys performed by LimnoTech for ORSANCO on the Ohio River in 1995 were used to confirm the lateral mixing model calibration. For this study, dye was released into the Ohio River via the Mill Creek Treatment Plant diffuser, which lies along the bottom of the Ohio River downstream of Mill Creek. Dye measurements were made at several transects downstream of the release. Data from a subset of the measurements have been compared to model predictions because spatial variability is too great near the diffuser pipe to make meaningful model-to-data comparisons.

The following section summarizes the results of the model calibration and confirmation by showing model to data comparisons.

Model-to-Data Comparisons

Comparisons between model predicted and measured dye concentrations were made at each transect for each survey. The concentration comparisons are shown on the following figures as individual measurements and as spatially-averaged measurements over each model grid cell for some transects.

Figures 2 – 10 show model results for the upstream 2005 USGS dye study using the distance from the left descending bank (LDB) as the reference for instream location. Generally, the model accurately represents the lateral and longitudinal variation in dye concentrations due to mixing. A constant horizontal momentum diffusivity of 0.05 m^2/s was used to calibrate lateral mixing. Factors affecting the ability of the model to reproduce the dye survey data are discussed in the next section.

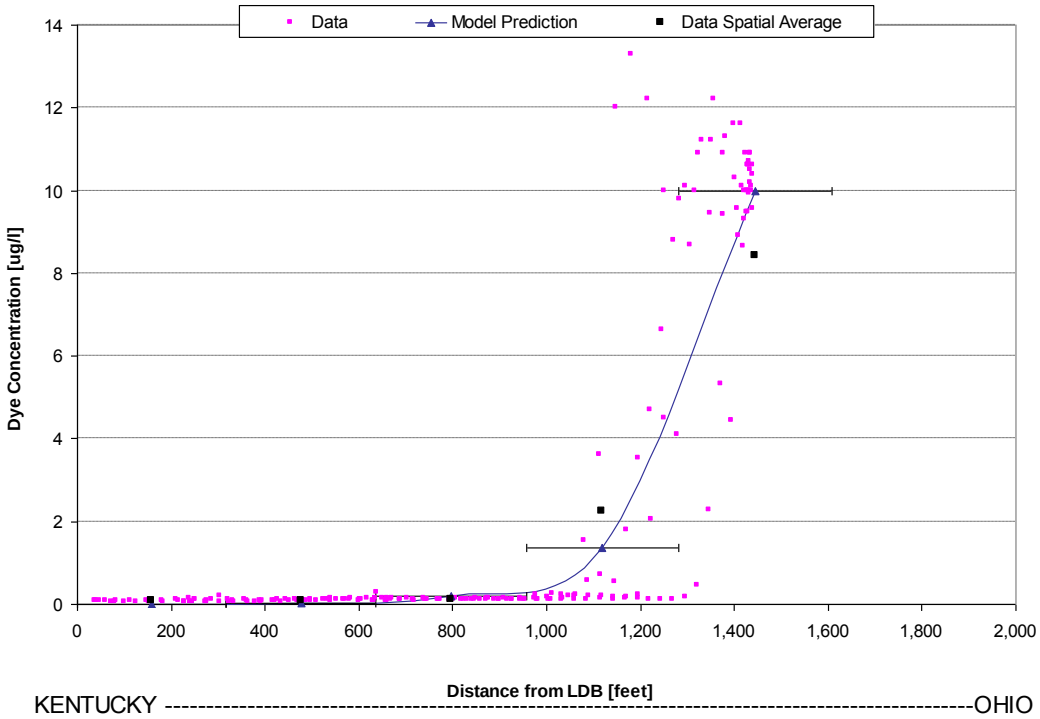

Figure 2: Measured and Predicted Dye Concentration Profiles at Transect OH1 (1.5 miles downstream of Dye Release)

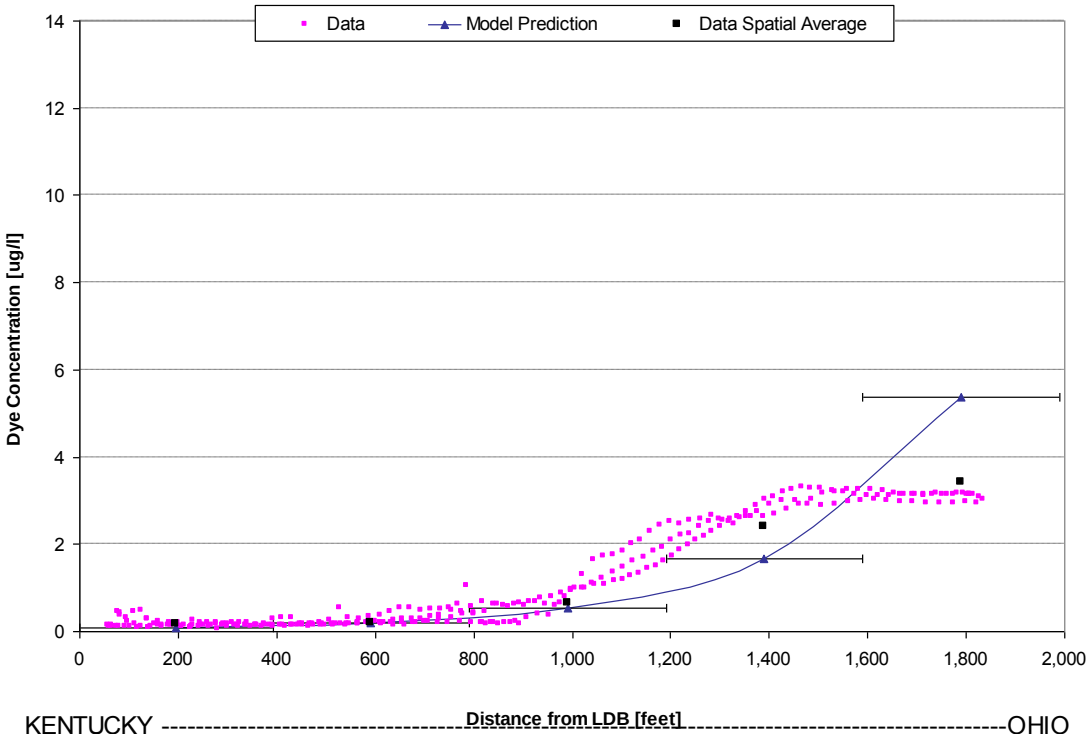

Figure 3: Measured and Predicted Dye Concentration Profiles at Transect OH2 (3.5 miles downstream of Dye Release)

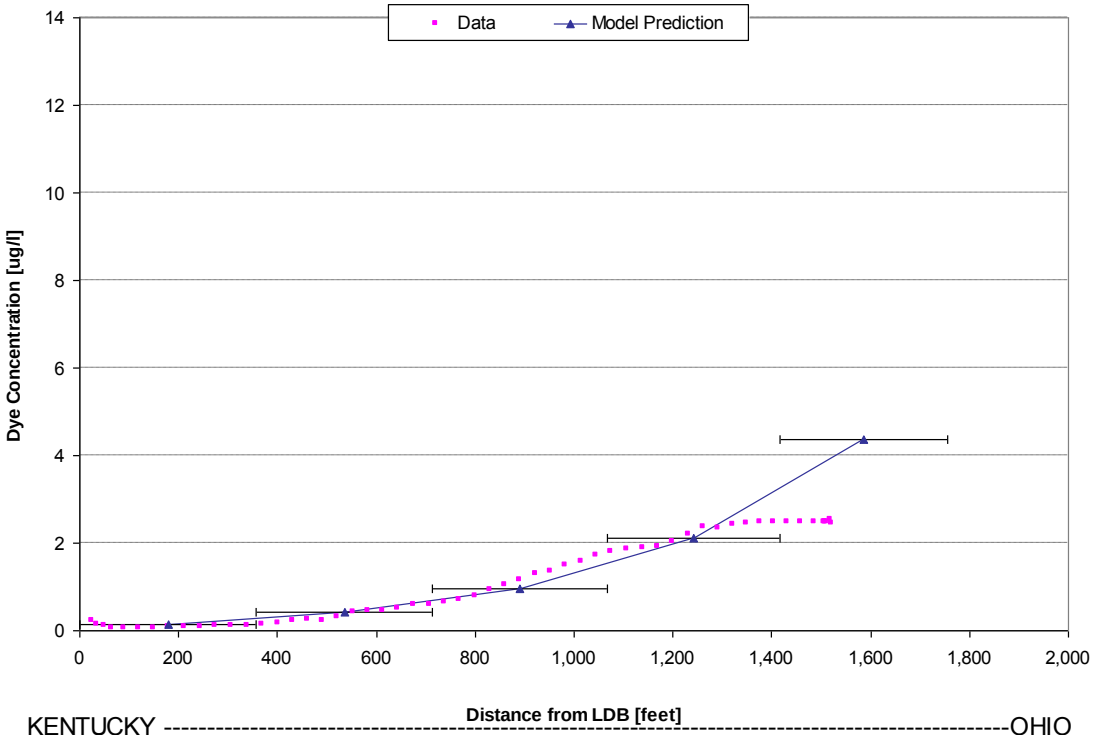

Figure 4: Measured and Predicted Dye Concentration Profiles at Transect OH3 (5.5 miles downstream of Dye Release)

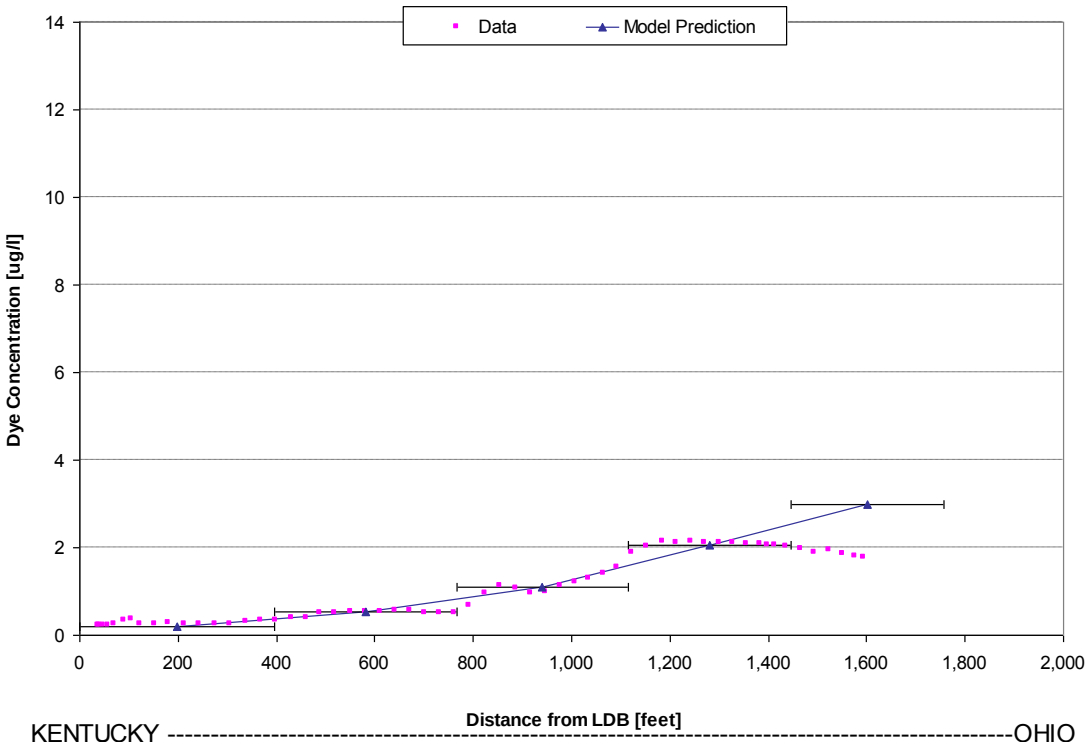

Figure 5: Measured and Predicted Dye Concentration Profiles at Transect OH4 (6.5 miles downstream of Dye Release)

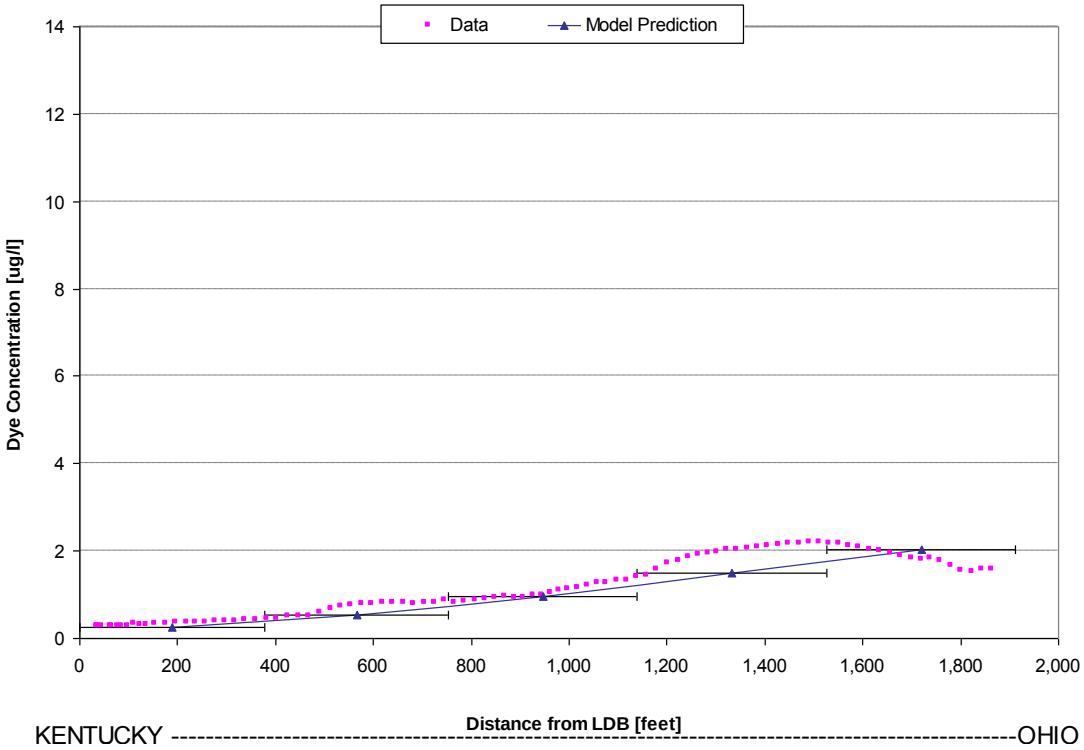

Figure 6: Measured and Predicted Dye Concentration Profiles at Transect OH5 (7.5 miles downstream of Dye Release)

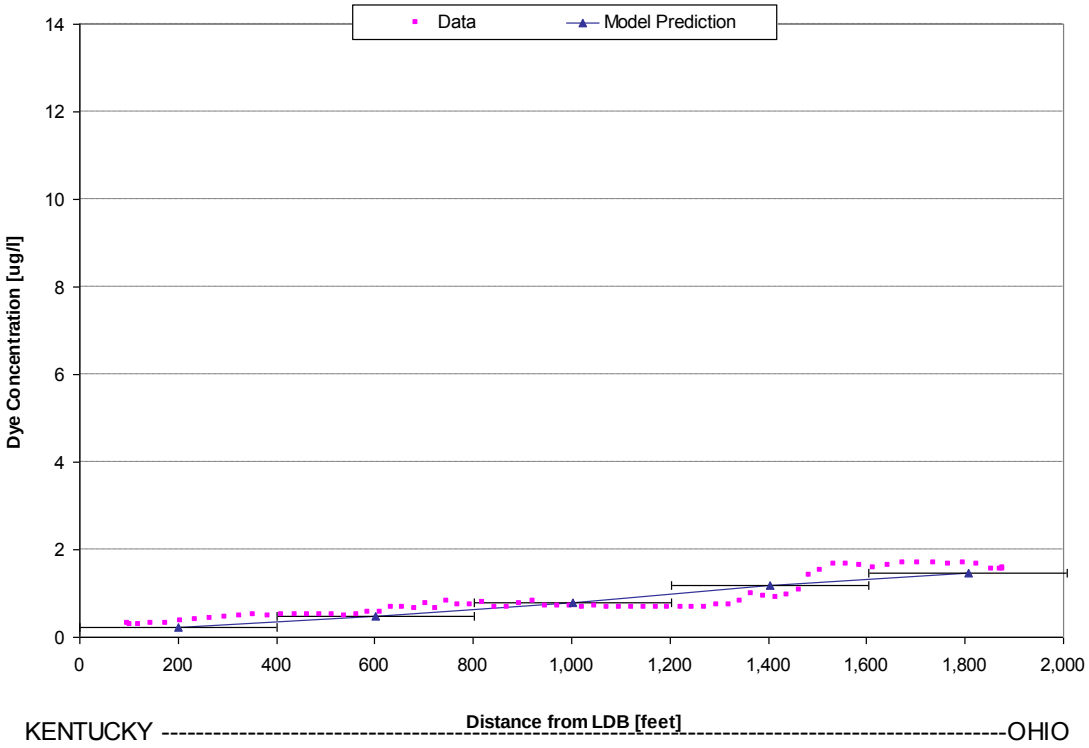

Figure 7: Measured and Predicted Dye Concentration Profiles at Transect OH6 (8.5 miles downstream of Dye Release)

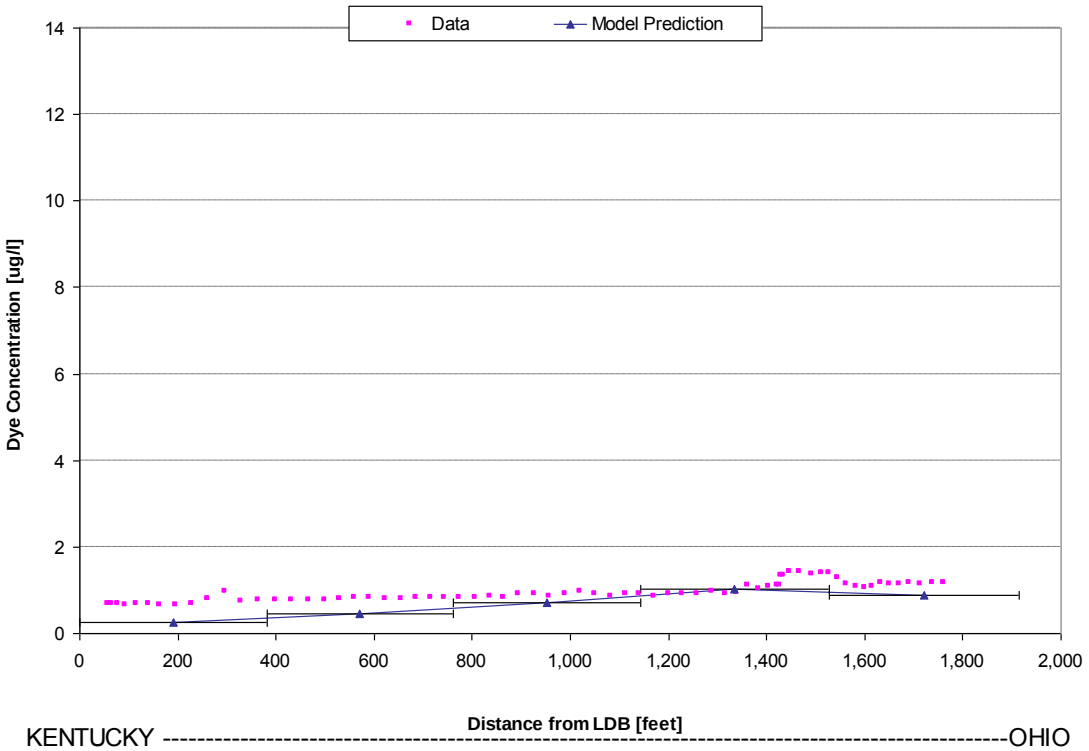

Figure 8: Measured and Predicted Dye Concentration Profiles at Transect OH7 (9.5 miles downstream of Dye Release)

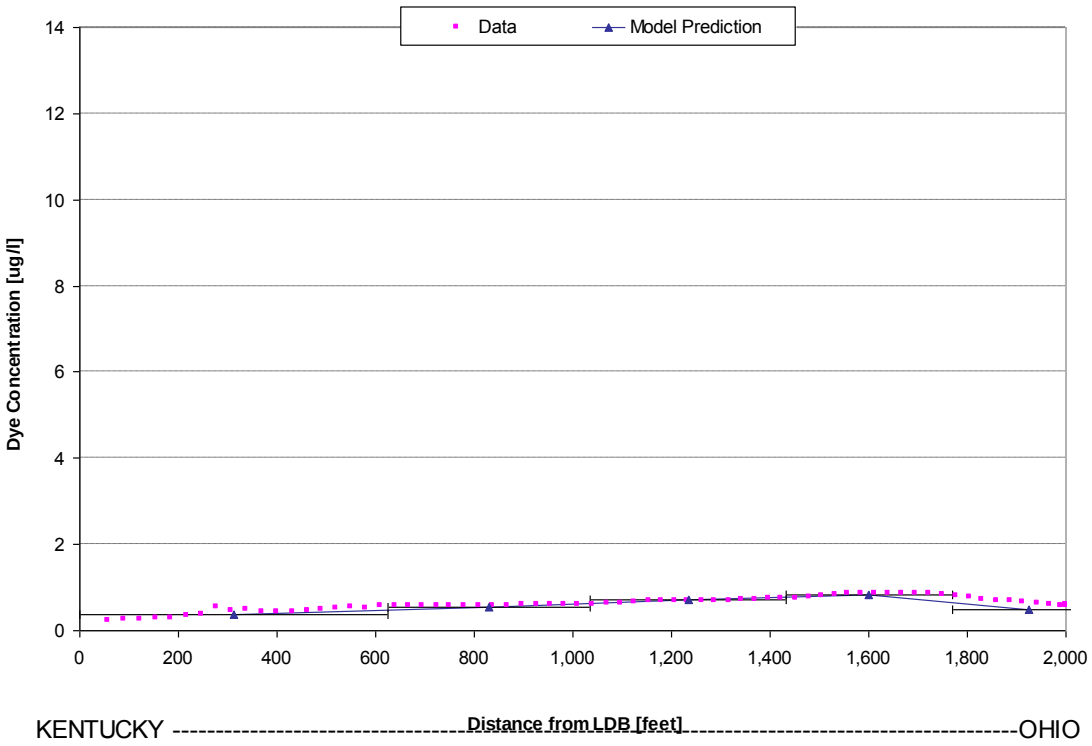

Figure 9: Measured and Predicted Dye Concentration Profiles at Transect OH8 (10.5 miles downstream of Dye Release)

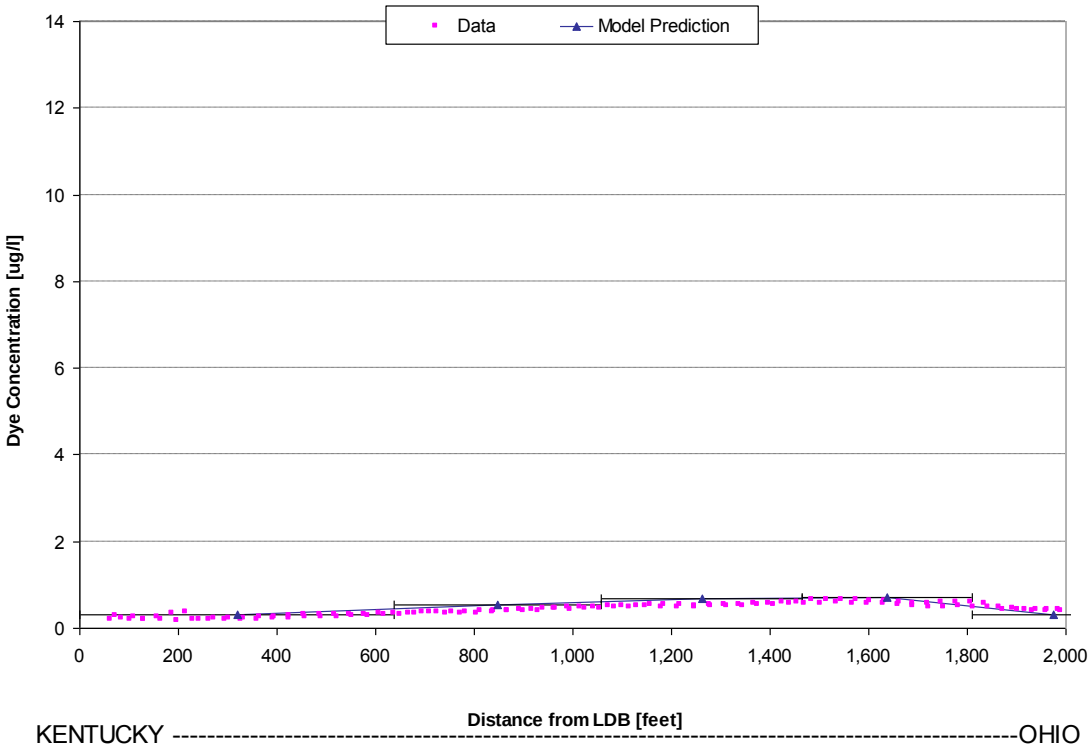

Figure 10: Measured and Predicted Dye Concentration Profiles at Transect OH9 (11.5 miles downstream of Dye Release)

Figures 11-19 show modeled and observed concentration comparisons for the downstream 2005 USGS dye study. At OH6 (Figure 11), the first transect downstream of the dye release, the model-predicted concentration is lower than the maximum observed concentration. Here, the model discretization has a much greater influence on the predicted dye profile compared to its influence on the upstream study results. Because the model grid is a spatially averaged representation of the river, the velocity and flow passing through each cell are average values. In a cell adjacent to the bank, the actual velocities across a cell can range quite a bit, from near zero at the bank to much higher values near the main channel edge of the cell. These ranges cannot be captured in the model. In this survey, the model cell into which dye is released receives a significantly higher flow (and corresponding velocity) than the dye would actually encounter when released into the system. As a result, the modeled dye concentrations near the dye release are quite low (due to dilution), and the remaining predicted dye profiles remain low compared to the measured profiles. However, the model reasonably captures the lateral concentration profile due to a near-bank load.

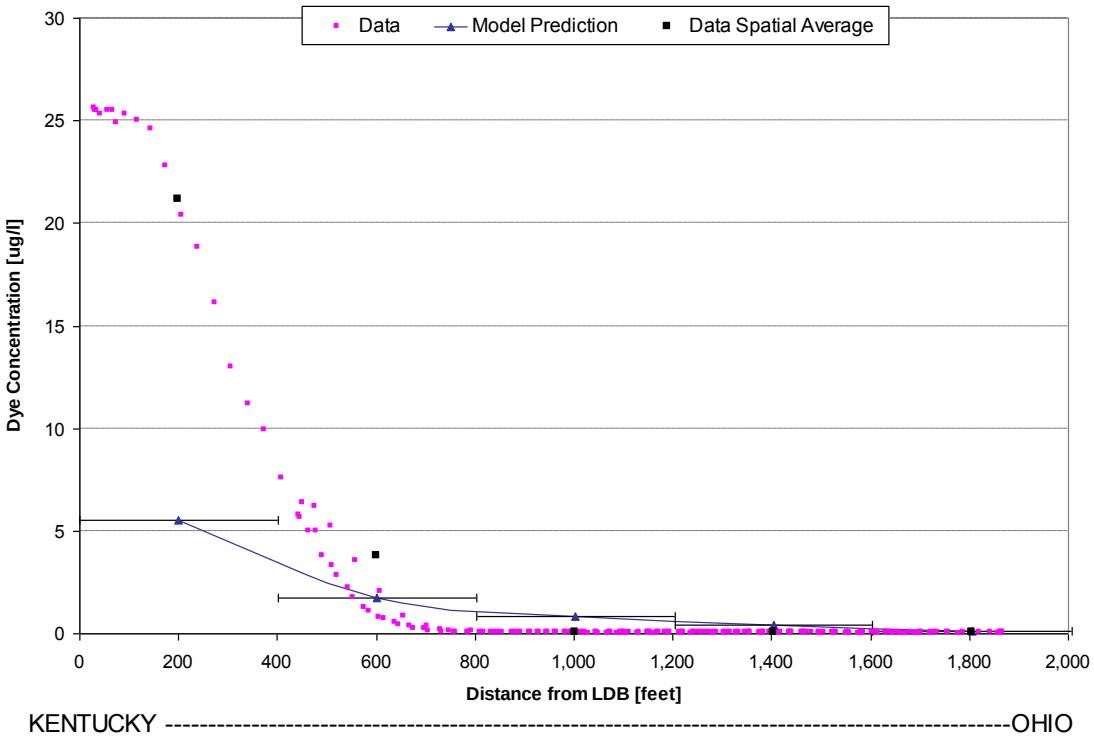

Figure 11: Measured and Predicted Dye Concentration Profiles at Transect OH6 (2 miles downstream of Dye Release)

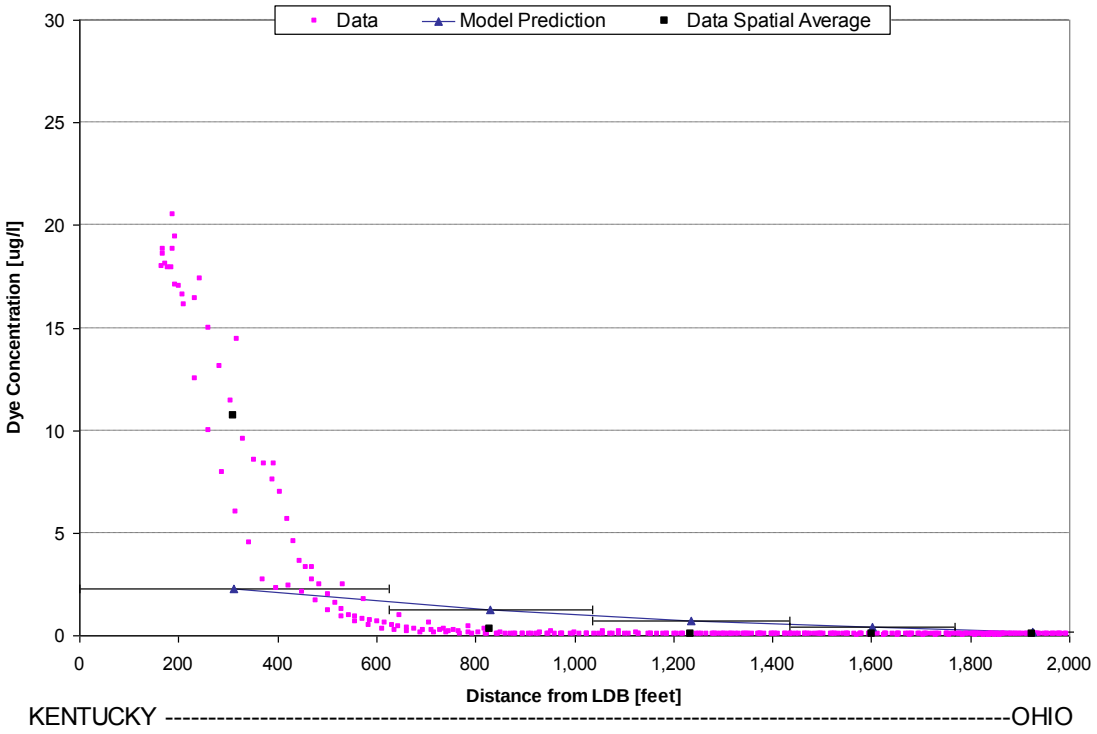

Figure 12: Measured and Predicted Dye Concentration Profiles at Transect OH8 (4 miles downstream of Dye Release)

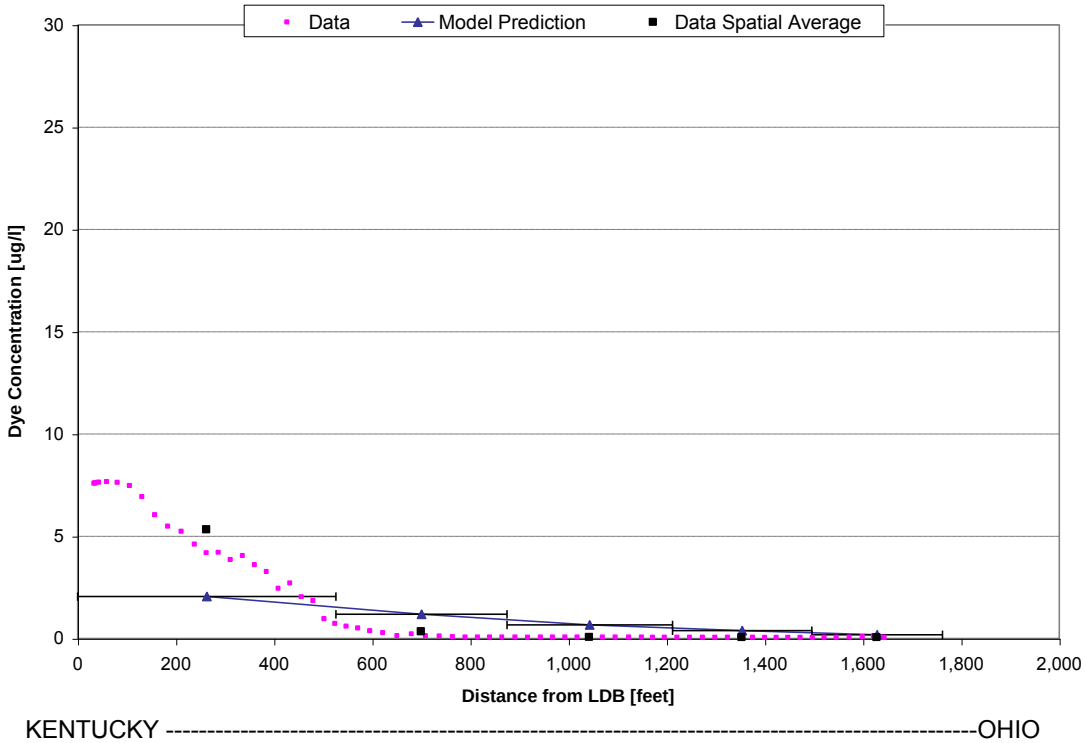

Figure 13: Measured and Predicted Dye Concentration Profiles at Transect OH10 (6 miles downstream of Dye Release)

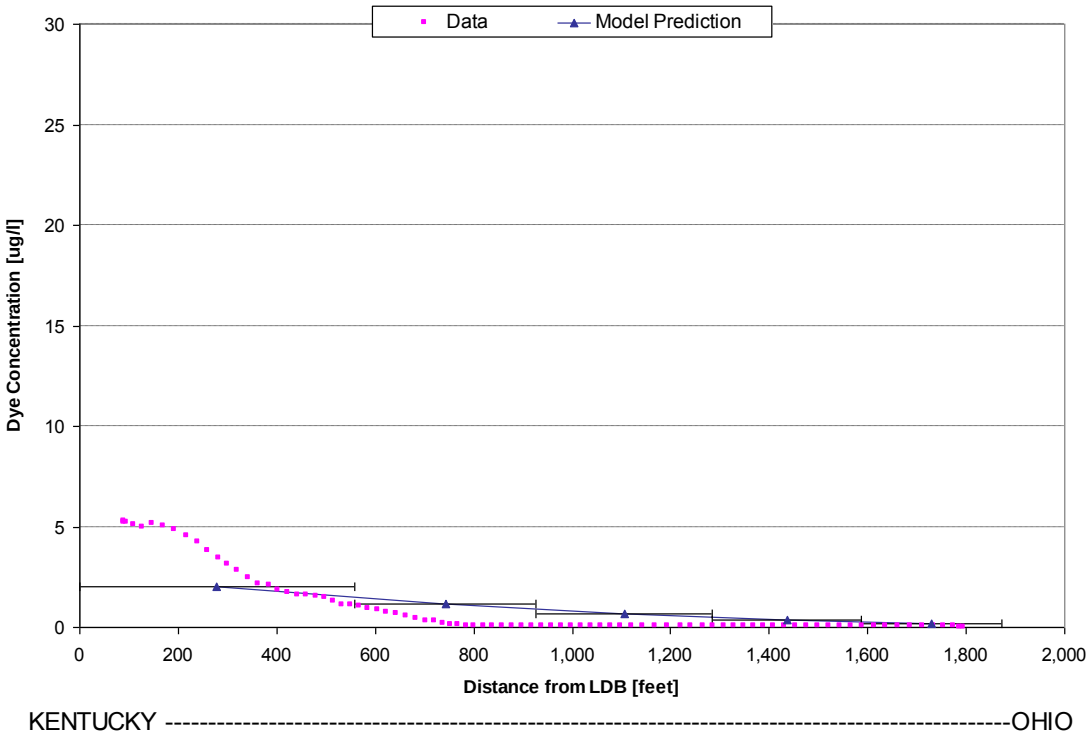

Figure 14: Measured and Predicted Dye Concentration Profiles at Transect OH11 (7 miles downstream of Dye Release)

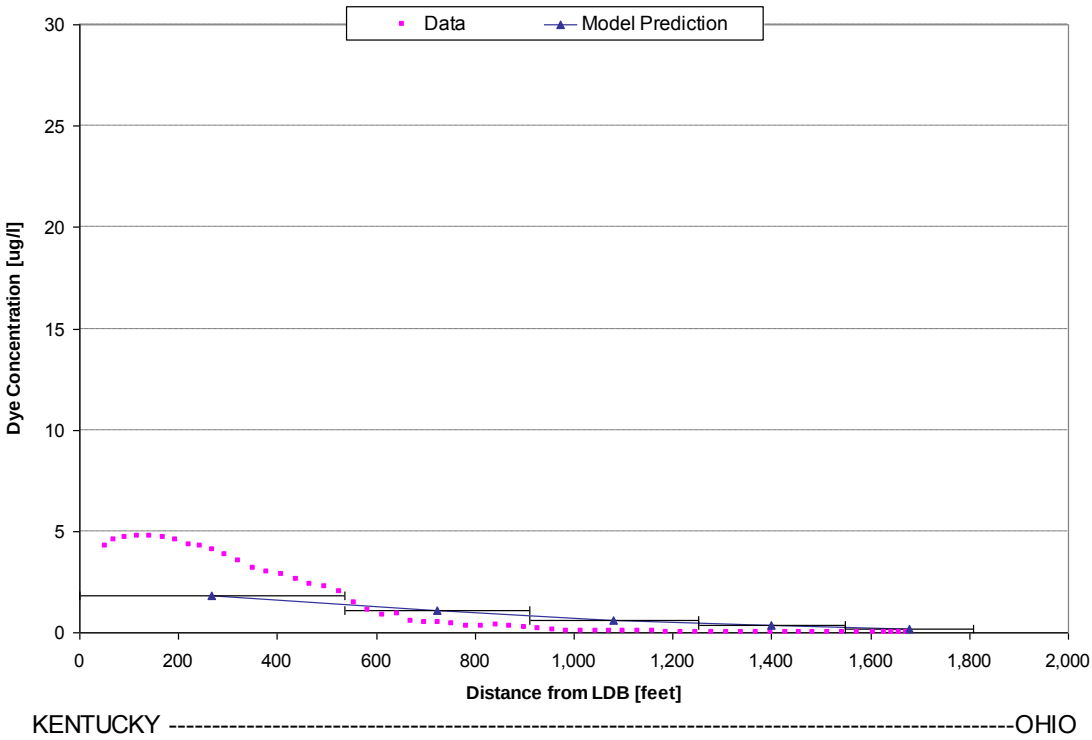

Figure 15: Measured and Predicted Dye Concentration Profiles at Transect OH12 (8 miles downstream of Dye Release)

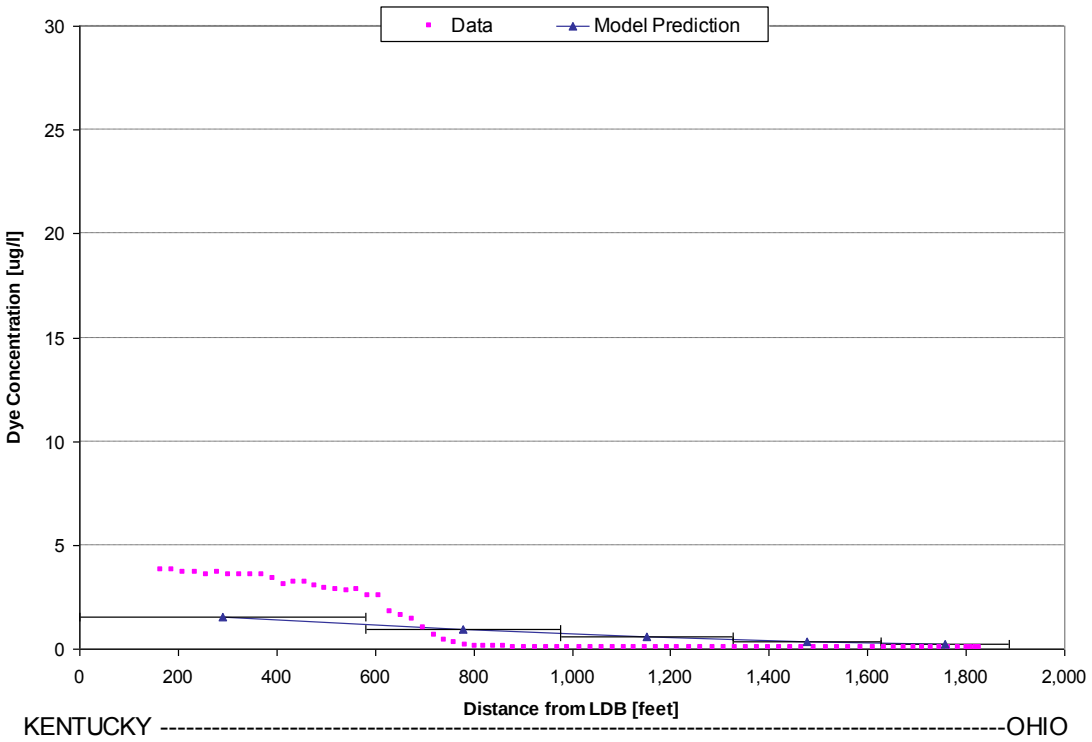

Figure 16: Measured and Predicted Dye Concentration Profiles at Transect OH13 (9 miles downstream of Dye Release)

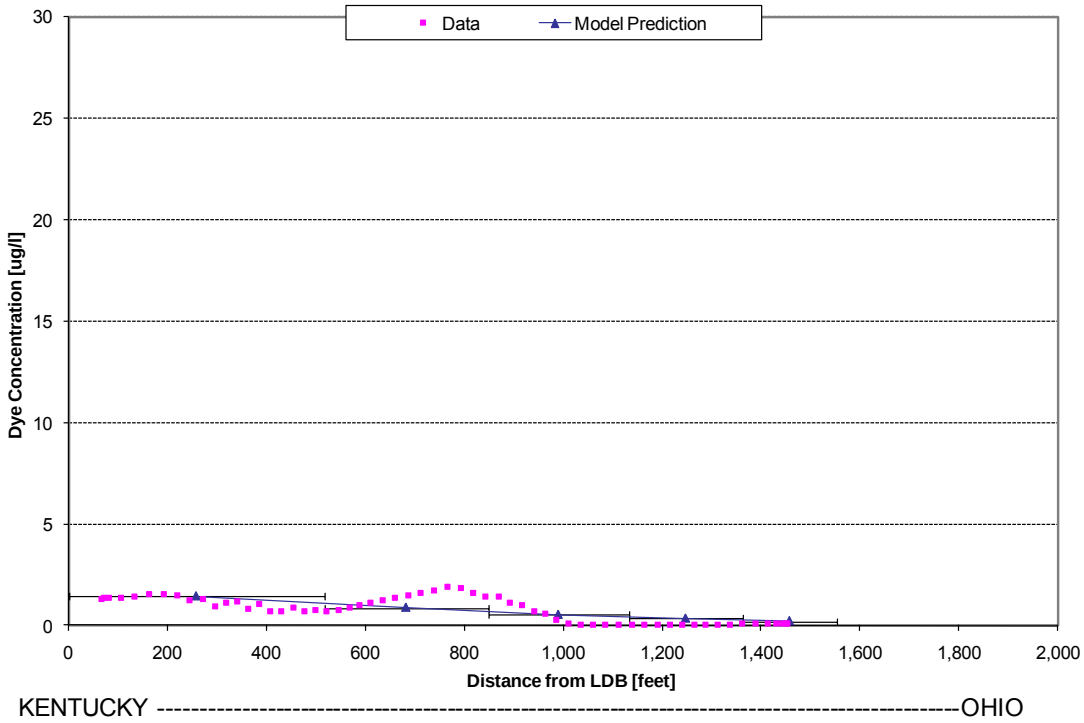

Figure 17: Measured and Predicted Dye Concentration Profiles at Transect OH14 (10 miles downstream of Dye Release)

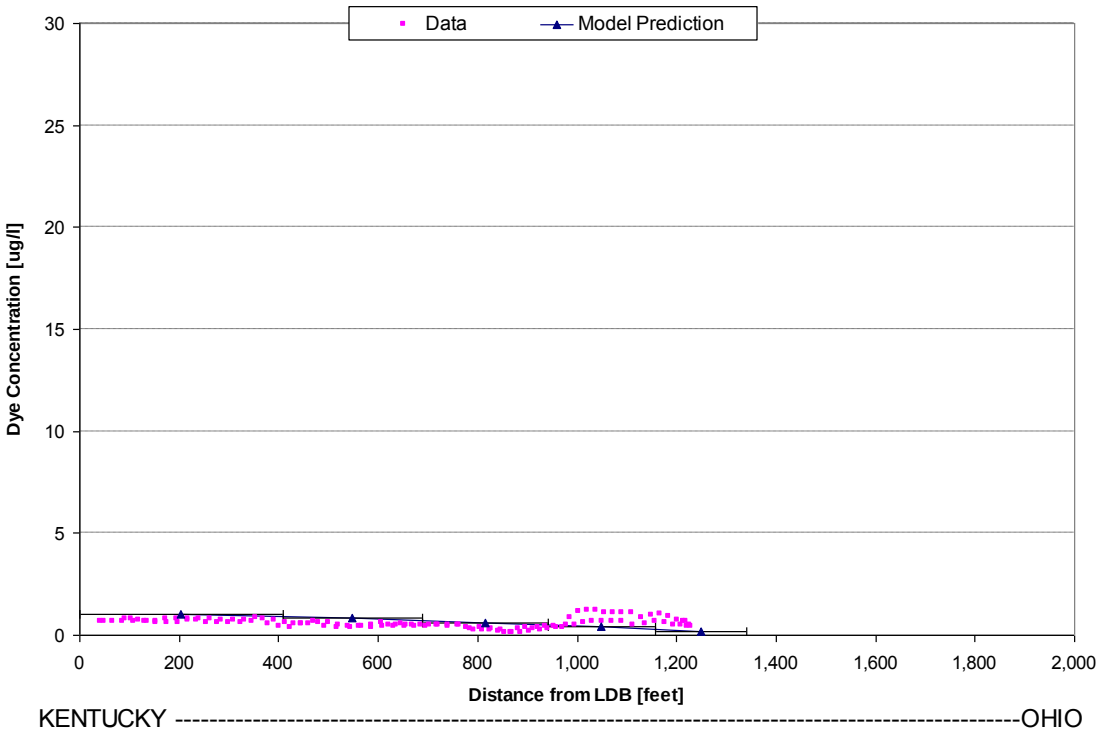

Figure 18: Measured and Predicted Dye Concentration Profiles at Transect OH15 (11 miles downstream of Dye Release)

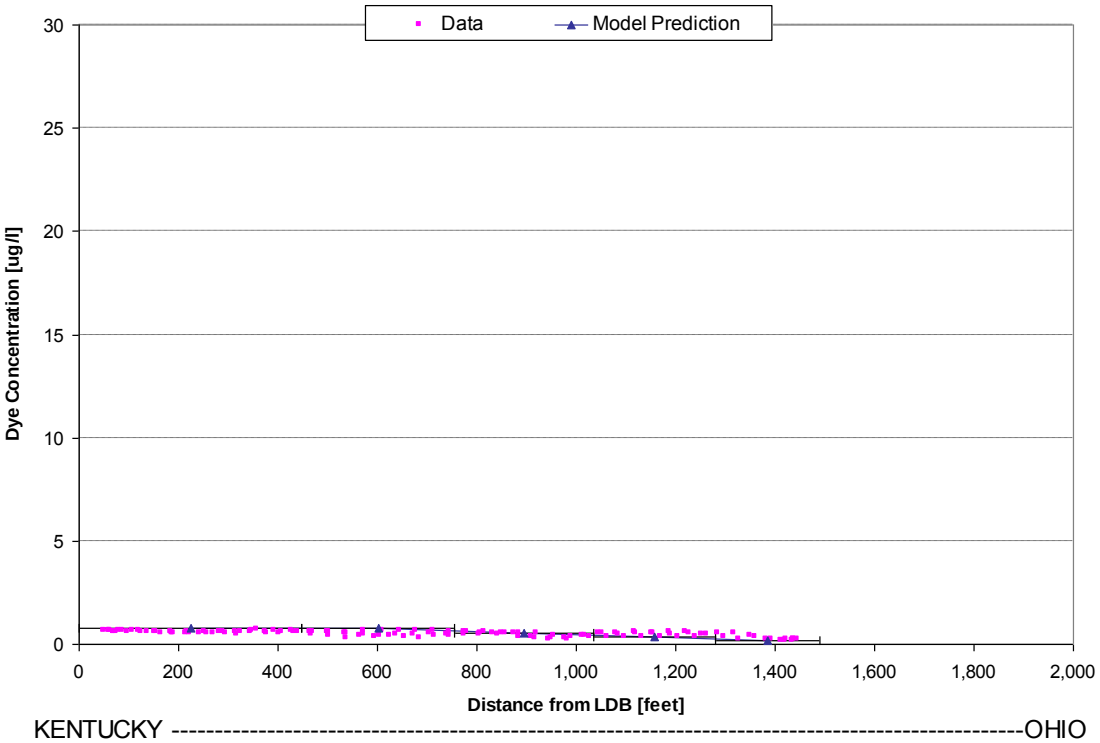

Figure 19: Measured and Predicted Dye Concentration Profiles at Transect OH16 (12 miles downstream of Dye Release)

As a confirmation of the lateral mixing calibration, simulations were run to replicate two dye surveys that were performed by LimnoTech in 1995. More information on the surveys is described in ORSANCO's project report (ORSANCO, 2002). Little information was available to confirm the distance into the Ohio River that the dye was released (e.g. the length of the diffuser pipe). The spatial variability of dye concentrations near the dye release location confounded the evaluation of these surveys. Model to data comparisons focused on fits at downstream transects because these transects are both well-mixed over the water column and also reflect the effects of lateral mixing moreso than data near the dye release location. The following figures show model-to-data comparisons for simulations of the two dye surveys performed in 1995.

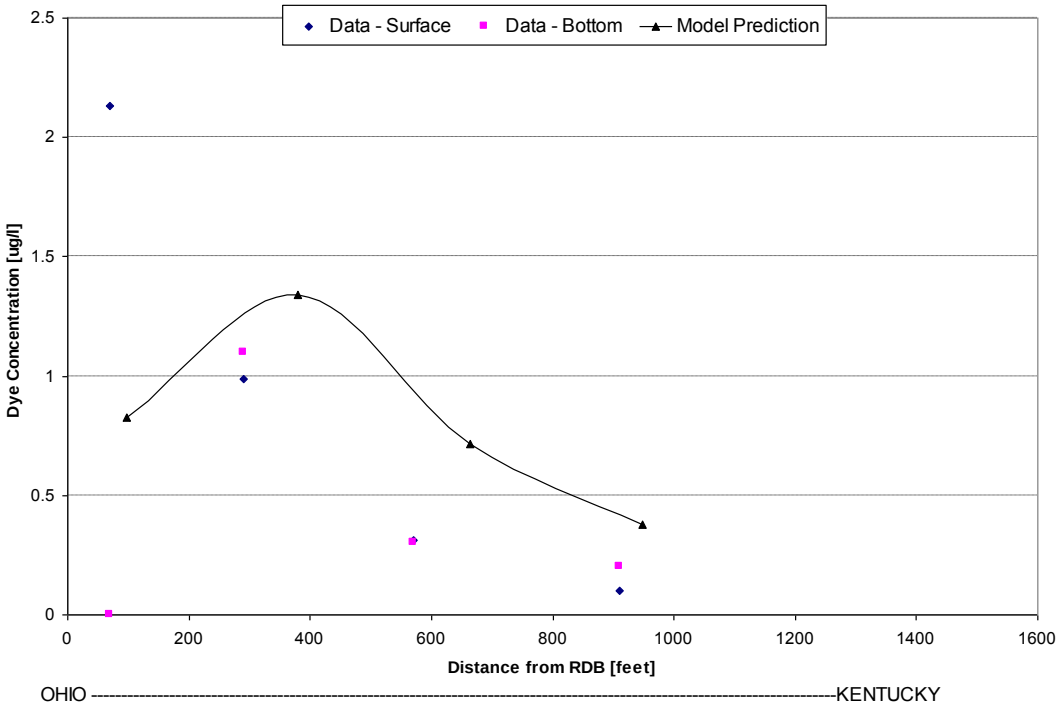

Figure 20: Measured and Predicted Dye Concentration Profiles at transect 4,000 feet (~0.75 miles) downstream of Mill Creek Treatment Plant Diffuser (10/17/1995 survey)

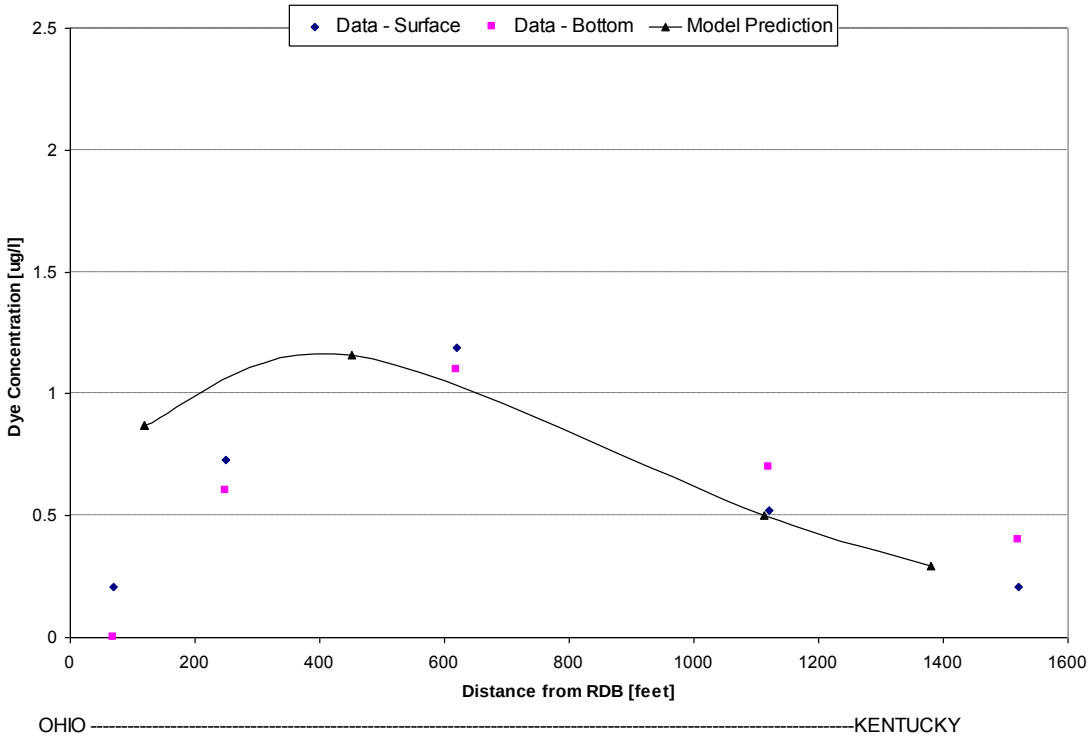

Figure 21: Measured and Predicted Dye Concentration Profiles at transect 14,000 feet (~2.65 miles) downstream of Mill Creek Treatment Plant Diffuser (10/17/1995 survey)

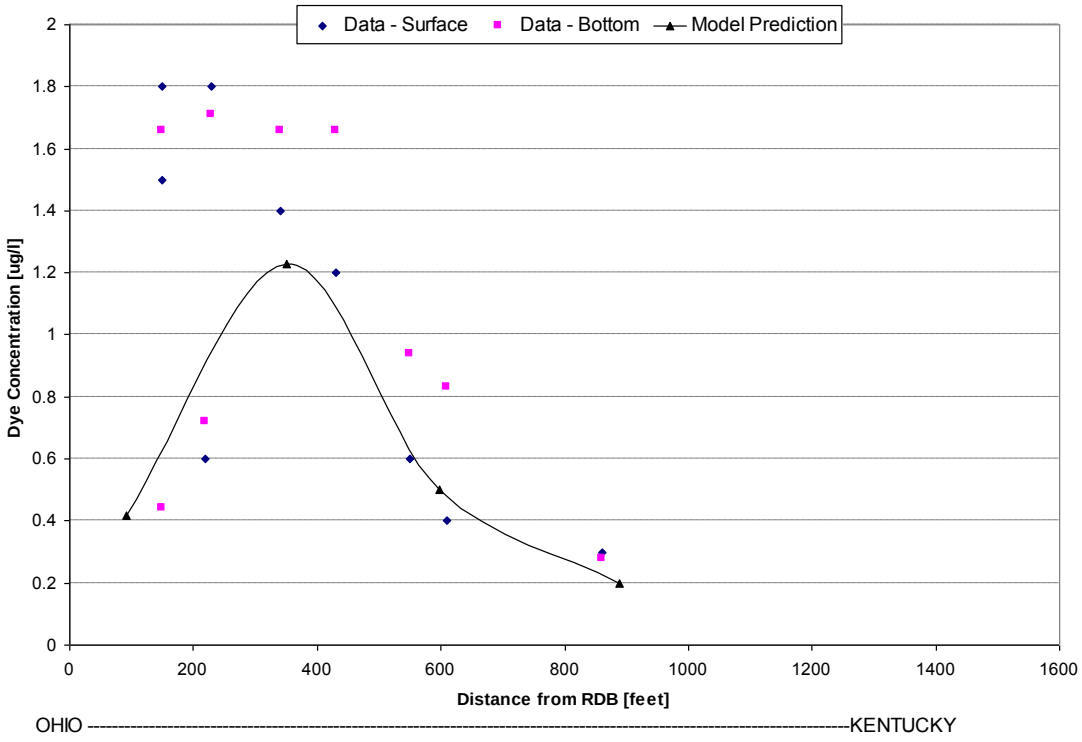

Figure 22: Measured and Predicted Dye Concentration Profiles at transect 4,000 feet (~0.75 miles) downstream of Mill Creek Treatment Plant Diffuser (11/28/1995 survey)

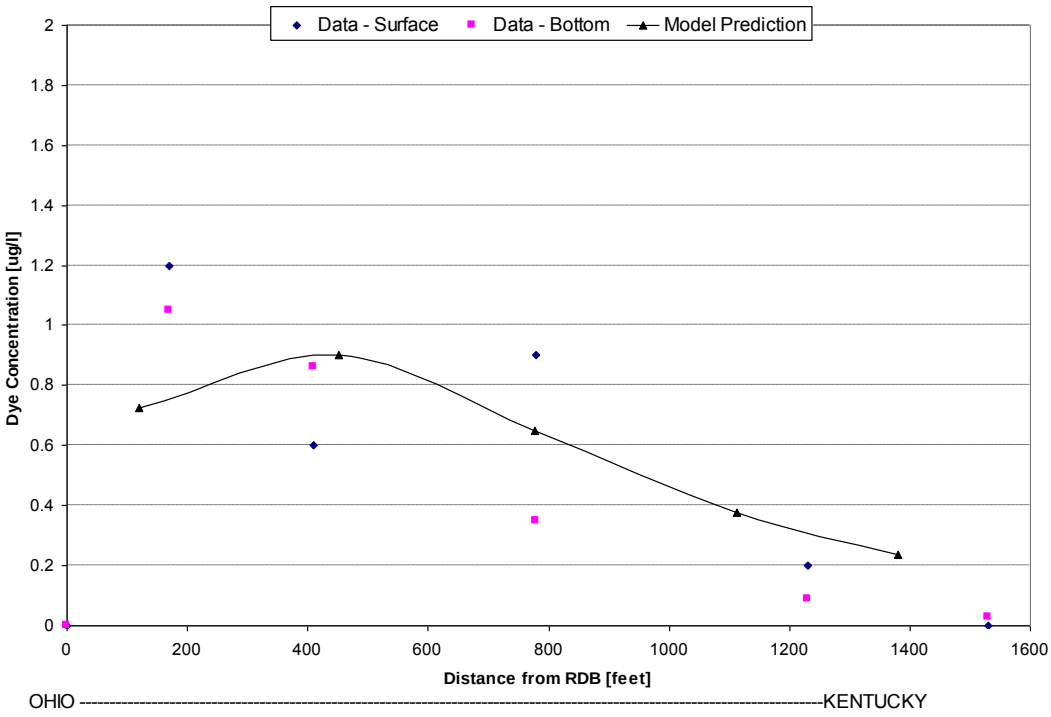

Figure 23: Measured and Predicted Dye Concentration Profiles at transect 14,000 feet (~2.65 miles) downstream of Mill Creek Treatment Plant Diffuser (11/28/1995 survey)

Analysis of Model Performance

The objective of the dye survey simulations was to optimize the model's parameterization so that it adequately represents the lateral mixing characteristics of the river, rather than to reproduce observed dye concentrations at each transect. The figures comparing simulated and observed lateral concentration gradients in each of the dye surveys illustrate that the calibration achieved this objective. However, understanding the model limitations and sources of error are also important factors to consider in evaluating the model performance. This section describes a statistical assessment of the calibration and sources of error in the lateral mixing calibration.

Table 1 presents a statistical analysis of the error associated with the model fit for different values of horizontal momentum diffusivity. In this table, lower numerical values indicate better model to data fit. Three measures of error were assessed:

1. Root mean square error (RMSE),
2. Absolute difference, and
3. Relative percent difference.

The relative percent difference indicates the direction of model bias. Large values (greater than 5%-10%) indicate a bias in the model performance. A positive value suggests that the model is biased high while a negative value suggests a negative bias. The absolute difference provides an assessment of the magnitude of the difference in model predicted concentrations compared to observed values. The root mean square error provides a total value that should be at a minimum when the model and observed concentrations

agree well. As the results in this table show, using a value of 0.05 m^2/s for the horizontal diffusion parameter produces the best fit to the data.

Table 1. Statistical Analysis of Horizontal Momentum Diffusivity Parameterization.

		Sum	Average
Diffusion Parameter [m^2/s]	RMS Error [ug/l]	Absolute Difference [ug/l]	Relative Difference (%)
0.01	0.65	17.20	15.1%
0.05	0.54	12.53	-3.9%
0.1	0.63	14.29	1.9%

The greatest source of error associated with the dye calibration is the dimensioning of the model grid. Two factors associated with model discretization have a substantial influence on reproducing the observed lateral mixing characteristics: cell size and dimensionality. The current EFDC model grid for the Ohio River has five cells spanning the width of the Ohio River. This level of discretization allows for the simulation of some lateral variability in hydrodynamic (e.g. velocity and depth) and water quality conditions while also allowing for reasonable model run-times. However, lateral variability in depth and velocity increases significantly near the banks of the river, where dye releases were made. The near shore velocity and depth characteristics cannot be represented in the model because the near shore conditions are physically aggregated into a larger cell that simulates average velocity and depth over the cell dimension.

A compromise between model run-time and the ability to represent elevated near-shore concentrations was made in the development of this model. A previous memorandum that documented the hydrodynamic calibration showed that the lateral velocity profile predicted by the model reasonably reproduces the available ADCP velocity data. However, in some places, near-bank water velocities change rapidly in the lateral direction, and the assumption of an average velocity over one fifth of the river causes error in the prediction of dye concentration profiles. The following figure illustrates the effect that averaging of near-bank velocities has on the model-predicted dye concentration profile.

Both plots show measured and predicted velocity and dye concentration profiles at the first transect downstream of each of the USGS dye survey release points. The first plot, from the upper survey, shows close agreement between both the velocity profile and dye concentration profile, especially near the release point. In the second plot, from the lower survey, the velocity profile is still relatively accurate, on average, but near the bank, the predicted velocity is significantly higher than at the release point. Because of this, the model predicts higher initial dilution than what actually occurs, and the simulated dye concentration in this cell is underestimated. However, as noted above, despite these near shore, near-release limitations, the overall model performance simulating the four dye surveys indicates that the model parameterization of the horizontal momentum diffusivity at 0.05 m^2/s resulted in a reasonably accurate reproduction of the lateral mixing characteristics observed across the datasets.

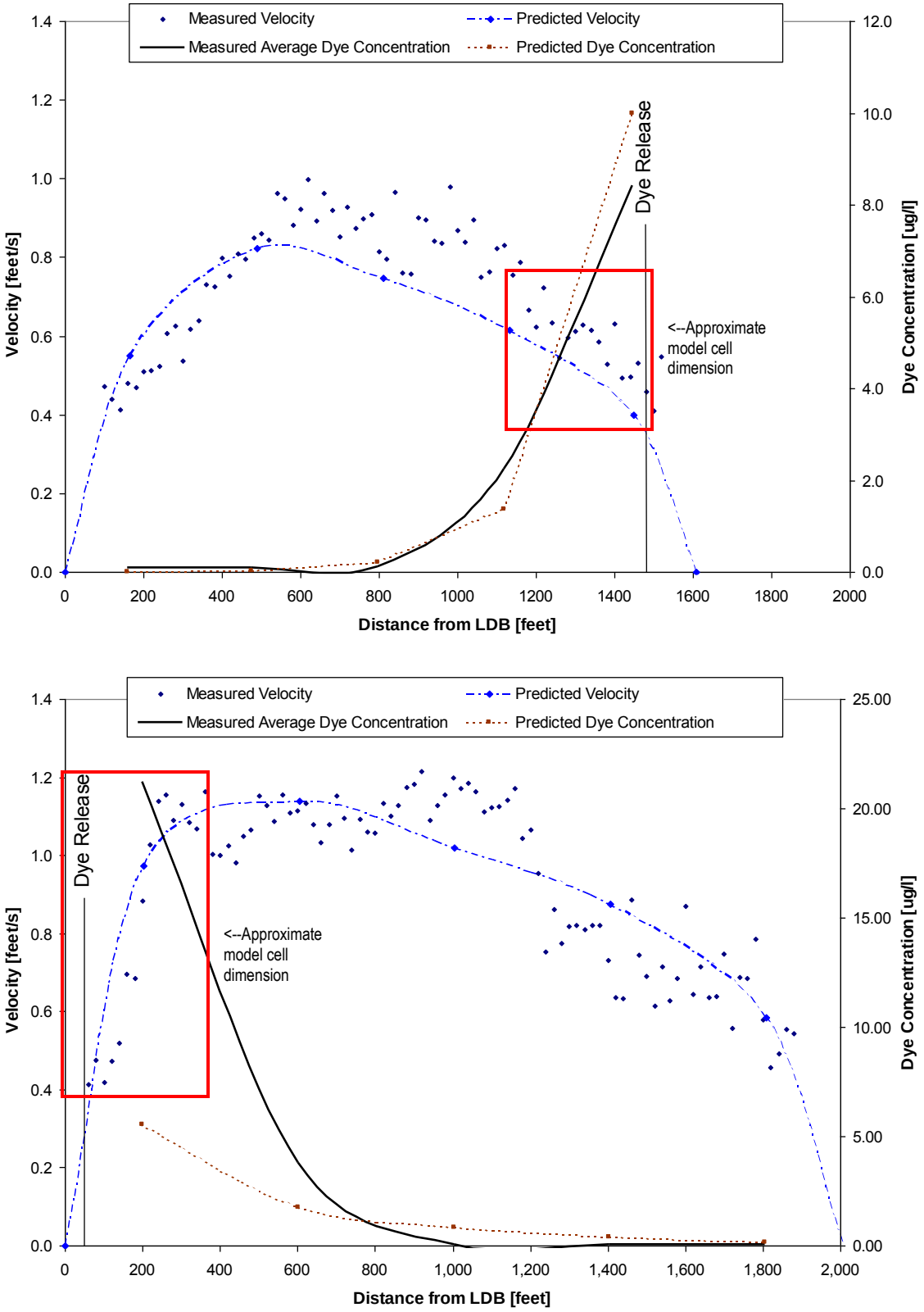

Figure 24: Effect of Grid Cell Size and Lateral Velocity Profile on Dye Calibration

Summary

The two-dimensional EFDC model of the Ohio River, Licking River, and Banklick Creek was calibrated using two comprehensive dye studies conducted by the USGS in 2005 and confirmed using two dye studies conducted by ORSANCO in 1995. The model reasonably reproduces the lateral and longitudinal variations in dye concentrations due to a near-shore dye release. Differences between the observed concentrations and the model predicted concentrations are mostly likely due to the coarseness of the grid cells and initial dilution of the dye.

The calibration of lateral mixing in the Ohio River led to four major findings:

1. The model accurately predicts the distance required to reach laterally well-mixed conditions;
2. The model reproduces the rate of lateral mixing in the downstream direction; and,
3. The model more accurately predicts the lateral and longitudinal profile of dye concentrations in areas where the model also accurately simulates the lateral velocity profile, especially near the river banks; and,
4. In areas near the dye release point where near-shore velocities are close to stagnant, the model underpredicts dye concentrations but downstream predictions suggest that the overall mass loading is consistent with the loading predicted by the data.

References

LimnoTech, 2008. "Hydraulic Calibration of the EFDC Model of the Ohio River." Memorandum prepared by LimnoTech for Sanitation District No. 1. March, 2008.

Ohio River Valley Water Sanitation Commission (ORSANCO), 2002. A Study of Impacts and Control of Wet Weather Sources of Pollution on Large Rivers. Final Report, January 2002.

USEPA, 1999. Combined Sewer Overflows: Guidance for Monitoring and Modeling. EPA 832-B-99-002. January, 1999.

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LimnoTech
Water | Environment | Scientists | Engineers

DATE: November 25, 2008

MEMORANDUM

FROM: Jeremy Grush

TO: Jim Gibson (SD1)

CC: Carrie Turner (LimnoTech), Mindy Scott (SD1)

SUBJECT: Development of Site-Specific Bacteria Loss Rate for Use in the EFDC Model of the Ohio River, Licking River and Banklick Creek

Introduction

The Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are an important contribution for watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) long-term control plan. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

The Sanitation District No. 1 and the Metropolitan Sewer District of Greater Cincinnati (MSD-GC) are collaborating to construct and calibrate an extended EFDC model of the Ohio River and its major tributaries. This work is being initiated by SD1 and will be conducted for SD1 by LimnoTech (LTI) building upon previous work conducted by XCG Consultants (XCG) for MSD-GC. In keeping with the common goal of addressing water quality issues through coordinated, watershed-based solutions, the intent of the two districts is to work cooperatively on the development of the model.

LimnoTech's calibration strategy for the Ohio River EFDC model is to calibrate physical processes of the system in a step-wise process where each step adds more complexity to the model representation of the study area. Important processes in the modeling of bacteria include hydrodynamic transport, lateral mixing, and the loss rate of bacteria. Previous memoranda described the calibration of hydrodynamic transport in the system and lateral mixing and showed that the model accurately predicted water levels, velocities, and lateral mixing rates throughout the system (LimnoTech, 2008a, LimnoTech, 2008b). The purpose of this memorandum is to describe LimnoTech's development of a site-specific *E. coli* and fecal coliform loss rates for use in the EFDC model.

Processes that influence the fate of bacteria species, such as fecal coliform and *E. coli*, after release into surface waters include net settling and die-off. These losses are often represented in water quality models using a single first-order decay rate to represent the cumulative effect of these processes on bacteria densities. Studies in the literature (EPA, 1985) indicate that the rate can range from 0.5 to 3.5 per day (though values outside of this range have also been reported). The selection of an appropriate loss rate can affect model simulations of downstream impacts and locations of peak instream densities, which can then affect decisions on prioritizing controls. It may be possible to use site-specific data to constrain the magnitude of the loss rate applied in the river model.

An average bacteria loss rate of 1.5/day was calculated for the Ohio River using 15 datasets collected by ORSANCO between 2003 and 2006. These datasets were chosen because the reaches were not significantly influenced by external (e.g. tributary) bacteria loadings, large flow additions, or significant

501 Avis Drive
Ann Arbor, MI 48108
734-332-1200
Fax: 734-332-1212
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lateral mixing, and the data showed measurable losses over the downstream extent of the reach. The selection of this loss rate was confirmed by evaluating the fit to data using alternate values (1/day and 2/day) and by simulating a dry weather survey with the EFDC model.

This memorandum describes this analysis in the following sections:

- Overview of Loss Rate Development
- Available Data
- Model to Data Comparisons
- Verification of Loss Rate Calibration using EFDC

Overview of Loss Rate Development

The loss rate analysis utilized fifteen datasets collected during dry-weather conditions in the Ohio River from ORSANCO's recent longitudinal monitoring program. These datasets were used in this analysis because they spanned much of the Ohio River, including a downstream portion where external bacteria loads were insignificant. When external or tributary bacteria loads are insignificant over a relatively long reach, the decreases in bacteria levels with distance downstream can be assumed to be solely attributed to bacteria losses. In the upstream reaches, tributary bacteria loads and their uncertainty complicate the estimation of instream losses from settling and die-off.

Because hydrodynamic and water quality conditions are relatively uniform during dry-weather conditions, a spreadsheet analysis was performed to estimate loss rates. After identifying reaches where external loads were insignificant compared to instream losses, a one-dimensional analysis of the river was conducted for each dataset. The Ohio River flow on the day of each dataset was assumed constant over that day and the corresponding average velocity was estimated by applying the EFDC model. The loss rate for each dataset was estimated using Equation 1:

$$C(x) = C_0 \exp(\frac{-kx}{V})$$

where C(x) is the average density at a distance of x feet from the origin, C_0 is the density at x = 0 (e.g. the most upstream transect of the river reach), k is the first order loss rate, and V is the constant, average velocity over the cross-section.

The loss rate was determined by comparing the bacteria densities predicted using Equation 1 for C(x) to the measured densities and adjusting the loss-rate until a reasonable fit was made between the predicted and the corresponding observed densities.

Available Data

Dry weather datasets from the Ohio River, Licking River and Banklick Creek were evaluated for use in this analysis. Conditions during each survey were evaluated to determine whether the data were consistent with the assumptions used in the spreadsheet analysis, primarily that densities are relatively constant in time (but not in space). Bacteria measurements, particularly along the Ohio River, were typically taken over the length of the day, so if densities were dynamic, then the computation of the loss rate would be flawed. Two aspects of the data were evaluated with respect to confirming simplifying assumptions:

- First, flow conditions on the Ohio River were checked to see if there was a significant change in flow rate over the period spanning when measurements were made;

- Second, bacteria densities in the Ohio River and major tributaries were checked to identify locations of significantly elevated densities. This was done because the Licking River could have elevated bacteria densities while the Ohio River flow is low because of the dramatic difference in watershed sizes and hydrologic response time. Datasets in which hydrodynamic or water quality conditions appeared to be more dynamic than desired were flagged so that these could be separated out from the analysis.

Fifteen dry weather surveys from the Ohio River collected between 2003 and 2006 were identified as candidate datasets. The Licking River and Banklick Creek survey data were not used because these datasets either exhibited load gains or the losses were not of sufficient magnitude to be confident that the dataset was reflecting the loss processes that the loss rate is intended to represent. It should be noted that during dry weather, the flow in the Licking River and Banklick Creek originating in their respective watersheds is often diluted by backwater from the Ohio River. Therefore, densities measured in the lower Licking River and lower Banklick Creek often reflect conditions in the Ohio River. The following table summarizes the datasets and reaches that were the subjects of this analysis:

Table 1: Summary of Dry-Weather Bacteria (E. coli) Datasets Used for Loss-Rate Analysis

Event Number	Date	Discharge [cfs]	Potentially Dynamic Conditions	Water Temperature [degC]	Analyzed Reach [River Miles]
1	5/23/06	100,000	No	20	518.5-528.4
2	5/31/06	80,000	Yes	20	498.0-508.3
3	6/6/06	120,000	Yes	25	436.8-528.4
4	6/14/06	30,000	Yes	25	482.2-493.2
4	6/14/06	30,000	Yes	25	513.4-528.4
5	6/21/06	25,000	Yes	25	498.0-513.4
6	9/30/03	120,000	Yes	20	503.1-523.4
7	10/7/03	70,000	Yes	20	513.4-528.4
8	10/14/03	40,000	Yes	20	508.3-523.4
9	10/21/03	80,000	Yes	20	513.4-528.4
10	10/28/03	60,000	No	20	n/a
11	5/10/05	70,000	No	17	489.7-518.5
12	5/18/05	90,000	No	17	486.2-518.5
13	5/24/05	100,000	No	20	489.7-513.4
14	5/31/05	50,000	No	20	503.1-513.4
15	6/8/05	40,000	Yes	25	482.2-518.5

Model to Data Comparisons

All of the datasets shown in Table 1 were used to estimate bacteria loss rates. However, some of the datasets were less useful because there was only a short distance of the Ohio River over which a bacteria loss was discernible. Figures 1 through 4 show predicted bacteria densities using the one-dimensional analysis versus measured bacteria densities. These four surveys were selected from the overall survey group because the datasets had longer reaches over which a consistent bacteria loss occurred. Longer reaches offer the advantage of measurements at multiple transects so it is easier to observe the first-order loss trend in the data. These surveys also offer a more robust dataset to evaluate the estimated loss rate. Therefore, these four datasets are more likely to produce the most reliable estimate of bacteria loss rate.

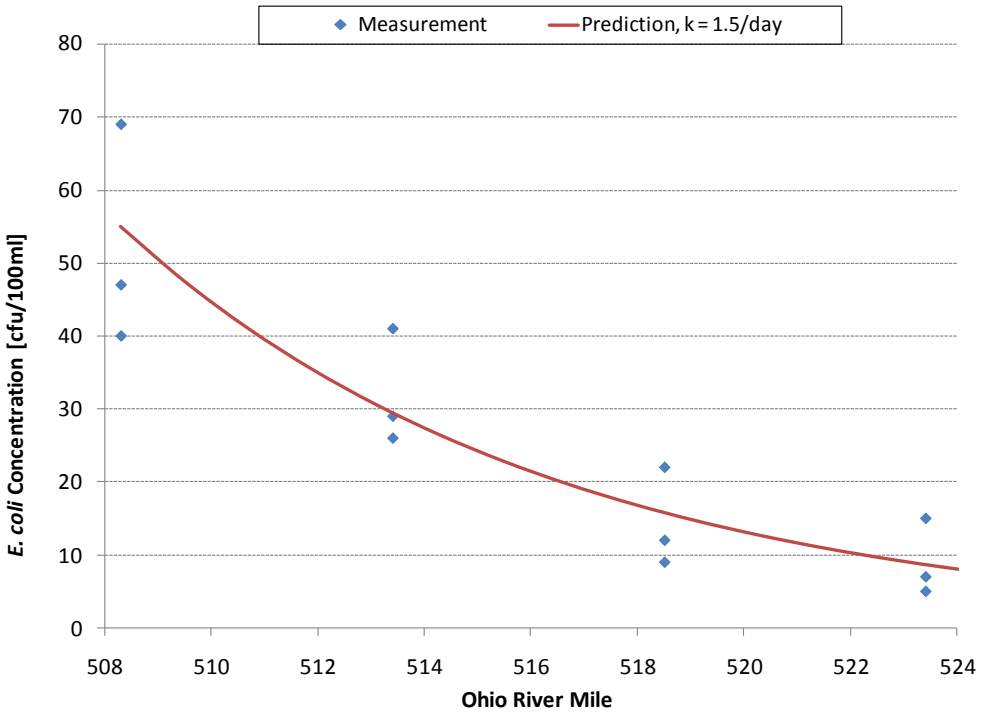

Figure 1: 10/14/2003 Event Loss-Rate Calculation

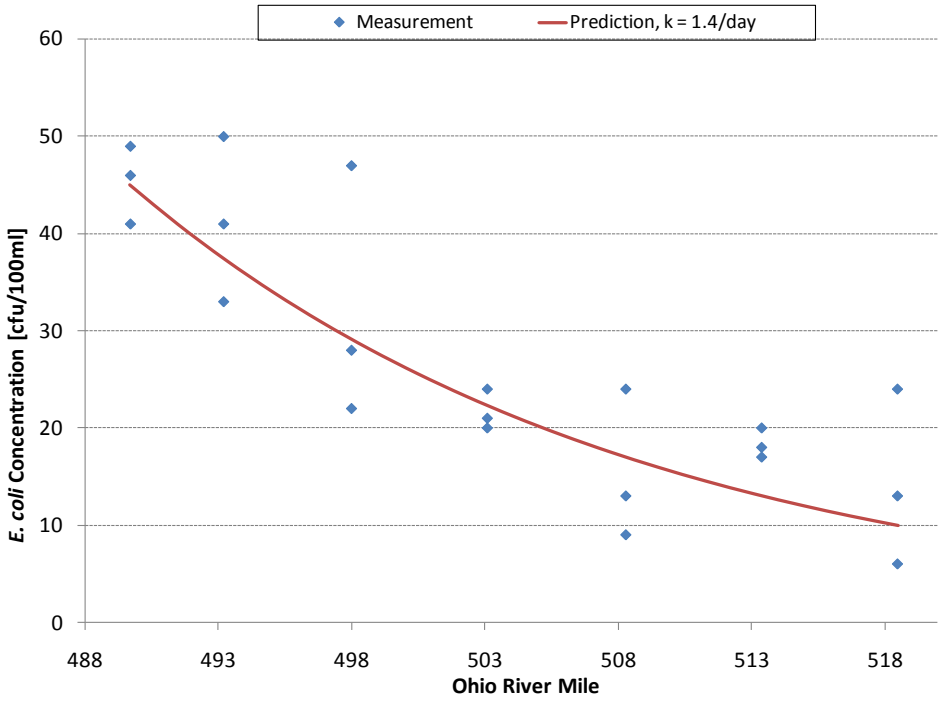

Figure 2: 5/10/2005 Event Loss-Rate Calculation

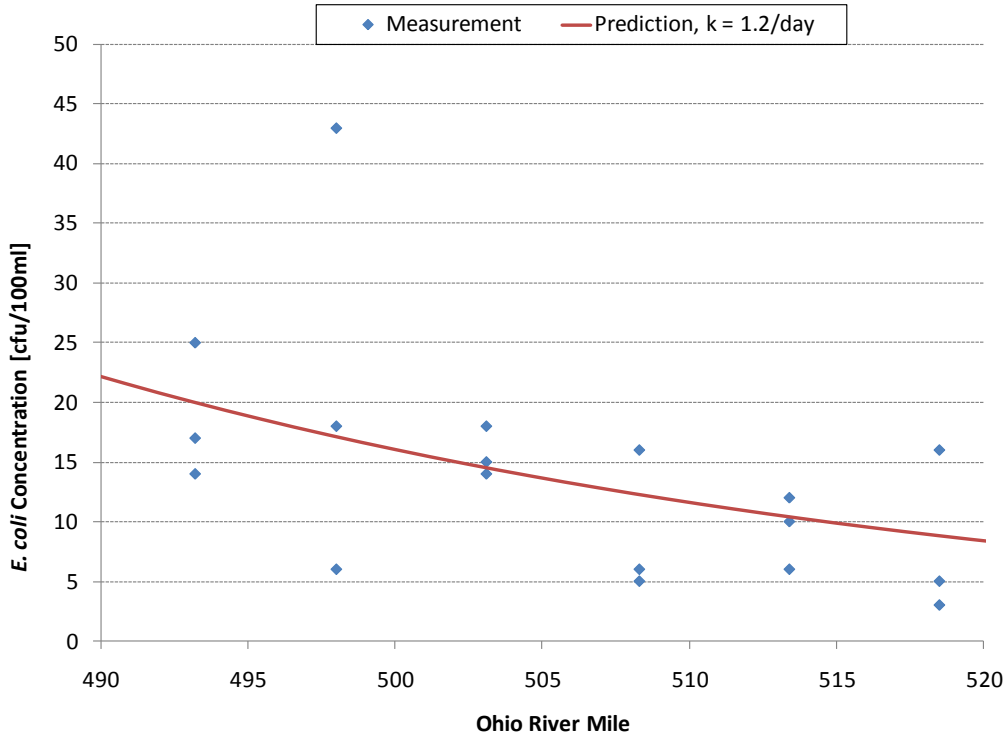

Figure 3: 5/18/2005 Event Loss-Rate Calculation

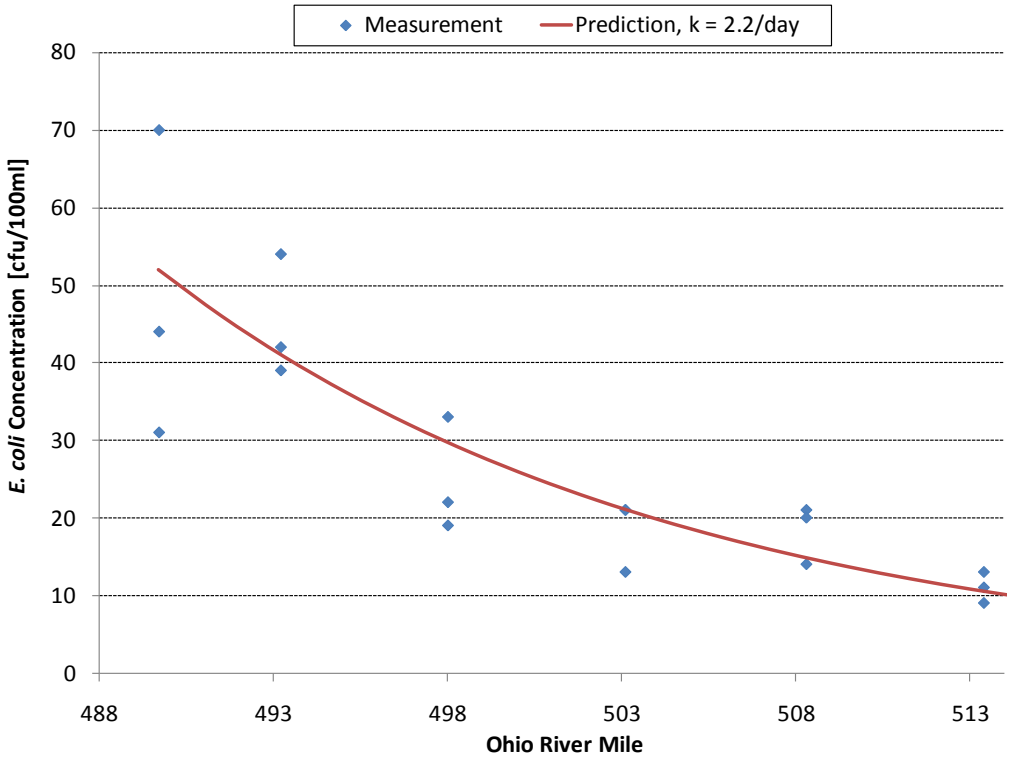

Figure 4: 5/24/2005 Event Loss-Rate Calculation

Loss rates calculated from these four datasets range from 1.2 day^{-1} to 2.2 day^{-1}, with an average of 1.5 day^{-1}. Each loss rate was adjusted to a temperature of twenty degrees Celsius using the Arrhenius equation ($\theta = 1.05$). Some variability in the loss rate is likely to occur due to influences other than temperature, such as variable settling rates and other factors affecting die-off. Using all fifteen datasets, the average bacteria loss rate was also approximately 1.5 day^{-1}. Therefore, a rate constant of 1.5 day^{-1} is proposed for use as the bacteria loss rate in the EFDC model.

Figure 5 shows the sensitivity of the predicted longitudinal bacteria profile to the estimated bacteria loss rate for the 10/14/2003 sampling event. Previous modeling studies used loss rates of 1/day (ORSANCO, 2002) and 2/day (MSDGC, 2006) to simulate bacteria in the Ohio River. As shown in Figure 5, the higher loss rate (2/day) occasionally underestimates all of the observed densities at a given transect while the opposite is true for the lower loss rate (the predicted density overestimates all of the densities at a transect). However, the 1.5/day loss rate provides the best fit to the entire dataset associated with this survey (note that similar analysis for other individual surveys may yield better fits to the data using other loss rate values).

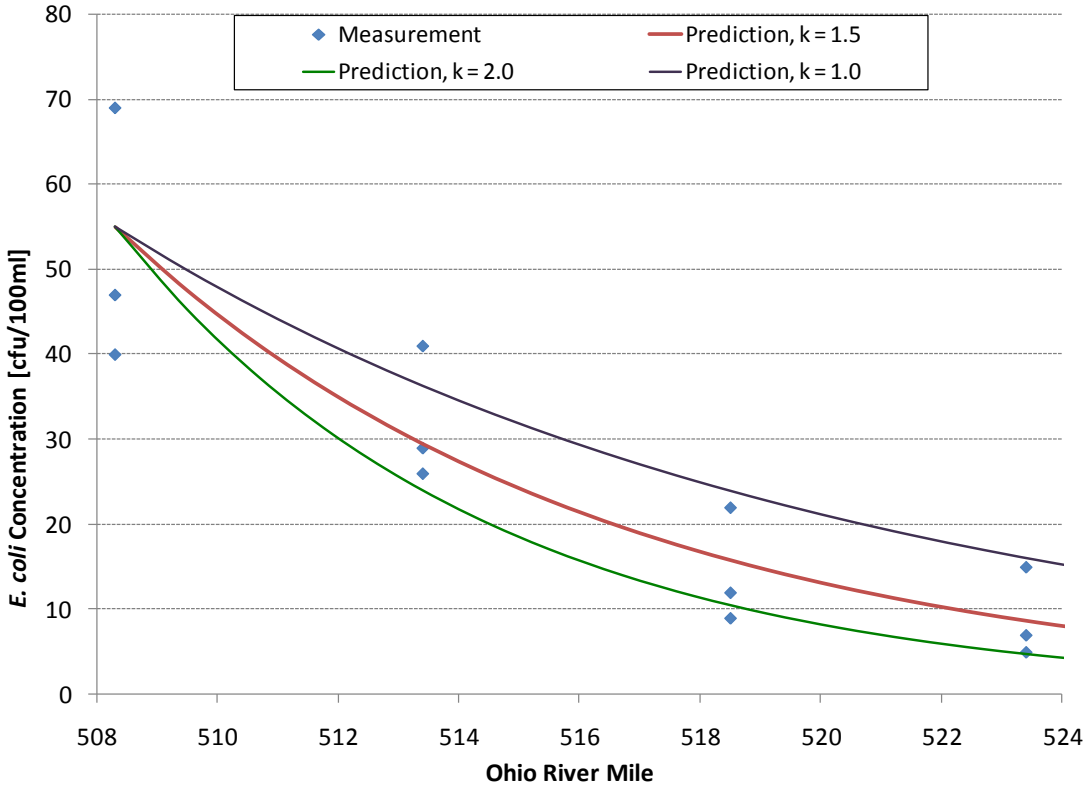

Figure 5: Sensitivity of Bacteria Densities to Loss Rate during the 10/14/2003 Event

Evaluation of Loss Rate Using EFDC

The analyses presented in the previous sections of the memorandum were based on a one-dimensional spreadsheet model of the Ohio River. The EFDC model was applied for the 5/10/2005 sampling event (described in Table 1) so that the effect of the loss rate over a two dimensional representation of the river could be evaluated. The results of this simulation indicate that a loss rate of 1.5/day accurately simulates bacteria loss processes that are observable in the data at different lateral locations in the river. Note however, that results from this simulation were intended only to verify that the modeled rate of bacteria

decline is consistent with the rate of decline observed in the data. The downstream portion of the model (below the Great Miami River confluence) has not been calibrated and is not intended for use as a tool for predicting instream densities at this time. Nevertheless, this downstream portion of the river is the best area to evaluate the modeled bacteria losses and so, was included in this simulation for the purpose noted above.

Few of the tributaries were monitored during the surveys used in this analysis. Therefore, as a first step, major tributary loadings into the model were reasonably-sized based on trends observed in each tributary dataset and the instream density profile in the Ohio River. For instance, a Licking River dry-weather bacteria density of 600 cfu/100ml (and corresponding flow of 4,300 cfs based on gage data) was used to calibrate the model. If the loss rate was significantly too high, tributary loadings would need to be high also to compensate for the unrealistically high losses of instream bacteria. However, the purpose of the simulation was to evaluate the effect of the loss rate on instream densities in reaches where tributary inflows and loadings were not significant. The EFDC model accurately predicts the rate of decline in bacteria densities over long reaches where no significant bacteria inputs occurred. Figures 6 through 8 illustrate that the model predicts a similar rate of bacteria losses between river miles (RM) 485 and 505 that can be observed in the data at the left descending quarter, mid-channel and right descending quarter. This reach of the Ohio River (RM 485-505) is appropriate for evaluation because no significant tributary loadings exist along it and changes in bacteria density due to lateral mixing are insignificant compared to changes due to bacteria losses.

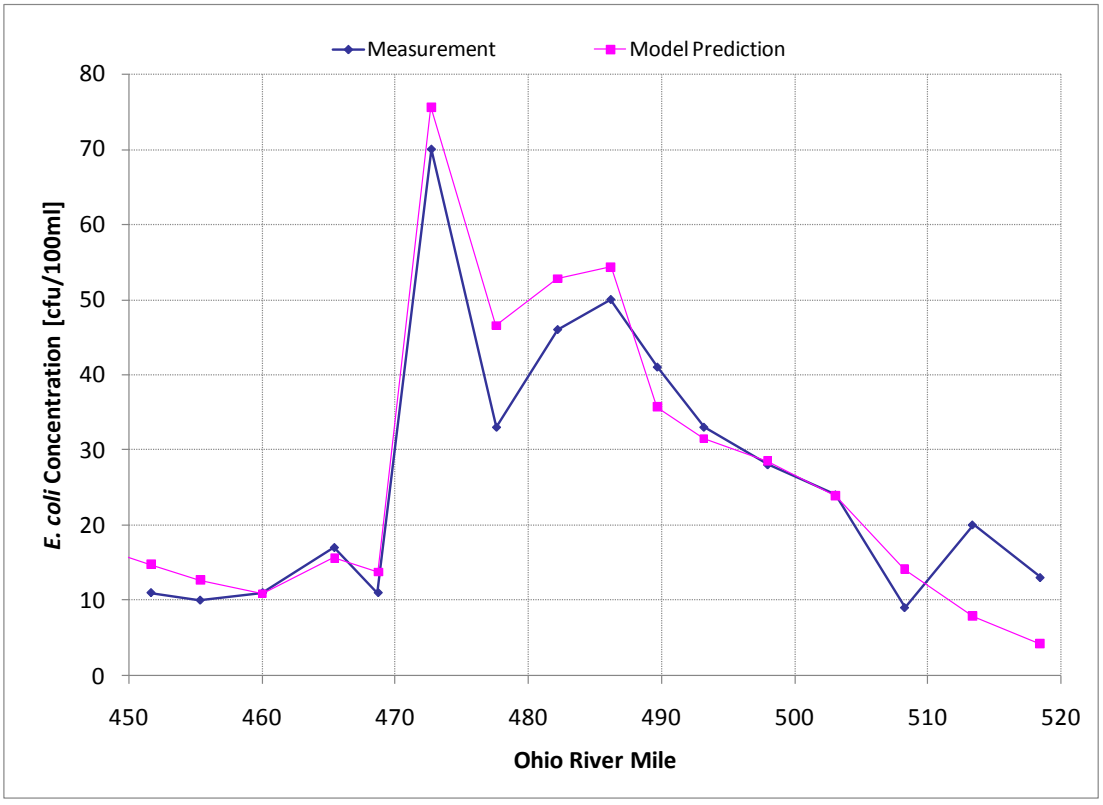

Figure 6: Longitudinal Profiles of Bacteria Density along the Left Descending Quarter

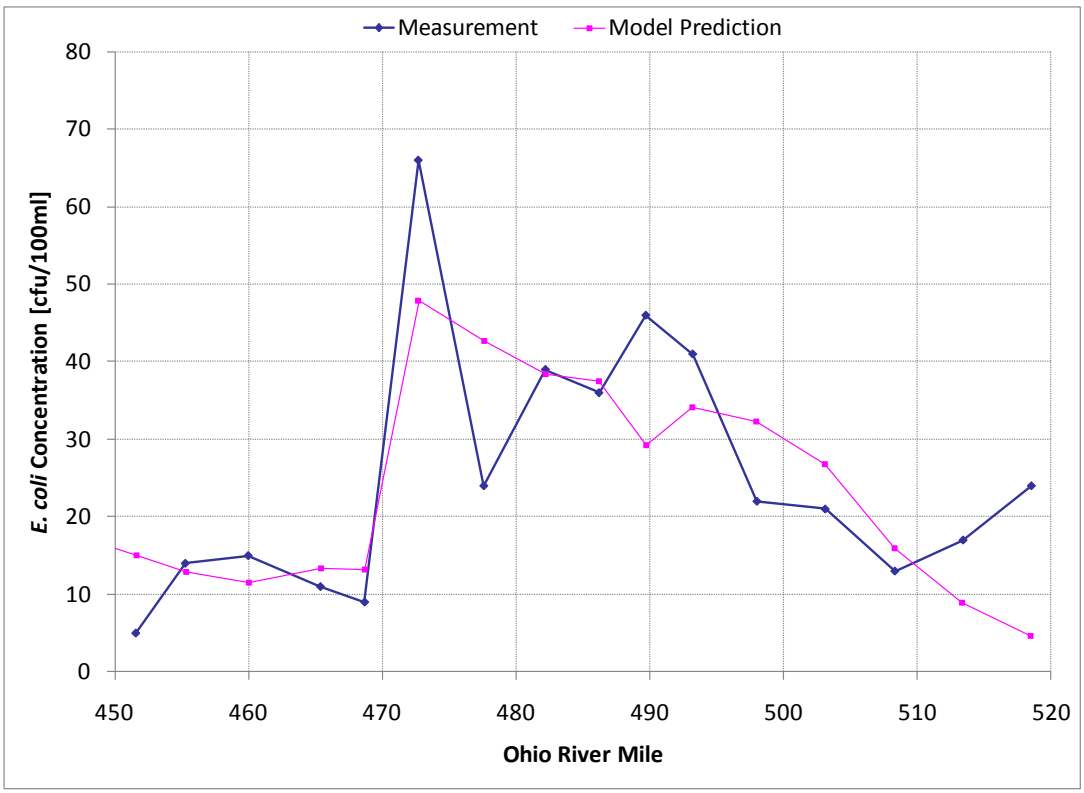

Figure 7: Longitudinal Profiles of Bacteria Density along the Center Channel

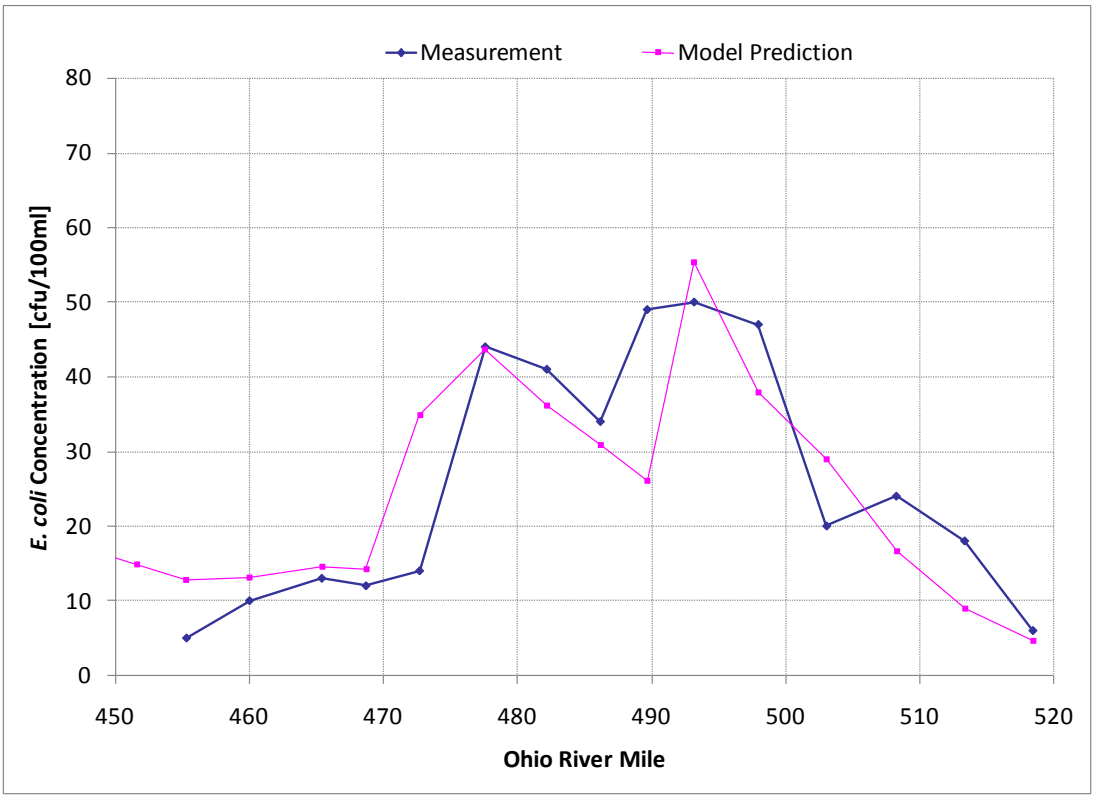

Figure 8: Longitudinal Profiles of Bacteria Density along the Right Descending Quarter

Additional evaluations of the loss rate will be conducted when the wet weather calibration of the model is conducted. During this process, additional refinements to the value of the loss rate used in the model may be made to complete the calibration.

References

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LimnoTech, 2008b. "Lateral Mixing Calibration of the EFDC Model of the Ohio River." Draft Memorandum prepared by LimnoTech for Sanitation District No. 1. August 21, 2008.

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LimnoTech
Water | Environment | Scientists | Engineers

DATE: January 15, 2009

MEMORANDUM

FROM: Jeremy Grush

TO: Jim Gibson (SD1), Mindy Scott (SD1)

CC: Carrie Turner (LimnoTech)

SUBJECT: Water Quality Calibration and Corroboration of Fecal Coliform in the EFDC Model of the Ohio River, Licking River and Banklick Creek

Introduction

The Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are an important contribution for watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) long-term control plan (LTCP). SD1's Consent Decree requires that the Watershed Plans include all of the elements of a LTCP. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

SD1 and the Metropolitan Sewer District of Greater Cincinnati (MSD-GC) are collaborating to construct and calibrate an extended EFDC model of the Ohio River and its major tributaries. This work is being initiated by SD1 and will be conducted for SD1 by LimnoTech (LTI) building upon previous work conducted by XCG Consultants (XCG) for MSD-GC. In keeping with the common goal of addressing water quality issues through coordinated, watershed-based solutions, the intent of the two districts is to work cooperatively on the development of the model.

LimnoTech's calibration strategy for the Ohio River EFDC model is to calibrate physical processes of the system in a step-wise process where each step adds more complexity to the model representation of the study area. Important processes in the modeling of bacteria include hydrodynamic transport, lateral mixing, and the loss rate of bacteria. Previous memoranda described the calibration of hydrodynamic transport in the system and lateral mixing. These memoranda illustrated that the model accurately predicted water levels, velocities, and lateral mixing rates throughout the system (LimnoTech, 2008a, LimnoTech, 2008b). Another previous memorandum described the development of a data-based estimate of the bacteria loss rate was being used in the model (LimnoTech, 2008c). The purpose of this memorandum is to describe the calibration of the EFDC model to fecal coliform data collected during wet weather events in Banklick Creek, the Licking River, and upper Ohio River.

The model calibration relies principally on reproducing the fecal coliform densities monitored in Banklick Creek and the Licking River during the May 2008 wet weather event. The model performance was further evaluated by simulating seven wet weather events in 1995 and 1996 in Banklick Creek and Licking River and a large wet weather event monitored in the upper Ohio River in 2007. Note however, that the conclusions regarding model performance for these periods are tempered by an understanding that the infrastructure model results, which are used as input to the river model, provided for 1995 and 1996 were based on the current configuration of the collection system rather than a historical representation of the collection system as it existed in 1995 and 1996. Therefore, accurate estimates of the overflow locations and volumes that occurred during these storms were not possible, given the changes and

501 Avis Drive
Ann Arbor, MI 48108
734-332-1200
Fax: 734-332-1212
www.limno.com

improvements made to the collection system between 1995 and the present. While the upper Ohio River simulation did not require infrastructure model results, the loadings for Twelvemile and Fourmile Creeks were calculated from available data and as such, are not mechanistic estimates of wet weather souce loadings from these tributaries. Nevertheless, these events function as corroboration tools for the EFDC model and provide additional support for assessing the model's performance as acceptable.

The model's sensitivity to critical settings was also evaluated as part of the calibration and corroboration process. Sensitivity runs were conducted with respect to CSO and SSO event mean concentrations, the instream loss rate value, and by simulating *E. coli* in addition to fecal coliform (because Kentucky and ORSANCO have water quality standards for both constituents). Additionally, the 2008 sampling event was simulated in two ways: once with a subset of the model grid that only represents the Licking River and Banklick Creek, and once with the full model grid including the Ohio River. Using a model grid that excludes the Ohio River saves a substantial amount of computational time, but this configuration may not be capable of reproducing the impact that elevated Ohio River bacteria densities have on the lower Licking River due to backwater effects. This simulation was produced to better understand the impact that the Ohio River has on bacteria densities in the lower Licking River.

Model simulations of the May 2008 wet weather event showed that the model reliably predicts fecal coliform densities throughout Banklick Creek and the Licking River. The model tended to slightly overpredict densities in Banklick and the Licking River left descending bank, which is likely due to high CSO loadings, which were estimated using an event mean concentration that may not be elevated compared to actual densities. The model's performance for each of the events simulated from the 1995 and 1996 period varied by event, with simulations of some events reproducing the data better than for other events. However, as noted above, locations with poor fits to the data may be a result of a missing or inaccurate external loading rather than a reflection of inaccurate model configuration or algorithms. The model also performed well for the upper Ohio River survey, though it should be noted that external loadings for the Kentucky tributaries were back-calculated from the survey data.

This memorandum describes the model calibration and validation in the following sections:

- Model Setup and Inputs
- Evaluation of Model Performance
- Conclusions

Model Setup and Inputs

This section presents a summary of the data used to calibrate and verify the model and a description of the methods. The data and methods used to specify the inputs used in the model for each event are presented in the next section. As noted in the Introduction, the EFDC model was applied in one of two configurations based on available data:

1. Licking and Banklick portions only
2. Licking, Banklick and Ohio River from the upstream boundary to the Great Miami River confluence.

Figure 1 shows the Licking and Banklick portions of the model and the location of SD1 sources within the watershed of the model domain. Figure 2 shows the full model domain with SD1 sources. Note, however, that not all of the SD1 overflows shown actually overflow during each of the simulated events. This is discussed in more detail in the model performance portion of the memorandum.

Figure 1. Licking/Banklick Portion of EFDC Model Domain (with SD1 Sources).

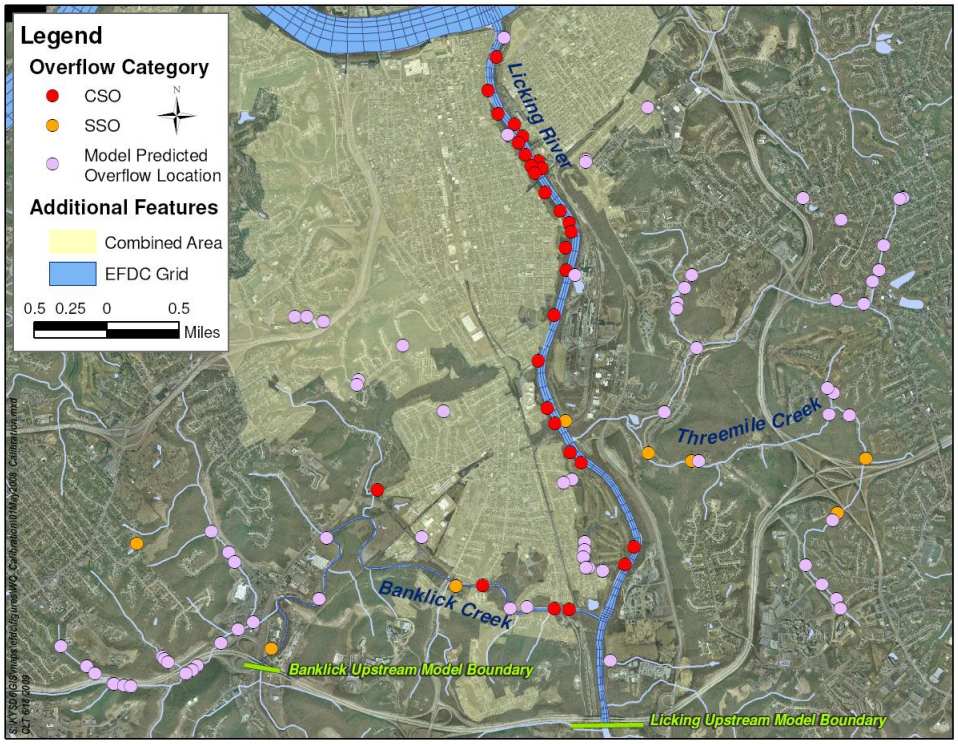
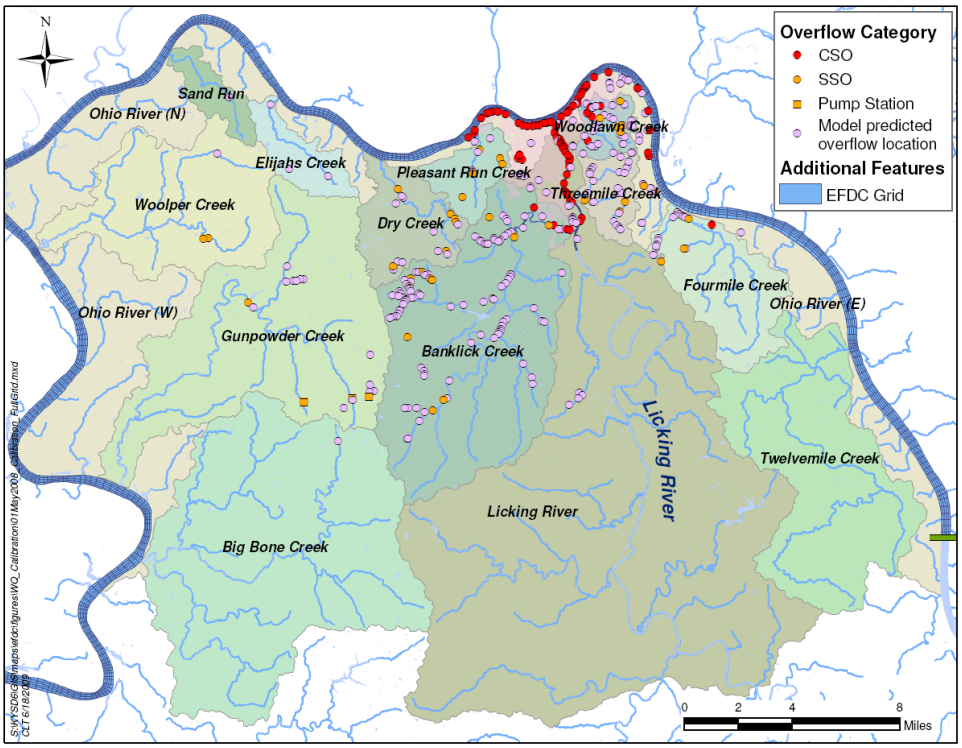


Figure 2. EFDC Model Domain and SD1 Sources.



Note: "Model predicted overflow locations" refer to manhole locations that have not been confirmed as recurring SSOs.

Summary of Calibration and Corroboration Datasets

SD1 has been very active in monitoring water quality in the Licking River, Banklick Creek and Ohio River during dry and wet weather. Wet weather data capture the impact of wet weather sources, such as CSOs and SSOs, on instream water quality. Eight wet weather surveys have been done specifically for the lower Licking and Banklick Creek between 1995 and 2008. These surveys, which span a range of storm, stream and seasonal conditions, provide a robust dataset for potential use in calibrating the EFDC model.

The Ohio River has also been actively monitored over the last ten years. SD1 has conducted two wet weather surveys (October 2007 and June 2008) in the upper portion of the river. SD1 has supported ORSANCO to conduct wet weather monitoring for five storm events in the middle portion of the Ohio River between 1995 and 2000 (ORSANCO, 2002). MSD-GC also monitored this portion of the river during a storm event in 2004 to support the development of their LTCP (MSDGC, 2006).

Every attempt was made to use as many of the wet weather surveys as possible, though, as noted in the Introduction section, use of some of the datasets were constrained by other factors, such as data availability and system configuration. The May 2008 event was the principle dataset used to calibrate the model. Additional survey periods were simulated with the model to verify that the model performance was reasonable.

Table 1 presents a summary of the rainfall, monitoring and source overflow characteristics of the datasets used to calibrate and verify the EFDC model.

Table 1. Wet Weather Event Datasets Used to Calibrate the Model.

Event	Total Rain (in)[a]	Max. Hourly Intensity (in/hr)	Storm Duration (hrs)	Sampling Extent	Number of Locations	Sampling Duration	Number of Sampling Rounds	Number of Results	Number of SD1 CSOs Activated [b]	Number of SD1 SSOs Activated [b]
May-2008	0.54[c]	0.10	17	Licking R. (RM 5.5 - RM0.5)[d] Banklick Cr (RM 3.9 - RM 0.3)[e]	BLC = 3 LIR = 12 (4 transects)[d] OHR = 1	3 days	7[f]	121	16	8
Upper Ohio Wet 1	4.87	0.60	44	Ohio River (RM 444- RM 462)[g]	OHR = 20 (4 transects) [g]	4 days	4	75	na	na
95-Wet1	0.50	0.18	16	Licking R. (RM 5.5 - RM 0.5)[h]	BLC=3 LIR = 21 (7 transects)[h]	2 days	5	85	13	1
95-Wet2	0.36	0.11	6	Banklick C. (RM 3.9 - RM 0.3)[e]		3 days	8	124	13	2
95-Wet3	0.32	0.17	6			3 days	6	108	14	2
96-Wet1	1.05	0.51	7	Licking R. (RM 6.2 - RM 0.5)[h,i]	BLC=3 LIR = 22 (8 transects)[h,i]	3 days	6	140	19	4
96-Wet2	0.11	0.08	2	Banklick C. (RM 3.9 - RM 0.3)[e]		4 days	7	169	8	1
96-Wet3	0.69	0.43	3			3 days	7	158	18	3
96-Wet4	1.62	0.71	9			4 days	7	169	25	15

Notes:

[a] Rainfall measured at Greater Cincinnati Airport, except as noted

[b] Number of locations activating based on results from InfoWorks model of SD1 collection system

[c] Rainfall measured at Banklick Creek USGS gage (gage ID: 03254550)

[d] Samples taken at three points across a transect at following four locations: RM 5.5, RM 3.3, RM 1.2, RM 0.5

[e] Samples taken at following locations: RM 3.9, RM 1.2, RM 0.3

[f] Includes a pre-event round of sampling

[g] Samples taken at five points across a transect at following four locations: RM 444, RM 451.6, RM 460, RM 462

[h] Samples taken at three points across a transect at following seven locations: RM 5.5, RM 4.8, RM 3.3, RM 2.3, RM 1.3, RM 0.8 and RM 0.5.

[I] Additional sample taken mid-channel at RM 6.2

Summary of River Model Inputs

The river model was applied for periods corresponding to the wet weather sampling surveys described in Table 1 to simulate instream fecal coliform densities. Successful calibration for bacteria within the EFDC model requires reasonably accurate representations of hydrodynamics, lateral mixing, the bacteria loss rate, infrastructure overflow volumes, upstream watershed loads, and the event mean bacteria concentration of SD1's overflows. Table 2 provides a brief summary of how each of these components impact application of the model to simulate bacteria.

Table 2: Impact of each Model Component on Bacteria Modeling.

Component	Method of Development	Relevance for Bacteria Modeling
Hydrodynamics	Hydraulic Calibration	Specifies rate at which bacteria is transported through system and cell volume (travel time, available dilution)
Lateral Mixing	Dye Survey Calibration	Specifies rate at which bacteria is dispersed across the Licking River and Ohio River
Bacteria Loss Rate	Loss Rate Calculation	Specifies rate at which instream bacteria densities decrease due to settling and die-off
SD1 Source Overflows	Collection System Modeling	Provides timing, volume and magnitude of CSOs and SSOs (and other SD1 sources)
SD1 Source Loads	Event Mean Concentration Analysis	Provides representative bacteria density to apply to system overflows so that bacteria loadings can be estimated
Upstream Loads	Watershed Modeling, Data	Specifies time series of flow and bacteria load present at each upstream boundary (Banklick, Licking and Ohio River)

The river model inputs needed for each of the survey simulation periods include estimates of flow and fecal coliform density at the model's upstream boundaries (e.g. see Figure 1 for Banklick Creek and Licking River and Figure 2 for Ohio River), flow and fecal coliform density from SD1's overflows, and stage data at the model's downstream boundary. The development of each of these inputs is described in additional detail below.

Upstream Flow

Daily flow data from the United States Geological Survey (USGS) measured at the gage at Catawba (Gage No: 03253500) were used to specify a flow times series for the Licking River upstream boundary at river mile 5.5. A watershed model developed for Banklick Creek (LimnoTech, 2008d) was used to estimate a flow time series at the Banklick Creek model boundary at river mile 3.9. Daily flow data for the Ohio River portion of the model were estimated from the rating curve at the USGS gage in Cincinnati (Gage No. 03255000) that was developed during the hydraulic calibration of the model (LimnoTech memo, 2008a).

Upstream Density

Each sampling survey included monitoring at the upstream boundary of the receiving waters. An hourly time series of model input densities at each of the model's boundaries were interpolated from these data for the Licking River and Ohio River. Hourly fecal coliform densities from the Banklick Creek HSPF watershed model were used to specify the input time series for the EFDC river model.

SD1 Source (CSO, SSO) Overflow Volume

SD1 has developed detailed models of their combined and sanitary collection systems using the InfoWorks modeling platform. These models were calibrated to flow data collected at multiple locations over a monitoring period that spanned a year (July 2007 – June 2008). Details on the model development and calibration can be provided by the SD1 infrastructure consultants (no documentation is available).

The collection system models were applied for the sampling survey periods to provide hourly output of overflow volume from each of SD1's CSOs, SSOs and pump stations. The models also predicted overflows at locations that have not been field verified as SSOs. These locations are noted as "model overflow points" or MOPs and treated as SSOs. Table 3 presents a summary of the number of CSOs, SSOs and MOPs discharging to each of the receiving waters in the EFDC model domain. The source type for each overflow was assigned using the SD1 infrastructure geodatabase overflow category. Note that the Ohio River receives overflows from sources directly adjacent to the river and from sources that discharge to tributaries that drain to the river (see Figure 2). There are SSOs and MOPs in Banklick Creek upstream of the EFDC model domain that are not tabulated in Table 3 but which are included as inputs in the Banklick Creek HSPF watershed model.

Table 3. Summary of SD1 Sources in Each Receiving Water in the EFDC River Model.

River	Number of CSOs	Number of SSOs	Number of Model Predicted Overflow Locations
Banklick Creek[a]	5	4	6
Licking River[b]	34 (34)	15 (2)	54 (28)
Ohio River[c]	57 (46)	48 (4)	112 (40)
Total[d]	96	67	172

Notes:

[a] There are other SSOs and MOPs located upstream of the EFDC model domain. However, the impact of these sources are characterized with the HSPF watershed model developed for the creek.

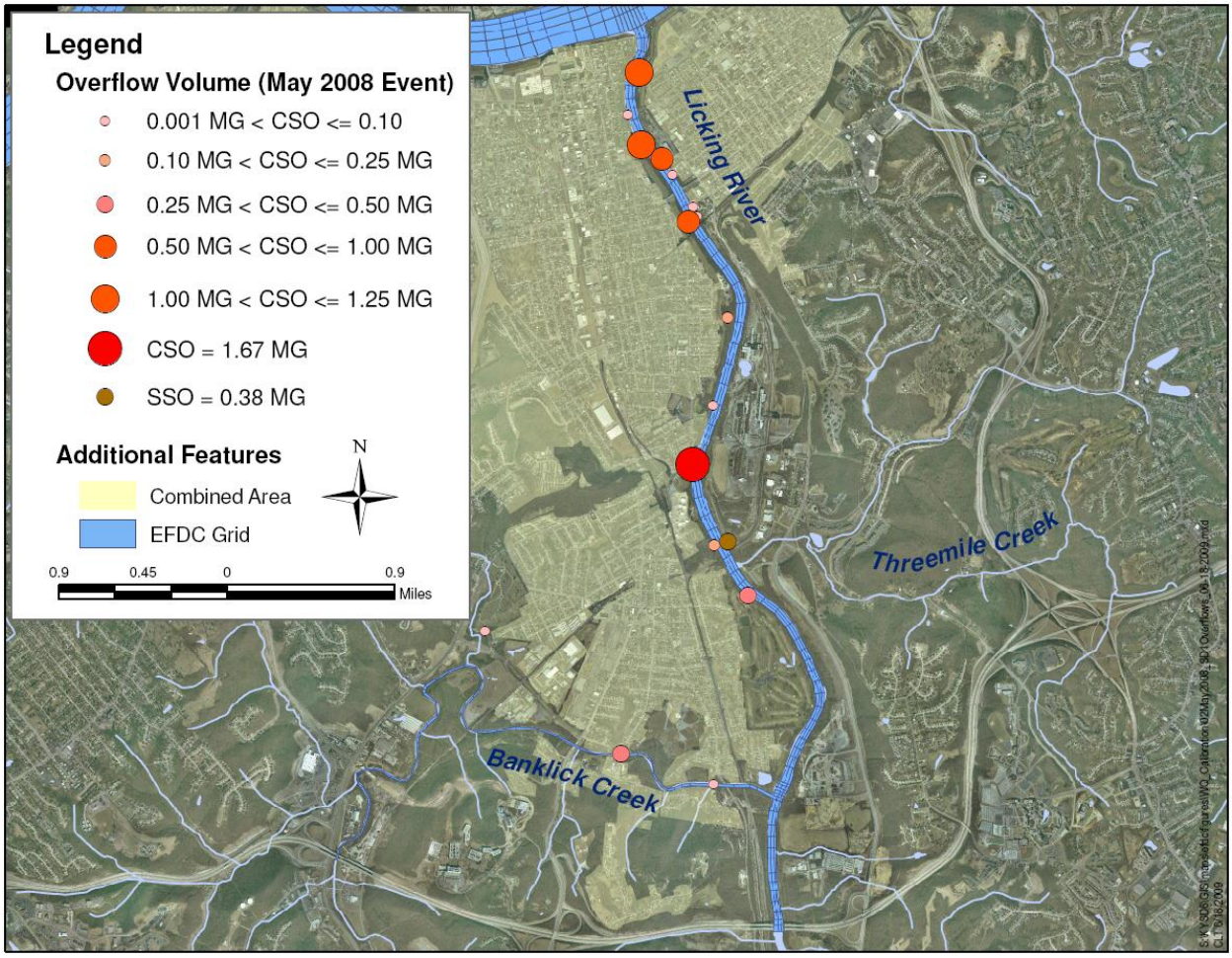
[b] Tallies include sources discharging directly to the Licking River (count shown in parentheses) and to Threemile Creek, a tributary to the Licking River.

[c] Tallies include sources discharging directly to the Ohio River (count shown in parentheses) and to tributaries to the river.

[d] Note that not all sources overflow during a given storm event.

As noted above, the May 2008 event was the principle calibration event. The rainfall during this event can be characterized as a long, slow drizzle. As such, not all of the SD1 sources overflowed, based on the infrastructure model results. Figure 3 shows the SD1 sources that overflowed during this event and the relative magnitude of the overflow volume. In the Licking River, 33 of the 34 CSOs and only 1 of the 15 SSOs overflowed. One model-predicted overflow location overflowed during this event. Three of the five CSOs overflowed in Banklick Creek but none of the SSOs or model-predicted overflow locations overflowed during this event.

Figure 3. SD1 Source Overflows during the May 2008 Storm Event.



SD1 Source (CSO, SSO) Overflow Density

SD1 has been conducting an extensive monitoring program to characterize the water quality of its overflows. A total of ten sampling events are planned and include sampling at twelve CSO, four SSO and six storm water (SWO) locations The data from the first seven events were used to develop representative event mean concentrations (EMCs) of fecal coliform density for each source type. As a first step in developing a representative density, flow-weighted EMCs were calculated for each individual event and location. Results are shown in Figure 4, 5 and 6, respectively for CSOs, SSOs and SWO (Malcolm Pirnie, personal communication, 2008).

Figure 4. CSO Event Mean Concentrations by Location and Storm Event.

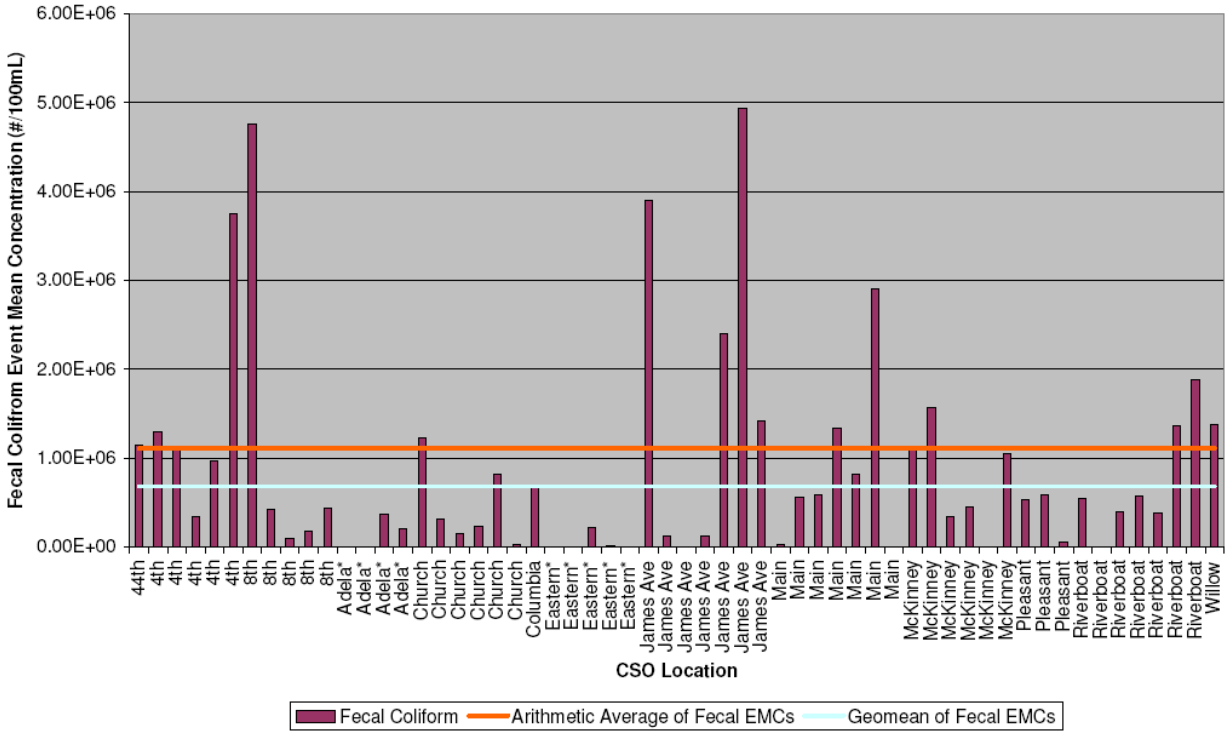


Figure 5. SSO Event Mean Concentrations by Location and Storm Event.

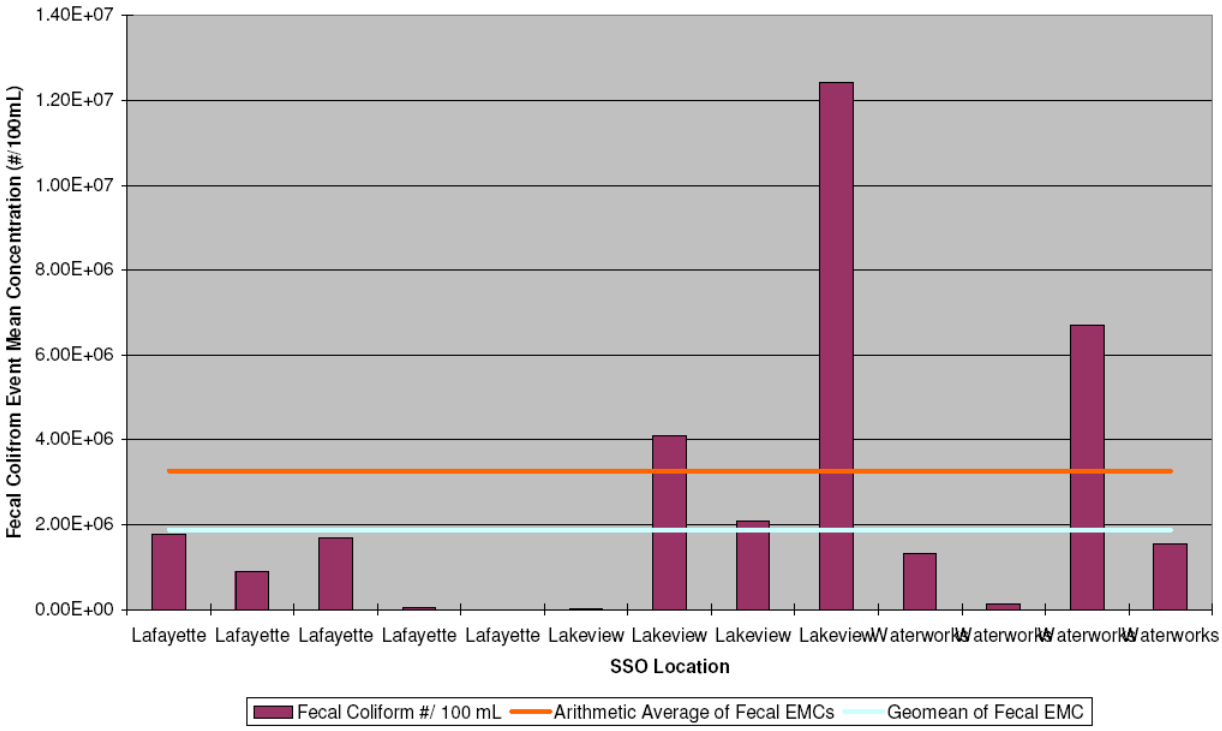
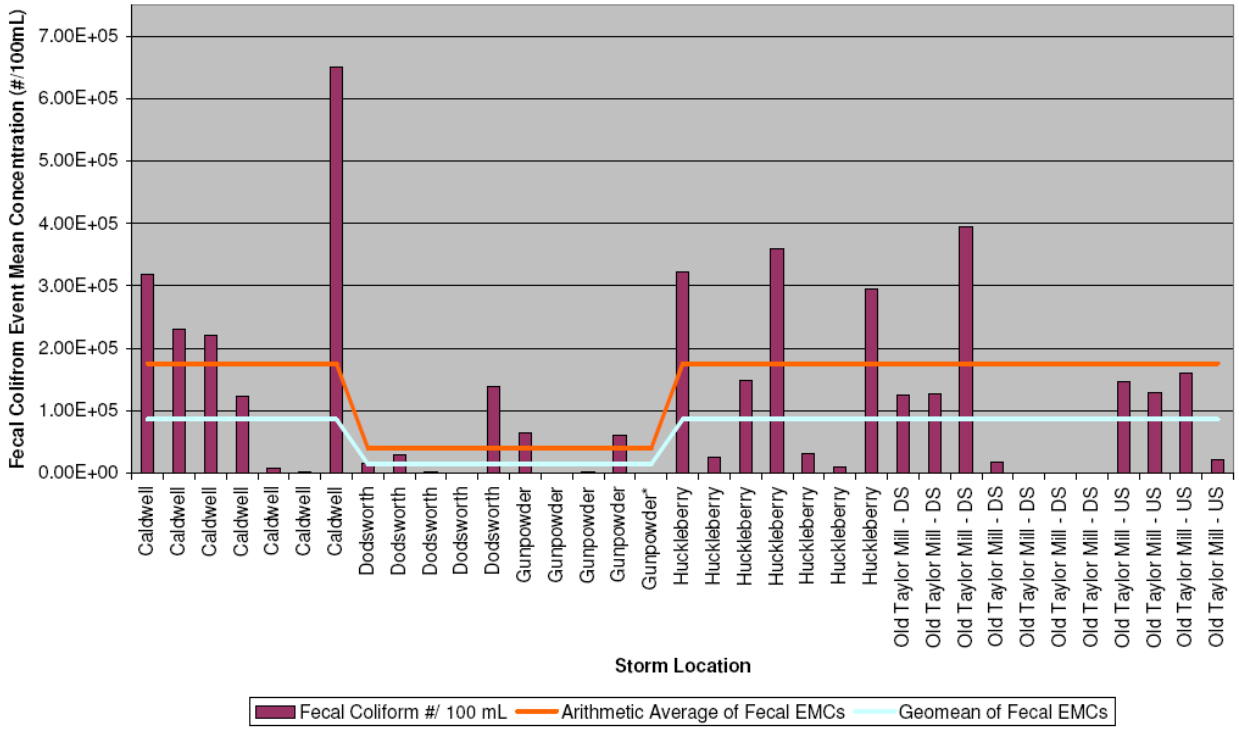


Figure 6. SWO Event Mean Concentrations by Location and Storm Event.



As these figures illustrate, individual storm event EMCs at any location varied from event to event and also varied within an individual event at different locations, often by a half an order of magnitude or more. It was not possible to discern a basis for specifying EMCs by location or to see a first flush effect in the data at each location (Malcolm Pirnie, personal communication). Therefore a single EMC, calculated as the geometric mean concentration of the flow-weighted event mean concentrations, was developed for CSOs and SSOs (shown as the light blue line in Figures 4-6). The storm water data indicated a difference in bacteria density that roughly correlated to age of development of the drainage basin so "old" and "new" storm water EMC values were developed. Note, however, that the EFDC model calibration included only CSO and SSO overflows. The source type EMCs used in the model are summarized in Table 4.

Table 4. Event Mean Concentrations for SD1 CSO, SSO and SWO Used in Water Quality Modeling.

Source Type	Fecal Coliform EMC (cfu/100 ml)	*E. coli* EMC (cfu/100 ml)
CSO	682,000	210,000
SSO	1,870,000	705,000
SWO-Older Area	86,000	17,000
SWO-Newer Area	14,000	6,800

The CSO and SSO EMCs were applied to the hourly overflow volumes predicted by the collection system models to input bacteria loads from these sources to the river models.

Downstream Stage

Stage data were used to specify the effect of Markland Dam on the river hydraulics upstream of the dam. In the simulations of sampling events conducted in the Licking and Banklick Creek (e.g. May 2008, 1995 and 1996 events), the stage data at the USGS gage in Cincinnati were used as the downstream boundary. When simulations included the Ohio River portion of the model (e.g. Upper Ohio October 2007 event), the stage data at Markland Dam were used as the downstream boundary.

Model Calibration Approach

The EFDC model relied on the May 2008 wet weather event for calibration. There were two reasons for this: 1) the survey data reflects the most recent instream conditions; 2) the collection system model configuration would be consistent with the actual conditions during this event. Once the model was calibrated, additional simulations of this survey period were done to determine the sensitivity of model calibration to the value of the event mean concentration used for CSOs and SSOs. The model was also run using *E. coli* as the indicator bacteria to evaluate whether a comparable performance could be achieved with this constituent.

Two other simulations were made with the EFDC model for model corroboration: the 1995-1996 wet weather sampling events and the 2007 Upper Ohio River wet weather sampling event. Additionally, the 2008 event was simulated in two ways: once with a subset of the model grid that only represents the Licking River and Banklick Creek, and once with the full model grid including the Ohio River. Using a model grid that excludes the Ohio River saves a substantial amount of computational time, but may not be capable of reproducing the impact that elevated Ohio River bacteria densities have on the lower Licking River. This simulation was produced to better understand the impact that the Ohio River has on bacteria densities in the lower Licking River.

Evaluation of Model Performance

Several tools for the evaluation of model performance were used because each tool provides a unique and beneficial view of the model results. Table 5 describes the model performance tools that were used and the purpose for using each:

Table 5: EFDC Model Performance Evaluation Tool Descriptions.

Evaluation Tool	What does it illustrate?	Why is it Used?
Temporal Profiles	Variation of bacteria density with time at a particular sampling location	Shows that model reproduces the timing and magnitude of instream response from increased bacteria loadings during a wet weather event
Scatter Plots	Comparison of model-predicted and measured bacteria densities	Shows that the model accurately predicts each measured bacteria density within range represented by uncertainty in data and model inputs
Cumulative Frequency Distributions	Comparison of variability in model-predicted and measured bacteria densities	Shows that the model predicts similar range of bacteria densities observed in the survey data at the same frequency as the data.
Summary Statistics	Comparison of sensitivity simulations using statistics	Provides a more quantitative statistical comparison of model performance relative to data

Calibration to May 2008 Event

This section presents model-to-data comparisons for the May 2008 event. As noted in the data description, the Licking River was monitored at four transects with samples collected at three points across each transect. Additional model-to-data evaluations were made to the Banklick Creek data, which were collected at three locations. The model reproduces the observed data very well, although the model performs better in the Licking River mid-channel and right descending bank than in the left descending bank or in Banklick Creek, where the model tends to overpredict observed densities. The left descending bank and Banklick Creek received most of the CSO volume from this event. One likely reason that the model overpredicts densities in these areas is that the event mean concentration applied to the CSO volumes may be higher than what actually occurred during this event, given the wide variability in densities in CSO quality (see Figure 4). The analysis of flow-weighted overflow bacteria densities from extensive outfall sampling provided a basis for estimating the event mean concentration. Therefore, the slight over-prediction of bacteria loads during a single modeled event does not warrant modifying the event mean concentration. Overall, as the following discussion and figures illustrate, the model calibration is reasonably accurate and provides confidence that it can be used as a decision-making tool. The following figures (Figures 7-11) of temporal profiles show that the model reasonably reproduces the variation of bacteria densities in time due to increased watershed loads and/or increased overflows.

Figure 7. Temporal Profiles of Model Results and Data in the Licking River at River Mile 0.5.

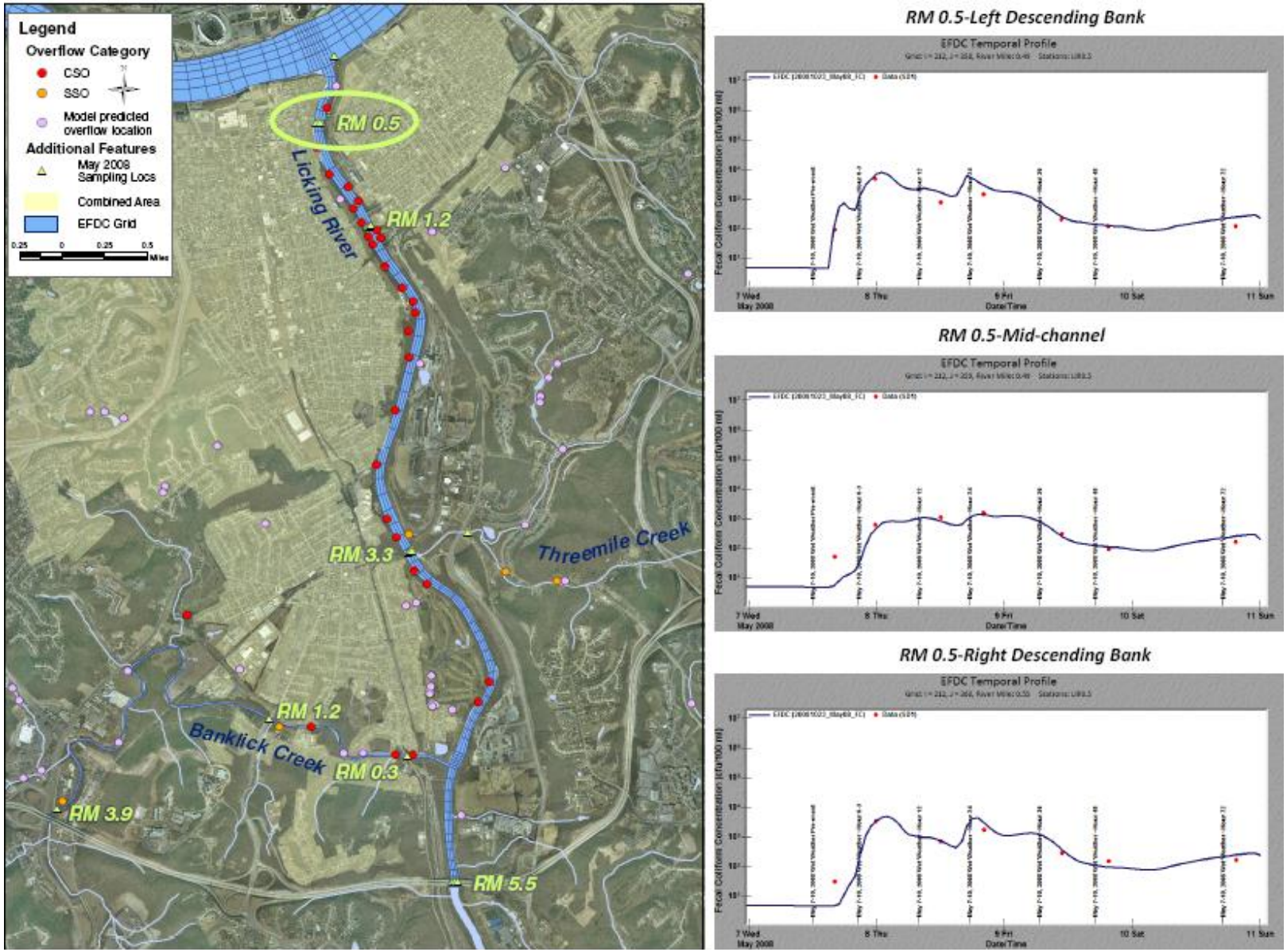
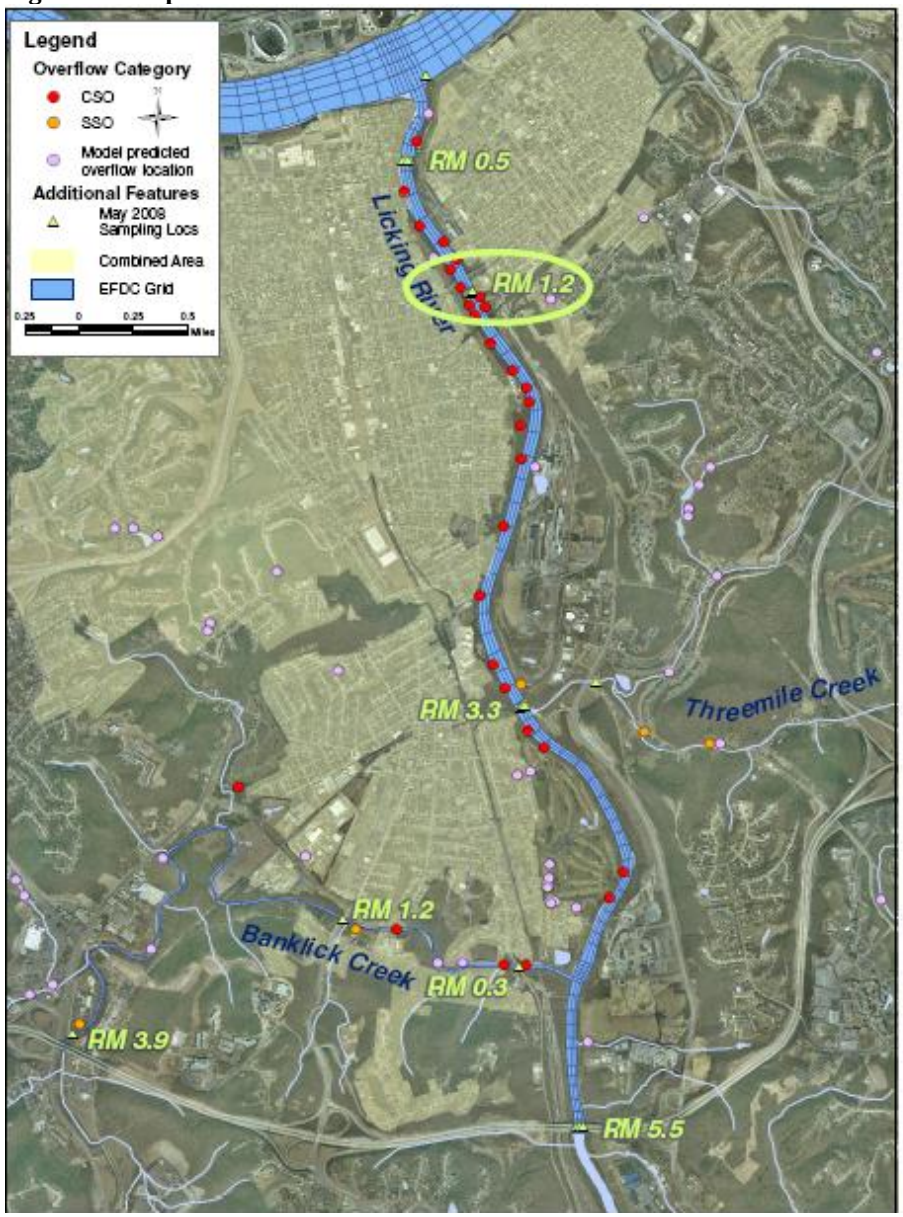
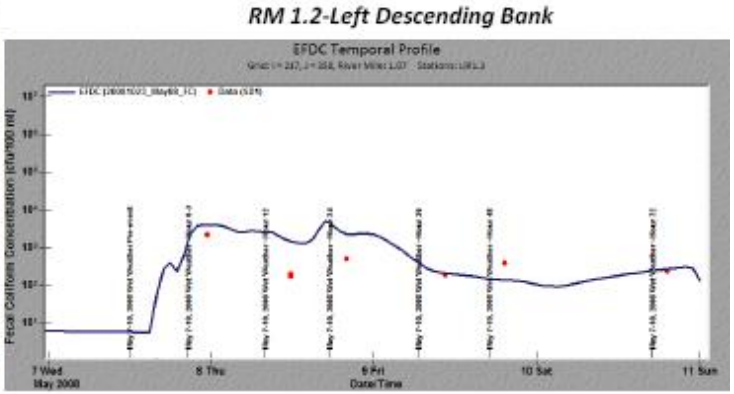
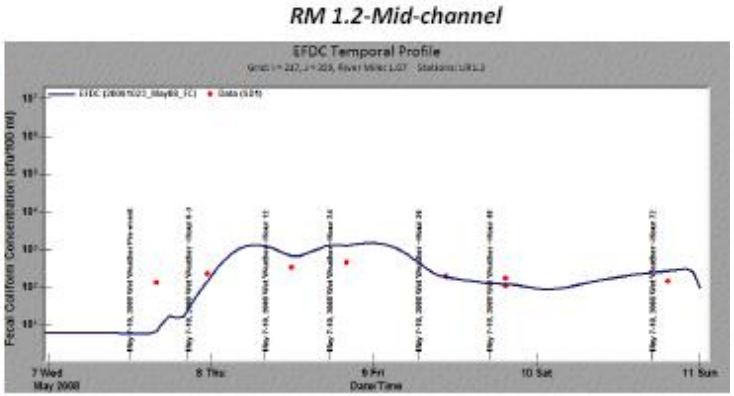


Figure 8. Temporal Profiles of Model Results and Fecal Coliform Data in the Licking River at River Mile 1.2.







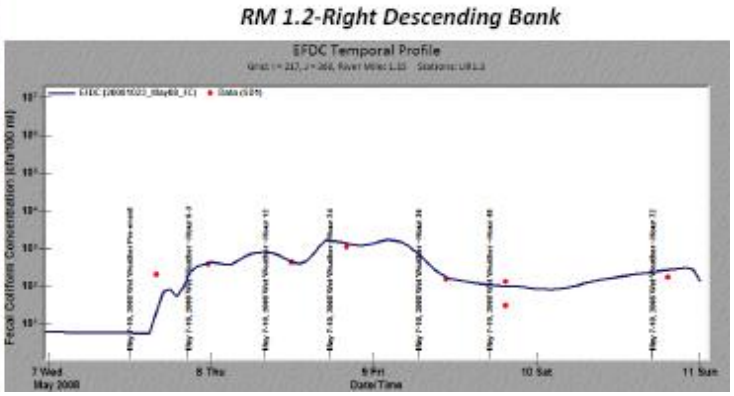


Figure 9. Temporal Profiles of Model Results and Fecal Coliform Data in the Licking River at River Mile 3.3.

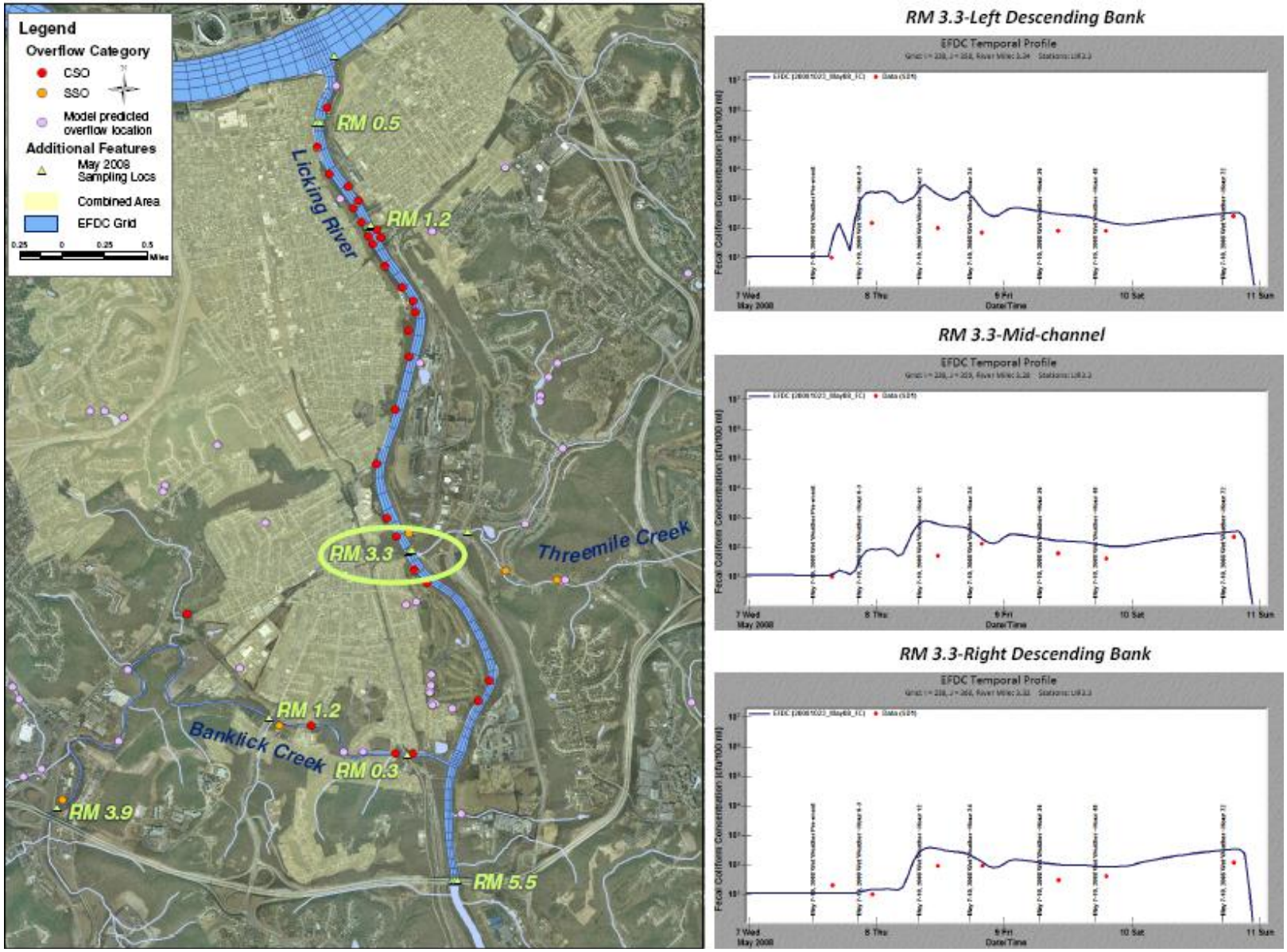


Figure 10. Temporal Profiles of Model Results and Fecal Coliform Data in the Licking River at River Mile 5.5.

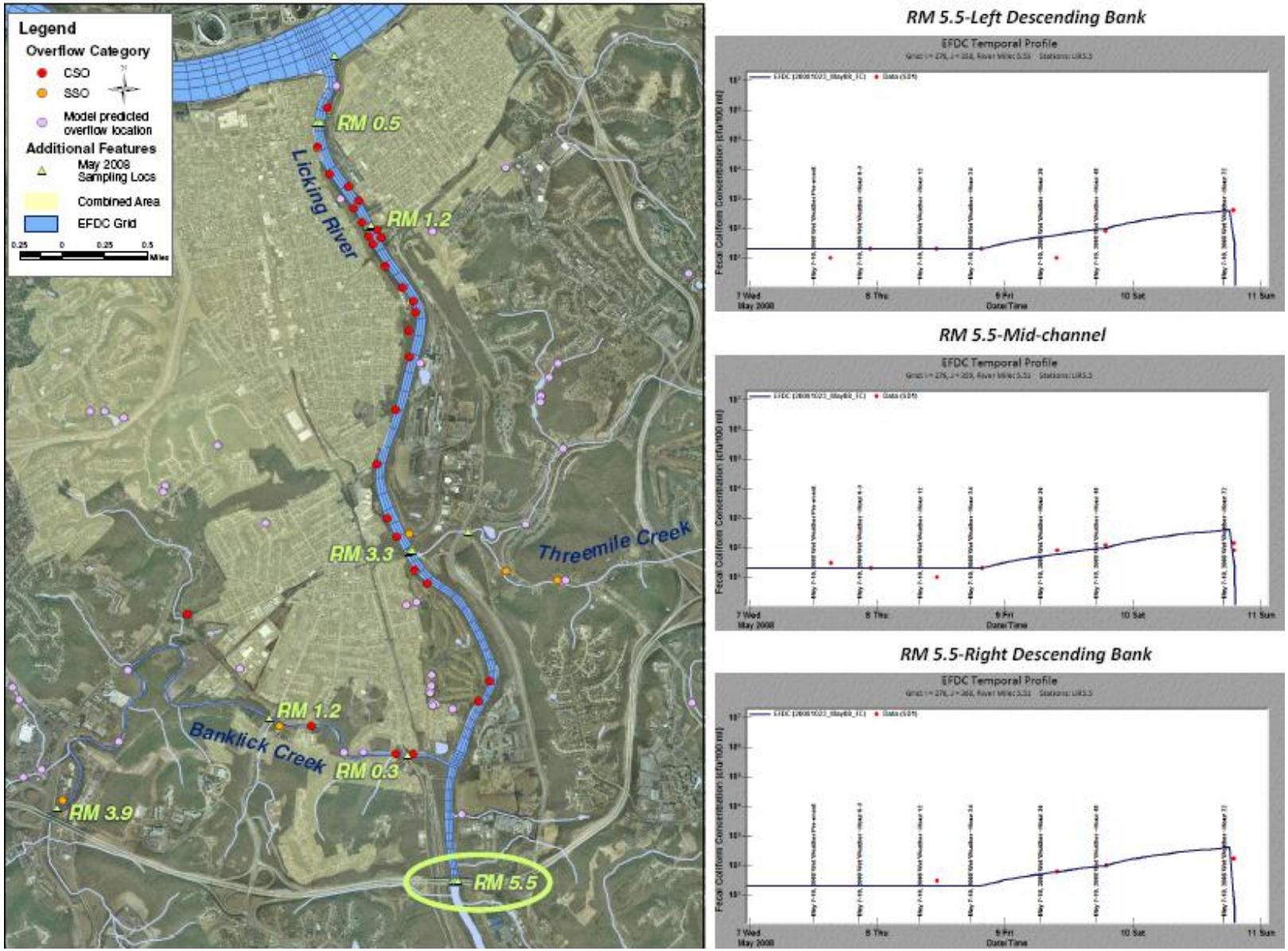
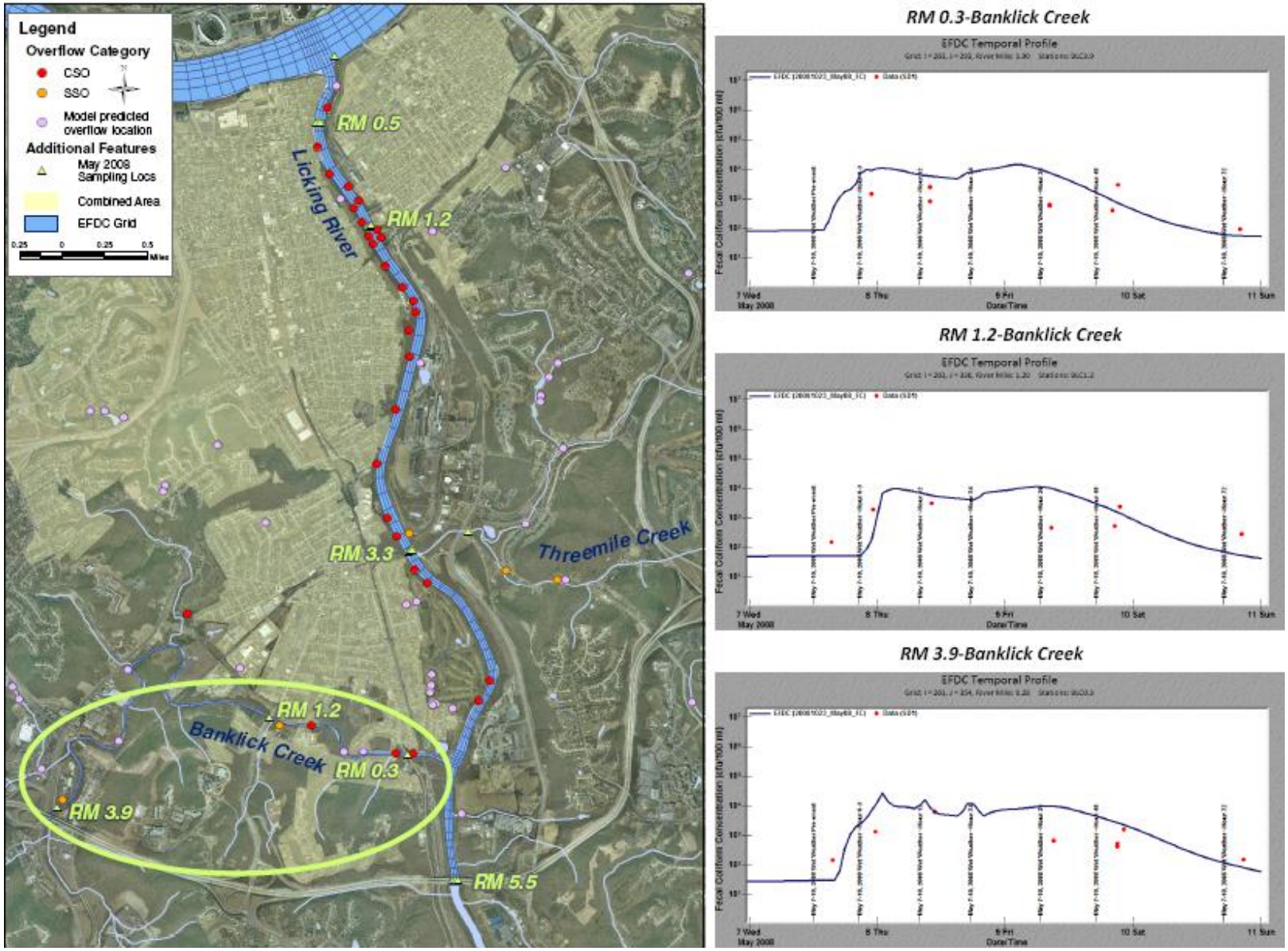


Figure 11. Temporal Profiles of Model Results and Fecal Coliform Data in Banklick Creek.



Scatter Plots (or one-to-one plots) of model simulated densities versus corresponding observed data are used to evaluate the model performance given sampling, analytical and model input uncertainty. If the model was reproducing exactly the observed densities, then all of the points would fall on the 1:1 line bisecting the plot area. Other criteria are included on each plot to use in evaluating the performance of the model. Points on the scatter plot that fall within the lines labeled '2x' are considered excellent predictions because they roughly correspond to the sampling and analytical accuracy limits of the bacteria count of the data. The wider band between the '10x' lines is a more liberal criteria for assessing the model to data comparisons; points that fall within these bands are accurate to one order of magnitude of the measured bacteria densities, which is a common threshold for evaluating acceptable model performance. The whiskers on each point indicate the minimum and maximum modeled values for the three hours before and three hours after each sample collection time, showing the variability of fecal coliform densities over a short time period during wet-weather events.

Figure 12 presents a scatter plot for all locations where data are available. Figures 13-16 present results by location profile (e.g. Licking River left descending bank, Licking River mid-channel, Licking River right descending bank, and Banklick Creek). Generally, the model performs very well in reproducing measured bacteria densities, as shown in Figure 12. In the Licking River, nearly all of the model-predicted densities are within the 2x line (Figures 13-15). More values in the Licking River left descending bank are between the 10x line than in the mid-channel and right-descending bank but only one value is outside the 10x line at all of the Licking locations. In Banklick Creek, the model tends to slightly overpredict observed densities (as indicated by the number of values above the 1:1 line). As noted in the temporal plot discussion, applying a representative density for overflow quality will not reflect the variation in quality that occurs from event to event (see Figures 4-6). Because Banklick Creek is a small stream compared to the Licking River, it has less assimilative capacity to dilute overflow loadings that are overestimated. Therefore, the uncertainty in the event mean concentration produces a more significant impact on Banklick Creek densities compared to Licking River densities.

Figure 12. Scatter Plot of Model Performance for Fecal Coliform During May 2008 Event.

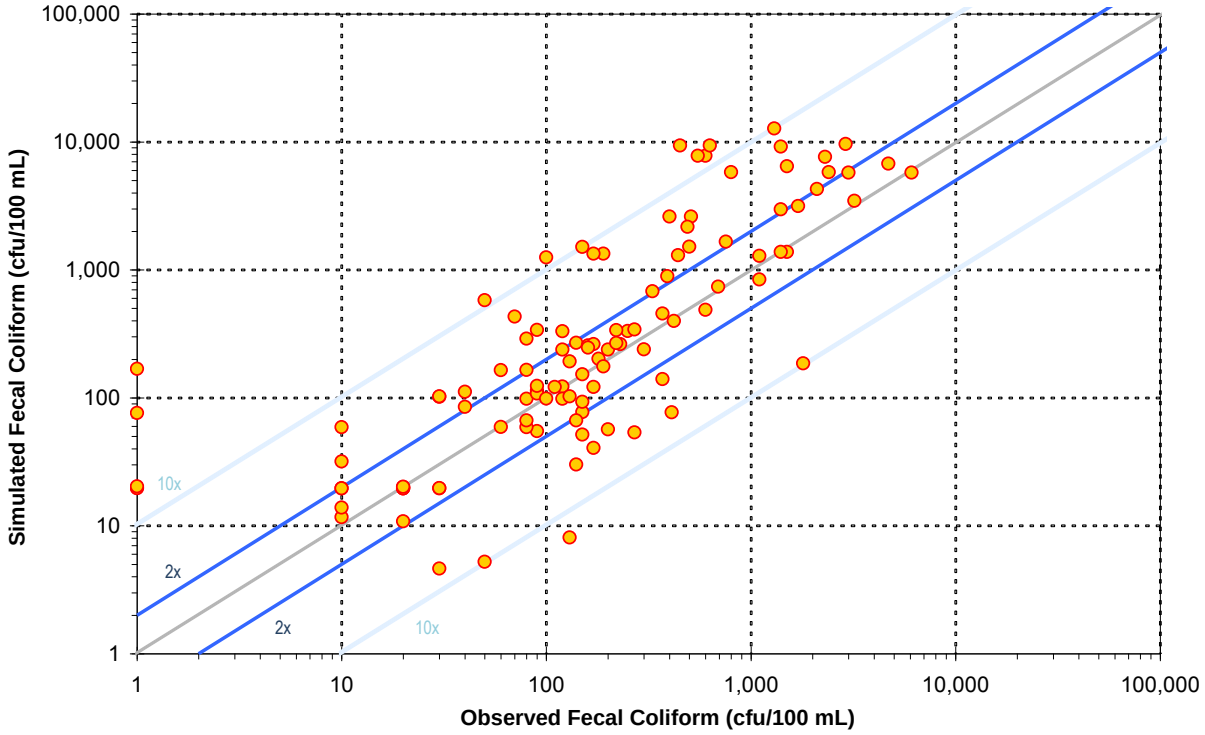


Figure 13. Scatter Plot of Model and Fecal Coliform Data Comparison in Licking River Left Descending Bank-May 2008 Event.

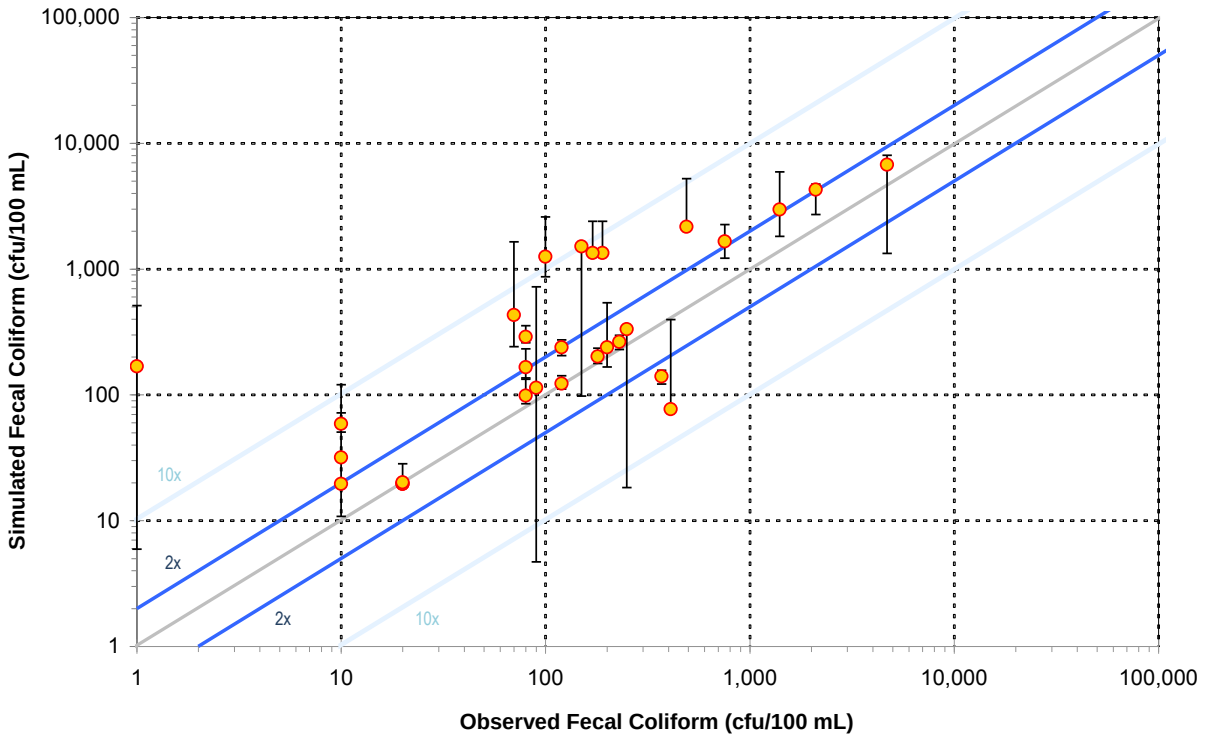


Figure 14. Scatter Plot of Model and Fecal Coliform Data Comparison in Licking River Mid-Channel-May 2008 Event.

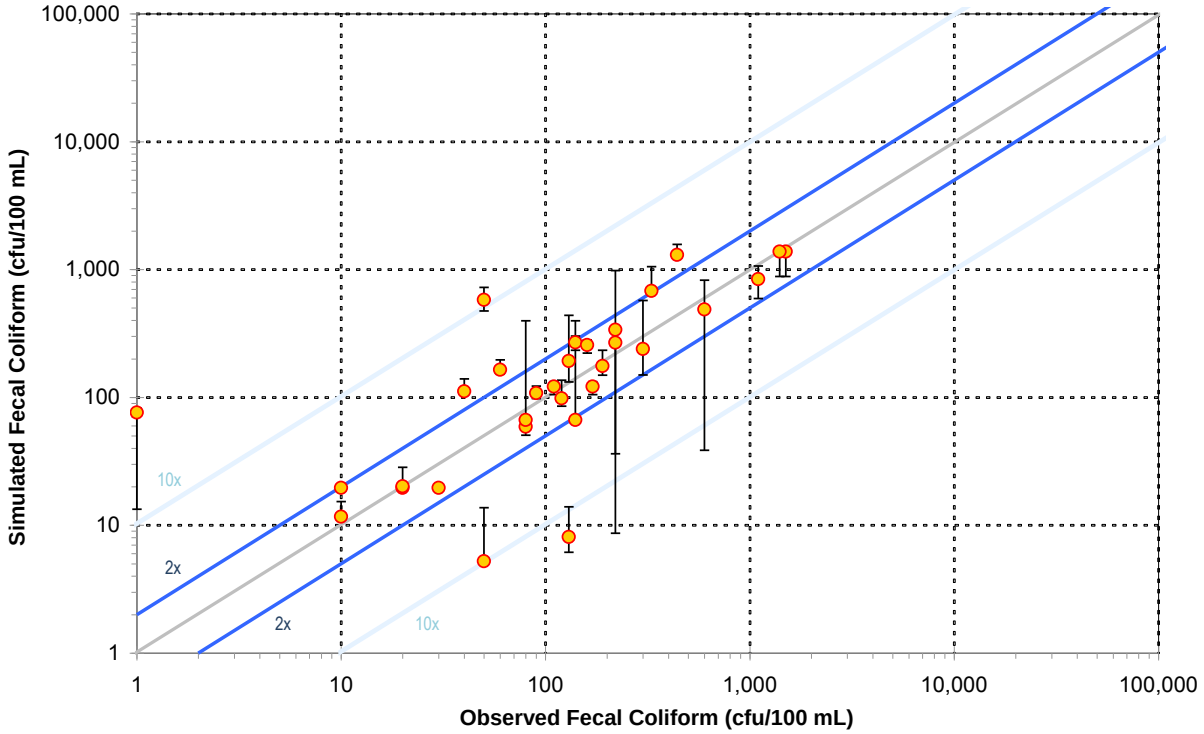


Figure 15. Scatter Plot of Model and Fecal Coliform Data Comparison in Licking River Right Descending Bank-May 2008 Event.

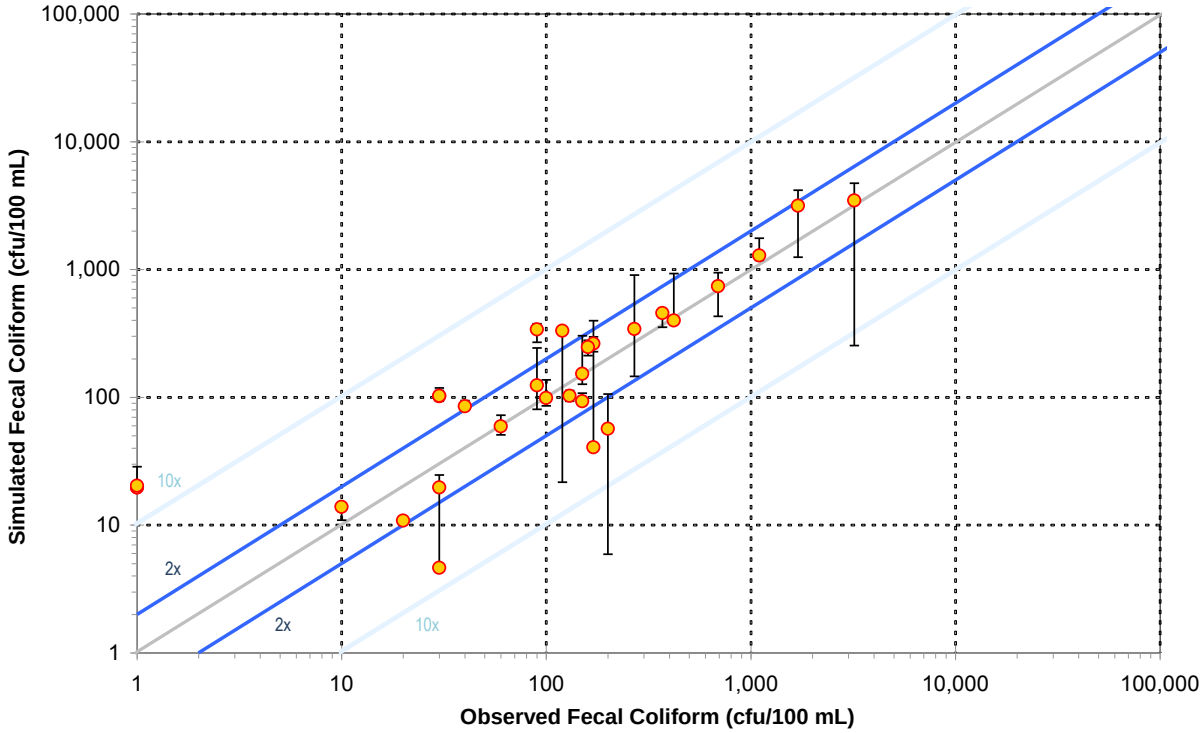
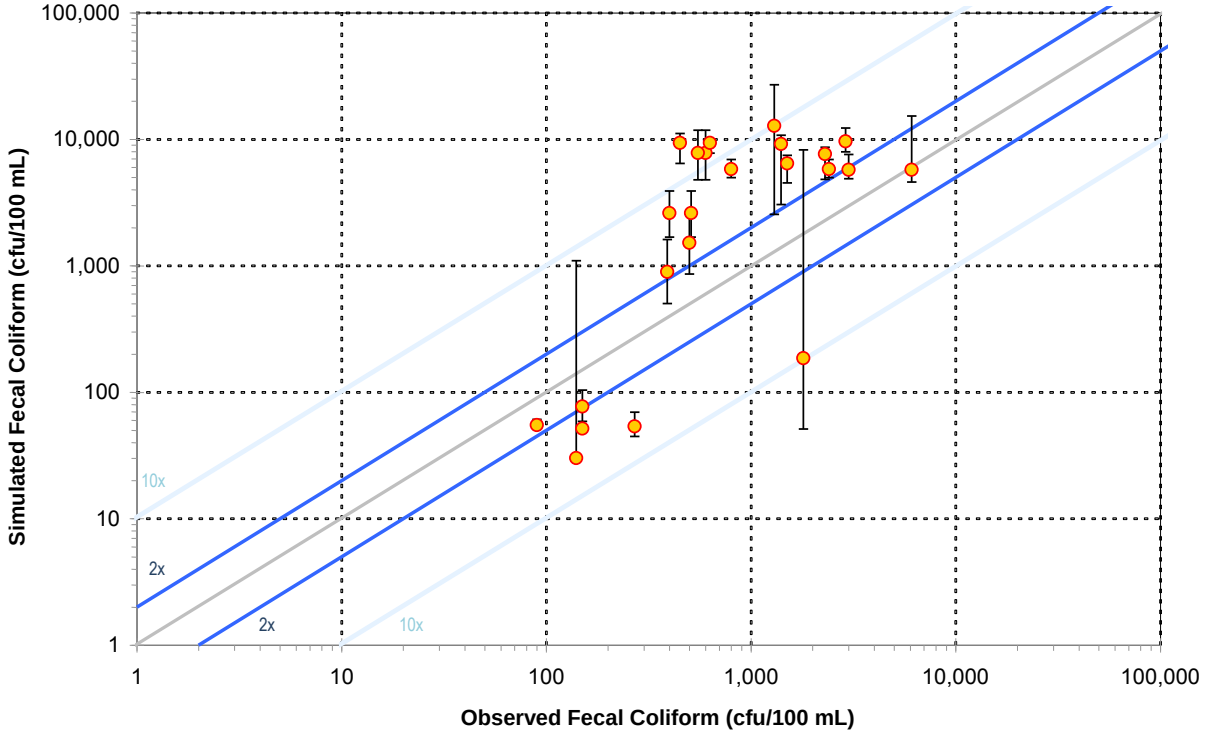


Figure 16. Scatter Plot of Model and Fecal Coliform Data Comparison in Banklick Creek May 2008 Event.



Cumulative Frequency Distribution plots (CFDs) are a tool to easily evaluate whether the model reproduces the range and frequency of occurrence of observed densities. The CFDs also can illustrate whether the model is conservative (e.g. models are considered "conservative" if they do not show a tendency to underpredict instream impacts from wet weather source loads). Figure 17 shows a CFD for all portions of the model, while Figures 18-21 show profiles in the model domain (e.g. Licking River left descending bank).

Figure 17. Cumulative Frequency Distribution of Model and Fecal Coliform Data from May 2008 Event.

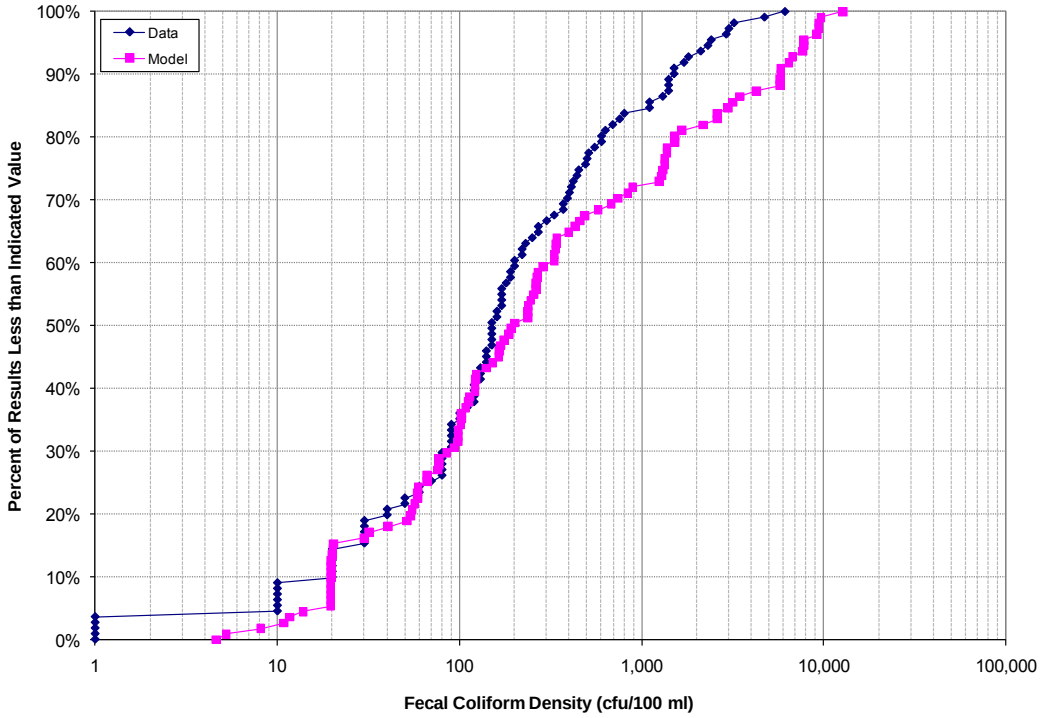


Figure 18. Cumulative Frequency Distribution of Model and Fecal Coliform Data Along Licking River Left Descending Bank from May 2008 Event.

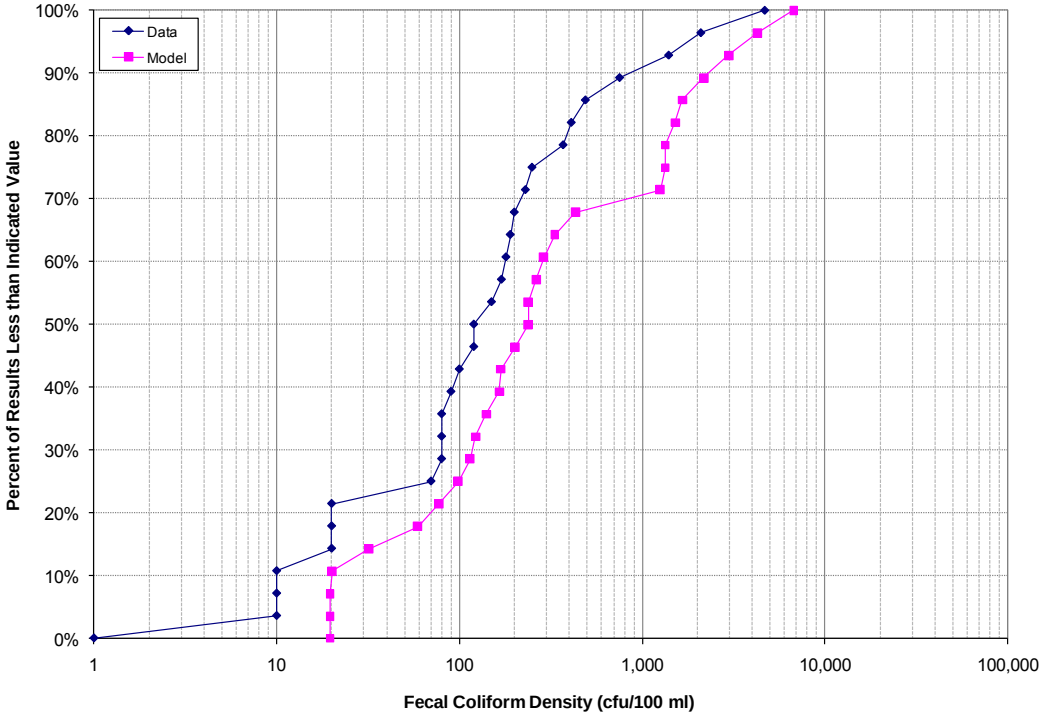


Figure 19. Cumulative Frequency Distribution of Model and Fecal Coliform Data Along Licking River Mid-Channel from May 2008 Event.

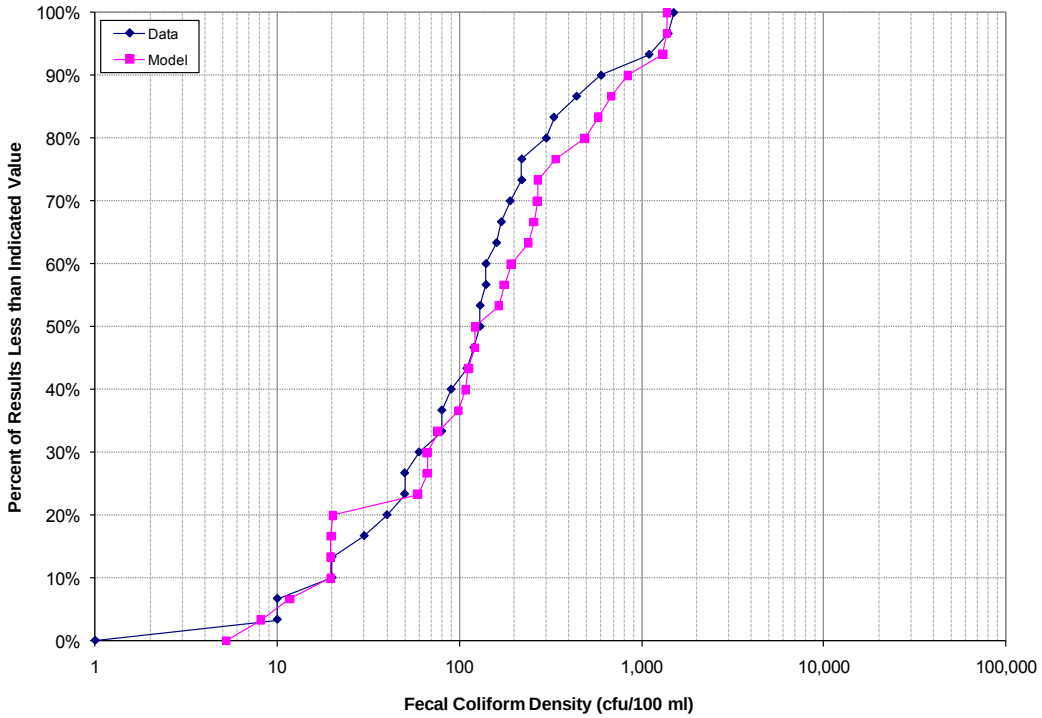


Figure 20. Cumulative Frequency Distribution of Model and Fecal Coliform Data Along Licking River Right Descending Bank from May 2008 Event.

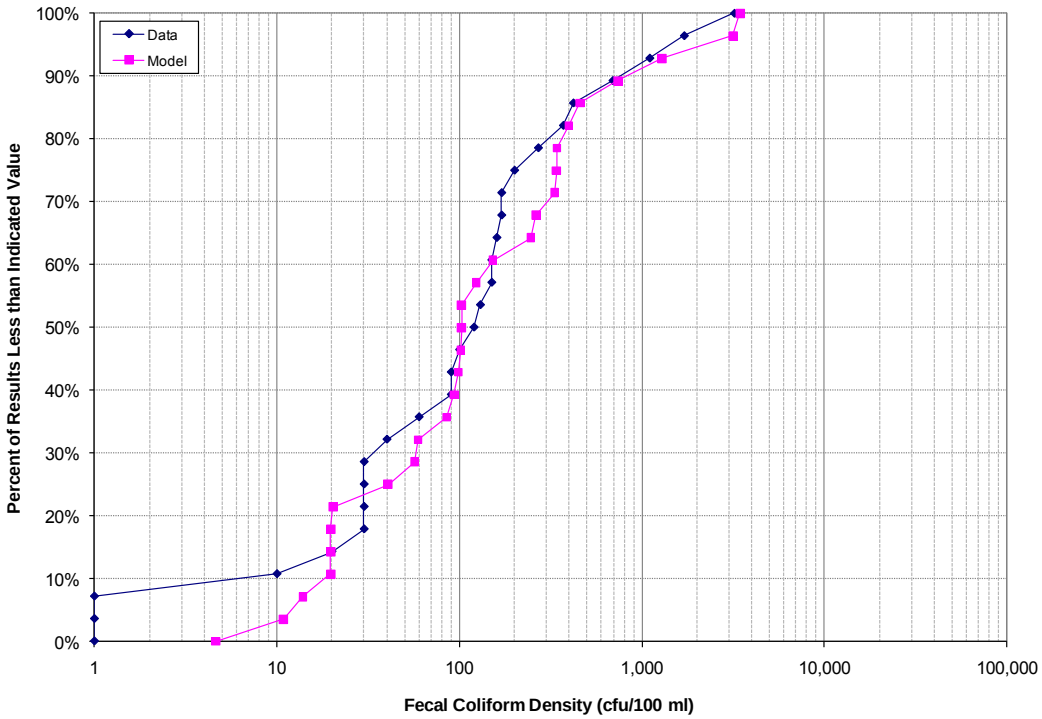
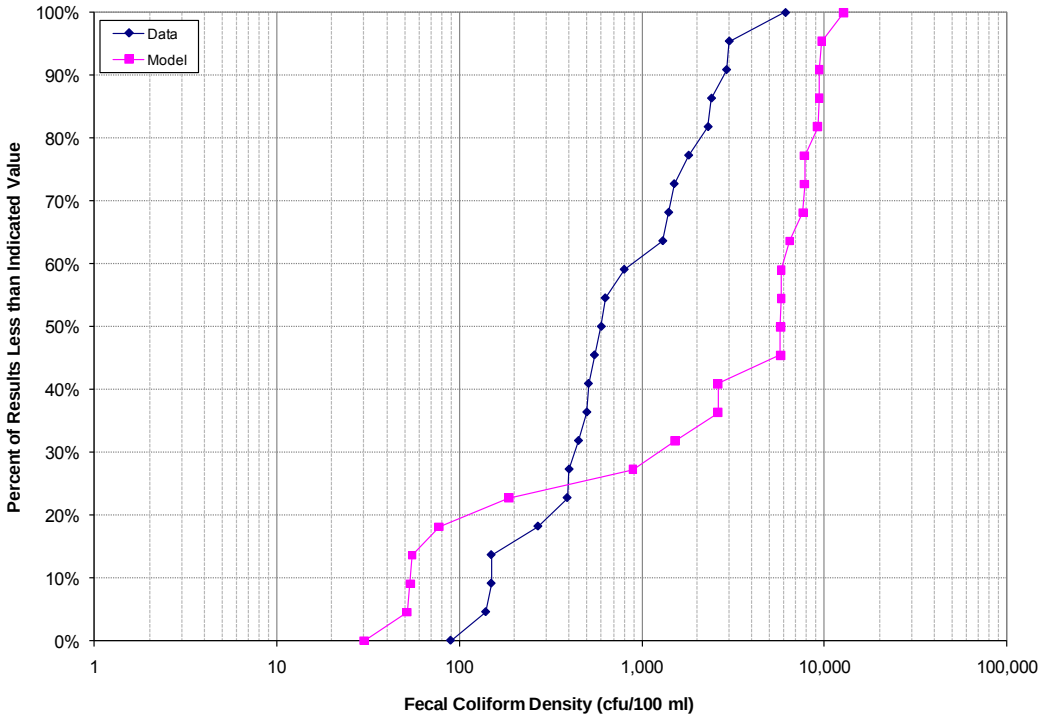


Figure 21. Cumulative Frequency Distribution of Model and Fecal Coliform Data Along Banklick Creek from May 2008 Event.



In general, the model reproduces the range of densities observed in the data and tends to be conservative. Many of the same performance observations made with the temporal and scatter plots are also evident in these figures. The model performs best in the Licking River right descending bank and mid-channel portions of the model (Figures 19 and 20) while tending to overpredict densities along the Licking River left descending bank (Figure 18) and Banklick Creek (Figure 21).

Model statistics provide a quantitative measure of evaluating multiple model results. The simple statistics presented in Table 6 require a normally distributed dataset for meaningful analysis. Both the data and model results were transformed to a log-10 basis so that their distribution would better resemble a normal distribution. The key statistical results in Table 6 for assessing accuracy and precision are the Mean Data/Model Ratio and the Relative Error. Perfect agreement between the model and data would yield a ratio of 1.00 and relative error of 0. Thus, values approaching 1.00 for the ratio and 0 for the relative error provide a basis for evaluating model performance. The data/model ratios at all profiles are greater than 0.85. This suggests that the model is reproducing the central tendency of the data fairly well. That all ratios are less than 1 provides additional confirmation that the model simulated densities are conservative and the model tends to overpredict rather than underpredict instream densities. All of the relative errors are less than 20% in this model calibration.

Table 6. Statistical Comparison of Log-transformed Model and Fecal Coliform Data for May 2008 Event.

Profile	Count	Data Geo-metric Mean	Model Geo-metric Mean	Data Median	Model Median	Data Std. Dev.	Model Std. Dev.	Mean Data/Model Ratio	Relative Error
Banklick Creek	23	2.85	3.23	2.78	3.76	0.49	0.92	0.88	13.42%
Licking River-LDB	29	2.05	2.42	2.08	2.38	0.78	0.74	0.85	18.05%
Licking River-MID	31	2.01	2.10	2.11	2.08	0.67	0.66	0.96	4.02%
Licking River-RDB	29	1.91	2.07	2.08	2.01	0.87	0.71	0.92	8.68%
All Locations	112	2.17	2.41	2.18	2.30	0.80	0.86	0.90	11.06%

Model Corroboration Simulations

Corroboration to 1995-96 Licking River/Banklick Creek Wet Weather Events

The Licking River and Banklick Creek portions of the EFDC model were verified by running simulations of seven wet weather events sampled in 1995 and 1996. Event characteristics were summarized in Table 1. Model inputs were developed using the same methods as for the calibration event (e.g. data for the upstream Licking River flows and densities, watershed model results for upstream Banklick Creek flows and densities, collection system model for external loadings).

It is important to note that the collection system model results used in these simulations were based on the current state of the collection system rather than reconfiguring the model to represent the collection system as it existed in 1995 and 1996. Therefore, some sources that have been eliminated or reduced between 1995 and today will not be accurately represented in these simulations. Rainfall data from the airport were used in the collection system modeling and so, highly localized rainfall and spatially variable rainfall patterns were not represented in the collection system results used in the river modeling.

Temporal profiles of 1995 and 1996 model-to-data comparisons are provided in Attachment A. In general, the model does reasonably well at reproducing the profile of the observed data. However, there are a couple of instances where the model fit to the data is not good. Further inspection suggests that these instances are most likely due to a change in source loading magnitude or localized rainfall that resulted in under-estimated loadings. However, analysis of the model results indicates that the configuration and algorithms in the river model itself are consistent with the calibration.

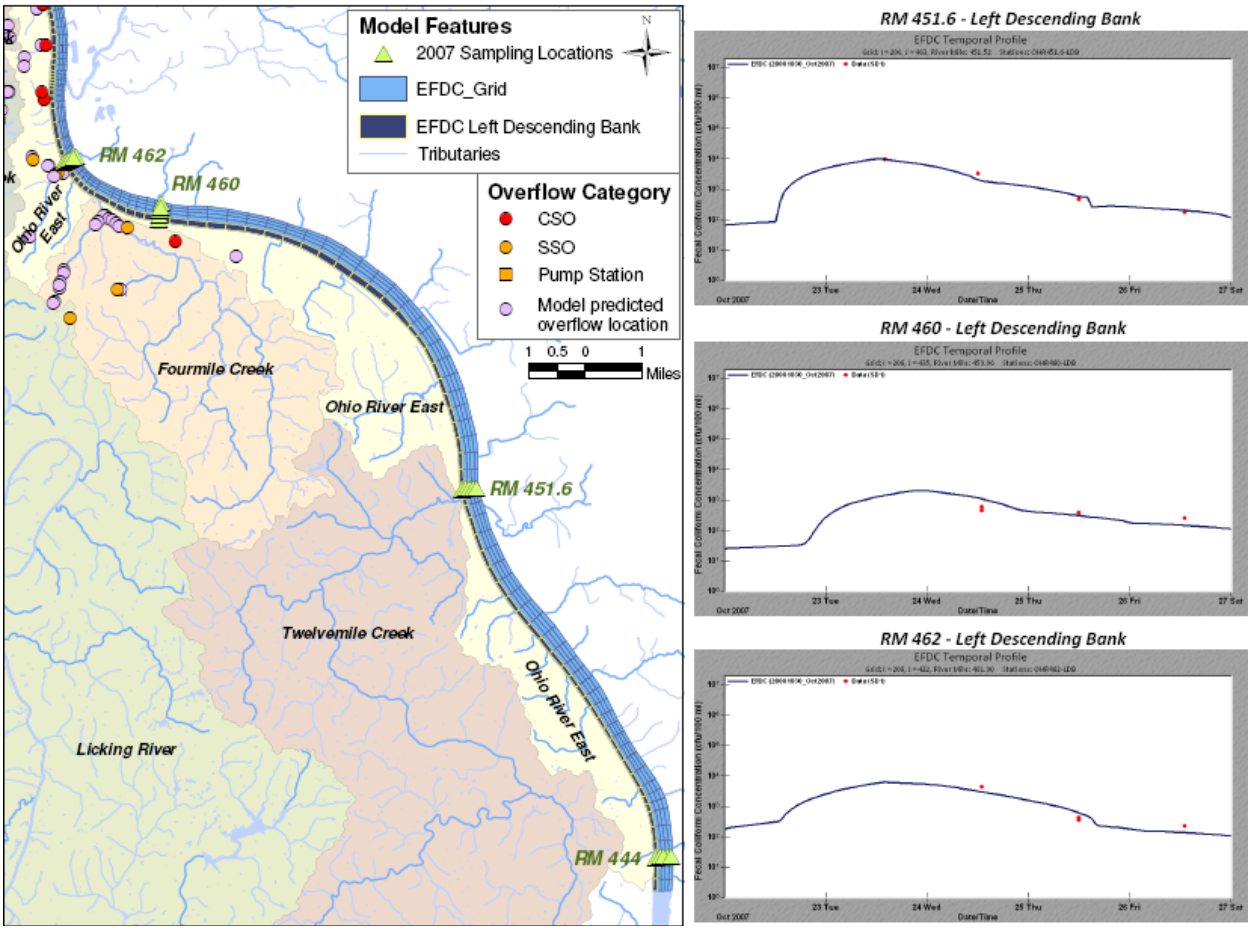
Upper Ohio River Corroboration to October 2007 Wet Weather Event

The upper Ohio River portion of the river model, from its start at river mile 444 downstream to just before the confluence with the Little Miami River at river mile 462, was evaluated by simulating a wet weather event from October 2007. Samples were collected every 24 hours at four transects in the river at five points across each transect over a four day period. As shown in Table 1, this event produced considerable rainfall, with over four inches of rainfall falling in a two day period.

The river model simulation included fecal coliform loadings from upstream on the Ohio River, Twelvemile Creek, and Fourmile Creek. Data from the event were used to specify upstream loads. The load from Twelvemile and Fourmile Creeks were back-calculated from the Ohio River data. No loads were included from the Ohio side of the river. Therefore, the primary purpose of this simulation was to evaluate the model settings (loss rate, travel times) for the large river portion of the model rather than to function as a calibration.

Temporal profiles from all transects are provided in Attachment A. Results for the left descending bank, which is adjacent to Kentucky are shown in Figure 22. Profiles from the left descending bank provide the most accurate comparison between model and data as the external loadings from Kentucky were input to the model whereas the Ohio side loads were not (though they are expected to be small in this portion of the watershed). The model performs very well at reproducing the observed data, even in locations where the loadings were not back-calculated and is within an order of magnitude of the data at all locations in the river, even the right descending bank, which would be most sensitive to the omission of Ohio-side loads.

Figure 22. Temporal Profile of EFDC River Model Results Along Left Descending Bank During October 2007 Wet Weather Event.



Model Sensitivity Analyses

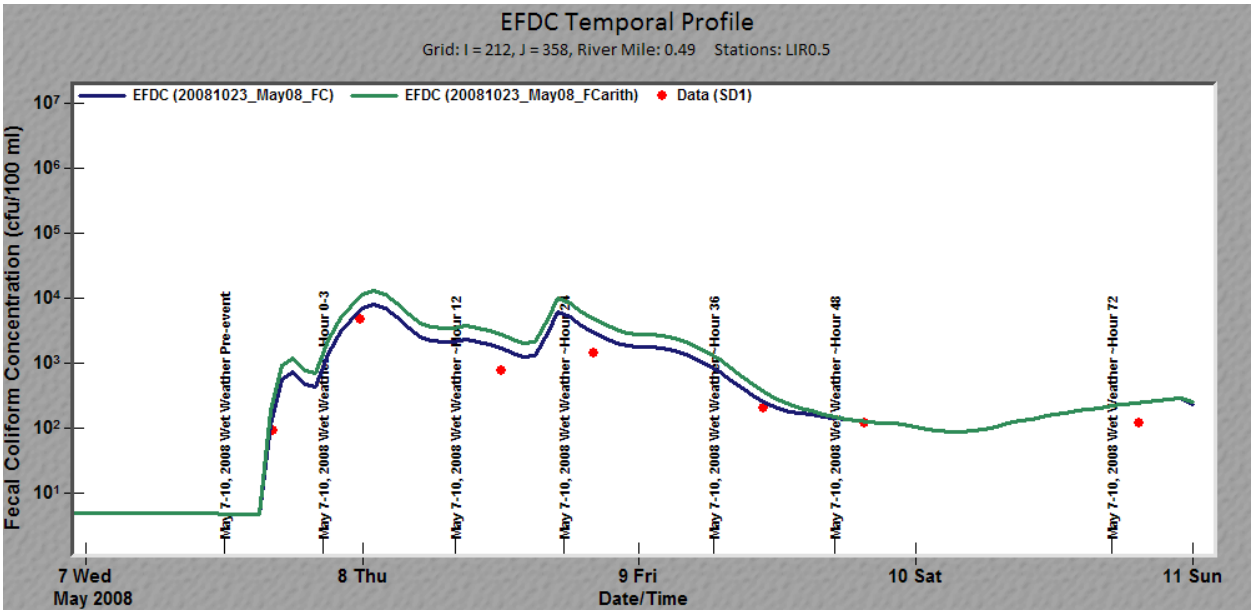
Sensitivity #1: Source Event Mean Concentration

Sampling data from combined sewer overflows and sanitary sewer overflows show that effluent densities range over several orders of magnitude. However, there is no reliable way to estimate how bacteria densities change with time at a particular overflow, or how bacteria densities in one overflow differ from densities in another. A sensitivity analysis on the overflow fecal coliform loads was performed by adjusting the event mean concentrations to the arithmetic average of the outfall water quality data (1,100,000 cfu/100 ml for CSO and 3,260,000 cfu/100 ml for SSO) and rerunning the May 2008 event.

Results were then compared to the calibration (which used geometric mean-based concentrations as CSO and SSO EMCs) to assess the sensitivity of model results to the choice of an event mean concentration.

A temporal profile of the Licking River left descending bank at river mile 0.5 is shown in Figure 23. The left descending bank receives the largest source loadings (see Figure 3) and river mile 0.5 is sufficiently downstream to illustrate the cumulative effect of multiple CSO overflows on river quality. The blue line is the calibrated model while the green line is the sensitivity using the arithmetic mean-based source EMCs. As this figure illustrates, the tendency of the model to overpredict densities is somewhat more pronounced in the sensitivity run than in the calibrated run. Note that the convergence of the model results during the last two days of the event is because the CSOs (and SSO) have stopped discharging and the instream density is primarily from upstream sources (which were kept constant in both runs).

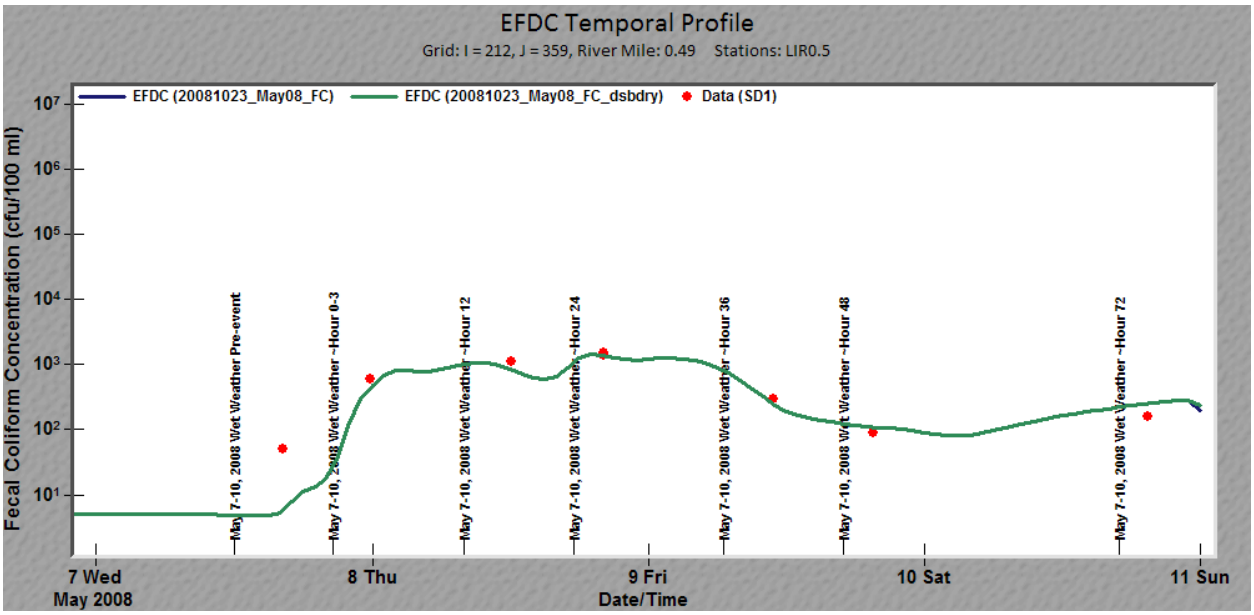
Figure 23. Model Sensitivity to SD1 Source EMC at River Mile 0.5 in Licking River Left Descending Bank.



Sensitivity #2: Downstream Density Boundary

The May 2008 event was rerun with the Ohio River portion of the model activated and with loads that discharged directly to the Ohio River. The purpose of this simulation was to evaluate the significance of Ohio River backwater effects on Licking River densities. Results from this simulation are shown in Figure 24 for the mid-channel location and show that the model was not significantly influenced by Ohio River loads.

Figure 24. River Model Sensitivity in Licking River (mid-channel) to Source Loads Discharged Directly to Ohio River During May 2008 Event.



Sensitivity #3: Bacteria Loss Rate

The EFDC model's sensitivity to the value of the first order loss rate, which represents the net effect of settling, resuspension, and die-off, was tested by rerunning the October 2007 wet weather event in the model with values higher (2 day^{-1}) and lower (1 day^{-1}) than the calibrated value of 1.5 day^{-1}. The Ohio River portion of the model was used for this analysis because this portion of the model has longer travel times than the Banklick Creek or Licking River portions of the model. Short travel times in the Licking River and Banklick Creek make the loss-rate relatively insignificant, while longer travel times in the Ohio River result in a greater impact of the bacteria loss rate. For these simulations, the instream bacteria densities were predicted for each loss rate value downstream to the confluence of the Great Miami River at river mile 490, which corresponds to a distance of approximately 45 miles.

Figure 25 shows a comparison of the model results and data at the left descending bank at river mile 462, which is the most downstream location where densities were monitored. The blue line in the figures is the loss rate used in the calibration (1.5 day^{-1}), the green line uses a loss rate of 1 day^{-1} and the yellow line uses a loss rate of 2 day^{-1}. Over the length of river that was monitored, differences in instream density are minor. The best overall fit to the data was obtained using a loss rate value of 1.5 day^{-1}.

Figure 25. Evaluation of EFDC River Model Sensitivity to Loss Rate Setting in Upper Ohio River.

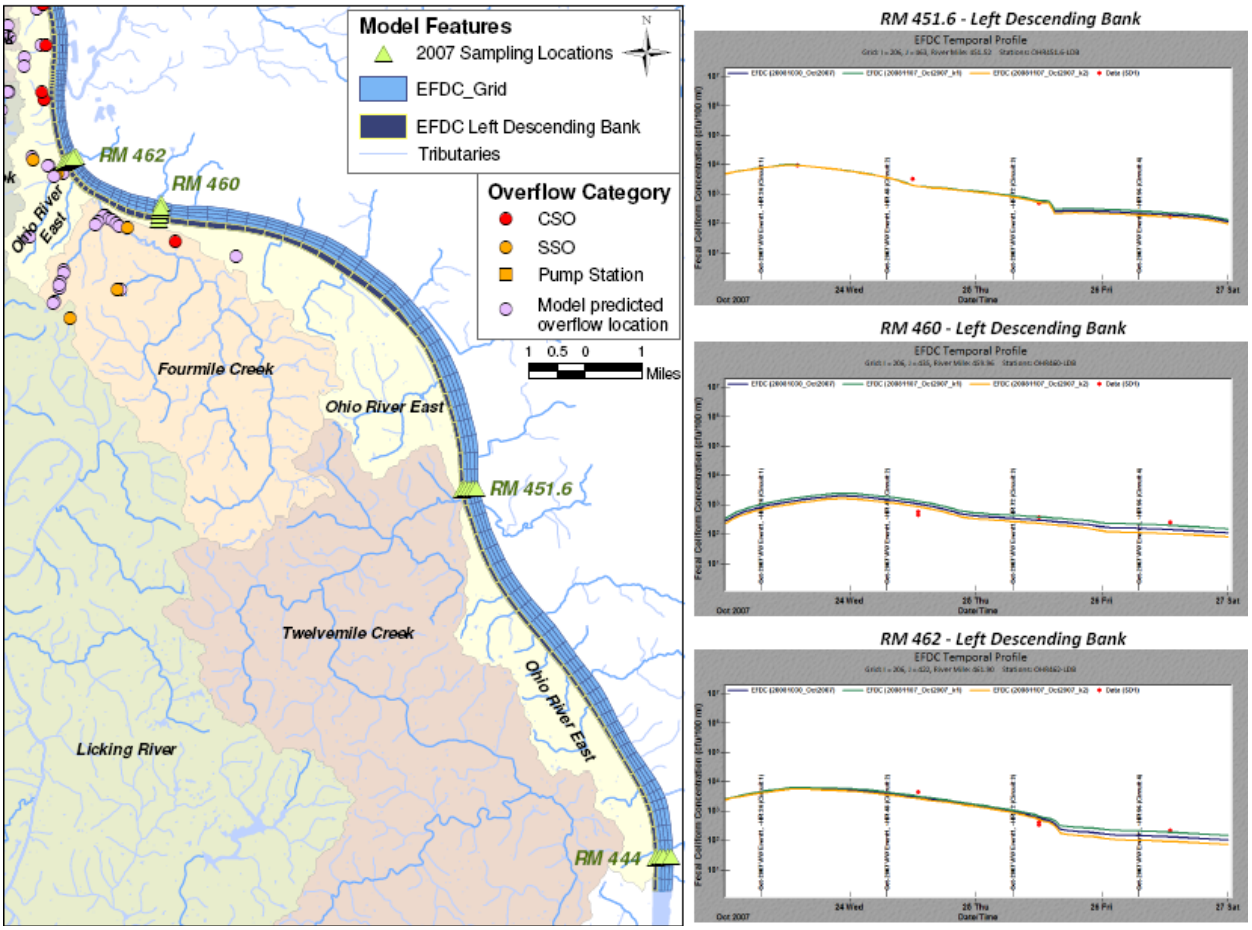
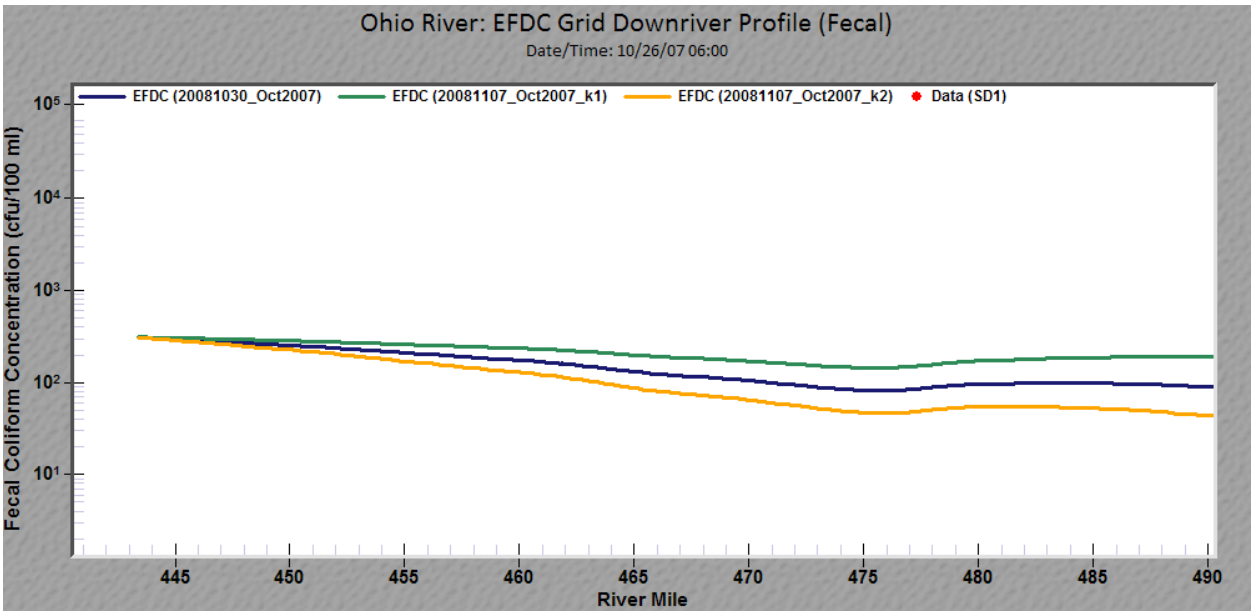


Figure 26 shows a spatial profile of instream density over the reach of the water quality portion of the model domain as well as the portion of the river receiving CSO overflows from SD1 (roughly from RM 463 to RM 475). Over the approximately 45 mile distance to the confluence with the Great Miami River, the difference in densities is within a factor of two of the calibration setting. This difference is within sampling and analytical uncertainty of measured densities so discerning an improvement in performance due to variation of the loss rate is impractical.

Figure 26. Comparison of Ohio River Densities with Different Values of Fecal Coliform Loss Rate.



Based on the overall fit to the data and the relatively small difference in densities at the most downstream extent of the modeling domain, use of loss rate value of 1.5/day is an appropriate value for use in the model, and the loss rate has a relatively small impact on instream bacteria densities.

Sensitivity #4: E. coli Simulations

Because many of the recent Ohio River sampling surveys and modeling efforts have used *E. coli* as the bacteria indicator species, the EFDC model was applied for the May 2008 event using *E. coli* as the modeled parameter. The same data sources and methods used to specify the inputs to the model for the fecal coliform calibration were used to specify *E. coli*-based model inputs. As shown in Table 4, the *E. coli* event mean concentration for the different outfall sources (e.g. CSO, SSO) were significantly smaller than the fecal coliform EMC. The ratio of *E. coli* to fecal coliform source EMCs were 0.31 and 0.38 for CSOs and SSO, respectively. A comparison of the May 2008 data indicated that the ratio of bacteria species, on average, was approximately 0.98. In effect, this simulation used smaller bacteria loads yet the instream data were very similar to fecal coliform levels. Since the model calibration tended to overpredict fecal coliform densities, the calibration to *E. coli* was expected to show a better fit to the data. Figure 27 presents a scatter plot of the model versus data comparison for *E. coli*. This figure is analogous to Figure 12 from the fecal coliform calibration.

Figure 27. Scatter Plot of Model Performance for *E. coli* During May 2008 Event.

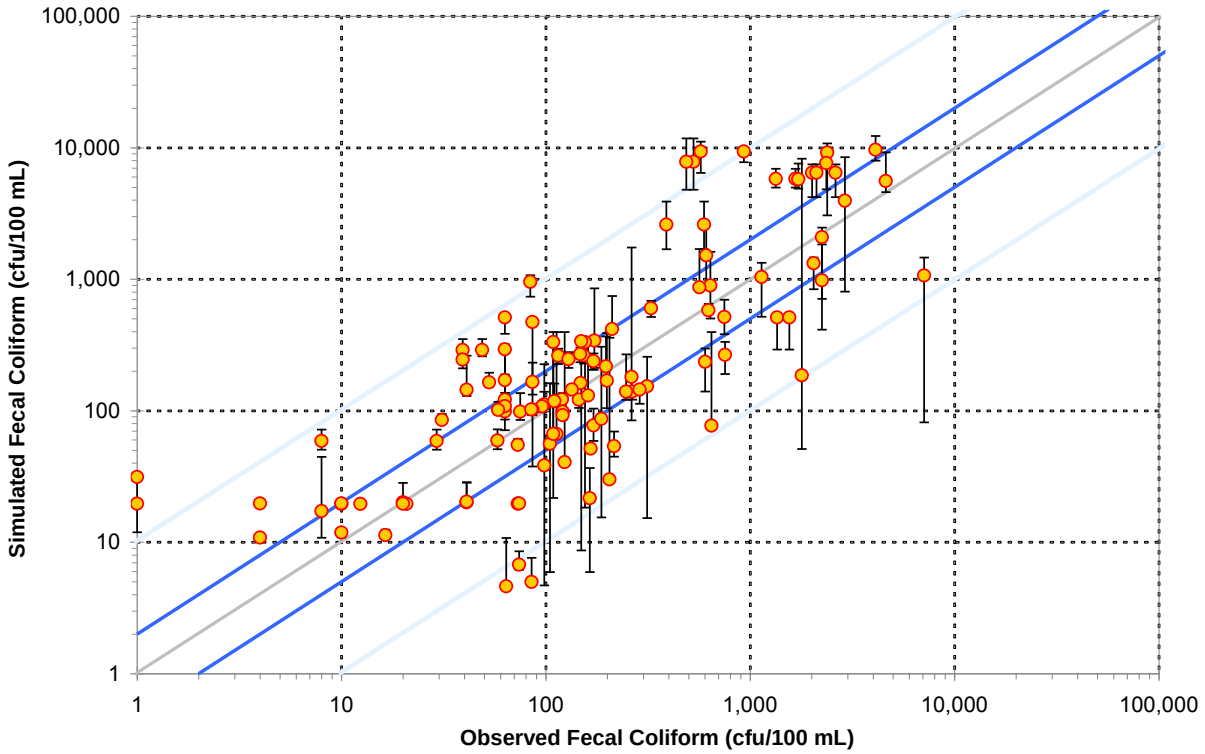


Table 7 presents a statistical analysis of log-transformed model results and *E. coli* data for this sensitivity run. The model compares more favorably to the *E. coli* data than to the fecal coliform data (see Table 6). The mean data/model ratio for all profiles are within 10% (e.g. greater than 0.90), indicating that the model reasonably reproduces the central tendency of the *E. coli* data. (Note: the ratio for the fecal coliform calibration was within 15% of the data). Similarly, the relative error for all locations is better for *E. coli* (5%) than for fecal colifrom (11%).

Table 7. Statistical Comparison of Model and Fecal Coliform Data for May 2008 Event.

Profile	Count	Data Geo-metric Mean	Model Geo-metric Mean	Data Median	Model Median	Data Std. Dev.	Model Std. Dev.	Mean Data/Model Ratio	Relative Error
Banklick Creek	23	2.92	3.22	2.89	3.75	0.49	0.88	0.91	10.31%
Licking River-LDB	29	2.07	2.22	2.02	2.22	0.68	0.60	0.93	7.38%
Licking River-MID	31	1.92	1.96	1.99	2.08	0.70	0.56	0.98	2.43%
Licking River-RDB	29	1.96	1.94	1.93	2.01	0.68	0.59	1.01	-1.19%
All Locations	112	2.19	2.30	2.13	2.19	0.75	0.83	0.95	5.16%

These results indicate that the model will perform comparably well should *E. coli* be used as the modeled parameter in the future instead of fecal coliform.

Conclusions

The Licking River and Banklick Creek portions of the EFDC river model have been calibrated and verified to fecal coliform using eight storm events monitored between 1995 and 2008. The ability of the model to simulate fecal coliform in the Ohio River was evaluated by simulating a storm event from October 2007 that was sampled in the upper portion of the river. A number of evaluation tools were used to evaluate the model's performance, including visual inspection of temporal and spatial profiles, and graphs and tables of statistical analyses. All of these evaluations provided similar insights into the model's performance and suggested that the model was reasonably calibrated. The model's sensitivity to key inputs, such as source loadings, loss rate and indicator species were also evaluated. Results suggest that the values used for the calibration and corroboration are appropriate and also that the model is capable of simulating *E. coli* as the indicator species instead of fecal coliform.

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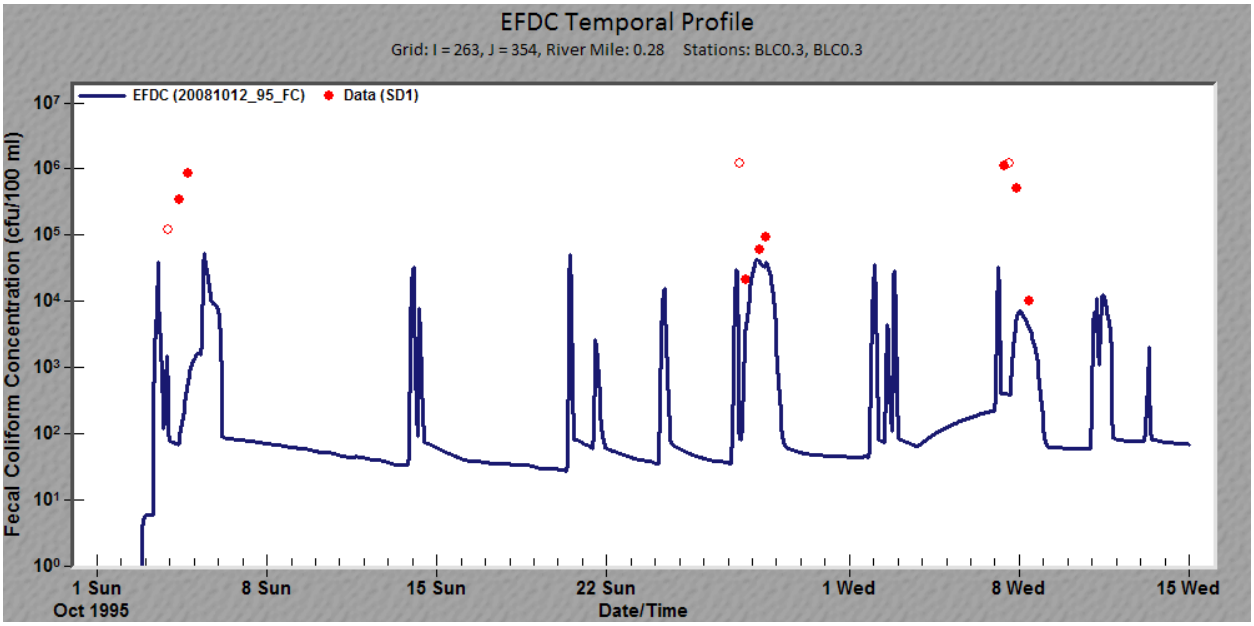
LimnoTech, 2008d. "Banklick Creek HSPF Model Calibration Update." Draft Memorandum preprared by LimnoTech for SD1. November 24, 2008.

Metropolitan Sewerage District of Greater Cincinnati. 2006. "Wet Weather Improvement Program". June 2006.

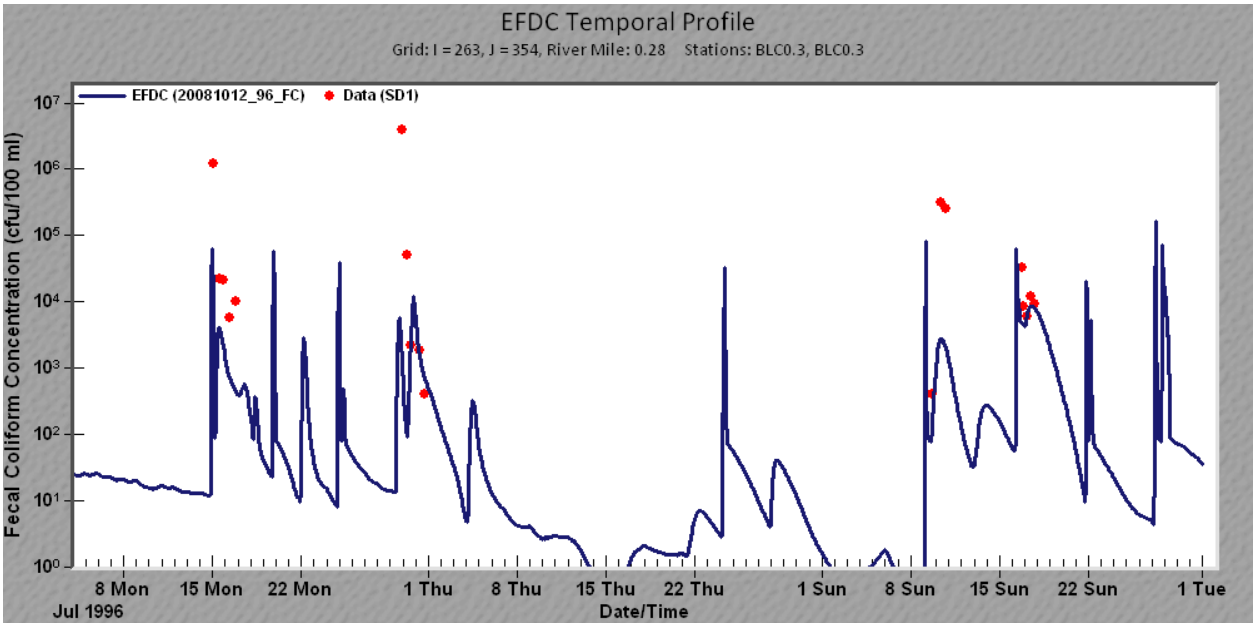
Ohio River Valley Water Sanitation Commission (ORSANCO), 2002. A Study of Impacts and Control of Wet Weather Sources of Pollution on Large Rivers. Final Report, January 2002.

Attachment A. Temporal Profiles of Fecal Coliform in Licking River and Banklick Creek During 1995-96 Wet Weather Events.

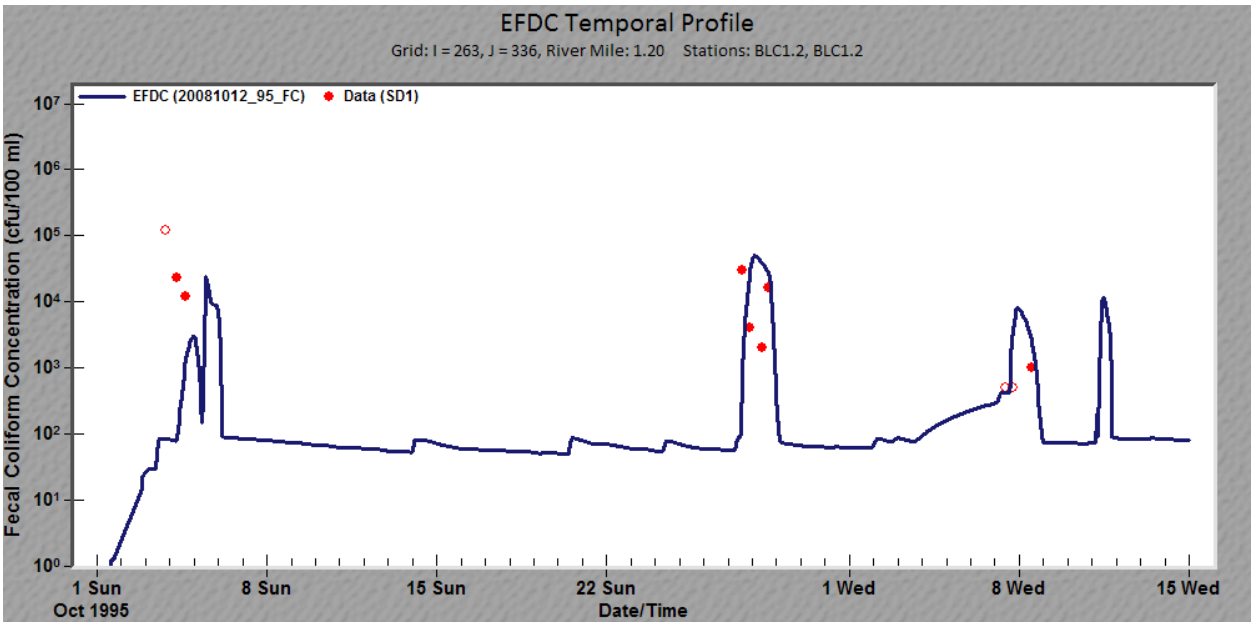
Banklick Creek at River Mile 0.3 (Decoursey Ave)-1995 Wet Weather Events.



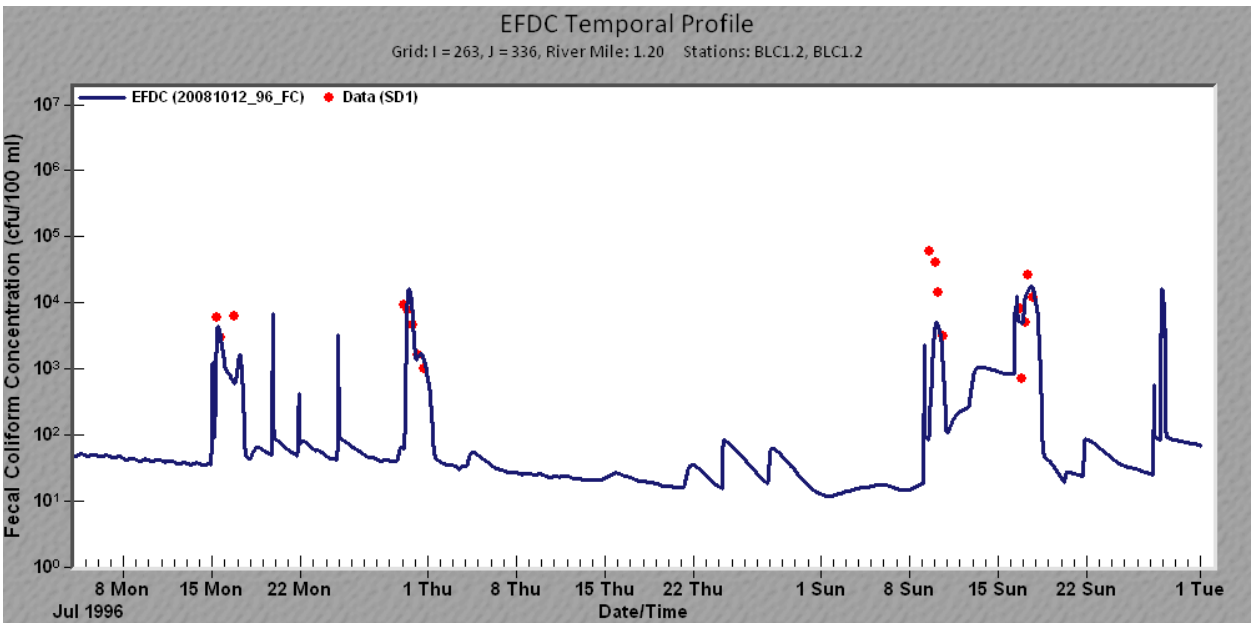
Banklick Creek at River Mile 0.3 (Decoursey Ave)-1996 Wet Weather Events.



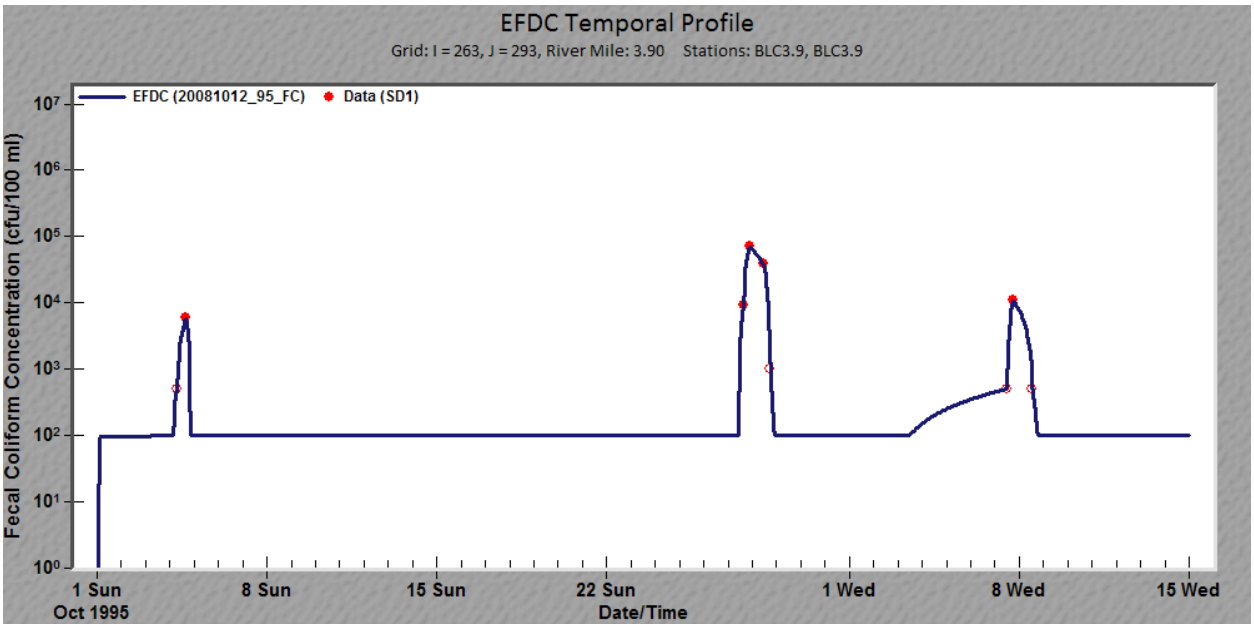
Banklick Creek at River Mile 1.2 (Winston Ave)-1995 Wet Weather Events.



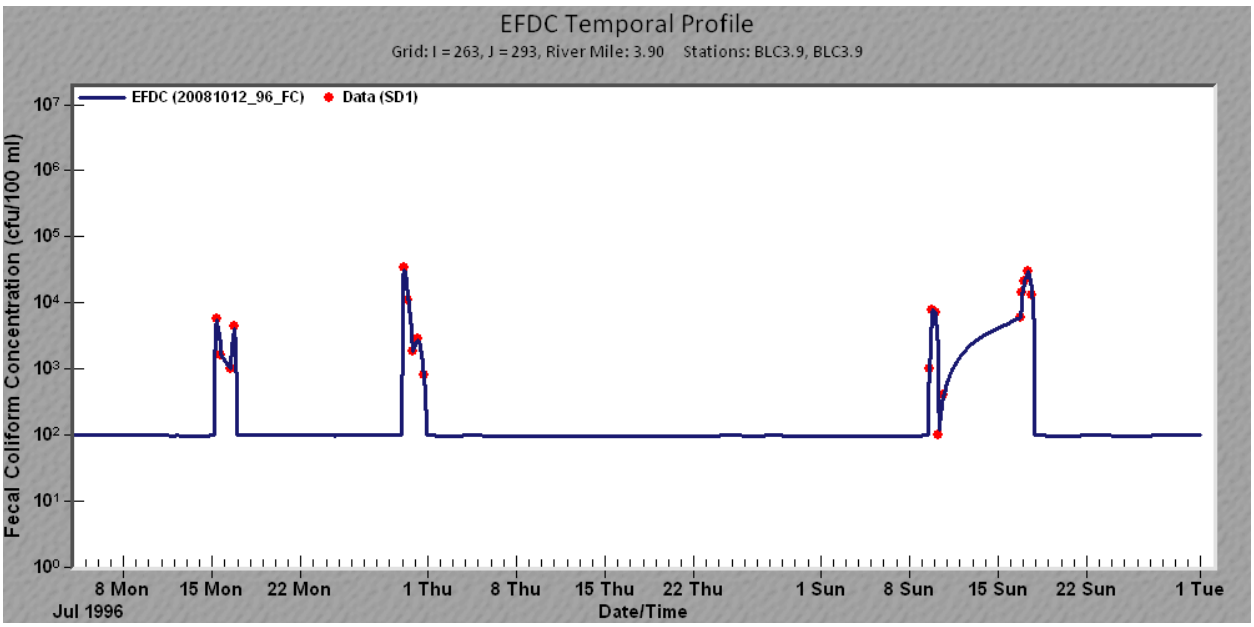
Banklick Creek at River Mile 1.2 (Winston Ave)-1996 Wet Weather Events.



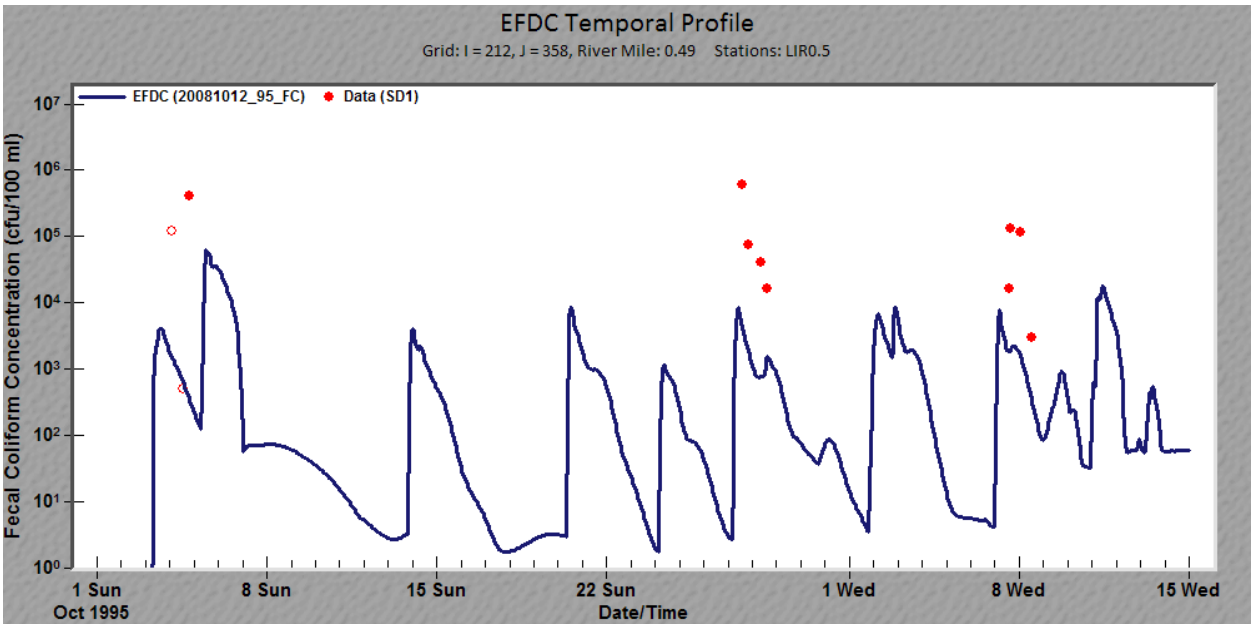
Banklick Creek at River Mile 3.9 (Eaton Dr.)-1995 Wet Weather Events.



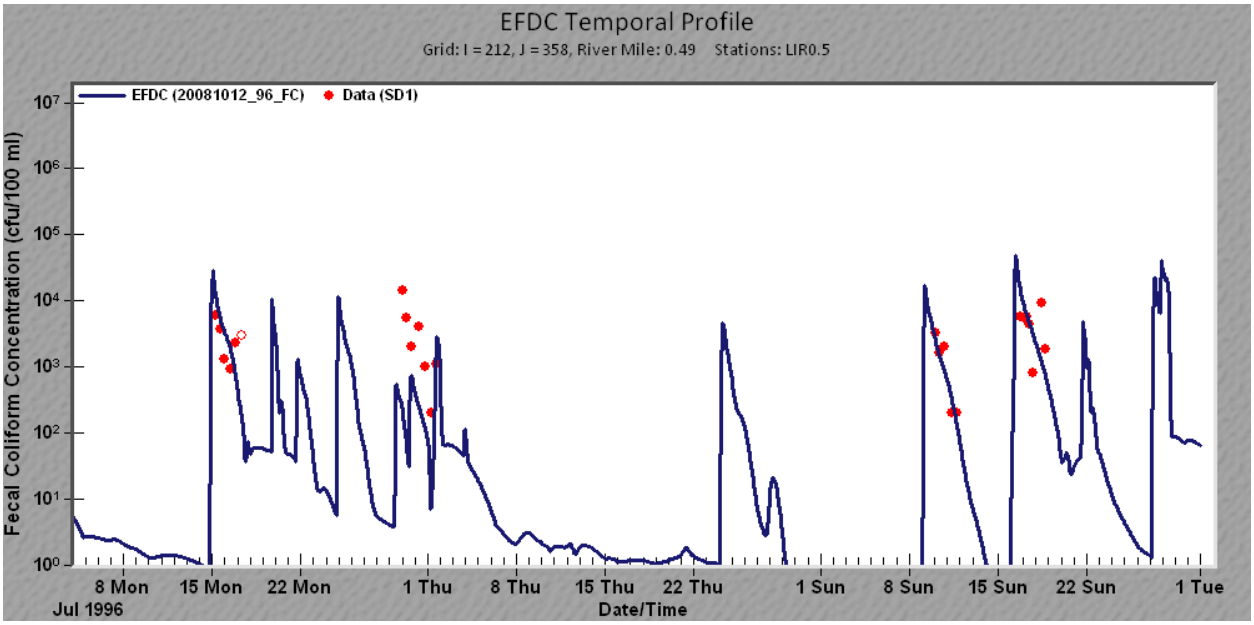
Banklick Creek at River Mile 3.9 (Eaton Dr.)-1996 Wet Weather Events.



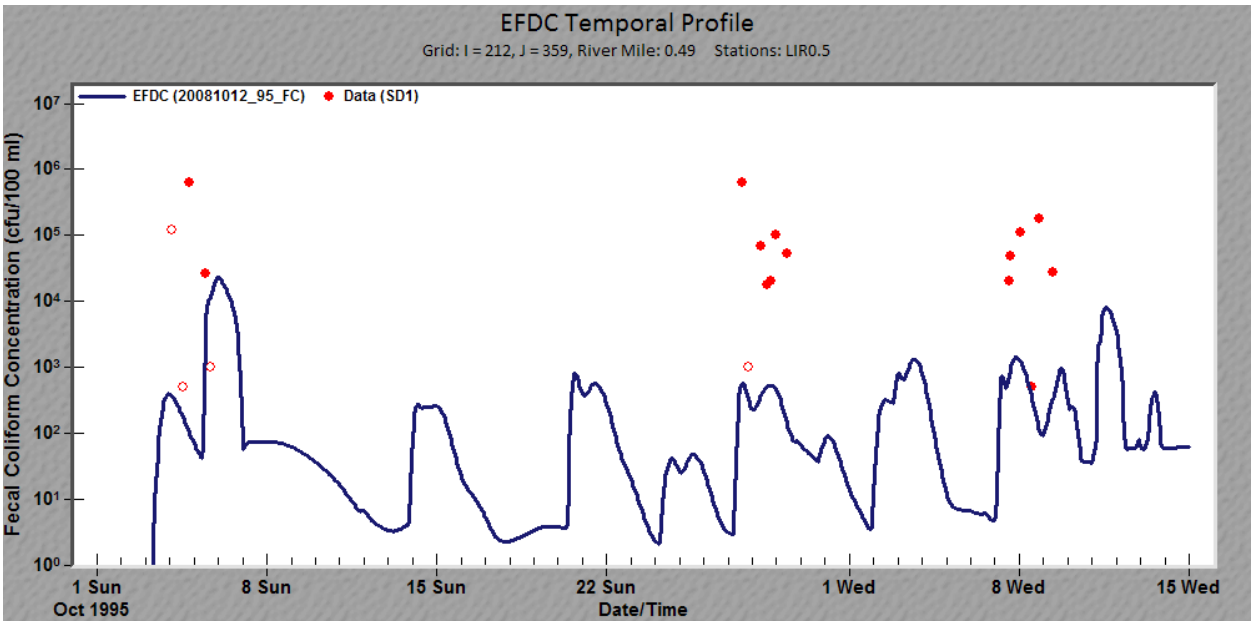
Licking River Left Descending Bank at River Mile 0.5-1995 Wet Weather Events



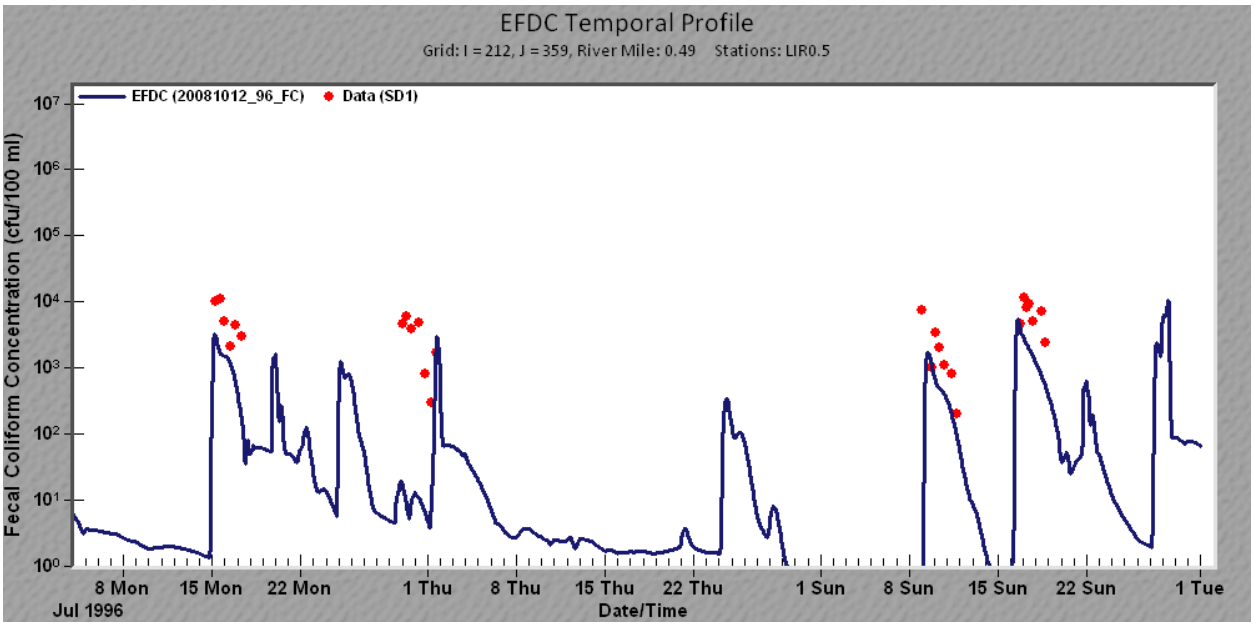
Licking River Left Descending Bank at River Mile 0.5-1996 Wet Weather Events



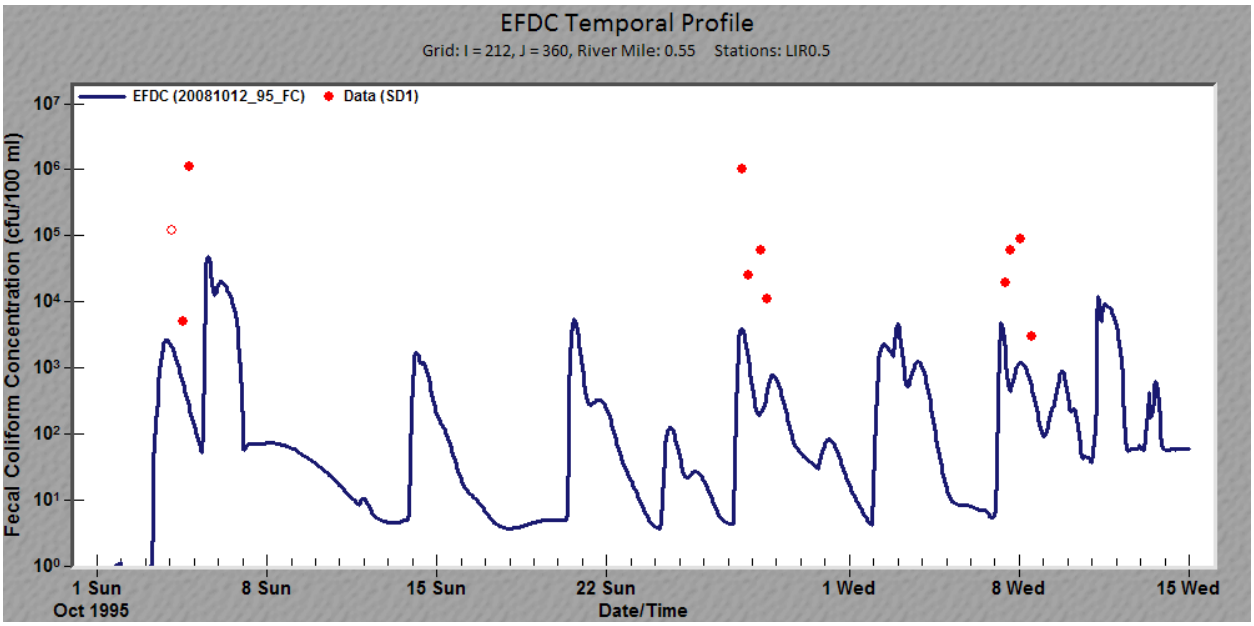
Licking River Mid-Channel at River Mile 0.5-1995 Wet Weather Events.



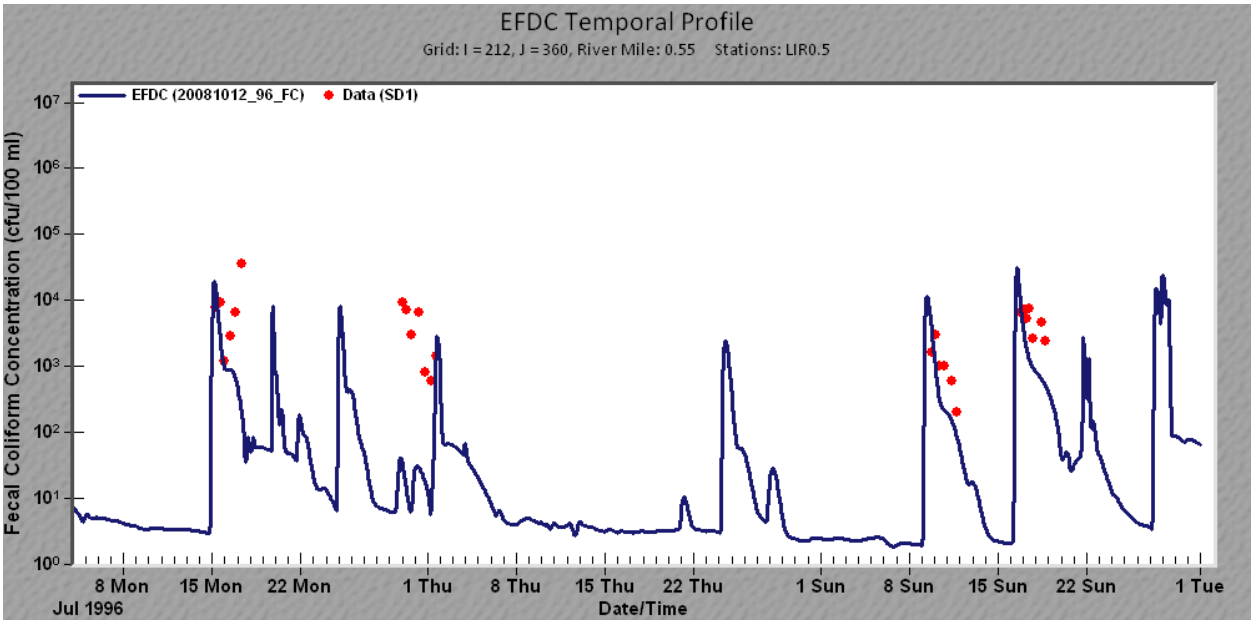
Licking River Mid-Channel at River Mile 0.5-1996 Wet Weather Events.



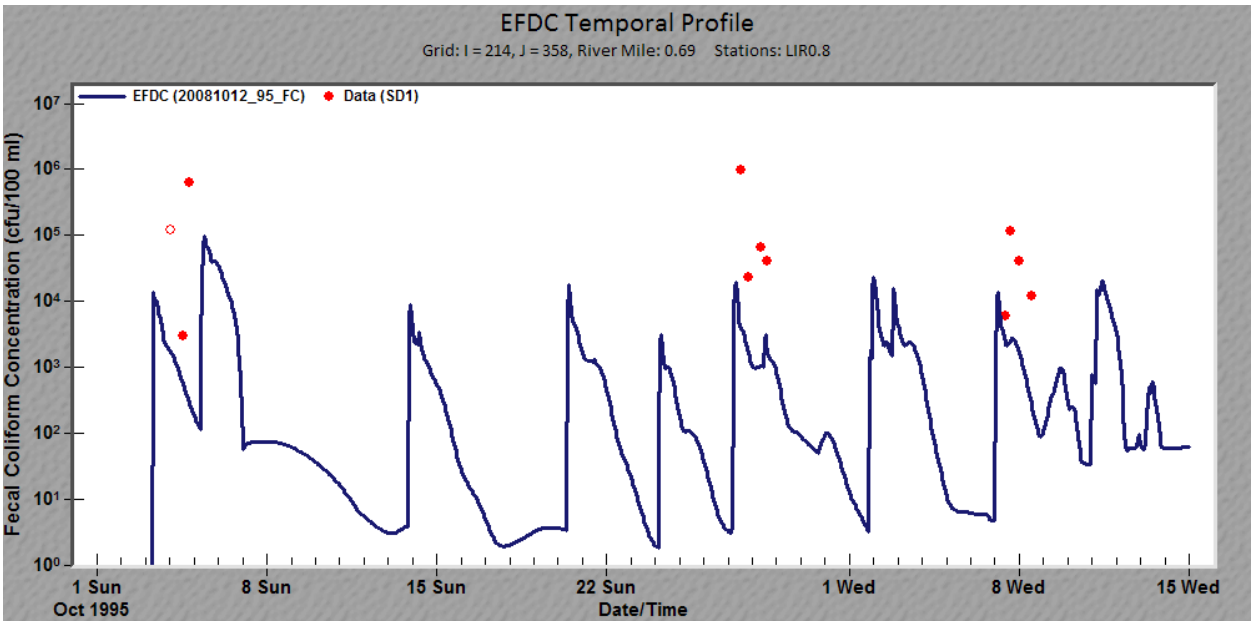
Licking River Right Descending Bank at River Mile 0.5-1995 Wet Weather Events.



Licking River Right Descending Bank at River Mile 0.5-1996 Wet Weather Events.



Licking River Left Descending Bank at River Mile 0.8-1995 Wet Weather Events.



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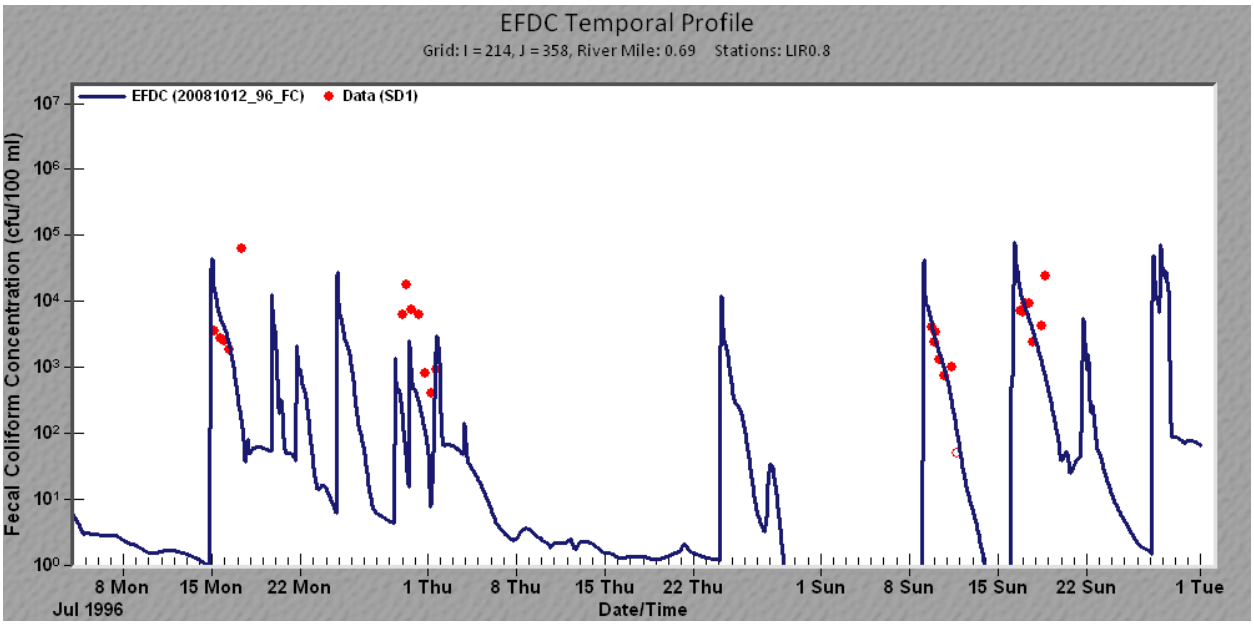
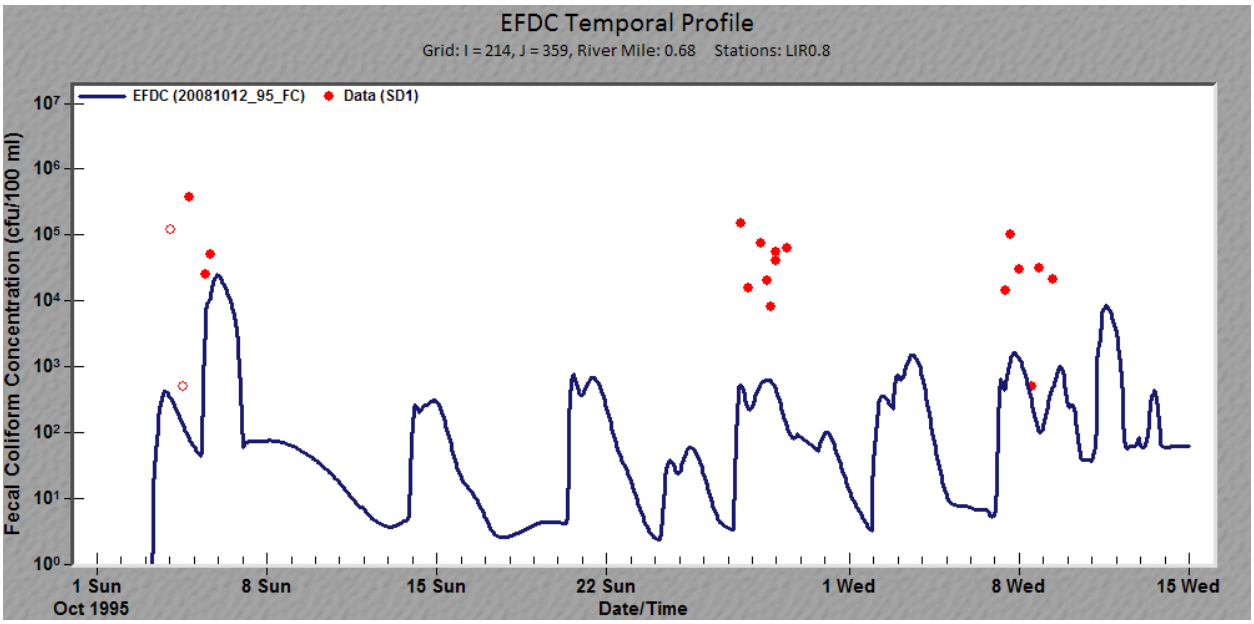
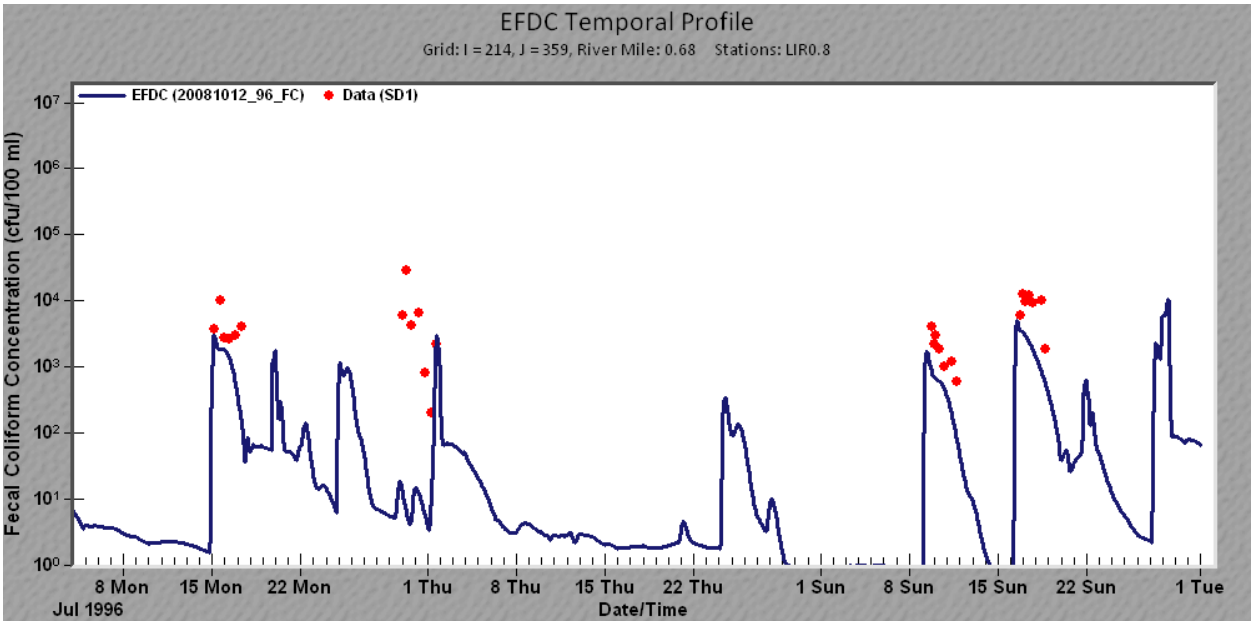


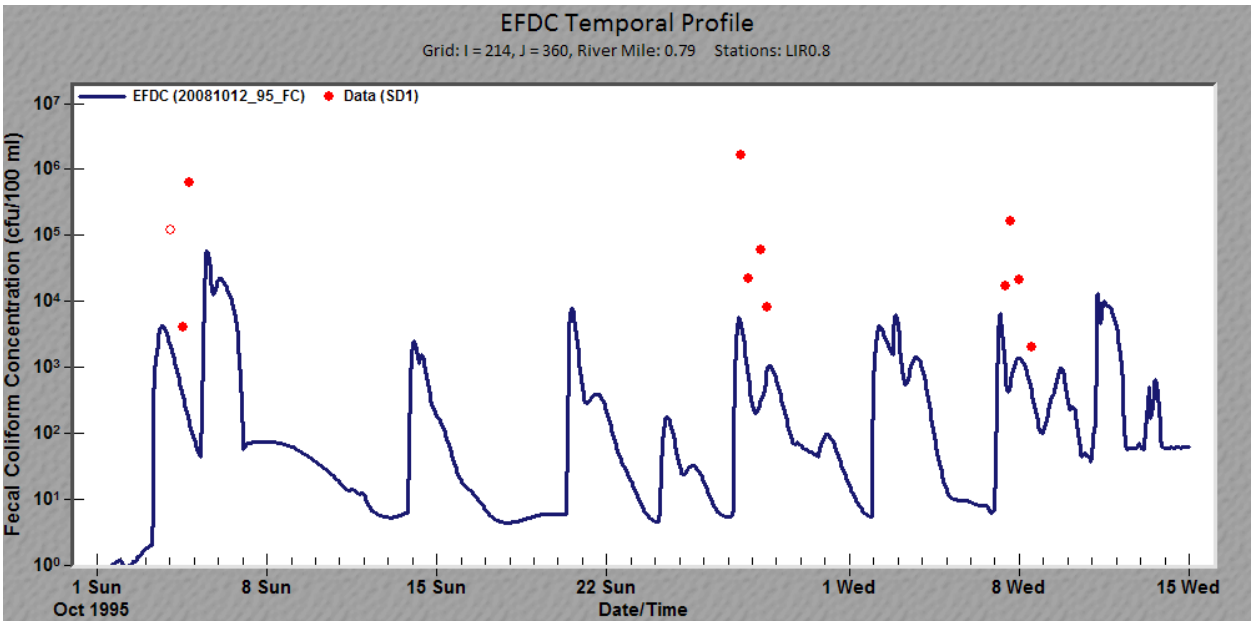
Licking River Mid-Channel at River Mile 0.8-1995 Wet Weather Events.



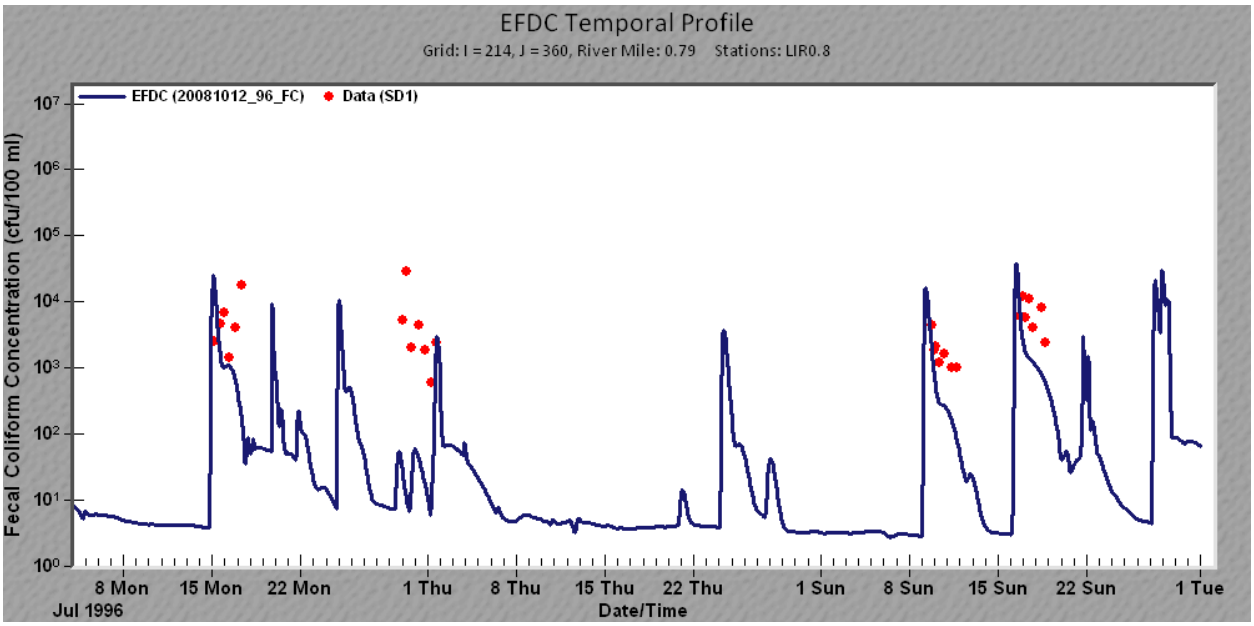
Licking River Mid-Channel at River Mile 0.8-1996 Wet Weather Events.



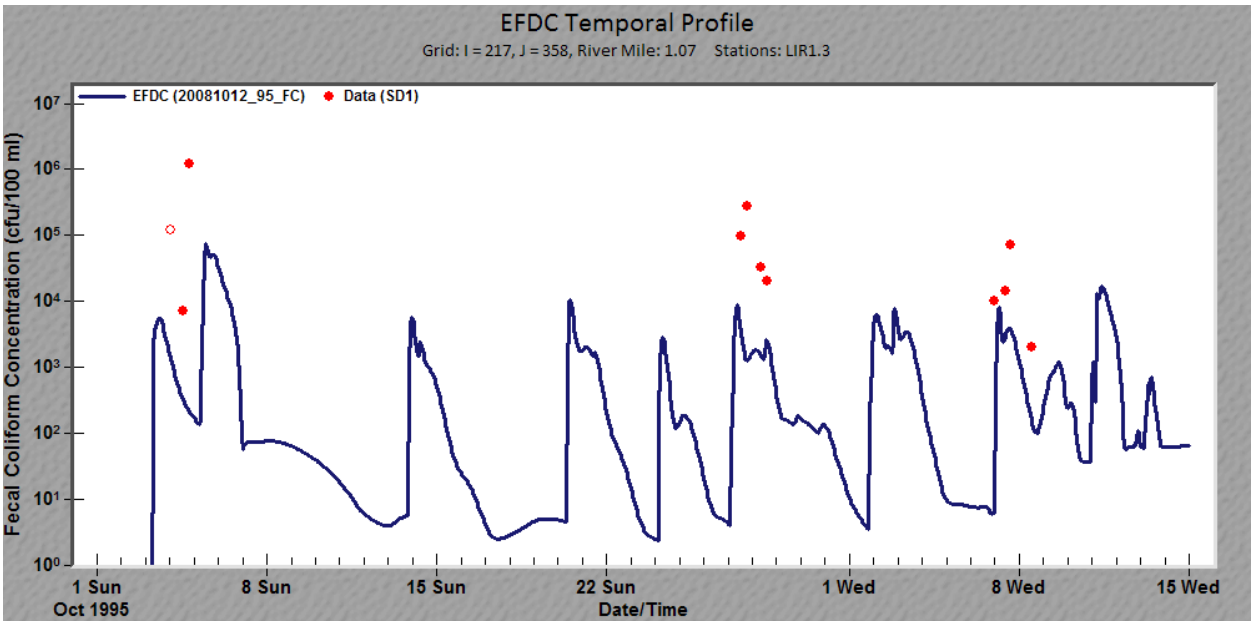
Licking River Right Descending Bank at River Mile 0.8-1995 Wet Weather Events.



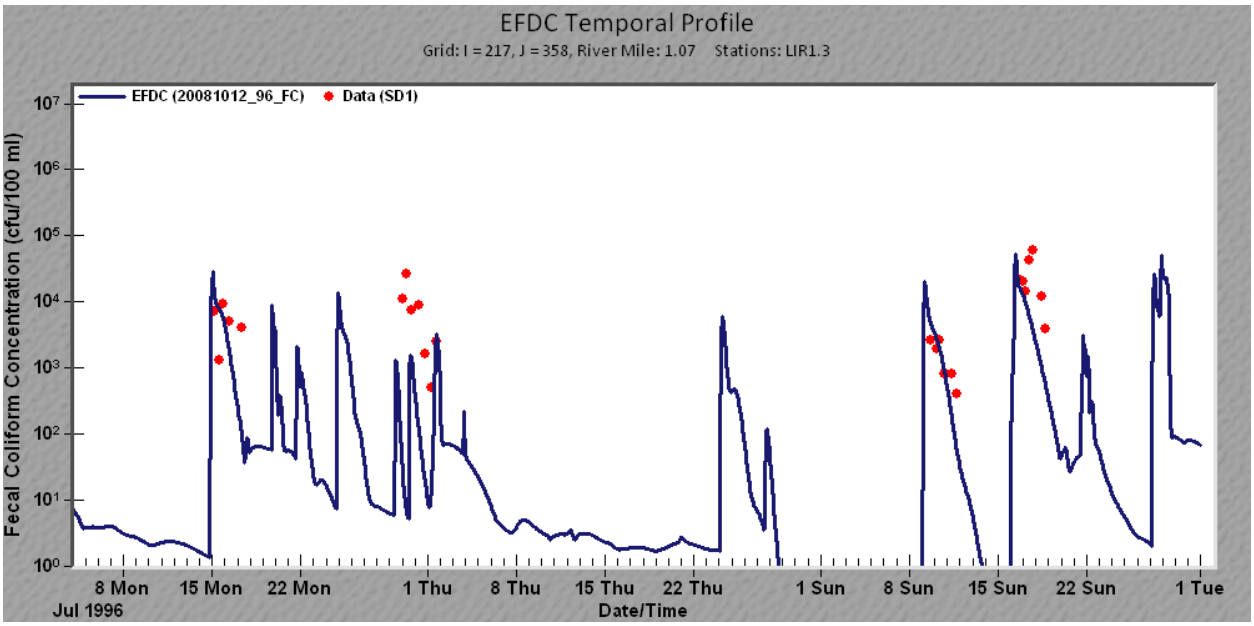
Licking River Right Descending Bank at River Mile 0.8-1996 Wet Weather Events.



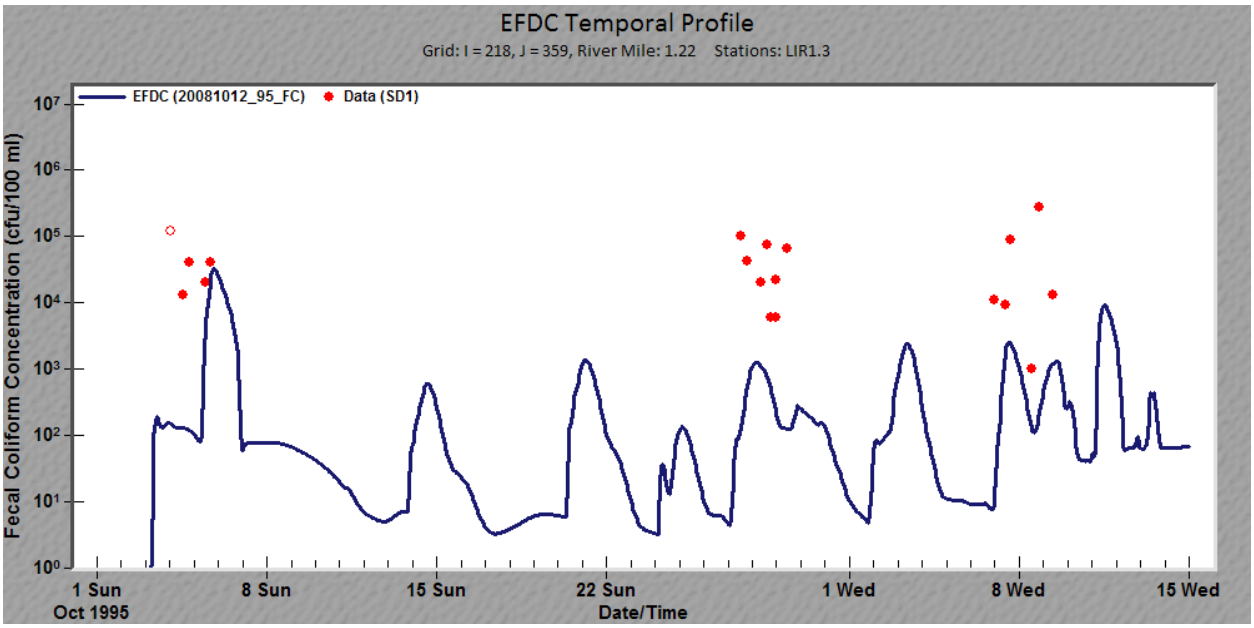
Licking River Left Descending Bank at River Mile 1.3-1995 Wet Weather Events.



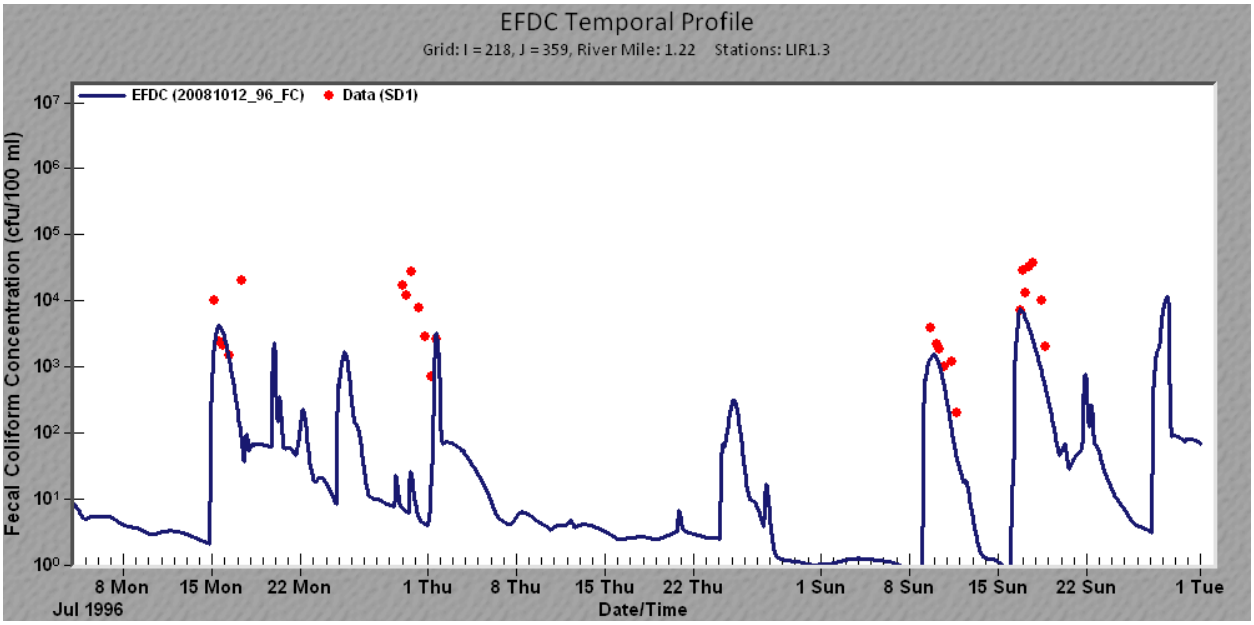
Licking River Left Descending Bank at River Mile 1.3-1996 Wet Weather Events.



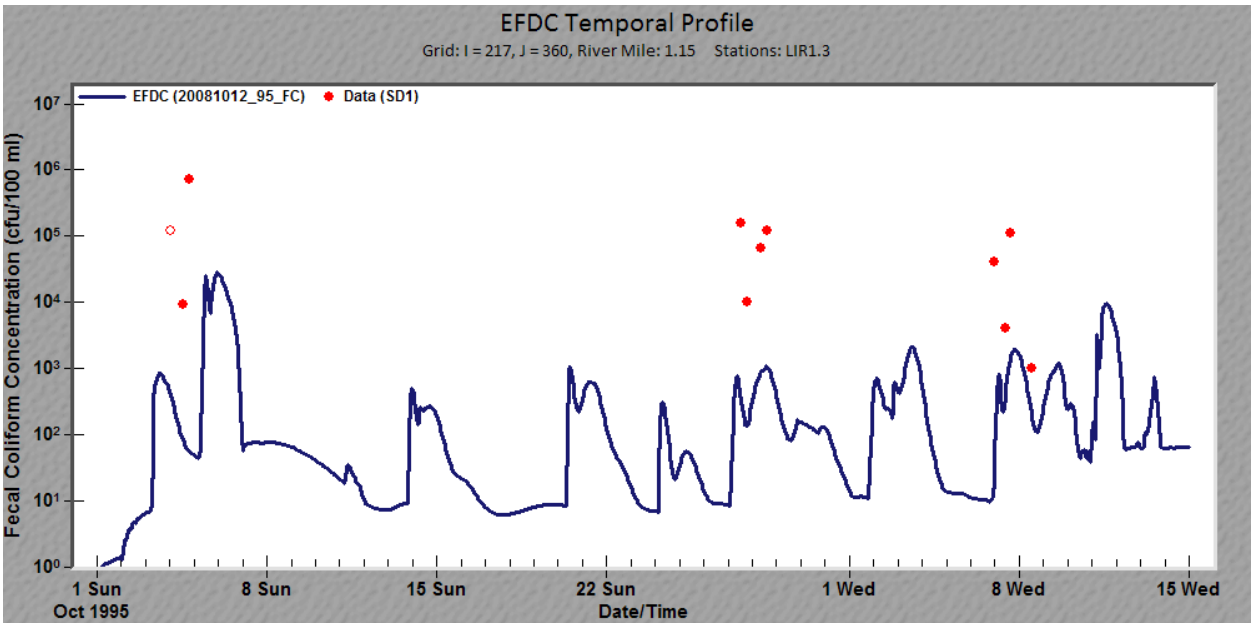
Licking River Mid-Channel at River Mile 1.3-1995 Wet Weather Events.



Licking River Mid-Channel at River Mile 1.3-1996 Wet Weather Events.



Licking River Right Descending Bank at River Mile 1.3-1995 Wet Weather Events.



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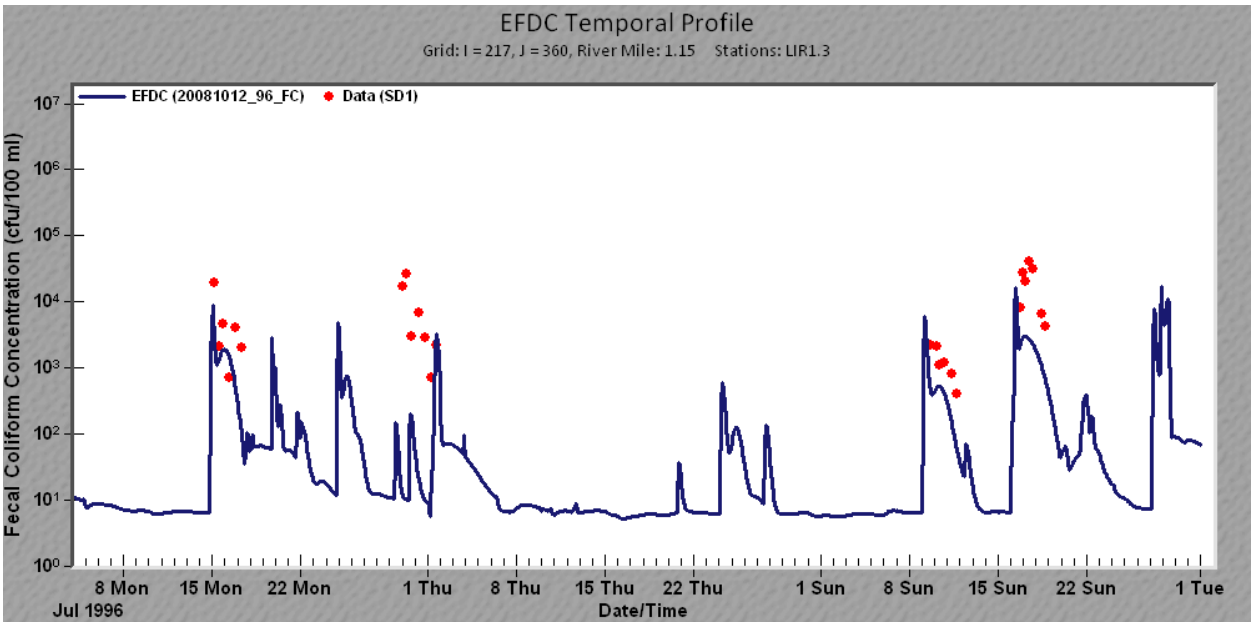
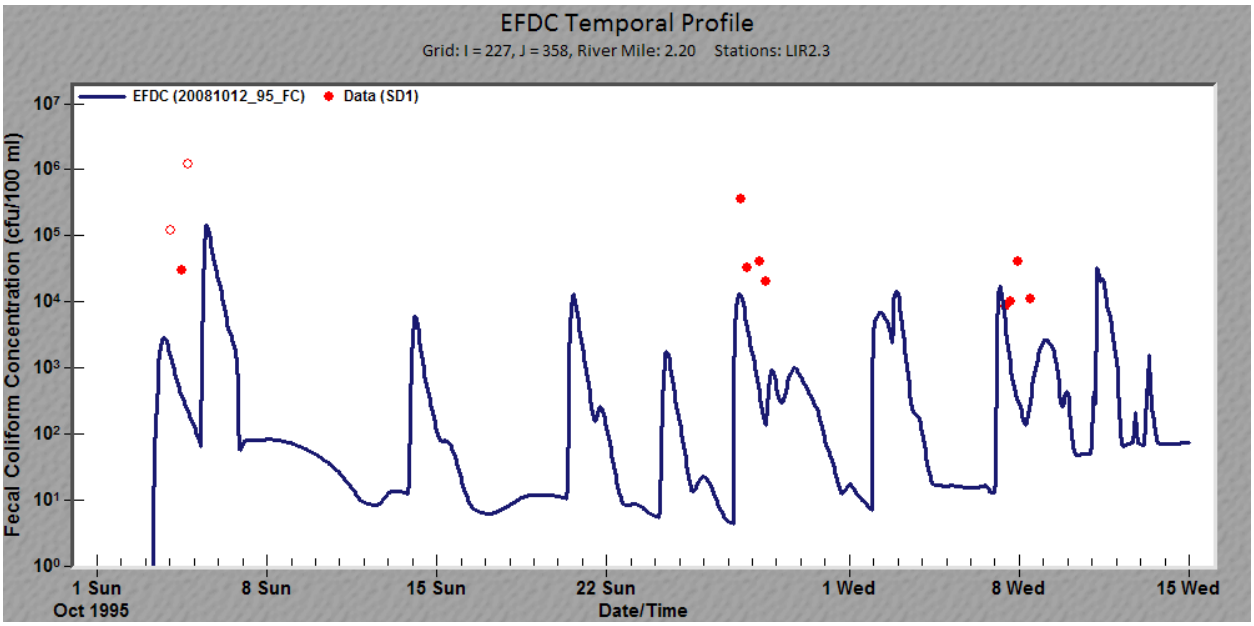
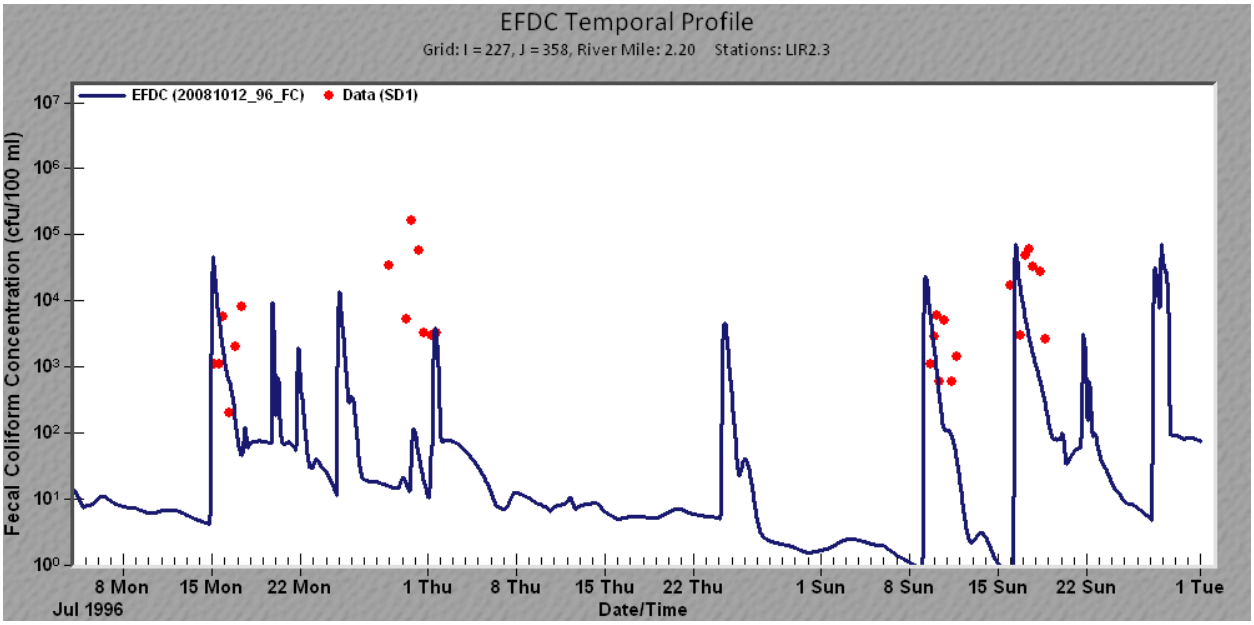


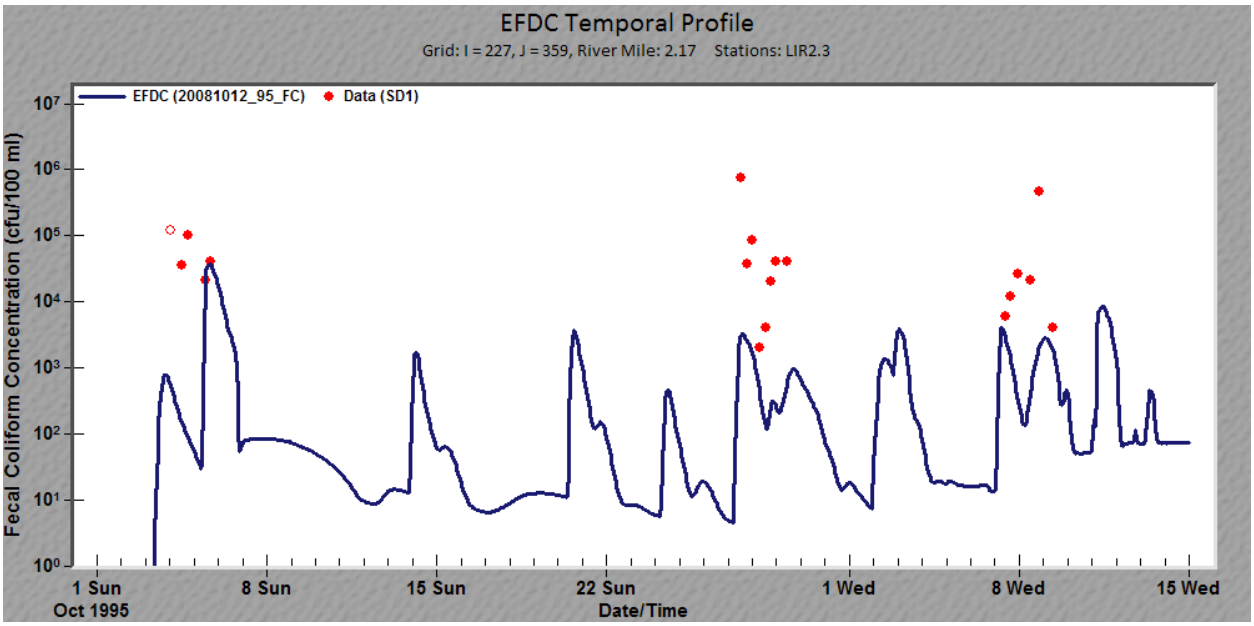
Licking River Left Descending Bank at River Mile 2.3-1995 Wet Weather Events.



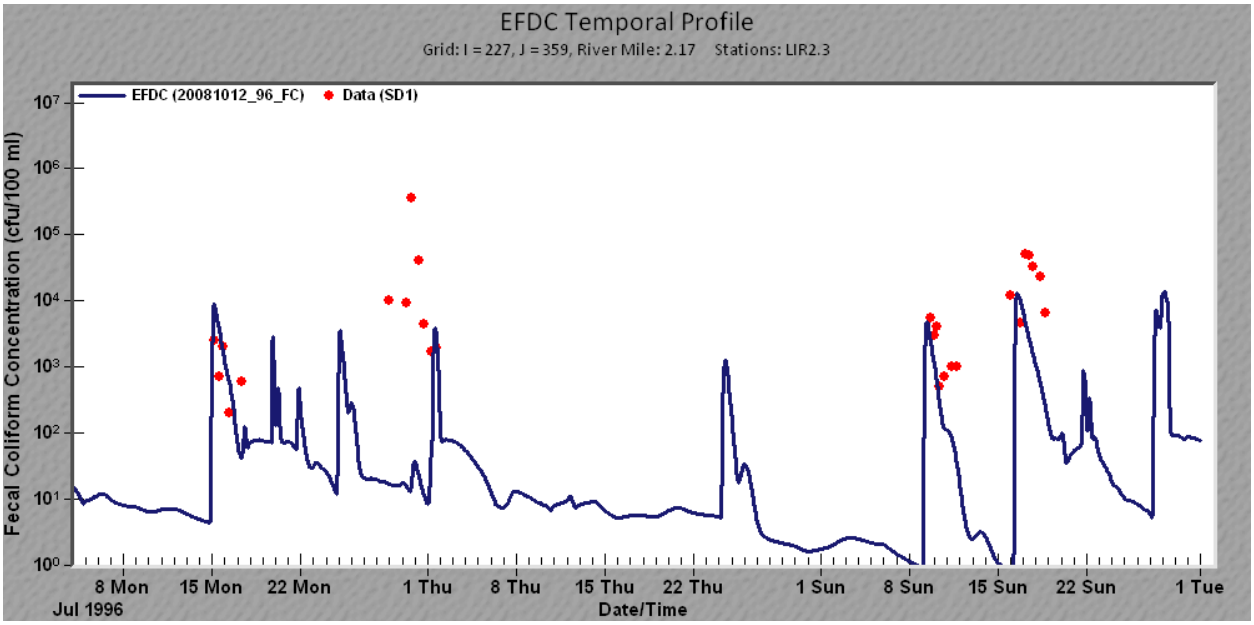
Licking River Left Descending Bank at River Mile 2.3-1996 Wet Weather Events.



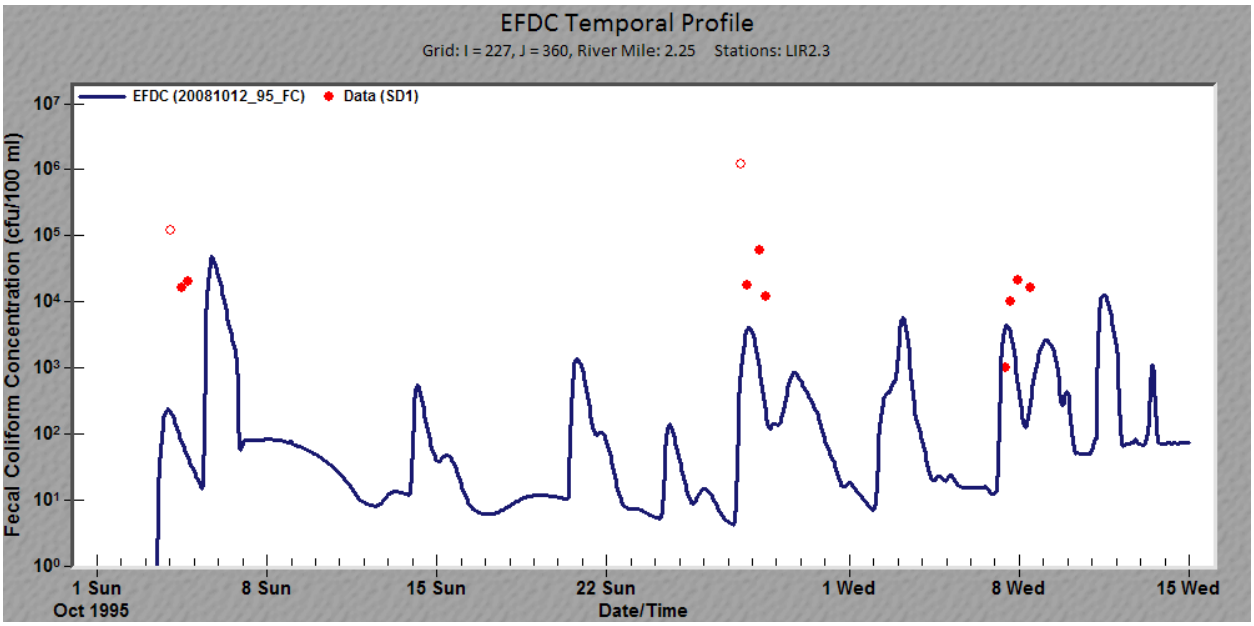
Licking River Mid-Channel at River Mile 2.3-1995 Wet Weather Events.



Licking River Mid-Channel at River Mile 2.3-1996 Wet Weather Events.



Licking River Right Descending Bank at River Mile 2.3-1995 Wet Weather Events.



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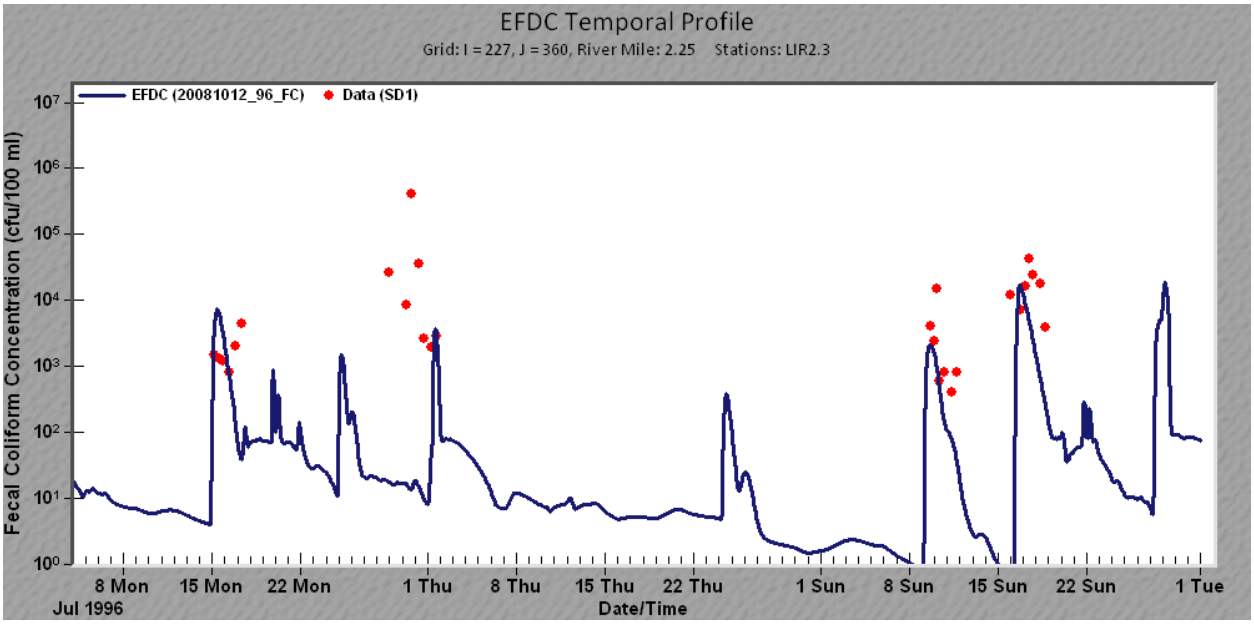
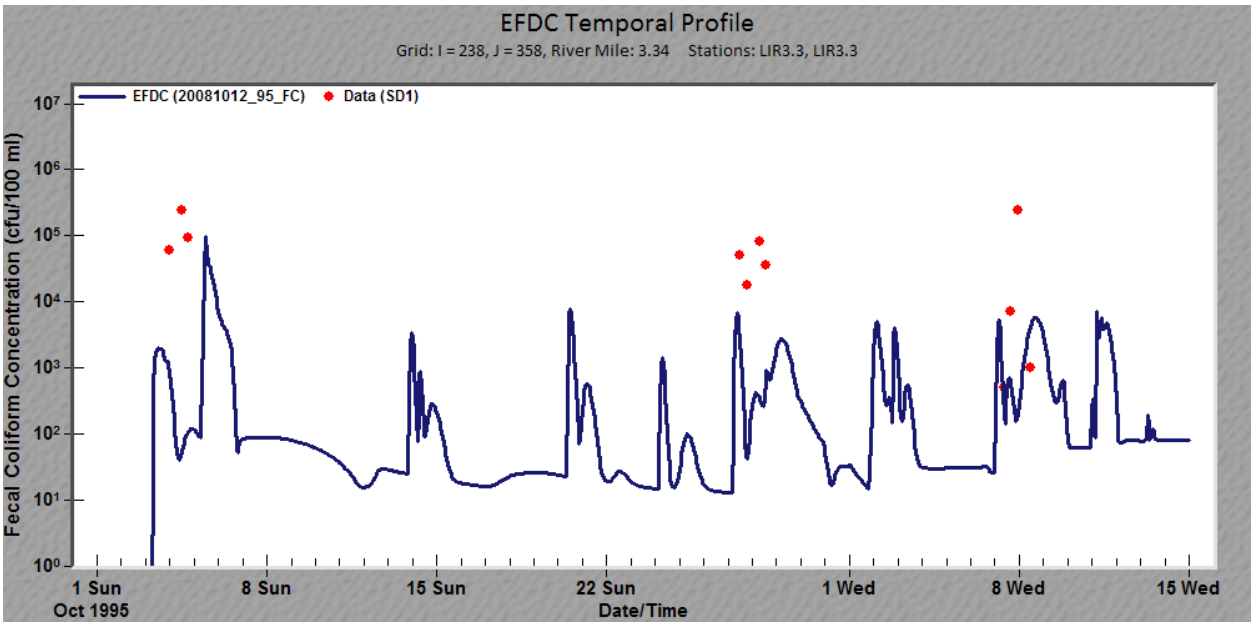
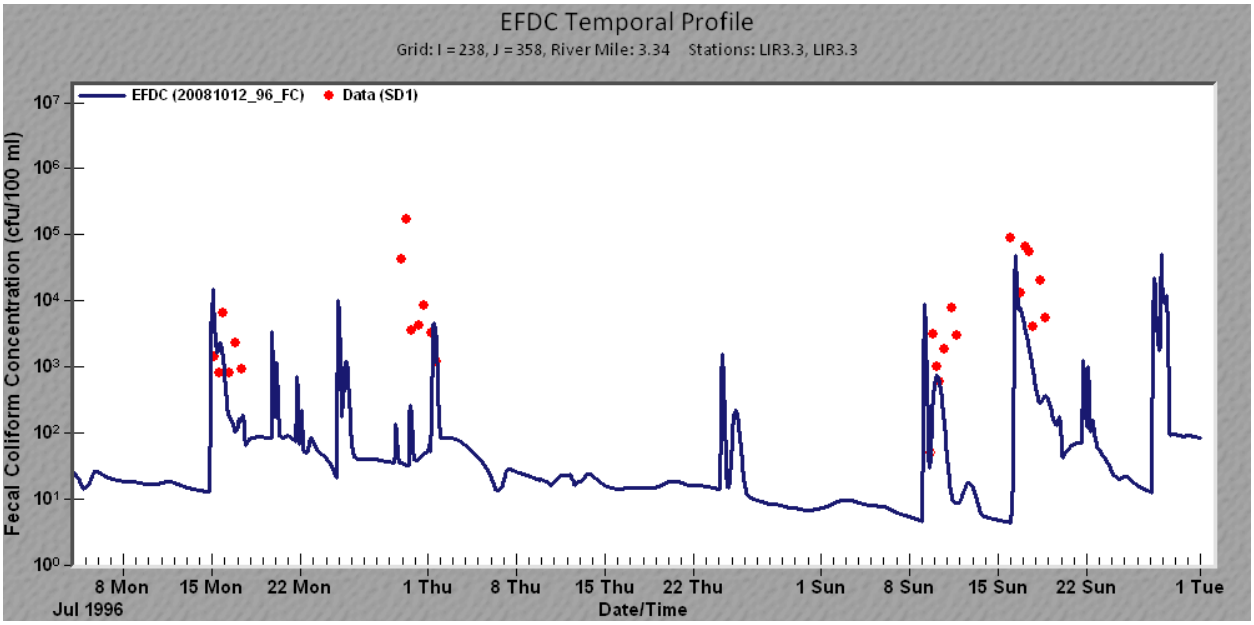


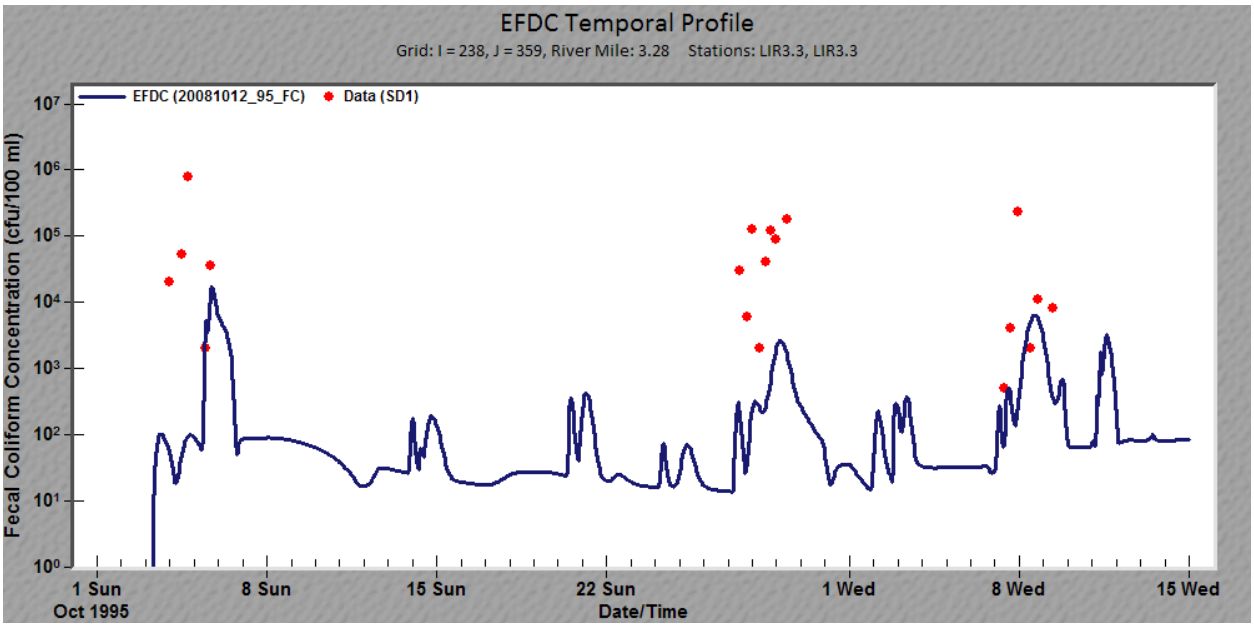
Licking River Left Descending Bank at River Mile 3.3-1995 Wet Weather Events.



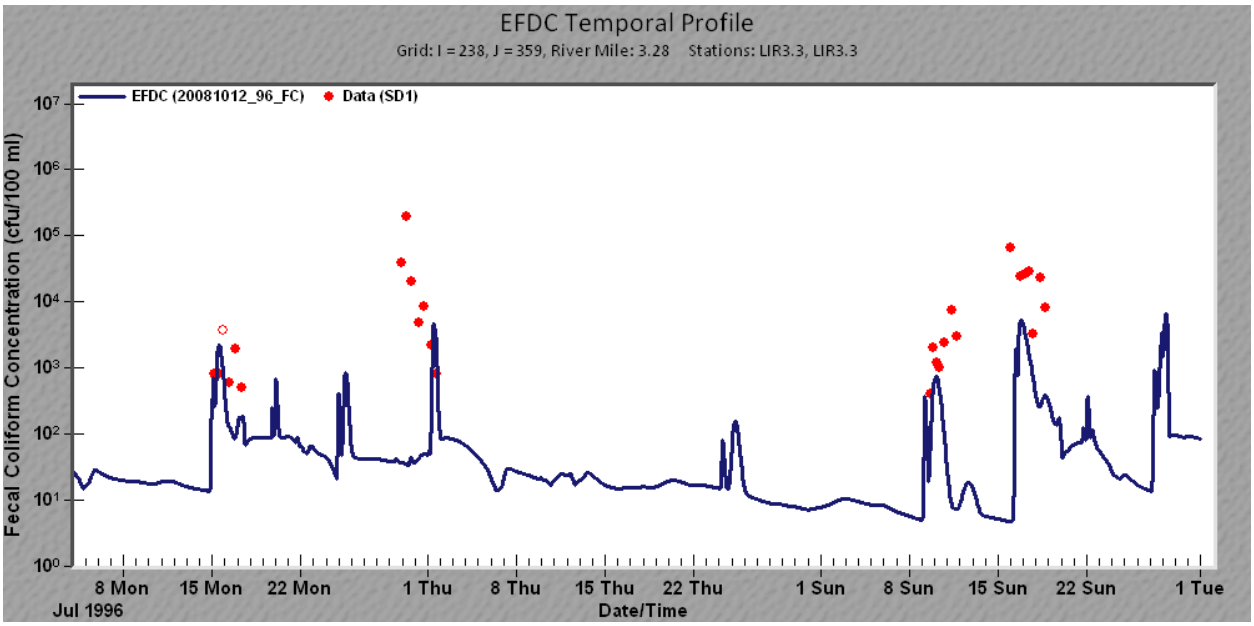
Licking River Left Descending Bank at River Mile 3.3-1996 Wet Weather Events.



Licking River Mid-Channel at River Mile 3.3-1995 Wet Weather Events.



Licking River Mid-Channel at River Mile 3.3-1996 Wet Weather Events.



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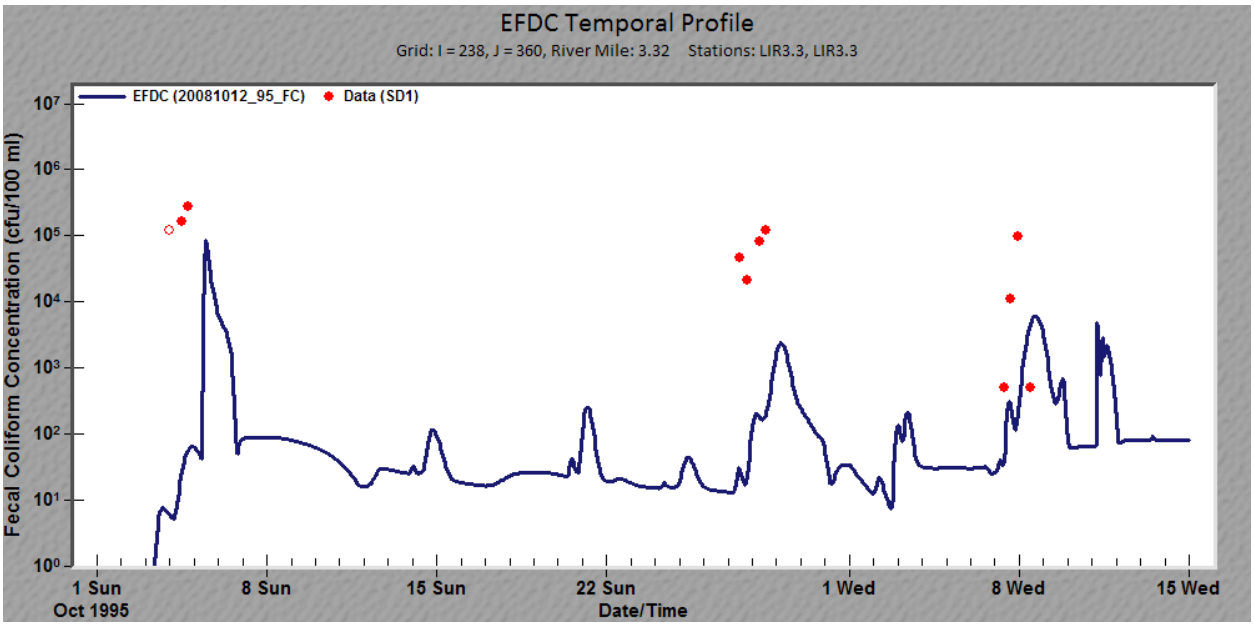

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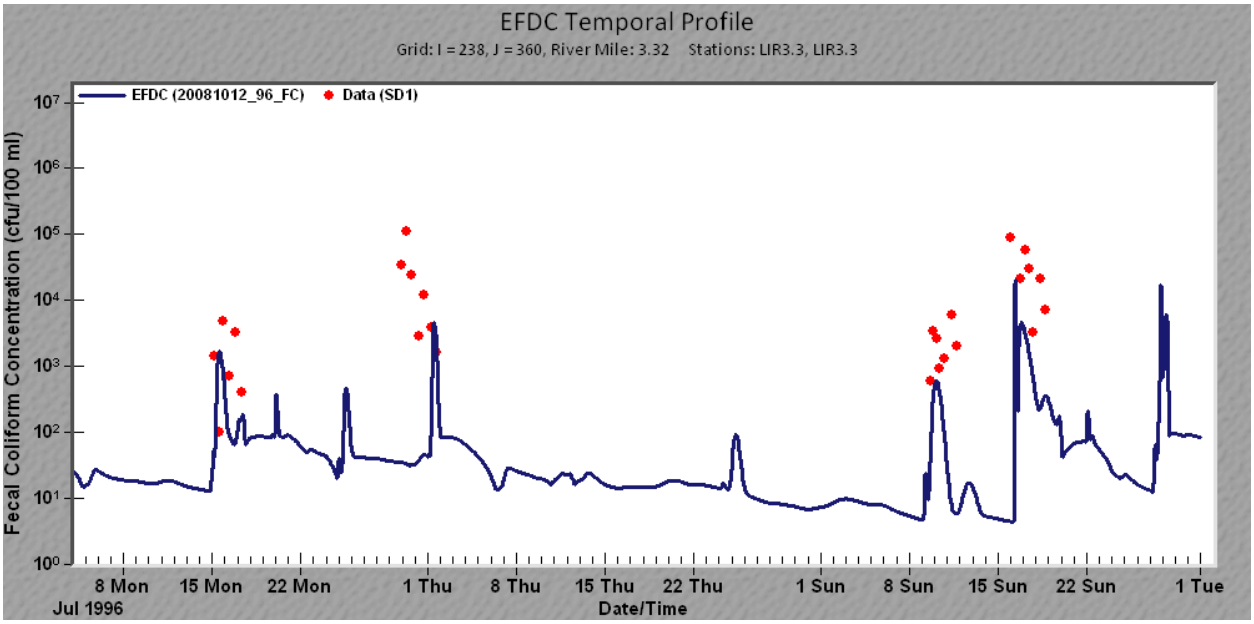
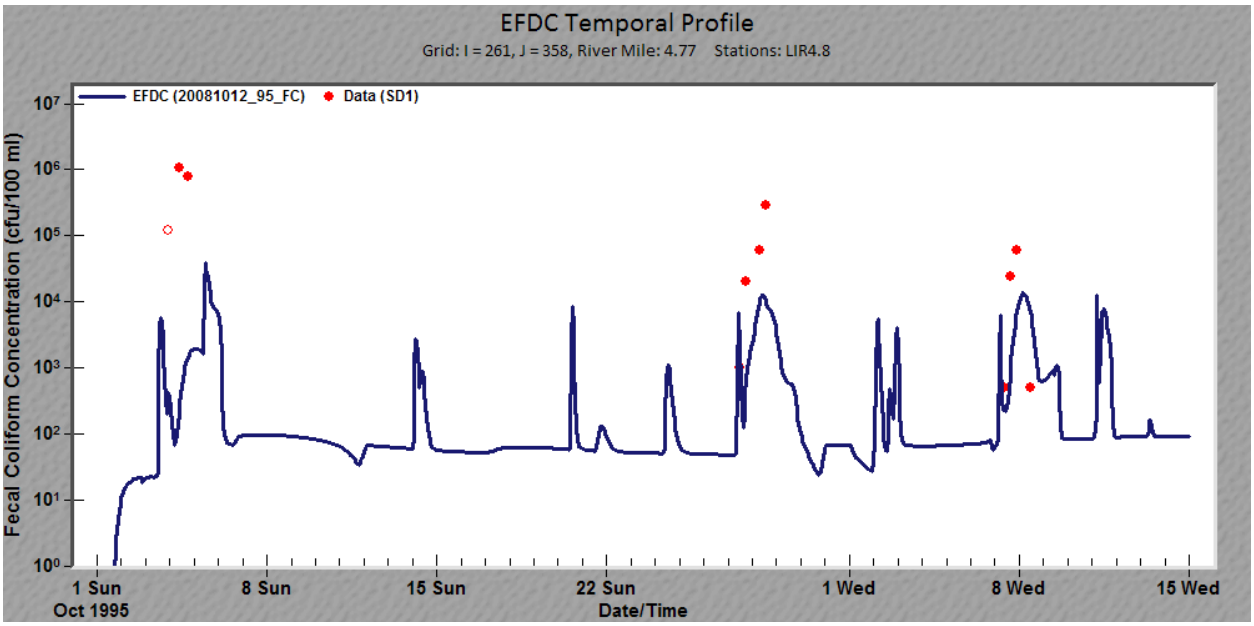


Licking River Left Descending Bank at River Mile 4.8-1995 Wet Weather Events.



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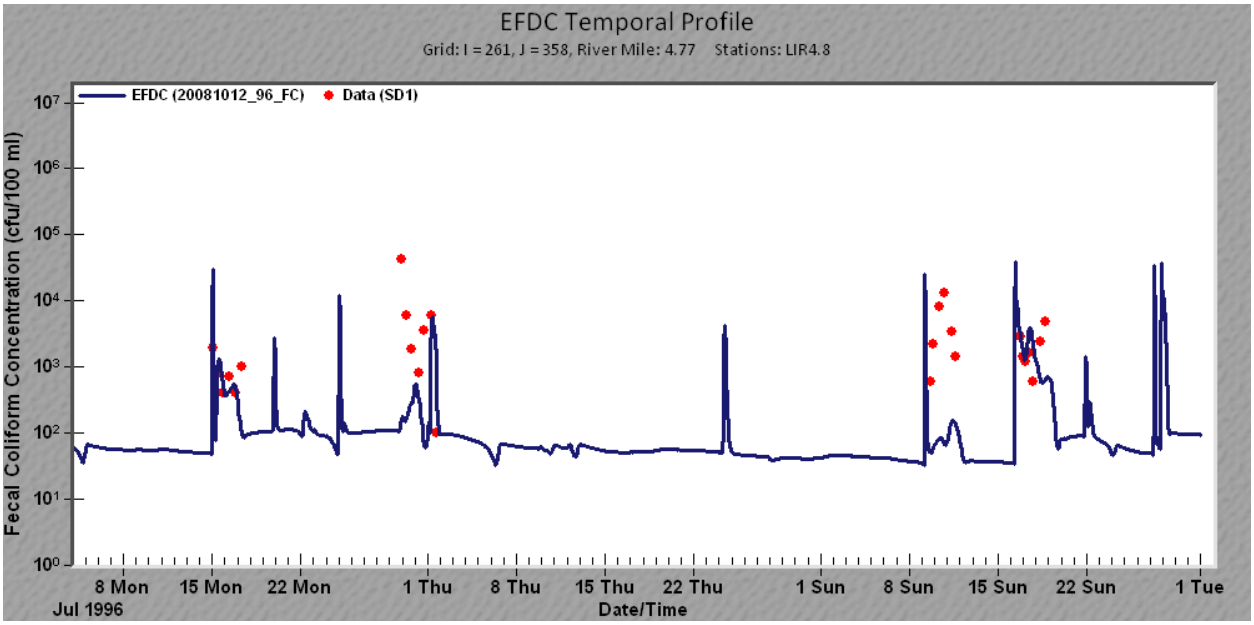
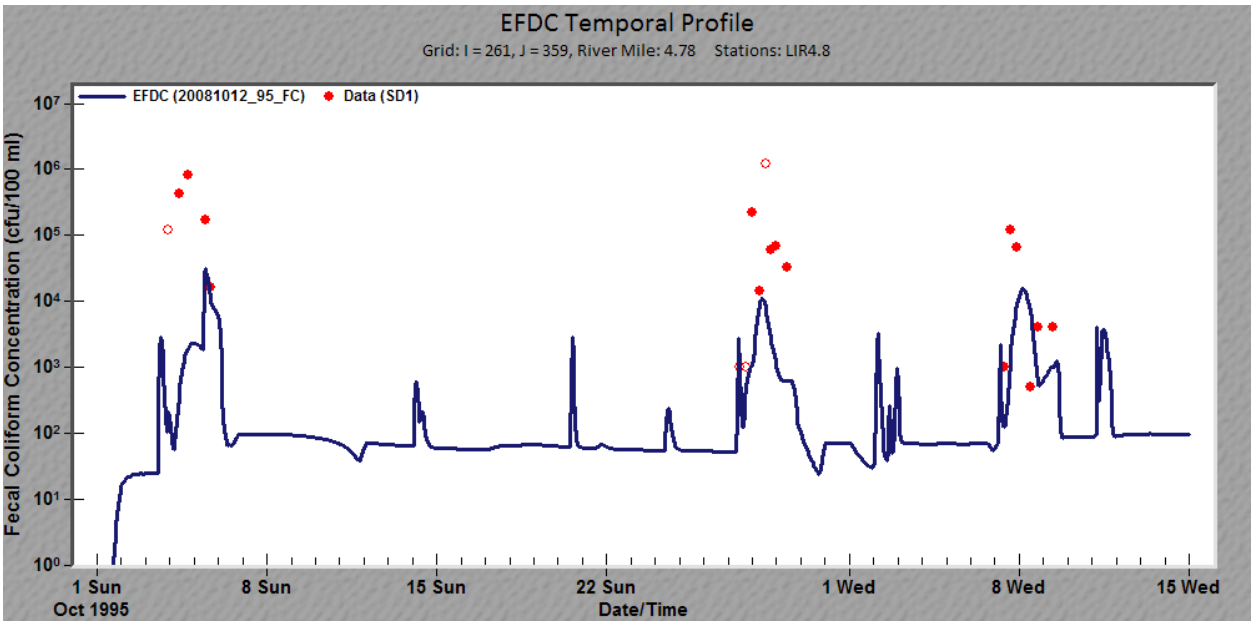
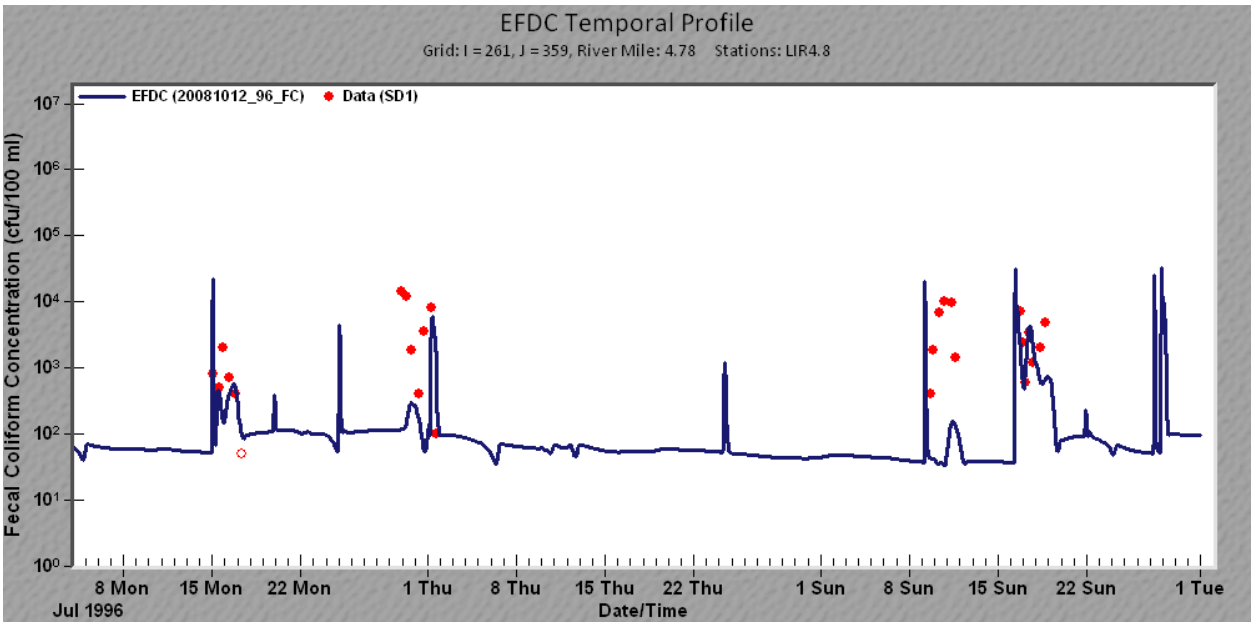


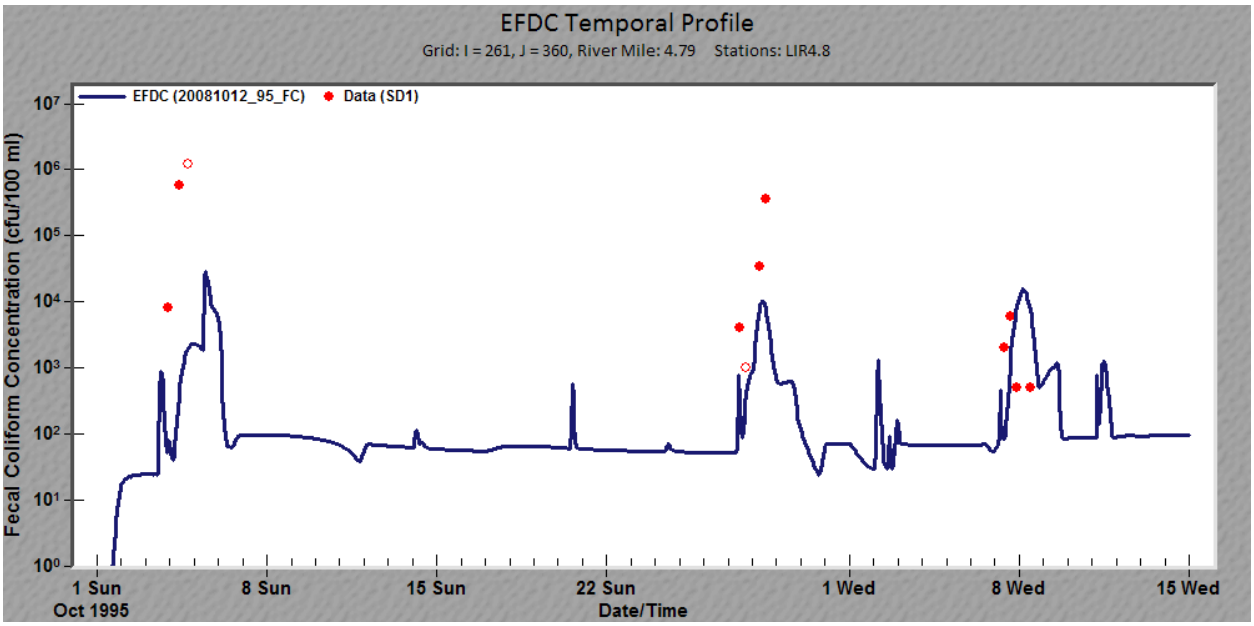
Licking River Mid-Channel at River Mile 4.8-1995 Wet Weather Events.



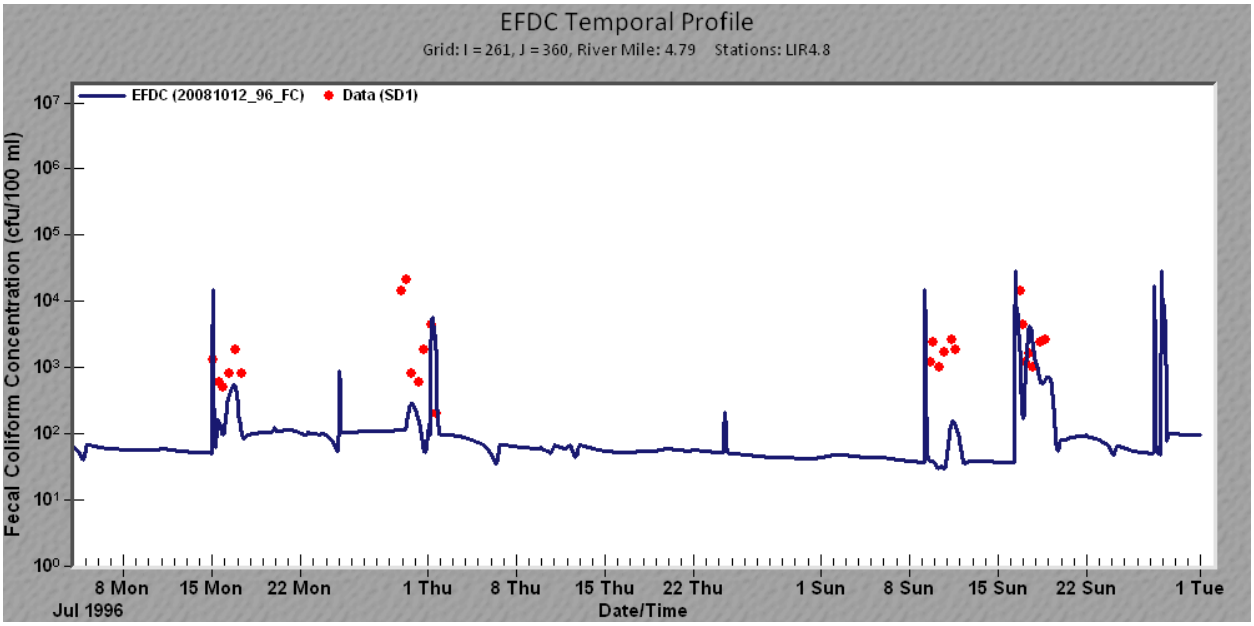
Licking River Mid-Channel at River Mile 4.8-1996 Wet Weather Events.



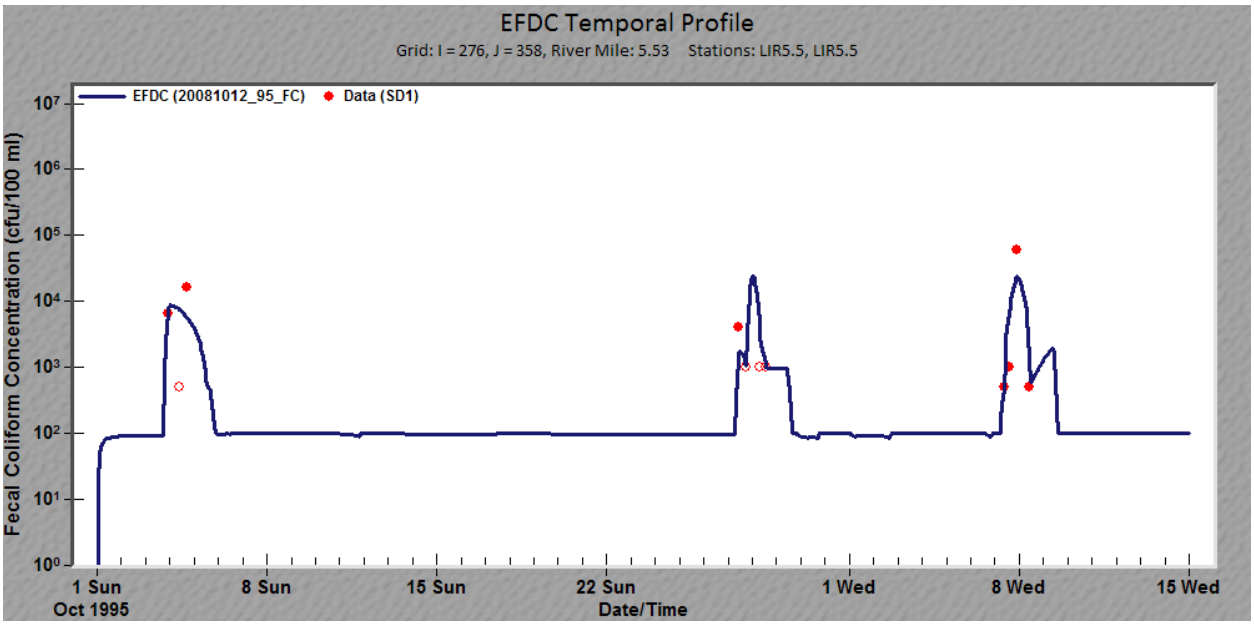
Licking River Right Descending Bank at River Mile 4.8-1995 Wet Weather Events.



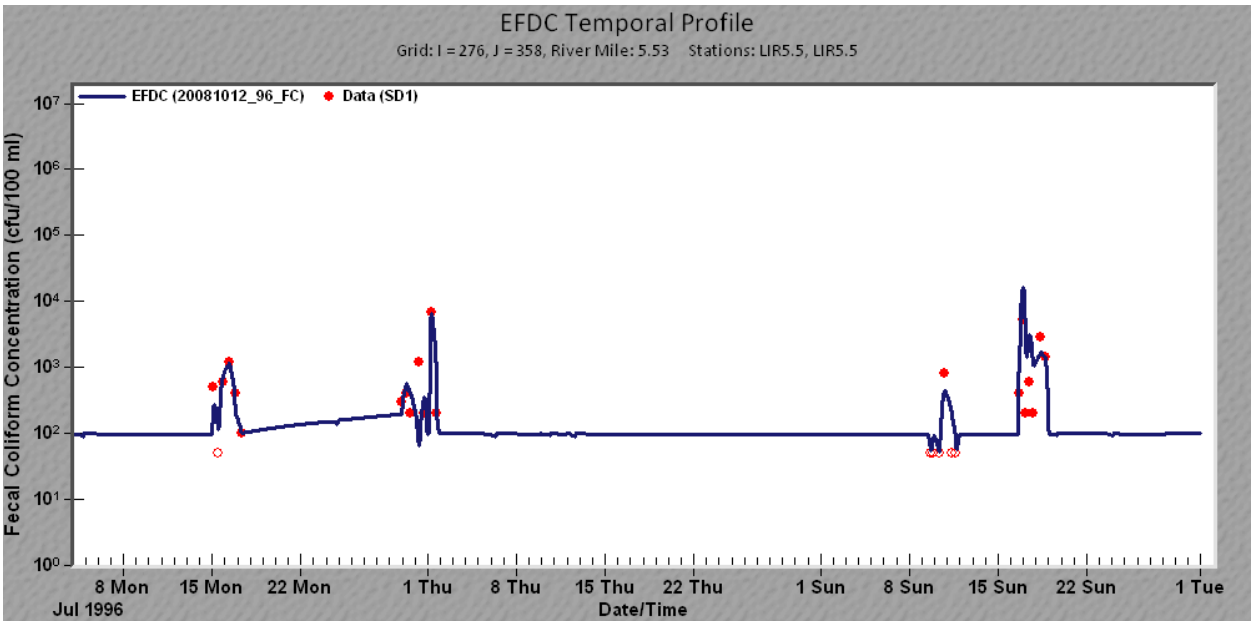
Licking River Right Descending Bank at River Mile 4.8-1996 Wet Weather Events.



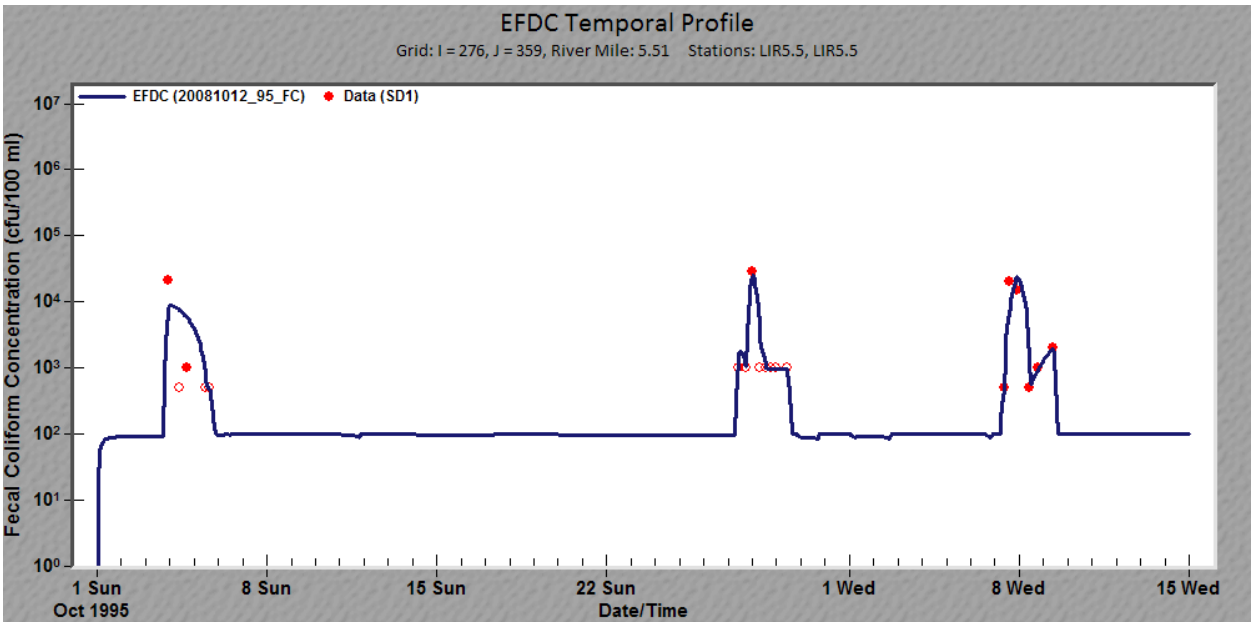
Licking River Left Descending Bank at River Mile 5.5-1995 Wet Weather Events.



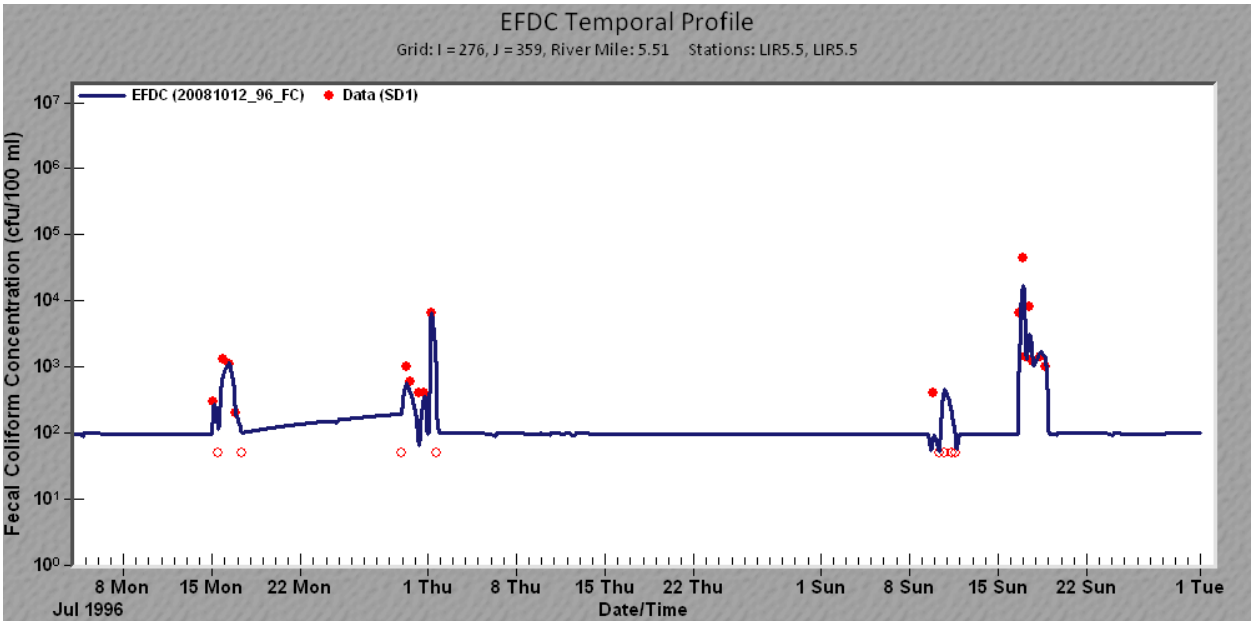
Licking River Left Descending Bank at River Mile 5.5-1996 Wet Weather Events.



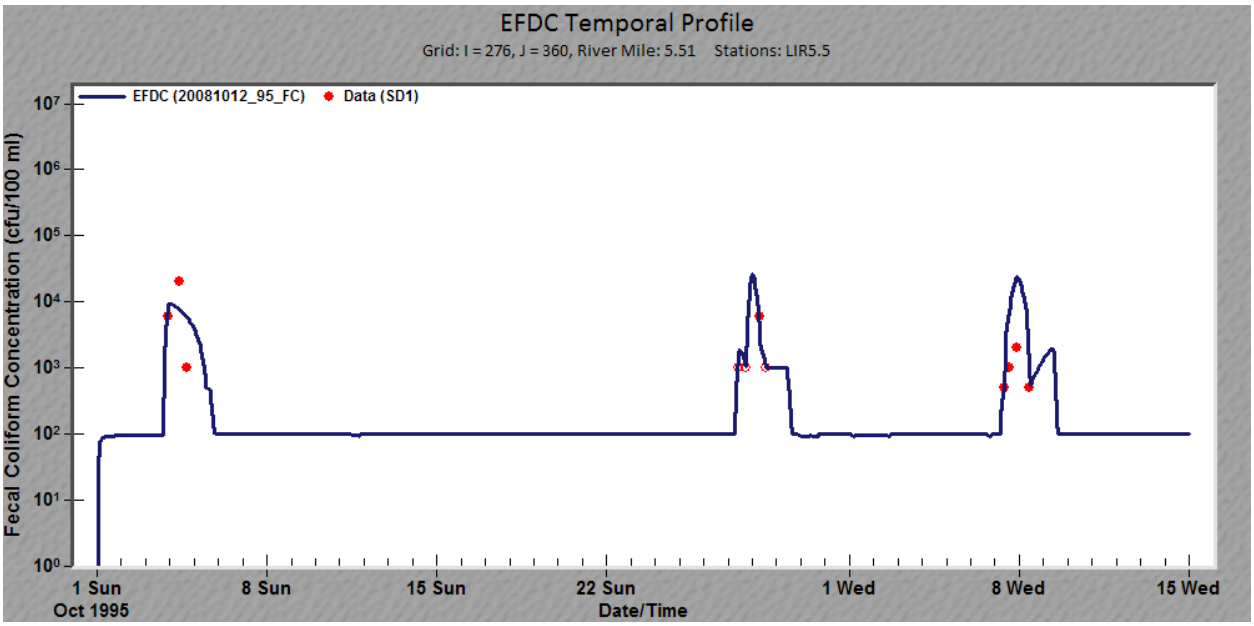
Licking River Mid-Channel at River Mile 5.5-1995 Wet Weather Events.



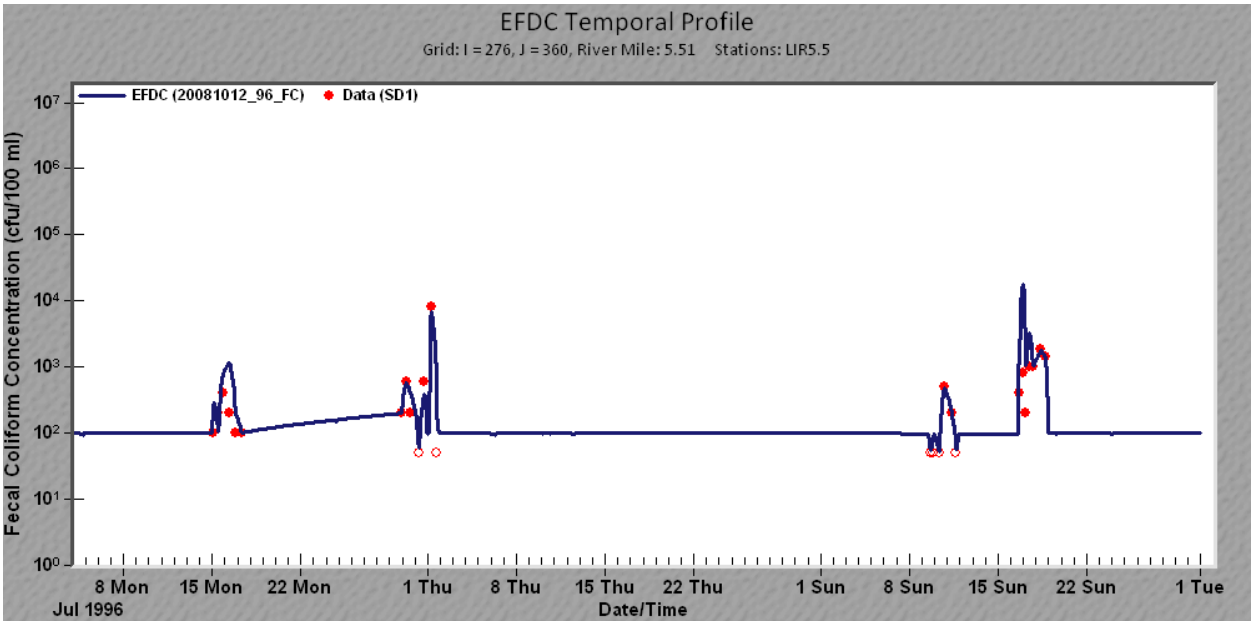
Licking River Mid-Channel at River Mile 5.5-1996 Wet Weather Events.



Licking River Right Descending Bank at River Mile 5.5-1995 Wet Weather Events.



Licking River Right Descending Bank at River Mile 5.5-1996 Wet Weather Events.



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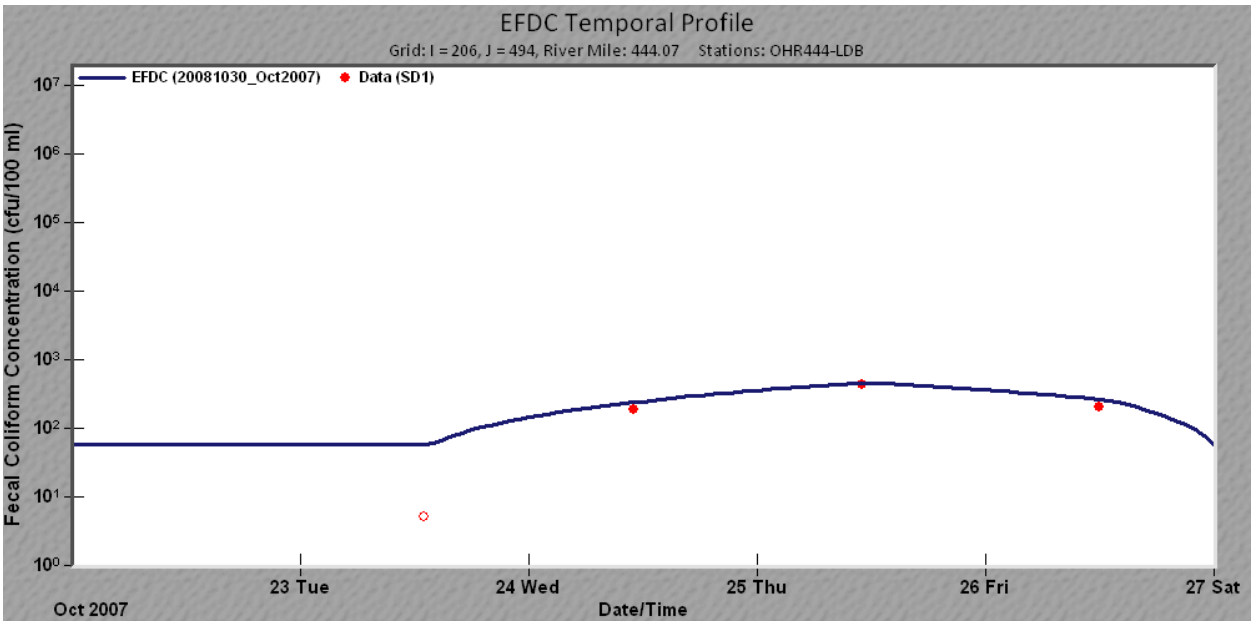
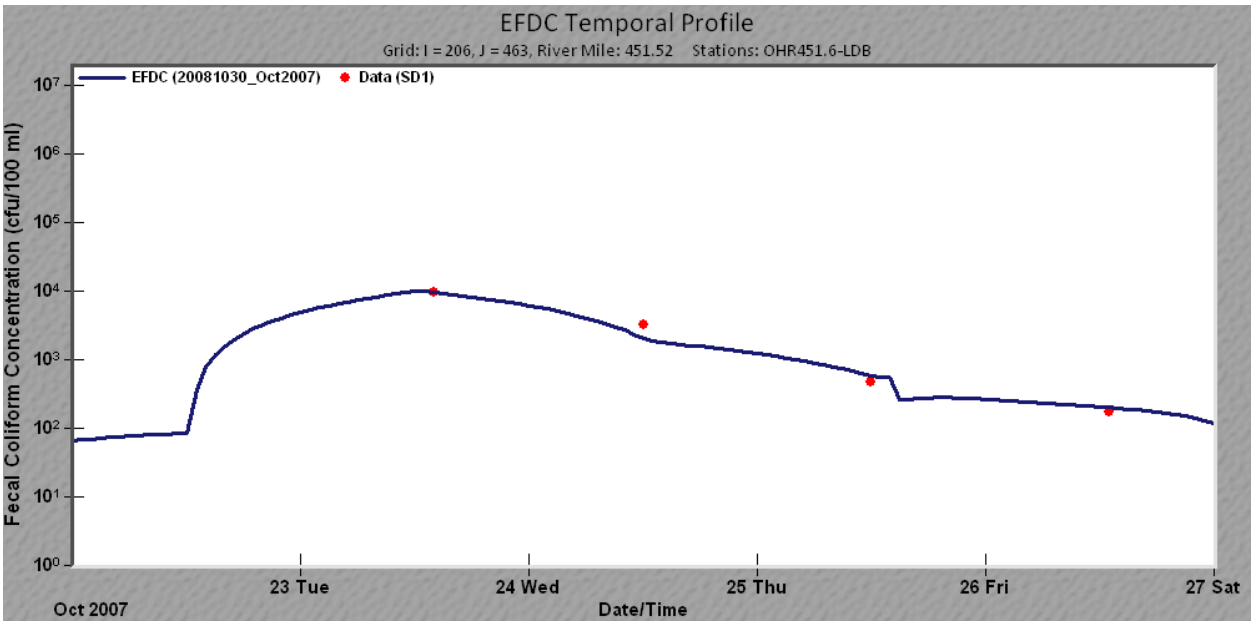
Attachment B. Temporal Profiles of Fecal Coliform in Upper Ohio River During October 2007 Wet Weather Event.

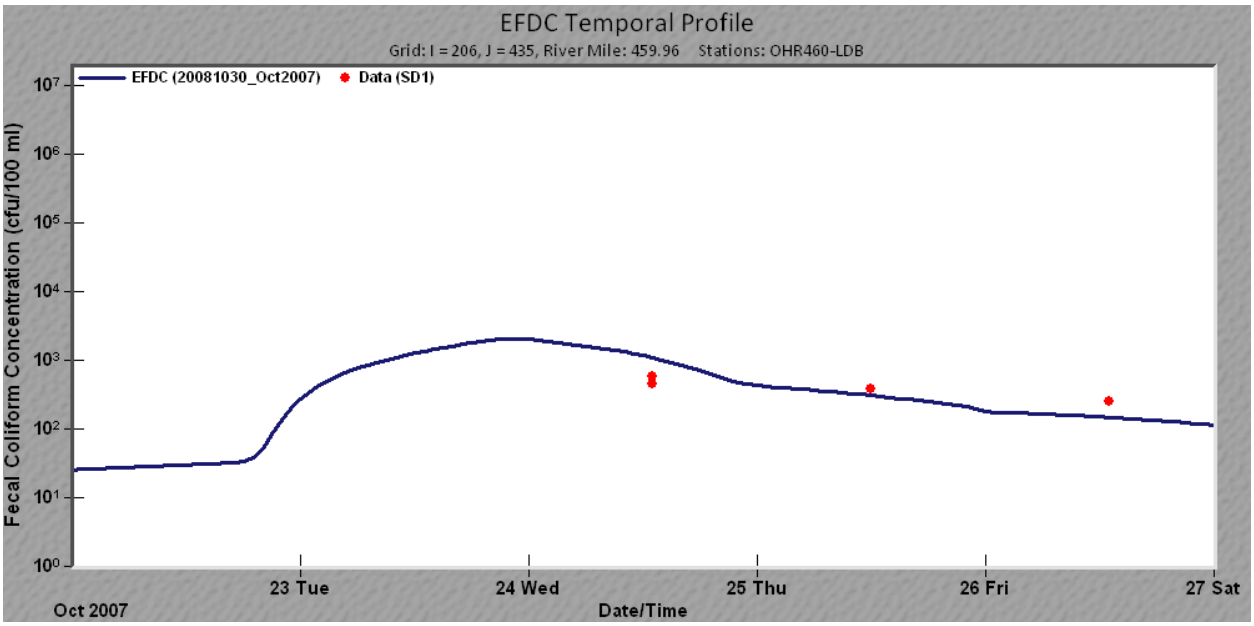
Ohio River –at RM 444 Left Descending Bank- October 2007 Wet Weather Event



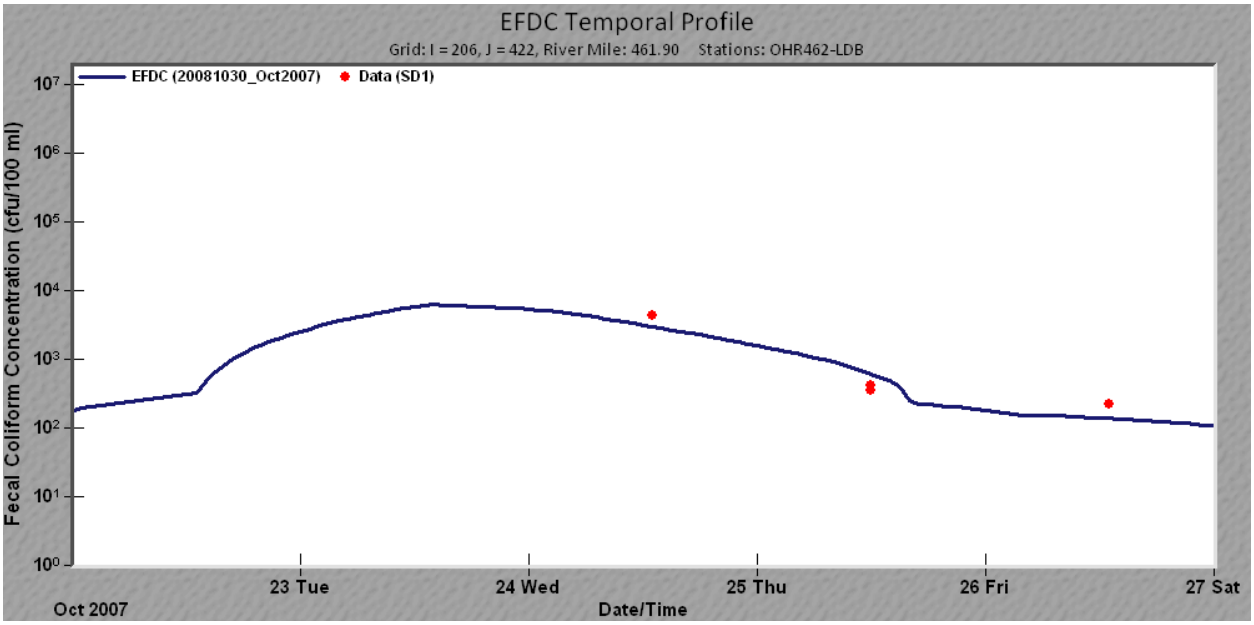
Ohio River –at RM 451.6 Left Descending Bank- October 2007 Wet Weather Event



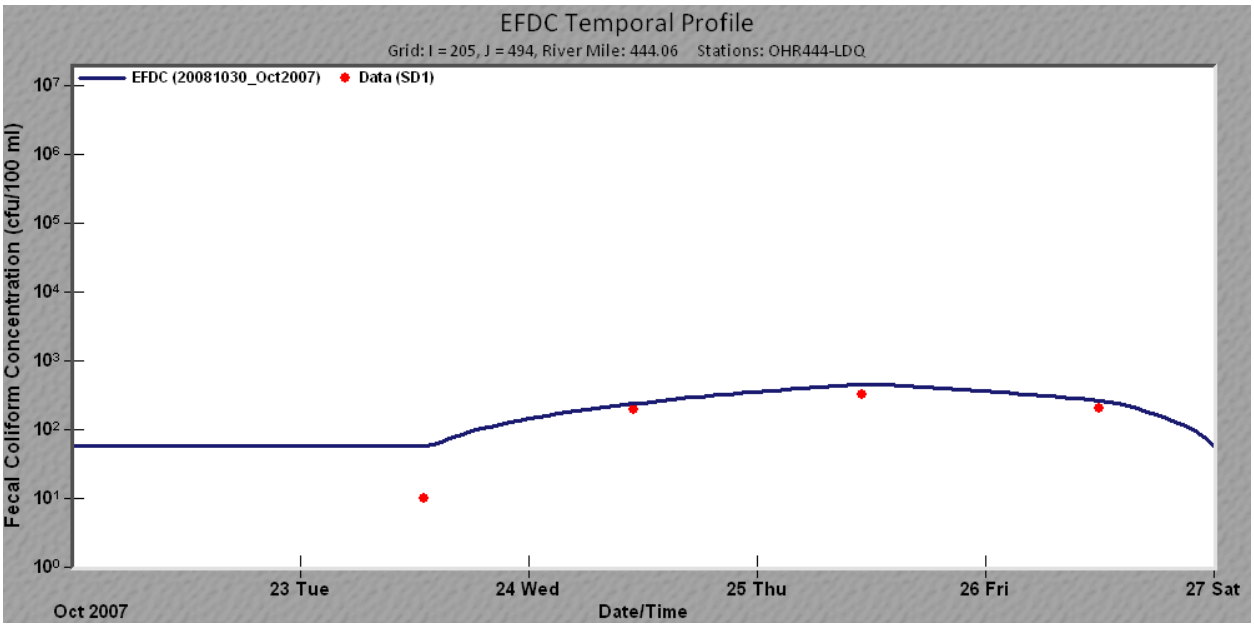
Ohio River –at RM 460 Left Descending Bank- October 2007 Wet Weather Event



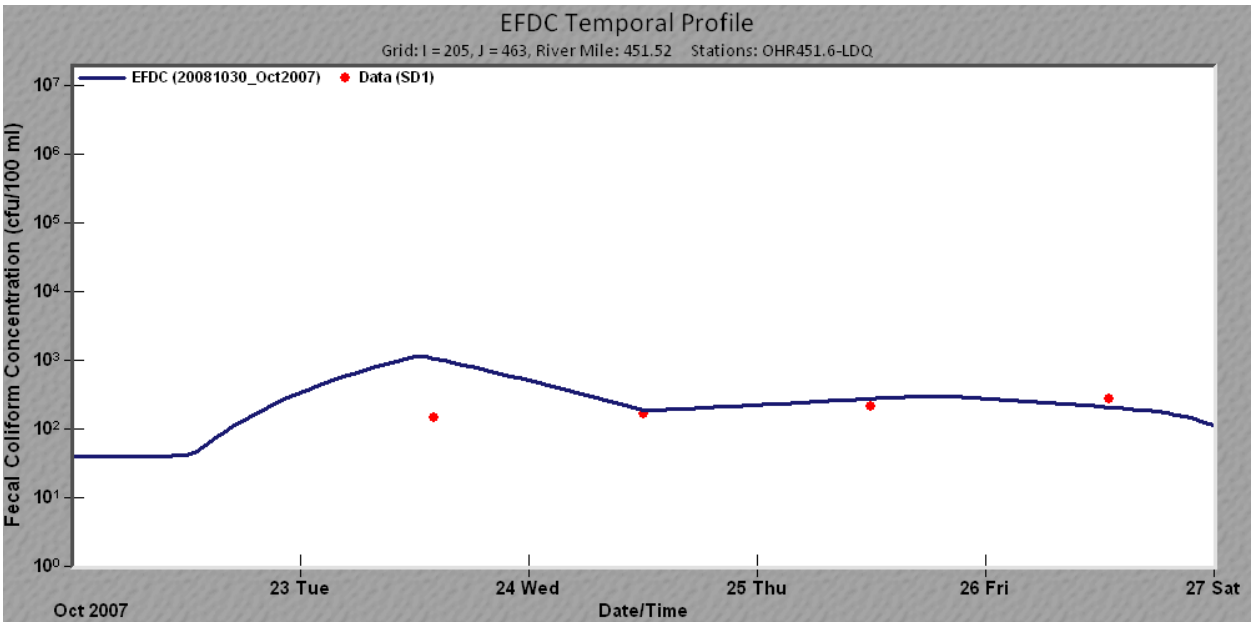
Ohio River –at RM 462 Left Descending Bank- October 2007 Wet Weather Event



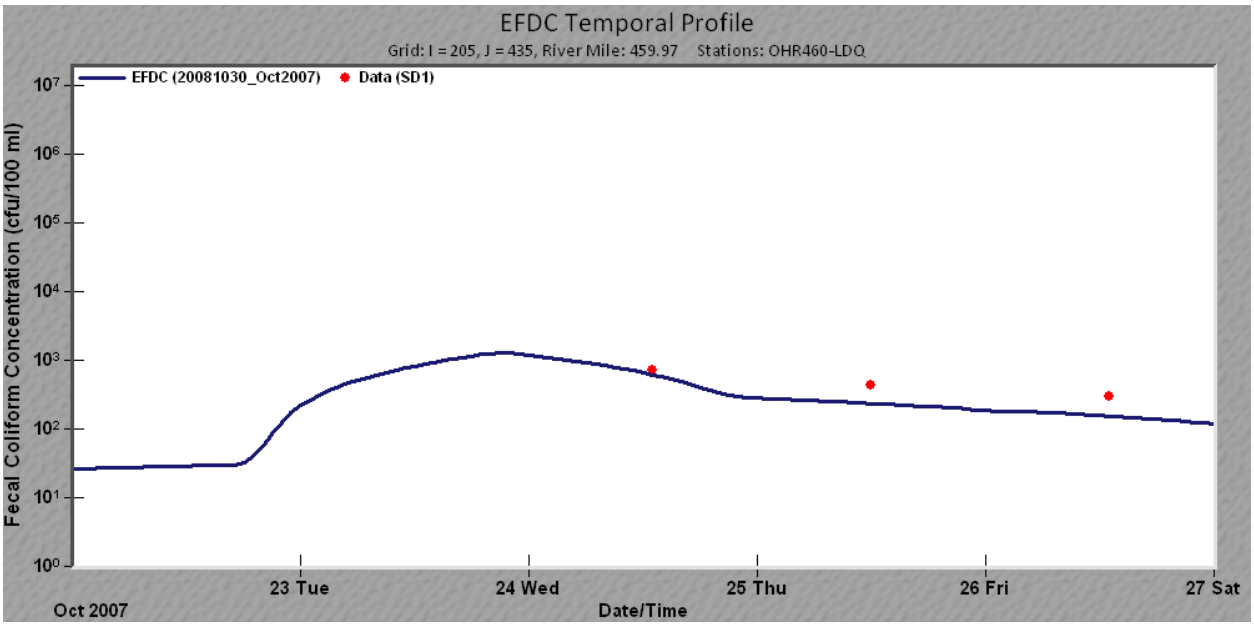
Ohio River –at RM 444 Left Descending Quarter- October 2007 Wet Weather Event



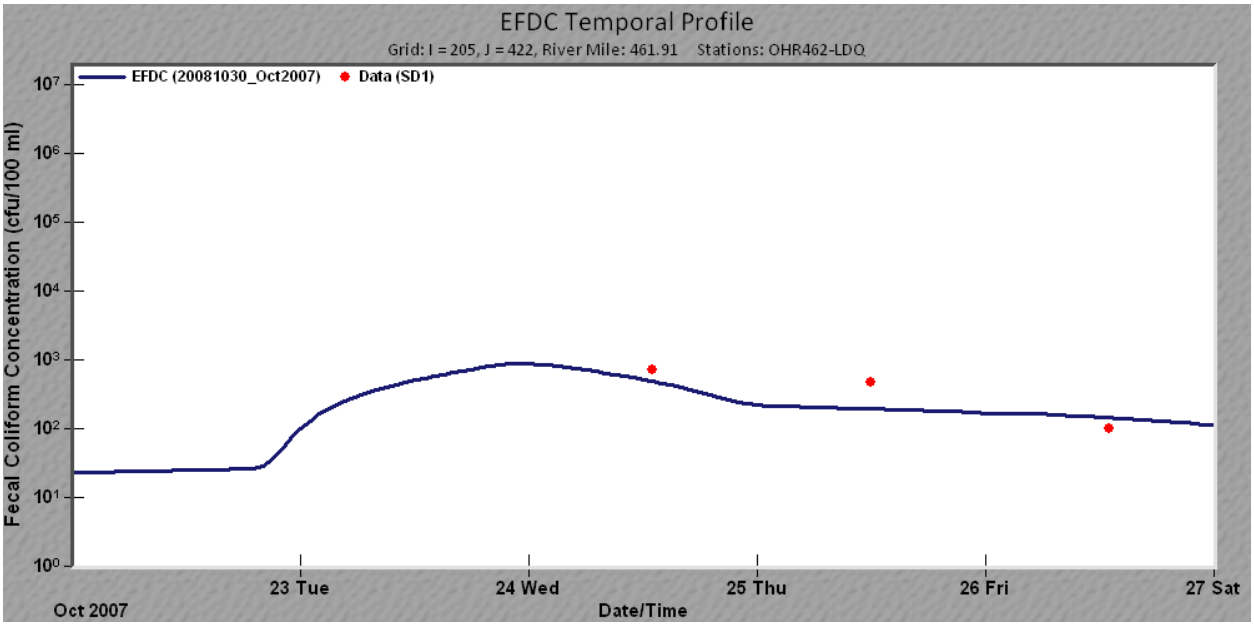
Ohio River –at RM 451.6 Left Descending Quarter- October 2007 Wet Weather Event



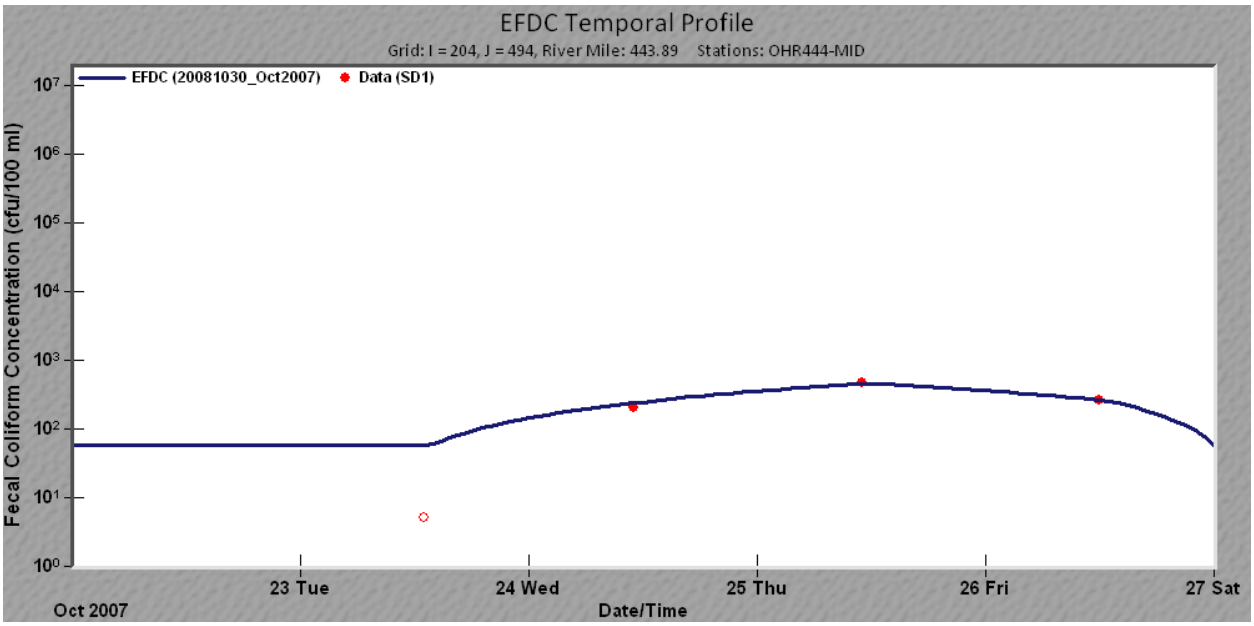
Ohio River –at RM 460 Left Descending Quarter- October 2007 Wet Weather Event



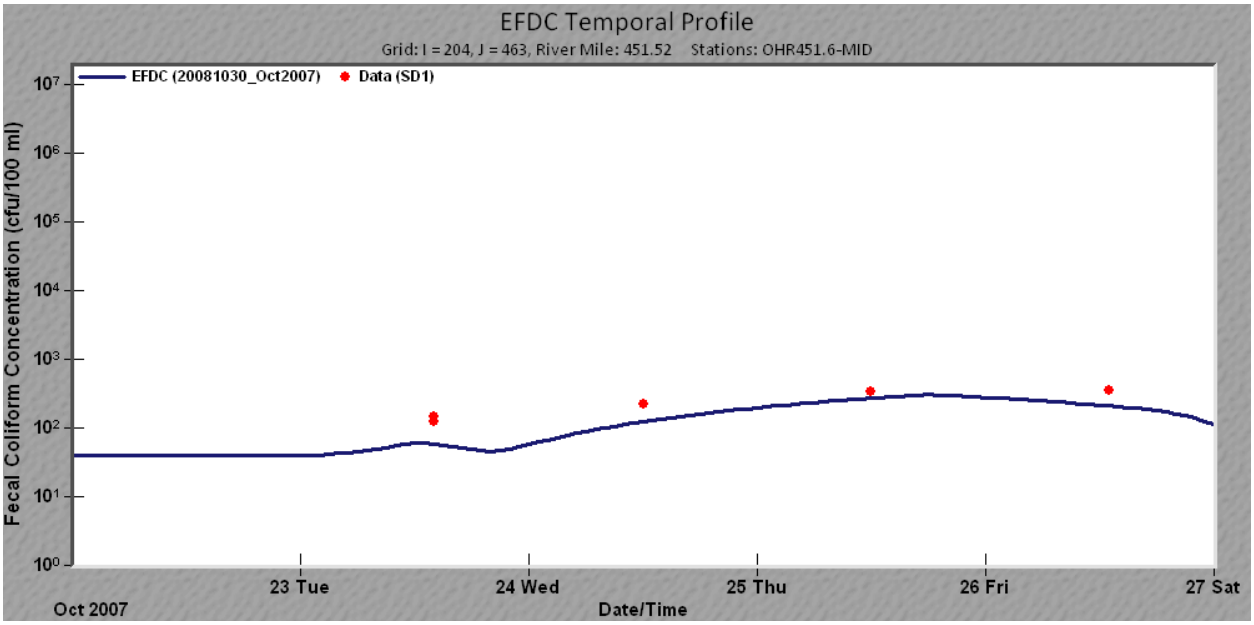
Ohio River –at RM 462 Left Descending Quarter- October 2007 Wet Weather Event



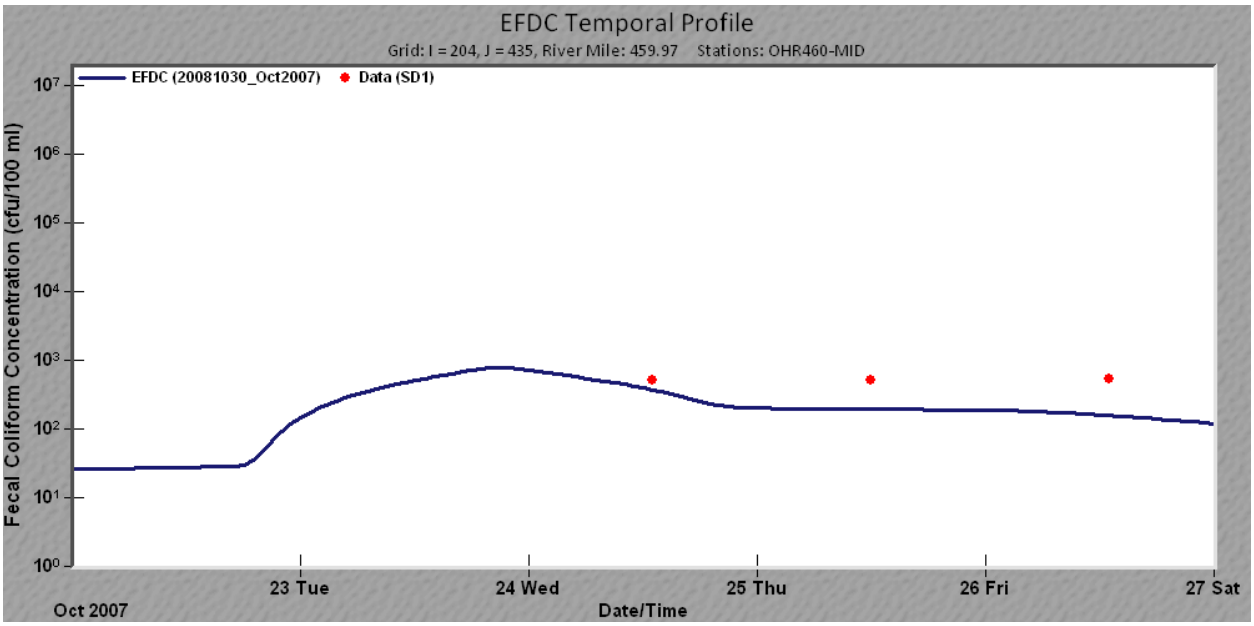
Ohio River –at RM 444 Mid-Channel- October 2007 Wet Weather Event



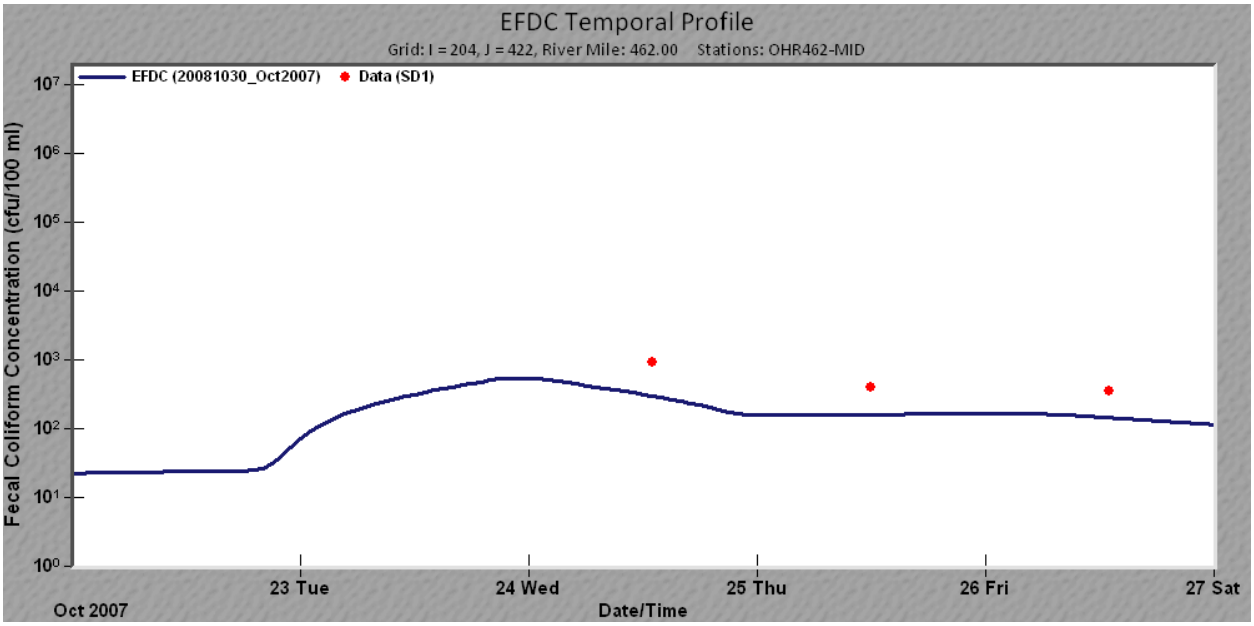
Ohio River –at RM 451.6 Mid-Channel- October 2007 Wet Weather Event



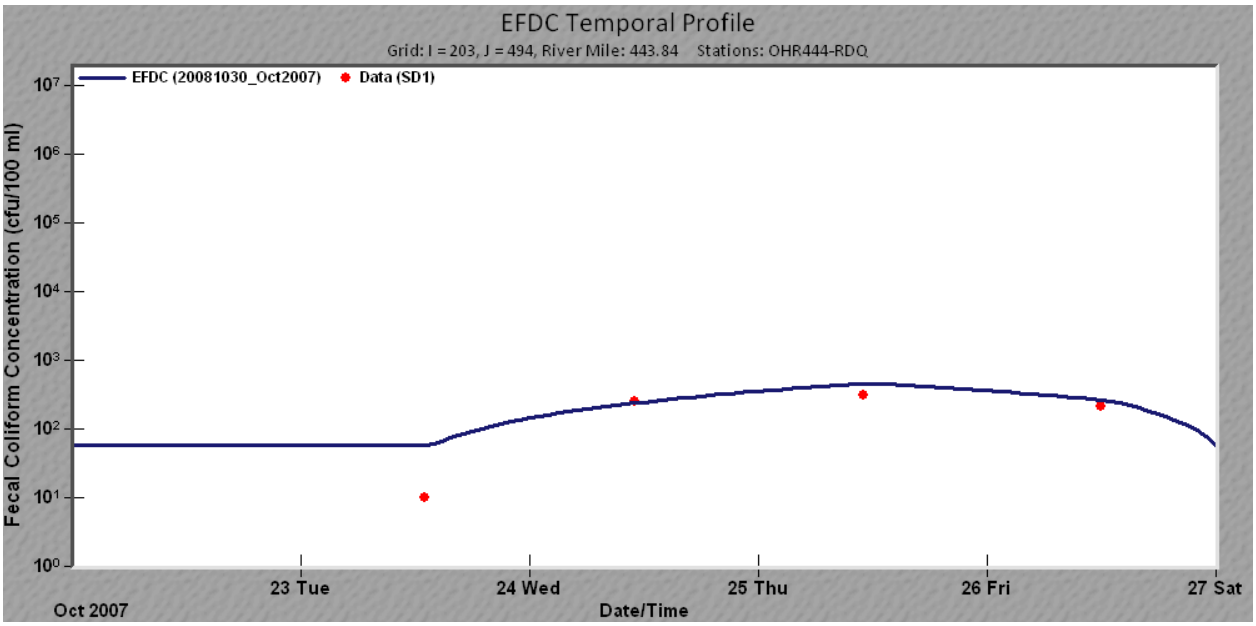
Ohio River –at RM 460 Mid-Channel- October 2007 Wet Weather Event



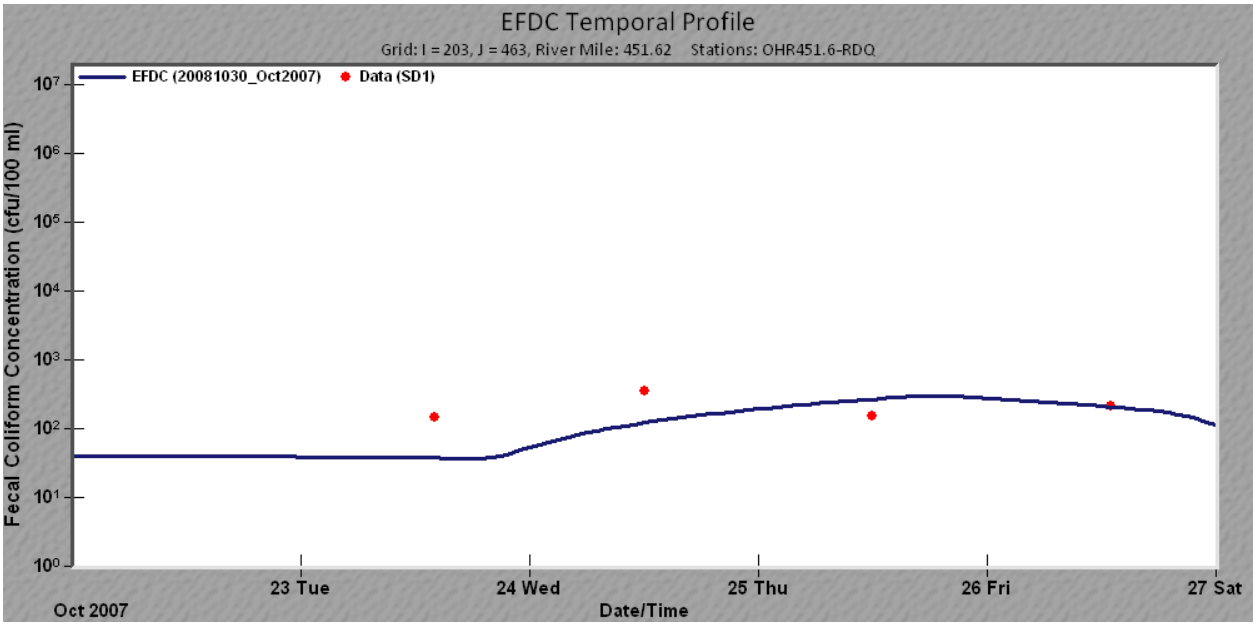
Ohio River –at RM 462 Mid-Channel- October 2007 Wet Weather Event



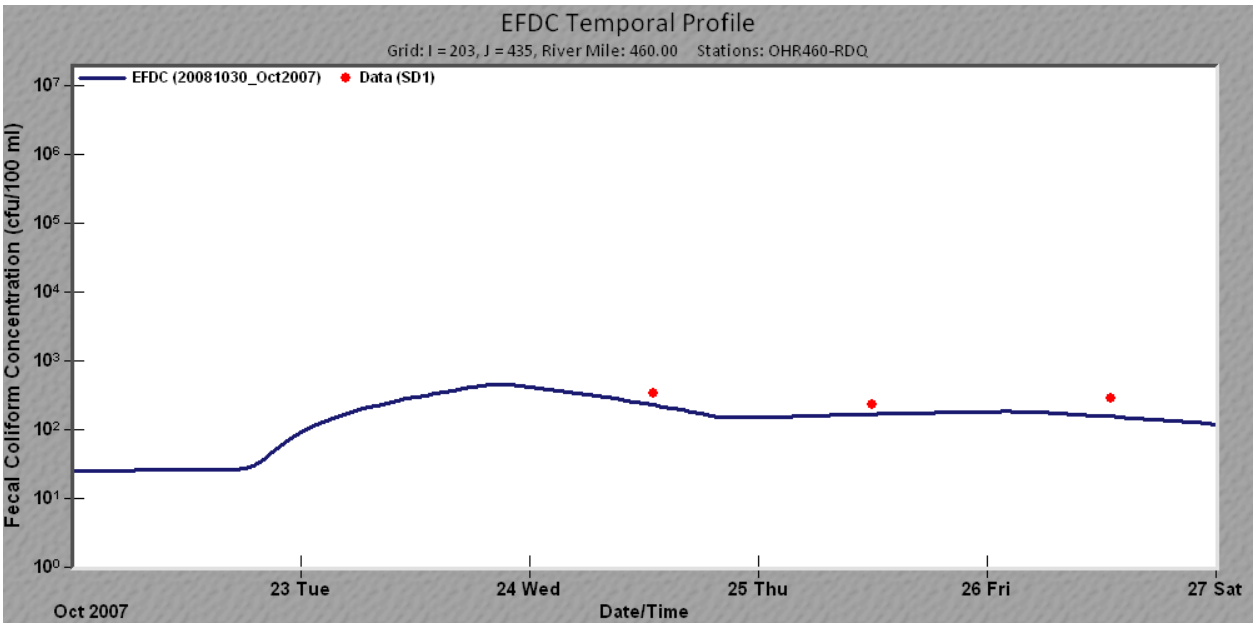
Ohio River –at RM 444 Right Descending Quarter- October 2007 Wet Weather Event



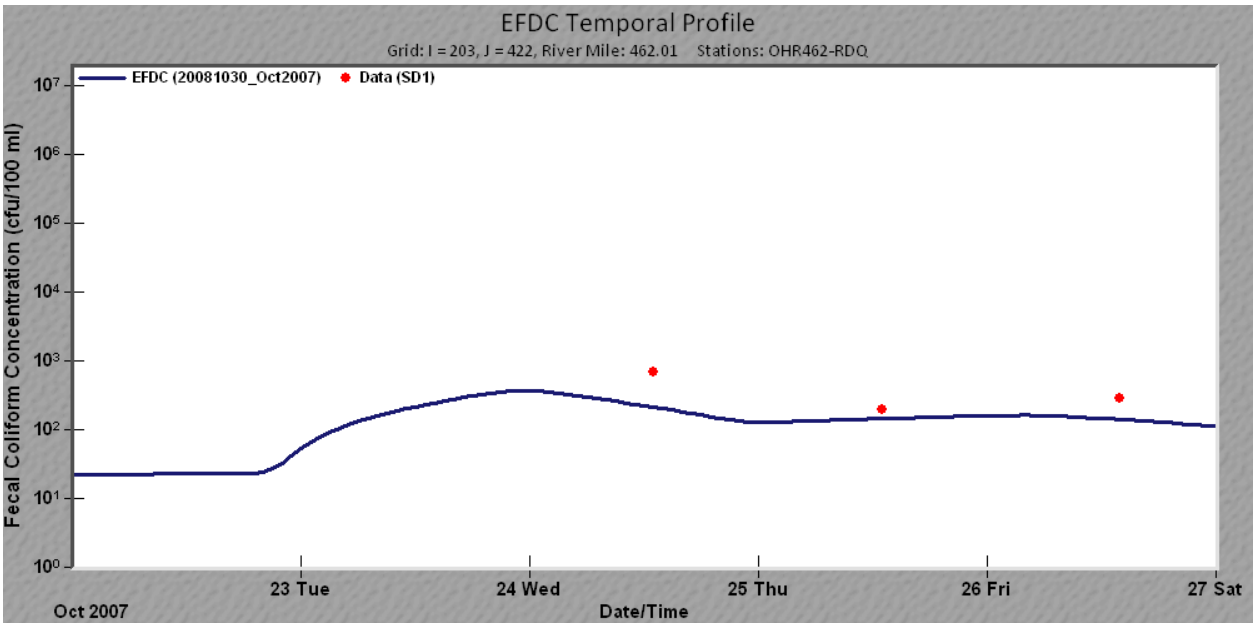
Ohio River –at RM 451.6 Right Descending Quarter- October 2007 Wet Weather Event



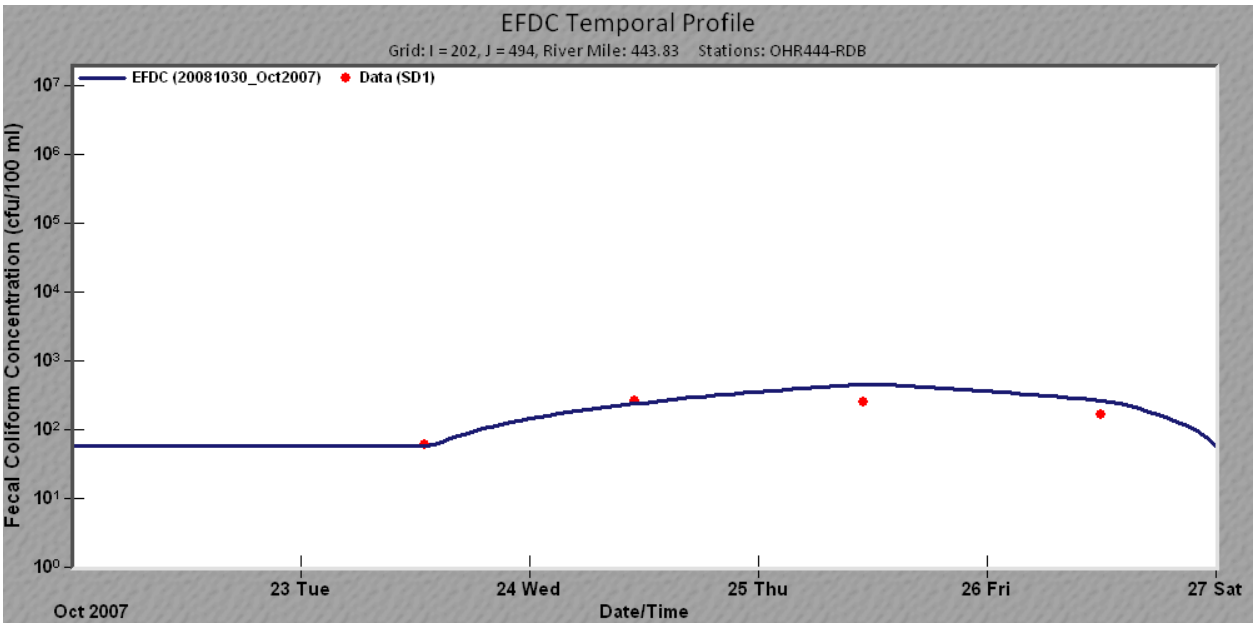
Ohio River –at RM 460 Right Descending Quarter- October 2007 Wet Weather Event



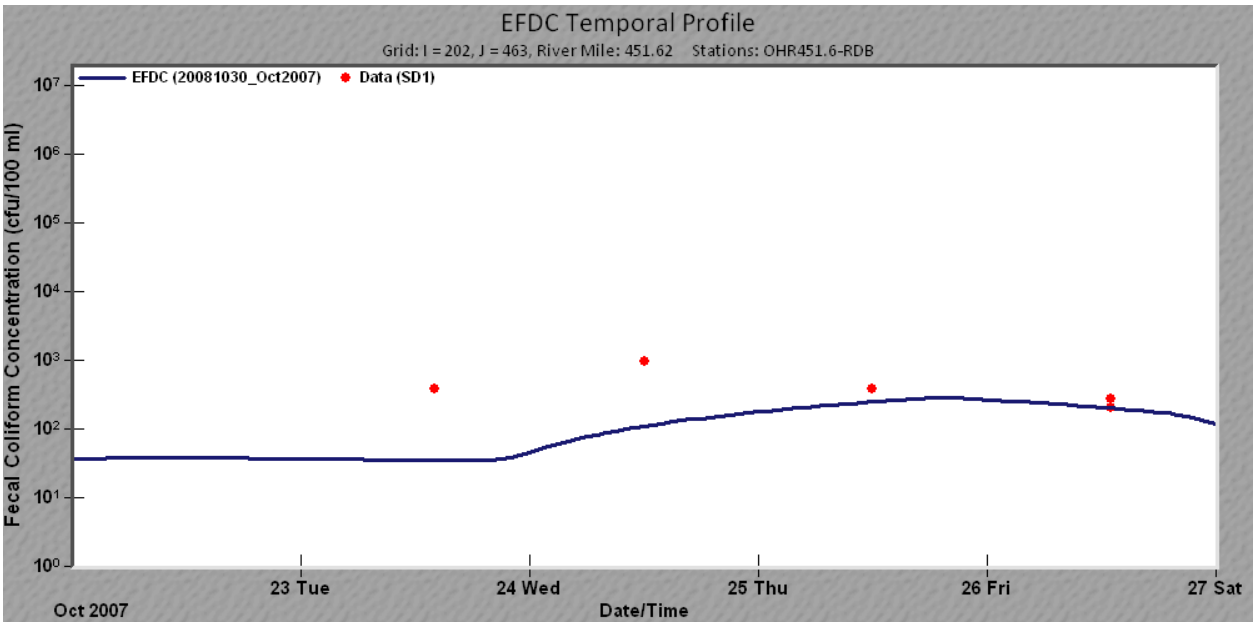
Ohio River –at RM 462 Right Descending Quarter- October 2007 Wet Weather Event



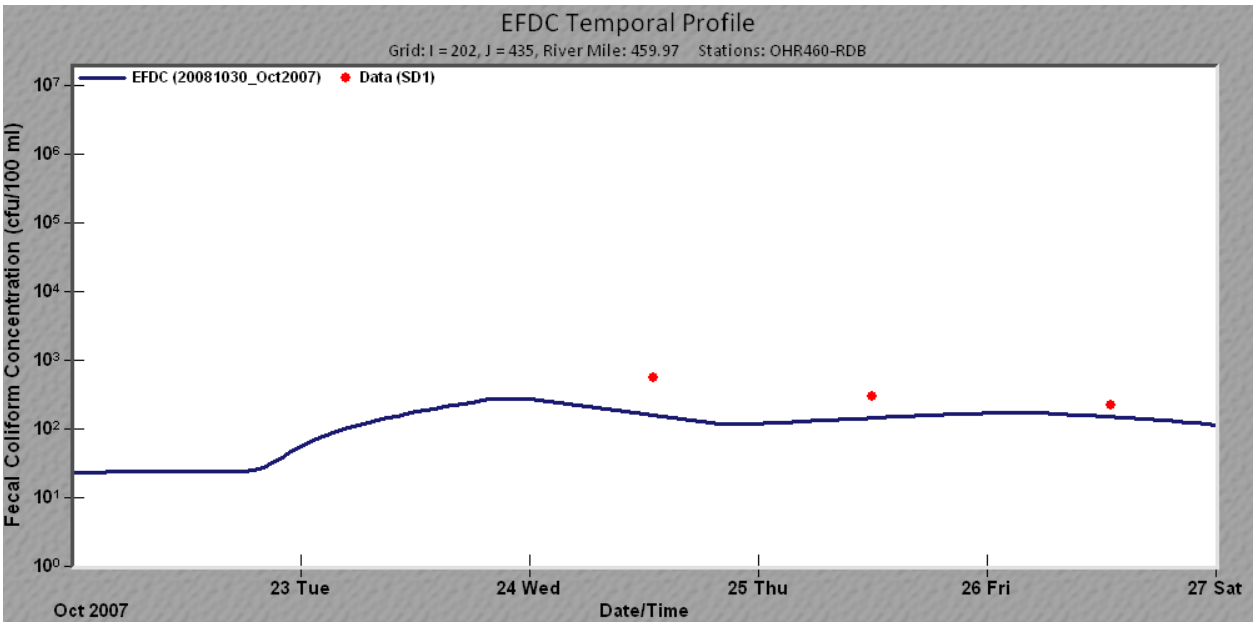
Ohio River –at RM 444 Right Descending Bank- October 2007 Wet Weather Event



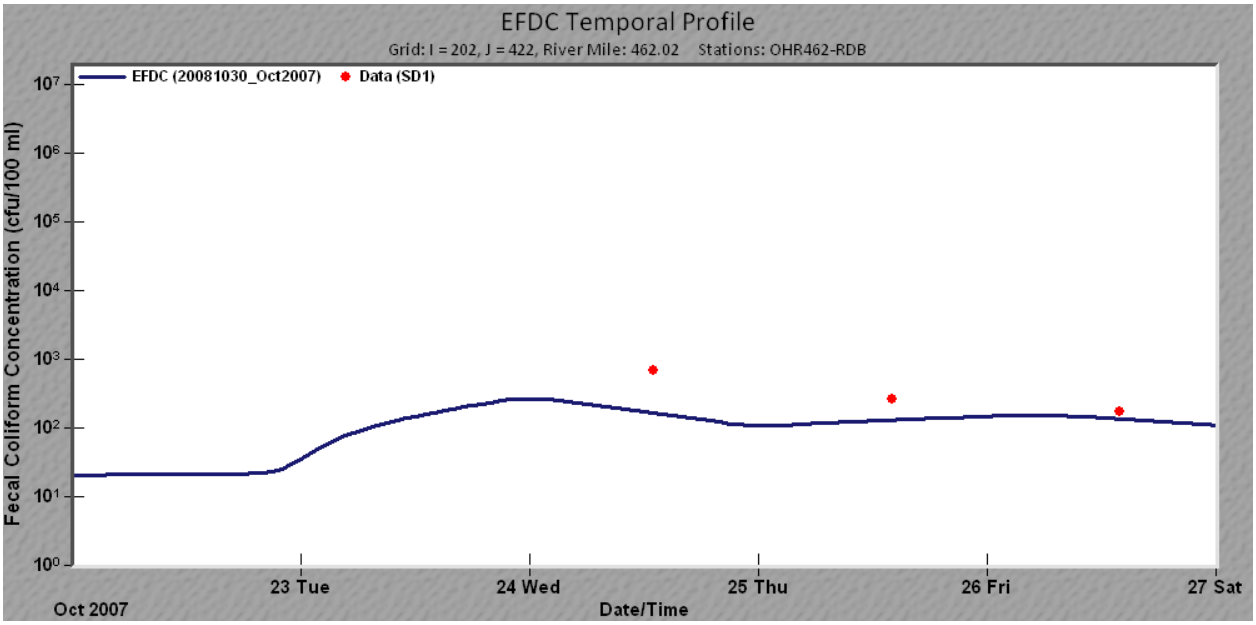
Ohio River –at RM 451.6 Right Descending Bank- October 2007 Wet Weather Event



Ohio River –at RM 460 Right Descending Bank- October 2007 Wet Weather Event



Ohio River –at RM 462 Right Descending Bank- October 2007 Wet Weather Event



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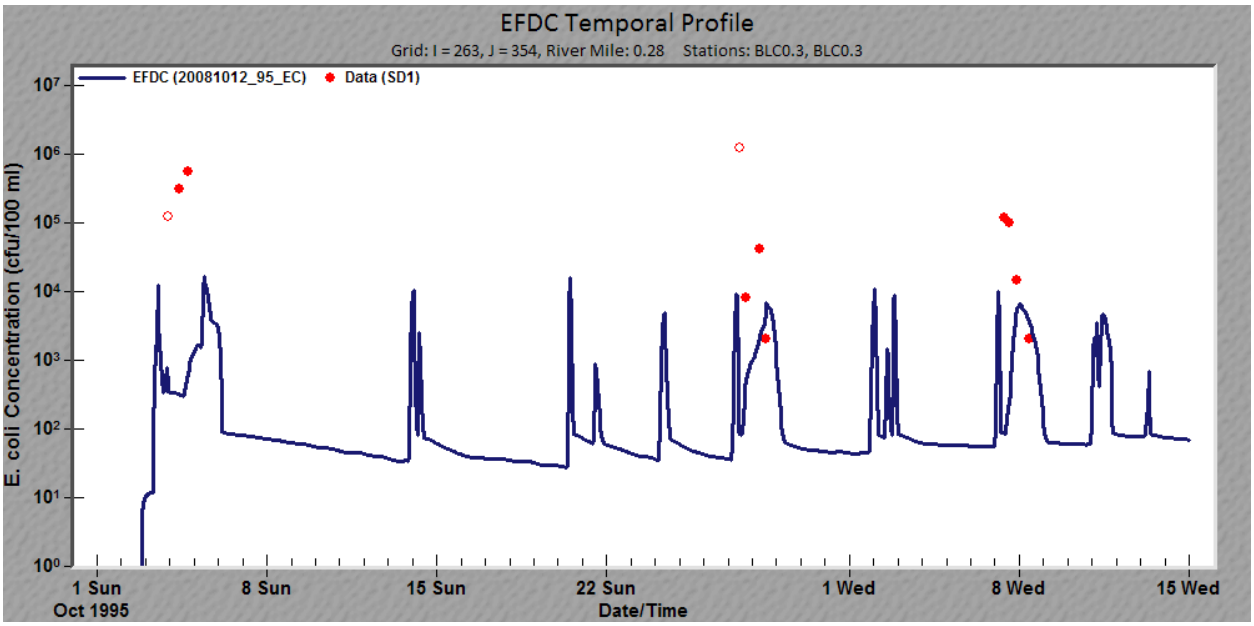
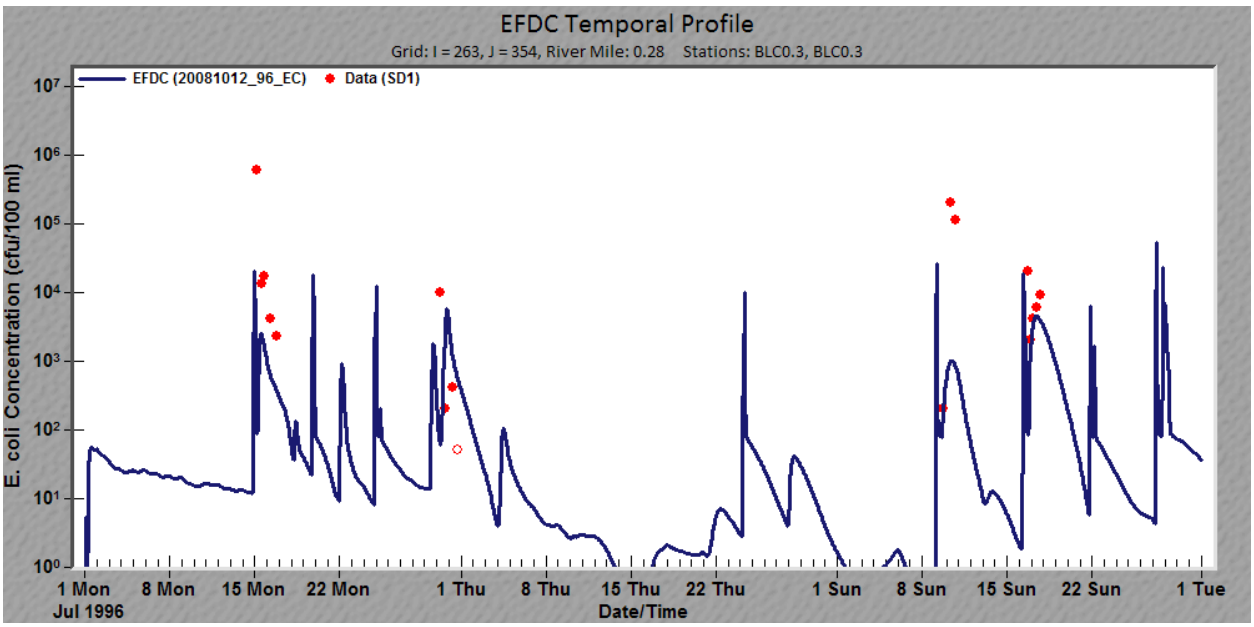
Attachment C. Temporal Profiles of *E. coli* in Licking River and Banklick Creek During 1995-96 Wet Weather Events.

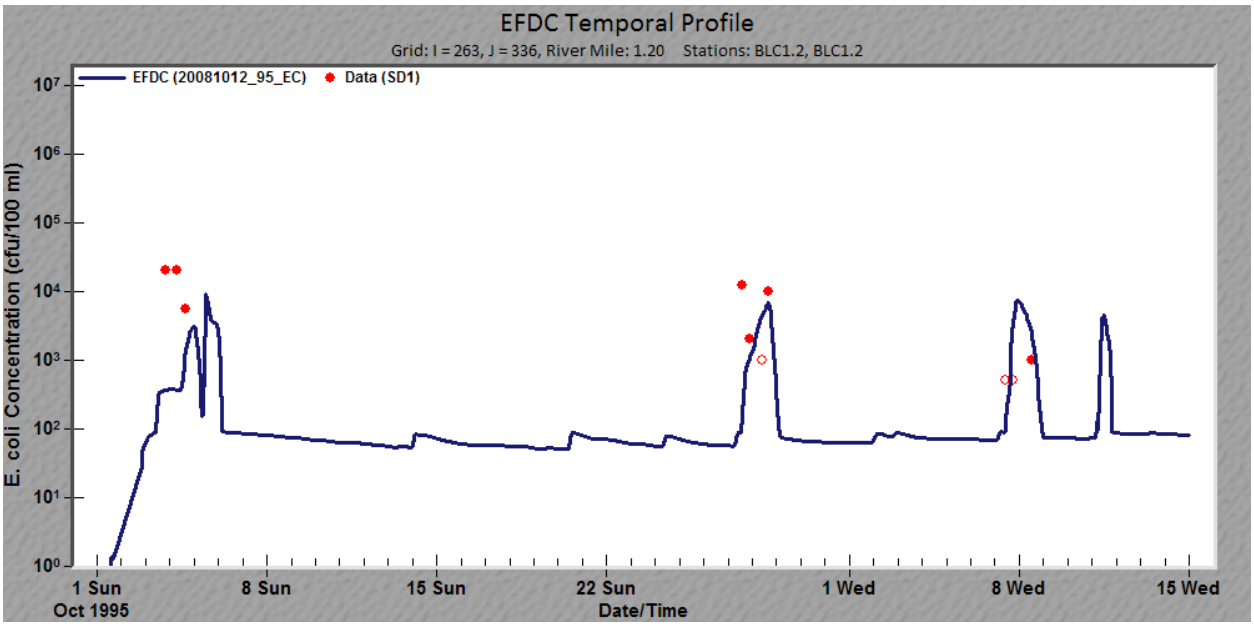
Banklick Creek at River Mile 0.3 (Decoursey Ave)-1995 Wet Weather Events.



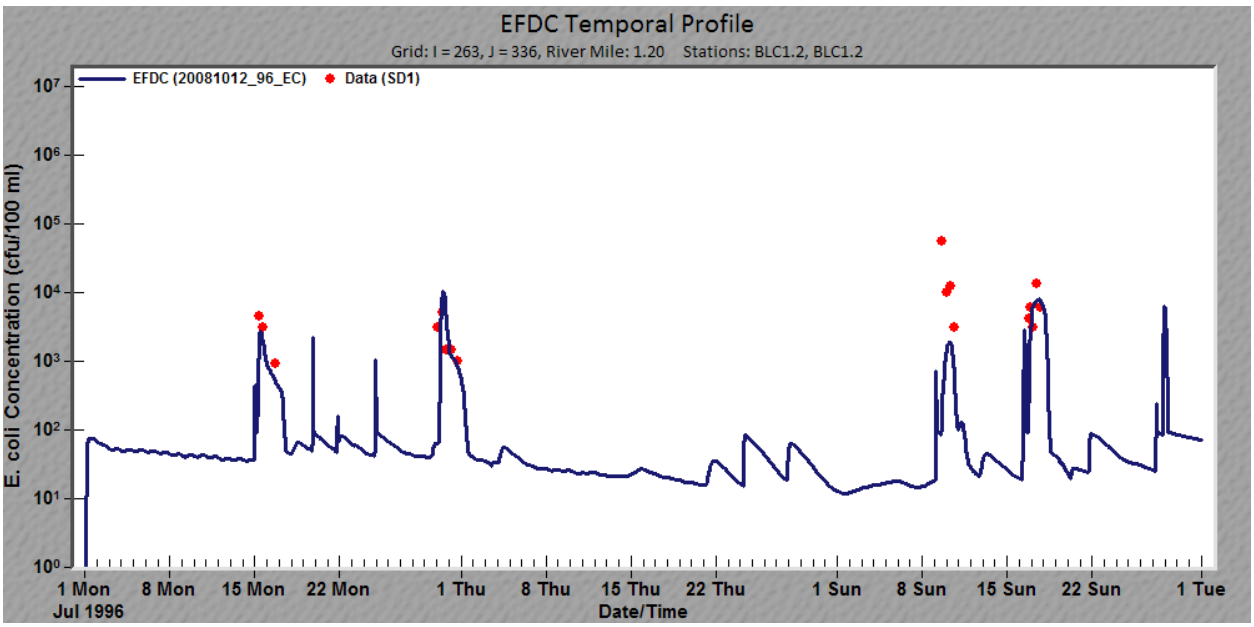
Banklick Creek at River Mile 0.3 (Decoursey Ave)-1996 Wet Weather Events.



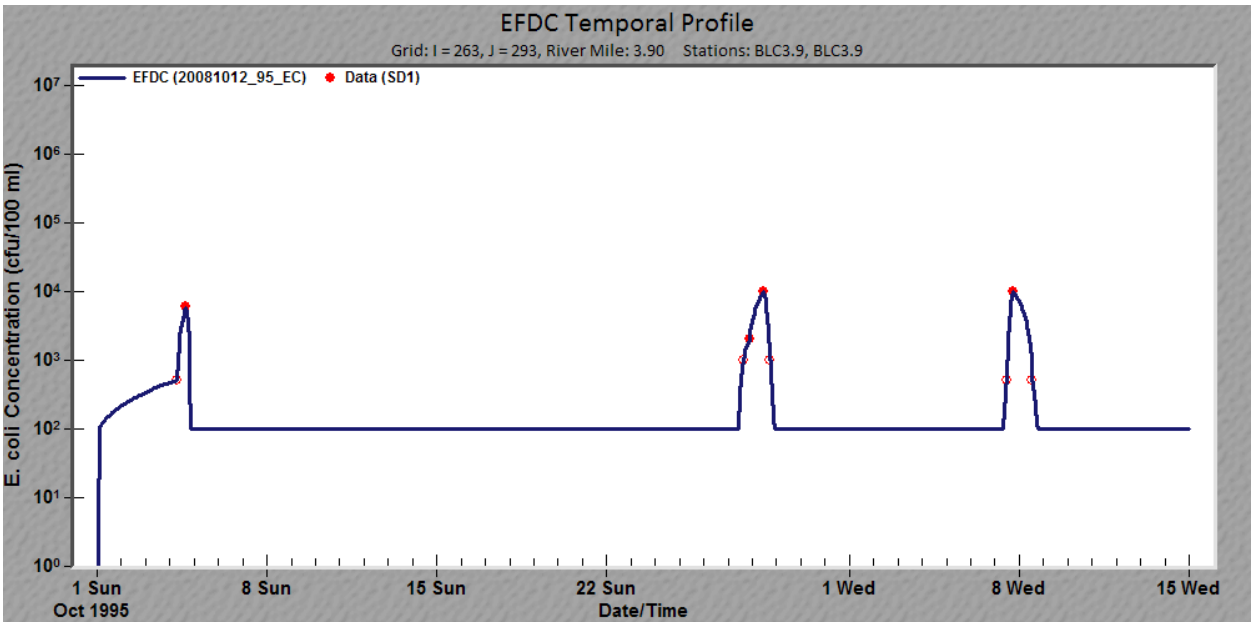
Banklick Creek at River Mile 1.2 (Winston Ave)-1995 Wet Weather Events.



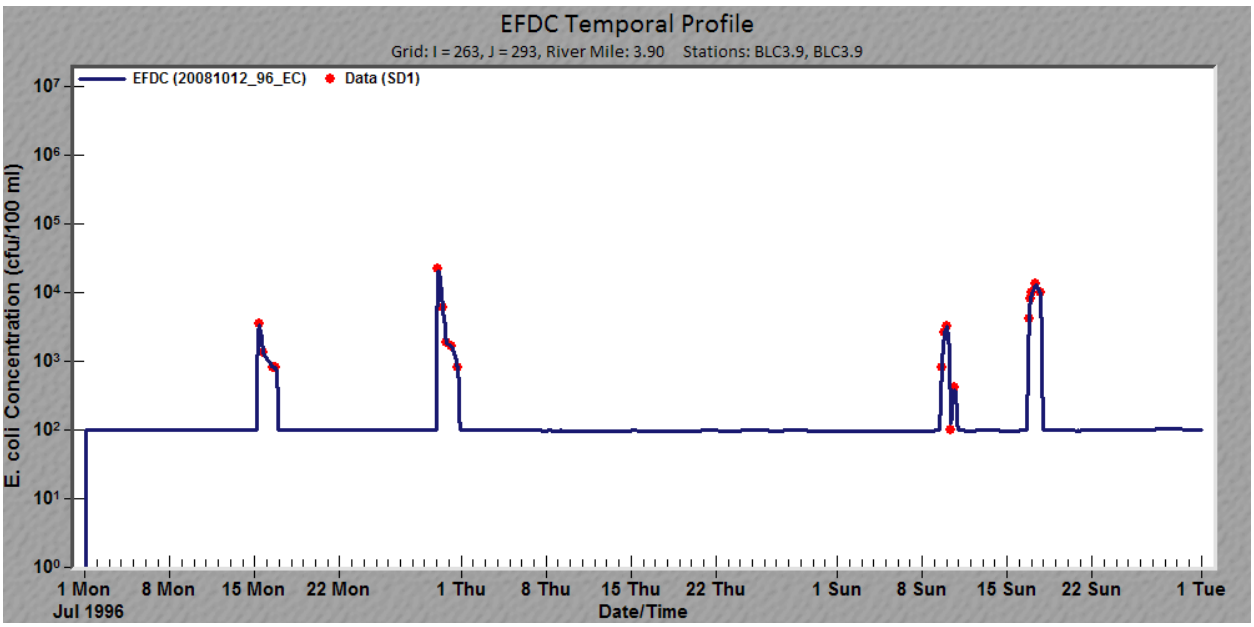
Banklick Creek at River Mile 1.2 (Winston Ave)-1996 Wet Weather Events.



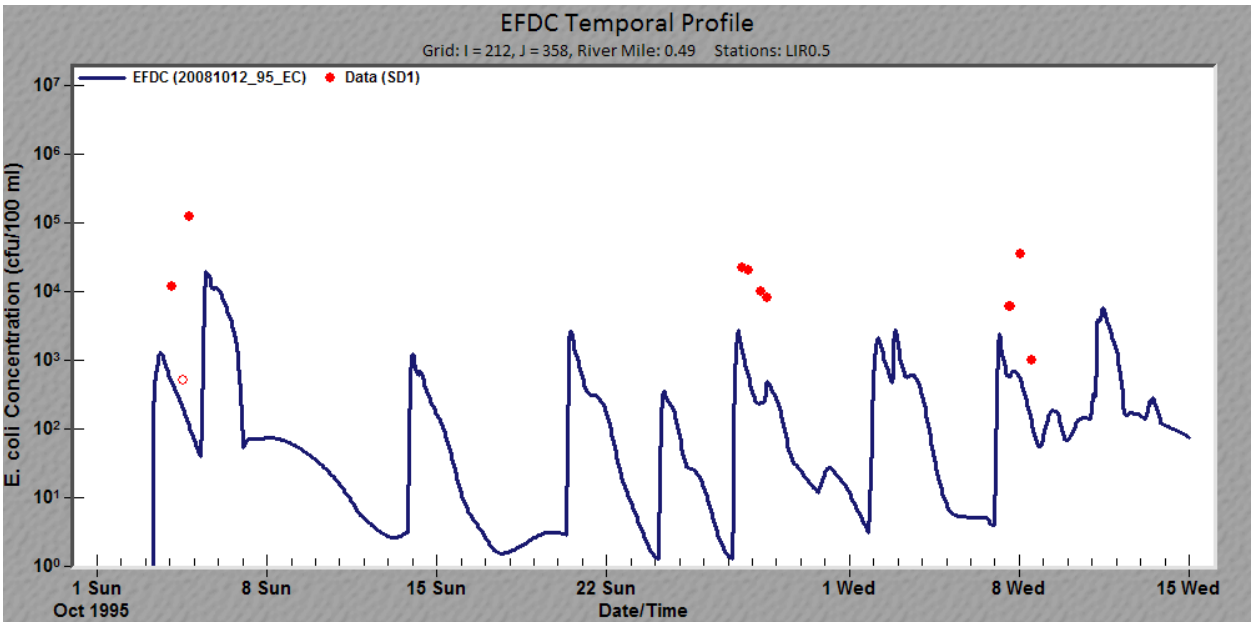
Banklick Creek at River Mile 3.9 (Eaton Dr.)-1995 Wet Weather Events.



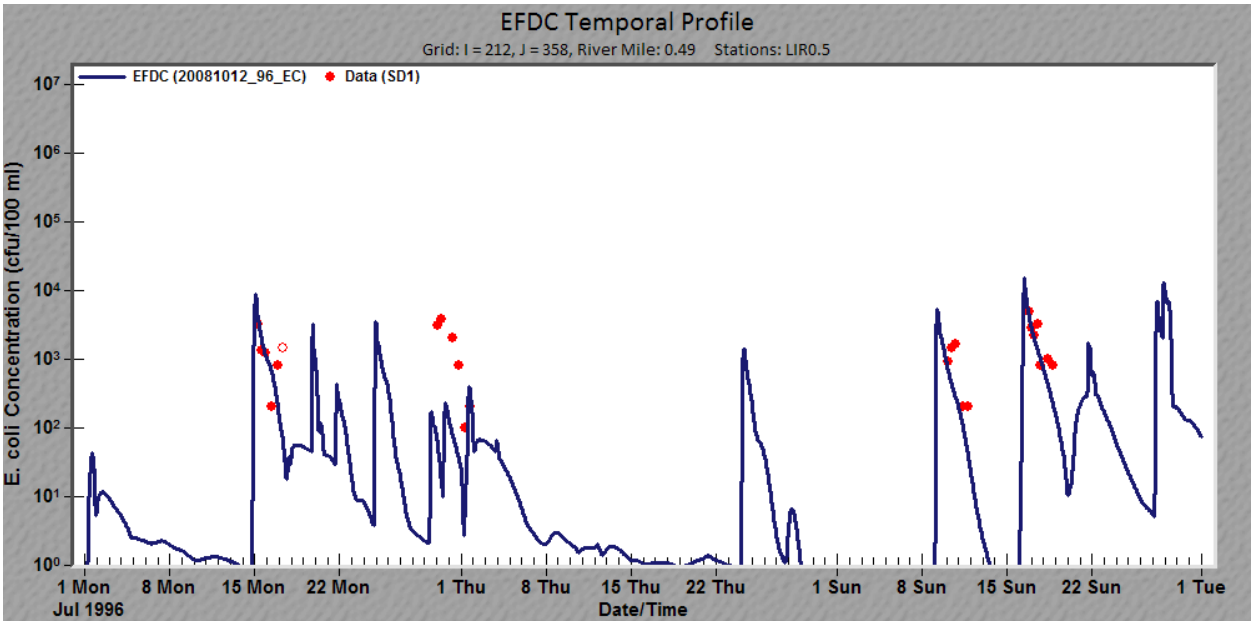
Banklick Creek at River Mile 3.9 (Eaton Dr.)-1996 Wet Weather Events.



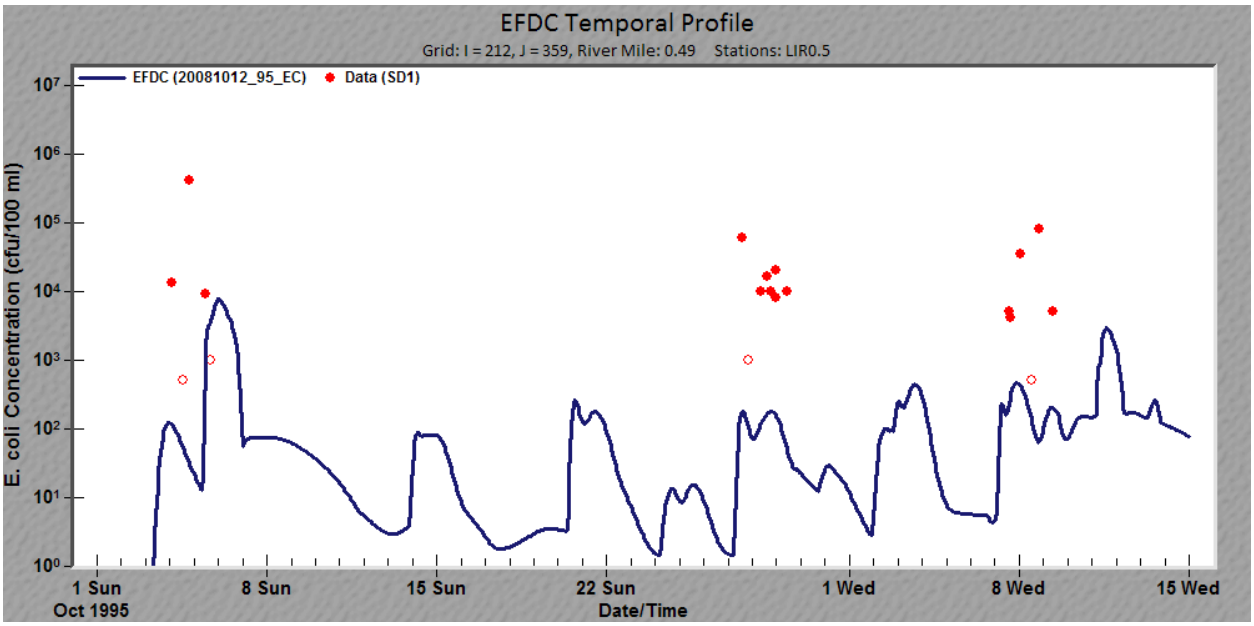
Licking River Left Descending Bank at River Mile 0.5-1995 Wet Weather Events



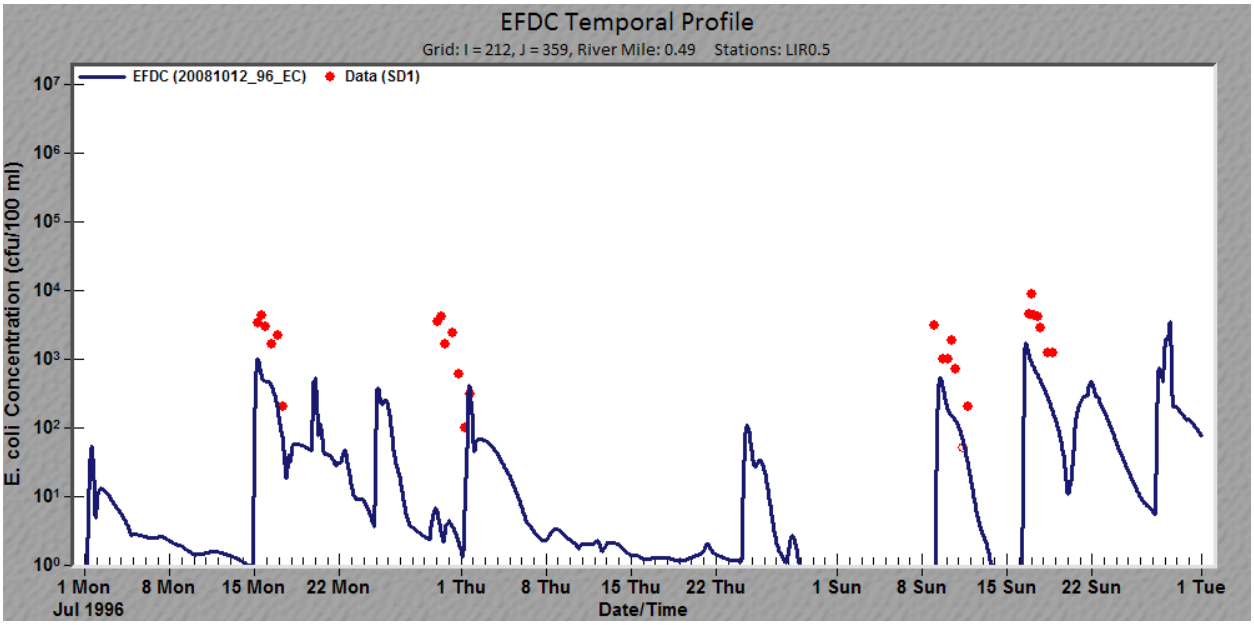
Licking River Left Descending Bank at River Mile 0.5-1996 Wet Weather Events



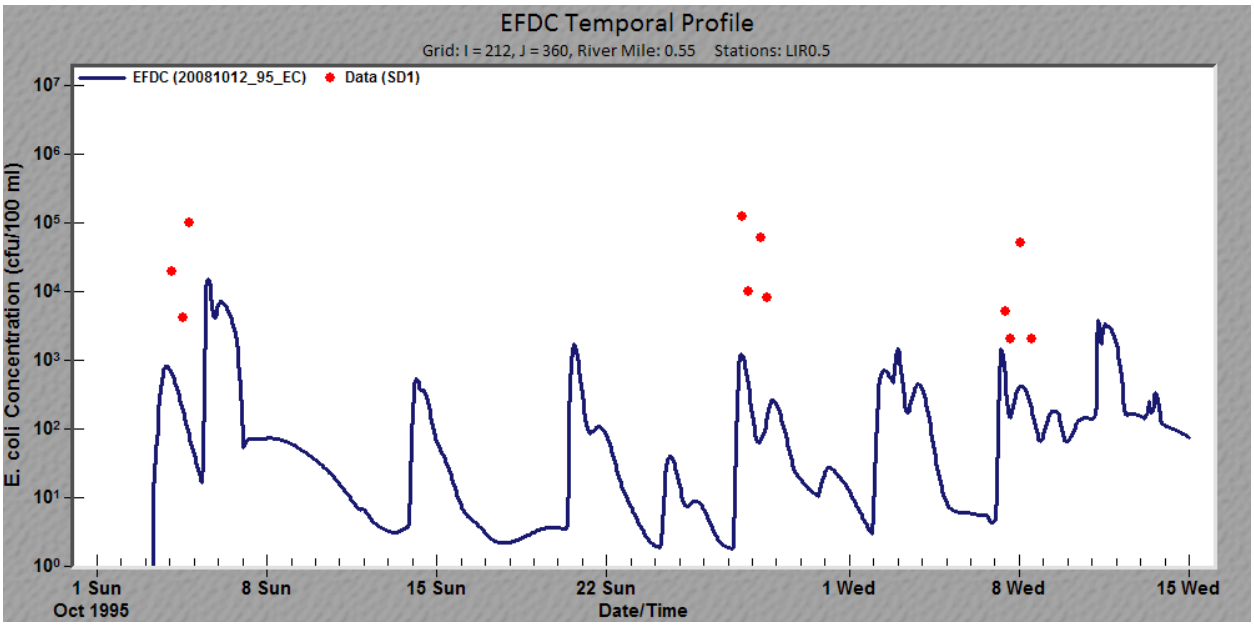
Licking River Mid-Channel at River Mile 0.5-1995 Wet Weather Events.



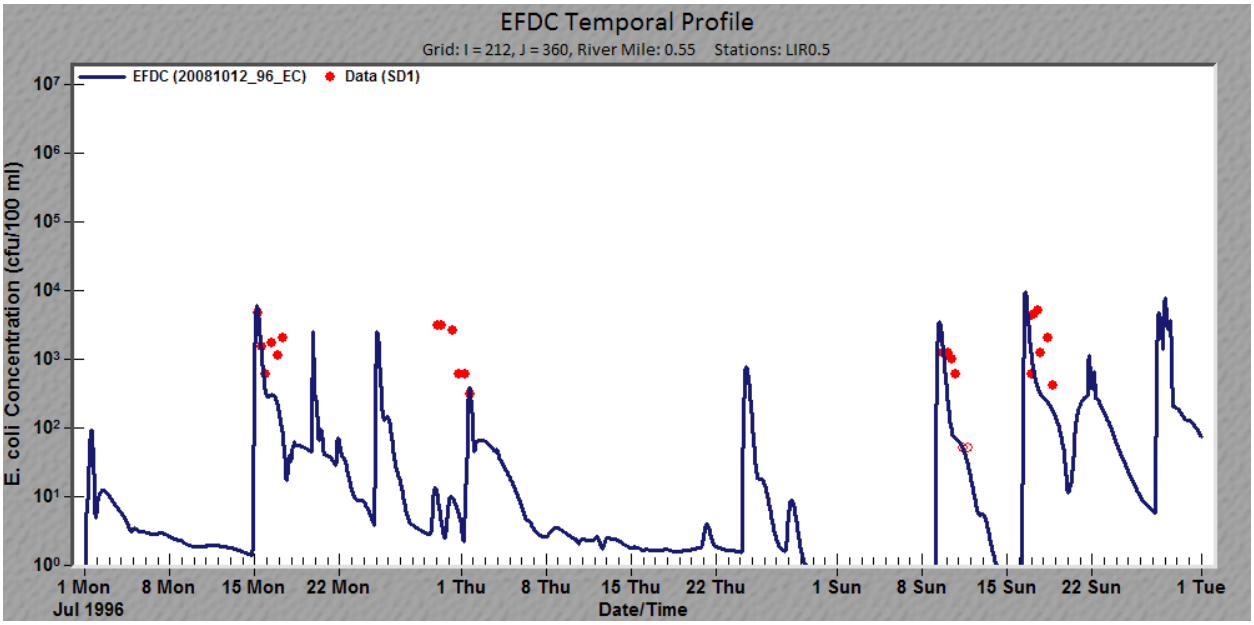
Licking River Mid-Channel at River Mile 0.5-1996 Wet Weather Events.



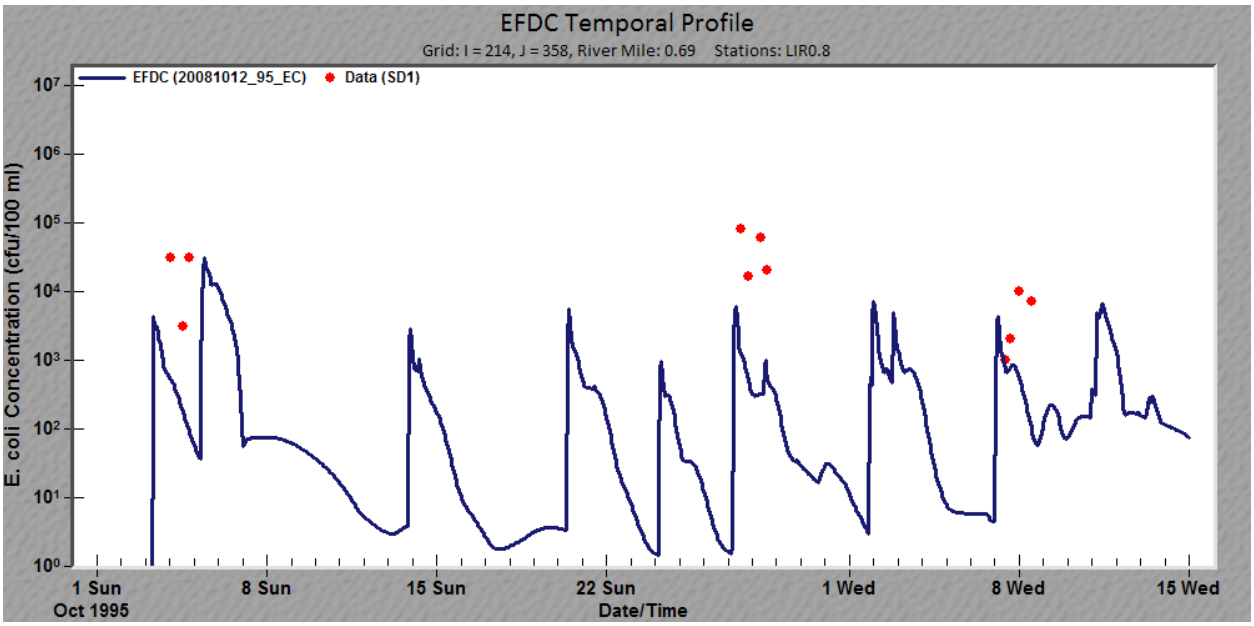
Licking River Right Descending Bank at River Mile 0.5-1995 Wet Weather Events.



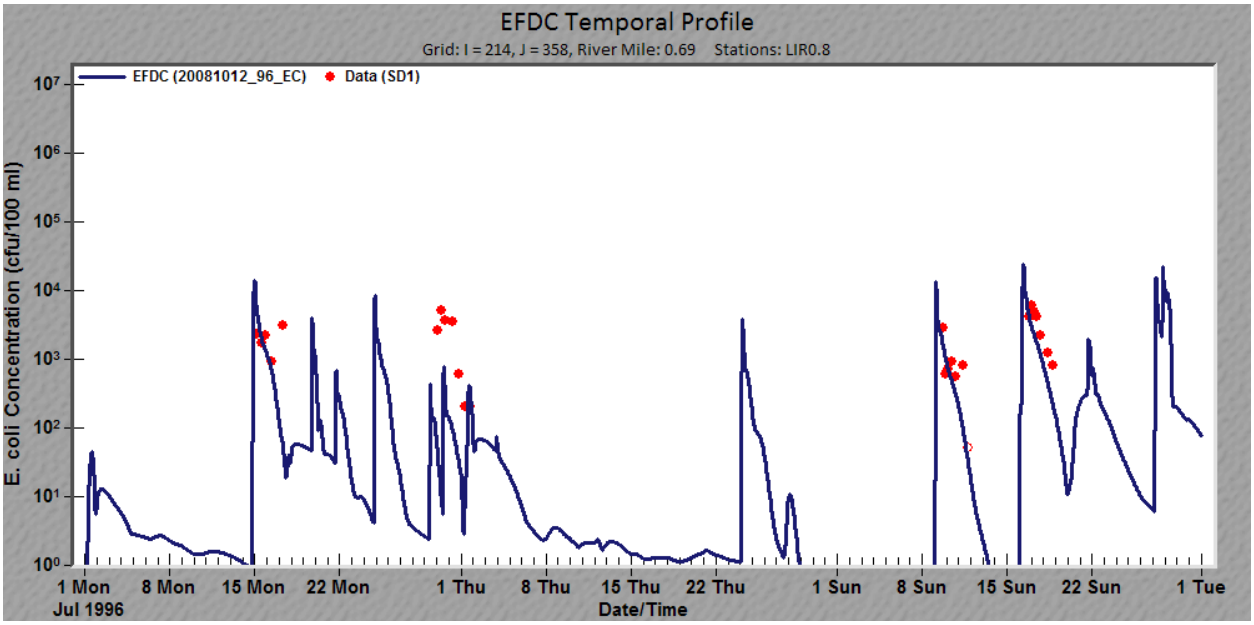
Licking River Right Descending Bank at River Mile 0.5-1996 Wet Weather Events.



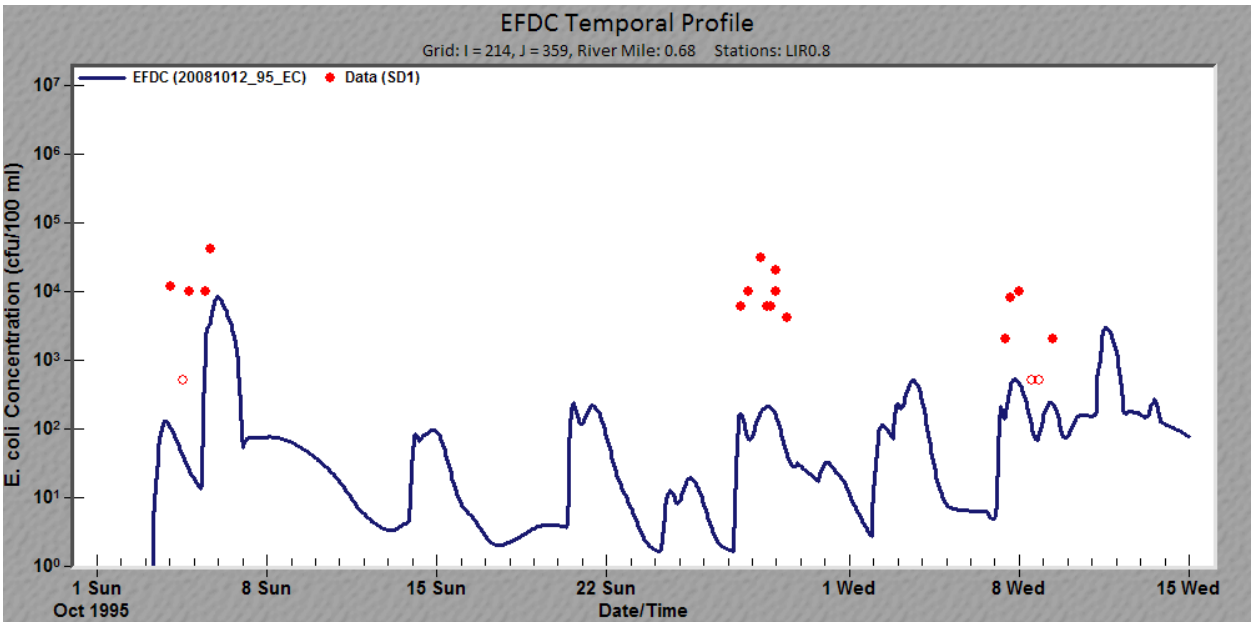
Licking River Left Descending Bank at River Mile 0.8-1995 Wet Weather Events.



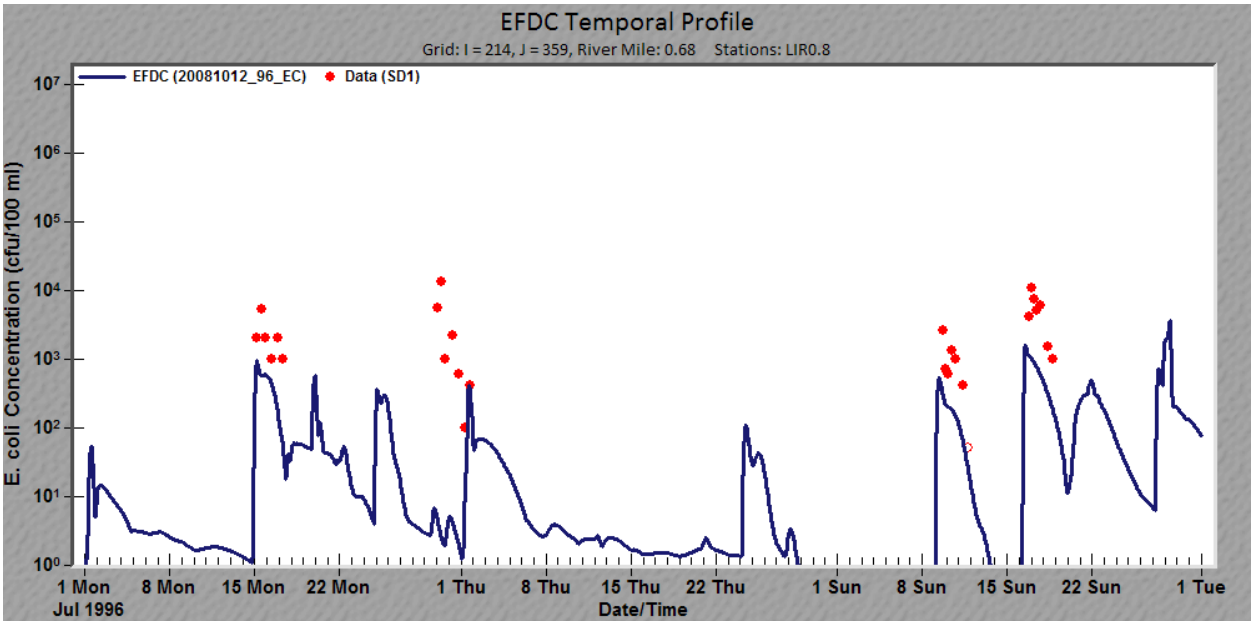
Licking River Left Descending Bank at River Mile 0.8-1996 Wet Weather Events.



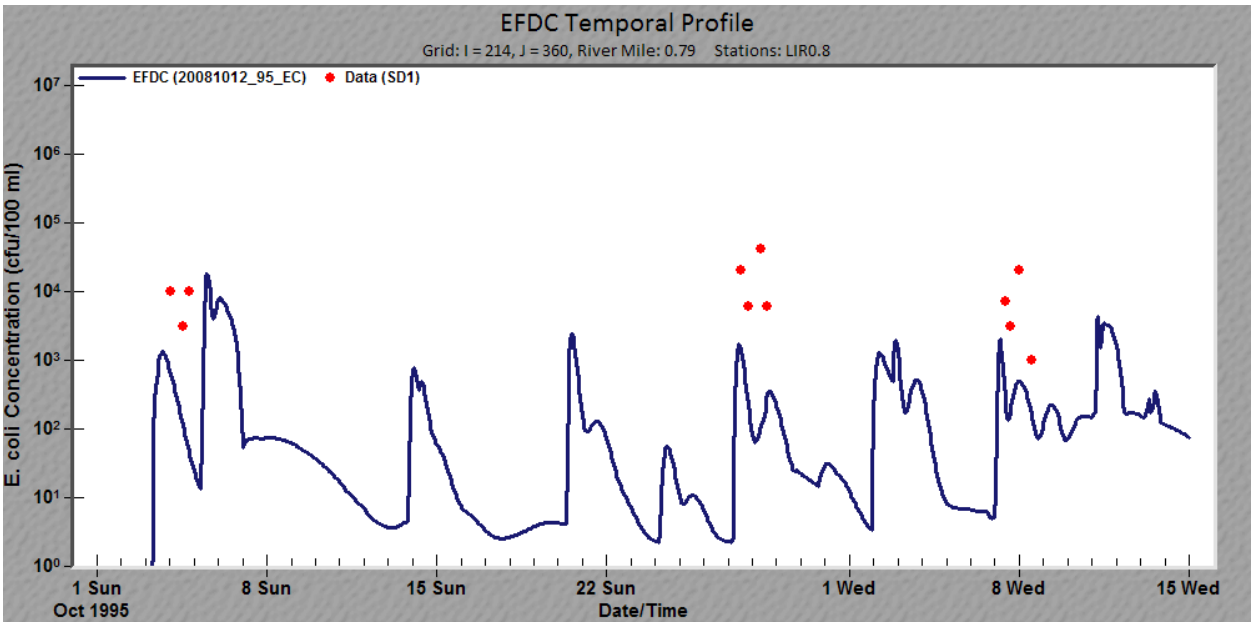
Licking River Mid-Channel at River Mile 0.8-1995 Wet Weather Events.



Licking River Mid-Channel at River Mile 0.8-1996 Wet Weather Events.



Licking River Right Descending Bank at River Mile 0.8-1995 Wet Weather Events.



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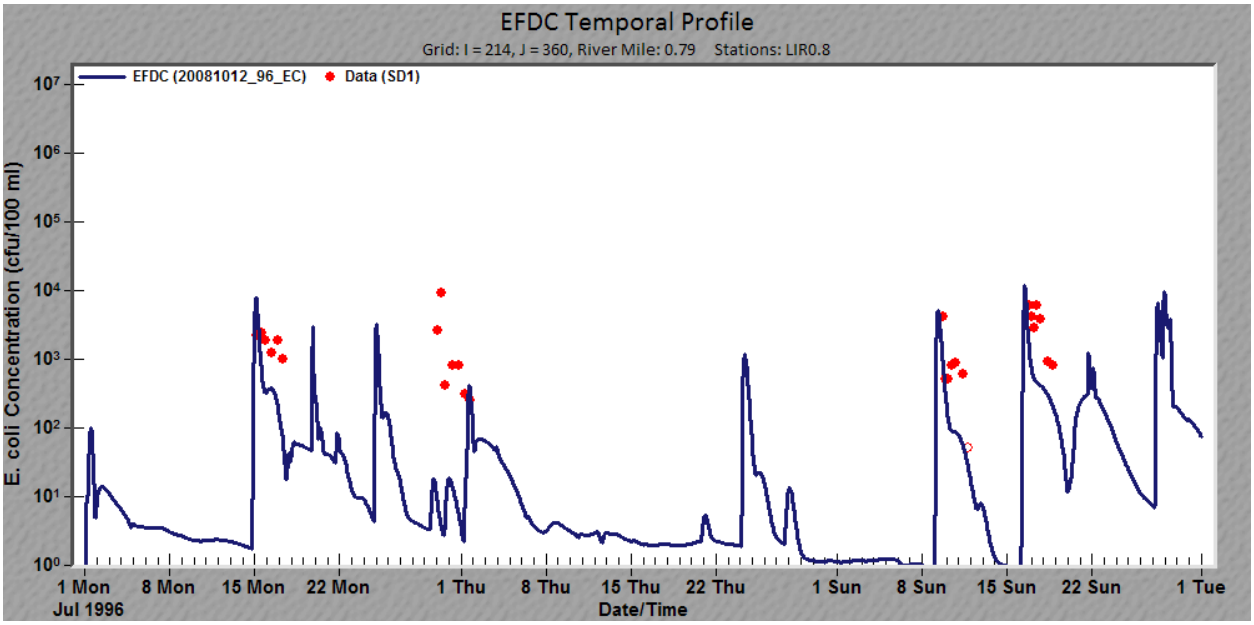
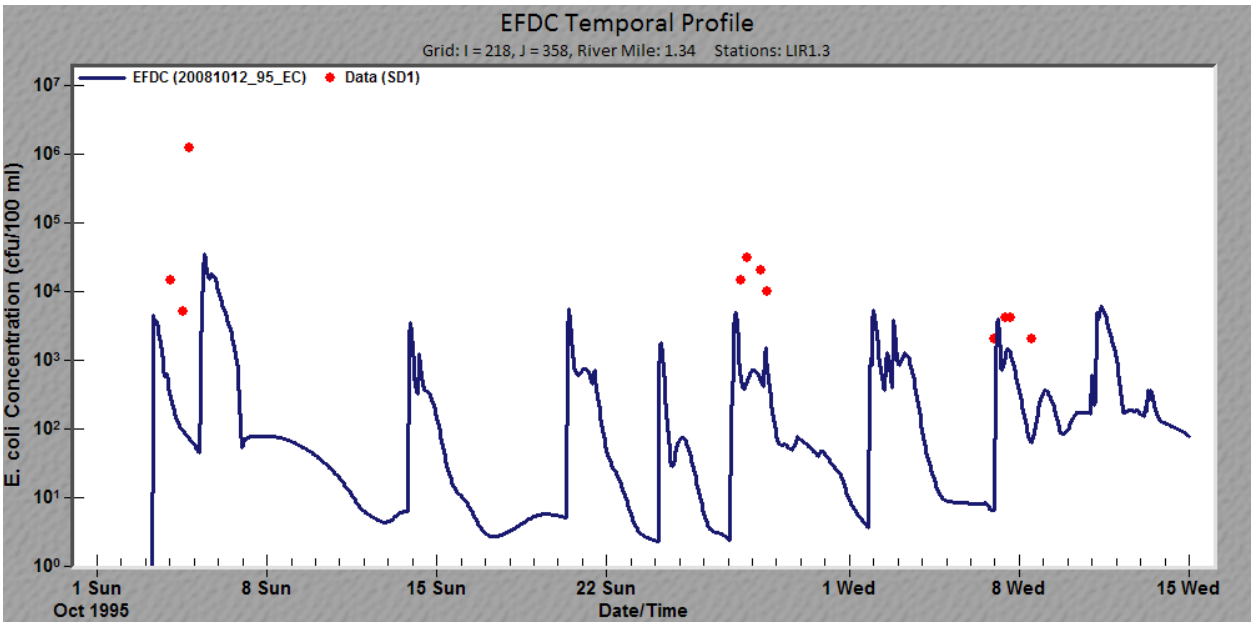
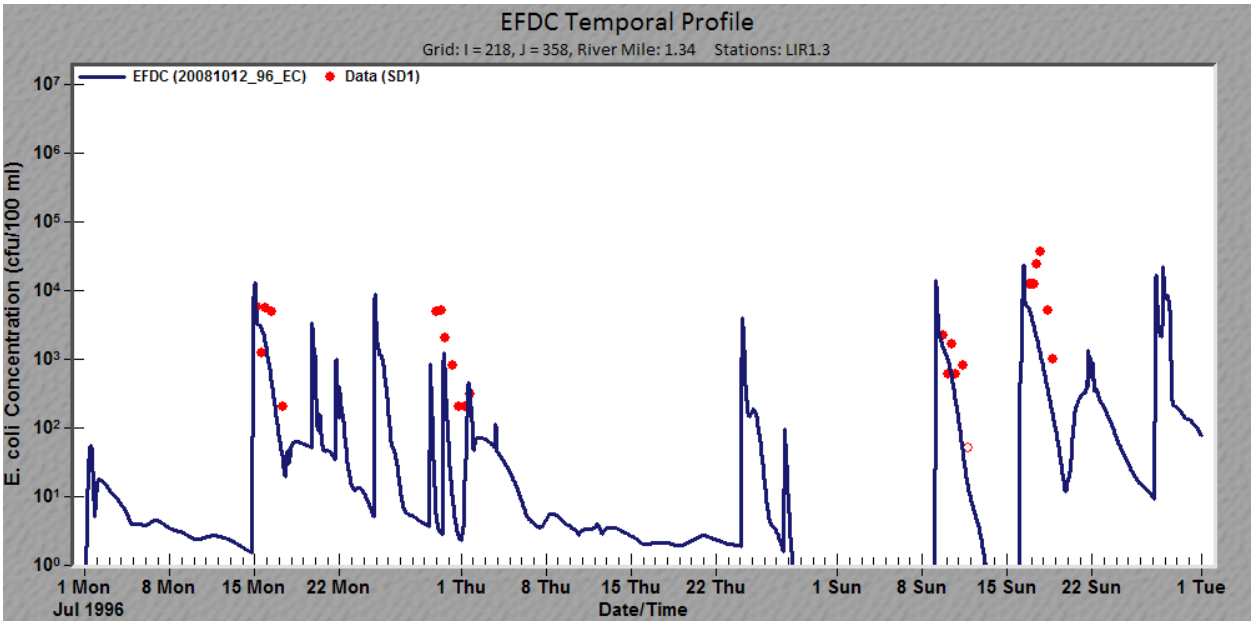


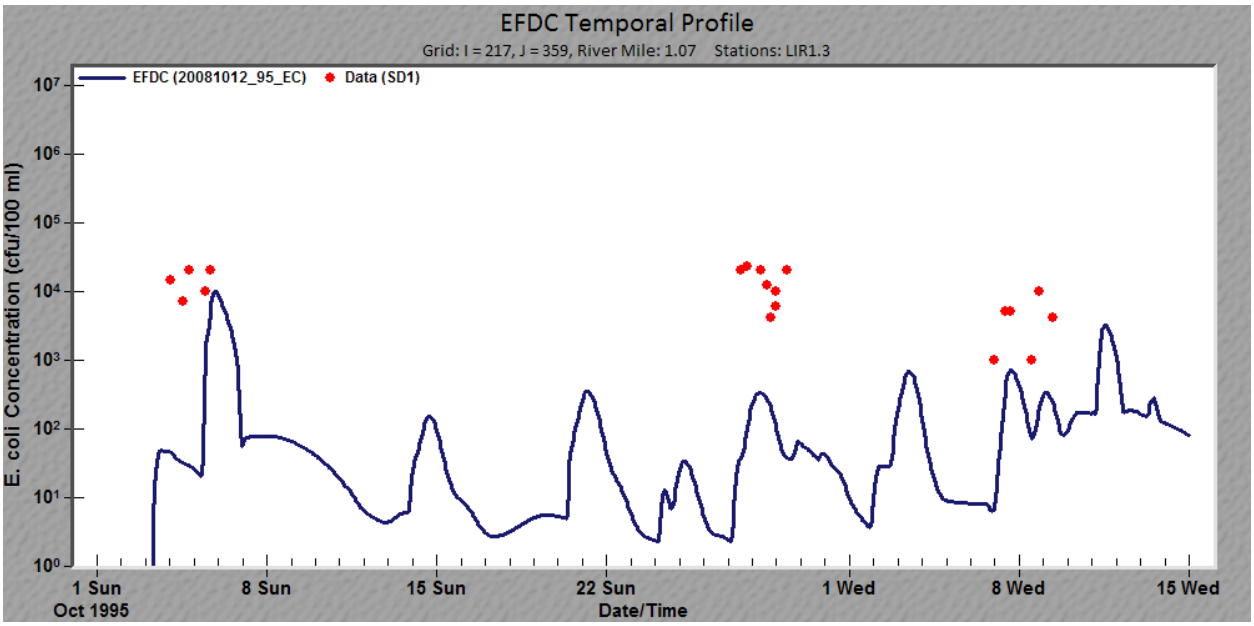
Licking River Left Descending Bank at River Mile 1.3-1995 Wet Weather Events.



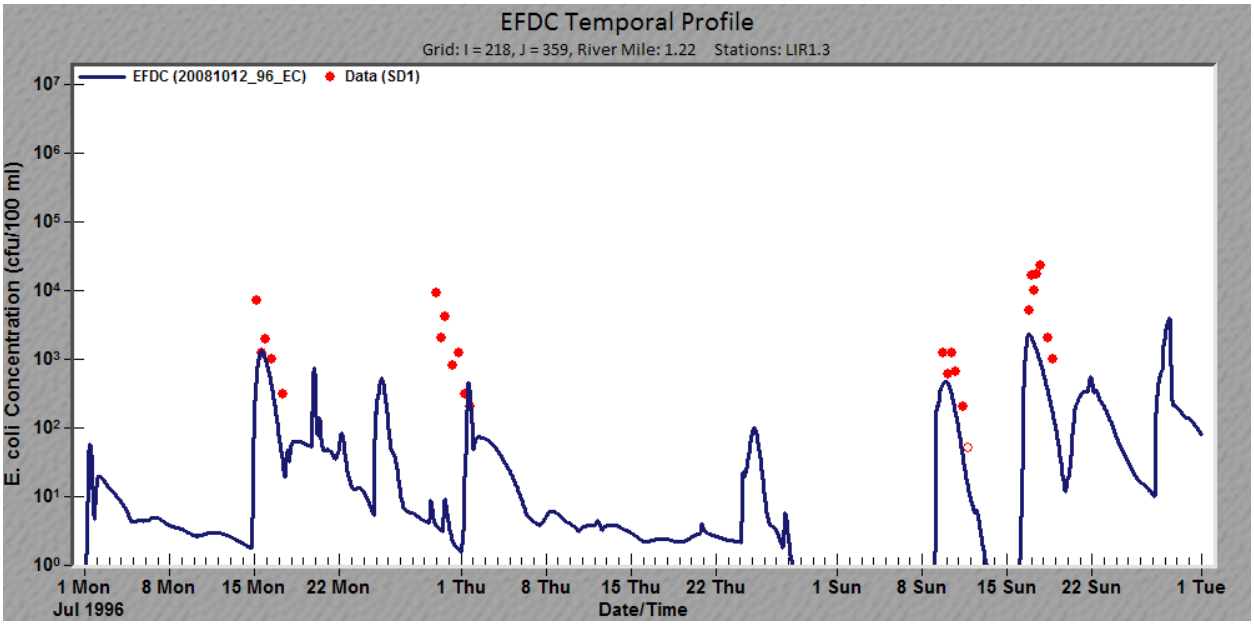
Licking River Left Descending Bank at River Mile 1.3-1996 Wet Weather Events.



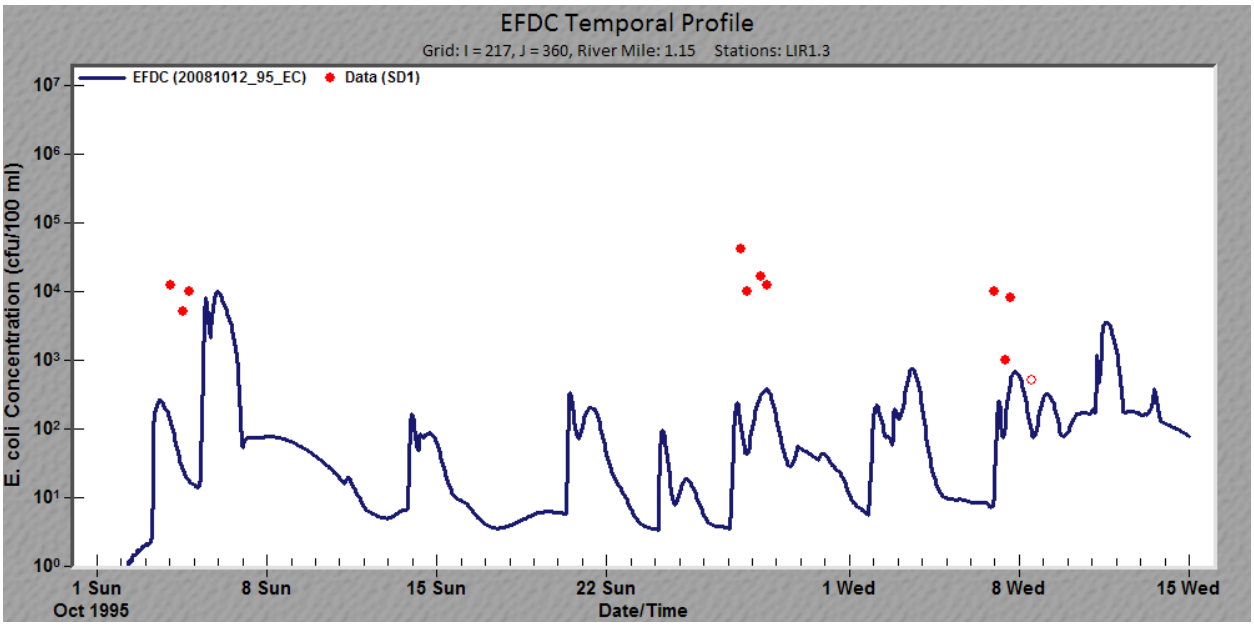
Licking River Mid-Channel at River Mile 1.3-1995 Wet Weather Events.



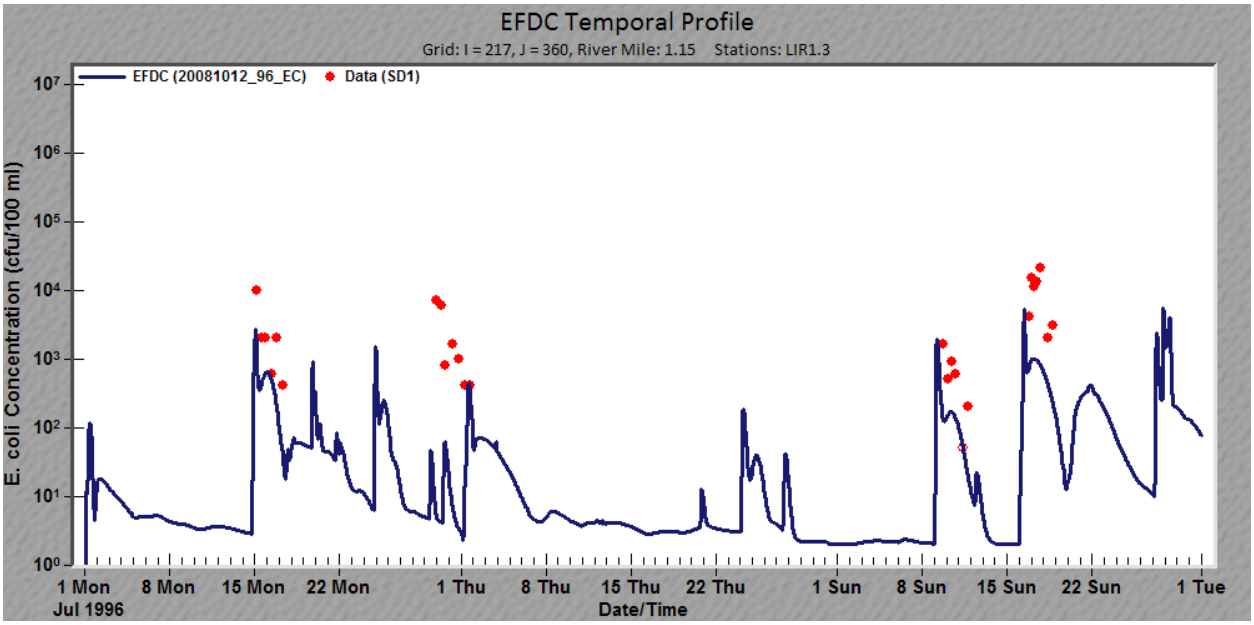
Licking River Mid-Channel at River Mile 1.3-1996 Wet Weather Events.



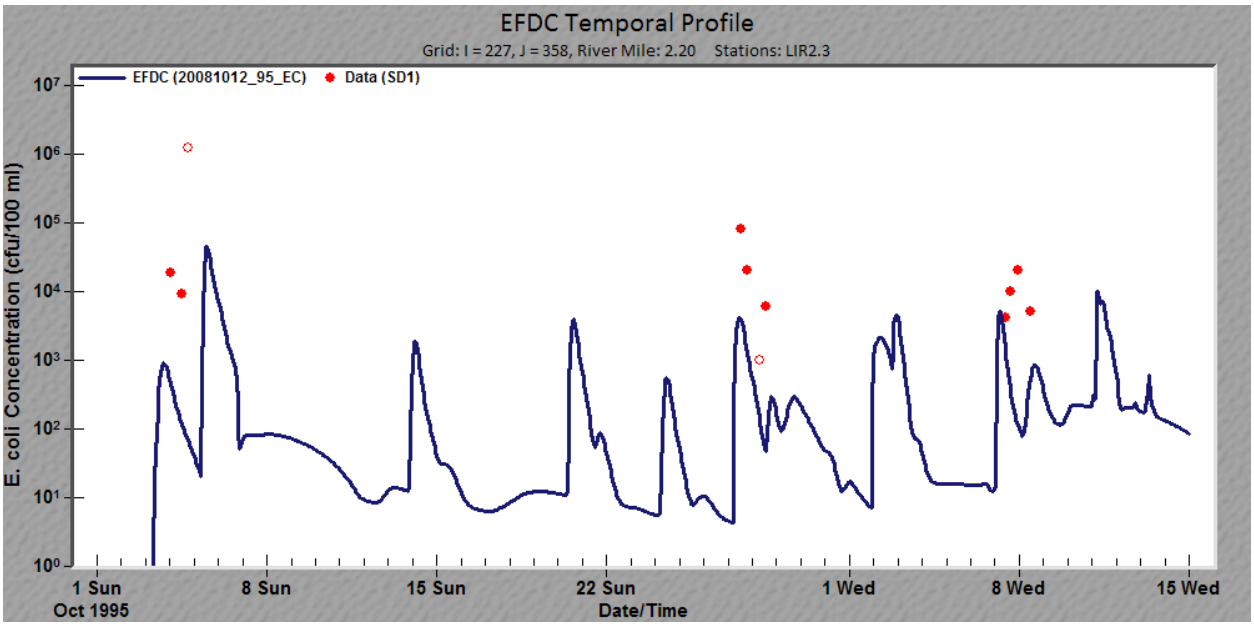
Licking River Right Descending Bank at River Mile 1.3-1995 Wet Weather Events.



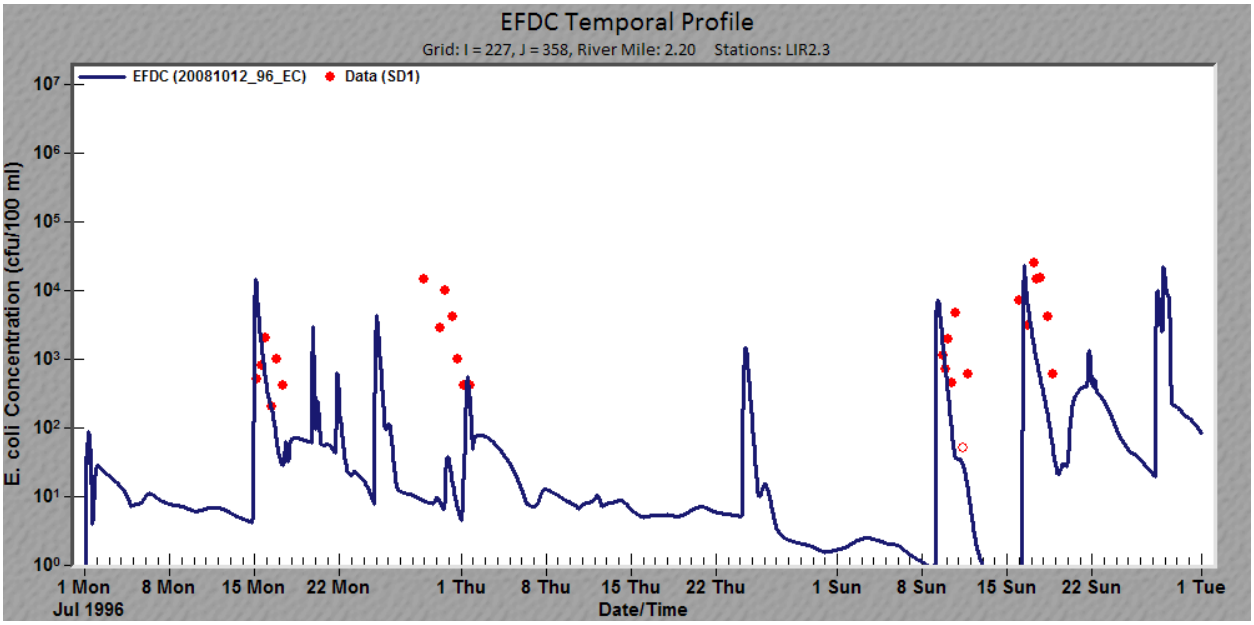
Licking River Right Descending Bank at River Mile 1.3-1996 Wet Weather Events.



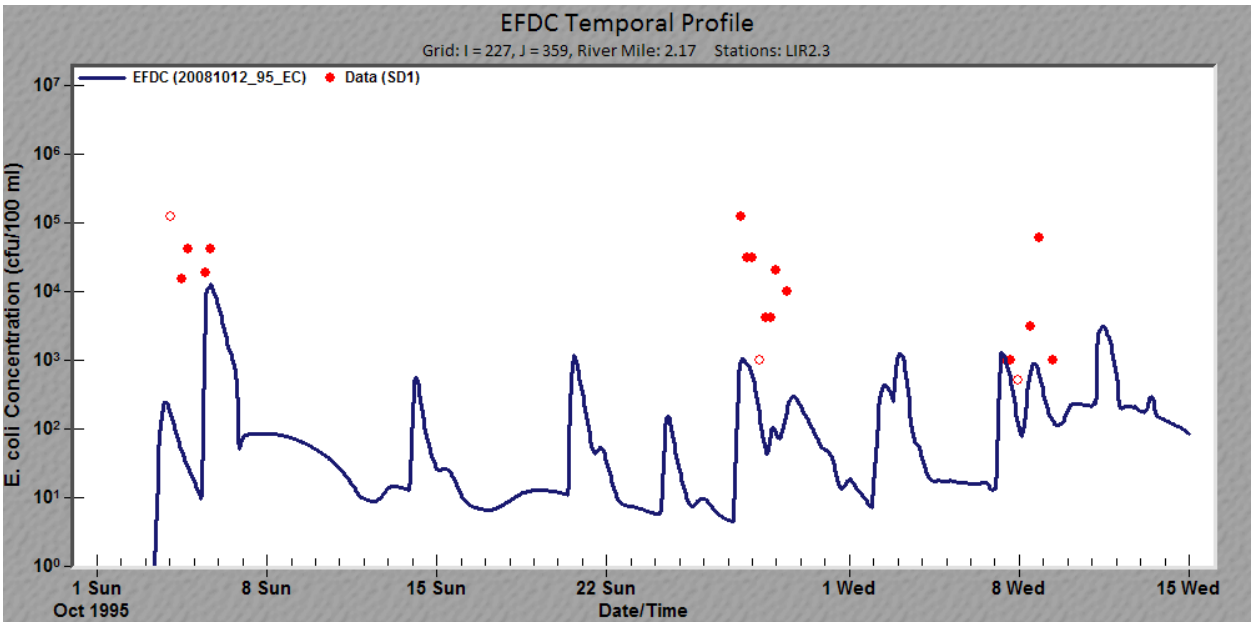
Licking River Left Descending Bank at River Mile 2.3-1995 Wet Weather Events.



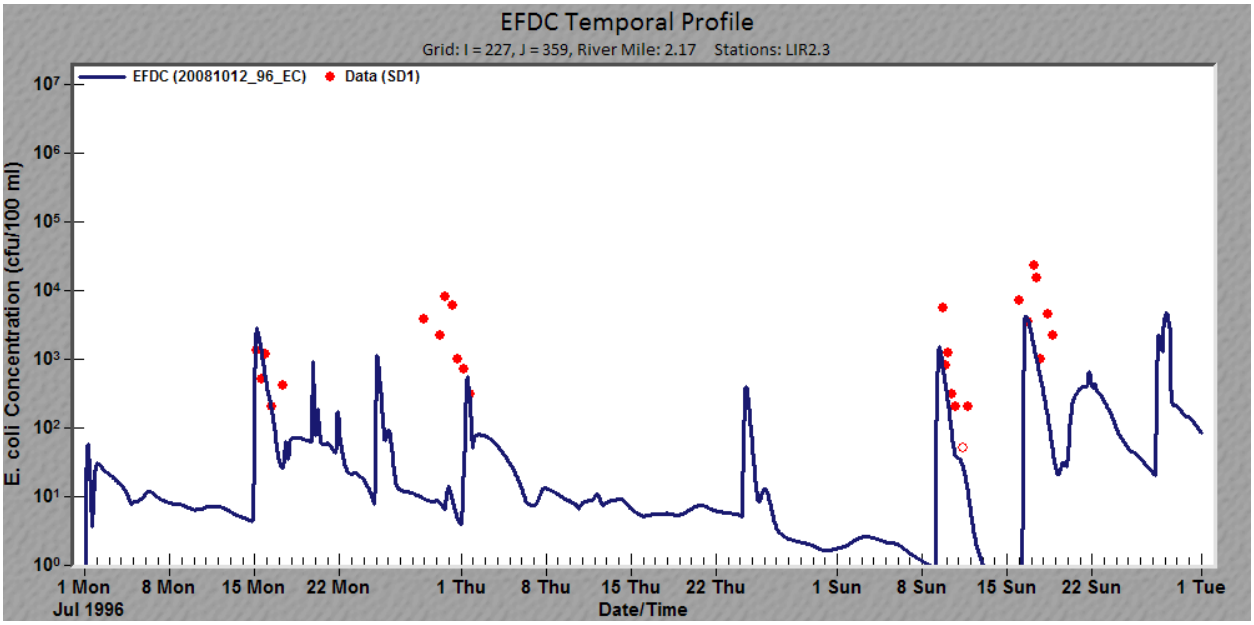
Licking River Left Descending Bank at River Mile 2.3-1996 Wet Weather Events.



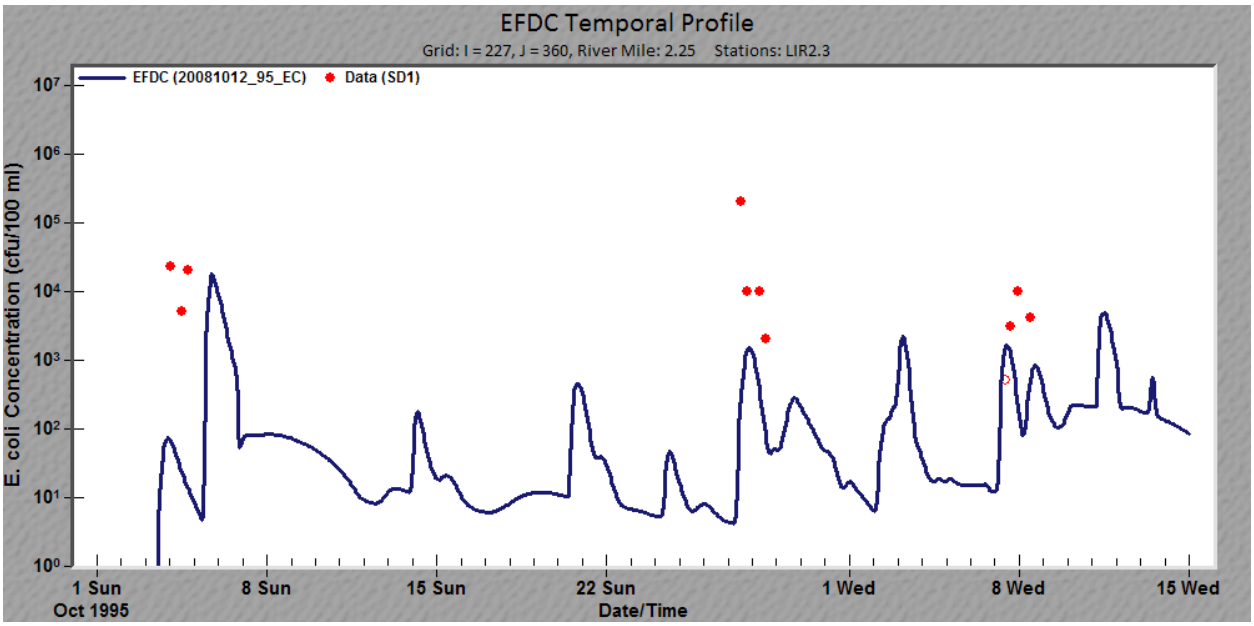
Licking River Mid-Channel at River Mile 2.3-1995 Wet Weather Events.



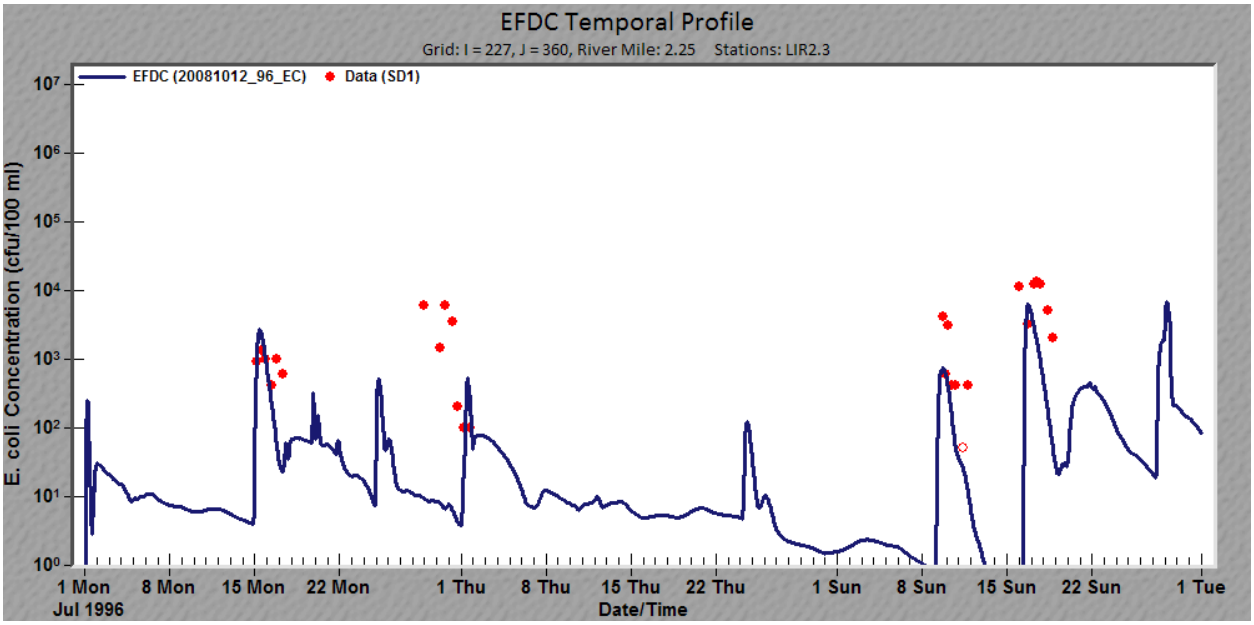
Licking River Mid-Channel at River Mile 2.3-1996 Wet Weather Events.



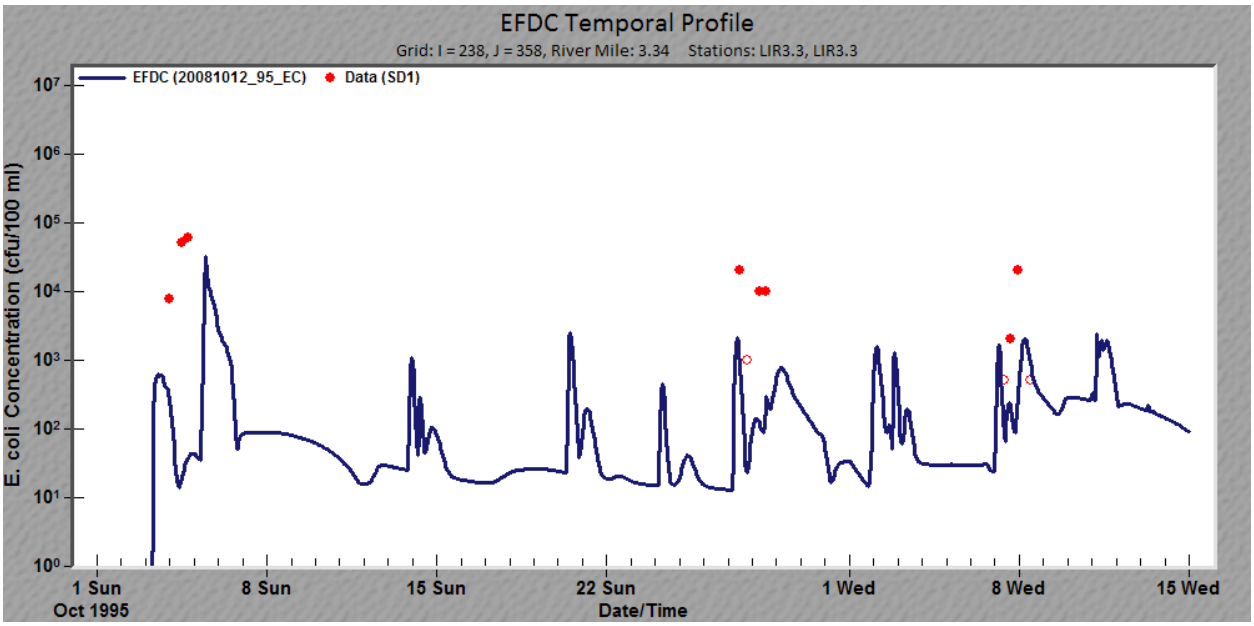
Licking River Right Descending Bank at River Mile 2.3-1995 Wet Weather Events.



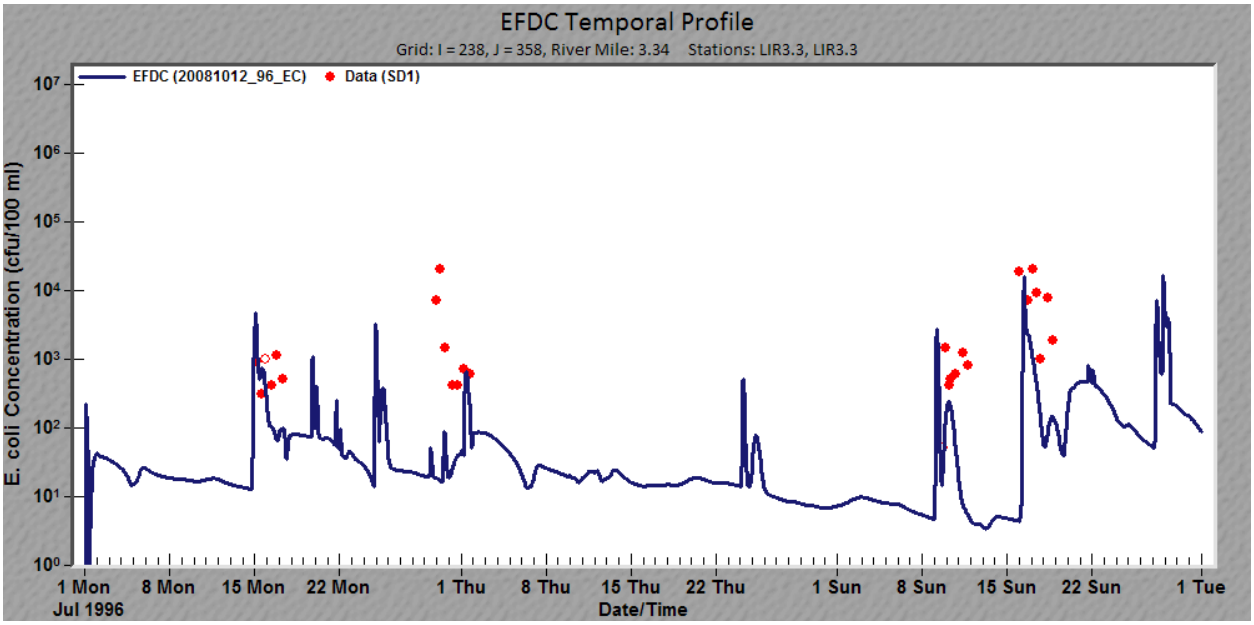
Licking River Right Descending Bank at River Mile 2.3-1996 Wet Weather Events.



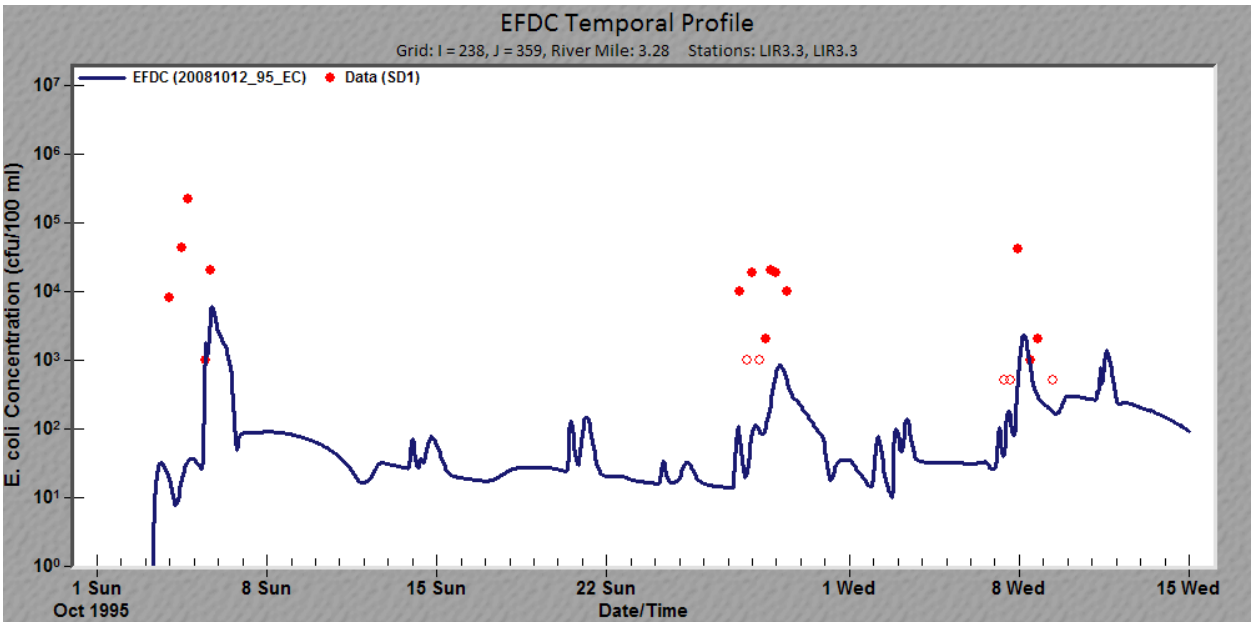
Licking River Left Descending Bank at River Mile 3.3-1995 Wet Weather Events.



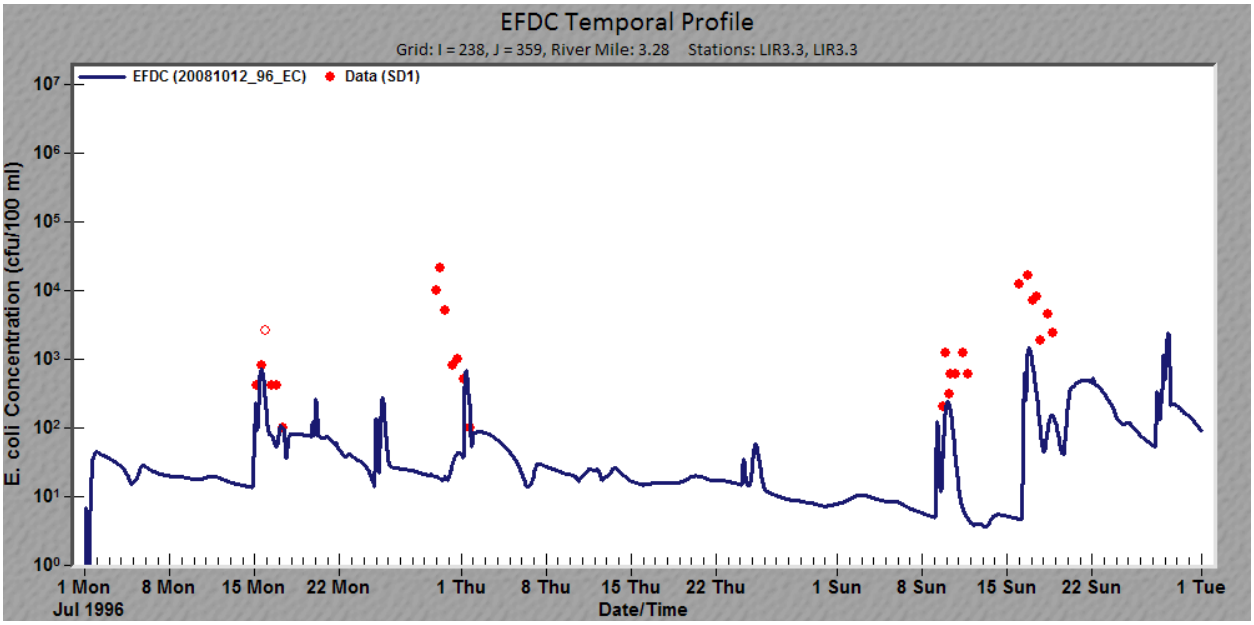
Licking River Left Descending Bank at River Mile 3.3-1996 Wet Weather Events.



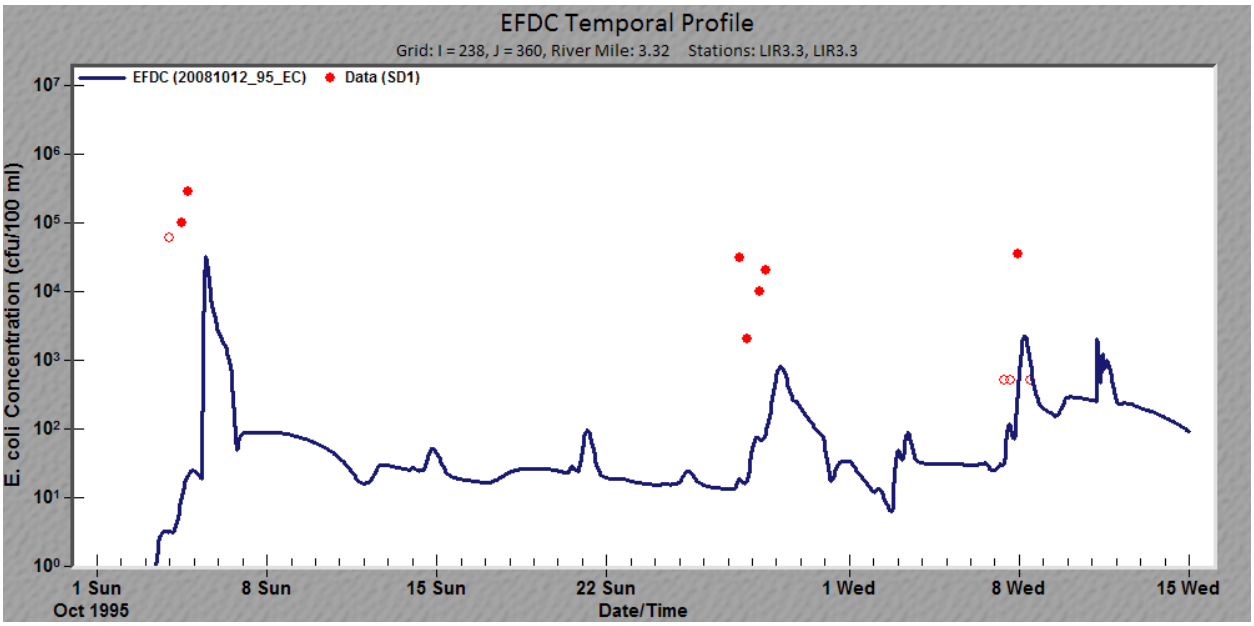
Licking River Mid-Channel at River Mile 3.3-1995 Wet Weather Events.



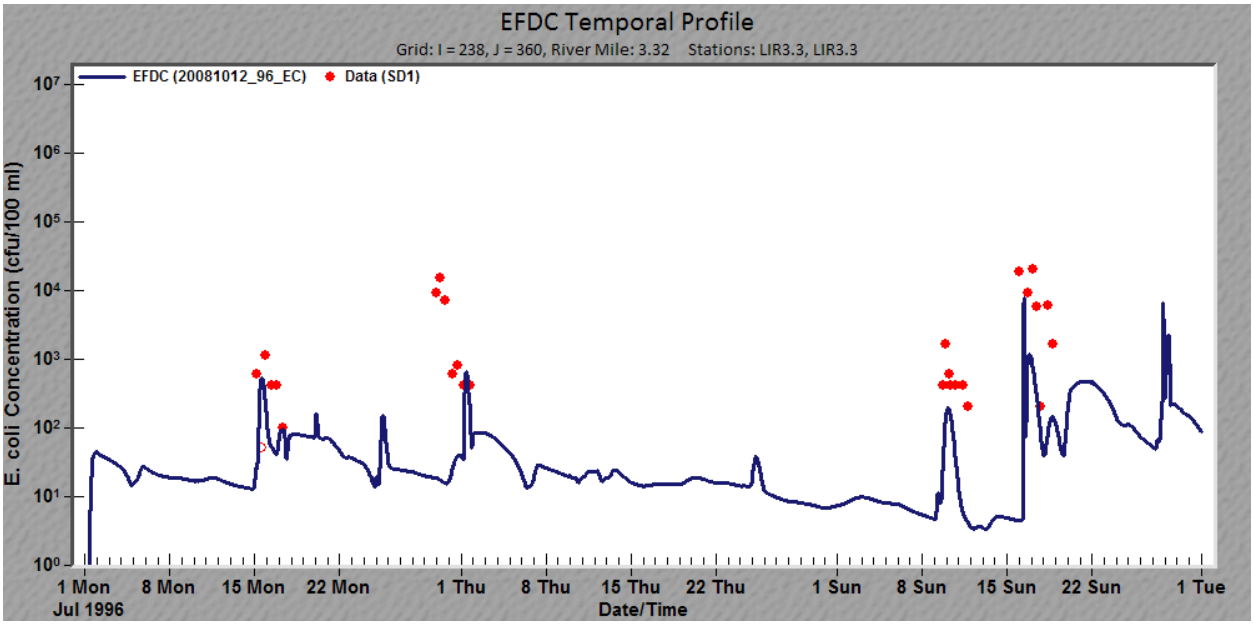
Licking River Mid-Channel at River Mile 3.3-1996 Wet Weather Events.



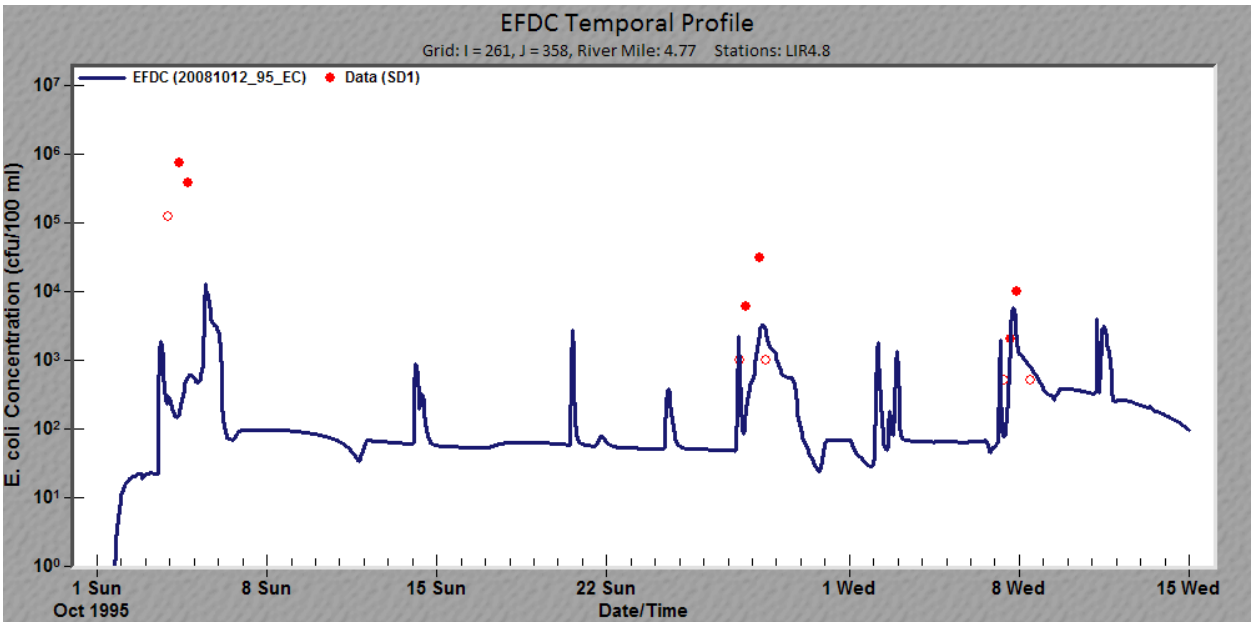
Licking River Right Descending Bank at River Mile 3.3-1995 Wet Weather Events.



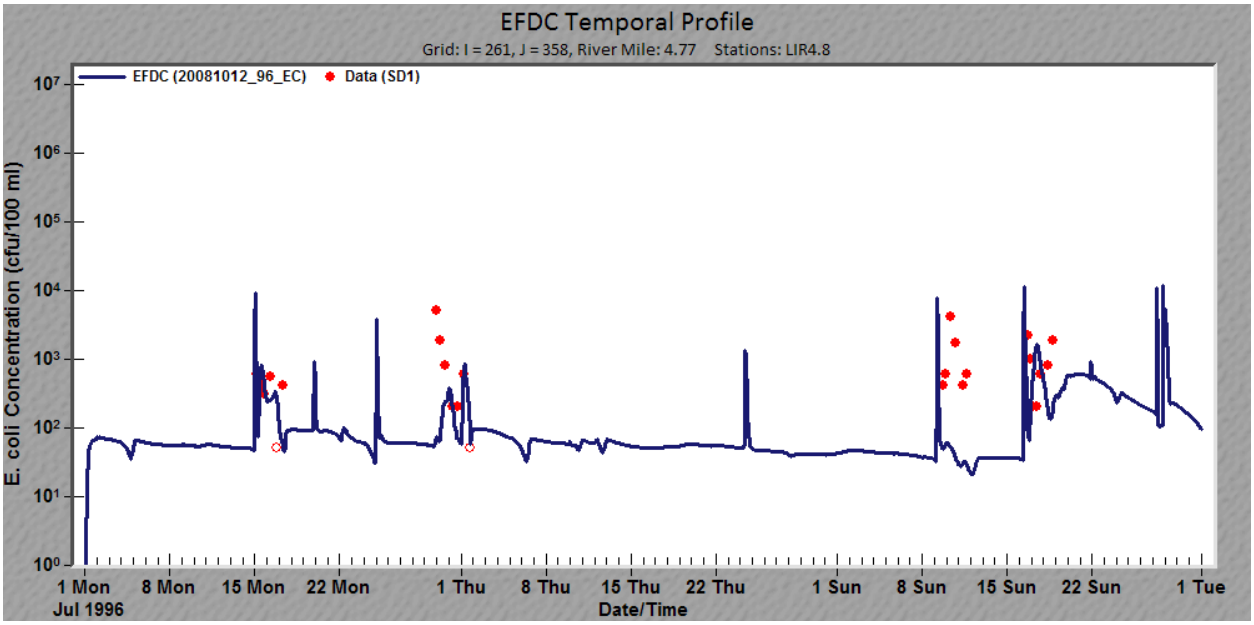
Licking River Right Descending Bank at River Mile 3.3-1996 Wet Weather Events.



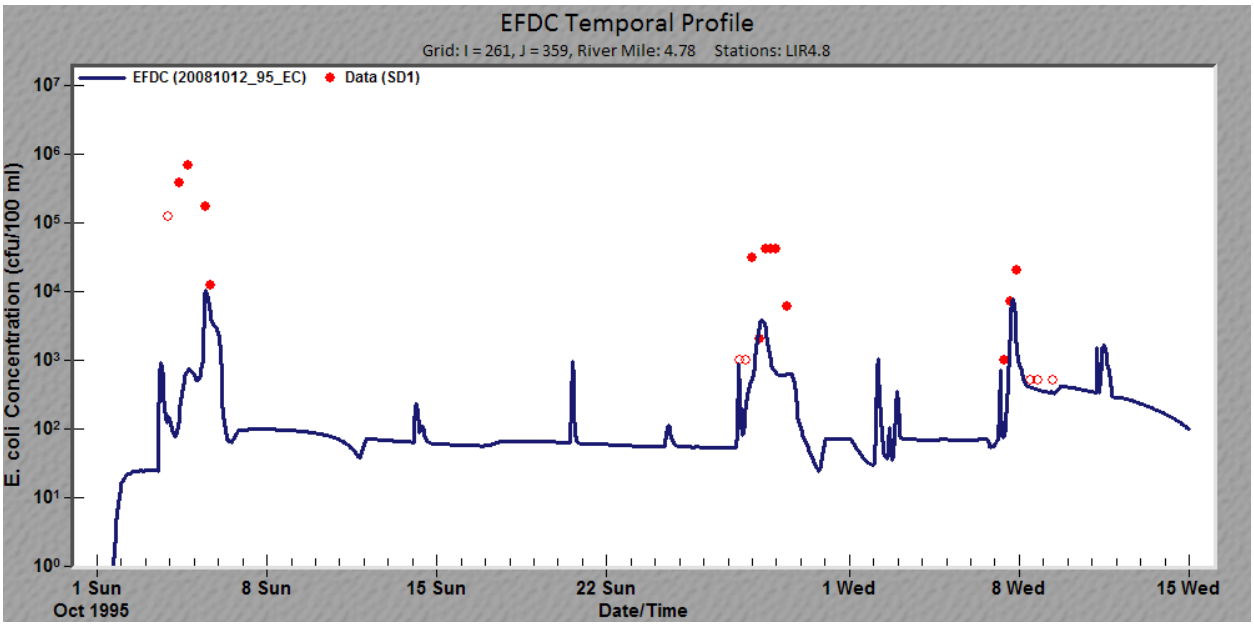
Licking River Left Descending Bank at River Mile 4.8-1995 Wet Weather Events.



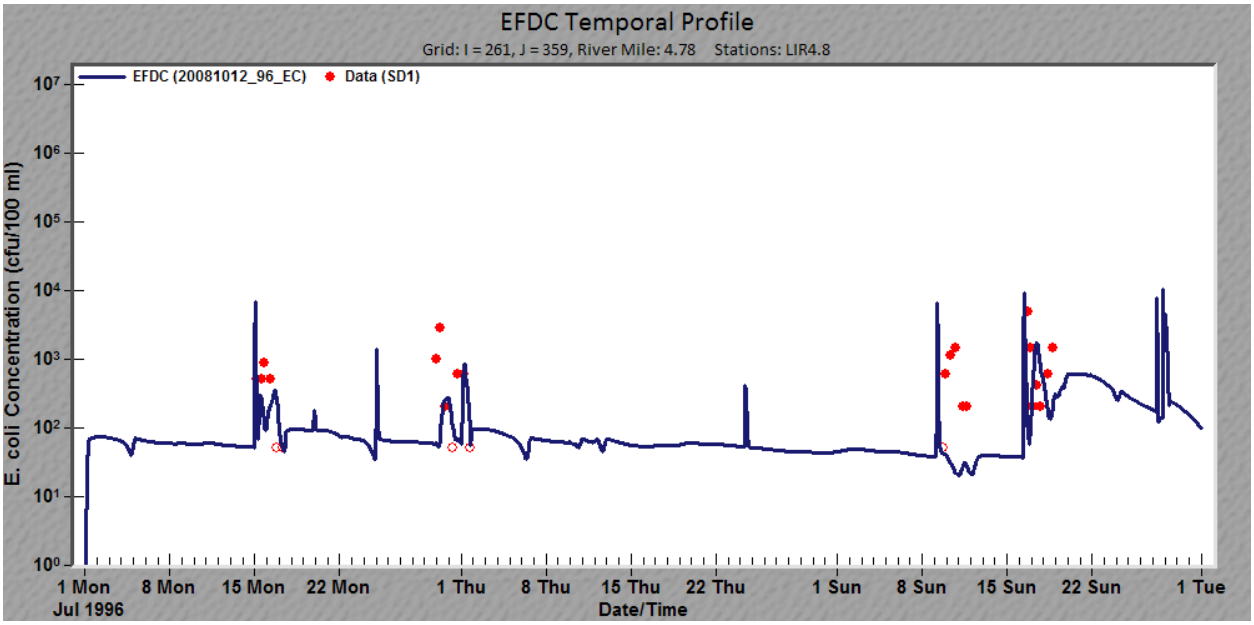
Licking River Left Descending Bank at River Mile 4.8-1996 Wet Weather Events.



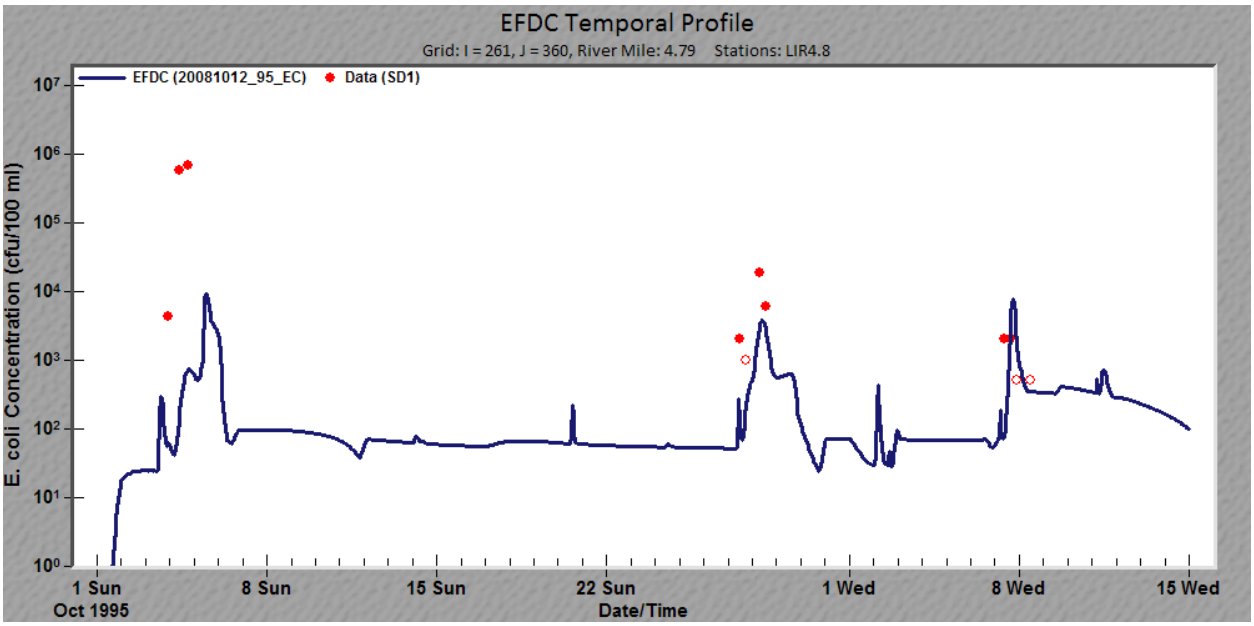
Licking River Mid-Channel at River Mile 4.8-1995 Wet Weather Events.



Licking River Mid-Channel at River Mile 4.8-1996 Wet Weather Events.



Licking River Right Descending Bank at River Mile 4.8-1995 Wet Weather Events.



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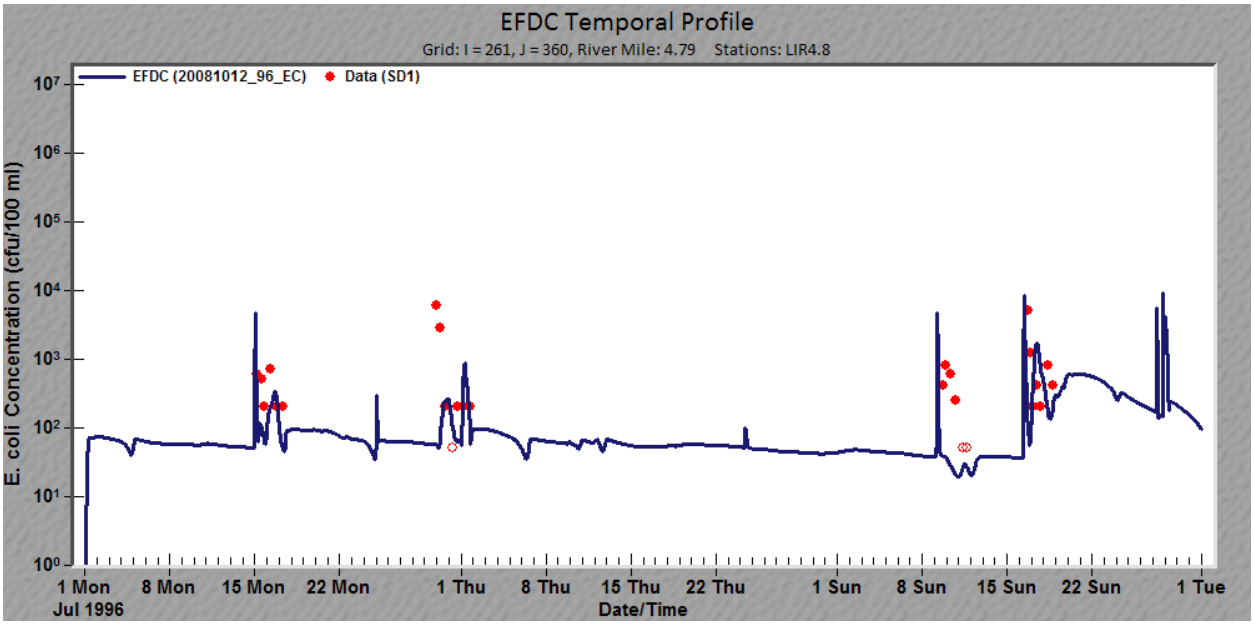

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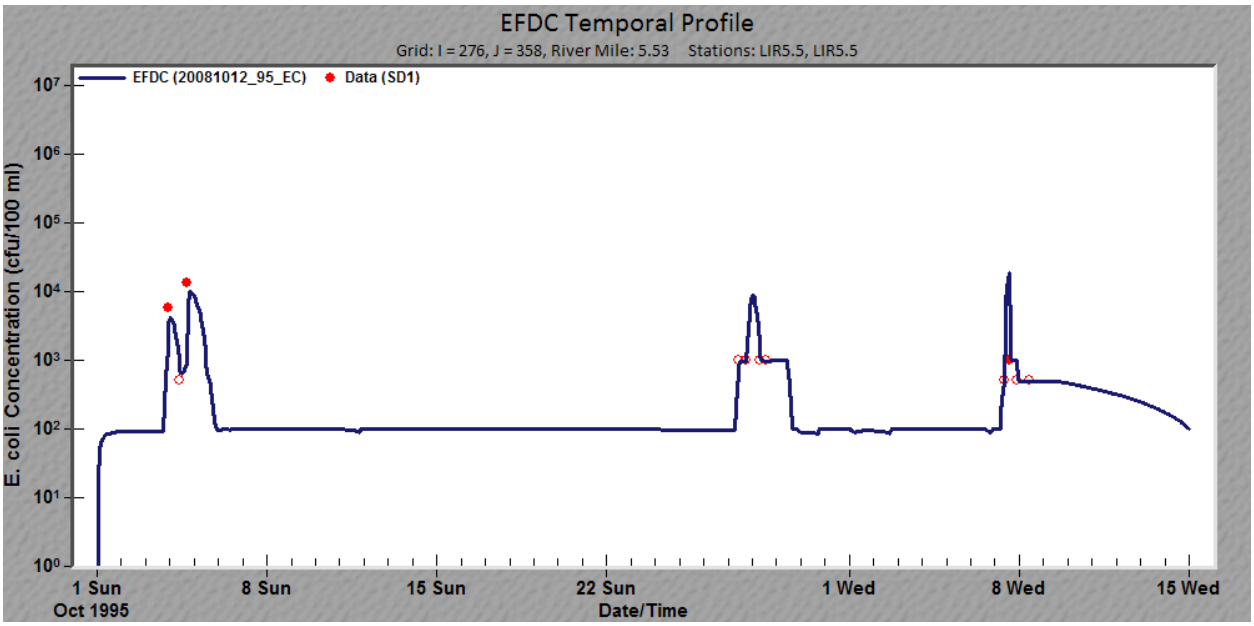
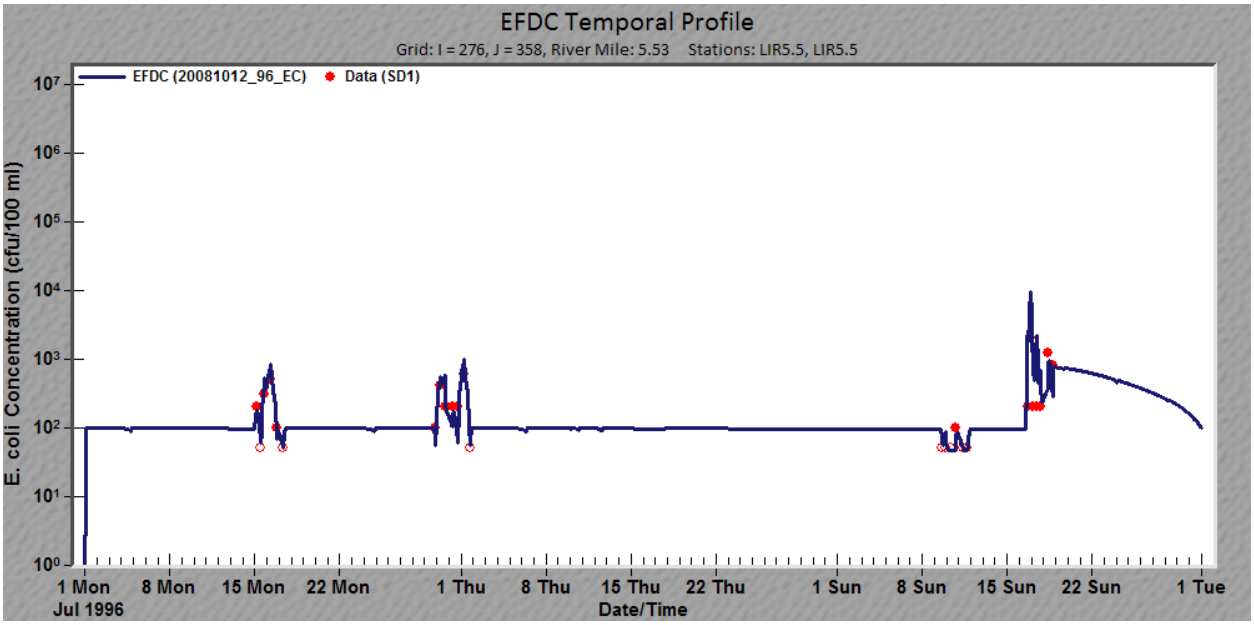


Licking River Left Descending Bank at River Mile 5.5-1996 Wet Weather Events.



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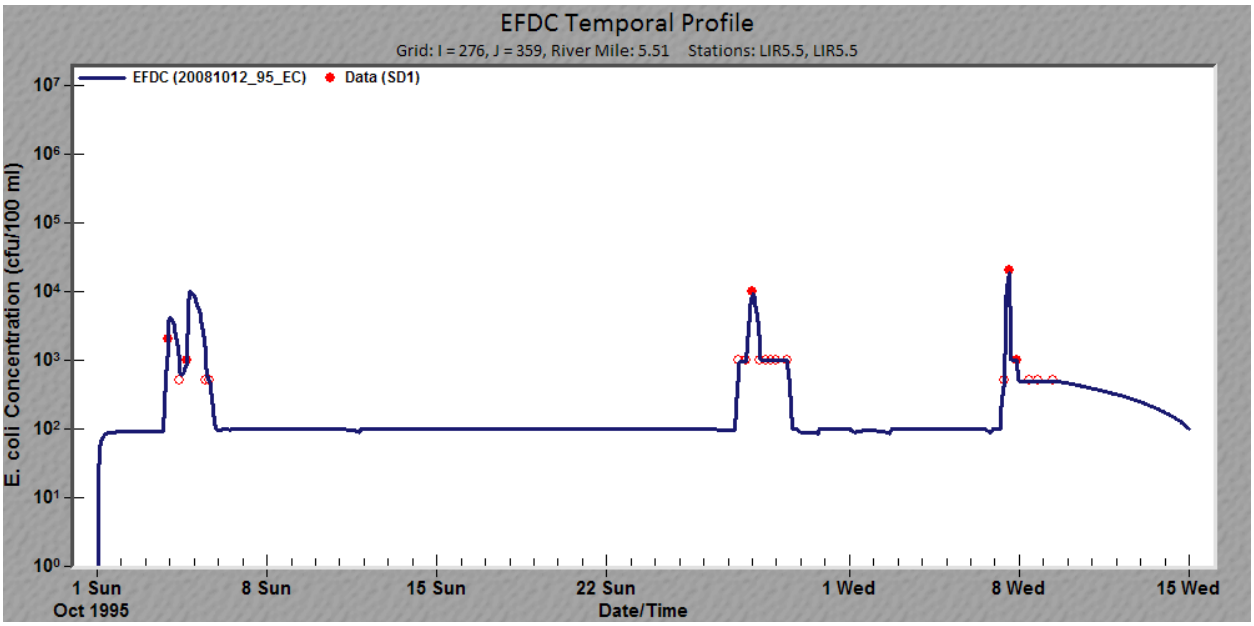

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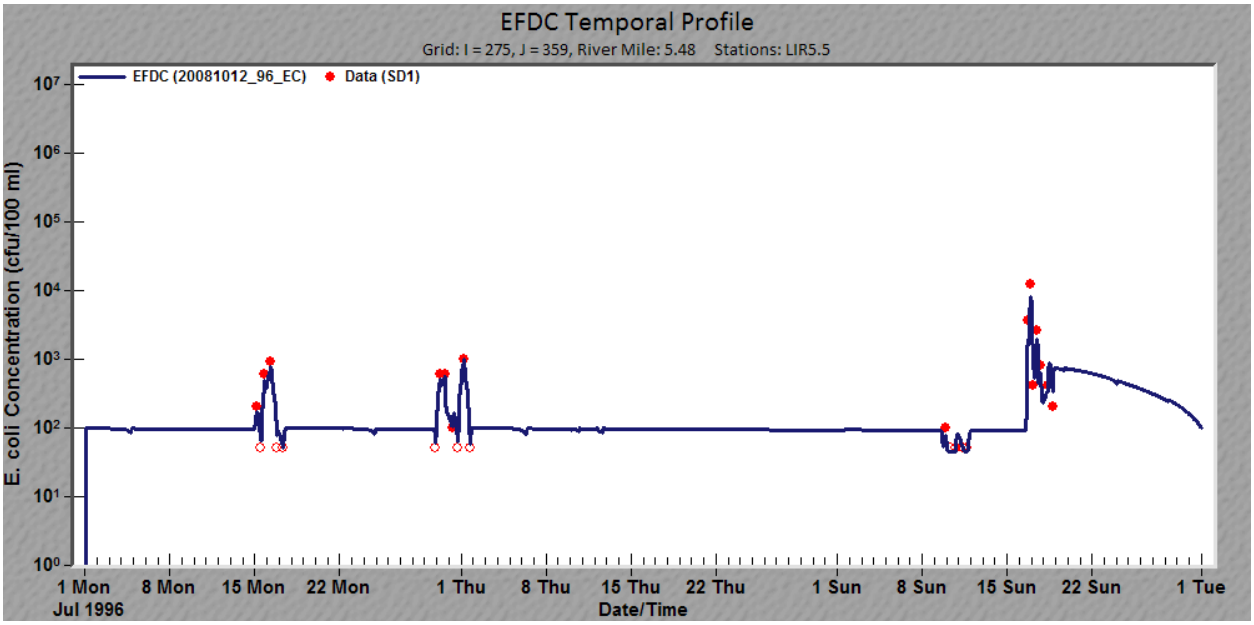

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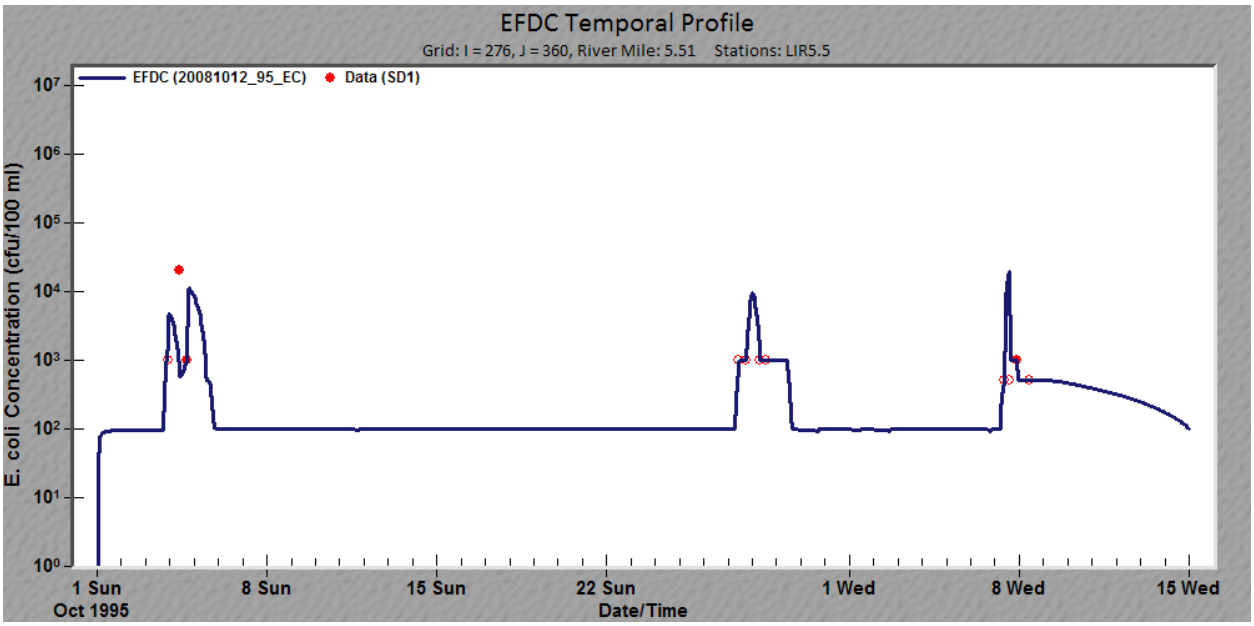
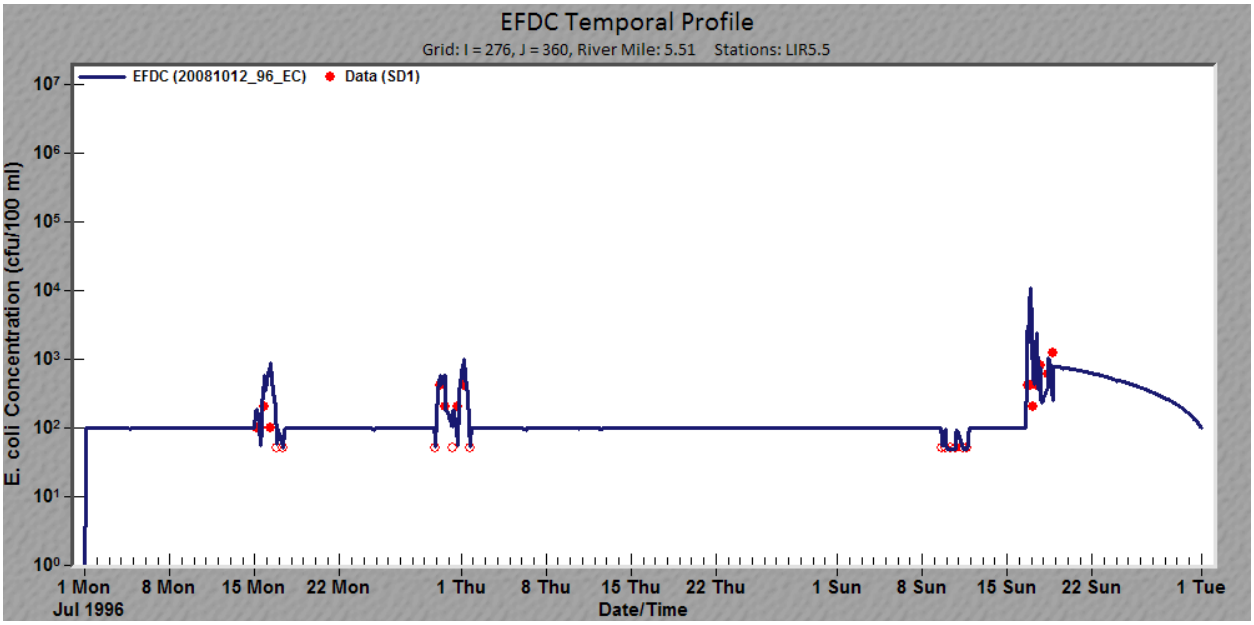


Licking River Right Descending Bank at River Mile 5.5-1996 Wet Weather Events.



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LimnoTech
Water | Environment | Scientists | Engineers

DATE: November 18, 2010

MEMORANDUM

FROM: Jeremy Grush

TO: Jim Gibson (SD1), Mindy Scott (SD1)

CC: Carrie Turner (LimnoTech)

SUBJECT: Water Quality Corroboration of Fecal Coliform Calculations in the EFDC Model of the Ohio River and Major Kentucky Tributaries

Introduction

Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are important tools facilitating watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) Long-term Control Plan (LTCP). SD1's Consent Decree requires that the Watershed Plans include all of the elements of a LTCP. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

SD1 and the Metropolitan Sewer District of Greater Cincinnati (MSD-GC) are collaborating to construct and calibrate an extended EFDC model of the Ohio River and its major tributaries. This work is being initiated by SD1 and will be conducted for SD1 by LimnoTech, building upon previous work conducted by XCG Consultants (XCG) for MSD-GC. In keeping with the common goal of addressing water quality issues through coordinated, watershed-based solutions, the intent of the two districts is to work cooperatively on the development of the model.

LimnoTech's calibration strategy for the Ohio River EFDC model was to calibrate physical processes of the system in a step-wise process where each step adds more complexity to the model representation of the study area. Important processes in the modeling of bacteria include hydrodynamic transport, lateral mixing, and the loss rate of bacteria. Previous memoranda described the calibration of hydrodynamic transport in the system and lateral mixing. These memoranda illustrated that the model accurately predicted water levels, velocities, and lateral mixing rates throughout the system (LimnoTech, 2008a, LimnoTech, 2008b). Another previous memorandum described the development of a data-based estimate of the bacteria loss rate used in the model (LimnoTech, 2008c). Lastly, the model was calibrated to multiple instream water quality datasets (LimnoTech, 2009). The purpose of this memorandum is to describe corroboration of the EFDC model's ability to calculate fecal coliform densities collected during wet weather events in Banklick Creek and the Licking River, during 2009.

This memorandum is organized into the following sections:

- Description of Sampling Events
- Description of Receiving Water Quality Data
- Summary of Model Inputs
- Evaluation of Model Performance
- Conclusions

Description of Sampling Events

SD1 has actively monitored water quality in the Licking River, Banklick Creek and Ohio River during dry and wet weather to characterize the impact of wet weather sources, such as storm water runoff, CSOs and SSOs, on instream water quality. Three wet weather surveys conducted in 2009 for the lower Licking River and Banklick Creek provide a robust dataset for use in verifying the EFDC model calibration.

These wet weather events differ from each other in hydrologic nature due to differences in rainfall intensity, duration, and spatial pattern. Describing the hydrologic nature of these events provides context for understanding the wet weather response of fecal coliform in these tributaries. The first event was a localized rainfall event that caused Banklick Creek flow to increase moderately up to 340 cubic feet per second while the Licking River flow remained low at 430 cubic feet per second. At the peak of this event, the Banklick Creek flow was nearly as great as the Licking River flow. During the second event, both the Banklick Creek and Licking River flows increased moderately to 240 cubic feet per second and 5,800 cubic feet per second, respectively. This event was different from the first event in that Banklick Creek flow was relatively insignificant compared to the Licking River flow. The third rainfall event was much more intense and produced high flows in both tributaries.

The following table presents a summary of hydrologic characteristics during the three events which were surveyed in 2009. Rainfall data were collected at USGS station number 03254480 (Cruises Creek at Highway 17 near Piner, KY).

Table 1: Summary of Sampling Event Hydrologic Characteristics

Event Dates	Total Rainfall [in]	Max Rainfall Intensity [in/hr]	Rainfall Duration [hrs]	Max Licking River Flow [cfs]	Max Banklick Creek Flow [cfs]
7/22-25/2009	1.16 (1.03, 1.16)	0.15 (0.15, 0.15)	23 (23, 24)	430	340
9/20-24/2009	1.28 (1.16, 1.28)	0.23 (0.28, 0.22)	19 (19, 20)	5,800	240
10/8-13/2009	4.62 (2.23, 4.62)	2.07 (0.52,1.06)	20 (22, 22)	19,000	6,000

Rainfall statistics are based on data from the USGS gage at Cruises Creek (gage ID 03254480). Similar rainfall characteristics for each event were observed at the USGS gage in the Licking River (gage ID 03254520) and at the Cincinnati/Northern Kentucky International Airport, which are shown in parentheses, respectively.

Description of Receiving Water Quality Data

During the three wet weather surveys, fecal coliform samples were collected at multiple stations in the Licking River and Banklick Creek over the course of each event. By sampling at multiple stations and at multiple times throughout the event, this dataset provides a detailed description of how fecal coliform densities vary through the system during dynamic wet weather conditions. Samples were collected approximately midway between the riverbanks. The following table summarizes wet weather receiving water quality data collected during the events.

Table 2: Summary of Sampling Water Quality Samples

Station	Number of Samples	Geometric Mean Fecal Coliform Density [cfu/100ml]	Maximum Fecal Coliform Density [cfu/100ml]	Percentage of Densities Greater than 400 cfu/100ml
Banklick RM 3.9	29	2,200	49,000	78%
Banklick RM 1.2	27	3,700	80,000	85%
Banklick RM 0.3	27	2,700	60,000	86%
Licking RM 4.9	33	260	41,000	53%
Licking RM 0.5	34	600	36,000	36%

Note: A total of 13 sites were sampled in each event but the sampling locations outside this model domain are not shown in this table because they were not used in this validation.

By comparing measured fecal coliform densities at each sampling station over time, some understanding of fecal coliform sources influencing the system can be developed.

The upstream station on the Licking River is just upstream of Banklick Creek, so comparing measured densities at the two Licking River stations provides some indication of the influence of Banklick Creek fecal coliform loads on Licking River fecal coliform densities. Some significant combined sewer overflows also influence water quality between these two Licking River stations.

During all three events, measured fecal coliform densities on Banklick Creek are relatively uniform among all three stations. This indicates that upstream loads from the watershed often drive elevated densities throughout Banklick Creek. The influence of fecal coliform sources between the two sampling stations on the Licking River is apparent from the increase in instream densities that occurs at multiple times during the sampling events. For instance, on July 22, densities in Banklick Creek are approximately 6,000 counts per hundred milliliters while Licking River densities upstream of Banklick are only 100 counts per hundred milliliters. Downstream of Banklick Creek on the Licking River, fecal coliform densities are significantly higher at 600 counts per hundred milliliters, partially due to the Banklick Creek load.

The above evaluation of the receiving water quality data indicates that the data exhibits physical processes that should be reproducible in the EFDC model through its modeling of bacteria sources, fluid transport, and bacteria die-off.

Summary of Model Inputs

Four sources of fecal coliform were modeled to account for the elevated fecal coliform densities observed during these wet weather events: Banklick Creek watershed loads (storm water runoff), Licking River watershed loads (storm water runoff), CSOs, and SSOs. Figures 1 through 3 illustrate the fecal coliform loads associated with each source through the duration of each sampling event. During the first two events, the Banklick Creek upstream load and overflow loads are very high relative to the Licking River load, so these sources have a major impact on Licking River water quality. In the third event, the Licking River upstream load is similar to other loads so the other sources have a relatively minor impact on Licking River water quality.

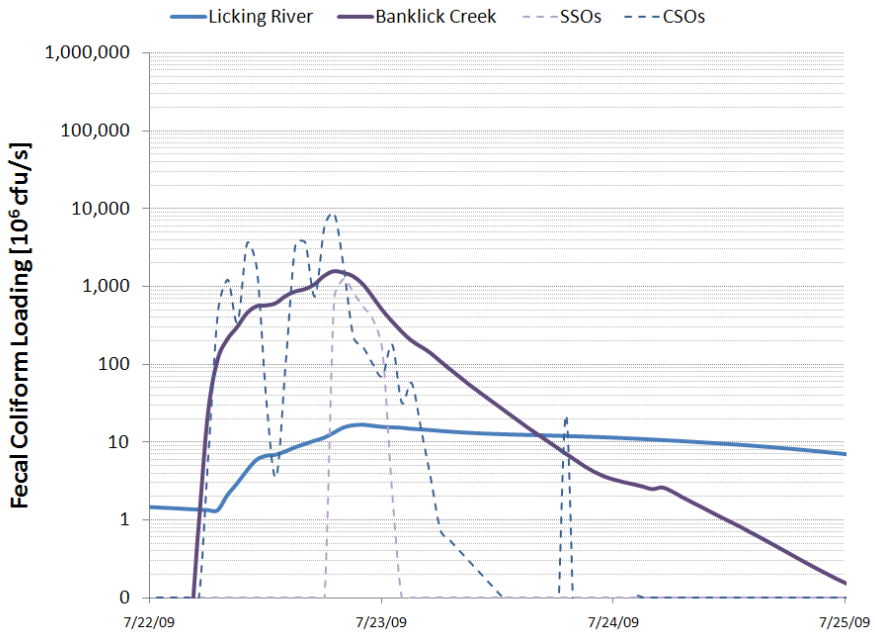

Figure 1: Modeled Fecal Coliform Loads during the July 2009 Event

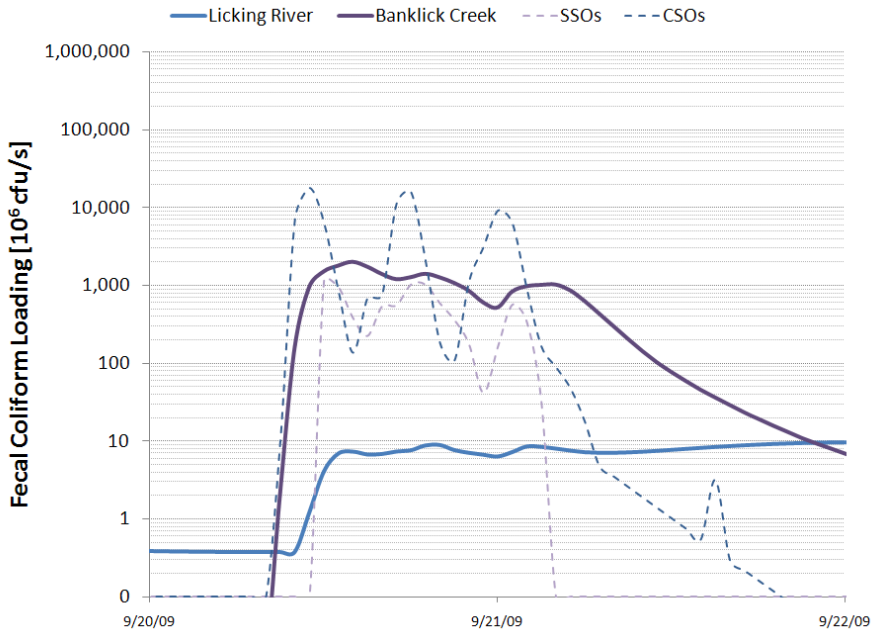

Figure 2: Modeled Fecal Coliform Loads during the September 2009 Event

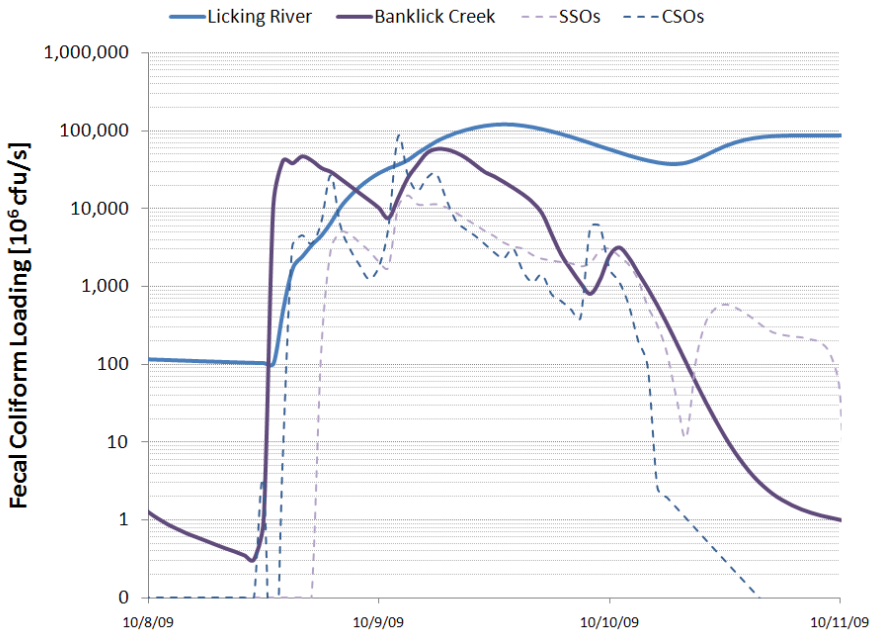

Figure 3: Modeled Fecal Coliform Loads during the October 2009 Event

All of these loads were estimated using numerical models. The Licking River and Banklick Creek loads were estimated using calibrated, detailed watershed (HSPF) models of these systems. Overflow loads were computed by multiplying modeled overflow flow rates by event mean concentrations for CSOs and SSOs developed and used previously in model calibration (LimnoTech, 2009). These load estimations strongly influence the ability of the EFDC model to accurately calculate instream densities of fecal coliform.

Evaluation of Model Performance

Model performance was evaluated by comparing model-calculated fecal coliform densities to measured fecal coliform densities. During model calibration, several comparisons between measured and modeled densities were made, using tools such as cumulative frequency distributions, comparative statistics, and one-to-one plots. However, for this model performance evaluation, only time series comparisons will be shown to illustrate that the model accurately represents instream fecal coliform densities.

Model Corroboration Simulations

The three monitored wet weather events were simulated using the EFDC model. Comparisons between modeled and measured fecal coliform densities are shown in the figures below. For the Licking River comparisons, the mid-channel model segment result was compared to the data measured at each river mile.

In general, the model accurately reproduces both the peak fecal coliform densities observed during each wet weather event and the duration of elevated fecal coliform densities following a precipitation event. Additionally, the model does not appear to be biased. In other words, the model does not tend to under-predict or over-predict fecal coliform densities during wet weather events. This evaluation of model performance during three wet weather events verifies that the model is capable of reasonably simulating receiving water quality in Banklick Creek and the Licking River.

Table 3. Statistical Comparison of Model and Fecal Coliform Data for Modeled Events

Profile	Count	Data Geo-metric Mean	Model Geo-metric Mean	Data Median	Model Median	Data Std. Dev.	Model Std. Dev.	Mean Data/Model Ratio	Relative Error
Banklick RM 0.3	24	3.28	3.29	3.62	4.06	0.86	1.08	1.15	-15.1%
Banklick RM 1.2	25	3.38	2.99	3.66	3.89	0.86	1.24	1.30	-29.8%
Banklick RM 3.9	24	3.22	3.52	3.53	4.07	0.82	0.90	1.00	-0.1%
Licking RM 0.5	29	2.61	2.66	2.78	3.08	0.90	1.01	1.20	-19.7%
Licking RM 4.9	28	2.15	2.38	2.07	2.69	1.06	1.07	0.98	2.0%
All Locations	129	2.85	2.93	3.11	3.50	1.00	1.11	1.11	-10.7%

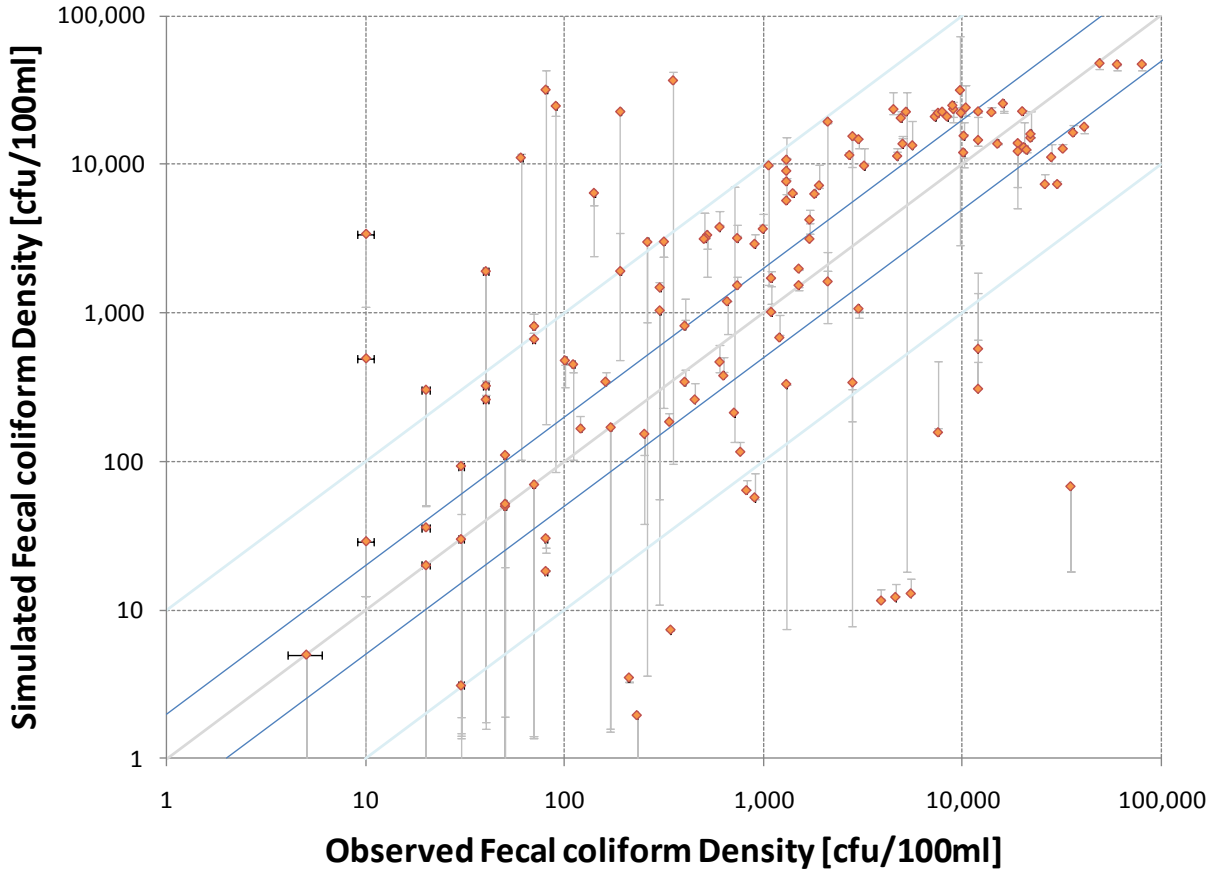

Figure 4: Scatter Plot of Model Results and Fecal Coliform Data for Wet Weather Events

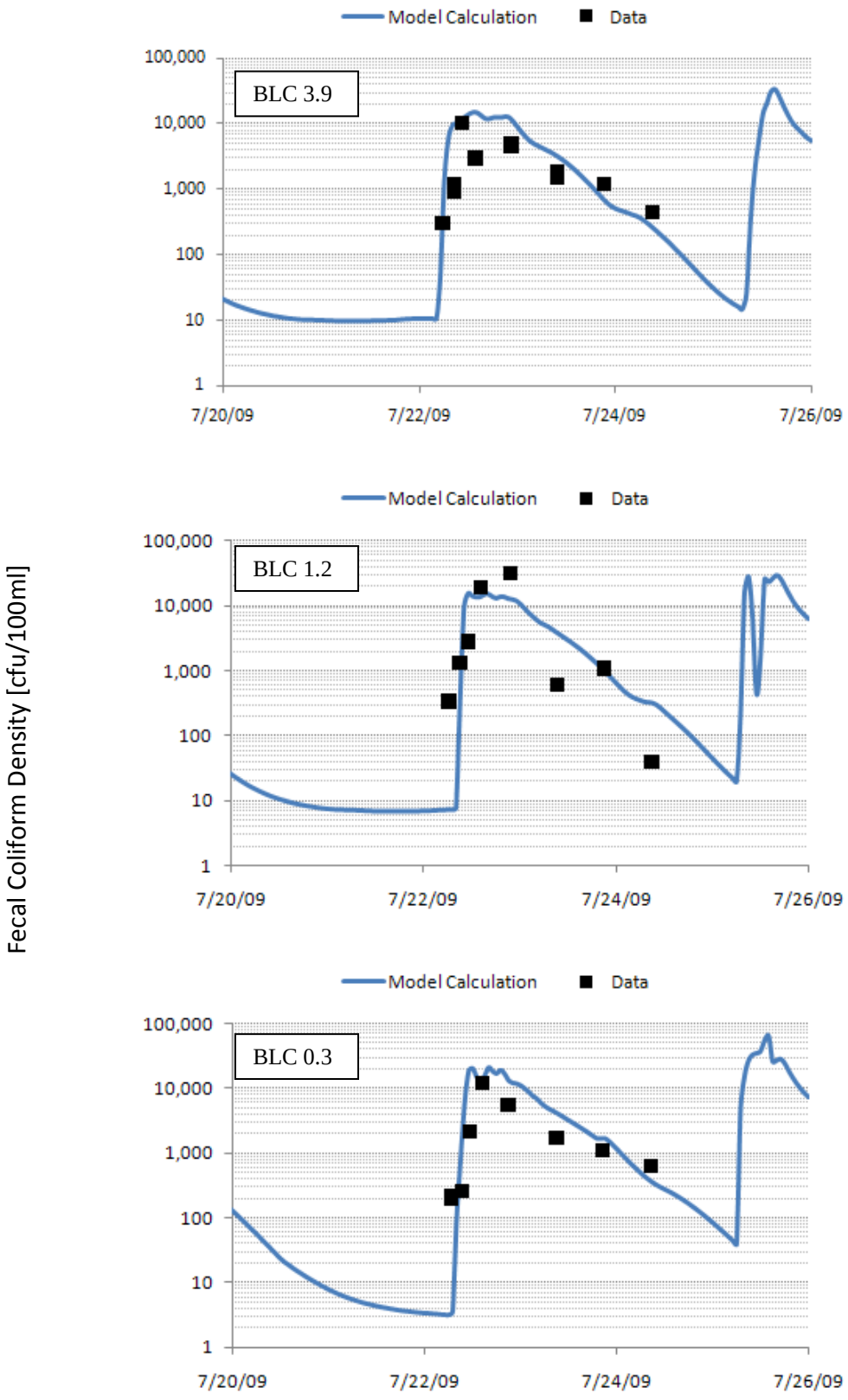

Figure 5: Banklick Creek Model-Data Comparisons – Event 1

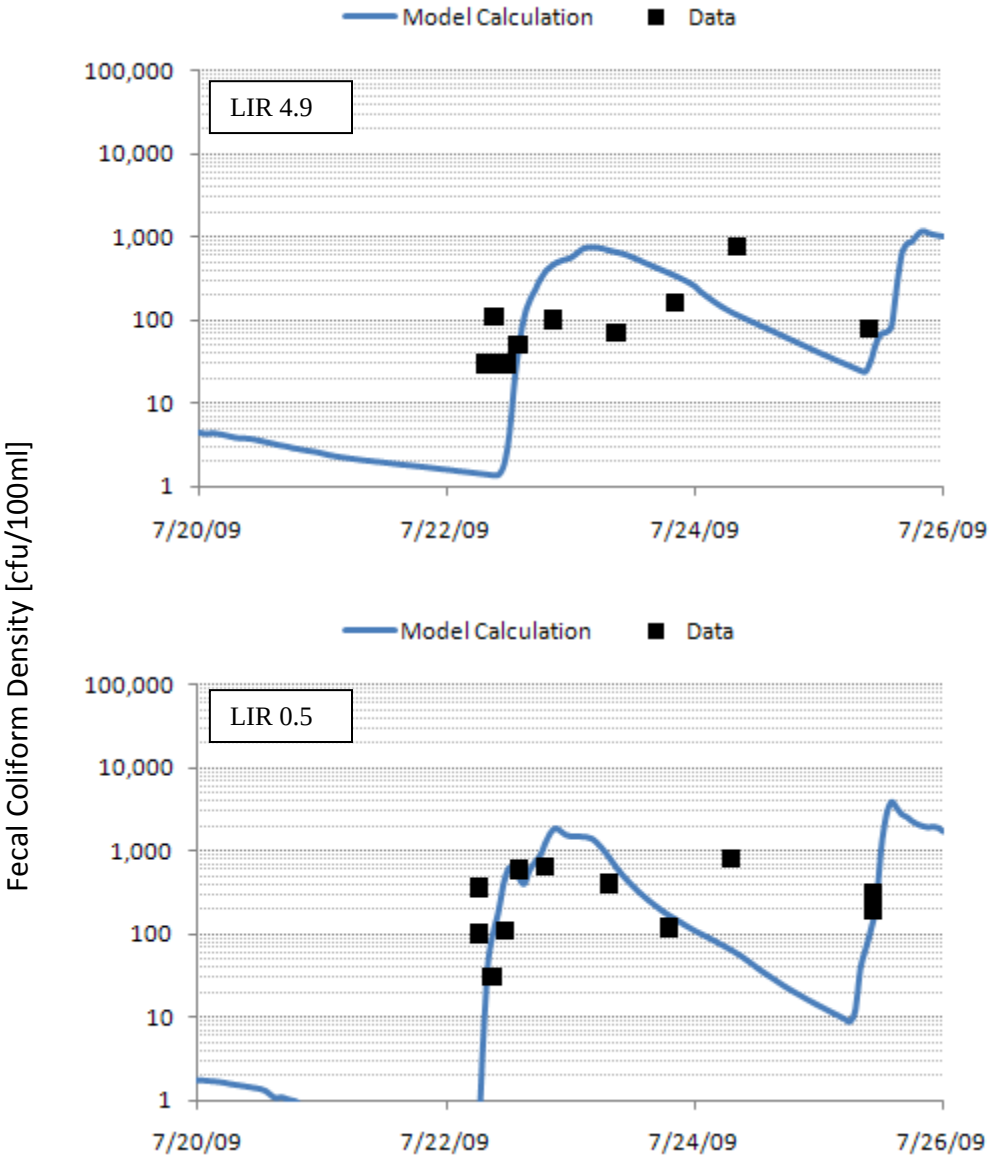

Figure 6: Licking River Model-Data Comparisons – Event 1

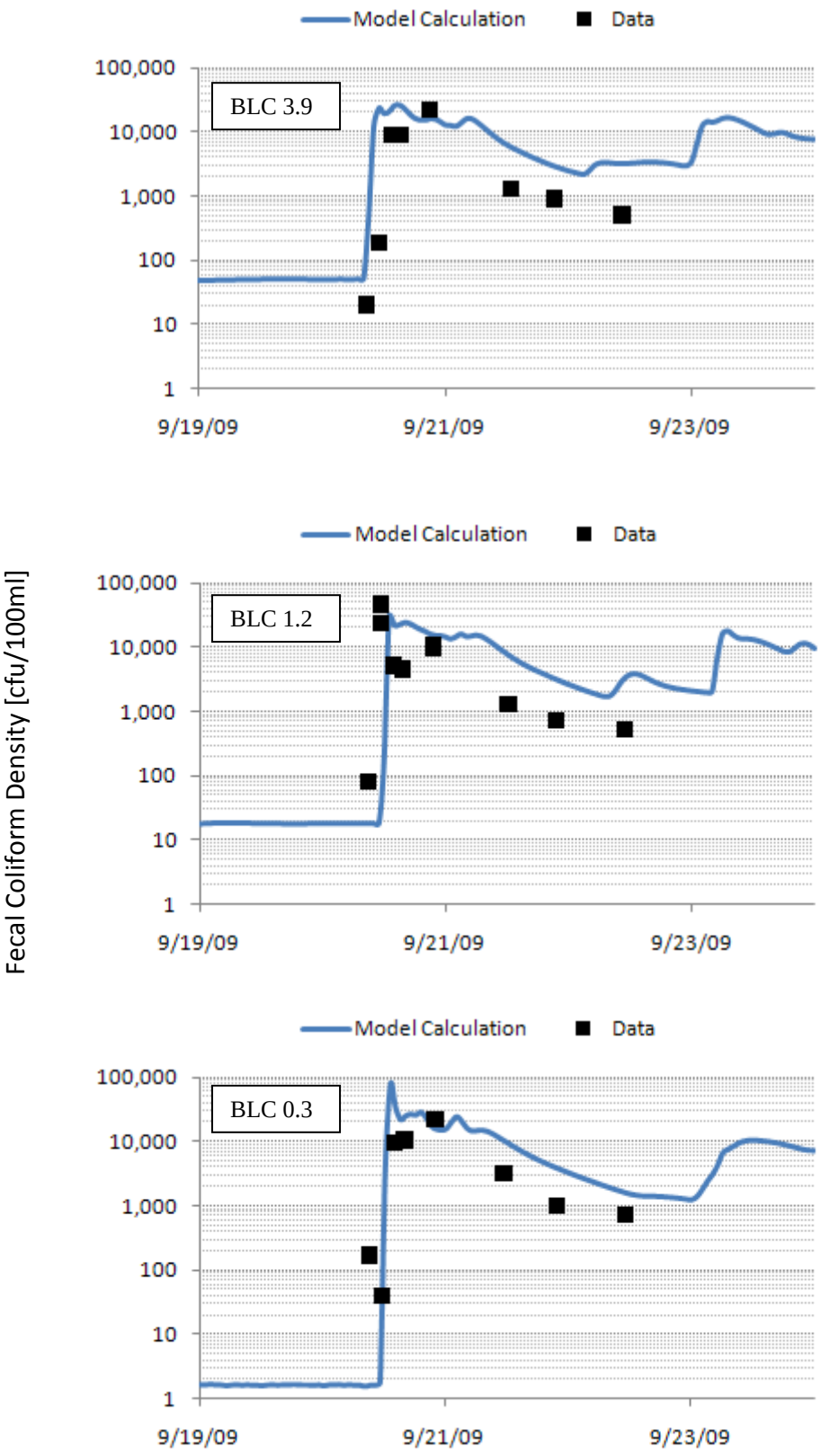

Figure 7: Banklick Creek Model-Data Comparisons – Event 2

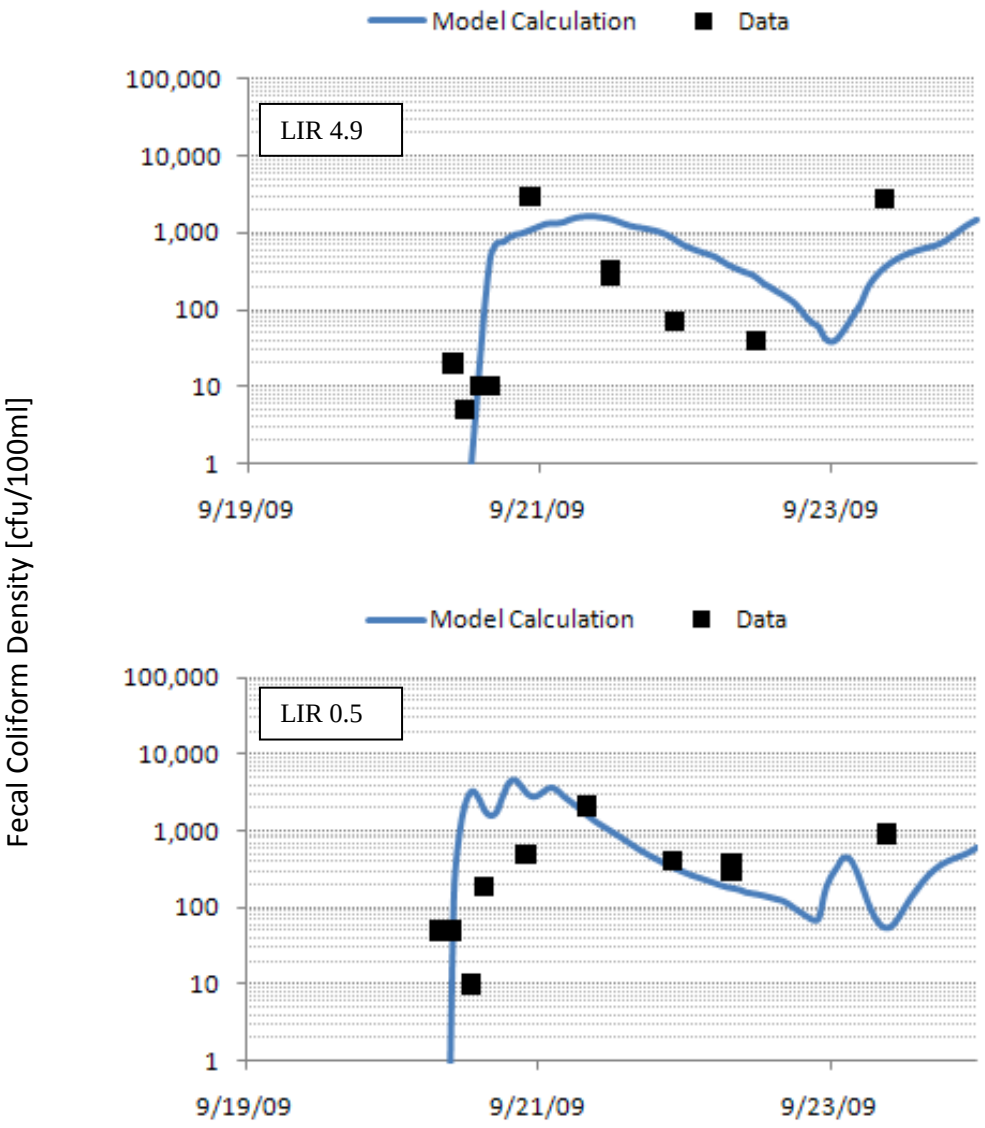

Figure 8: Licking River Model-Data Comparisons – Event 2

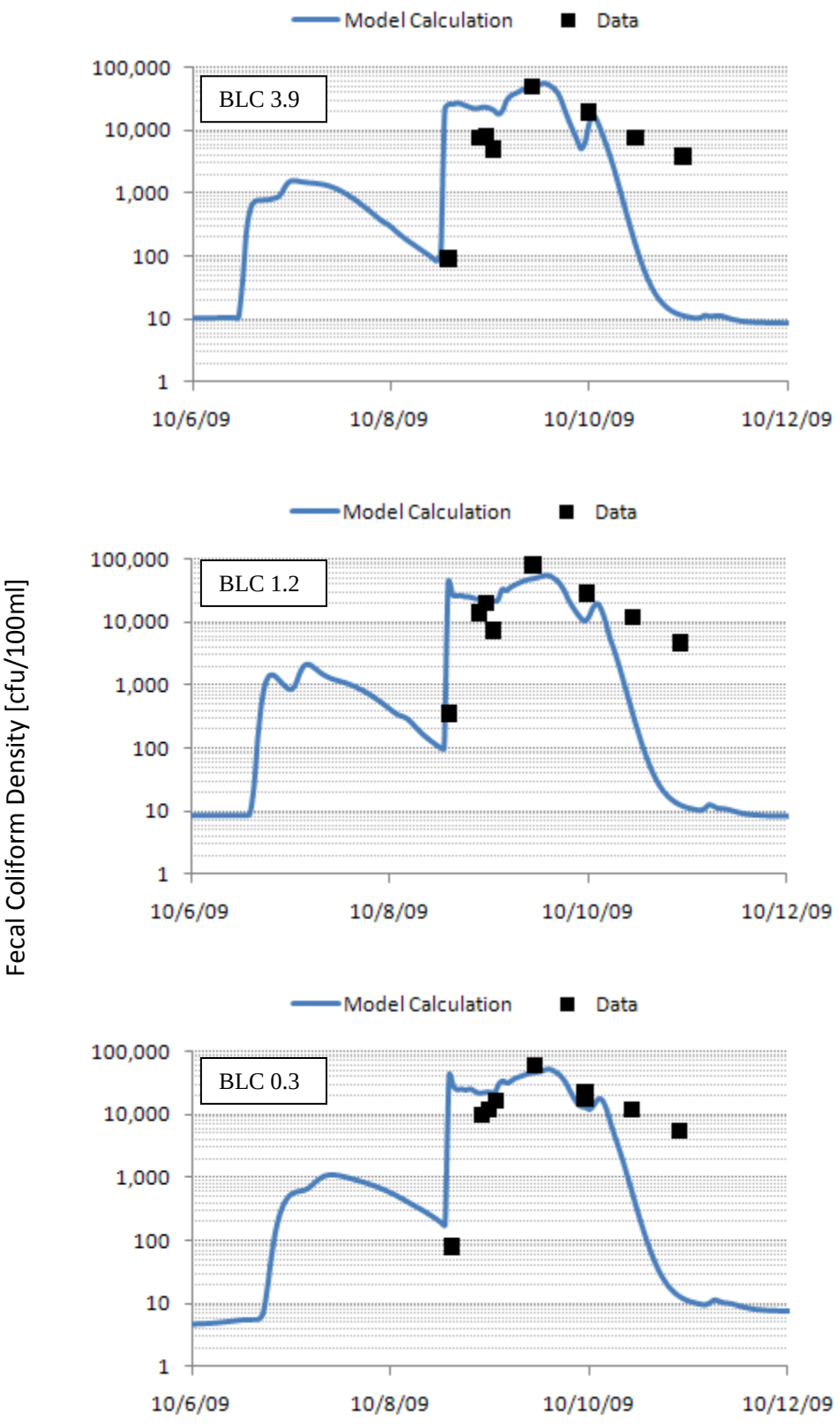

Figure 9: Banklick Creek Model-Data Comparisons – Event 3

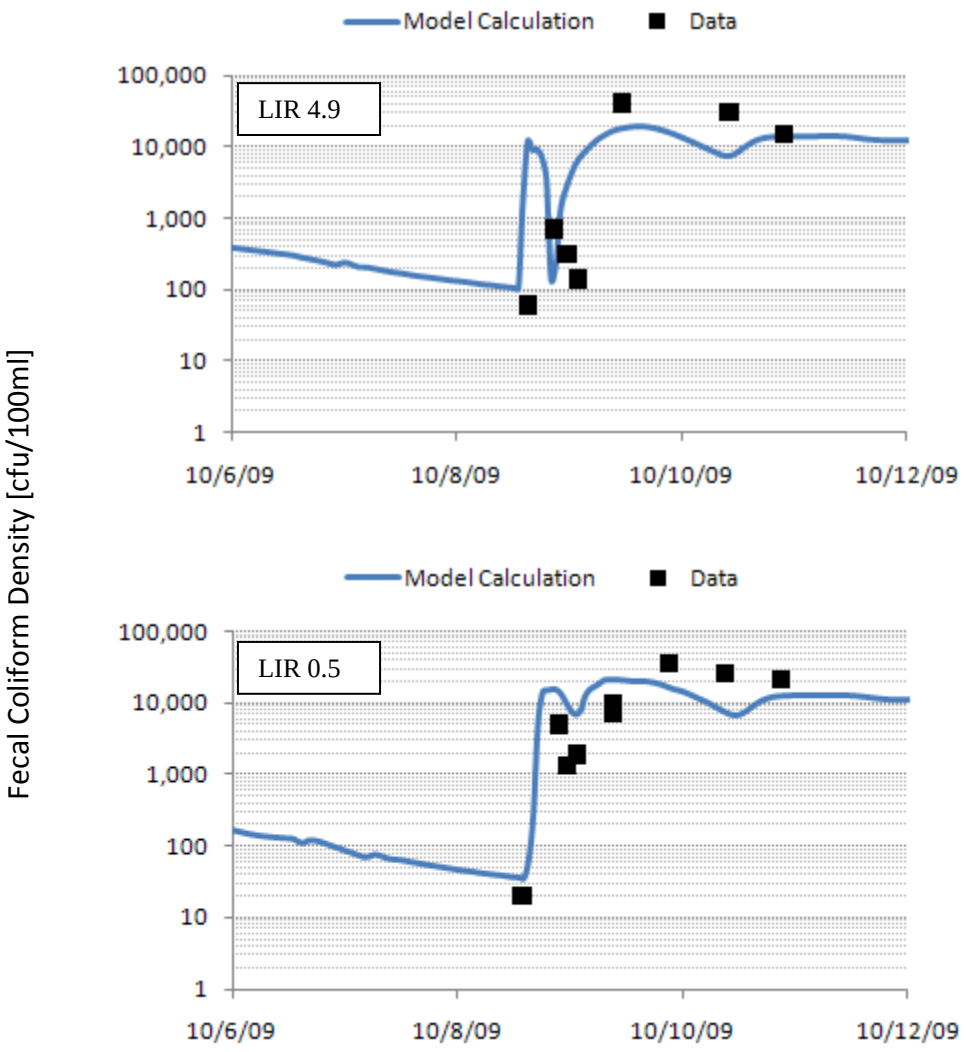

Figure 10: Licking River Model-Data Comparisons – Event 3

Conclusions

SD1 has actively monitored water quality in the Licking River, Banklick Creek and Ohio River during dry and wet weather to characterize the impact of wet weather sources, such as storm water, CSOs and SSOs, on instream water quality. Three wet weather surveys were conducted in 2009 for the lower Licking River and Banklick Creek. These surveys provided a robust dataset for use in verifying the EFDC model calibration. Comparisons between model-calculated fecal coliform densities and measured fecal coliform densities illustrate that the model reliably estimates water quality in the Licking River and Banklick Creek.

References

LimnoTech, 2008a. "Hydraulic Calibration of the EFDC Model of the Ohio River." Memorandum prepared by LimnoTech for SD1. March, 2008.

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LimnoTech
Water | Environment | Scientists | Engineers

DATE: November 30, 2008

Memorandum

FROM: Carrie Turner
TO: Jim Gibson (SD1)

CC: Mindy Scott (SD1)

SUBJECT: Taylor Creek SWMM Model Hydrology and Water Quality Calibration.

1 Summary

The Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are an important contribution for watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) long-term control plan. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

A model of the Taylor Creek watershed using the EPA's Storm Water Management Model (SWMM) Version 4.4h was originally developed in 2004 as part of a storm water plan (XCG, 2006) for the Taylor Creek watershed (also sometimes referred to as Woodlawn Creek). The model was developed to assess hydrology and hydraulics, primarily to address localized flooding resulting from surface runoff. In 2008, the model was upgraded to SWMM5 and water quality simulation capability was added. The updated model was recalibrated for both hydraulics and water quality to accommodate long term (e.g. one-year) simulations. This memorandum describes the updates to the Taylor model and presents a comparison of modeled versus measured values for flow, dry weather-related fecal coliform density, and wet weather-related fecal coliform density.

2 Background & Purpose

SD1 is currently faced with the need to evaluate a combination of water-related concerns in the different watersheds in its jurisdiction. These concerns include CSO and SSO control, storm water planning, flooding, habitat restoration, green infrastructure and site design, and compliance with instream water quality criteria. Understanding how to address these concerns often requires the simulation of three components - hydrology, hydraulics, and water quality - with detailed computer models. Using a single model framework that is able to simulate all three components increases efficiency and ensures consistent applications for each purpose.

As part of SD1's watershed characterization process in support of the Consent Decree, LimnoTech and Strand developed a draft recommendation for a unified modeling framework (EPA's SWMM5 model) for SD1 watersheds (LimnoTech, 2008a). SWMM was developed for urban areas to dynamically simulate rainfall-runoff for either single event or long-term (e.g. continuous) simulation. The runoff component is applied to a set of subcatchment areas comprising the watershed. These subcatchments receive rainfall and generate runoff and pollutant loads. The routing component of the model then transports the runoff through nodes and conduits that represent the site-specific series of pipes, open channels, storage basins, pumps and regulators. The model tracks the quantity and quality of runoff in each subcatchments, and the

501 Avis Dr.
Ann Arbor, MI 48103
734-332-1200
Fax: 734-332-1212
www.limno.com

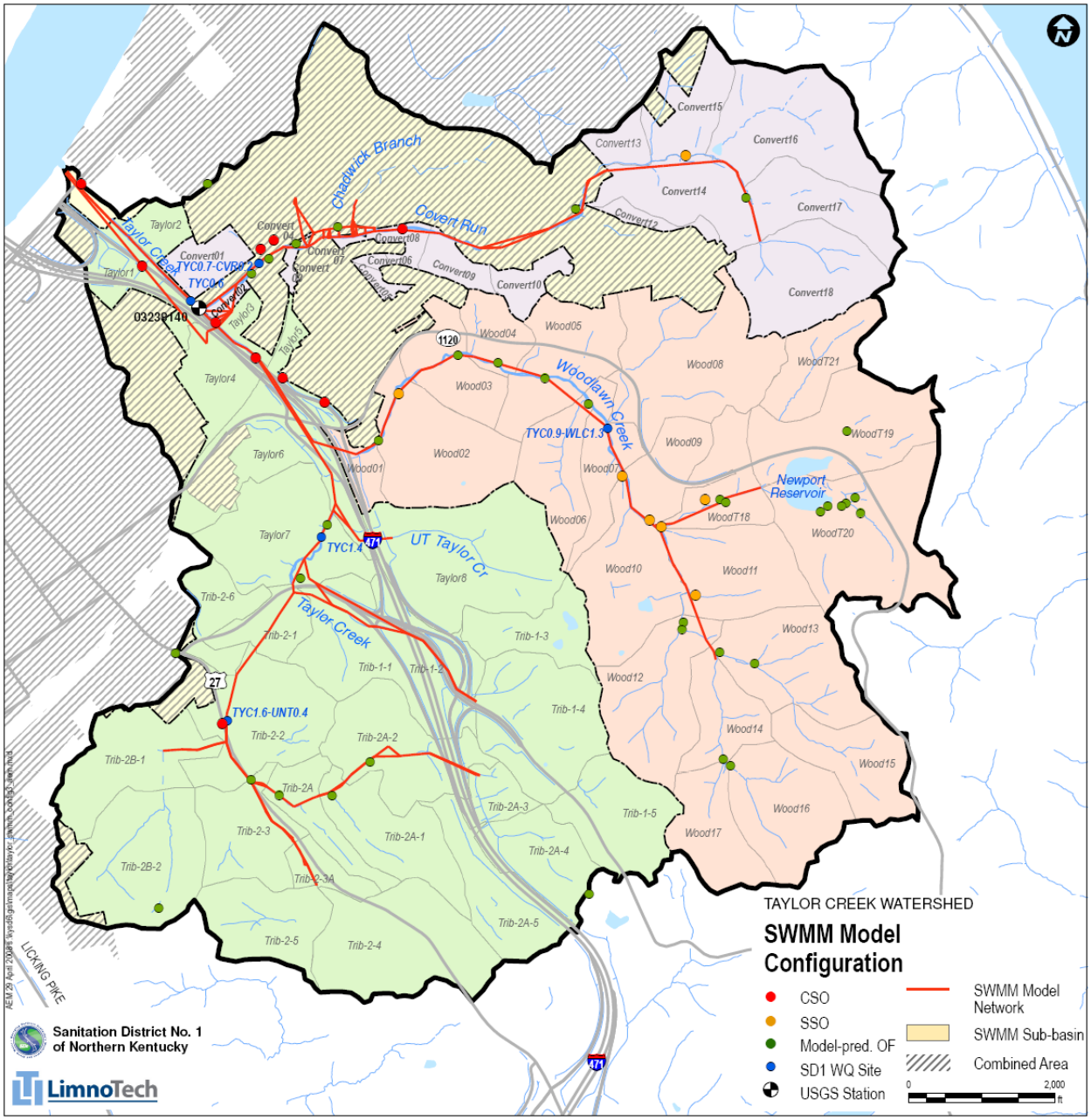
flow rate, depth and quality of water in each node and conduit at a user-specified frequency (e.g. hourly output). Additional details on the SWMM capabilities are described elsewhere (EPA, 2008).

The SWMM model was recommended as the most suitable framework for modeling hydrology, hydraulics, and water quality in SD1's service area because:

1) It can simulate the dynamic conditions of both closed- and open-channel flow;
2) It can account for backwater effects from flood-related ponding and from the Ohio River; and,
3) It can easily be modified to simulate the effects of storage-based and other controls, such as retention basins, used in storm water master planning and watershed planning.

The Taylor Creek watershed is highly urbanized and the stream network has undergone extensive hydromodification, including long sections that are culverted or piped. The Taylor Creek SWMM model describes the stream and storm water drainage network, and includes inputs from the adjacent combined sewer area. The model divides the watershed into three subwatersheds, Taylor Creek, Woodlawn Creek and Covert Run. The area within each subwatershed was divided into subcatchments as shown in Figure 1.

Figure 1. SWMM Model Configuration of Taylor Creek.



This memo summarizes the expansion of the model to include water quality predictions, the calibration process, and includes all changes to the model's hydrologic, hydraulic, and time series inputs to support the long-term simulations used in the watershed planning process.

3 Taylor Creek Model Updates

The structure of the SWMM model for the Taylor Creek watershed developed in SWMM4 was conceptually maintained for the Watershed Plans. However, the model required several revisions and updates to accommodate the water quality component and to reflect changes in the watershed since the

original model was developed. This section describes the modifications to the model and the upgrade to SWMM5.

3.1 *Data Updates*

The original model was developed in 2004. As part of the Watershed Plan activities, SD1 has embarked on an extensive data collection and standardization effort so the watershed characterization required by the Consent Decree incorporates the most recent data and information. The Taylor Creek model was updated to reflect new GIS data provided by SD1. These updates are summarized in Table 1.

Table 1. GIS data Used to Update Taylor Creek Watershed Model.

Data Type	Original 2004 Model[1]	Updated Data (2008 Model)[2]
Land Use/Land Cover	1995 SD1 data	2005 NLCD Land Cover Updated to 2007 with SD1 Data[3]
Streams	SD1 Storm lines GIS Coverage	2006 USGS High Resolution National Hydrography Dataset (NHD)
Slope	Northern Kentucky Area Planning; 1999 Ortho DTM update by GRW	2006 USGS National Elevation Dataset (NED) 2 foot contours
Soils	USDA SSURGO	USDA SSURGO
Impervious areas	Calculated % impervious from land use-based literature values (average, min, and max from several sources)[4]	Calculated Using SD1 Data[5]
Bacteria Unit Area Loads (UALs)	n/a	HSPF model of Banklick Creek[6]
Sewer network	~2004 SD1 GIS layers	2008 SD1 GIS layers[7]

Notes:

[1] This original version of the model was developed in 2004 to support storm water master planning.

[2] The model was updated in 2008 for use in analyzing control alternatives for the Watershed Plans.

[3] SD1 data included:

- Aerial photography from 2006 from the National Resource Conservation Service;
- Open space land delineation obtained in 2007 from the Ohio-Kentucky-Indiana Council of Governments;
- Building footprints provided by SD1 in 2007; and,
- Pavement provided by SD1 in 2007.

[4] See Section 3 of XCG, 2006 for details.

[5] Imperviousness was calculated using the SD1 data for building footprints, roads and aerial photos.

[6] The Banklick Creek model was developed in 2004 and updated in 2007. See LimnoTech, 2008b.

[7] SD1 layers comprising the separate sewer network include storm_conduits.shp and storm_structures.shp.

3.2 *Revisions to Hydrologic Model Catchment Parameters*

As shown in Figure 1, the Taylor Creek watershed was subdivided into three major subwatersheds, which were further divided into smaller units called subcatchments. Runoff volume from individual subcatchments is a function of slope, impervious area, infiltration (soil type), depression storage and flow path widths. Runoff quality is also a function of land use. Runoff from a subcatchment is routed to either another subcatchment or to a node representing a channel or pipe inflow point.

Inspection of the original Taylor Creek model suggested it included both the separate and combined sewer areas. However, SD1 has developed a detailed hydraulic model to simulate the combined area, so this area was removed from the SWMM watershed model to ensure that the storm water flow generated in the combined area was not double-counted by both the hydraulic and watershed models. The area of the

original model, with the CSO area included, was 2,702 acres. With the combined area removed, the updated model covers 2,256 acres. Removing the CSO area required re-delineating some catchment areas so that catchments which had previously contained portions of combined area could remain contiguous and route runoff properly to another subcatchment or channel node. This version of the model is shown in Figure 1.

The input characteristics of the subcatchments were updated using the data described in Section 3.1. The percent impervious area for each catchment was recalculated using SD1 GIS data for roads and building footprints (Table 1). After comparing the content of the GIS coverages for roads and building footprints with satellite images, it became obvious that most of the driveways, sidewalks and a number of small roads were missing in the GIS data. The missing areas were estimated to be 10% in the roads coverage and 30% in the building footprint coverage. Thus, the originally computed percent impervious area from roads was scaled by an additional 10% and the building footprint data were scaled by an additional 30% to account for the missing features. A comparison of the watershed-average impervious area for the model is shown in Table 2.

Table 2. Comparison of Impervious Area in Taylor Creek Watershed Model Versions.

Characteristic	Original 2004 Model[1]	Updated Model with New Data[2]	New Model Post-Calibration[3]
% Impervious Area	19.3%	21.1%	25.6%

Notes:

[1] This value was calculated using the original version of the model (XCG, 2006).

[2] This value was calculated using SD1 GIS data for building footprints and roadways only.

[3] This value was calculated by adjusting the building footprint area by an additional 30% and the roadway area by an additional 10%. These adjustments were determined from aerial photographs of the watershed taken in 2006.

The catchment connection points, slopes, and flow path widths were re-evaluated using a GIS topography (DEM data) layer provided by SD1. Flowpaths and slopes for each subcatchment were recalculated. The average subcatchment slopes used in the model increased from around 5.5% to 9%. Some catchment connections were changed from hydraulic model nodes to adjacent subcatchments, to more accurately reflect flow paths.

Infiltration characteristics are represented in SWMM using the Horton infiltration model. Horton infiltration minimum and maximum rates were re-calculated based on recommended parameter ranges in the SWMM manual. The maximum infiltration rate was based on the soil type and the expected vegetation covers for each land use while the minimum rate was based on soil type. The Horton's infiltration recovery parameter, was changed from its original expression as a constant value with units of days to values that more accurately reflect reasonable recovery times of the soil types in the watershed.

Hydrologic model parameters that remained unchanged included depression storage, held constant at 0.08 inches for impervious areas and 0.2 inches for pervious areas, and the Horton's infiltration decay rate of 4.5 hr^{-1}.

3.3 *Hydraulics*

The hydraulic portion of the model simulates channelized (stream) flow. Hydraulic features in the original model were developed using cross-sectional measurements in the stream network or pipe information in the enclosed sections of the stream (XCG, 2006). The channel conditions in Taylor Creek are fairly complex because flow in portions of the creek and its branches are routed to culverted pipes, daylighted into natural channels, or directed through hydromodified sections. In some portions of the

creek, a main channel and an overflow (high flow) channel exist side-by-side, and then join together at a downstream point.

No changes were made to the channel cross-sections and other parameters from the original model. However, the numerous damper elements added to the original hydraulic model, apparently added in order to reduce model instabilities, were removed from the model network. This did not have a significant effect on model stability or model results. Also, several closely-spaced model nodes, which necessitated several short channel segments, were eliminated, and the short channel segments were replaced with one long channel segment, which reduced model instability.

3.4 *Model Conversion*

The existing SWMM model was based on PC SWMM 2003, a commercial modeling framework based on EPA SWMM4. Because of the modeling needs of the project, the existing model was converted to EPA SWMM5, the most recent version of the model. To confirm model consistency between the model versions, the 100 year storm scenario of the old model was rerun on the converted EPA SWMM5 version. The results were not identical, due to model instabilities which were not as apparent in the prior model version. These problems have been resolved by edits to the hydraulic model (see section 3.3).

4 Calibration

The SWMM model was calibrated in a series of steps starting with the hydrologic (runoff) and hydraulic calibration, followed by the water quality calibration. The calibrations were confirmed, when possible, by comparing model results to an independent dataset from the one used for the calibration. This section describes the data, inputs and results of each of these calibration activities.

4.1 *Hydrologic Calibration*

The flow portion of the model was calibrated to flow and stage data from a continuous USGS/SD1 gage recently installed approximately 0.6 miles upstream from the mouth of Taylor Creek (USGS gage ID: 03238140), as shown in Figure 1. Only ten months of data (October 2007 – July 2008) had been collected at the time the Taylor Creek hydrologic calibration was conducted. The rating curve (flow predicted from stage) and inputs developed using data from this gage has more uncertainty than data from a gage with a longer period of record.

4.1.1 Hydrologic and Hydraulic Inputs

Rainfall data is input to the SWMM model to generate runoff during storm events. SD1 installed numerous rain gages in the three-county study area as part of its sewer system flow monitoring program. Data were collected at five-minute intervals between 2007 and 2008 (June 25, 2007 through June 30, 2008). One of these gages, #2 at the Superbowl, is located in the center of the watershed near Woodlawn Creek, and was used as the rainfall data source for the calibrations.

The downstream stage boundary at the confluence of Taylor Creek with the Ohio River was specified using Ohio River stage data from the USGS gage in Cincinnati (gage ID: 03255000). Additional flow inputs for the calibration include SD1 overflows and base flow. Hourly flow inputs for CSOs, SSOs and model-predicted overflow locations were specified using output from SD1's hydraulic model. Volumes were combined into a single time series in locations where multiple SD1 overflows discharge to the same model node. The total watershed base flow was calculated using flow data during dry weather conditions from the Taylor Creek USGS gage (gage ID: 03238140). Monthly averaged base flows were calculated and distributed to each model subcatchment on an area-weighted basis. For the two months where gage data are not available (August and September), base flows were interpolated from the months with data.

4.1.2 Calibration Results

The SWMM model was applied for the 10-month period comprising the USGS data collection period and results were compared to the gage data. Flows at the gage were developed using a preliminary stage-discharge rating curve developed by the USGS. (Note: USGS has recently published a rating curve for the gage and a comparison of the rating curve to the model curve will be conducted as part of the updates to the model over the next five year planning cycle). The model was calibrated to match dry weather flows as well as wet weather flow volumes and peak flows. Figure 2 shows a comparison of the distribution of gage and simulated flows over the ten-month simulation period. Table 3 show the distribution of modeled and measured hourly flows for key statistical measures during the full ten-month period and for the portion of the data record that corresponds to the recreation season (May-October). These comparisons demonstrate that the model is reproducing the central tendency of the measured values but overpredicts low flows and underpredicts high flows.

Figure 2. Distribution of Measured and Modeled Hourly Flows at USGS/SD1 Gage (03238140).

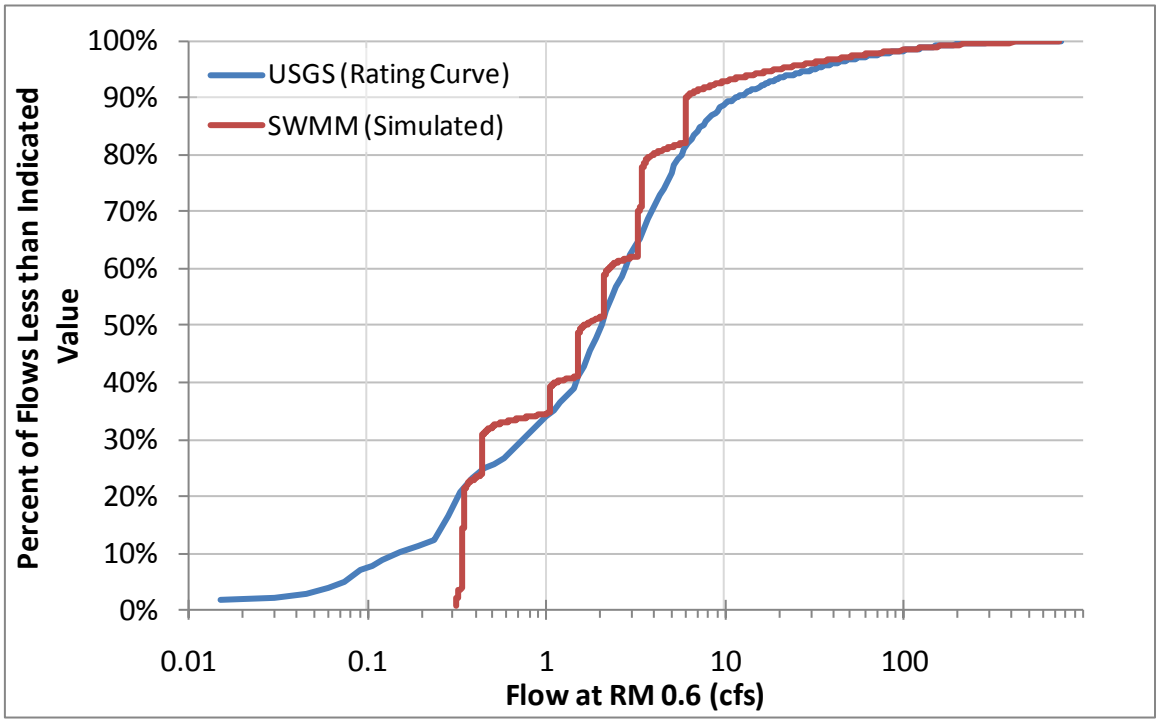


Table 3. Distribution of Measured and Modeled Hourly Flows at USGS/SD1 Gage.

Statistic	Full comparison period		Recreation season	
	Measured (cfs)	Modeled (cfs)	Measured (cfs)	Modeled (cfs)
Mean	7.86	7.24	5.83	5.79
Geometric Mean	1.68	1.67	0.60	0.66
5th percentile	0.08	0.34	0.02	0.32
25th percentile	0.45	0.44	0.11	0.34
50th percentile	1.91	1.65	0.39	0.34
75th percentile	4.56	3.43	1.65	1.05
95th percentile	30.78	18.91	19.69	17.63

The calibration results indicate that the model tends to underpredict the gage flows during wet weather. Peak flows and flow volumes for rainfall events of all magnitudes are usually slightly below observed values. The total simulated wet weather volume is 90% of the wet weather volume calculated from the gage data. In addition, the model predicts the timing of the wet weather response very well. Figure 3 shows the modeled peak flow rate compared to the corresponding measured value for storms generating a significant runoff volume (storms > 0.2"). Figure 4 shows a comparison of the modeled event volume to the measured event volume for the same storm events.

Figure 3. Comparison of Measured and Modeled Event Peak Flows at USGS/SD1 Gage (03238140).

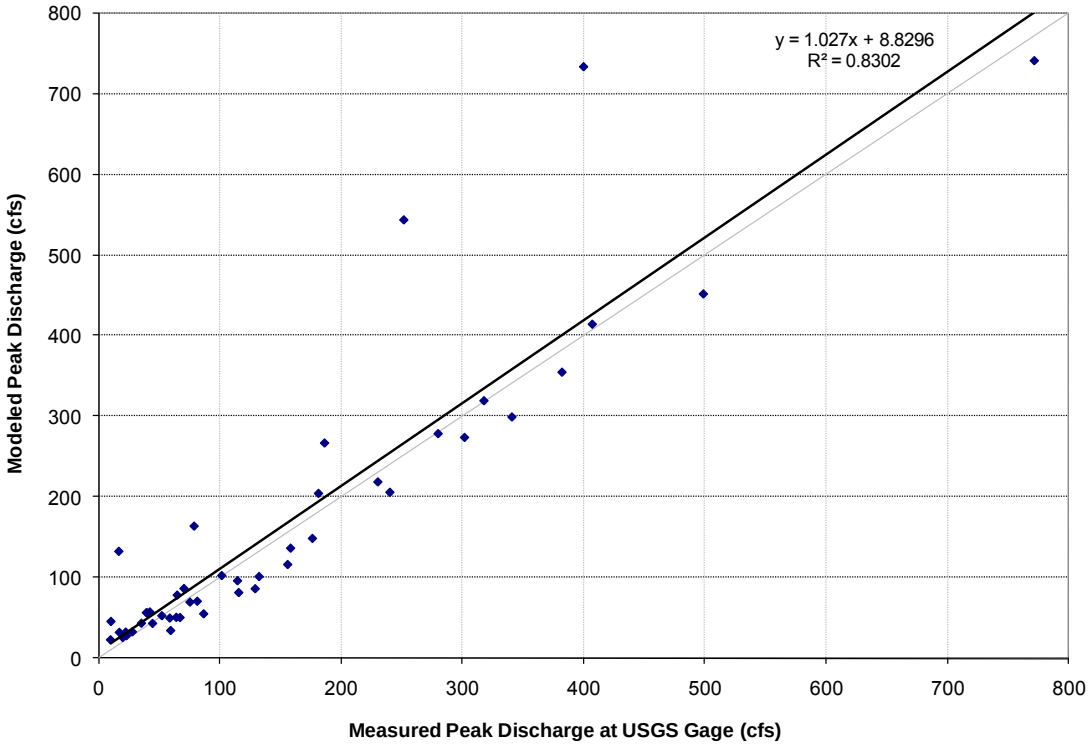
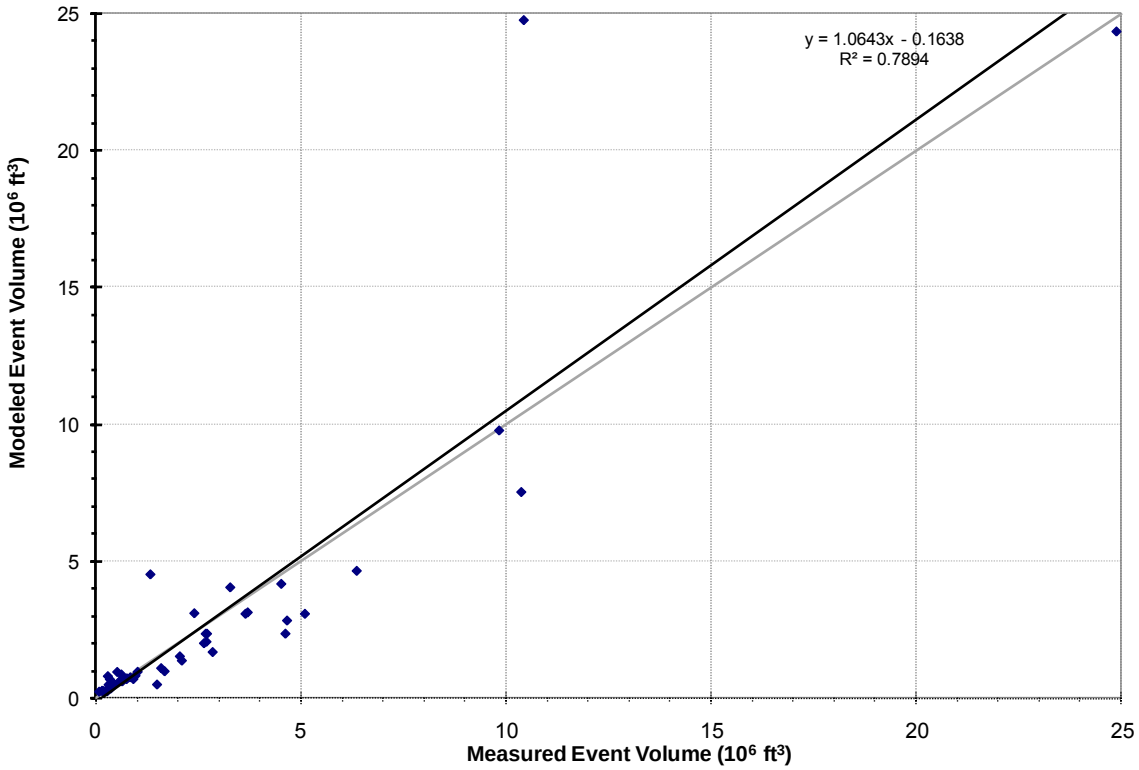


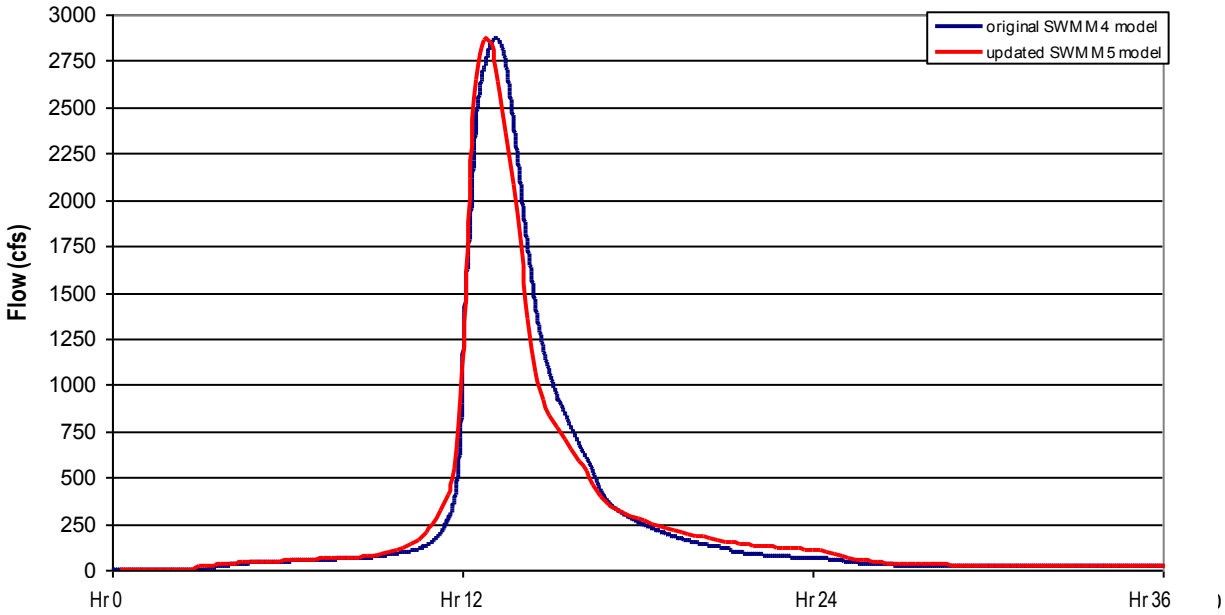
Figure 4. Comparison of Measured and Modeled Event Volumes at USGS/SD1 Gage (03238140).



If the model was able to perfectly predict the observed data, all of the points would fall on the 1:1 line (the gray line) in these figures. The slope of the regression lines shown in these figures (black line) indicate that the overall model fit to the data is within 10% of the 1:1 line. The calculated total flow volume for all wet weather events during the calibration period is 99% of the observed flow volume.

As a confirmation of the hydraulic calibration, the Soil Conservation Service (SCS) 24 hour type II 100 year design storm was modeled with the updated SWMM 5 model and compared with the previous SWMM 4 model. Figure 5 depicts the flow hydrograph for both models at the location of the USGS gage in Taylor Creek. The current model reproduces the hydrograph predicted by the previous version of the model. Note that this is not a true corroboration because the model results are not compared to an independent dataset. However, this analysis provides a useful assessment of model performance.

Figure 5. Comparison of Model Simulations of SCS 100-Year Design Storm at Taylor Creek Gage



4.2 *Water quality*

The water quality portion of the model was calibrated and validated to data from three wet weather events surveyed in 2007. Samples were collected at four locations, one each in the major branches of the watershed (Covert Run, Woodlawn Creek, and Taylor Creek) and one in an unnamed tributary of Taylor Creek. However, the model was calibrated to the data from the three downstream locations.

4.2.1 Water Quality Inputs

Wet weather sources of fecal coliform bacteria include both runoff sources and sources from the SD1 collection system. In SWMM, the runoff source load is calculated based on a build-up and wash-off routine for each land use/land cover (LULC) type specified in the model.

The parameterization for the existing land uses in the SWMM model is shown in Table 4. All land use parameters except the washoff for developed areas (footnoted) are literature values. The washoff parameters for developed areas were calculated by multiplying the literature values by a scaling factor of 15 to match the average storm water bacteria density calculated from the SD1 outfall sampling data (86,000 CFU/100ml).

Table 4. Fecal coliform Buildup / Washoff parameters used in the SWMM model

	Buildup		Washoff
Land Use	Rate Constant (cfu/acre/day)	Maximum Buildup Rate (cfu/acre)	Event Mean Concentration (cfu/100 ml)
Developed, open space	4.50E+09	2.30E+12	64,100
Developed, low intensity	9.70E+09	4.90E+12	124,000
Developed, medium intensity	9.70E+09	4.90E+12	124,000
Developed, high intensity	1.40E+10	7.00E+12	164,000

Land Use	Buildup		Washoff
	Rate Constant (cfu/acre/day)	Maximum Buildup Rate (cfu/acre)	Event Mean Concentration (cfu/100 ml)
Barren land (rock/sand/clay)	5.00E+07	2.50E+11	1,000
Deciduous forest	2.00E+07	1.00E+10	1,000
Evergreen forest	2.00E+07	1.00E+10	1,000
Mixed forest	2.00E+07	1.00E+10	1,000
Shrub/scrub	2.00E+07	1.00E+10	1,000
Grassland/herbaceous	2.00E+07	1.00E+10	1,000
Pasture/hay	3.00E+09	1.50E+12	10,000
Cultivated crops	1.80E+09	9.00E+11	67,000
Woody wetlands	2.00E+07	1.00E+10	1,000
Emergent herbaceous wetlands	2.00E+07	1.00E+10	1,000

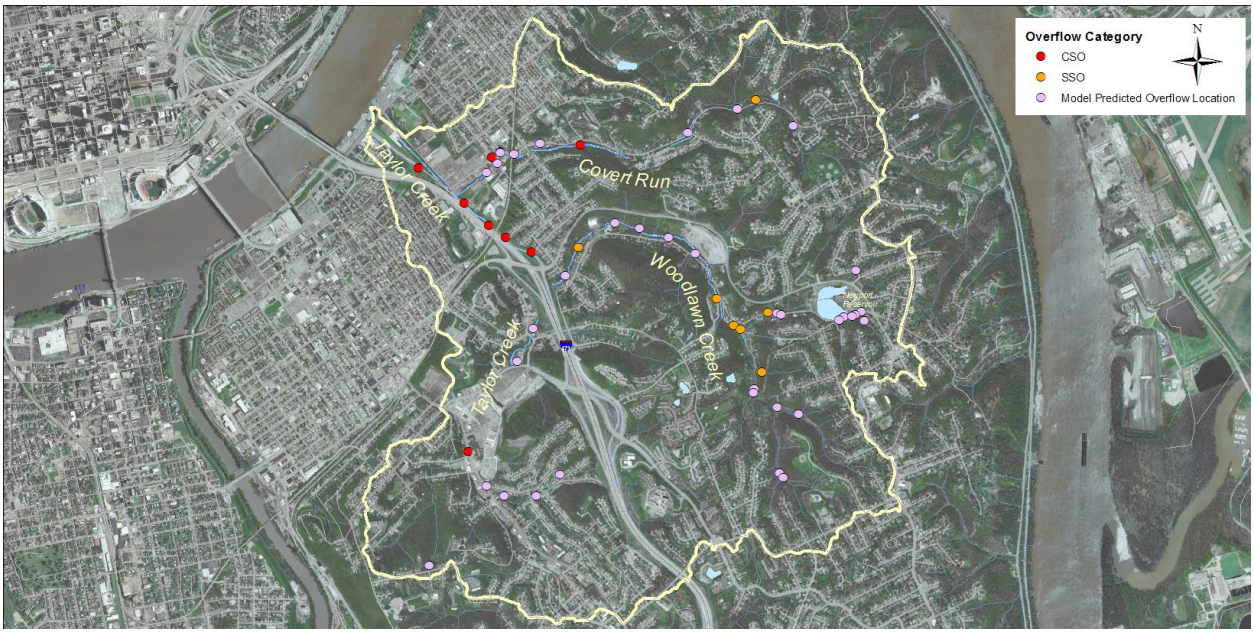
Limited fecal coliform data have been collected to characterize conditions in the creeks during dry weather. The averages of these data in each branch of the creek were used as background densities in the creek loads, as shown in Table 5.

Table 5: Average Fecal coliform Densities Calculated from Dry Weather Data

Waterbody	Fecal coliform Density (cfu/100 ml)
Covert Run	1,568
Lower Taylor Creek (~RM 1.45 to RM 0)	2,433
Upper Taylor Creek (Headwaters to ~RM 1.45)	3,410
Woodlawn Creek	1,083

The SD1 infrastructure sources are input to the watershed model based on output from the collection system models. These sources include CSOs, SSOs, and model-predicted overflow locations). The loads from these sources are calculated by assigning a fecal coliform density to modeled overflows. SD1 outfall monitoring data was used to determine the appropriate density for these sources. For the model calibration, the geometric mean densities of measured fecal coliform density in CSOs (682,000 cfu/100 mL) and SSOs (1,870,000 cfu/100 mL) were used. Because the model-predicted overflow locations occur in the sanitary sewer areas, they were assigned the SSO density. Figure 6 shows the locations of the SD1 infrastructure sources in the Taylor Creek watershed.

Figure 6. Location of SD1 Sources in the Taylor Creek Watershed.



Consistent with the other detailed models, a loss rate of 1.5/day was applied to the instream fecal coliform load to account for the physical and chemical losses, such as die-off, settling and resuspension.

4.2.2 Water Quality Calibration Results

Water quality in Taylor Creek has not been monitored as frequently or for as long as the other watersheds with detailed models (Banklick Creek, Licking River and Ohio River). The water quality portion of the model was calibrated by comparing predicted and measured instream fecal coliform densities at four locations in the Taylor Creek watershed during three separate storm events in 2007 (June 22-24, July 19-22, and October 22-26). During each event, multiple samples were collected at each location at event initiation, hour 2, hour 4, hour 6, hour 12, hour 24, hour 36 and hour 48. Because the October 2007 event was a large storm, additional samples were collected at hour 72 and hour 96. Samples were collected at one location in Woodlawn Creek, Covert Run, Taylor Creek and an unnamed tributary of Taylor Creek.

In general, the water quality model reproduces the magnitude and timing of the fecal coliform load during wet weather. Figure 7 shows the model and data comparison for the June 2007 event at the four sampling locations. Figure 8 shows the model and data comparison for the July 2007 event. Figure 9 shows the model and data comparison for the October 2007 event. As these figures illustrate, the model performs well in the October 2007 event but tends to underpredict observed densities in most locations in the other events. Also, the temporal trend of the data is difficult to reproduce in the model with the current understanding of the pollutant source loadings. For example, concentrations at the unnamed tributary start to increase approximately two days after the peak loadings that the model cannot reproduce without inputting additional bacteria load to the model at that time. These trends in the data are not well understood and are difficult to address within the model. Therefore, the model to data fit in some locations and portions of events is not very good. The difficulties in reproducing the timing of source load delivery to the creeks will not affect comparisons of relative benefits of different control scenarios that will be evaluated with the model. SD1 is continuing to collect data and information as part of their watershed planning efforts and the results of these activities will be incorporated into the model.

Figure 7. Model and Data Comparison for June 2007 Wet Weather Event.

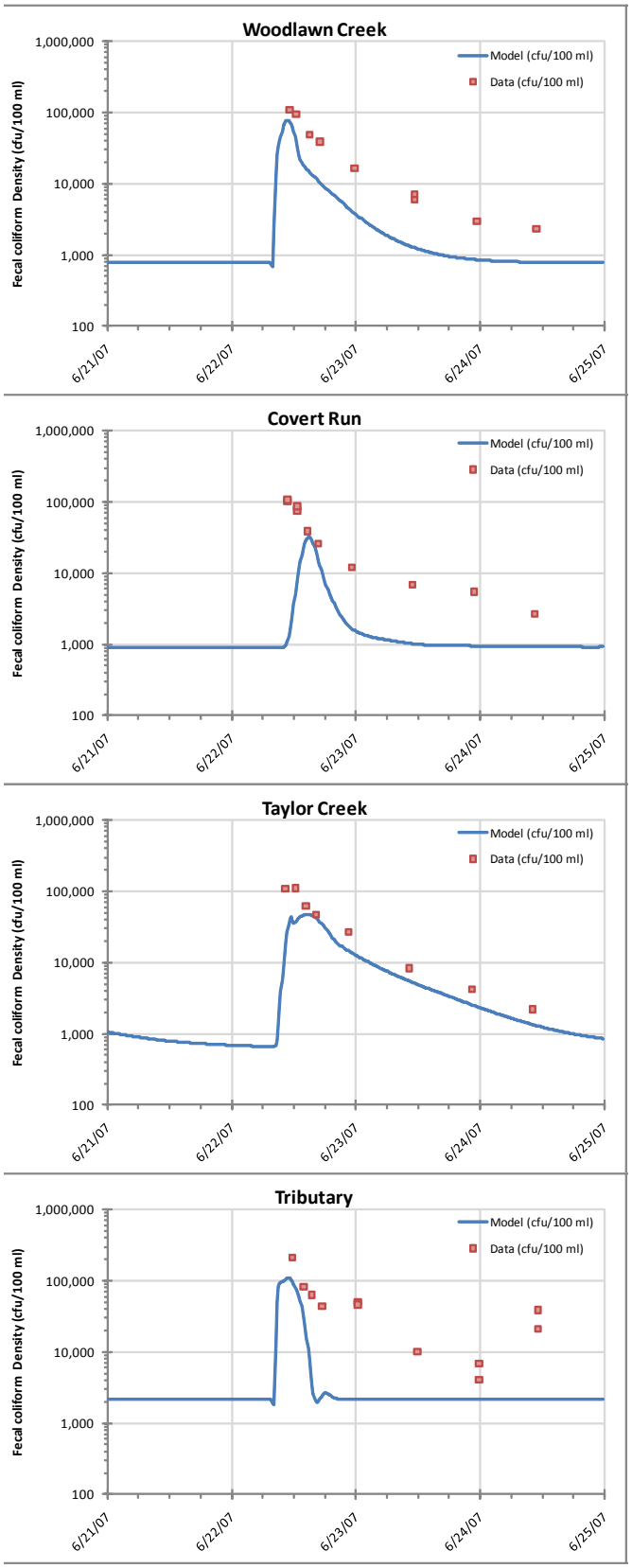


Figure 8. Model and Data Comparison for July 2007 Wet Weather Event.

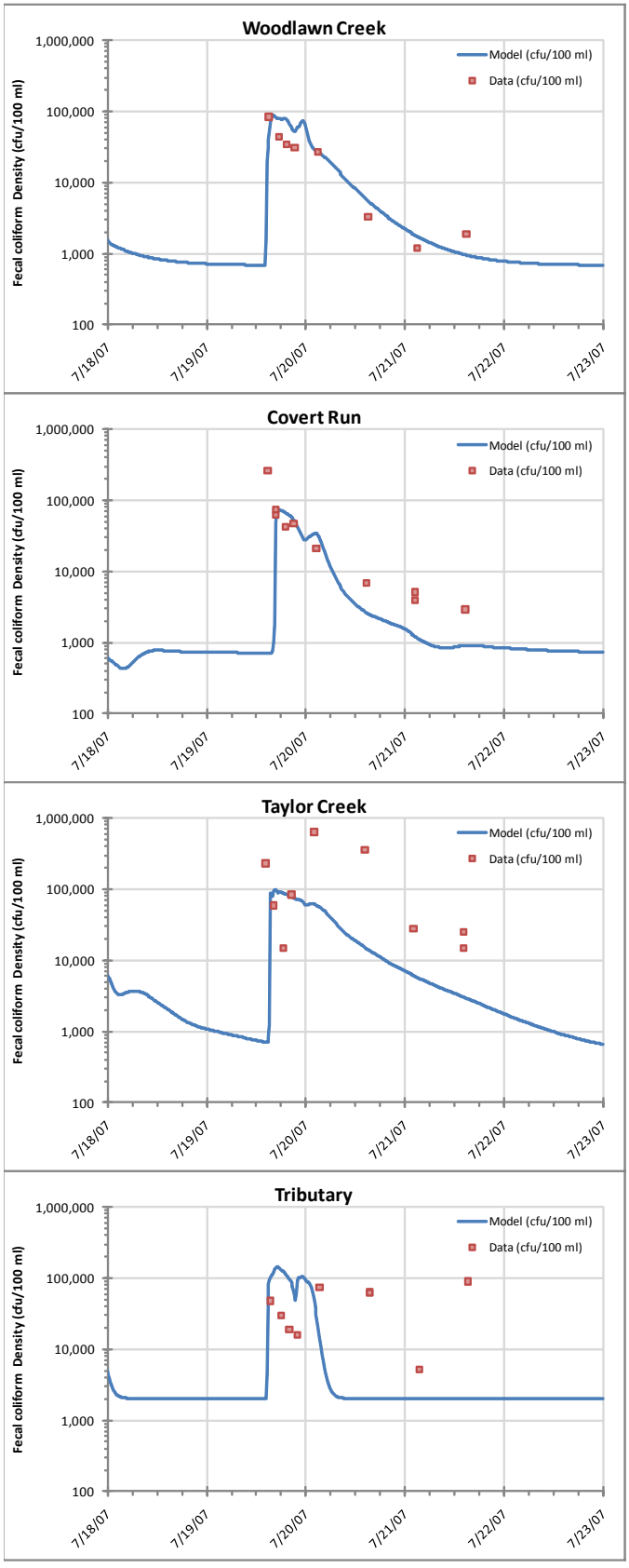


Figure 9. Model and Data Comparison for October 2007 Wet Weather Event.

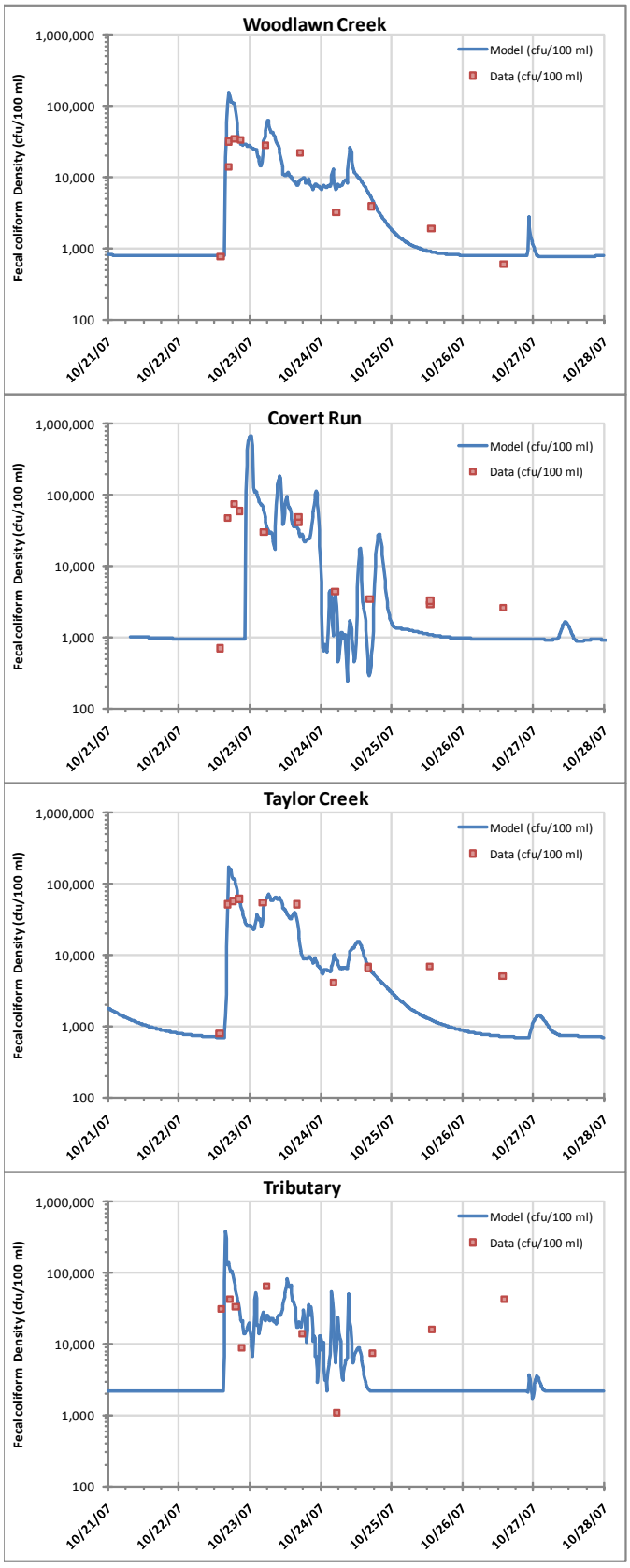


Table 6 presents a statistical summary of the model to data comparison for the calibrated Taylor model for samples collected during wet-weather events at each of the sampling locations. The table shows the observed and modeled geometric means, the observed and modeled exceedance of the single sample maximum criterion of 400 cfu/100 mL, and the mean relative and absolute percent differences of the logarithm transformed modeled and observed values. Comparing observed and modeled geometric means allows for an evaluation of how well the model is reproducing the central tendency of the measured values. The modeled geometric means tend to be lower at all of the sampled locations. The model reasonably reproduces the observed geometric mean in Woodlawn Creek but is lower in Taylor Creek, Covert Run and the unnamed tributary. Additionally, the model produces exceedance rates with the single-sample maximum similar to observed values. The magnitude of the mean Relative Percent Difference (RPD) of the log transformed values is less than 11% at all locations except Covert Run and the mean absolute percent difference is less than 20% at all locations, suggesting that the model is not grossly underpredicting observed densities.

Table 6. Summary statistics comparing predicted and instream fecal coliform measurements for the calibrated model.

Location	n	Observed Geomean (cfu/100 ml)	Model Geomean (cfu/100 mL)	% Observed Exceedance of SSMax	% Modeled Exceedance of SSMax	Mean Relative % Difference of Log Values	Mean Absolute % Difference of Log Values
Woodlawn Creek	30	11,122	9,195	100%	100%	-2.1%	8.8%
Covert Run	32	17,507	3,787	100%	97%	-15.0%	16.4%
Taylor Creek	29	23,735	10,616	100%	100%	-7.3%	10.1%
Tributary	30	26,141	8,184	100%	100%	-10.6%	18.2%

5 Conclusions

The information from the Taylor Creek watershed modeling effort can be summarized as follows:

- The SWMM model provides a reasonable reproduction of flow and fecal coliform densities in Taylor Creek for a range of environmental conditions;
- The calibration suggests that the methods used for quantifying fecal coliform loading are providing reasonable estimates of overflow and runoff source bacteria loads;
- The water quality model will be a useful tool for quantifying potential benefits of various control scenarios considered for the Watershed Plan.

The calibration to instream values indicates that it is capable of reproducing the timing and magnitude of most of the observed data. It is the best tool available for evaluating instream impacts from fecal coliform sources, including CSOs and SSOs, under a range of environmental conditions and control scenarios. The model is suitable for evaluating the water quality benefits of traditional infrastructure, green infrastructure, and watershed control alternatives in the Taylor Creek watershed.

6 References

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LimnoTech
Water | Environment | Scientists | Engineers

DATE: September 28, 2010

MEMORANDUM

FROM: Carrie Turner, Jeremy Grush, Steve Skripnik

TO: Jim Gibson, Mindy Scott

CC: Adrienne Nemura

SUBJECT: Development of an HSPF Watershed Model of the Lower Licking River watershed

Introduction

The Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are an important contribution to watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) long-term control plan. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

An HSPF model of the watershed corresponding to the southern portion of the Licking River watershed in Campbell and Kenton Counties was developed by LimnoTech to provide mechanistic model-based inputs into the detailed EFDC model of the lower Licking River (which also includes lower Banklick Creek, and the Ohio River). The purpose of these models is to determine the relative importance of CSO and SSO sources compared to upstream sources in the Licking River watershed under differing environmental conditions. The EFDC river and HSPF watershed models may also be used to respond to the Ohio River bacteria TMDL and issues that affect SD1 related to nutrients in the Gulf of Mexico. This memorandum describes the development of the HSPF watershed model by discussing model configuration, model calibration, and future model applications.

Lower Licking River Watershed Model Overview

The Lower Licking River Watershed Model represents approximately seven percent of the entire Licking River watershed (Figure 1). The watershed model includes areas in Campbell, Kenton, Boone, Grant and Pendleton Counties. The model covers most of the Licking River watershed within the SD1 service area but excludes the Banklick Creek watershed, Threemile Creek watersheds, and drainage near the Licking River mouth within sewered areas. These areas are represented in other existing models: a separate HSPF model has been developed for Banklick Creek, the Threemile Creek watershed is modeled in the Ohio River Tributary HSPF watershed model, and the drainage near the Licking River mouth is part of SD1's combined sewer service area so it is modeled with a collection system model.

Table 1 summarizes characteristics of the Lower Licking River Watershed Model. As the table illustrates, the watershed is largely rural and undeveloped (in contrast to the Banklick Creek watershed, which is more developed. (e.g. Banklick Creek is 10% impervious (vs. 1.6%), 20% of area is residential and commercial (vs. 3% in the Lower Licking River watershed)).

501 Avis Drive
Ann Arbor, MI 48108
734-332-1200
Fax: 734-332-1212
www.limno.com

Table 1: Modeled Licking River Watershed Area Characteristics

Watershed Characteristic	*Lower Licking River Watershed Model Description*
Surface Area	263.3 square miles
Average Slope	5.5%
Percent Impervious	1.6%
Major Land Cover Types	Forest (56%), Pasture (29%), Developed Open Space (8%)

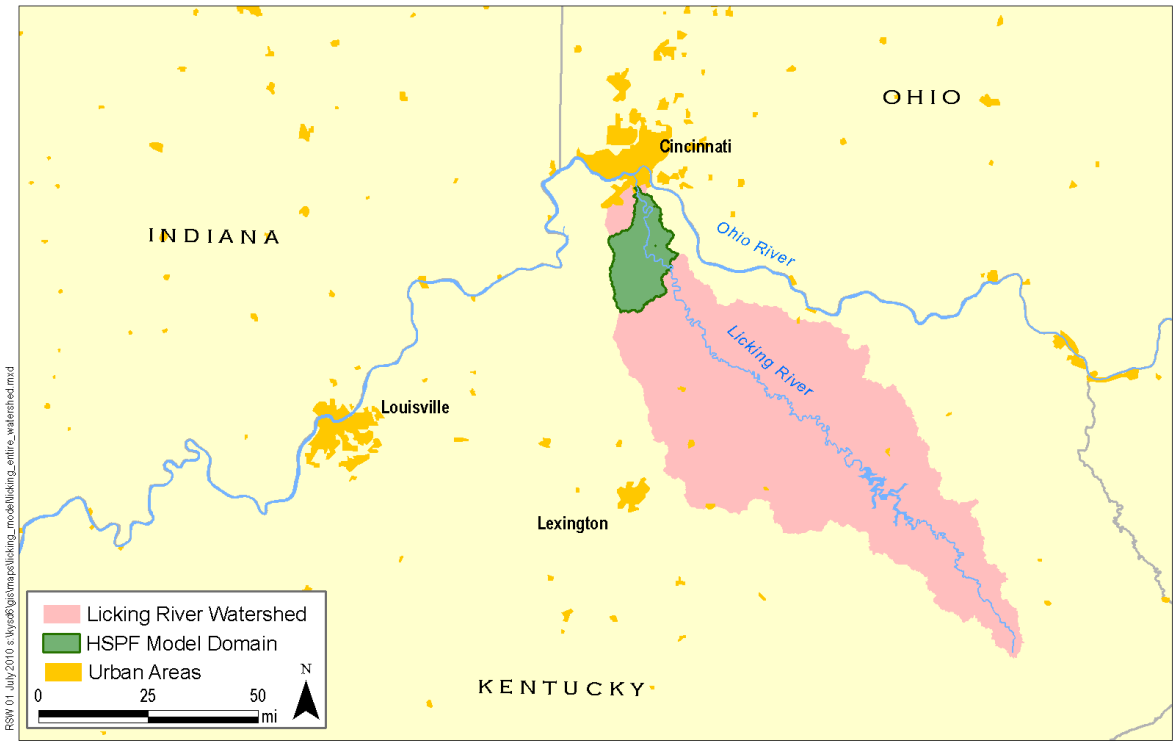


Figure 1: Overview of Licking River Watershed and Modeled Area

This model domain has been subdivided into seventy-one model subwatersheds based on fourteen-digit hydrologic units. The average subwatershed size is 3.7 square miles. Figure 2 illustrates the division of the Lower Licking River Watershed Model into modeled subwatersheds. In the model, each subwatershed is attributed with distinct physical and hydrologic characteristics, such as average surface slope or percentage of impervious area, that define a subwatershed's response to rainfall events.

Note that a portion of the Lower Licking Watershed Model domain overlaps the portion of the Licking River simulated with the EFDC model. The models overlap so that the areas draining directly to the EFDC model outside of the combined sewer system area can be more realistically modeled in the watershed model than with existing tools. Also note that the EFDC model has been extended up the Licking River to approximately river mile 11 so that the full range of Ohio River backwater effects on the Licking River can be simulated with the EFDC model.

This HSPF model simulates runoff of water and washoff of bacteria from the land surface, flow and bacteria routing through streams, and instream losses of bacteria. Land surfaces in this model are either described as pervious or impervious. Impervious surfaces transmit all rainfall that reaches the land surface to runoff, while pervious surfaces transmit a portion of the rainfall depending on surface and soil properties, with the remaining portion routed to groundwater, interflow, evaporation and transpiration. Instream bacteria loss is described using a first-order decay rate.

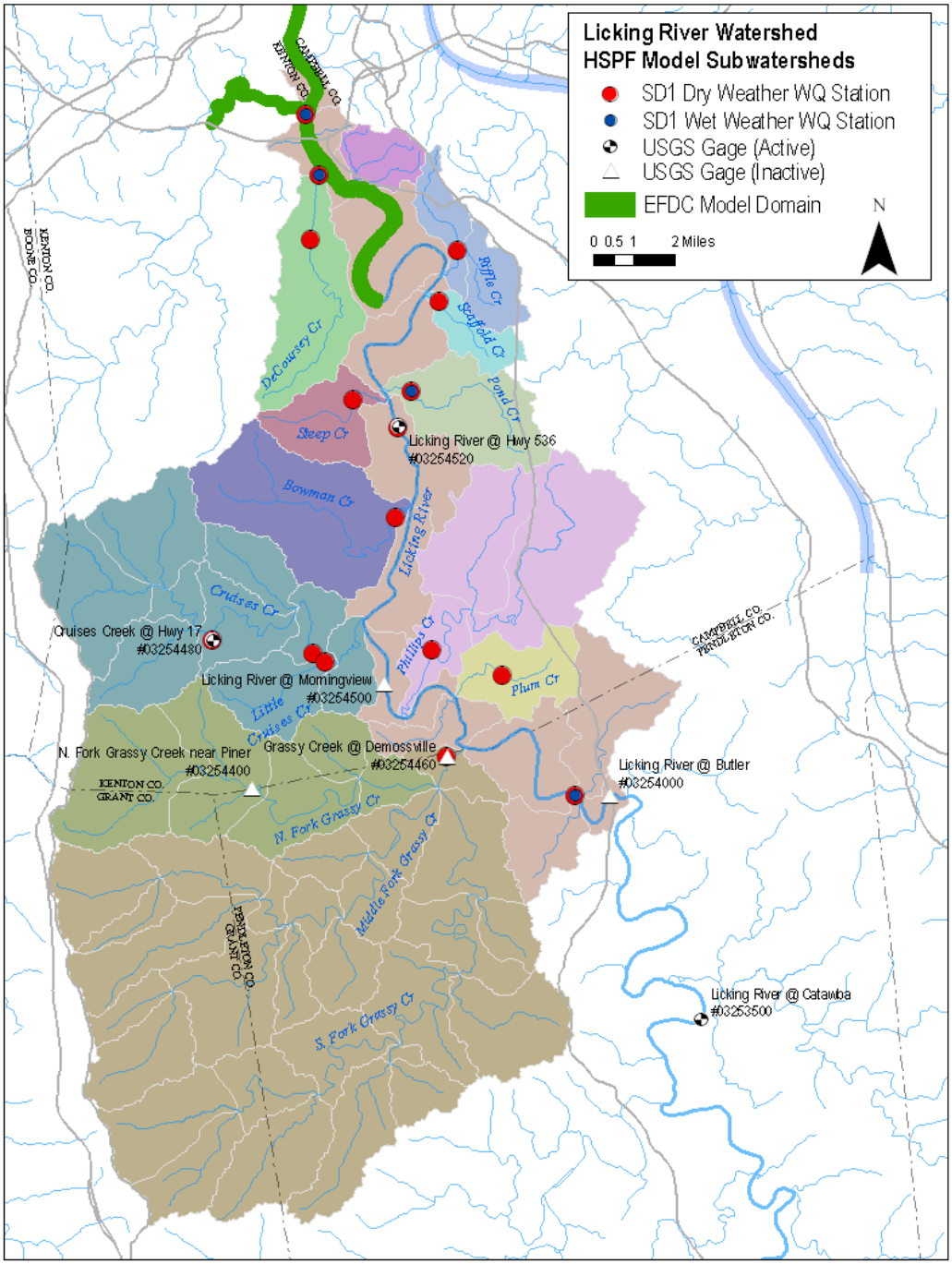


Figure 2: Overview of Licking River Watershed Model Domain

Model Input Development

Site-specific model inputs were developed to describe local conditions in the Licking River watershed. The model capitalizes on the extensive data collection efforts that SD1 has engaged in as part of the Watershed Plan activities. The following list summarizes types of information that were compiled and applied for this model:

- Land use and land cover information
- Topographic data
- Meteorological data
- Stream geometry
- River flow data
- Instream fecal coliform densities

Each dataset applied in the model is described in detail below.

Land use and land cover information
Both land use and land cover (LULC) data were available for the majority of the modeled watershed. Land use data were supplied from individual counties. Land cover data were based on the 2005 NLCD Land Cover dataset that was updated to 2007 conditions with SD1 data (same dataset used in the Banklick and Taylor watershed models). In locations where land use data were unavailable (e.g. Grant County), these characteristics were estimated by assuming they were similar to nearby locations where data were available. For instance, land use in Grant County was assumed to be distributed similarly as it is in Pendleton County. Because seventy percent of Pendleton County areas that are classified as low intensity development are residential, then this same fraction of areas classified as low intensity development in Grant County were also considered residential.

Land use and land cover information was simplified so that sixteen types of pervious land surfaces were simulated in the model. These sixteen types of land surfaces have distinct hydrologic and water quality characteristics. For instance, a land surface classified as 'high intensity – industrial' typically contributes more runoff than a forested land surface. These two land surfaces also differ in the amount of bacteria that build up on the land surface over time. Differences in land surface and soil characteristics are largely what drive the complex response between rainfall, runoff and water quality constituents in a rural watershed like this one. In contrast, a watershed that is highly developed is less dependent on soil characteristics because more of the land surface is impervious. Figure 3 illustrates the distribution of combined land use and land cover data that applied in the model.

Topographic data
Topographic data were available for the entire modeled area and were used to estimate the average land slope in each subwatershed and the average channel slope in the each creek. To describe watershed topography, a 2006 National Elevation Dataset (NED) digital elevation model (DEM) was used.

Meteorological data
Meteorological data was obtained from the National Climactic Data Center (NCDC) for a monitoring station at the Cincinnati/Northern Kentucky International Airport (WMO ID = 72421) for the following parameters required as input to the watershed model: air temperature, cloud cover, precipitation, dew point, and wind speed and direction. Potential evapotranspiration (PET), another required input, was calculated as a function of air temperature and daylight hours (based on latitude) using the Hamon PET

method (Humel, et al. 2001). Solar radiation inputs were calculated as a function of cloud cover and daylight hours (based on latitude) using the Hamon algorithm contained in model's WDMUtil tool.

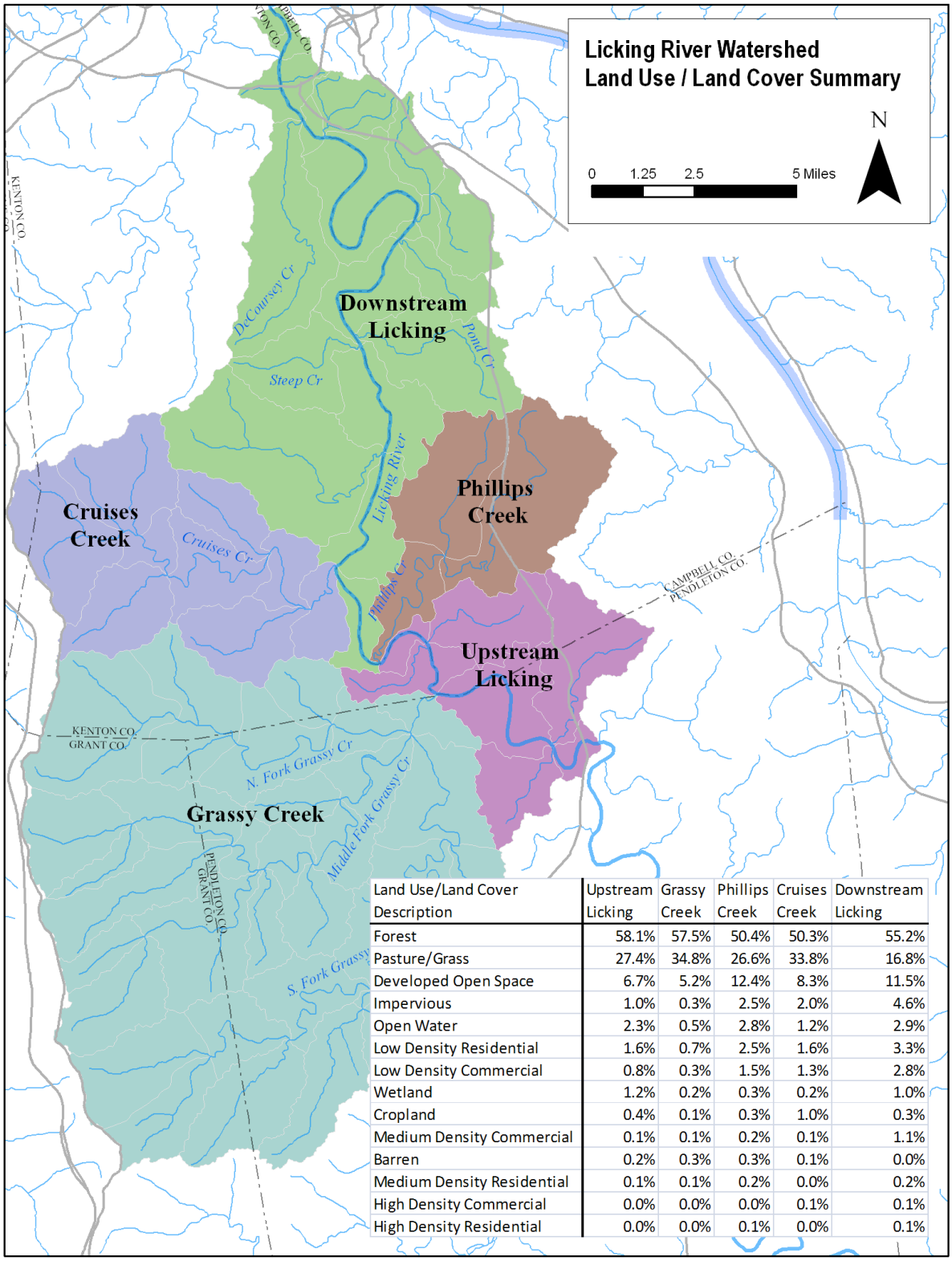
Precipitation data from the Cincinnati Northern Kentucky Airport (NWS WMO gage ID 72421) was supplemented by precipitation data at the USGS gages at Cruises Creek (gage number 03254480) and Licking River (gage number 03254520). Precipitation data from this USGS gages were used to calibrate the model instead of the airport precipitation data because the USGS rain gages are located within the watershed, while the airport is several miles outside the watershed. The rainfall data from the Licking River gage were similar in total rainfall depth, maximum intensity and storm duration to the data from the Cruises Creek gage for the water quality calibration periods (see details and discussion associated with Table 6). However, the Licking River gage period of record begins with water year 2007 while the Cruises Creek gage period of record begins with water year 2000. Model hydrology was calibrated to the Cruises Creek watershed, so applying this nearby Cruises Creek rainfall data to the model was ideal for hydrology and water quality model calibration. No seemingly erroneous or anomalous data were recorded at the Cruises Creek gage during the period used to calibrate the model.

Stream Geometry

The geometry for stream reaches in the model was developed using a combination of aerial photographs, elevation data, and published values. The stream bed was assumed to be trapezoidal with a slope calculated from the DEM file. River widths were estimated from aerial photography. For the Licking River, additional bed elevation information was taken from FEMA flood elevation studies of the area. Note that the geometry is not used directly in the watershed model but rather to develop rating curves (called F-Tables) relating flow to depth, which is described in further detail in the hydrology calibration section.

Licking River Upstream Boundary Inputs

Because this watershed model only represents the lower Licking River, and not the entire Licking River watershed, it was necessary to input river flow and bacteria loads into the upstream reach of the watershed model. Licking River flow data was obtained from the USGS for the Licking River gage near Catawba, Kentucky (gage number 03253500). Daily-average flow data were used as the upstream boundary flow record. Upstream boundary bacteria densities were estimated based on instream fecal coliform measurements made by SD1 (2006-2009).



Land Use/Land Cover Description	Upstream Licking	Grassy Creek	Phillips Creek	Cruises Creek	Downstream Licking
Forest	58.1%	57.5%	50.4%	50.3%	55.2%
Pasture/Grass	27.4%	34.8%	26.6%	33.8%	16.8%
Developed Open Space	6.7%	5.2%	12.4%	8.3%	11.5%
Impervious	1.0%	0.3%	2.5%	2.0%	4.6%
Open Water	2.3%	0.5%	2.8%	1.2%	2.9%
Low Density Residential	1.6%	0.7%	2.5%	1.6%	3.3%
Low Density Commercial	0.8%	0.3%	1.5%	1.3%	2.8%
Wetland	1.2%	0.2%	0.3%	0.2%	1.0%
Cropland	0.4%	0.1%	0.3%	1.0%	0.3%
Medium Density Commercial	0.1%	0.1%	0.2%	0.1%	1.1%
Barren	0.2%	0.3%	0.3%	0.1%	0.0%
Medium Density Residential	0.1%	0.1%	0.2%	0.0%	0.2%
High Density Commercial	0.0%	0.0%	0.0%	0.1%	0.1%
High Density Residential	0.0%	0.0%	0.1%	0.0%	0.1%

Figure 3: Summary of Licking River Land Use and Land Cover Data

Model Calibration

Model calibration was performed in two steps: first, a hydrologic calibration followed by the water quality calibration, which builds on the calibrated hydrology model.

Hydrology Calibration

The goal of hydrologic calibration is to ensure that the model accurately represents the transport of water from precipitation to river flow. The model domain includes two active gages: one at Cruises Creek (USGS gage 03254480) and one in the Licking River near Alexandria (USGS gage 03254520). The flow measured at the Licking River gage is largely comprised of flow from upstream and is not as responsive to precipitation events as the gage at Cruises Creek. Therefore, the modeled flow at the Cruises Creek gage was used as a hydrologic calibration location and compared to the monitored flow at the same location using several metrics. The parameters applied in the calibrated Cruises Creek watershed were then applied throughout the model domain. The hydrologic calibration was performed in several steps, as described below.

Land runoff

Water runoff from the land surface in HSPF is governed by several variables; the major calibration parameters and values are shown in Table 2. Initial values for these variables were based on literature values and calibrated values from the Banklick Creek HSPF watershed model. These values were adjusted within the accepted range until the most accurate calibration to the flow observed at the Cruises Creek USGS gage was achieved.

Table 2: Major HSPF Hydrology Calibration Parameters

Parameter	Description	Acceptable Range[1]	Calibrated Model Value	Source
INFILT	Infiltration capacity of the soil	0.0001 – 100.0 in/hr	0.02 – 0.35 in/hr	Range depends on soil type and land cover
LZSN	Lower zone nominal soil moisture storage	0.01-100 in	3.0 in	Calibrated value based on soil type
LSUR	Length of the assumed overland flow plane	1 ft – no limit	100 ft	Calibrated value based on watershed shape.
SLSUR	Slope of the assumed overland flow plane	10^{-7}-10 ft/ft	Varies	Actual watershed surface slope
AGWRC	Basic groundwater recession rate	0.001-0.999 day^{-1}	0.97 – 0.98 day^{-1}	Calibrated based on observed flow hydrograph
DEEPER	Fraction of groundwater lost to deep (inactive) groundwater	0.0-1.0	0.0	Calibrated based on annual water balance
BASETP	Fraction of PET which can be satisfied by baseflow	0.0-1.0	0.04	Estimated from land cover and calibrated based on annual water balance
AGWETP	Fraction of remaining PET which can be satisfied from active groundwater storage	0.0-1.0	0.01	Estimated from land cover and calibrated based on annual water balance

Parameter	Description	Acceptable Range[1]	Calibrated Model Value	Source
CEPSC	Interception storage capacity	0.0-10.0 in	0.10 – 0.25 in	Based on land cover and seasonal growing patterns
UZSN	Upper zone nominal storage	0.01 – 10.0 in	0.1-1.0 in	Estimated from land cover and calibrated based on annual water balance
NSUR	Manning's n for overland flow	0.001-1.0	0.20-0.37	Estimated based on land cover
INTFW	Interflow inflow parameter	0.0 – no limit	1.0-2.0	Estimated based on soil and calibrated based on observed flow hydrograph
IRC	Interflow recession parameter	10^{-30} – 0.999	0.4-0.6	Estimated based on soil and calibrated based on observed flow hydrograph
LZETP	Lower zone E-T parameter. An index to the density of deep-rooted vegetation	0.0 – 0.999	0.10-0.70	Estimated based on land cover and calibrated based on observed flow hydrograph

1 – Source: USEPA, 2000 and Bicknell, et al., 2005

Stream Routing

Water in the water bodies are routed from upstream to downstream using relationships between flow and channel geometry stored in tables (called FTABLES) in the model. These tables were developed using stream geometry methods described above and slopes taken from the local 30-meter Digital Elevation Model (DEM) from the National Elevation Dataset. Because these values were based on physical measurements, they were not changed during model calibration.

Calibration Performance

The hydrology was calibrated to flow data from Cruises Creek by comparing simulated flow to measured flow at the gage for the five year period 2000-2005. The calibration period was selected as an extended period that provides a wide range of hydrologic conditions including high flow events, low flow events, extended dry periods, and extended wet periods. The gage location is shown in Figure 2.

The model calibration was evaluated in terms of total annual flow, monthly flow, and daily flow. Table 3 shows the distribution of modeled and measured daily flow values at the Cruises Creek USGS gage for each year of the modeled period and the cumulative performance. In general, a hydrology calibration error of less than 15% is considered good for modeling period. The calibration error of -6.4% is within this range. Figure 3 shows the distribution of modeled and measured daily flow values at the USGS gage.

Table 3: Annual Calibration Statistics at Cruises Creek USGS Gage

	Average Discharge (cfs)		Total Volume (MG)		
Year	Modeled	Observed	Modeled	Observed	Error
2001	16.53	21.94	3,900	5,175	-24.6%
2002	34.66	30.90	8,178	7,291	12.2%
2003	33.58	35.49	7,923	8,372	-5.4%
2004	33.34	37.55	7,886	8,883	-11.2%
2005	25.78	27.81	6,082	6,560	-7.3%
All (2001-2005)	28.78	30.74	33,970	36,281	-6.4%

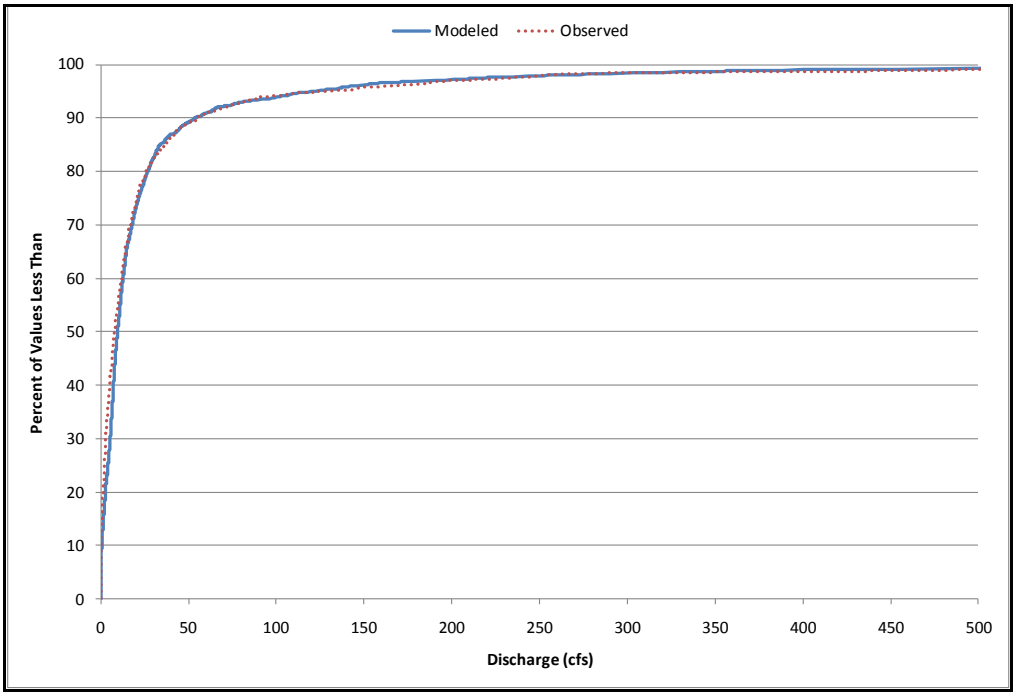


Figure 3: Distribution of Modeled and Observed Daily Flows at Cruises Creek Gage

To characterize the ability of the model to reproduce the timing of observed flow conditions, observed flow rates were compared to model flow rates for the same time period. The results were plotted on scatter plot for daily and monthly flow values for the entire five-year calibration period and the recreation seasons (May-October) within the calibration period (see Figures 4-7). Comparing monthly modeled data to observed data gives a high-level view of the model performance with regard to seasonality and total water balance. The daily modeled and observed data comparison provides insight into the model's timing for individual short-term events. The model's performance is discussed following the figures.

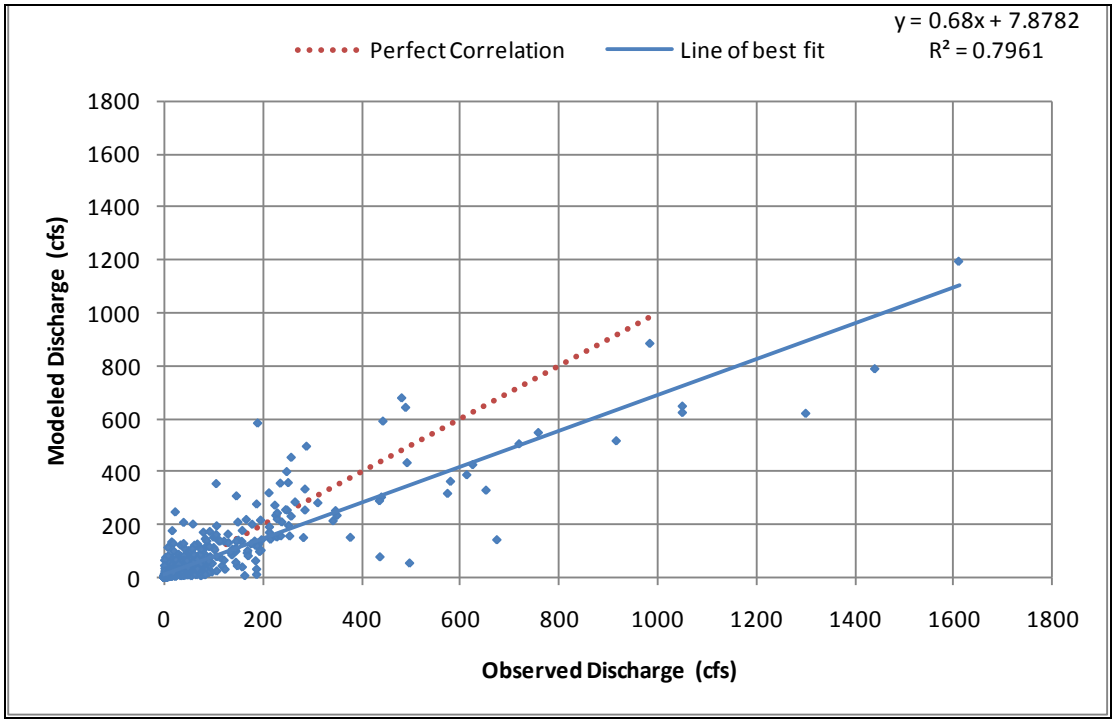


Figure 4: Daily Observed vs. Modeled Flow – 2000-2005 (Full Calibration Period)

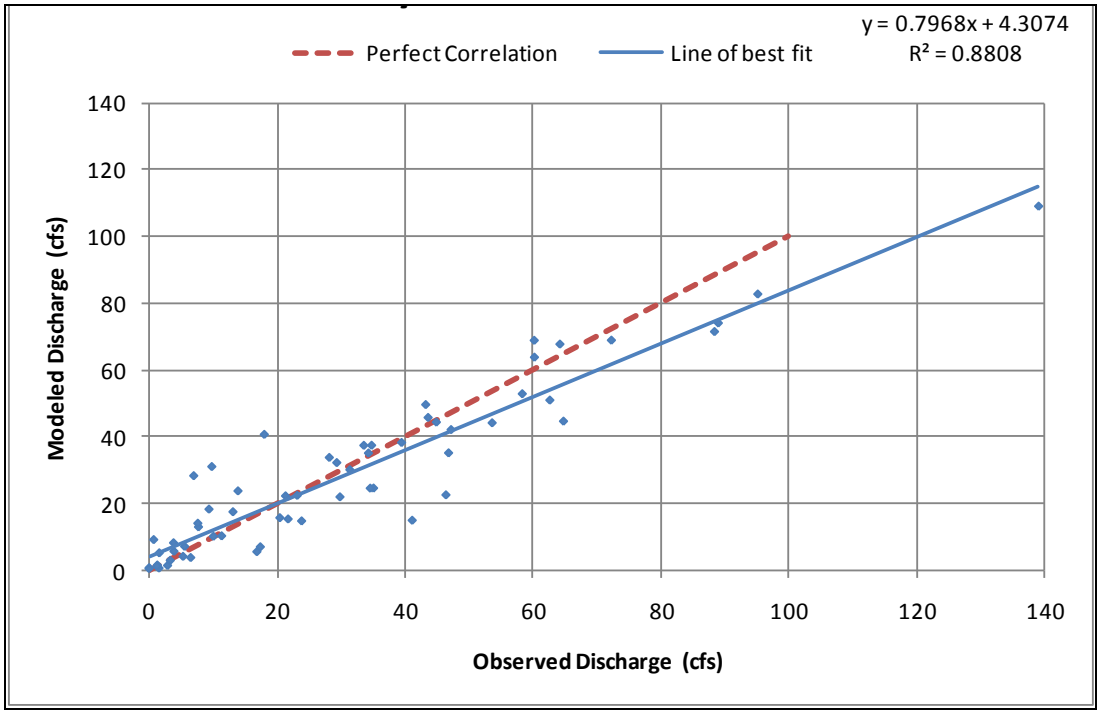


Figure 5: Monthly Observed vs. Modeled Flow – 2000-2005 (Full Calibration Period)

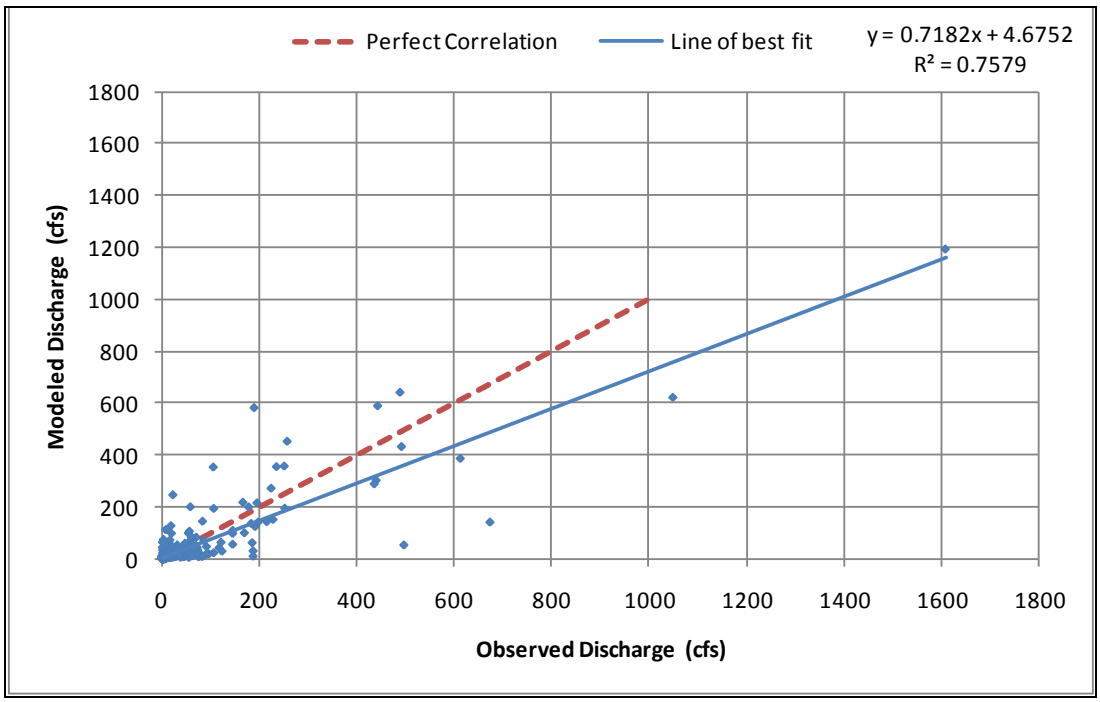


Figure 6: Daily Observed vs. Modeled Flow – 2000-2005 Recreation Seasons

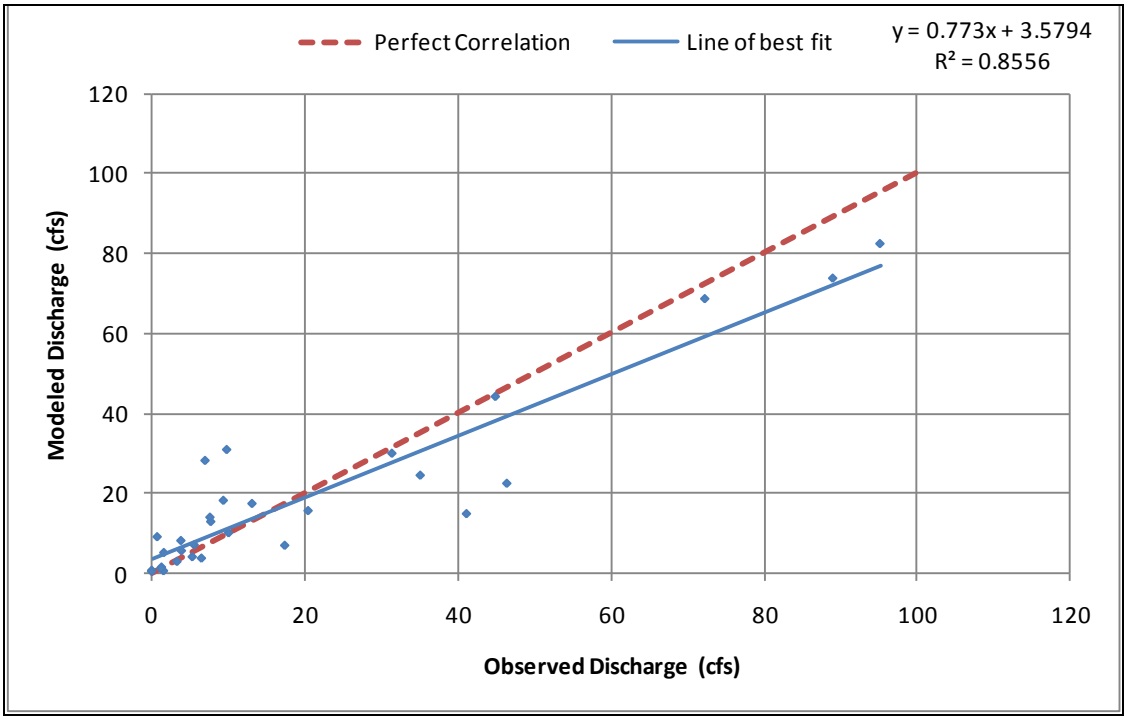


Figure 7: Monthly Observed vs. Modeled Flow – 2000-2005 Recreation Seasons

The full period and the recreation seasons comprising the calibration period were evaluated for calibration. The recreation season is important for evaluating bacteria water quality impacts so having a well-calibrated hydrologic calibration is important for ensuring reasonable estimates of water quality during these periods. A summary of the correlation coefficients (R and R^2) for each scenario is shown in Table 4. The correlation coefficients were compared to suggested model performance benchmarks to establish model performance for each scenario (Donigian, 2002). Overall, the hydrology calibration is quite good compared to these suggested benchmarks.

Table 4: Correlation Statistics for Cruises Creek Gage

	R	R^2	Model Performance
Daily – Full model period	0.89	0.80	Good
Monthly – Full model period	0.93	0.88	Very Good
Daily – Recreation season	0.87	0.76	Good
Monthly – Recreation season	0.92	0.85	Good

Water Quality Calibration

The goal of water quality calibration is to verify that the model's representation of dry and wet weather fecal coliform loadings reflect observed conditions in the watershed during these periods. Differences between these two loading types required separate evaluations during the model's water quality calibration. Dry weather loads cannot typically be attributed to specific sources in a watershed without in-depth field studies, while wet weather sources can typically be linked to specific sources and processes, such as runoff from land surfaces or sewer discharges, and they can be reasonably represented in the model using literature values or site-specific data. During storm events, loadings from runoff are the predominant source of pollutants affecting instream water quality. While dry weather sources tend to be much smaller than loads from wet weather sources, they can significantly reduce a stream's assimilative capacity for additional loads from other sources. Compliance with State thirty-day bacteria geometric mean criteria can be quite sensitive to the magnitude of dry weather source loads in the waterbodies.

Dry weather calibration was performed to ensure that the model represented variations in the measured instream dry weather fecal coliform densities. For most tributaries in the model domain, SD1 has collected multiple water quality samples during dry weather/base flow conditions. These data were analyzed by location/subwatershed for three characteristics that were used as model calibration targets: the arithmetic average dry weather fecal coliform density, the maximum dry-weather fecal coliform density, and the fraction of samples with measured fecal coliform density greater than 200 colony forming units per hundred milliliters (cfu/100 ml). The fraction of samples greater than 200 cfu/100ml is a surrogate for the tendency of a particular waterbody reach to be non-compliant with the State's water quality standards. Table 5 summarizes these three characteristics from the dry weather water quality samples in the Licking River and the tributaries within the model domain.

Table 5. Dry-weather fecal coliform densities in the lower Licking River and its tributaries

Waterbody Reach	# of Samples	Average Density [cfu/100ml]	Maximum Density [cfu/100ml]	Percent > 200 cfu/100ml
Bowman Creek	6	165	640	16.7%
Cruises Creek	4	397	940	50.0%
Decoursey Creek	10	441	945	70.0%
Grassy Creek	6	278	600	50.0%
Licking River	6	313	1,000	33.3%
Phillips Creek	5	120	270	20.0%
Plum Creek	4	263	520	50.0%
Pond Creek	11	1,050	5,700	63.6%
Riffle Creek	3	285	400	66.7%
Scaffold Creek	5	315	540	60.0%
Steep Creek	5	241	940	20.0%

To represent dry weather sources in the model, fecal coliform loadings were added to the most upstream reaches of each tributary. This was done because dry weather source locations have not been identified, so it was appropriate to assume that sources exist throughout each subwatershed. These sources were added to the model as oscillating loads to reflect the variability observed in the data. The amplitude and period of the oscillating load was constructed to reproduce the average and maximum values observed in sampling data and the percentage of time that fecal coliform densities were greater than 200 cfu/100ml. Figure 6 illustrates the oscillating dry weather load for Decoursey Creek. Similar series were developed for the other tributaries and for the most upstream reach of the Licking River within the model.

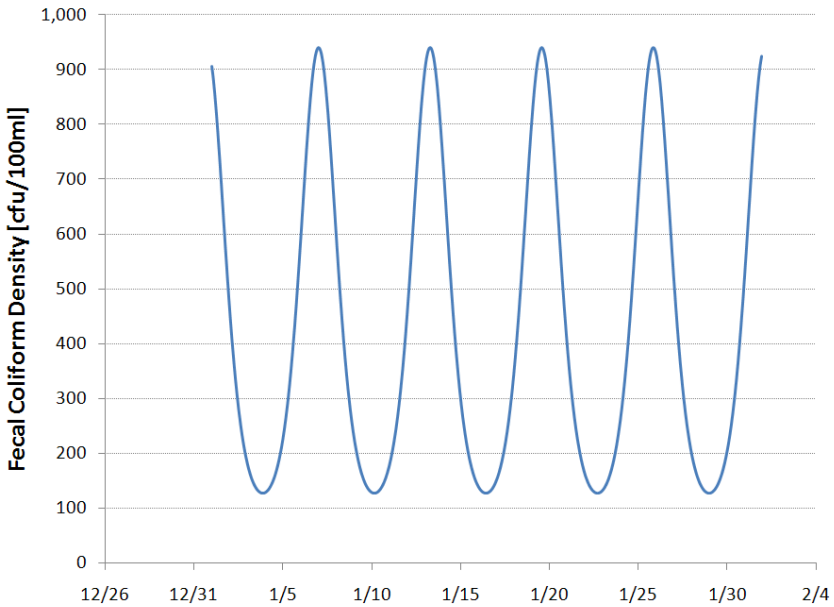


Figure 6. Oscillating Dry-Weather Load Time Series for Decoursey Creek

Figures 7, 8, and 9 illustrate the dry weather calibration results. In general, the average and maximum dry weather bacteria densities and the percent of bacteria densities greater than 200 cfu/100ml is accurately represented in the model across all of the tributary subwatersheds.

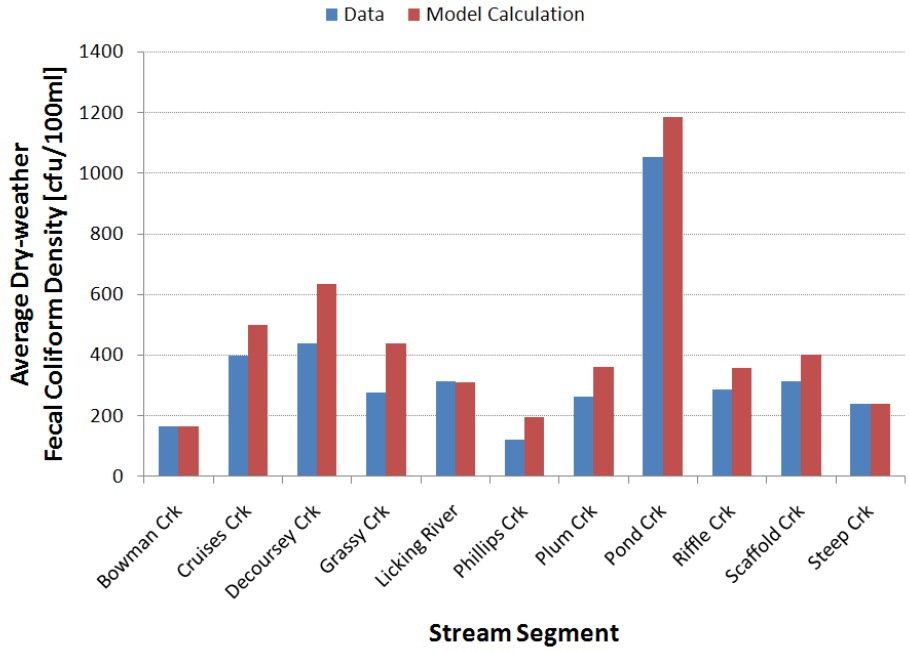


Figure 7: Comparison of Observed and Modeled Average Dry Weather Bacteria Densities

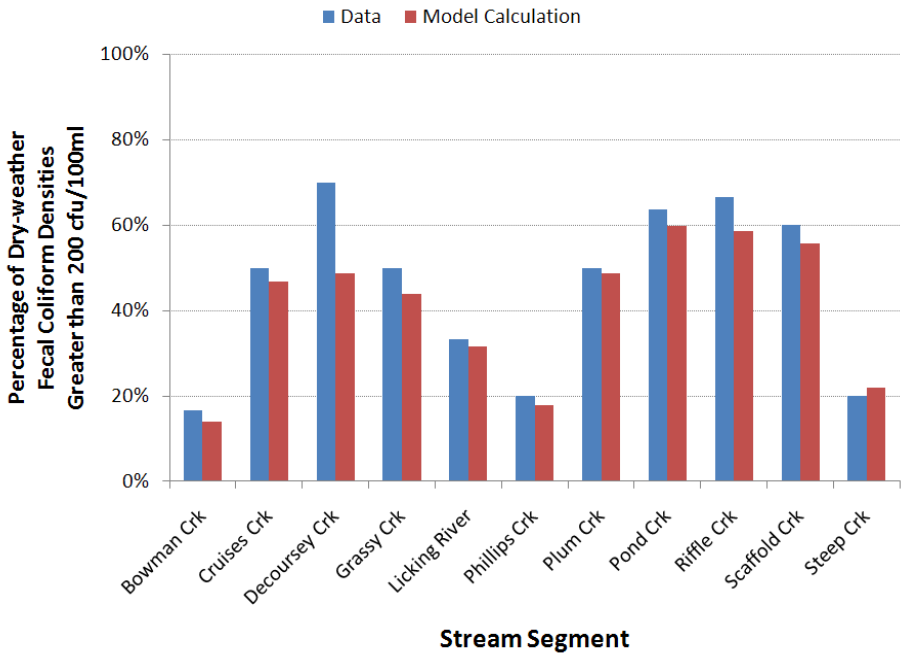


Figure 8: Comparison of Observed and Modeled Frequency of Dry Weather Bacteria Densities Exceeding 200 cfu/100ml

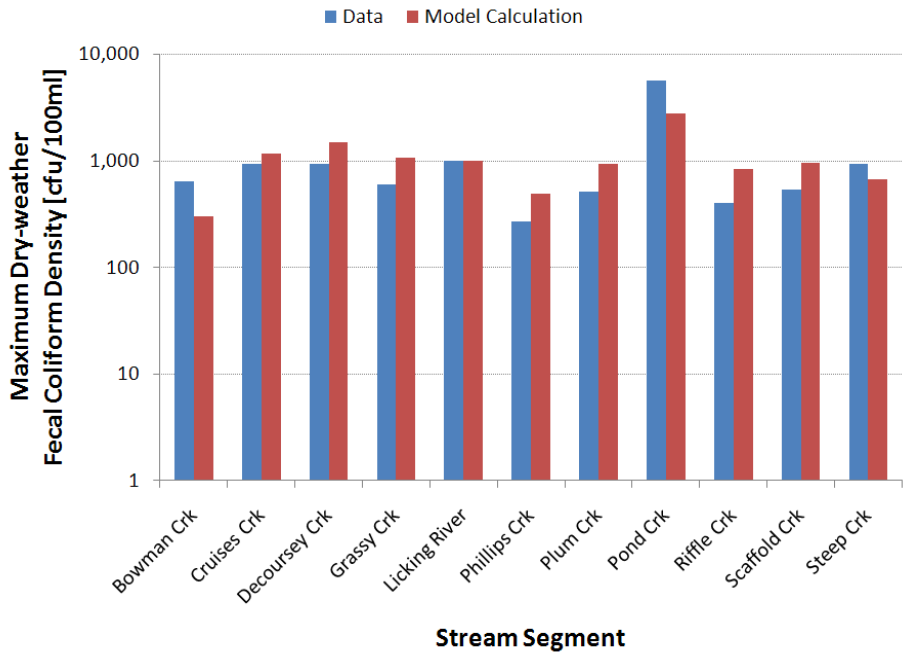


Figure 9: Comparison of Observed and Modeled Maximum Dry Weather Bacteria Densities.

Unlike dry weather loads, wet weather loads can often be attributed to specific sources within a watershed. Typically, wet weather loads can either be associated with land-side loads due to the buildup of bacteria on the land surface that wash off when it rains, or from point discharges, such as sewer overflows, that discharge during wet weather. No significant sewer overflows are contained within the model domain, so this model only simulates wet weather loads associated with buildup and washoff of bacteria from land surfaces.

Each land type in the model has distinct bacteria buildup and washoff parameters. These parameters were initially selected based on literature values, but were then adjusted so that the model reasonably replicated measured instream bacteria densities. Note that there are multiple combinations of build-up/washoff parameters across the different land uses included in the model that will produce similar instream densities. This model was calibrated by constraining the build-up/washoff parameters so that the rank order of the magnitude of bacteria in the runoff by land use was consistent with literature and previous watershed modeling. For example, runoff from agricultural land uses typically have higher bacteria densities than runoff from commercial/industrial land uses due to the presence of livestock or application of manure to agricultural land uses.

The model was calibrated to three wet weather events in 2009 that were sampled by SD1 (see Figure 2 for sampling locations). SD1 measured instream fecal coliform densities during the storm event at the following intervals: start of the storm (hour 0), hour 2, hour 4, hour 6, hour 12, hour 24, hour 48, hour 72 and hour 96. The three events provide a robust dataset for calibrating and validating the model because they capture a range of conditions, as shown in Table 6.

Table 6. Rainfall, Flow and Fecal Coliform Characteristics for 2009 Wet Weather Events

Characteristic	Condition	Wet Weather Event 1 (07/22-25/09)	Wet Weather Event 2 (09/20-24/09)	Wet Weather Event 3 (10/08-13/09)
Rainfall[1]	Total rainfall (in)	1.16 (1.03, 1.16)	1.28 (1.16, 1.28)	4.62 (2.23, 4.62)
	Storm duration (hrs)	23 (23, 24)	19 (19, 20)	20 (22, 22)
	Max intensity (in/hr)	0.15 (0.15, 0.15)	0.23 (0.28, 0.22)	2.07 (0.52,1.06)
Flow[2]	Range of Licking River Flow (cfs)	330 – 500	170 – 5,600	1,400 – 19,000
	Range of Cruises Creek Flow (cfs)	1 – 12	6 – 22	8 – 430
Fecal Coliform[3]	Range in densities at LIR35.5	20 – 310	120 – 17,000	100 – 38,000
	Range in densities at LIR19.3	20 – 720	10 – 17,000	70 – 52,000
	Range in densities at LIR4.9	30 – 760	10 – 3,000	60 – 41,000
	Range in densities at DCC0.2	250 – 16,000	50 – 10,000	680 – 47,000
	Range in densities at POC0.9	130 – 22,000	50 – 9,200	490 – 55,000

Notes:

[1] Rainfall statistics are based on data from the USGS gage at Cruises Creek (gage ID 03254480). Similar rainfall characteristics for each event were observed at the USGS gage in the Licking River (gage ID 03254520) and at the Greater Cincinnati airport, which are shown in parentheses, respectively.

[2] Flow values for the Licking River are from the USGS gage at Alexandria (gage ID 03254520). Flow values for Cruises Creek are from the USGS gage at Highway 17 (gage ID 03254480).

[3] LIR 35.5 is the sampling location in the Licking River at river mile 35.5; LIR 19.3 is the sampling location in the Licking River at river mile 19.3; LIR 4.9 is the sampling location in the Licking River at river mile 4.9; DCC0.2 is the sampling location in Decoursey Creek at river mile 0.2; POC0.9 is the sampling location in Pond Creek at river mile 0.9.

Wet weather model calibration was performed by ensuring that the model reasonably reproduced the timing, magnitude and range of observed instream fecal coliform densities observed during and after each storm event in each monitored waterbodies. Figures 10 -13 illustrate the model's ability to reproduce the range of measured instream fecal coliform densities for the three storm events at each sampling location. The data from the most upstream station in the Licking River (LIR35.5) was used to specify the upstream boundary inputs to the model rather than as a calibration location.

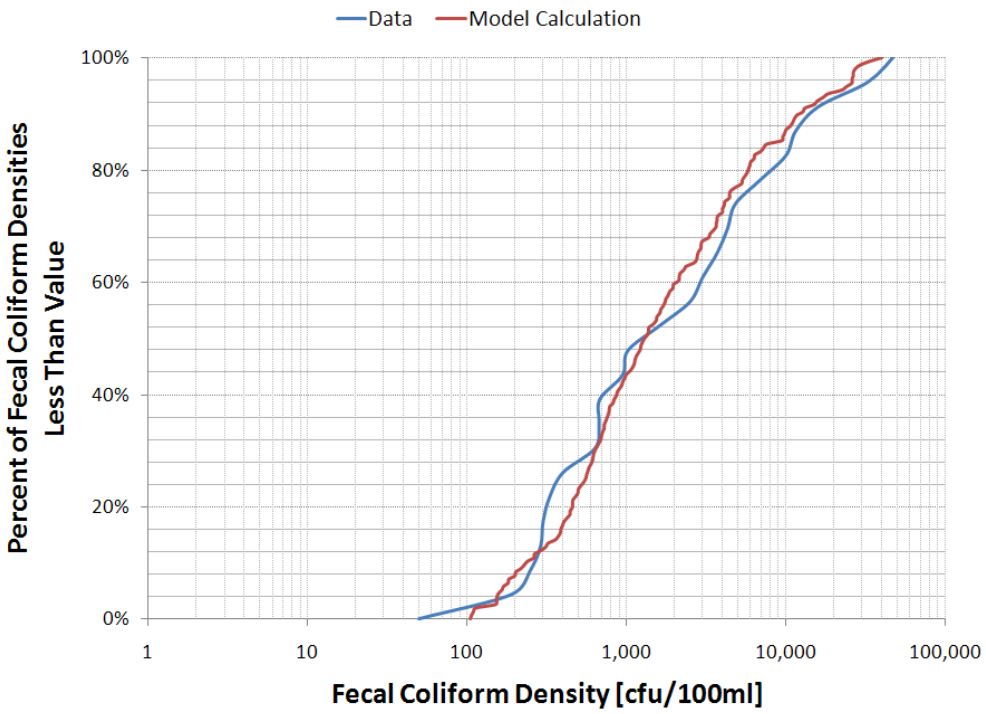


Figure 10: Comparison of Modeled and Measured Fecal Coliform in Decoursey Creek

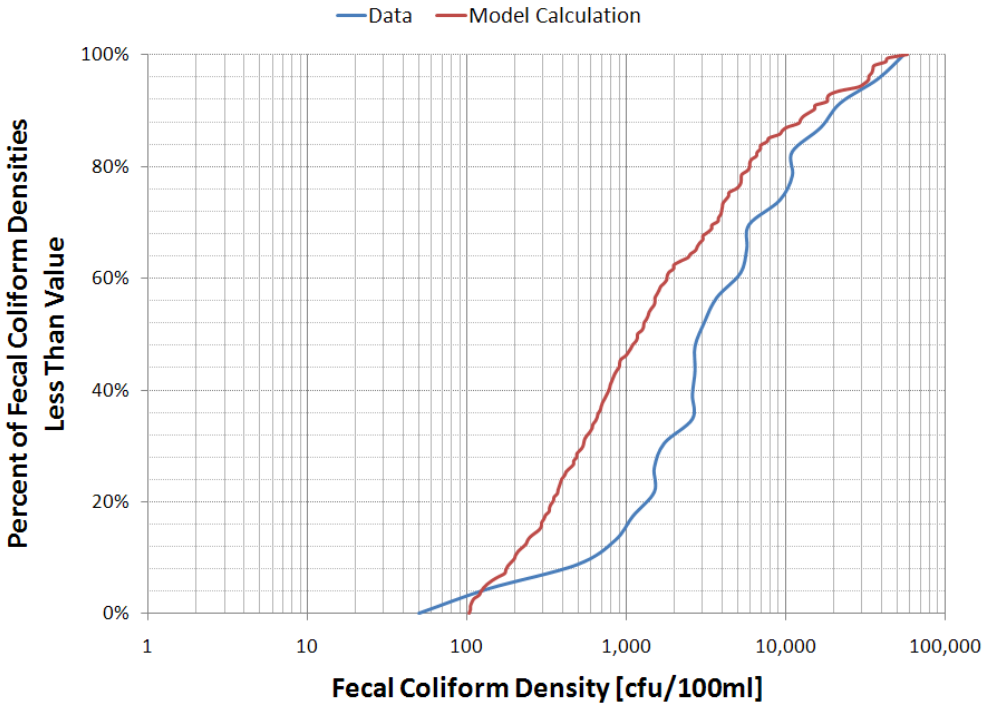


Figure 11: Comparison of Modeled and Measured Fecal Coliform in Pond Creek

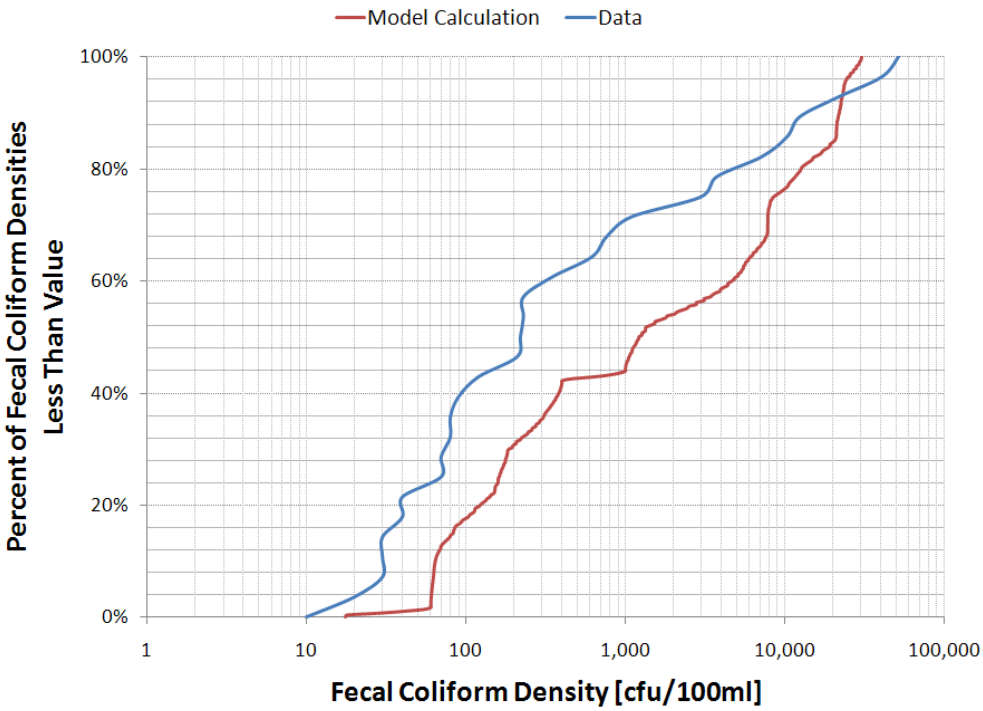


Figure 12: Comparison of Modeled and Measured Fecal Coliform at Licking River RM 19.3

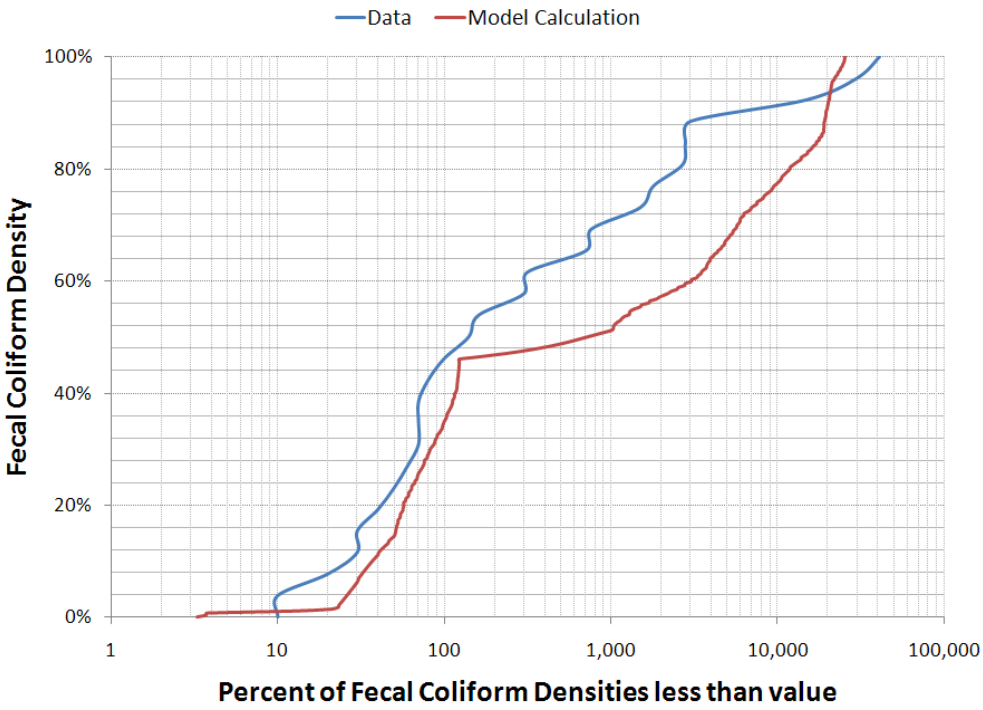


Figure 13: Comparison of Modeled and Measured Fecal Coliform at Licking River RM 4.9

The model accurately represents the range of sampled fecal coliform densities in Pond Creek, Decoursey Creek, and at Licking River mile 19.3. At Licking River mile 4.9, the model is biased slightly high relative to the data. Upon review of the data, it is apparent that water samples collected at river mile 4.9 either did not capture peak fecal coliform densities during the events (significantly higher fecal coliform densities were measured at river mile 19.3 than at river mile 4.9) or was diluted by backwater from the Ohio River. The lower Licking River EFDC model includes the portion of the Licking River at river mile 4.9 and is better suited to model water quality at this location because it can simulate backwater effects from the Ohio River. Therefore, more weight was given to the model-data fits at the other three locations in the watershed model.

Figures 14 through 17 illustrate the model calibration by comparing the time series of modeled fecal coliform densities to the measurements of fecal coliform densities. These figures illustrate that, for four different locations in the model, peak fecal coliform densities are well-represented and the bacteria load timing is captured by the model.

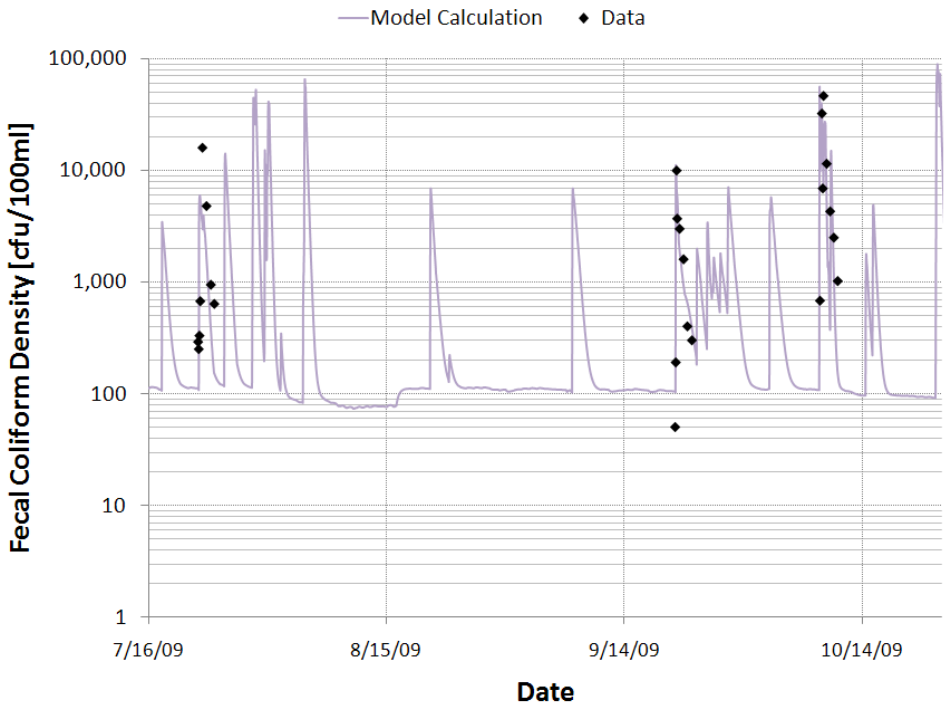


Figure 14: Comparison of Modeled and Measured Fecal Coliform in Decoursey Creek

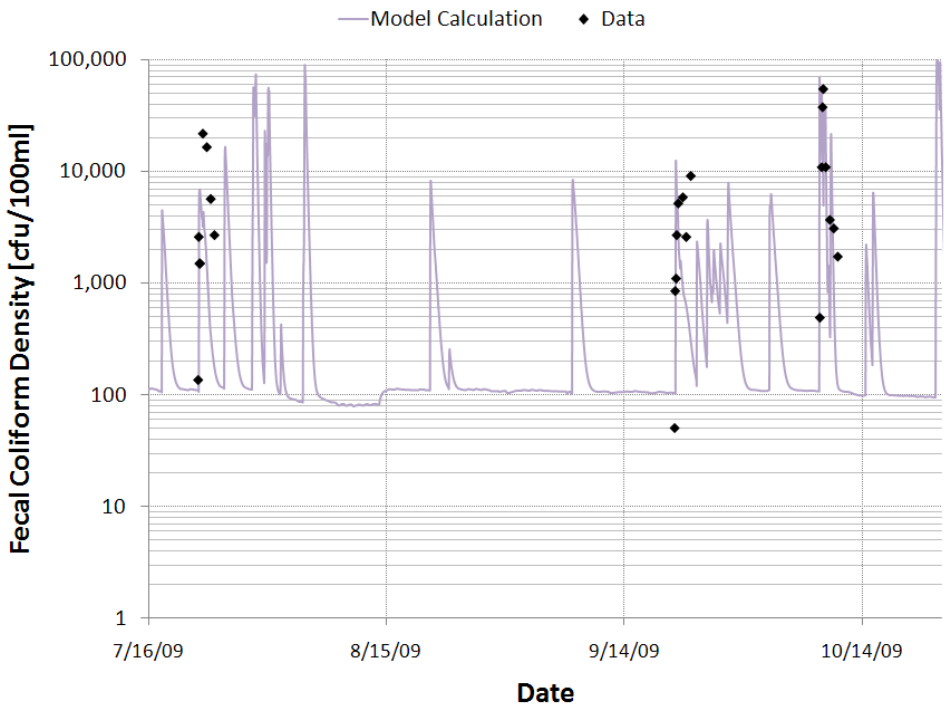


Figure 15: Comparison of Modeled and Measured Fecal Coliform in Pond Creek

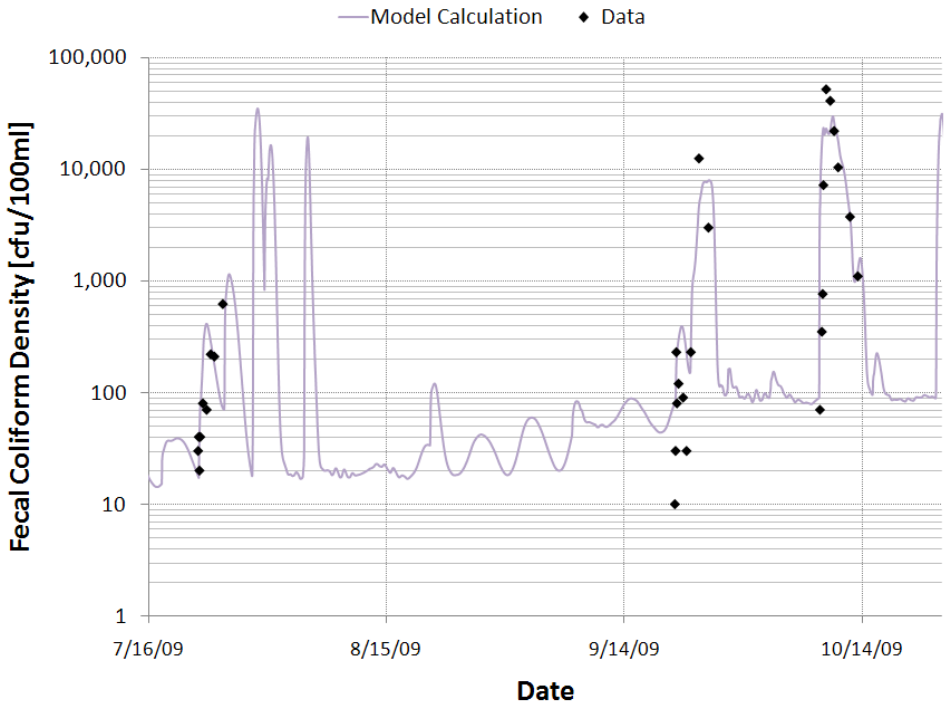


Figure 16: Comparison of Modeled and Measured Fecal Coliform at Licking River RM 19.3

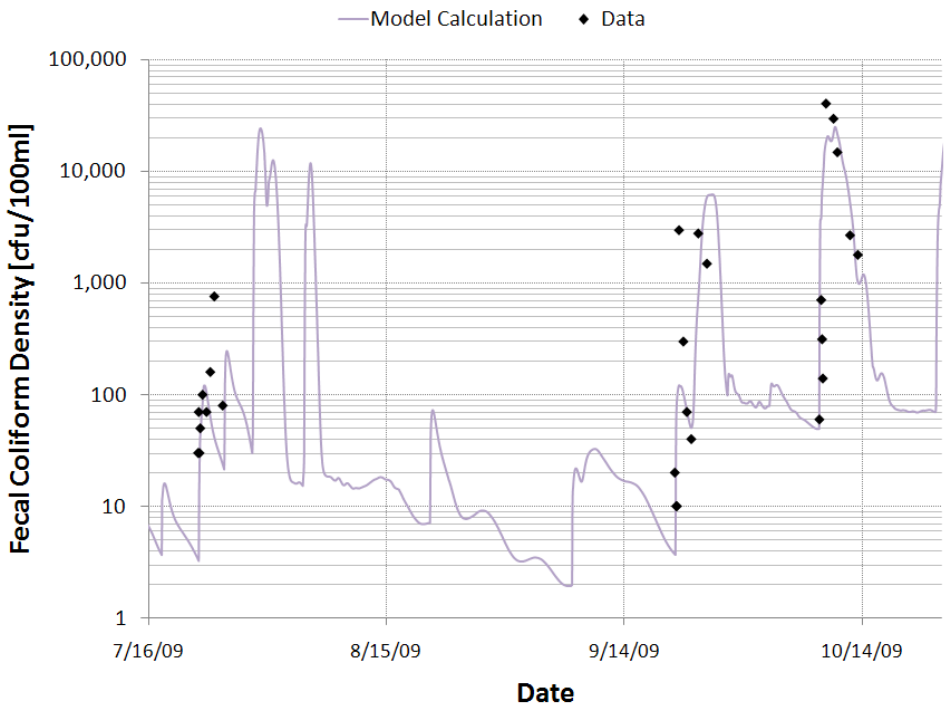


Figure 17: Comparison of Modeled and Measured Fecal Coliform at Licking River RM 4.9

To ensure consistency with previous watershed modeling done in the area (e.g. Banklick Creek Watershed Model), unit area loads (UALs) from the Licking River HSPF model were compared to UALs from the Banklick Creek HSPF model. These UALs represent the mass loading of fecal coliform per acre of a particular land use type. While Licking River model UALs are slightly higher (3-5X) than Banklick Creek UALs, the range of values in the literature suggest that these models are fairly similar. The ranking of UALs among various land use types is consistent between the models. For instance, in both models, high-density residential surfaces have the highest unit area loads while forested areas have the lowest unit area loads. Because the ranking of land use types is similar in both models, applying the UALs from this model in the Watershed Assessment Tool (WAT!) would likely yield the same relative rankings as with the UALs from the Banklick Creek Watershed Model. Hydrologic differences between the two models likely account for the differences in magnitudes of the UALs.

Table 7. Comparison of Unit Area Loads in Licking River and Banklick Creek Watershed Models

Land Use Description	Banklick Model UAL [cfu/acre-year]	Licking Model UAL [cfu/acre-year]
Residential – High Density	5.1E+11	2.5E+12
Pasture/Grassland	5.8E+11	1.8E+12
Residential – Medium Density	3.5E+11	1.9E+12
Residential – Low Density	3.5E+11	1.9E+12
Cropland	2.9E+11	1.2E+12
Comm/Industrial – High Density	2.1E+11	1.3E+12
Comm/Industrial – Medium Density	2.1E+11	1.1E+12

Land Use Description	Banklick Model UAL [cfu/acre-year]	Licking Model UAL [cfu/acre-year]
Comm/Industrial – Low Density	2.1E+11	1.1E+12
Developed Open Space	1.7E+10	1.8E+10
Barren	1.2E+10	4.2E+10
Forest	3.2E+09	1.4E+10

Conclusions

The information from the Lower Licking River watershed modeling effort can be summarized as follows:

- The HSPF model provides a reasonable reproduction of flow and fecal coliform densities in the Licking River and its tributaries for a range of environmental conditions;
- The calibration suggests that the methods used for quantifying fecal coliform loading are providing reasonable estimates of nonpoint source bacteria loads;
- The model provides a more mechanistic estimate of flow and water quality to the upstream boundary of the EFDC model of the Lower Licking River than current methods, which will improve the accuracy of model-simulated densities in that model and ultimately to the Ohio River;
- The model will be a useful tool for quantifying potential benefits of various control scenarios considered for the Watershed Plans, responding to the Ohio River bacteria TMDL, or other needs.

The calibration to instream values indicates that it is capable of reproducing the timing and magnitude of most of the observed data. It is the best tool available for evaluating instream impacts from fecal coliform sources under a range of environmental conditions and control scenarios. The model is suitable for evaluating the water quality benefits of traditional infrastructure, green infrastructure, and watershed control alternatives in the Lower Licking River watershed.

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LimnoTech
Water | Environment | Scientists | Engineers

DATE: December 17, 2010

MEMORANDUM

FROM: Tim Towey, Jeremy Grush, Carrie Turner

TO: Jim Gibson, Mindy Scott

CC: Adrienne Nemura

SUBJECT: Development of an HSPF Watershed Model of the Ohio River Tributaries

Introduction

The Sanitation District No. 1 (SD1) is investing in the development of detailed water quality models in several watersheds. These models are an important contribution to watershed and water quality characterization, which is a required element of a combined sewer overflow (CSO) long-term control plan. The models are also necessary to establish appropriate goals for CSO and sanitary sewer overflow (SSO) control using the watershed approach. This is done by applying the models to look at the relative effectiveness of these controls when compared to controls of other pollutant sources, such as dry weather sources and runoff from agricultural and urban areas.

Previously, detailed models of Banklick Creek, Taylor Creek, and the lower Licking River were developed for SD1. However, a large portion of the SD1 service area is outside of these watersheds. Therefore, the Hydrologic Simulation Program in Fortran (HSPF) was used to develop models for the Ohio River tributaries in the SD1 service area where a detailed model had not been previously developed. The purpose of these models is to evaluate the water-quality impacts of CSOs, SSOs, and non-point sources in these tributaries and the Ohio River under a variety of environmental conditions and to generate tools that will allow for the quantification of potential benefits of various control scenarios considered for the Watershed Plans. This memorandum describes the development of the HSPF watershed models, including model configuration, inputs, and calibration.

Ohio River Tributary Watershed Model Overview

The Ohio River Tributary Watershed Model includes areas in Campbell, Kenton, Boone, Grant and Pendleton Counties. The model covers 355 square miles within the SD1 service area and encompasses Big Bone Creek, Dry Creek, Elijahs Creek, Fourmile Creek, Gunpowder Creek, Pleasant Run Creek, Sand Run, Threemile Creek, Twelvemile Creek, Woolper Creek, and several areas with direct drainage to the Ohio River. This model domain has been subdivided into 88 model subwatersheds based on 14-digit hydrologic units, which is the same subwatershed scale used to model the Lower Licking River watershed in HSPF (LimnoTech, 2010). To facilitate faster run-times and to avoid exceeding the HSPF element limit, the area was modeled as two separate sets of subwatersheds: Set 1 and Set 2. Figure 1 illustrates the division of the Ohio River Tributary Watershed Model into modeled subwatersheds.

In the model, each subwatershed is attributed with distinct physical and hydrologic characteristics, such as surface slope and percentage of impervious area, that define a subwatershed's response to rainfall events. Table 1 summarizes the characteristics of the modeled Ohio River tributary watersheds. These characteristics were derived from spatial data as described in the following section.

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Ann Arbor, MI 48108
734-332-1200
Fax: 734-332-1212
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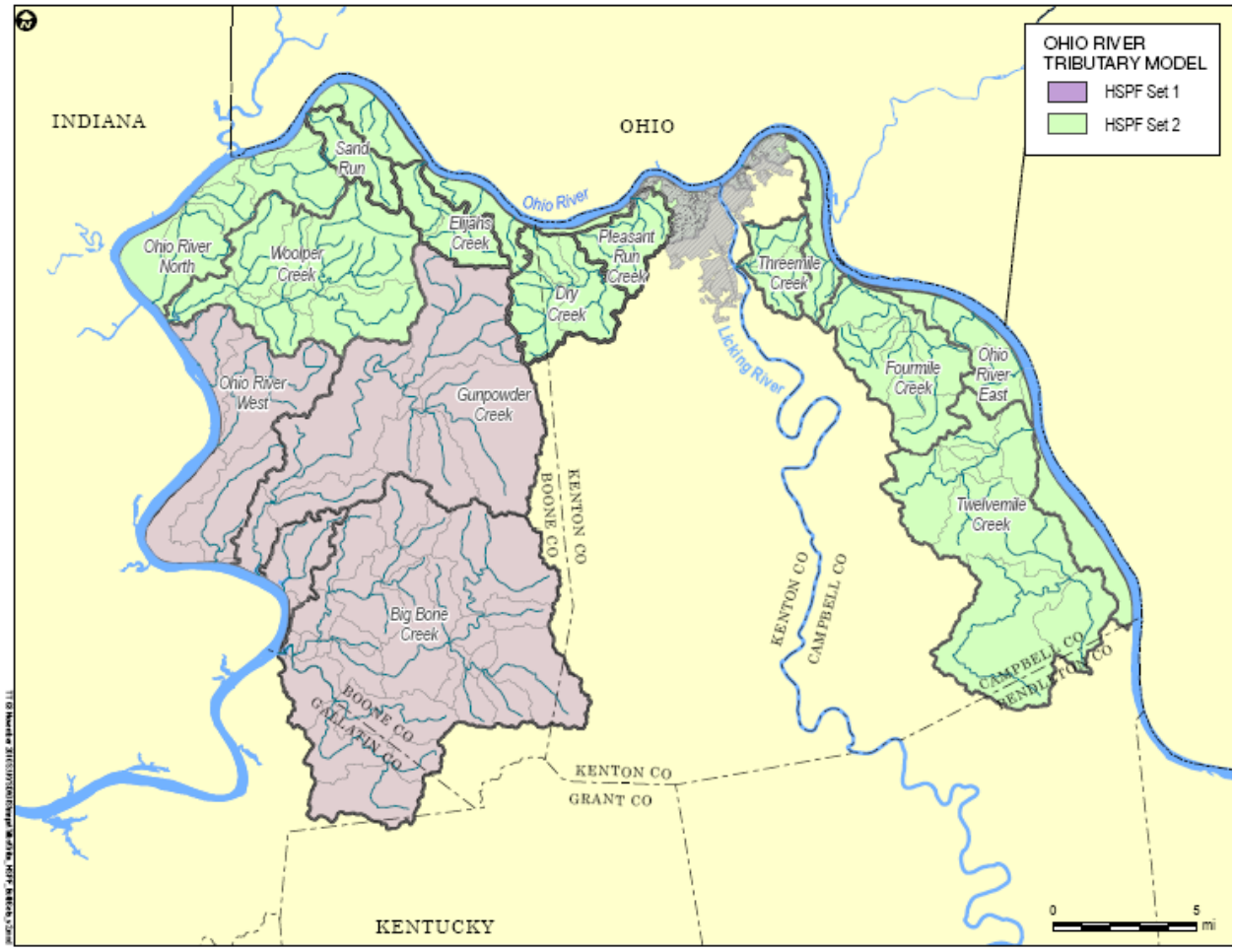

Figure 1: Ohio River Tributary HSPF Model Domain

Table 1: Ohio River Tributary Model Watershed Characteristics

Watershed	*Surface Area (sq mi)*	*Number of Subsheds*	*Average Slope (ft/ft)*	*Percent Impervious*
Set 1				
Big Bone Creek	82.6	26	0.16	3%
Gunpowder Creek	58.2	9	0.12	13%
Ohio River West	33.0	7	0.17	2%
Set 2				
Dry Creek	12.4	3	0.11	26%
Elijahs Creek	6.7	2	0.10	26%
Fourmile Creek	17.8	6	0.19	7%
Ohio River East	18.6	5	0.17	6%
Ohio River North	29.3	10	0.16	5%
Pleasant Run Creek	6.4	1	0.15	19%
Sand Run	5.0	1	0.14	13%
Threemile Creek	5.9	2	0.18	18%
Twelvemile Creek	46.1	8	0.17	3%
Woolper Creek	33.0	8	0.13	5%

This HSPF model simulates runoff of water and washoff of bacteria from the land surface, flow and bacteria routing through streams, and instream loss of bacteria. Land surfaces in this model are either described as pervious or impervious. Impervious surfaces transmit all rainfall that reaches the land surface to runoff, while pervious surfaces transmit a portion of the rainfall depending on surface and soil properties, with the remaining portion routed to groundwater, interflow, evaporation and transpiration. Instream bacteria loss is described using a first-order decay rate.

Model Input Development

Site-specific model inputs were developed to describe local conditions in the tributary watersheds. The model capitalizes on the extensive data collection efforts that SD1 has engaged in as part of the Watershed Plan activities. The following list summarizes types of information that were compiled and applied for this model:

- Land use and land cover information
- Topographic data
- Meteorological data
- Stream geometry
- River flow data
- Instream fecal coliform densities

Each dataset applied in the model is described in detail below.

Land use and land cover information

Both land use and land cover (LULC) data were available for the majority of the modeled watershed. Land use data were supplied from individual counties. Land cover data were based on the 2005 NLCD Land Cover dataset that was updated to 2007 conditions with SD1 data, which is consistent with the dataset used in previous SD1 watershed modeling efforts.

Land use and land cover information was simplified so that sixteen types of pervious land surfaces were simulated in the model. These sixteen types of land surfaces have distinct hydrologic and water quality characteristics. For instance, a land surface classified as 'high intensity – industrial' typically contributes more runoff than a forested land surface. These two land surfaces also differ in the amount of bacteria that build up on the land surface over time. Land surface and soil characteristics are the most important characteristics affecting runoff and water quality constituents in rural watersheds. In contrast, a watershed that is highly developed is less dependent on soil characteristics because more of the land surface is impervious. Table 2 summarizes the land use characteristics of each modeled watershed.

Table 2: Ohio River Tributary Model Land Use and Land Cover

	Residential, Low Intensity	Residential, Medium Intensity	Residential, High Intensity	Comm/Ind, Low Intensity	Comm/Ind, Medium Intensity	Comm/Ind, High Intensity	Developed, open space	Barren	Forest	Pasture/Grass	Cropland	Wetland	Impervious
Set 1													
Big Bone Creek	2%	0%	0%	2%	0%	0%	9%	0%	48%	33%	0%	1%	3%
Gunpowder Creek	6%	1%	0%	6%	2%	1%	19%	0%	36%	14%	2%	0%	13%
Ohio River West	2%	0%	0%	1%	0%	0%	5%	0%	63%	16%	8%	1%	2%
Set 2													
Dry Creek	10%	1%	0%	11%	5%	1%	20%	0%	21%	5%	0%	0%	26%
Elijahs Creek	3%	0%	0%	8%	4%	1%	26%	0%	24%	7%	0%	0%	26%
Fourmile Creek	6%	0%	0%	3%	1%	0%	17%	0%	51%	14%	0%	0%	7%
Ohio River East	5%	0%	0%	4%	1%	0%	13%	0%	52%	13%	3%	1%	6%
Ohio River North	2%	0%	0%	3%	1%	0%	9%	0%	59%	14%	7%	1%	5%
Pleasant Run Creek	13%	1%	0%	8%	2%	1%	24%	0%	31%	0%	0%	0%	19%
Sand Run	8%	1%	0%	4%	2%	1%	10%	0%	46%	11%	3%	1%	13%
Threemile Creek	8%	1%	0%	12%	5%	1%	24%	0%	27%	3%	0%	0%	18%
Twelvemile Creek	3%	0%	0%	1%	0%	0%	12%	0%	48%	32%	0%	0%	3%
Woolper Creek	4%	0%	0%	3%	1%	0%	14%	0%	48%	22%	2%	0%	5%

Topographic data

Topographic data were available for the entire modeled area and were used to estimate the average land slope in each subwatershed and the average channel slope in the each creek. To describe watershed topography, a two-foot contour dataset provided by SD1 was used.

Meteorological data

Meteorological data was obtained from the National Climactic Data Center (NCDC) for a monitoring station at the Cincinnati/Northern Kentucky International Airport (WMO ID = 72421) for the following parameters required as input to the watershed model: air temperature, cloud cover, precipitation, dew point, and wind speed and direction. Potential evapotranspiration (PET), another required input, was calculated as a function of air temperature and daylight hours (based on latitude) using the Hamon PET method (Humel, et al. 2001). Solar radiation inputs were calculated as a function of cloud cover and daylight hours (based on latitude) using the Hamon algorithm contained in model's WDMUtil tool.

Hourly precipitation data from the airport gage were used as input to the model for all watersheds except Twelvemile and Fourmile Creeks. Twelvemile and Fourmile Creek watersheds are the easternmost watersheds while the airport is located in the western portion of the three-county area. Inspection of the precipitation data from local gages in these watersheds indicated that the distance between these

watersheds and the airport results in differences in timing and magnitude of rainfall between the gages so using local gage data in these watersheds was appropriate. Thus, precipitation data from the local USGS gages in Twelvemile and Fourmile Creek watersheds (gage numbers 03238745 and 03238772, respectively) were used instead of the airport data for the periods where wet-weather fecal coliform results from those creeks were available.

Stream Geometry

The geometry for stream reaches in the model was developed using a combination of aerial photographs, elevation data, and published values. The stream bed was assumed to be trapezoidal with a slope calculated from the Digital Elevation Model (DEM) file published by the USGS. River widths were estimated from aerial photography. Note that the geometry is not used directly in the watershed model but rather to develop rating curves (called F-Tables) relating flow to depth, which is described in further detail in the hydrology calibration section.

Model Calibration

Model calibration was performed in two steps: first, a hydrologic calibration followed by the water quality calibration, which builds on the calibrated hydrology model. The goal of the model calibration was to find calibration parameters for land use and land cover types that resulted in the overall best fit of the data across the model domain, rather than to adjust the calibration for each individual watershed.

Hydrology Calibration

The goal of hydrologic calibration is to ensure that the model accurately represents the transport of water from precipitation to river flow. Water runoff from the land surface in HSPF is governed by several variables; the major calibration parameters and values are shown in Table 3. Initial values for these variables were based on literature values and calibrated values from the Banklick Creek and Lower Licking River Watershed Models. These values were adjusted within the accepted range, if needed, to better reproduce observed values.

Table 3: Major HSPF Hydrology Calibration Parameters

Parameter	Description	Acceptable Range[1]	Calibrated Model Value	Source
INFILT	Infiltration capacity of the soil	0.0001 – 100.0 in/hr	0.02 – 0.35 in/hr	Range depends on soil type and land cover
LZSN	Lower zone nominal soil moisture storage	0.01-100 in	3.0 in	Calibrated value based on soil type
LSUR	Length of the assumed overland flow plane	1 ft – no limit	100 ft	Calibrated value based on watershed shape.
SLSUR	Slope of the assumed overland flow plane	10^{-7}-10 ft/ft	Varies	Actual watershed surface slope
AGWRC	Basic groundwater recession rate	0.001-0.999 day^{-1}	0.97 – 0.98 day^{-1}	Calibrated based on observed flow hydrograph

Parameter	Description	Acceptable Range[1]	Calibrated Model Value	Source
DEEPER	Fraction of groundwater lost to deep (inactive) groundwater	0.0-1.0	0.0	Calibrated based on annual water balance
BASETP	Fraction of PET which can be satisfied by baseflow	0.0-1.0	0.04	Estimated from land cover and calibrated based on annual water balance
AGWETP	Fraction of remaining PET which can be satisfied from active groundwater storage	0.0-1.0	0.01	Estimated from land cover and calibrated based on annual water balance
CEPSC	Interception storage capacity	0.0-10.0 in	0.10 – 0.25 in	Based on land cover and seasonal growing patterns
UZSN	Upper zone nominal storage	0.01 – 10.0 in	0.1-1.0 in	Estimated from land cover and calibrated based on annual water balance
NSUR	Manning's n for overland flow	0.001-1.0	0.20-0.37	Estimated based on land cover
INTFW	Interflow inflow parameter	0.0 – no limit	1.0-2.0	Estimated based on soil and calibrated based on observed flow hydrograph
IRC	Interflow recession parameter	10^{-30} – 0.999	0.4-0.6	Estimated based on soil and calibrated based on observed flow hydrograph
LZETP	Lower zone E-T parameter. An index to the density of deep-rooted vegetation	0.0 – 0.999	0.10-0.70	Estimated based on land cover and calibrated based on observed flow hydrograph

1 – Source: USEPA, 2000 and Bicknell, et al., 2005

Water in the water bodies are routed from upstream to downstream using relationships between flow and channel geometry stored in tables (called FTABLES) in the model. These tables were developed using stream geometry methods described above and slopes taken from the local 30-meter Digital Elevation Model (DEM) from the National Elevation Dataset. Because these values were based on physical measurements, they were not changed during model calibration.

The hydrology was calibrated to flow data from USGS gages on Big Bone Creek, Gunpowder Creek, Elijahs Creek, Fourmile Creek, Twelvemile Creek, and Woolper Creek by comparing simulated flow to measured flow at the USGS gages for the five year period from 2001-2006. The calibration period was selected as an extended period that provides a wide range of hydrologic conditions including high flow events, low flow events, extended dry periods, and extended wet periods. Because the model hydrologic parameters are applied consistently across all watersheds, the watersheds that do not have gage data (Threemile Creek, Pleasant Run, Dry Creek, and Sand Run) were deemed calibrated once the gaged watersheds were calibrated.

The model calibration was evaluated in terms of total annual flow, monthly flow, and daily flow. Table 4 shows the modeled and measured annual flows at the USGS gages and the model error for the calibration

period ([modeled-observed]/observed). A hydrology calibration error of less than 15% is considered good (Donigian, 2002). The calibration error for each of the watersheds is within this range.

Table 4: Annual Calibration Statistics for Ohio River Tributaries with USGS Gage

Tributary	USGS Gage	Annual Volume (MG)		Error
		Modeled	Observed	
Set 1				
Big Bone Creek	03277130	13,274	13,042	1.8%
Gunpowder Creek	03277075	14,885	14,379	3.5%
Set 2				
Elijahs Creek	03260100	1,860	1,964	-2.3%
Fourmile Creek	03238772	1,160	1,105	5.0%
Twelvemile Creek	03238745	13,974	12,205	14.5%
Woolper Creek	03262001	8,955	8,702	2.9%
Entire model domain		9,040	8,590	5.2%

To characterize the ability of the model to reproduce the timing of observed flow conditions, observed flow rates were compared to model flow rates for the same time period. Comparing monthly modeled data to observed data gives a high-level view of the model performance with regard to seasonality and total water balance. The daily modeled and observed data comparison provides insight into the model's timing for individual short-term events.

A summary of the correlation coefficients (R) for each watershed is shown in Table 5. The correlation coefficients were compared to suggested model performance benchmarks for each watershed (Donigian, 2002). The hydrology calibration is acceptable for all of the tributaries. Only the monthly evaluation of Elijahs Creek has an R value that puts the model performance at less than fair. However, the daily and annual comparisons for Elijahs Creek are good, suggesting that the model is accurately representing the overall hydrologic conditions. A few over-predictions during very dry months appear to be causing a less than desirable monthly correlation for Elijahs Creek.

Table 5: Hydrology Calibration Statistics for Ohio River Tributaries with USGS Gages

Tributary	Daily		Monthly	
	R	Model Performance	R	Model Performance
Set 1				
Big Bone Creek	0.84	Fair-Good	0.91	Good
Gunpowder Creek	0.90	Good-Very Good	0.93	Good-Very Good
Set 2				
Elijahs Creek	0.87	Good	0.79	Poor-Fair
Fourmile Creek	0.79	Fair	0.86	Fair
Twelvemile Creek	0.82	Fair	0.89	Good
Woolper Creek	0.89	Good-Very Good	0.94	Very Good
Entire model domain	0.86	Good	0.94	Very Good

Figure 2. R and R^2 values for the evaluation of model performance from Donigian, 2002.

In addition to the correlation statistics, cumulative frequency distribution plots were used to compare the distributions of observed and modeled flows. Figure 3 shows the cumulative frequency distribution of the observed and modeled daily average flow for all of the calibration locations in the entire model domain. Cumulative frequency plots for each calibration location are included in the attachment to this memorandum. The plots show that the modeled instream flows are accurately reproducing the distribution of observed flows.

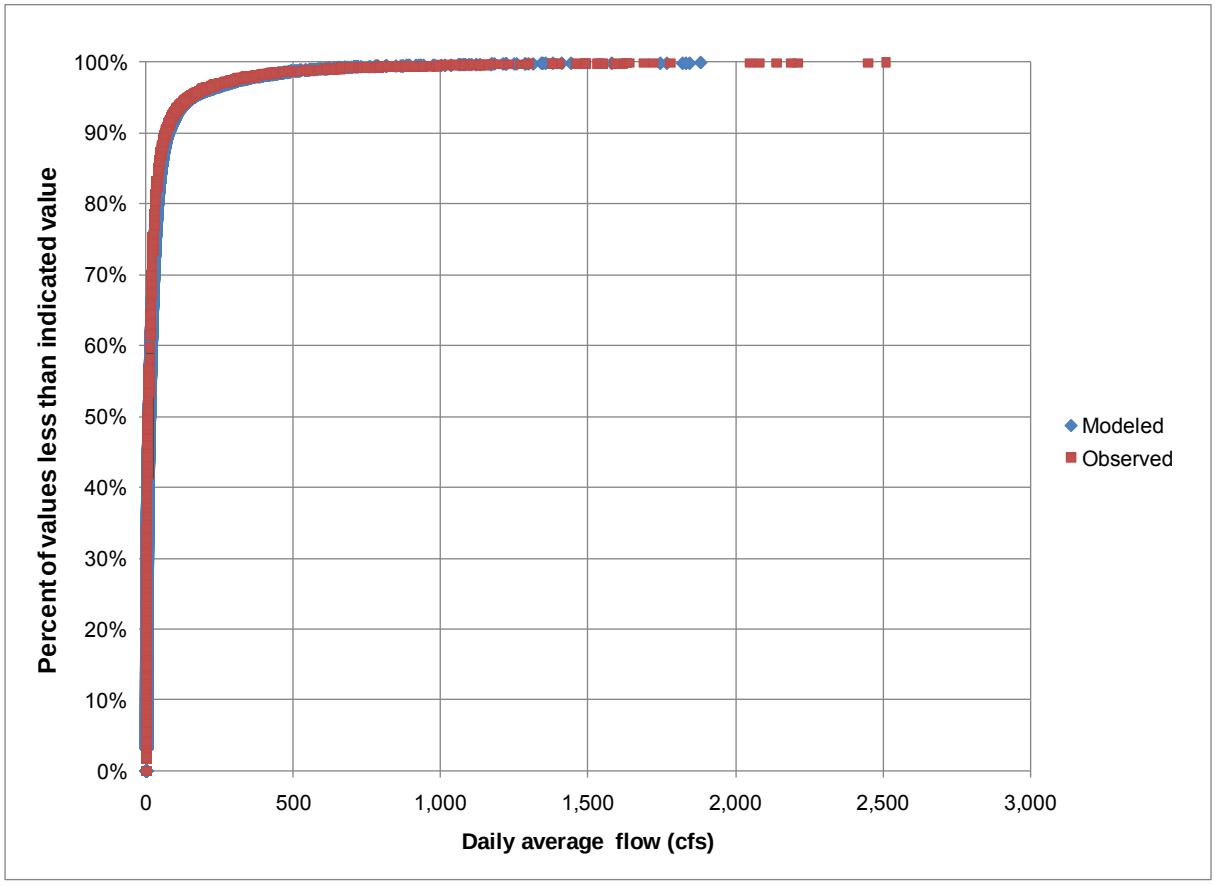

Figure 3: Distribution of Modeled and Observed Daily Flows Across Entire Model Domain.

The attachment also contains cumulative volume comparisons for the calibration period at each gage. These figures were useful in diagnosing problems with the calibration and noting limitations in the model. For example, the model and data trends in Elijahs Creek depart significantly after October 2004 (Water Year 2005). Changes in hydrologic parameters (e.g. land use, etc.) corresponding to this time frame were not noted. One possible explanation is that the USGS changed the rating curve for this gage around this

time and so the model, which is limited to a single set of hydraulic characteristics to describe each reach, could not dynamically reflect the change.

Water Quality Calibration

The goal of water quality calibration is to verify that the model's representation of dry and wet weather fecal coliform loadings reflect observed conditions in the watershed during these periods. Differences between these two loading types required separate evaluations during the model's water quality calibration. Dry weather loads cannot typically be attributed to specific sources in a watershed without in-depth field studies, while wet weather sources can typically be linked to specific sources and processes, such as runoff from land surfaces or sewer discharges, and they can be reasonably represented in the model using literature values or site-specific data. During storm events, loadings from runoff are the predominant source of pollutants affecting instream water quality. While dry weather sources tend to be much smaller than loads from wet weather sources, they can significantly reduce a stream's assimilative capacity for additional loads from other sources. Compliance with State water quality standards can be quite sensitive to the magnitude of dry weather source loads in the waterbodies.

Dry Weather Water Quality Calibration

Dry weather calibration was performed to ensure that the model represented variations in the measured instream dry weather fecal coliform densities. For most tributaries in the model domain, SD1 has collected multiple water quality samples during dry weather/base flow conditions. These data were analyzed by location/subwatershed for three characteristics that were used as model calibration targets: the geometric mean dry weather fecal coliform density, the maximum dry-weather fecal coliform density, and the fraction of samples with measured fecal coliform density greater than 400 colony forming units per hundred milliliters (cfu/100 ml). The fraction of samples greater than 400 cfu/100ml is a surrogate for the tendency of a particular waterbody reach to be non-compliant with the State's water quality standards. Table 6 summarizes these three characteristics from the dry weather water quality samples in the Ohio River tributaries within the model domain.

To represent dry weather sources in the model, fecal coliform loadings were added to the most upstream reaches of each tributary. This was done because dry weather source locations have not been identified, so it was appropriate to assume that sources exist throughout each subwatershed. These sources were added to the model as oscillating loads to reflect the variability observed in the data. The amplitude and period of the oscillating load was constructed to reproduce the average and maximum values observed in sampling data and the percentage of time that fecal coliform densities were greater than 400 cfu/100ml.

Table 6. Dry-weather fecal coliform densities in the Ohio River Tributaries with available data

Watershed	# of Samples	Dry Weather Data			Model Results		
		Geometric Mean [cfu/100ml]	Maximum Density [cfu/100ml]	Percent > 400 cfu/100ml	Geometric Mean [cfu/100ml]	Maximum Density [cfu/100ml]	Percent > 400 cfu/100ml
Set 1							
Big Bone Creek	26	131	1,400	19%	110	1,916	25%
Gunpowder Creek	29	121	2,300	14%	81	1,977	24%
Set 2							
Dry Creek	21	289	2,900	38%	266	1,946	43%
Elijahs Creek	11	158	500	18%	152	719	30%
Fourmile Creek	27	164	960	22%	154	955	29%
Pleasant Run Creek	13	389	2,500	46%	365	3,062	50%
Sand Run	8	328	2,000	38%	295	2,468	44%
Threemile Creek	17	367	1,280	47%	367	1,944	49%
Twelvemile Creek	28	88	960	11%	58	869	15%
Woolper Creek	29	92	1,280	7%	70	834	15%
Ohio River - Direct	42	139	1,700	24%	123	1,627	22%
Overall							
All Watersheds	251	205	1,616	26%	185	1,665	32%

Note: Results for the three Ohio River Direct watersheds (West, North and East) were combined and considered together so that these watersheds did not exert an overly significant influence on the Overall statistical evaluation as they would if they were evaluated individually. Results for the individual Ohio River Direct watersheds are shown graphically in Figures 4, 5 and 6.

Table 6 also summarizes the model and data comparisons within each watershed and over the entire model domain. However, as the table illustrates, the model achieves an overall balance of fitting the data for each of these metrics, although the goodness of fit varies within individual watersheds. As noted earlier, the calibration objective was to achieve a balanced calibration that represented the data across all of the modeled area.

Figures 4, 5, and 6 illustrate the dry weather calibration results. In general, the geometric mean fecal coliform density, the 95th percentile density, and the percentage of days with fecal coliform levels greater than 400 cfu/100ml is reasonably reproduced in the model for all tributaries with available dry-weather fecal coliform data.

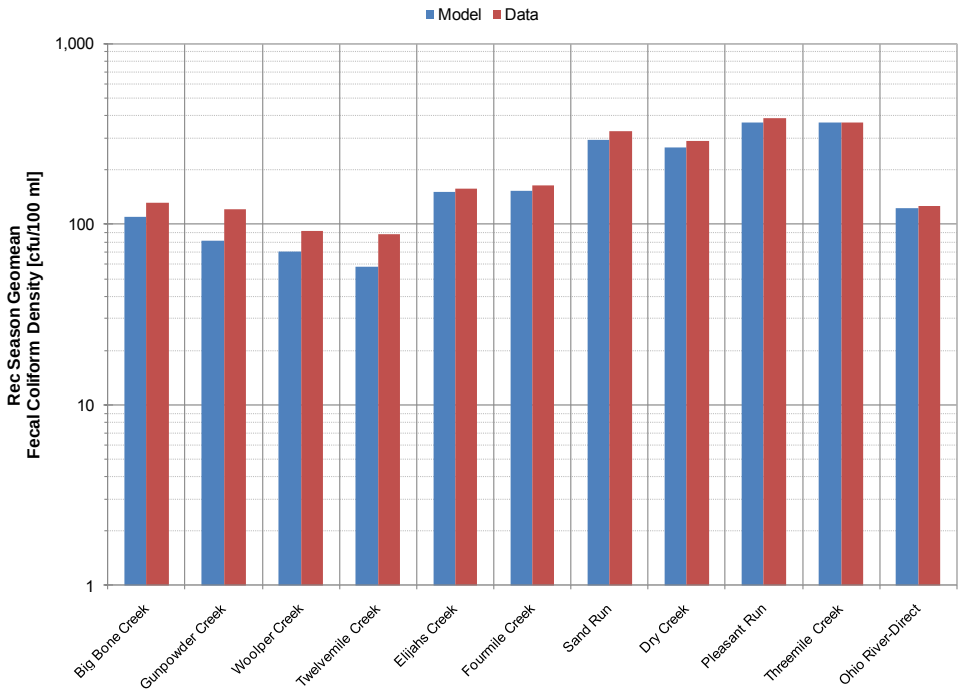

Figure 4: Comparison of Observed and Modeled Geometric Mean Dry Weather Bacteria Densities.

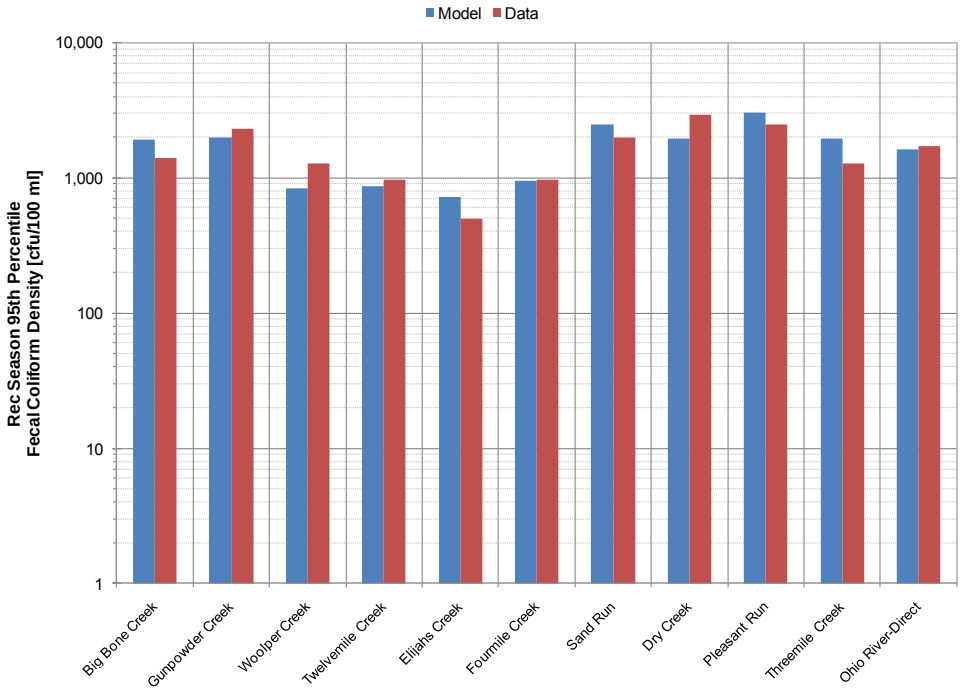

Figure 5: Comparison of Observed and Modeled 95th Percentile Dry Weather Bacteria Densities

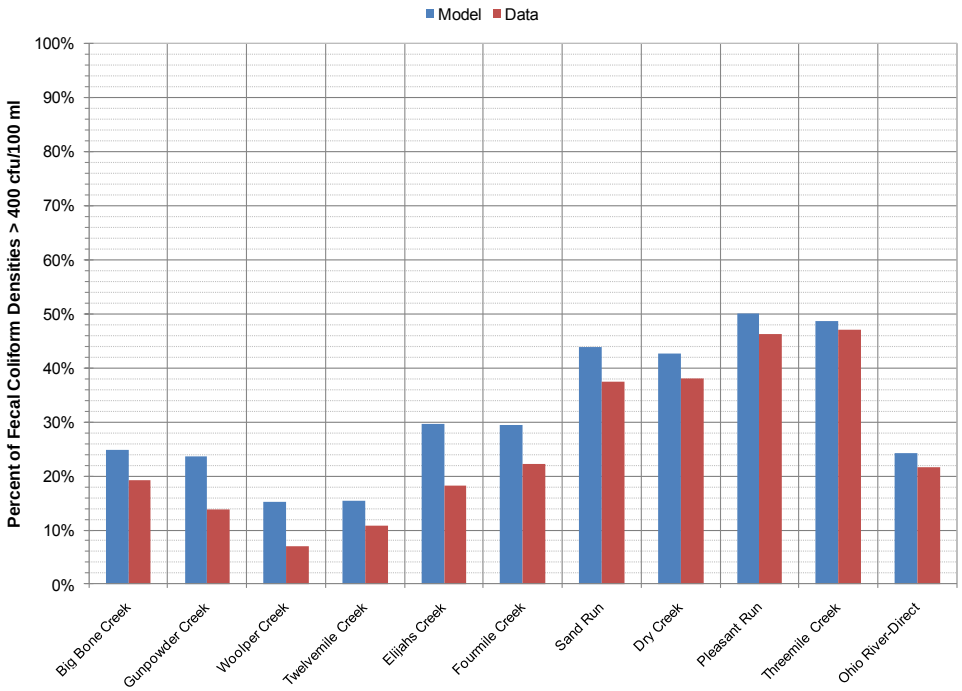

Figure 6: Comparison of Observed and Modeled Percentage of Days Exceeding Fecal Coliform Densities of 400 cfu/100 mL.

Matching the percentage of dry weather fecal coliform densities exceeding 400 cfu/100 ml was the most challenging calibration target. The model is currently configured to provide a conservative (e.g. higher) estimate of this metric than observed in the data. It should be noted that some of the sampling stations located near the mouths of the tributaries may be impacted by Ohio River backwater during some sampling events and this may result in lower densities at the mouths of the tributaries than the HSPF model can predict. Some of the overestimation of the percent of values exceeding 400 cfu/100 ml may be attributed to this limitation. However, if watershed projects that treat some or all dry weather flow are proposed in a specific watershed, a more detailed evaluation of the dry weather loading time series in that watershed may be warranted before modeling any control scenarios.

Wet Weather Water Quality Calibration

The model was calibrated to wet weather events in 2006, 2007, 2008, and 2009 that were sampled by SD1. No wet-weather samples were available in Big Bone or Gunpowder Creeks, so the wet-weather calibration was only performed for the Set 2 watersheds. SD1 measured instream fecal coliform densities during the storm events at the following intervals: start of the storm (hour 0), hour 2, hour 4, hour 6, hour 12, hour 24, hour 36, and hour 48. If the rainfall pattern warrants, samples may be collected in hour 72 and hour 96. If a single model reach/subwatershed was sampled in more than one location, only the results from the downstream reach were used for comparison to the model, because the model output represents values at the outlet of a given reach. A total of 41 events were in 22reaches were used in the calibration, providing a robust dataset that captures a range of wet-weather conditions. Table 7 summarizes the rainfall and fecal coliform characteristics for each sampling event used in the calibration.

Table 7. Rainfall and Fecal Coliform Characteristics for Wet Weather Events Used in the Model Calibration.

Watershed	Survey ID	Survey Date Range	Total Rain (in)	Maximum Rainfall Intensity (in/hr)	Duration (hrs)	Fecal coliform range
Twelvemile Creek	06_TMC_WET1	09/27/2006 - 09/30/2006	0.59	0.16	20	270 - 4,200
	06_TMC_WET2	10/26/2006 - 10/30/2006	3.1	0.44	55	30 - 37,000
Fourmile Creek	07_FMC_WET1	07/19/2007 - 07/21/2007	0.53	0.39	5	100 - 45,000
	07_FMC_WET2	10/22/2007 - 10/26/2007	5.25	0.9	47	170 - 39,000
	08_FMC_WET3	10/08/2008 - 10/10/2008	0.82	0.17	16	240 - 39,000
Dry Creek	08_DRC_WET1	05/07/2008 - 05/09/2008	0.99	0.12	29	140 - 23,000
	08_DRC_WET2	06/03/2008 - 06/06/2008	1.64	0.56	10	570 - 152,000
	08_DRC_WET3	06/13/2008 - 06/15/2008	0.16	0.07	6	450 - 58,000
Pleasant Run Creek	08_PRC_WET1	05/07/2008 - 05/09/2008	0.99	0.12	29	300 - 17,000
	08_PRC_WET2	06/03/2008 - 06/06/2008	3.57	0.91	37	827 - 47,000
	08_PRC_WET3	06/13/2008 - 06/15/2008	0.16	0.07	6	914 - 54,000
Elijahs Creek	09_EJC_WET1	06/10/2009 - 06/13/2009	1.20	0.43	8	340 - 50,000
	09_EJC_WET2	06/16/2009 - 06/18/2009	0.24	0.16	4	230 - 12,000
	09_EJC_WET3	07/21/2009 - 07/24/2009	0.96	0.14	21	50 - 20,000
Sand Run	09_SDR_WET1	06/10/2009 - 06/13/2009	1.20	0.43	8	280 - 43,000
	09_SDR_WET2	06/16/2009 - 06/18/2009	0.24	0.16	4	960 - 7,000
	09_SDR_WET3	07/22/2009 - 07/24/2009	0.96	0.14	21	310 - 3,600
Threemile Creek	08_BLC_LIR_WET1	05/07/2008 - 05/10/2008	0.99	0.12	29	120 - 3,400
	09_THC_WET1	07/22/2009 - 07/24/2009	0.96	0.14	21	130 - 45,000
	09_THC_WET2	09/20/2009 - 09/22/2009	1.39	0.24	18	50 - 36,000
	09_THC_WET3	10/08/2009 - 10/10/2009	2.16	0.72	37	30 - 52,000
Woolper Creek	09_WPC_WET1	09/20/2009 - 09/22/2009	1.39	0.24	18	30 - 53,000
	09_WPC_WET2	10/22/2009 - 10/25/2009	1.02	0.39	14	10 - 50,000

Note: Rainfall statistics are based on data from the Cincinnati/Northern Kentucky Airport. This data was replaced by precipitation data from the USGS gages at Twelvemile Creek and Fourmile Creek for the periods where wet-weather fecal coliform results from those creeks were available.

Unlike dry weather loads, wet weather loads can often be attributed to specific sources within a watershed. Wet weather loads can either be associated with land-side loads due to the buildup of bacteria on the land surface that wash off when it rains, or from point discharges, such as sewer overflows, that discharge during wet weather.

The point source discharges (e.g. CSO, SSO) are included as flow and fecal coliform load time series. Flows are based on collection system model output and the fecal coliform loads are the product of the flow and representative fecal coliform densities from monitoring data (682,000 cfu/100 mL for CSOs and 1,870,000 cfu/100 mL for SSOs).

Non-point sources are modeled within HSPF based on user-specified build-up and washoff parameters. Previous modeling efforts in Banklick Creek and the Licking River resulted in different sets of unit area loads (UALs). Build-up and washoff parameters in the Ohio River Tributary Model were evaluated to determine if either set of previously developed UALs reasonably reproduced observed instream values. The UALs from the Licking River Model were determined to provide a reasonable water quality calibration for the Ohio River tributaries. A comparison of the UALs from the three models is presented in Table 8.

Table 8. Comparison of Unit Area Loads in Licking River and Banklick Creek Watershed Models

Land Use Description	Banklick Model UAL [cfu/acre-year] New Storm/Old Storm[1]	Licking Model UAL [cfu/acre-year]	Ohio River Tributary Model UAL [cfu/acre-year]
Residential – High Density	5.1E+11 / 3.2E+12	2.5E+12	2.5E+12
Residential – Medium Density	3.5E+11 / 2.1E+12	1.9E+12	1.9E+12
Residential – Low Density	3.5E+11 / 2.1E+12	1.9E+12	1.9E+12
Comm/Industrial – High Density	2.1E+11 / 1.3E+12	1.3E+12	1.3E+12
Comm/Industrial – Medium Density	2.1E+11 / 1.3E+12	1.1E+12	1.1E+12
Comm/Industrial – Low Density	2.1E+11 / 1.3E+12	1.1E+12	1.1E+12
Developed Open Space	1.7E+10	1.8E+10	1.8E+10
Barren	1.2E+10	4.2E+10	4.2E+10
Forest	3.2E+09	1.4E+10	1.4E+10
Pasture/Grassland	5.8E+11	1.8E+12	1.8E+12
Cropland	2.9E+11	1.2E+12	1.2E+12

[1]Because of differences observed in storm water monitoring fecal coliform levels, different Banklick storm water loads were applied to old and new storm water areas.

Wet weather model calibration was performed by ensuring that the model reasonably reproduced the timing, magnitude, and range of observed instream fecal coliform densities observed during and after each storm event in each monitored waterbodies. Cumulative frequency distribution plots show the percent of values within the dataset that are less than each observed or simulated density. They are useful for comparing the range of observed and simulated densities and the relative frequencies at which they occur. Figure 7 shows the cumulative frequency distribution of the observed and modeled fecal coliform density for all of the locations in the entire model domain (in Set 2).

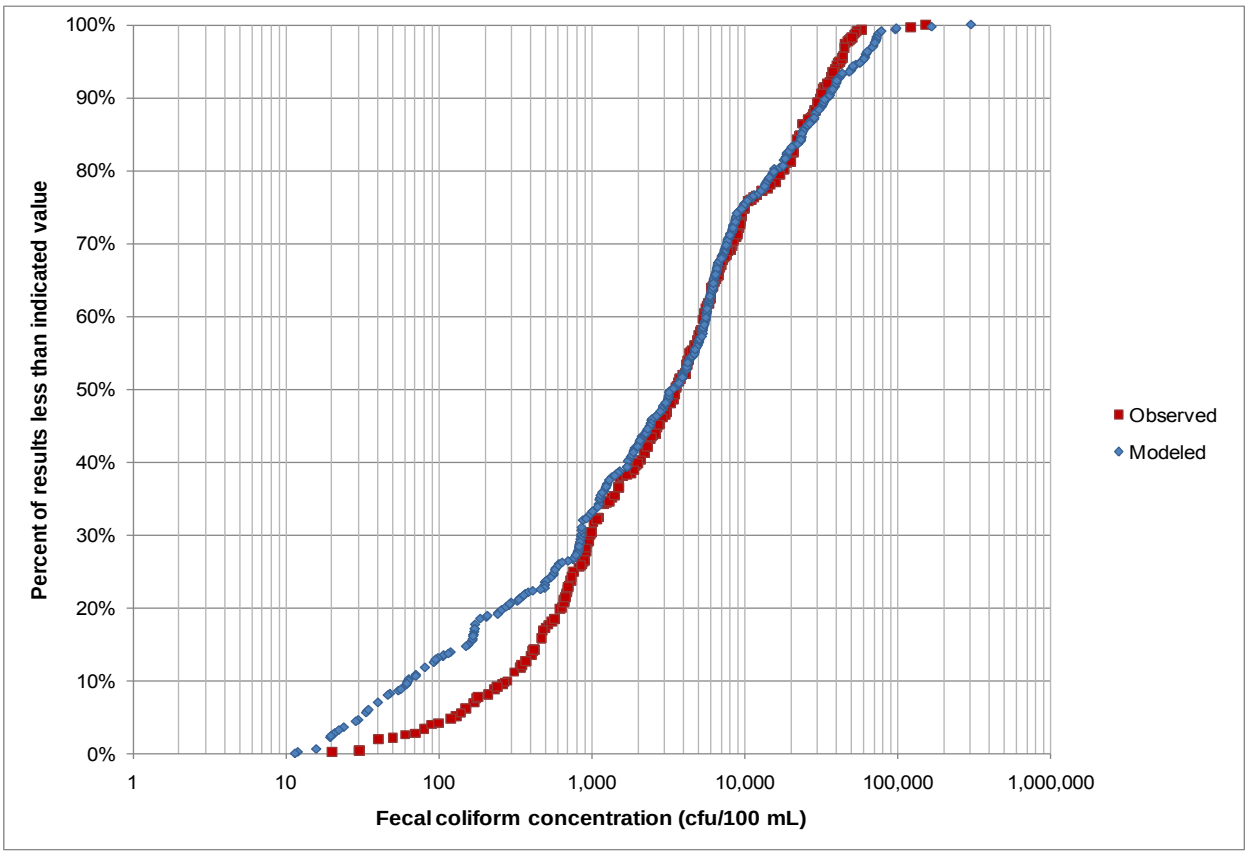

Figure 7: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform for All Calibration Locations.

The cumulative frequency distribution plots of the observed and modeled fecal coliform densities match fairly well, indicating that the model is successfully reproducing the range of observed densities at the appropriate frequency across all of the Set 2 watersheds in the model. Cumulative frequency distribution plots at each sampling location are included in the attachment to this memorandum. These plots show the model is successfully reproducing the range of observed data at most locations. Some locations (e.g. WPC1.4) are impacted by Ohio River backwater that dilute/reduce the bacteria load from the tributary watershed, however backwater effects cannot be simulated within HSPF. Therefore, the HSPF model provides a conservative (e.g. potentially higher) estimate of tributary bacteria loads being delivered to the Ohio River than would be calculated if backwater effects were accounted for.

This is further illustrated in Figure 8a and 8b, which show box-and-whisker comparisons of model-simulated densities and data at each sampling location. (Note that the sampling location identifier consists of a three-letter code for the waterbody and the river mile of the waterbody where the station is located). The "box" portion of the charts display the range of densities between the 25th and 75th percentiles and the "whiskers" display the 5th and 95th percentile densities. These figures illustrate the model's ability to reproduce the range of observed values at each location.

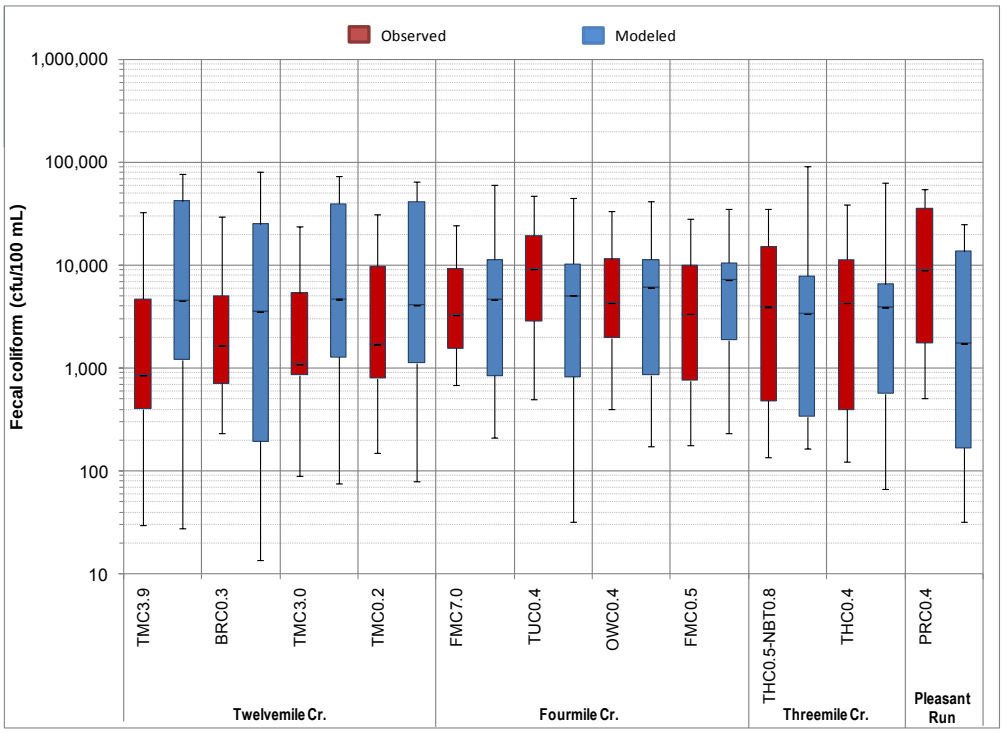

Figure 8a: Box-and-Whisker Comparison of Modeled and Observed Fecal Coliform for All Calibration Locations in Twelvemile, Fourmile, Threemile and Pleasant Run Creeks.

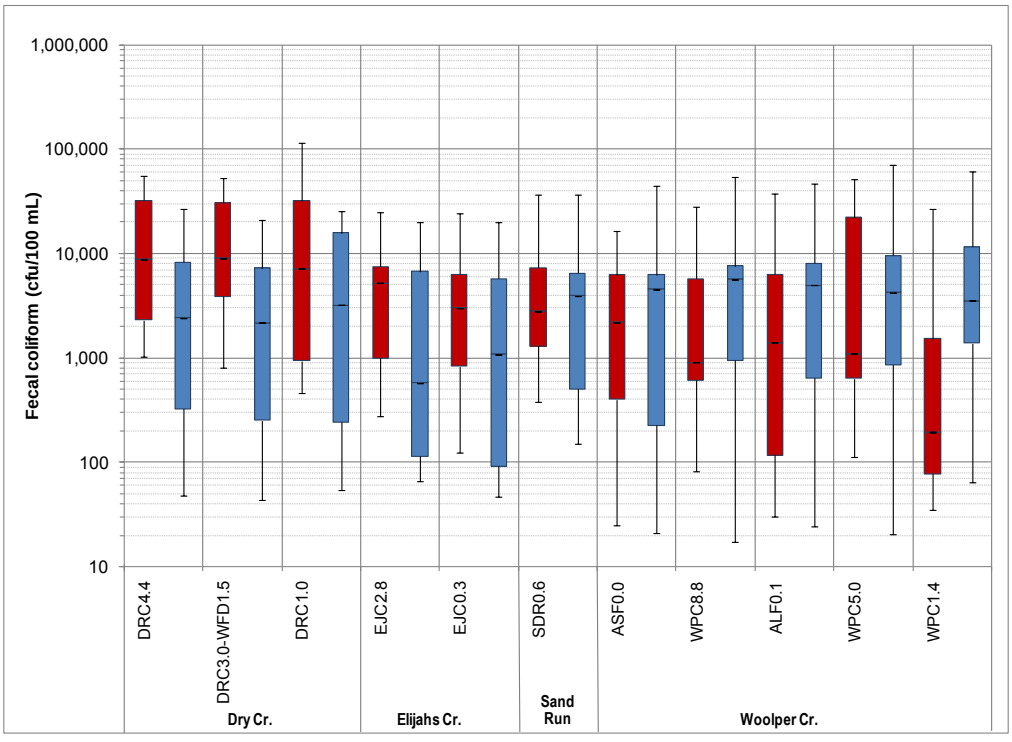

Figure 8b: Box-and-Whisker Comparison of Modeled and Observed Fecal Coliform for All Calibration Locations in Dry, Elijahs, Sand Run and Woolper Creeks.

As these figures illustrate, for most locations, there is good agreement between the model and data. However, some locations, like WPC1.4, show that the model is overpredicting the range observed in the data, likely due to Ohio River backwater effects on the data. However, there are other locations, such as the stations in Twelvemile Creek and Dry Creek, where the model overpredicts and underpredicts, respectively, for reasons that are not clear. Plots of the time series of modeled and measured fecal coliform densities suggest that the discrepancy in the box-and-whisker results may be due to difficulty in reproducing the timing of the event in the model. An example time series plot is shown in Figure 9 for the sampling location in Woolper Creek at river mile 5.0 (WPC5.0). Comparable figures are shown for all calibration locations in the attachment and show that peak fecal coliform densities are well-represented and the bacteria load timing is captured within a few hours observed in the data.

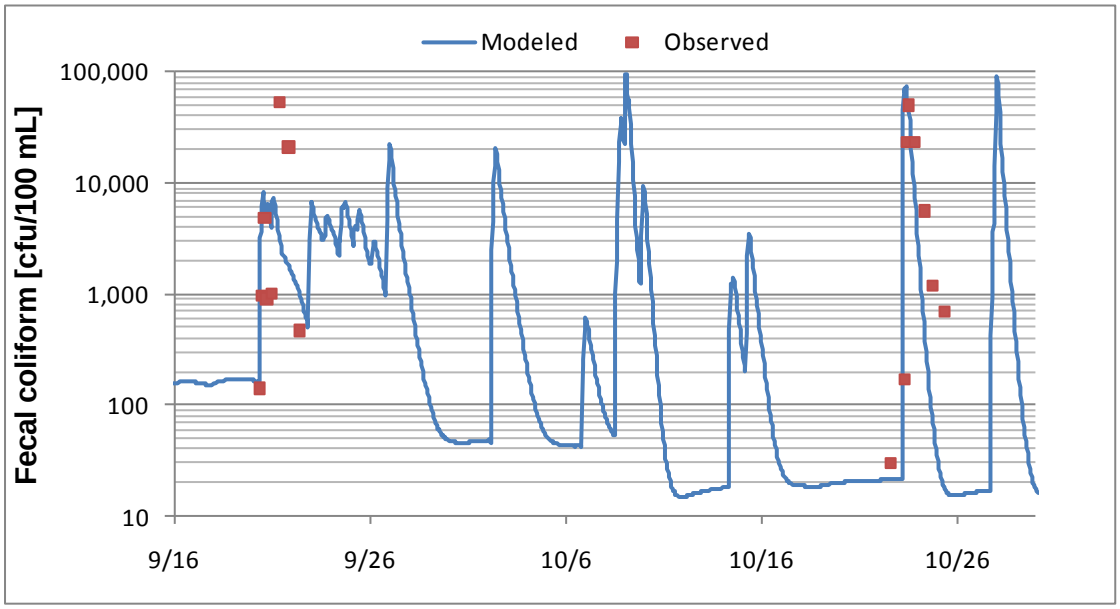

Figure 9: Comparison of Modeled and Observed Fecal Coliform in Woolper Creek at River Mile 5.0.

Conclusions

The information from the Ohio River Tributary Watershed Modeling effort can be summarized as follows:

- The HSPF model provides a reasonable reproduction of flow and fecal coliform levels in the Ohio River tributaries for a range of environmental conditions;
- The calibration suggests that the fecal coliform unit area loads developed for the lower Licking River are providing reasonable estimates of nonpoint source bacteria loads for the Ohio River Tributaries;
- The model will be a useful tool for quantifying potential benefits of various control scenarios considered for the Watershed Plans, responding to the Ohio River bacteria TMDL, or other needs.

The calibration to instream values indicates that it is capable of reproducing the timing and magnitude of most of the observed data. It is the best tool available for evaluating instream impacts from fecal coliform sources under a range of environmental conditions and control scenarios. The model is suitable for

evaluating the water quality benefits of traditional infrastructure, green infrastructure, and watershed control alternatives in the Ohio River tributaries in the SD1 jurisdictional area.

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Donigian, A.S. Jr. 2002. Watershed Model Calibration and Validation: The HSPF Experience. WEF National TMDL Science and Policy 2002, November 13-16, 2002. Phoenix, AZ. WEF Specialty Conference Proceedings on CD-ROM.

Humel, P., J. Kittle, Jr., M. Gray. 2001. WDMUtil: A Tool for Managing Watershed Modeling Time-Series Data User's Manual. AQUA TERRA Consultants. March 2001.

LimnoTech. 2010. "Development of an HSPF Watershed Model of the Lower Licking River Watershed". Memorandum to SD1 on September 28, 2010.

United States Environmental Protection Agency. 2000. EPA BASINS Technical Note 6: Estimating Hydrology and Hydraulic Parameters for HSPF. June 2000.

Attachment A:

Supporting Hydrologic Calibration Figures-

Cumulative Frequency Distributions of Flow and Volume at Each Calibration Location

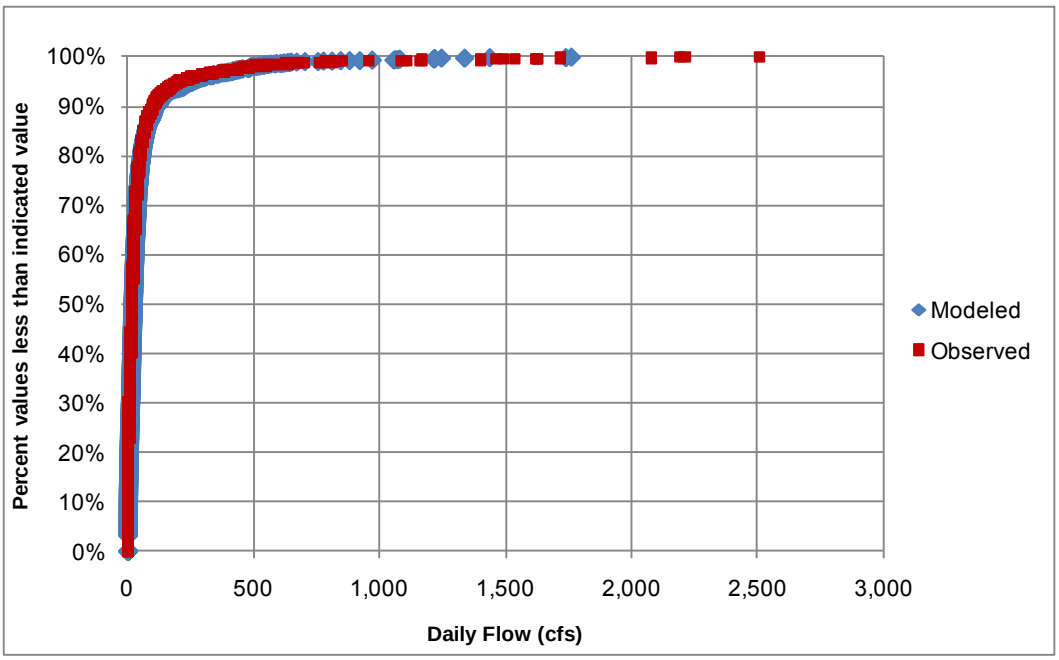

Figure A-1: Distribution of Modeled and Observed Daily Flows at Big Bone Creek

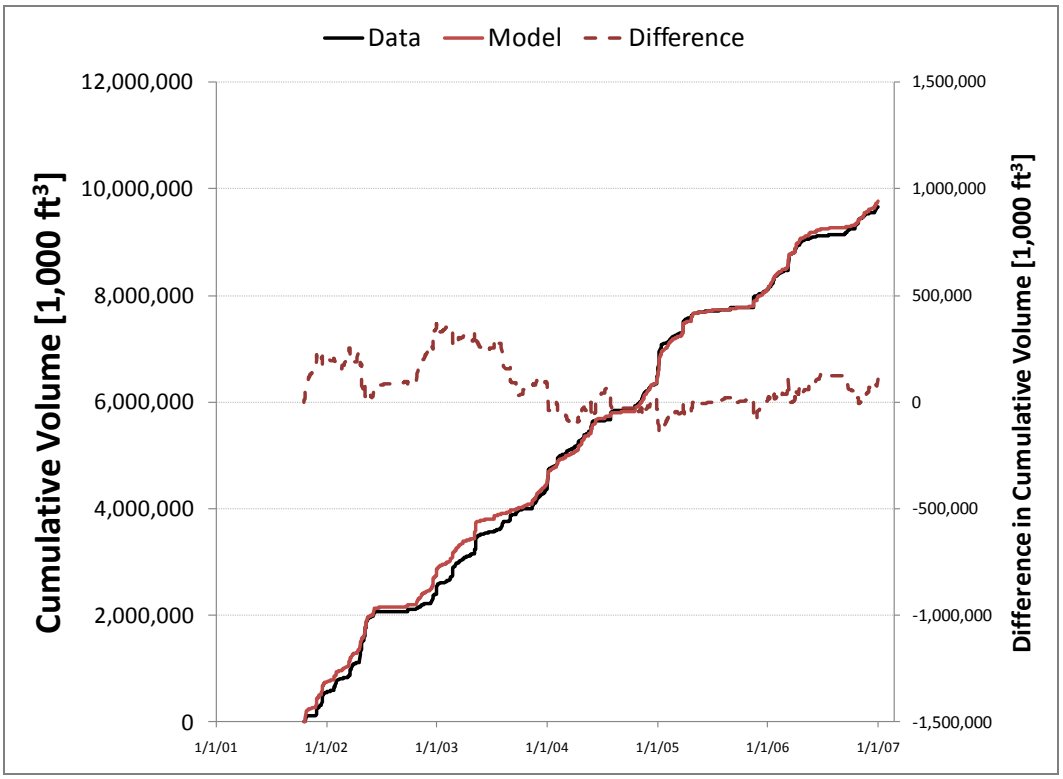

Figure A-2: Distribution of Modeled and Observed Volumes at Big Bone Creek

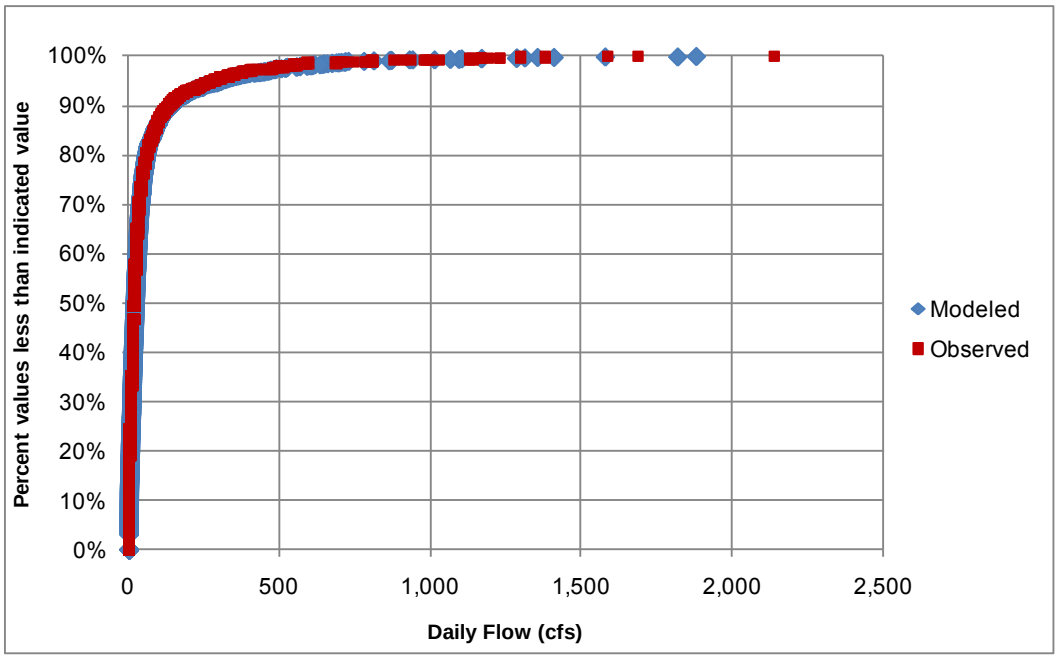

Figure A-3: Distribution of Modeled and Observed Daily Flows at Gunpowder Creek.

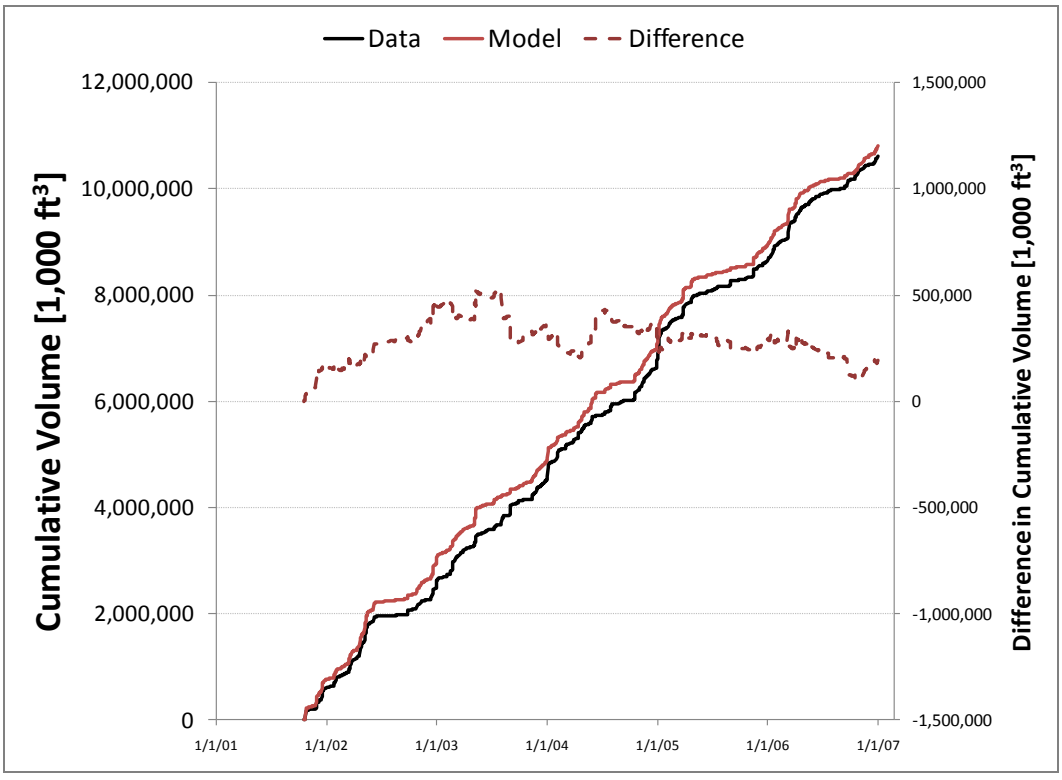

Figure A-4: Distribution of Modeled and Observed Volumes at Gunpowder Creek.

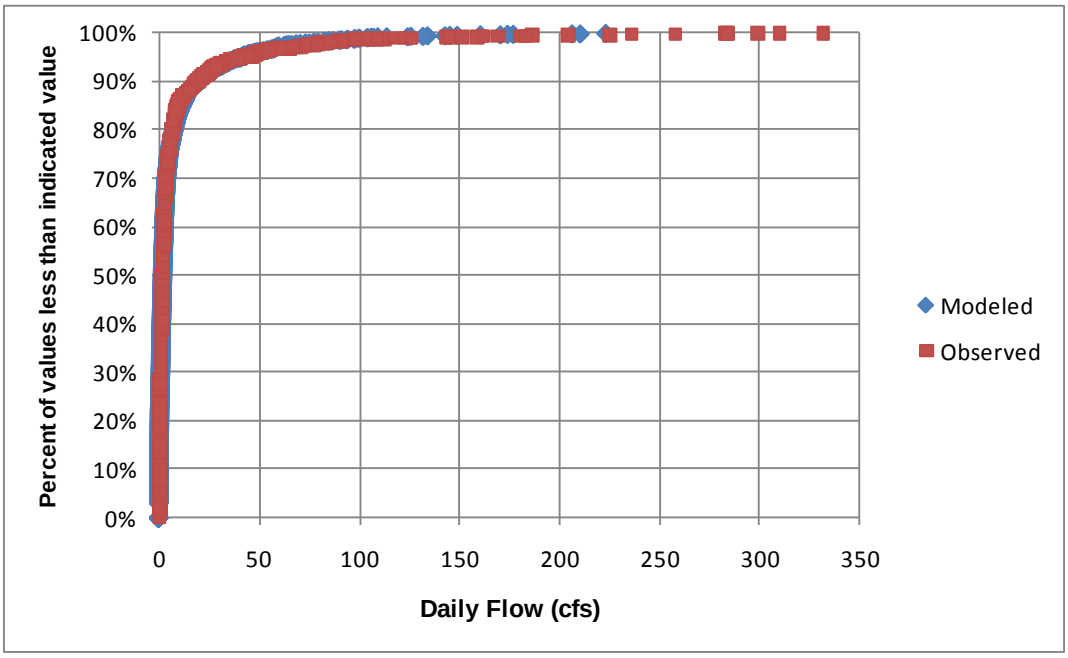

Figure A-5: Distribution of Modeled and Observed Daily Flows at Elijahs Creek.

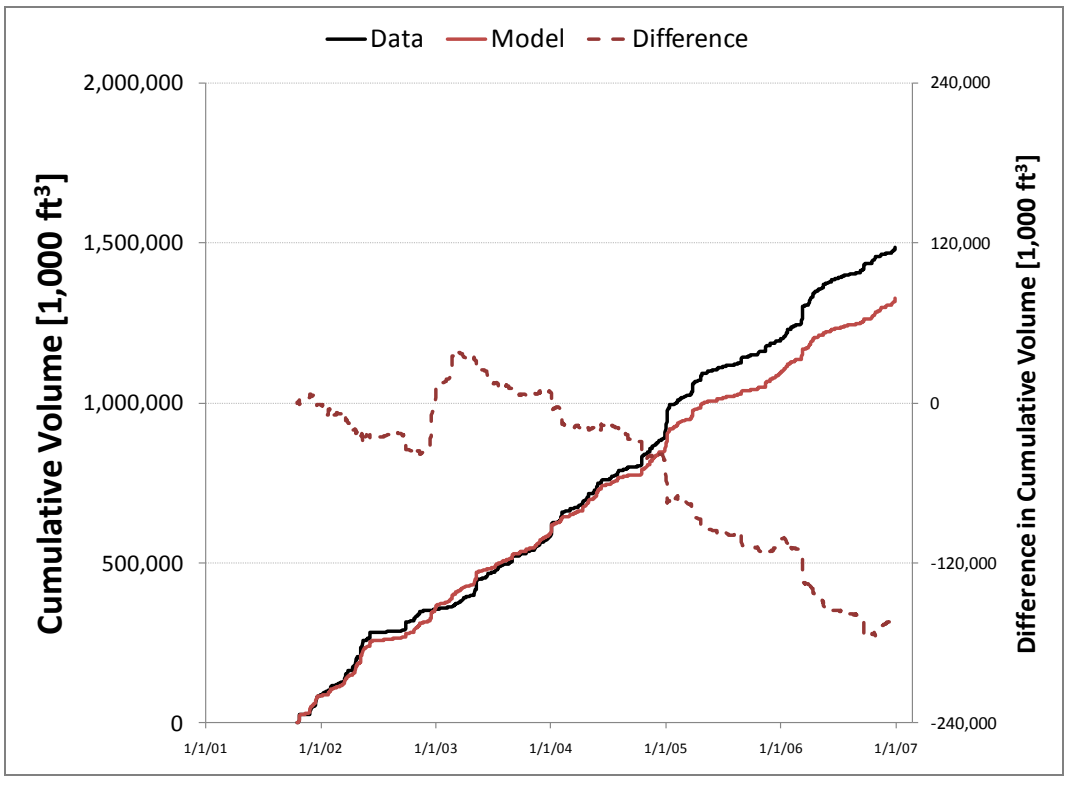

Figure A-6: Distribution of Modeled and Observed Volumes at Elijahs Creek.

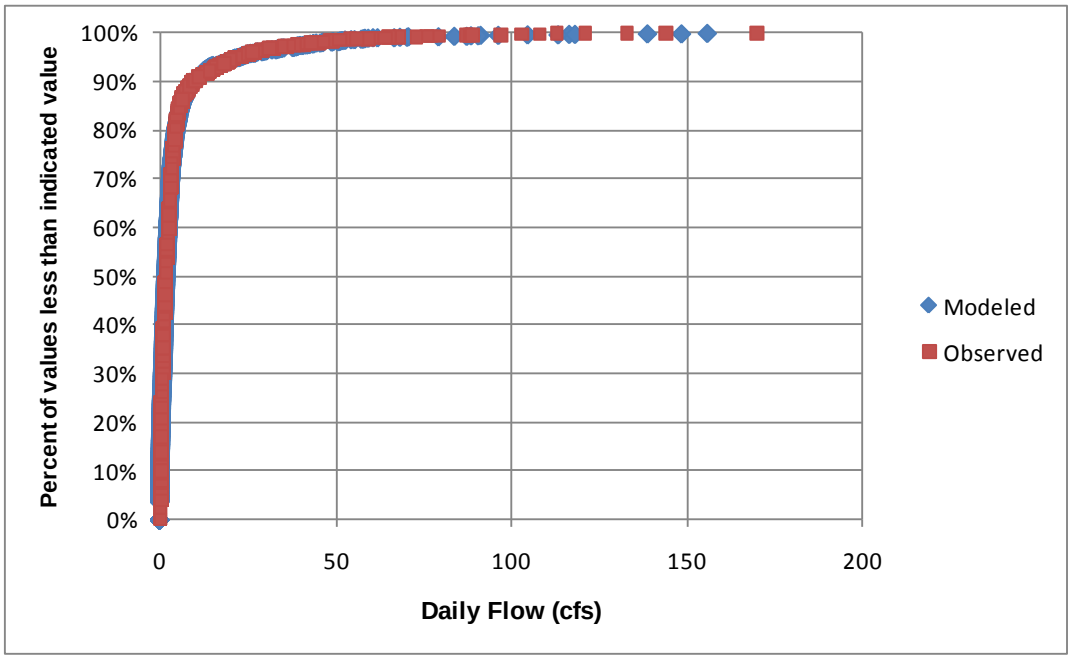

Figure A-7: Distribution of Modeled and Observed Daily Flows at Fourmile Creek.

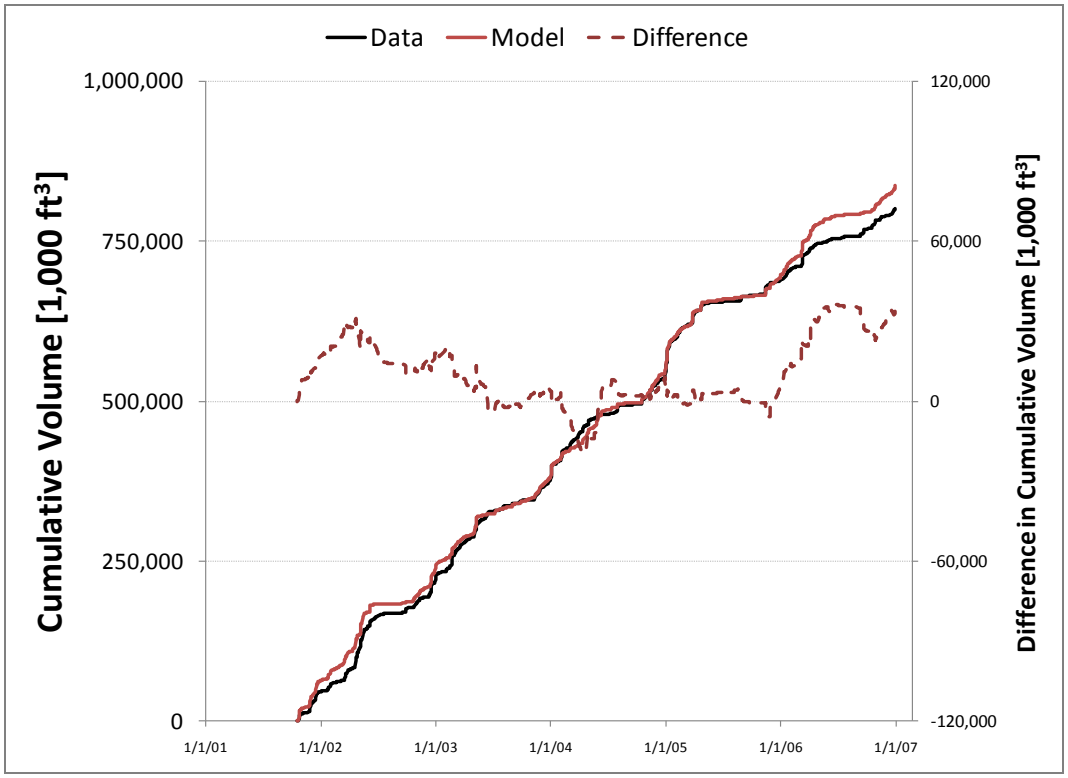

Figure A-8: Distribution of Modeled and Observed Volumes at Fourmile Creek.

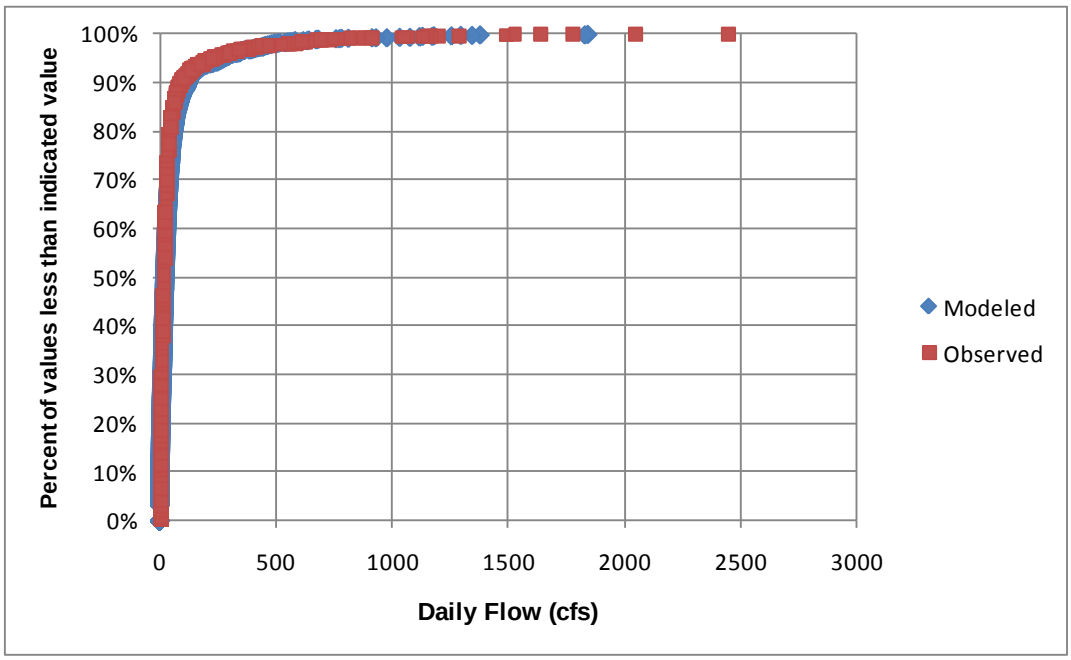

Figure A-9: Distribution of Modeled and Observed Daily Flows at Twelvemile Creek.

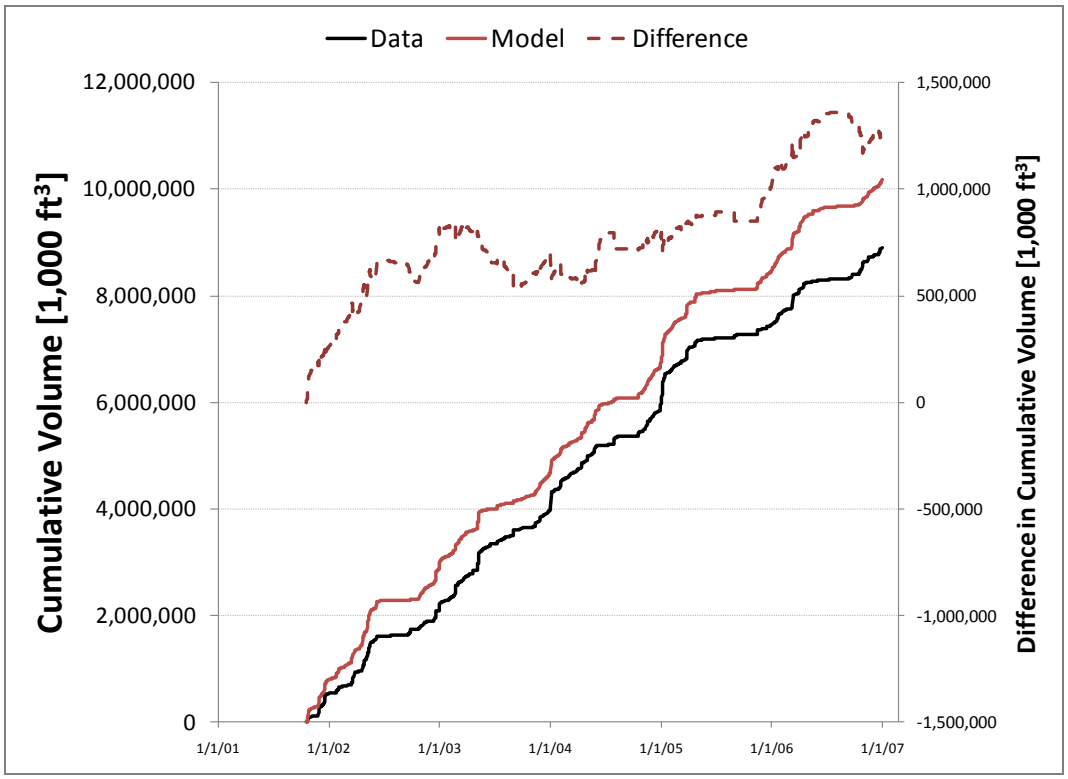

Figure A-10: Distribution of Modeled and Observed Volumes at Twelvemile Creek.

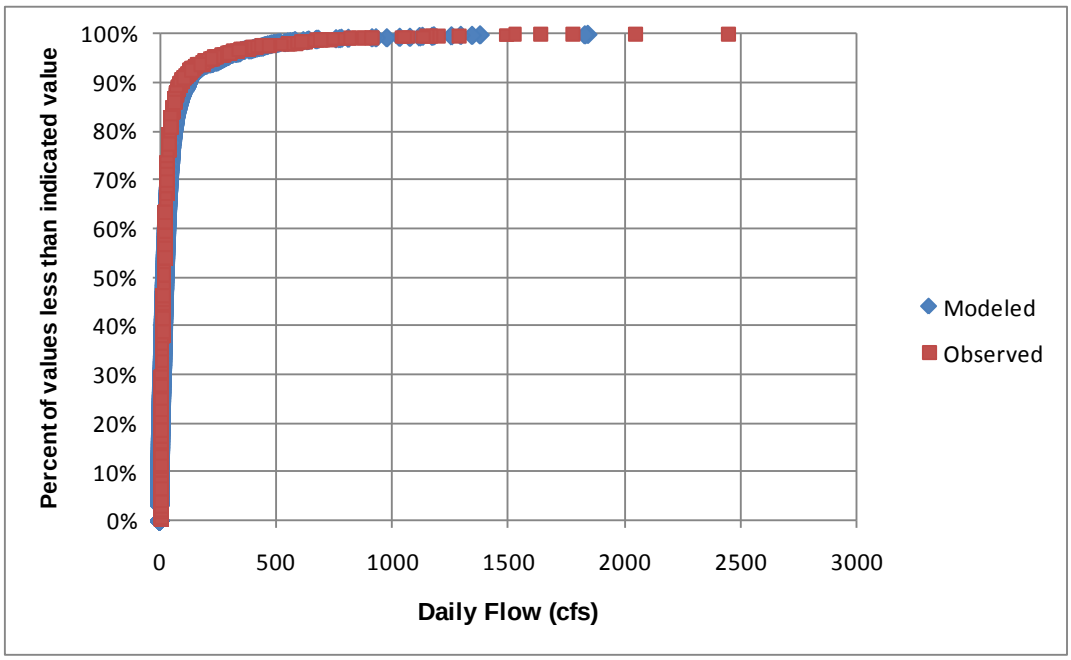

Figure A-11: Distribution of Modeled and Observed Daily Flows at Woolper Creek.

Figure A-12: Distribution of Modeled and Observed Volumes at Woolper Creek.

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Attachment B:

Supporting Water Quality Calibration Figures-Cumulative Frequency Distributions of Fecal Coliform Densities in Each Watershed

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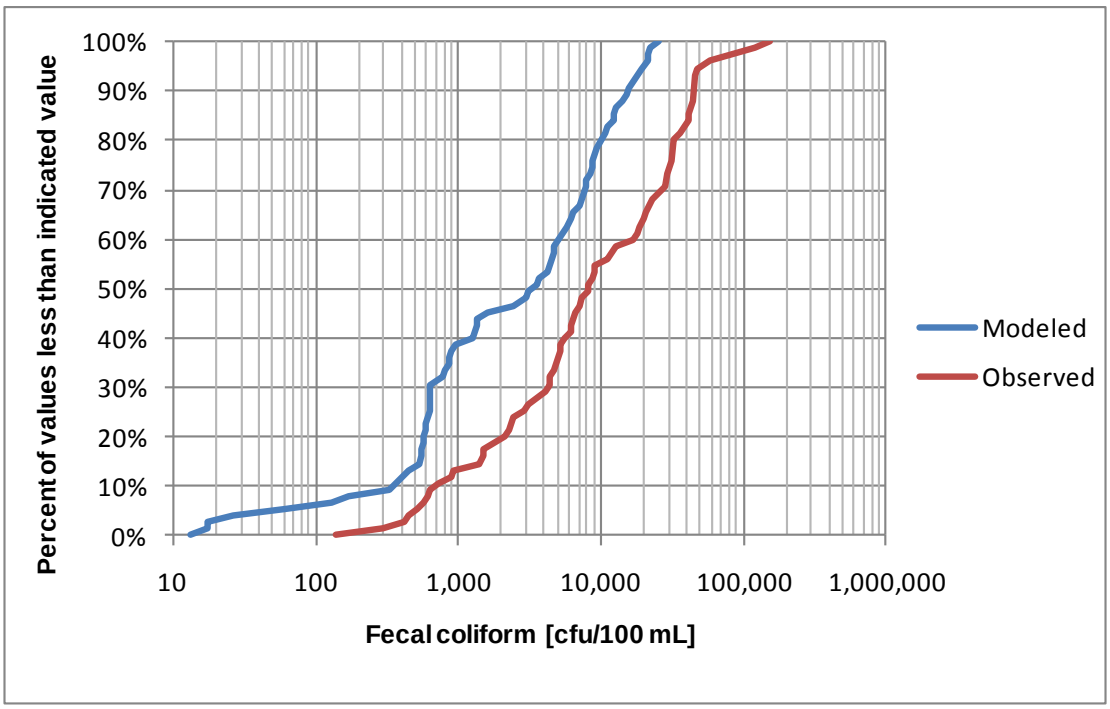

Figure B-1: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Dry Creek Watershed.

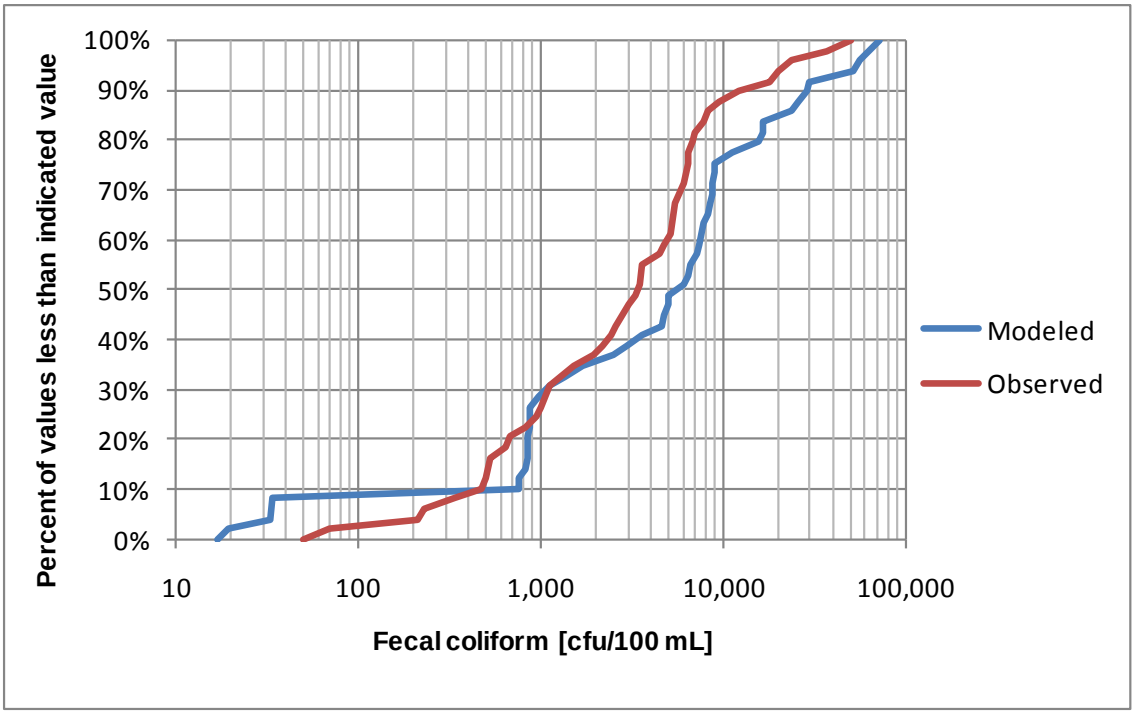

Figure B-2: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Elijahs Creek Watershed.

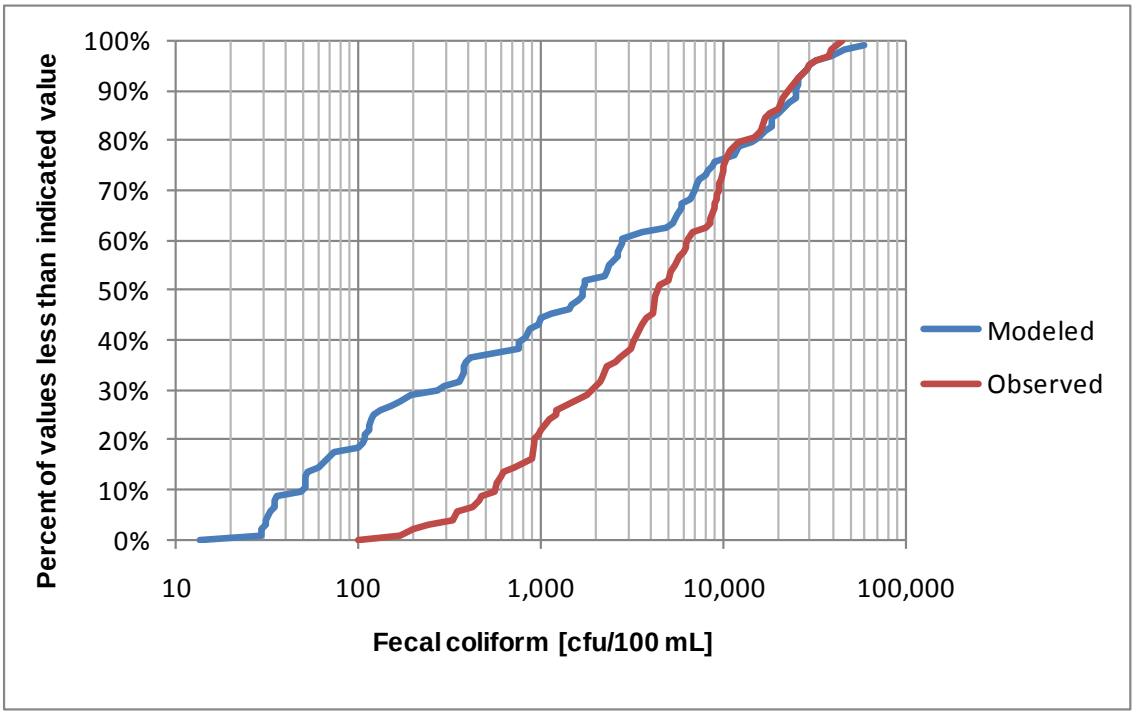

Figure B-3: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Fourmile Creek Watershed.

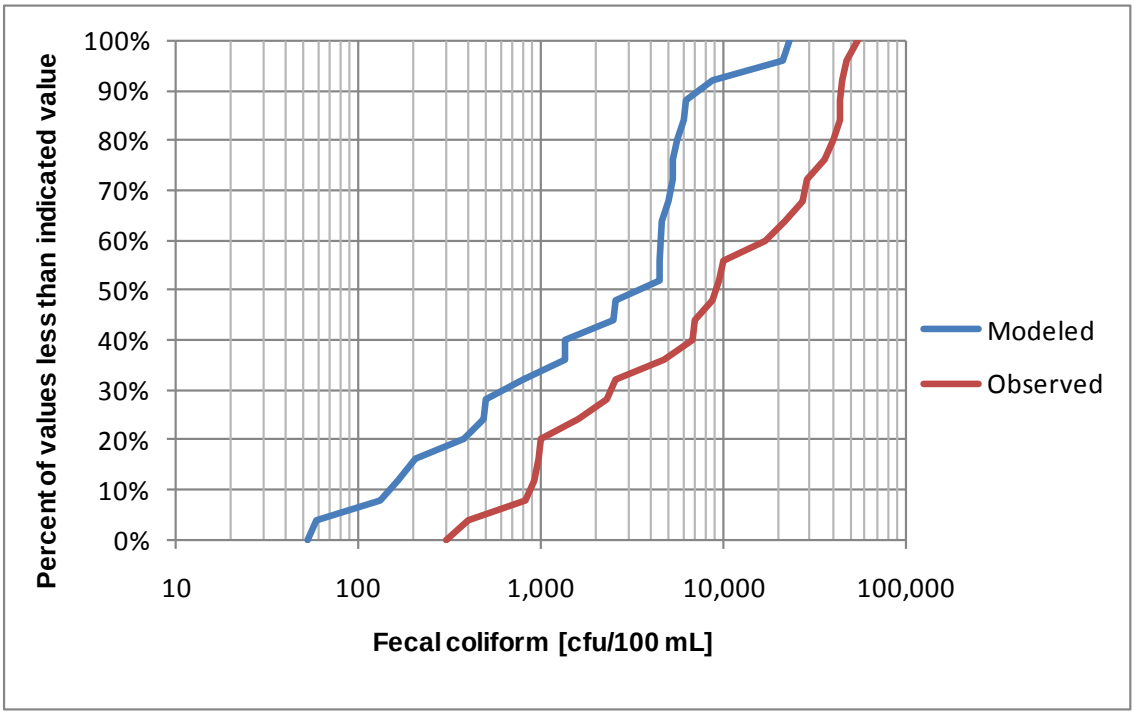

Figure B-4: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Pleasant Run Creek Watershed.

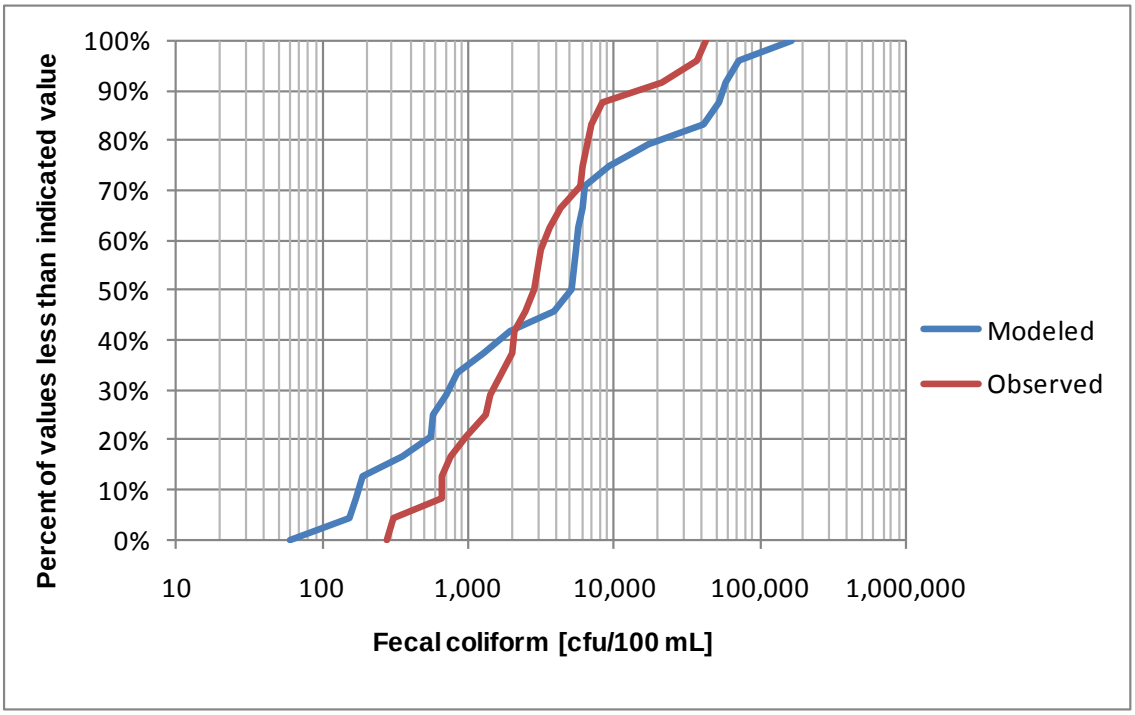

Figure B-5: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Sand Run Watershed.

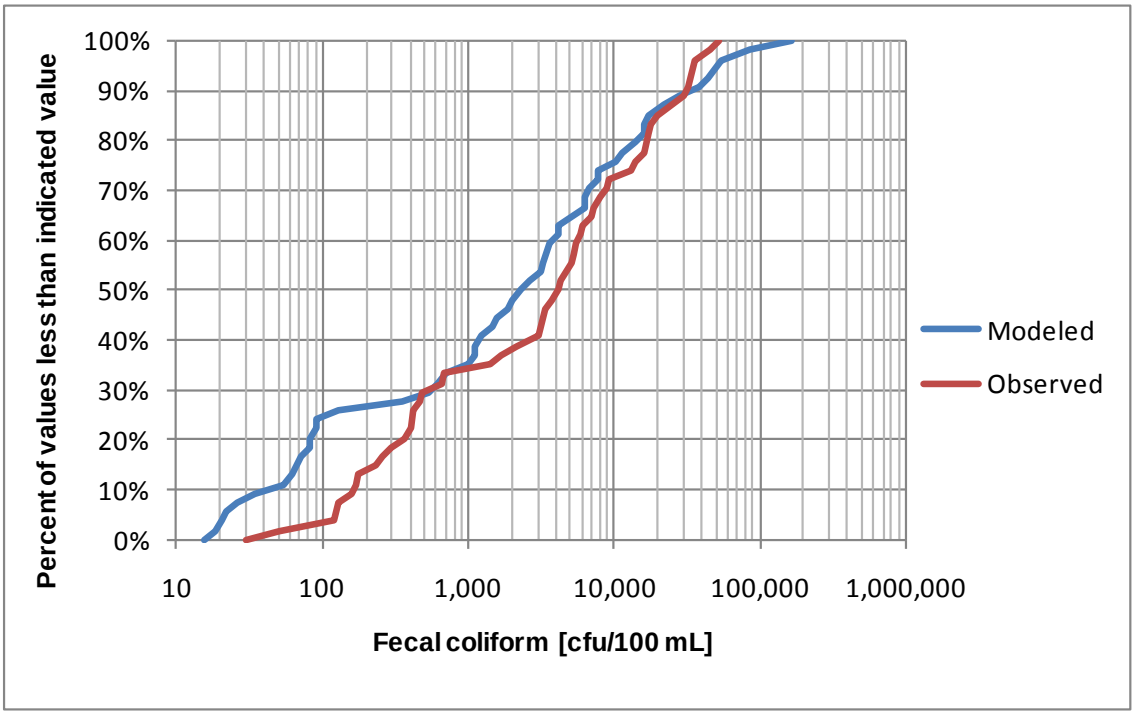

Figure B-6: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Threemile Creek Watershed.

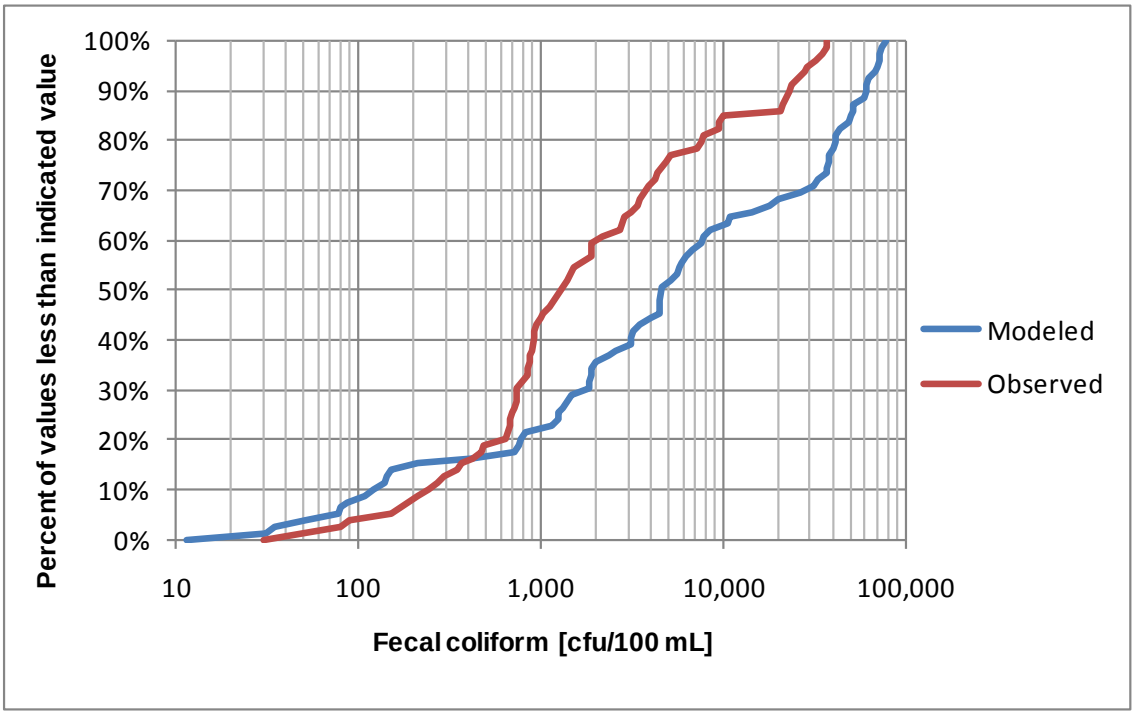

Figure B-7: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Twelvemile Creek Watershed.

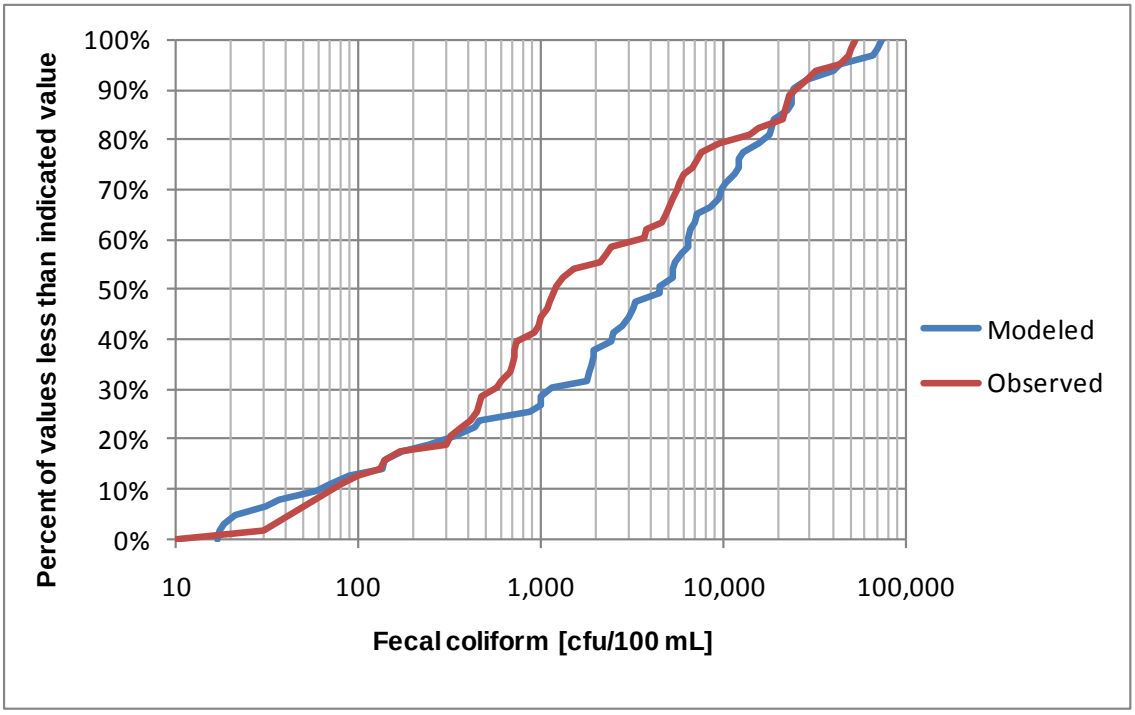

Figure B-8: Cumulative Frequency Distribution of Modeled and Observed Fecal Coliform Densities in Woolper Creek Watershed, excluding River Mile 1.4.

Attachment C:

Supporting Water Quality Calibration Figures

Temporal Profiles of Fecal Coliform Densities at Each Sampling Location

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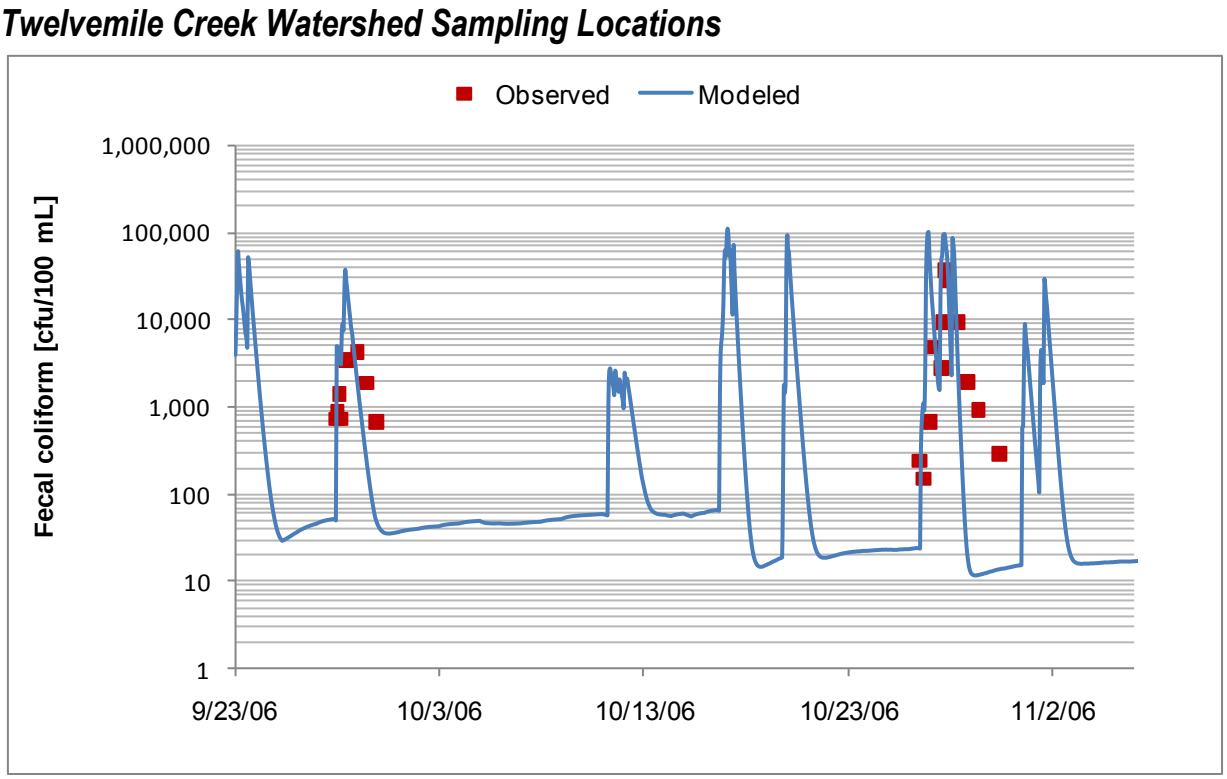

Figure C-1: Comparison of Modeled and Observed Fecal Coliform at Brush Creek RM 0.3.

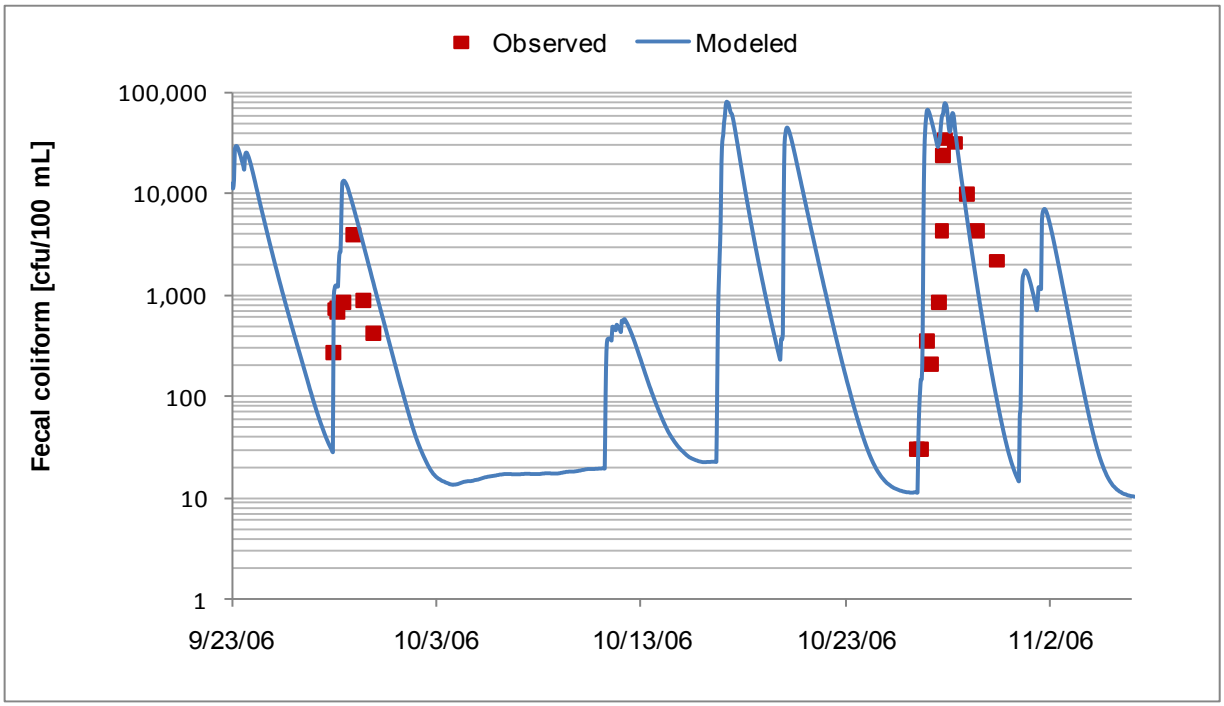

Figure C-2: Comparison of Modeled and Observed Fecal Coliform at Twelvemile Creek RM 3.9.

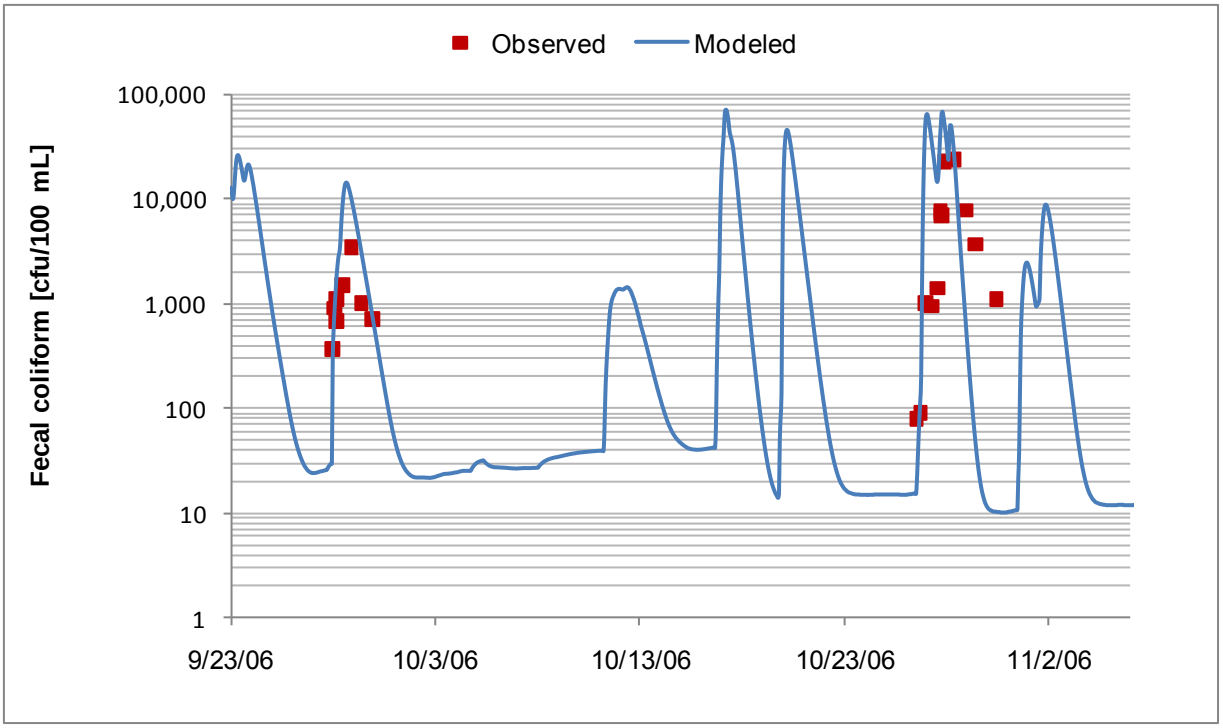

Figure C-3: Comparison of Modeled and Observed Fecal Coliform at Twelvemile Creek RM 3.0.

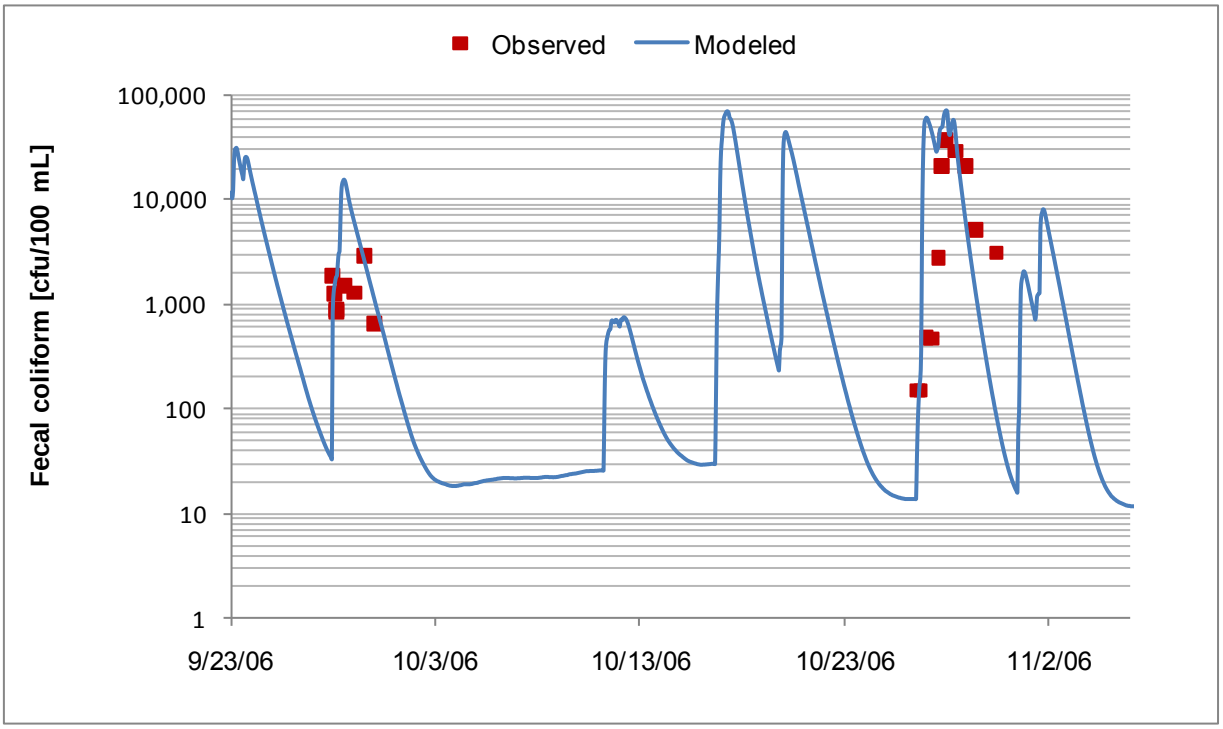

Figure C-4: Comparison of Modeled and Observed Fecal Coliform at Twelvemile Creek RM 0.2.

Fourmile Creek Watershed Sampling Locations

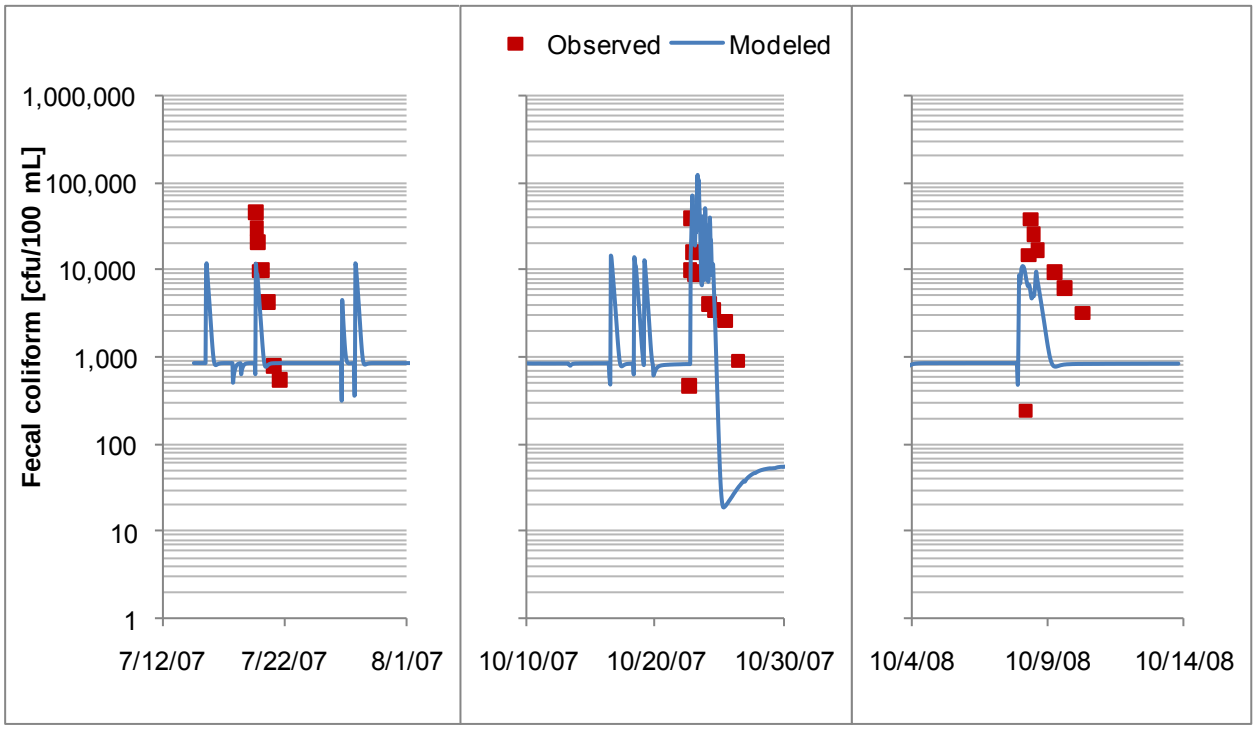

Figure C-5: Comparison of Modeled and Observed Fecal Coliform at Tug Creek at RM 0.4.

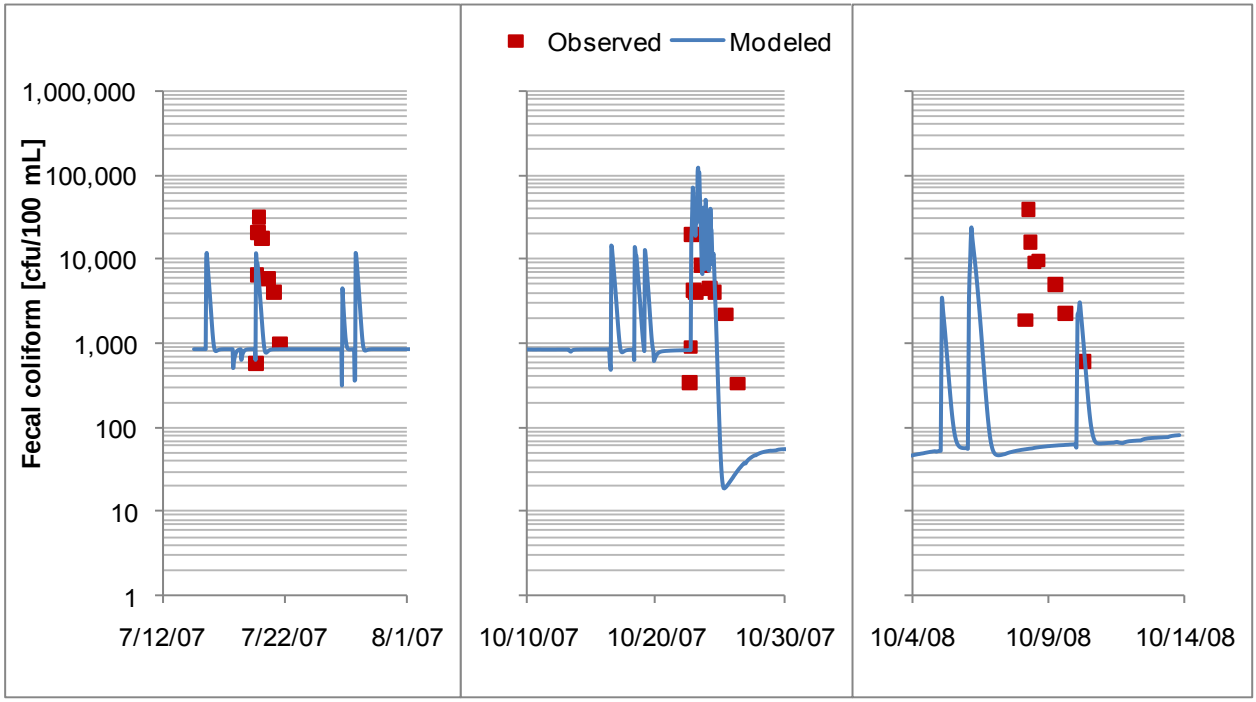

Figure C-6: Comparison of Modeled and Observed Fecal Coliform at Owl Creek at RM 0.4.

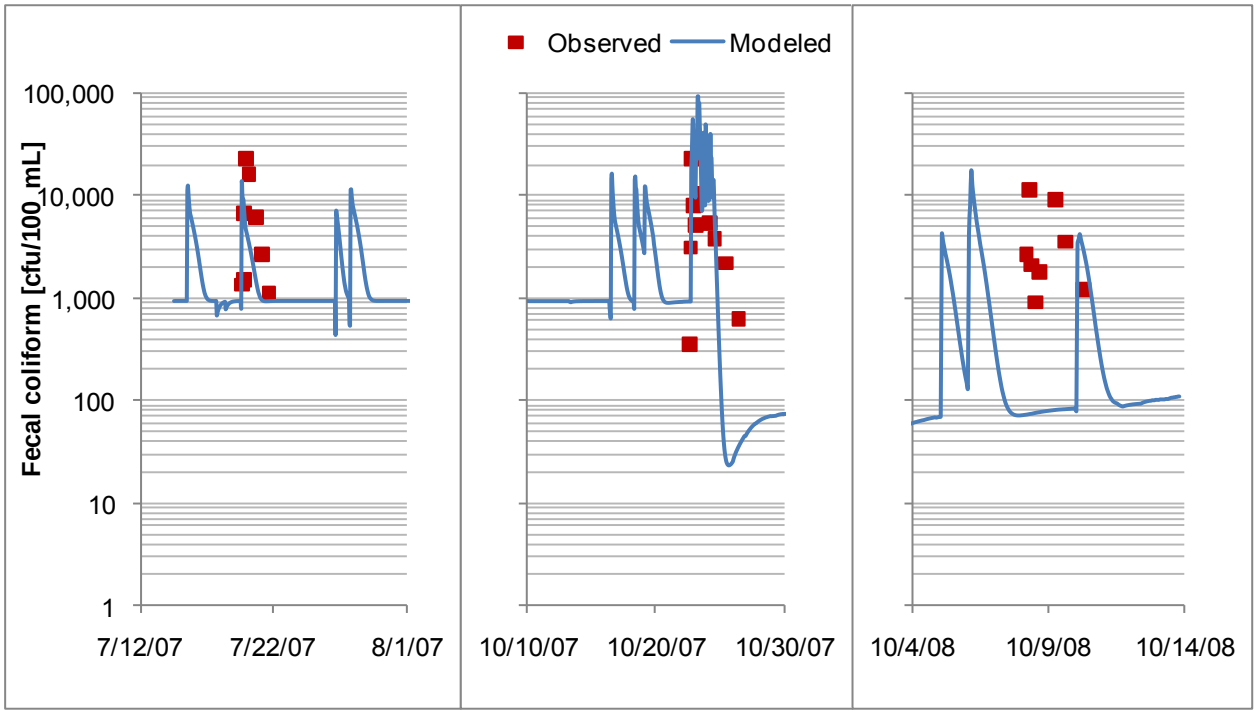

Figure C-7: Comparison of Modeled and Observed Fecal Coliform at Fourmile Creek RM 7.0.

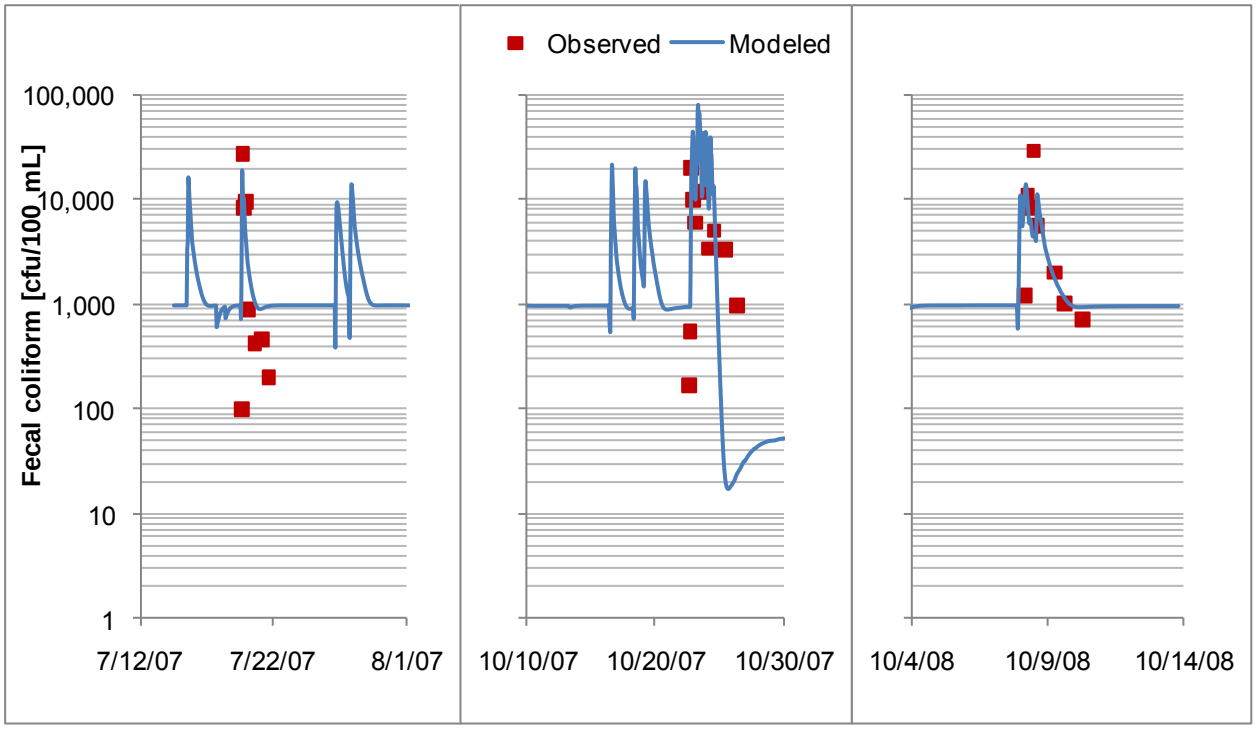

Figure C-8: Comparison of Modeled and Observed Fecal Coliform at Fourmile Creek RM 0.5.

Pleasant Run Watershed Sampling Locations

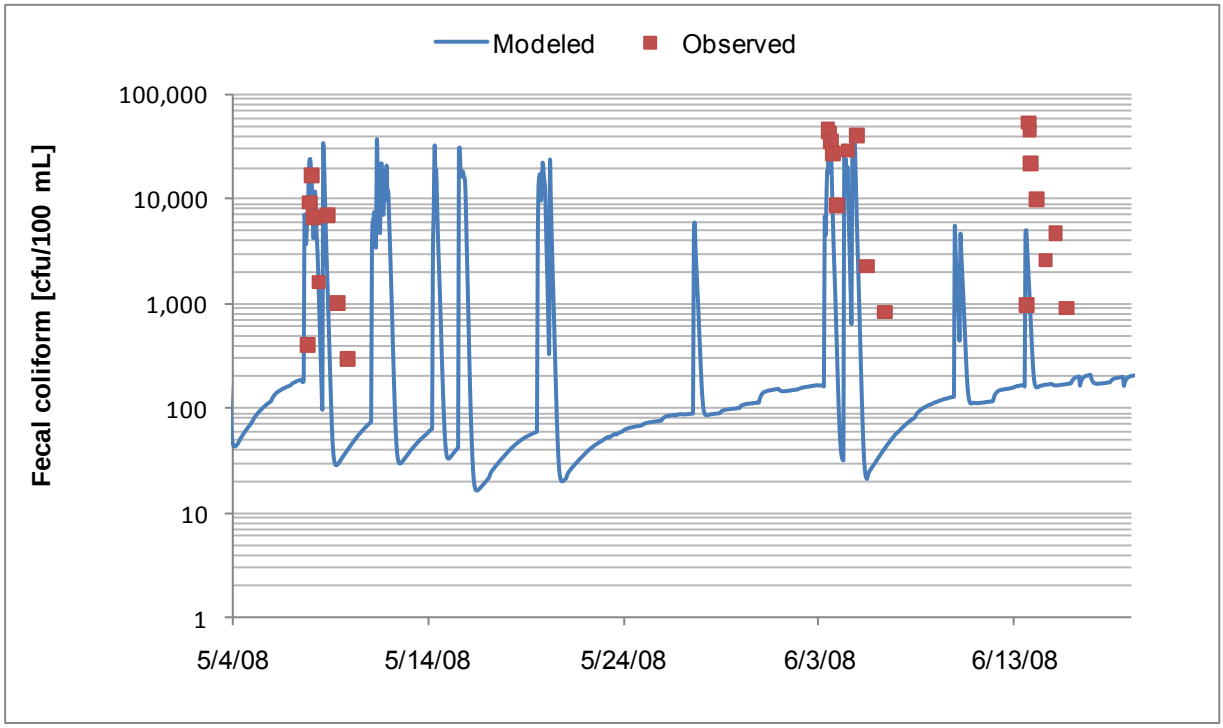

Figure C-9: Comparison of Modeled and Observed Fecal Coliform at Pleasant Run Creek RM 0.4.

Dry Creek Watershed Sampling Locations

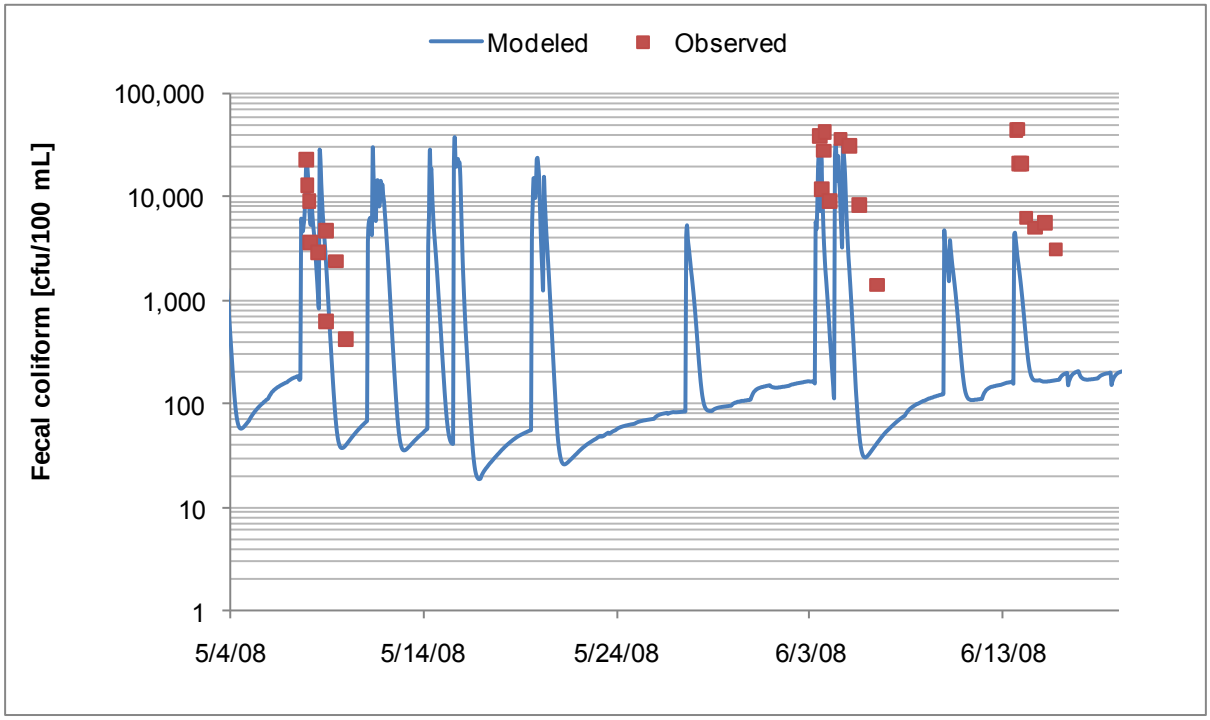

Figure C-10: Comparison of Modeled and Observed Fecal Coliform at West Fork Dry Creek RM 1.5.

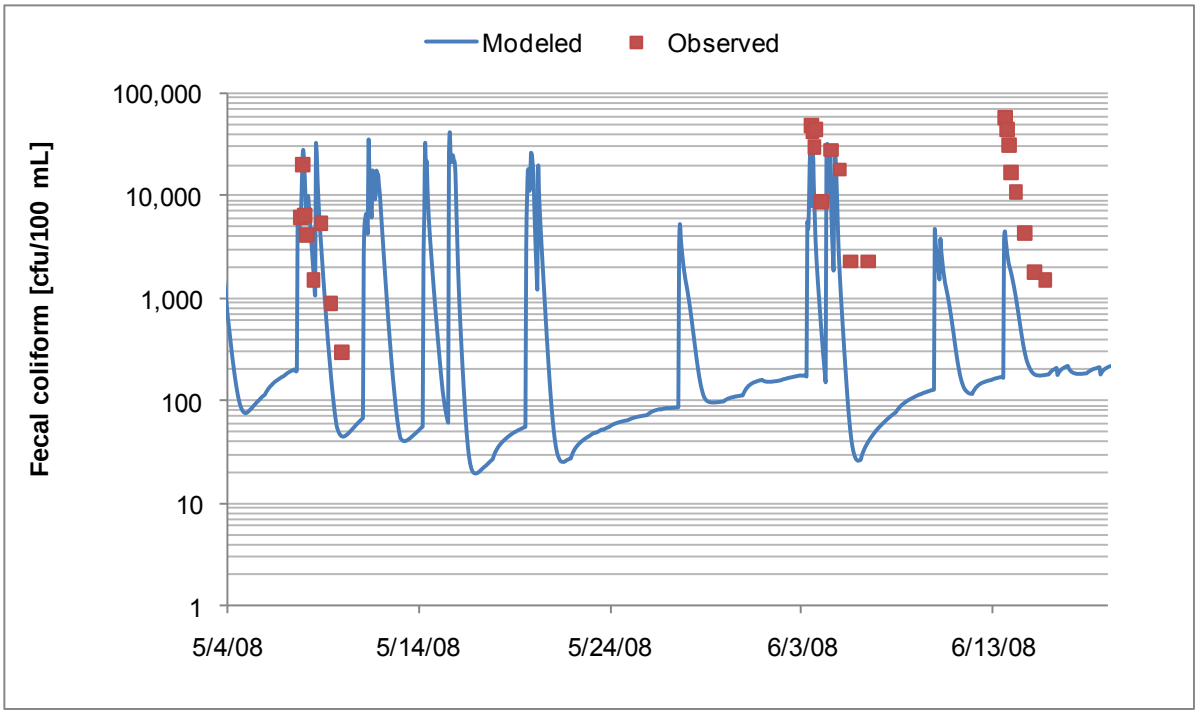

Figure C-11: Comparison of Modeled and Observed Fecal Coliform at Dry Creek RM 4.4.

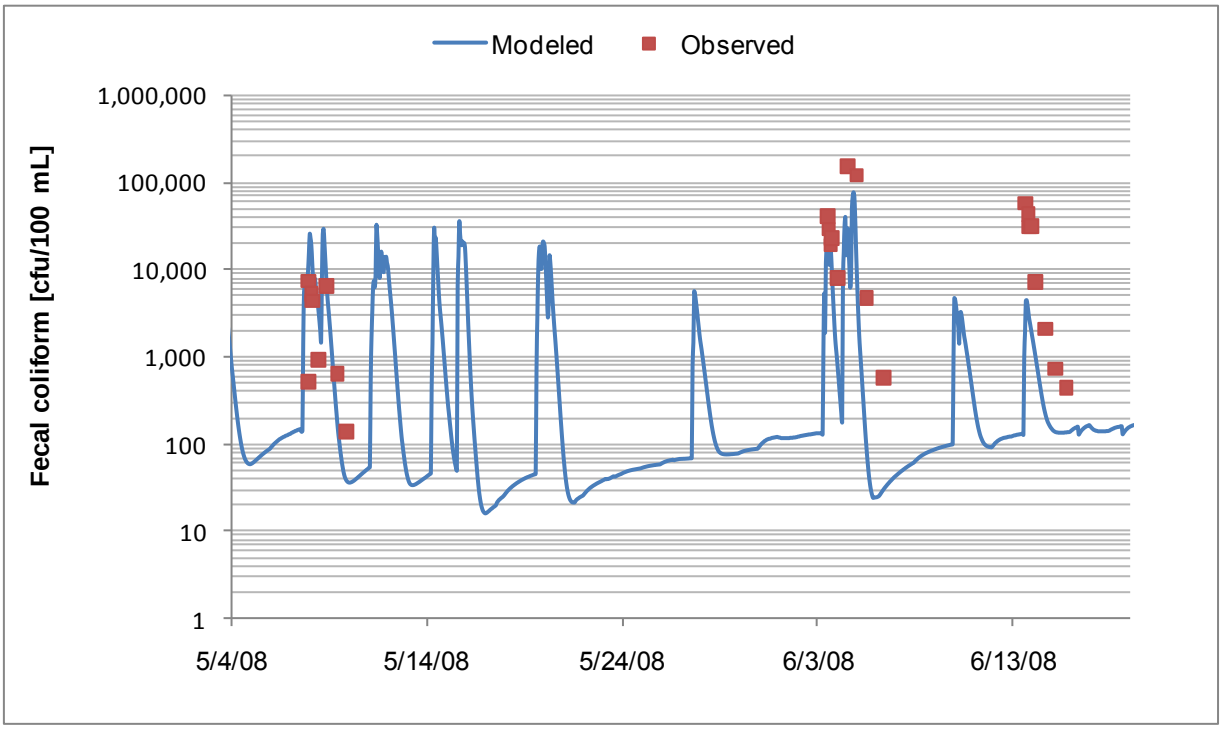

Figure C-12: Comparison of Modeled and Observed Fecal Coliform at Dry Creek RM 1.0.

Elijahs Creek Watershed Sampling Locations

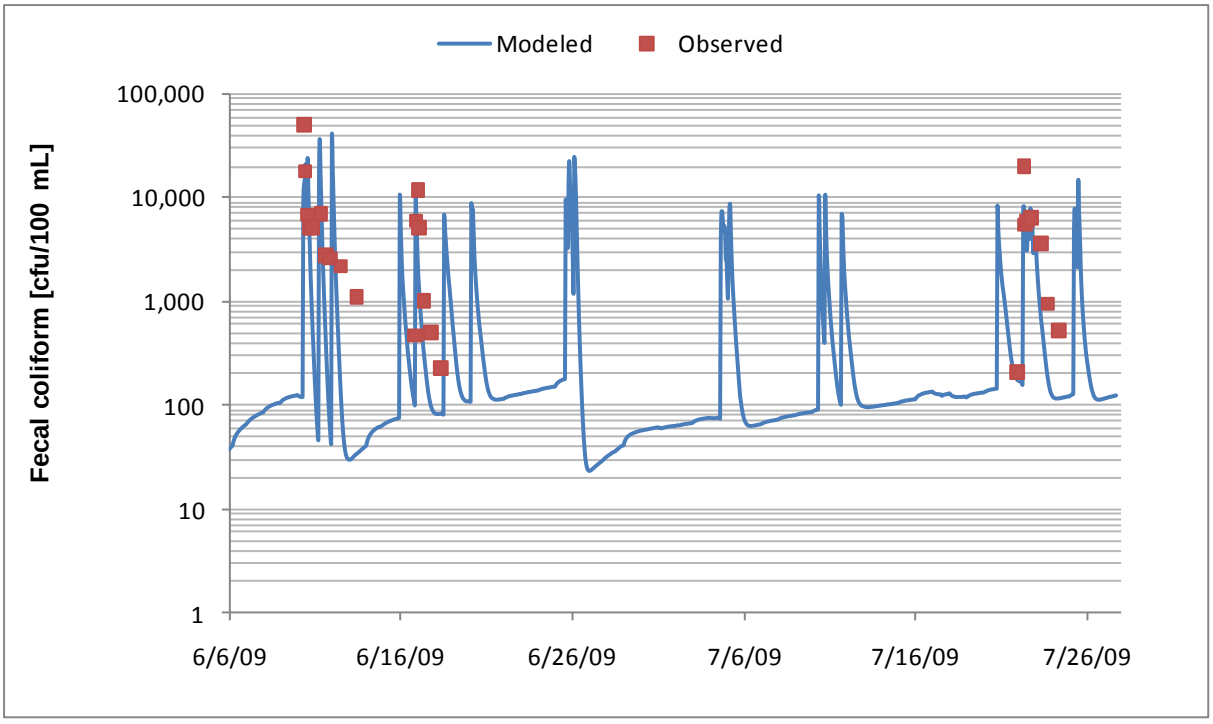

Figure C-13: Comparison of Modeled and Observed Fecal Coliform at Elijahs Creek RM 2.8.

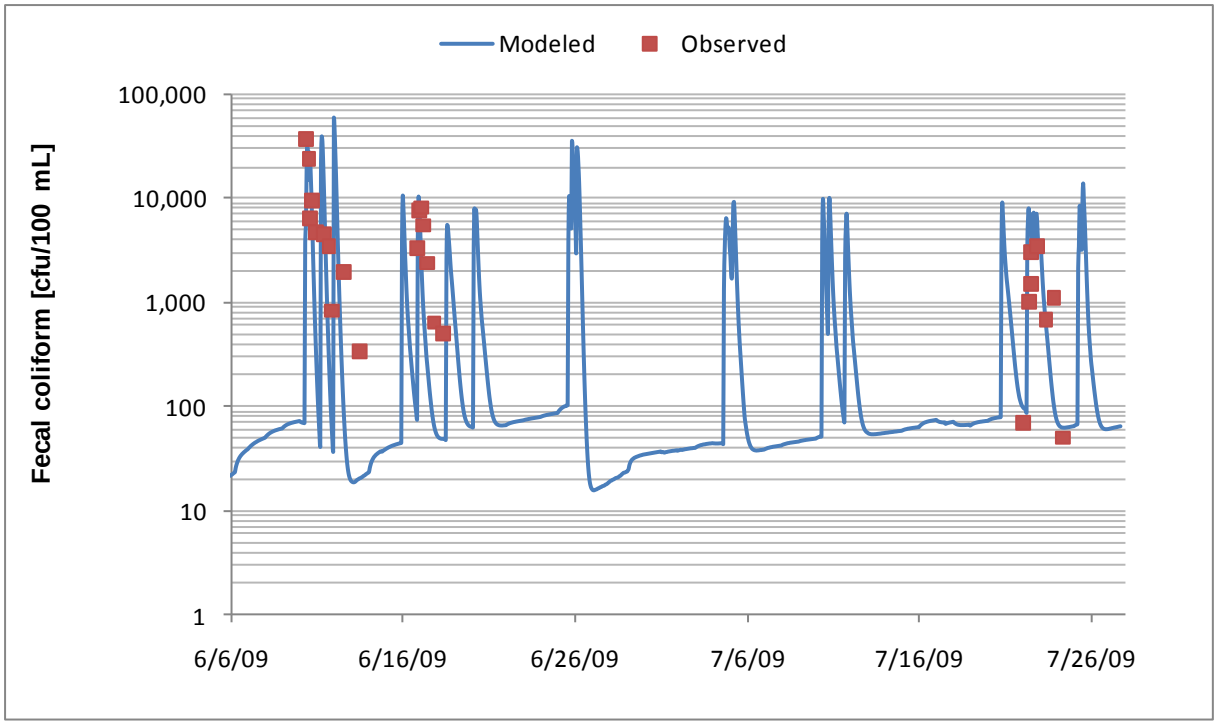

Figure C-14: Comparison of Modeled and Observed Fecal Coliform at Elijah's Creek RM 0.3.

Sand Run Watershed Sampling Locations

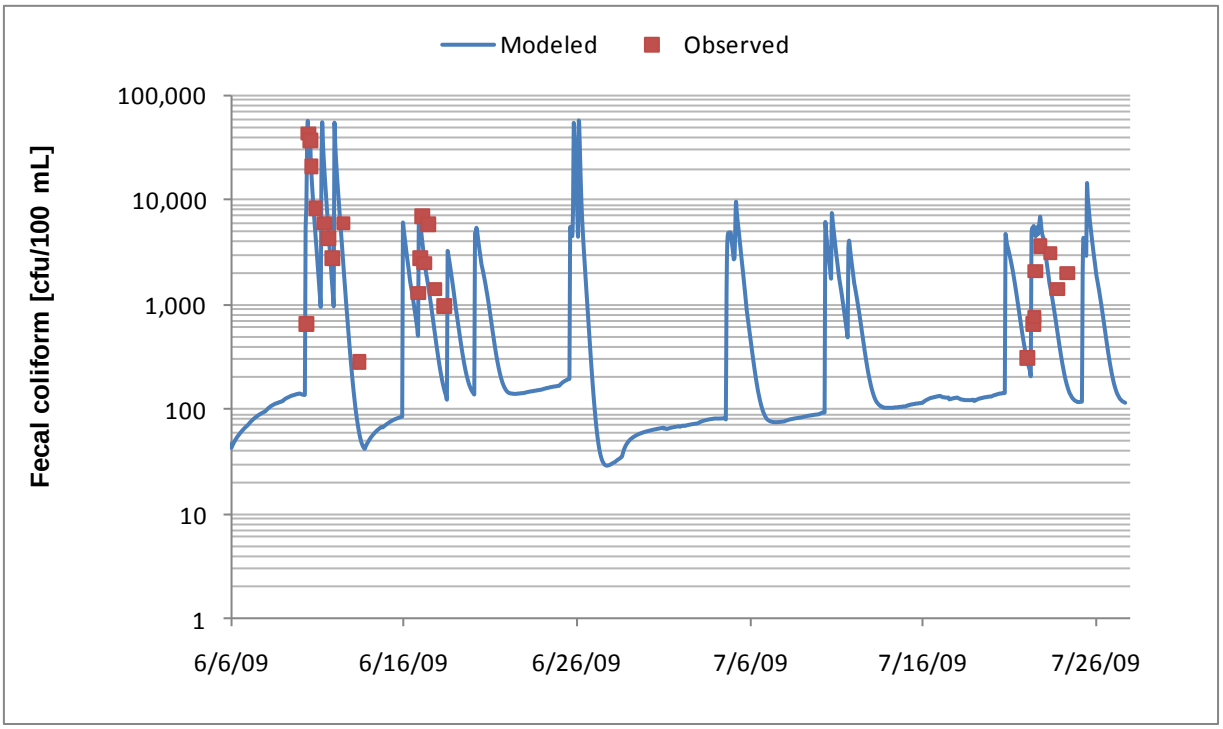

Figure C-15: Comparison of Modeled and Observed Fecal Coliform at Sand Run RM 0.6.

Threemile Creek Watershed Sampling Locations

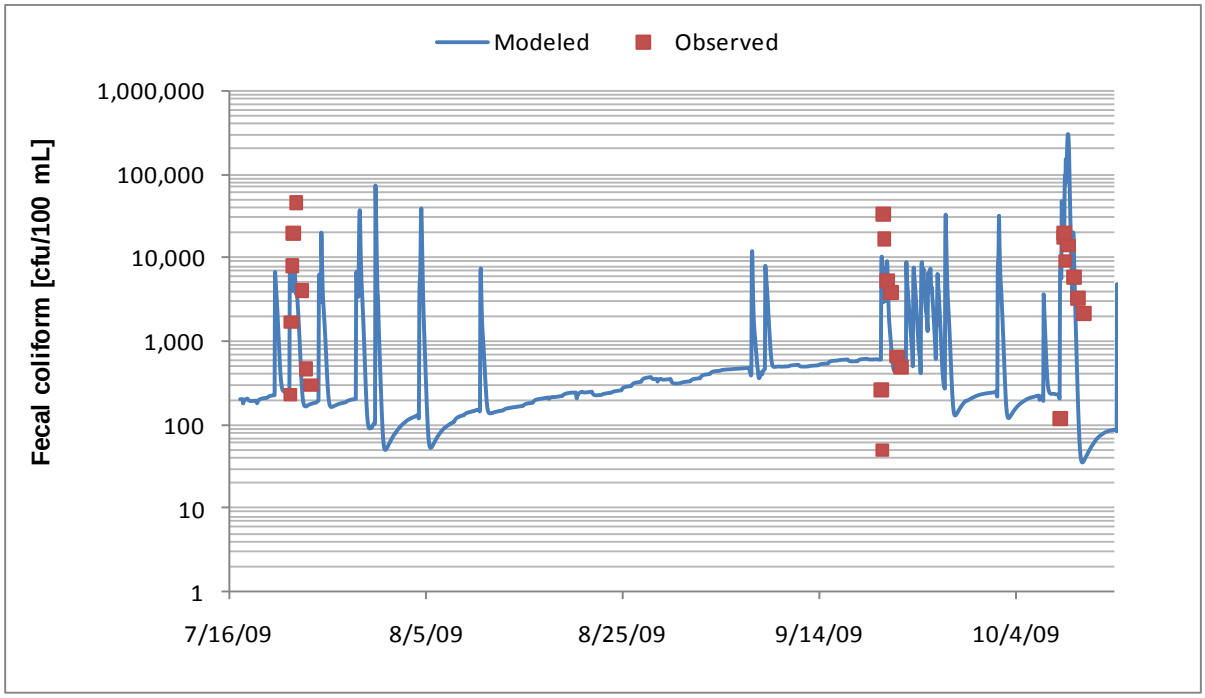

Figure C-16: Comparison of Modeled and Observed Fecal Coliform at North Branch of Threemile Creek RM 0.8.

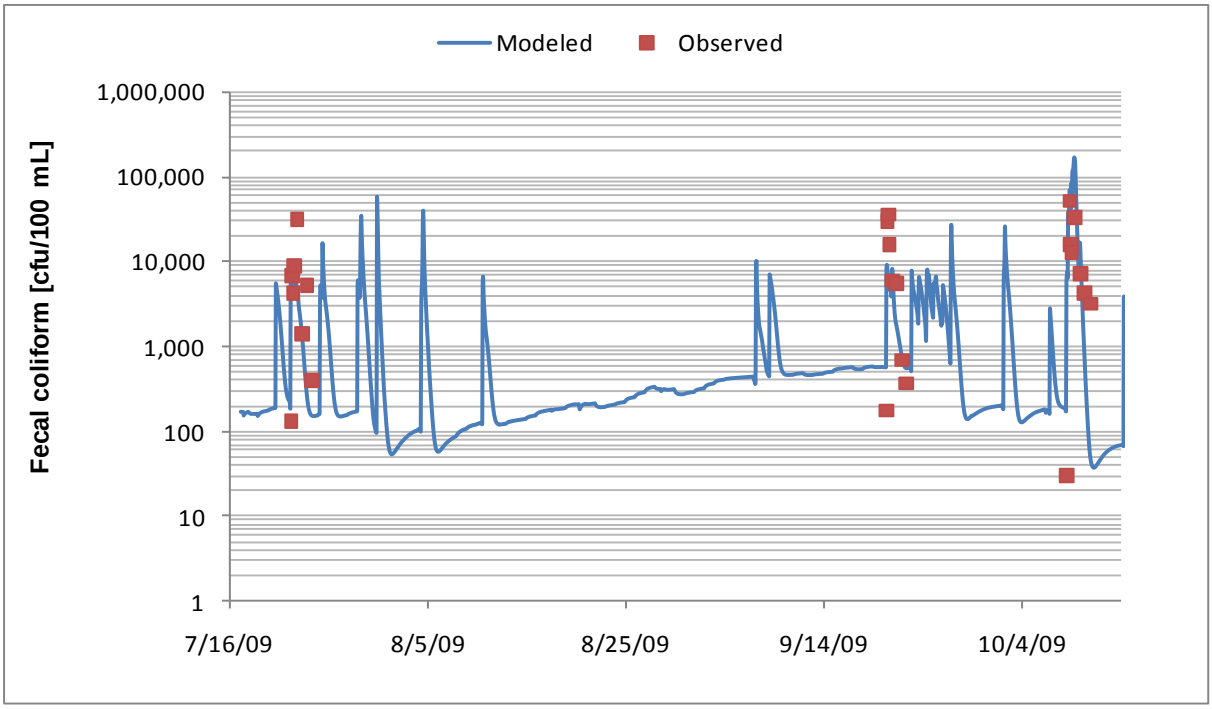

Figure C-17: Comparison of Modeled and Observed Fecal Coliform at Threemile Creek RM 0.4.

Woolper Creek Watershed Sampling Locations

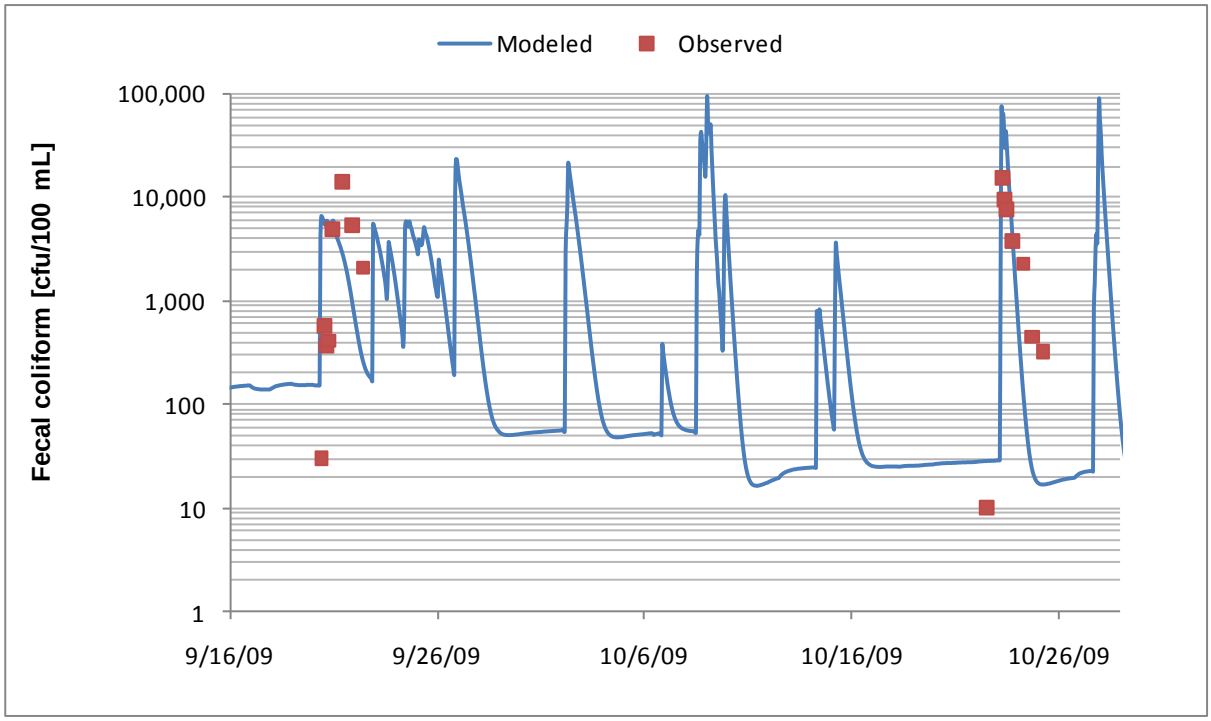

Figure C-18: Comparison of Modeled and Observed Fecal Coliform at Ashby's Fork RM 0.0.

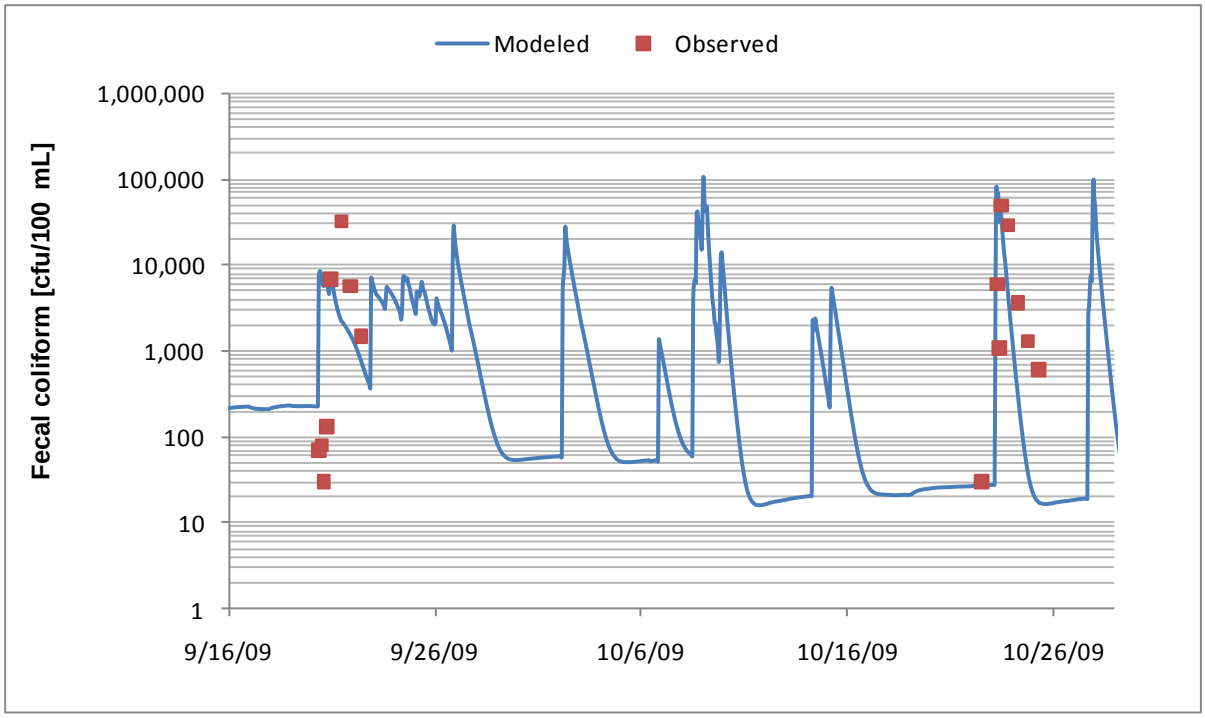

Figure C-19: Comparison of Modeled and Observed Fecal Coliform at Allen Fork RM 0.1.

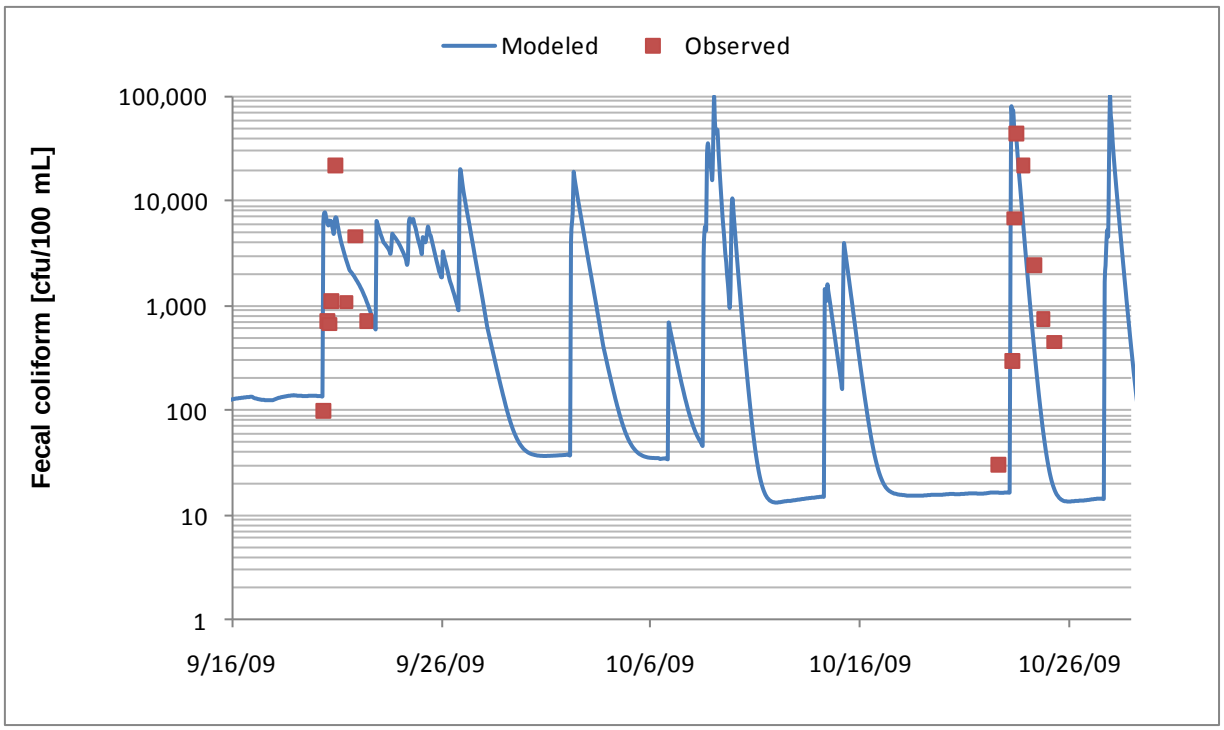

Figure C-20: Comparison of Modeled and Observed Fecal Coliform at Woolper Creek RM 8.8.

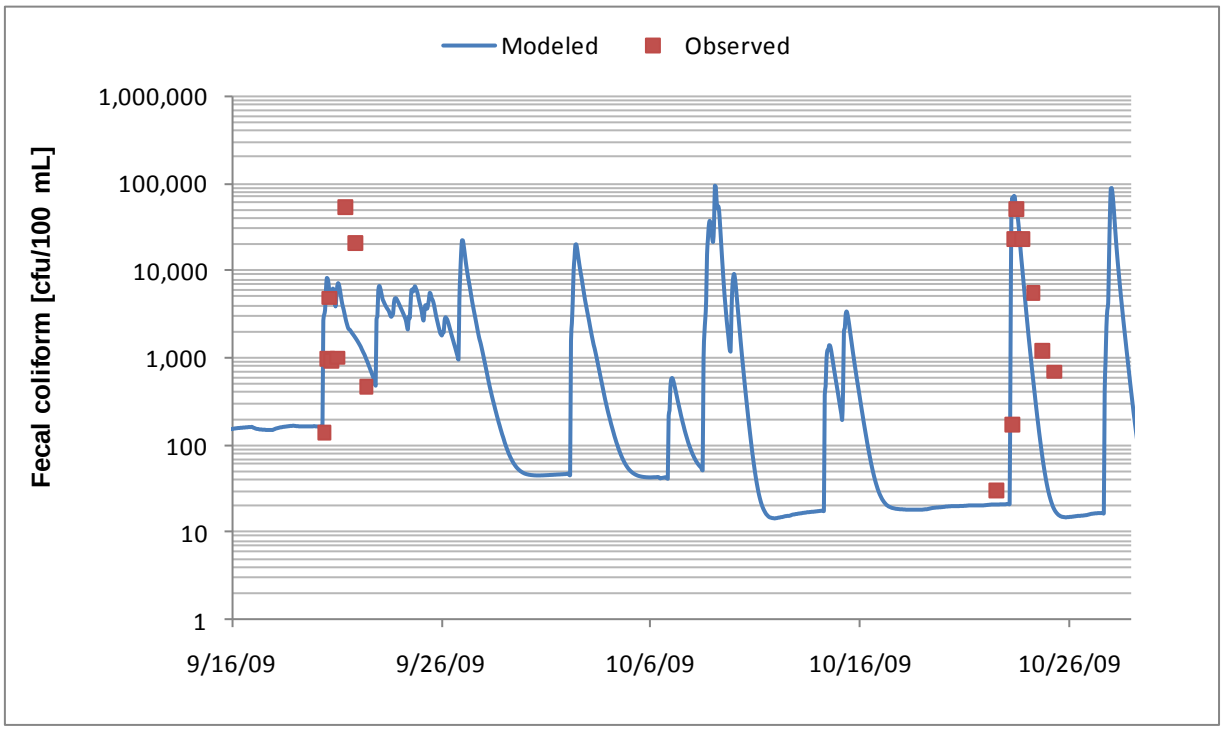

Figure C-21: Comparison of Modeled and Observed Fecal Coliform at Woolper Creek RM 5.0.

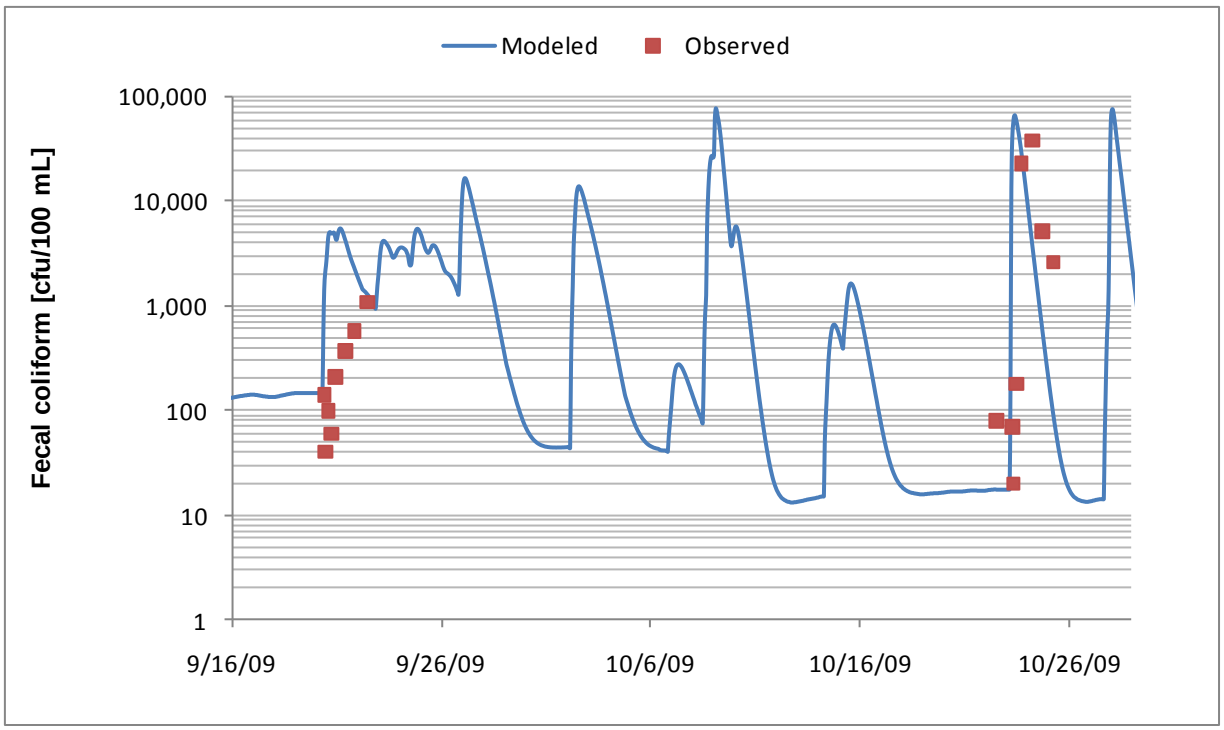

Figure C-22: Comparison of Modeled and Observed Fecal Coliform at Woolper Creek RM 1.4 (Backwater-impacted sampling location).

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Watershed Assessment Tool – WAT!
Model Documentation

Prepared for:

Sanitation District No. 1 of Northern Kentucky

March 21, 2011

LimnoTech
Water | Environment | Scientists | Engineers

Ann Arbor, Michigan
www.limno.com

DOCUMENT HISTORY

ORIGINAL: June 23, 2009

REVISION No.1: March 21, 2011

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Attachment B – Land cover GIS Layer

Attachment C – Hydrologic Features GIS Layer

Attachment D – Point Source GIS Layer

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1 Overview

This document describes the development and initial application of the Watershed Assessment Tool (WAT!), a relative risk scoring tool for water quality impacts of sources within the jurisdiction of Sanitation District No. 1 of Northern Kentucky (SD1). This document is divided into sections describing:
Study area – the study area to which the WAT! has been applied

- Methodology – approach used to calculate scores
- General Inputs
- Variable-Specific Inputs
- WAT! Outputs – tabular, graphical, and spatial results from the model
- Analysis of Results

BACKGROUND

SD1 is responsible for the collection and treatment of Northern Kentucky's wastewater, as well as regional storm water management. SD1, which serves communities in Boone, Campbell, and Kenton Counties, has entered into a Consent Decree with the Kentucky Energy and Environment Cabinet and the U.S. Department of Justice (on behalf of the US Environmental Protection Agency) to address sewage overflows in its jurisdiction.

SD1's Consent Decree is the country's first enforcement action that allows a community to use the watershed management approach to more efficiently and cost-effectively meet federal Clean Water Act requirements for addressing CSOs and SSOs. This approach is based on the fact that sewer overflows are not the sole source of impairment for Northern Kentucky's streams and rivers. Traditionally, most Consent Decrees focus solely on CSOs and SSOs, with an emphasis on gray infrastructure solutions. SD1's watershed approach identifies the characteristics of individual watersheds and considers CSOs and SSOs along with other sources impacting the waterways (such as runoff and dry weather sources).

1.1 GOAL

As part of the watershed management approach, SD1 has performed a comprehensive watershed inventory. The WAT! forms part of the inventory process and acts as a gateway to source information and a mechanism for identifying and prioritizing mitigation opportunities. The WAT! also evaluates relative risk from pollutant contributions associated with inventoried sources (e.g., septic systems, runoff, CSOs, SSOs, and other KPDES-permitted point sources) and provides a uniform and objective methodology for estimating pollutant contributions and ranking subwatersheds according to potential impact on instream water quality. This supports the targeting of subwatersheds, watersheds and sources for action in order to improve water quality.

WAT! does not calculate instream water quality and should therefore not be used to evaluate compliance with water quality standards.

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2 Study Area

The WAT! is applied to 128 subwatersheds that are organized into sixteen watersheds in four basins, as shown in Figure 1. This study area – which is based on natural hydrologic boundaries - includes most of SD1's jurisdiction of Boone, Kenton, and Campbell Counties in Northern Kentucky. Small portions of southeastern Boone County and southwestern Kenton County that drain to Tenmile Creek in Grant County, and portions of southeastern Campbell County that drain to Goose Creek and Stepstone Creek are excluded from the study area. Also, portions of Pendleton, Grant and Gallatin Counties that drain to streams inside of SD1's jurisdiction are included in the study area.

The watersheds listed in Table 1 are the major organizational units being used by SD1 in the characterization process. The watersheds are grouped into the West, North, Central, and East Basins. These basins correspond to basins specified in the Consent Decree. WAT! results are presented by watershed and by subwatershed.

The WAT! study area is reported by GIS to be 378,620 acres (approximately 592 square miles).

Table 1. Watersheds by Basin

West Basin	Central Basin
Big Bone Creek	Banklick Creek
Gunpowder Creek	Licking River
Ohio River Tributaries and Direct Drainage (West)	Threemile Creek
North Basin	**East Basin**
Woolper Creek	Fourmile Creek
Sand Run	Taylor Creek
Elijahs Creek	Twelvemile Creek
Dry Creek	Ohio River Tributaries and Direct Drainage (East)
Pleasant Run Creek	
Ohio River Tributaries and Direct Drainage (North)	

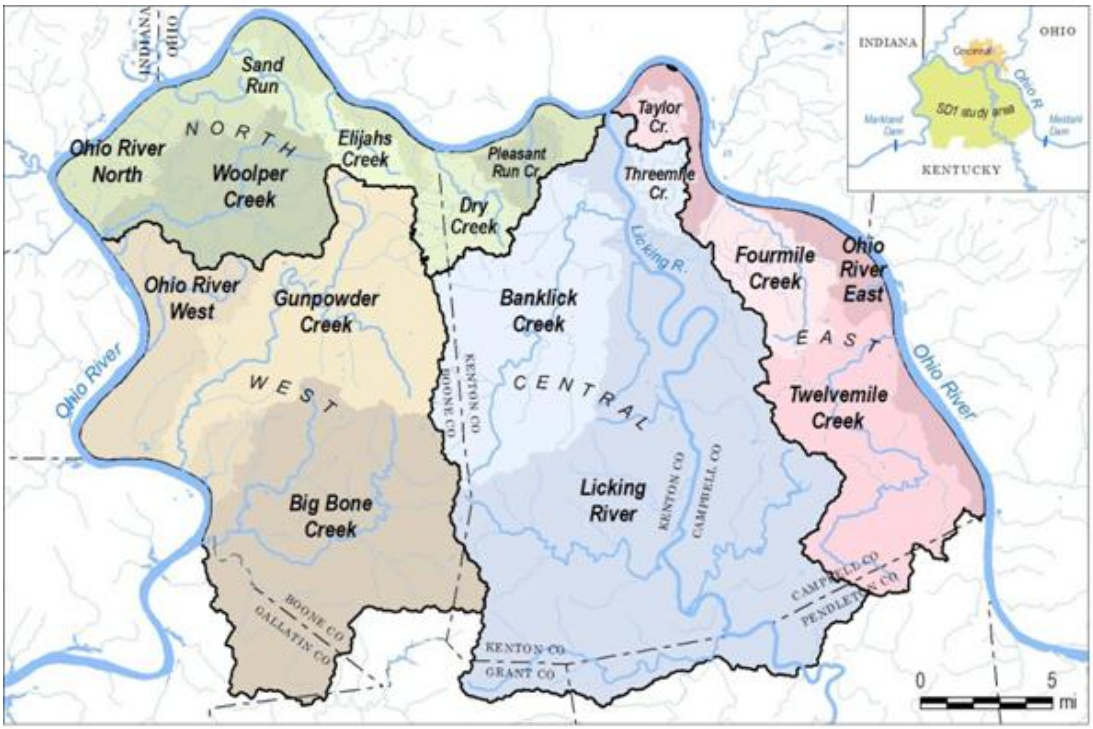


Figure 1. WAT! Study Area

3 Methodology

This section describes the approach used by WAT! to calculate watershed and subwatershed impact scores. The scores represent the potential risk of an area to instream water quality and are calculated separately for bacteria, nutrients and solids, with higher scores representing higher risks. The scores reflect pollutant loads and other factors affecting pollutant delivery such as slope, soil properties, and proximity of the source to waterways.

Scores can be used to assess and prioritize areas and sources for improvement projects. The score for a watershed (or subwatershed) can be compared to other scores to identify risk relative to other subwatersheds and watersheds. This approach is based on previous work performed by Malcolm Pirnie and LimnoTech to develop relative risk assessment rankings for the basins and subbasins of the Croton (NY) watershed (Malcolm Pirnie 2002a, 2002b). The approach is implemented as a series of Visual Basic for Applications (VBA) macros in the ESRI ArcGIS geographic information system.

The basic steps in calculating impact scores are:

- Calculate the impact value for a source, by variable (pollutant); impact value is analogous to a load.
- Assign a scalar based on site-specific factors (proximity of source to waterways, slope, and soil properties).
- Calculate an impact score for each source (e.g. Impact score = impact value * scalar).

Total annual impact scores for individual source areas are calculated for 100 feet (ft) x 100 ft cells across the study area, aggregated into cumulative scores for subwatersheds and watersheds, and then area-normalized for comparison.

$$Score_{Variable} = \sum_{\substack{area,\\ source}} impact\ value \times scalars$$

$$Normalized\ Score_{Variable} = \frac{Score_{Variable}}{area}$$

The components of the score calculation – variables, sources, impact values, scalars, aggregation, accumulation, and normalization – are defined below.

3.1 VARIABLES

The WAT! variables are the pollutants of interest for which the methodology is applied to develop relative risk scores. These pollutants are bacteria, total suspended solids, and nutrients (total phosphorus and total nitrogen). Scores for bacteria are

currently based on fecal coliform information but will be able to move to an *E. coli* basis when sufficient data exist to characterize source impact values.

3.2 SOURCES

Point and nonpoint sources are included in WAT!. Point sources include combined sewer overflows (CSOs), recurring sanitary sewer overflows (SSOs) at manhole locations, SSOs at pump station locations, SSOs at model-predicted overflow locations[1], and other KPDES-permitted dischargers to surface waters (e.g., wastewater treatment plants). Nonpoint sources include runoff from different land uses (e.g., residential, agricultural) and septic systems. A source may encompass many contributing factors. For example, the "land" source may include runoff from individual land cover types, atmospheric dry deposition, and rain-deposited pollutants.

3.3 IMPACT VALUES

A WAT! impact value is the value assigned to a source to qualitatively represent its contribution of a given variable. An impact value is analogous to a load and may be based on loading calculations from other model investigations or on literature-reported values. It represents an average condition that may be modulated by location-specific source conditions (scalars) as discussed in Section 3.4

The use in WAT! of impact values instead of loads allows the consideration of potential impairment from sources that may not be easily quantified. For example, potential impacts from broken sewers might be assigned a high impact value of 5 where large, older sewers cross streams and a low impact value of 1 where small sewers are well-installed and deeply buried. These impact values will not match measured loads from actual sewer breaks, but will provide a basis for assessing which areas may be at higher risk.

Strategies for assigning impact values are described in Section 5 of this document.

3.4 SCALARS

The conditions at the actual location of the source may increase or decrease the potential of a source to impact water quality. In WAT!, scalars are used to quantify the potential effect of these local conditions on a source. For example, less-permeable soils may produce above-average runoff and thereby increase transport of a source contribution to a nearby stream. A scalar can be designed to quantify this runoff effect, with higher scalar values assigned to regions of relatively impermeable soil and lower values assigned to regions of more permeable soils.

Impact values are multiplied by all applicable scalars to give scaled source values.

[1] Model predicted overflow locations are predicted to overflow by SD1's collection system model, but that have not yet been confirmed in the field as recurring.

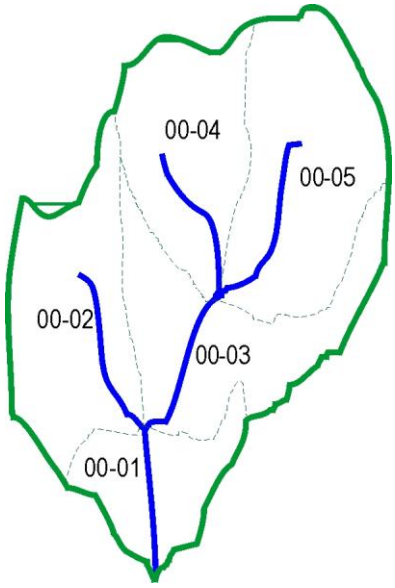
3.5 AGGREGATION

Scaled source values are accumulated in WAT! by areas of interest to give cumulative scores that are roughly analogous to loads. The areas of interest can be drawn arbitrarily, but typically correspond to jurisdictional boundaries or to hydrologic boundaries. Areas of interest can also be defined to match contributing areas upstream of a sampling point.

In the WAT! application, the areas of interest are drawn to match the 128 subwatersheds that make up the study area described in Section 2. Therefore, 128 subwatershed scores are generated for each variable. These aggregated scores are the sums of impairment risks for the subwatersheds.

3.6 ACCUMULATION

WAT! also accumulates aggregated subwatershed scores along stream flow paths. A downstream subwatershed identifier is included to indicate flow direction. This identifier is used to accumulate subwatershed scores (*SScore00-xx* below) along the direction of stream flow. For example, if subwatersheds 00-04 and 00-05 flow into subwatershed 00-03, and subwatersheds 00-03 and 00-02 flow into subwatershed 00-01, the cumulative watershed scores (*CScore00-xx* below) would be:



CScore00-05 = SScore00-05
(SScore = subwatershed score)

CScore00-04 = SScore00-04

CScore00-03 = SScore00-03 + CScore00-04 + CScore00-05

CScore00-02 = SScore00-02

CScore00-01 = SScore00-01 + CScore00-02 + CScore00-03

Substituting, the cumulative score for subwatershed 00-01 will be:

CScore00-01 = SScore00-01 + SScore00-02 + SScore00-03 + SScore00-04 + SScore00-05

The accumulation of subwatershed scores helps identify spatially where impacts may be the highest within a watershed, helping to narrow down where mitigation and management measures should be implemented.

3.7 NORMALIZATION

Aggregated and cumulative scores in WAT!, especially for runoff sources, will tend to correlate with land area, and the highest scores will often be found for the largest land areas. WAT! calculates area-normalized scores ("unit-area scores") to allow the user to compare results for areas of different sizes. These area-normalized scores are similar to unit area loads and can act as surrogates for water quality. Specifically, area-normalized loads are reflective of bulk runoff concentrations for an area of interest:

W = total load
A = total area
D = rainfall (inches/year)
V = runoff volume = A x D
C = bulk concentration = W / V

If rainfall is assumed not to vary significantly across the study area,

$C = W / V = W / (A \times constant)$
$C \sim W / A$

In other words, concentration is roughly proportional to W/A, which is the unit area load.

The area-normalized scores can be used to assess the relative impact on instream water quality from different sources. Area-normalized scores can then be used to compare relative degree of risk between watersheds and subwatersheds of widely varying sizes.

4 General Inputs

This section describes the WAT! inputs that are used in calculating impact scores for all variables.

4.1 SUBWATERSHEDS AND WATERSHEDS

The subwatershed is the fundamental unit for assessment in the WAT!. Subwatersheds are based on USGS 14-digit hydrologic cataloging units as modified by LimnoTech, and are grouped into SD1's study watersheds. Information is assigned to each subwatershed to indicate the direction of flow from subwatershed to subwatershed.

The entire study area is divided into a grid of 100 ft x 100 ft cells which are used to calculate scalars (for all sources) and runoff impact scores. Each cell is assigned to a subwatershed for aggregation of source values and normalization of these values by subwatershed area.

Additional detail about the subwatershed GIS layer is included in Attachment A. During development of the WAT!, the Bullock Pen subwatershed (08-06) was subdivided into six smaller subwatersheds, matching reaches delineated for the more detailed Banklick Creek HSPF model (LimnoTech, 2008). The additional level of detail for these subwatersheds was needed to better represent spatial variation in the Census-reported age of dwellings, which is used to differentiate between "old" and "new" development for calculation of runoff impacts. Storm water outfall water quality data collected by SD1 showed that bacteria densities were lower in runoff from areas developed more recently, and model parameters were set to reflect this difference (see Section 5.1.3).

4.2 LAND COVER – PRESENT AND FUTURE

The risk to water quality from runoff is incorporated in WAT! by associating impact values with different types of land cover. This application uses 2001 satellite imagery of land cover, modified by LimnoTech to reflect current (2006) and future (2030) land use maps provided by SD1. Land cover classifications are shown in Table 2.

Land cover was selected as the basis for nonpoint WAT! runoff evaluations instead of land use for several reasons:

- Available land use datasets were inconsistent and unreliable. For example, comparison of 1995 regional land use data to planned development shows several already-developed areas being converted back to forest or agricultural land in the future.

- Parcel-level data, though generally current and providing high-quality boundary information, are administered separately by the three counties within Northern Kentucky and do not provide consistent land use information across the area.

- Land cover better represents actual surface conditions and is consistent with the Soil Conservation Service (SCS) curve number approach (USDA, 1986) used in the WAT! methodology.

- Land cover datasets are generally available and extend beyond SD1's jurisdictional boundaries into areas that are part of the study watersheds but not part of the three counties in the study area.

- Detailed watershed models (Banklick Creek and Taylor Creek) were calibrated for instream hydraulics and water quality using land cover information for the runoff component of the calibrations.

Although land cover is preferred to land use, it may also have limitations. For example, land cover derived from multispectral satellite imagery can sometimes incorporate misclassifications, such as misidentifying urban grassed areas as pasture or hay. LimnoTech confirmed that although there were likely some land cover misclassifications, the effects of these possible misclassifications (as described in Section 7.2) did not affect the ranking of higher priority watersheds. It was therefore determined that land use data would present greater limitations as described above than the use of land cover data.

The land cover classifications, shown in Table 2, correspond directly to the classifications used in the 2001 National Land Cover Dataset (USEPA, 2003).

Table 2. Land Cover Classifications Used In WAT!

Developed, low intensity	Deciduous forest
Developed, medium intensity	Evergreen forest
Developed, high intensity	Mixed forest
Developed, open space	Shrub/scrub
Buildings	Open water
Roads	
	Barren land (rock/sand/clay)
Pasture/hay	
Grassland/herbaceous	Woody wetlands
Cultivated crops	

Additional detail about the land cover GIS layers, including a description of the modifications to reflect current conditions, full descriptions of the land cover classifications, and a summary table showing the distribution of land cover by watershed, is included in Attachment B.

In order to provide an improved representation of current conditions in Northern Kentucky watersheds, the initial land cover layers were enhanced during the WAT! development process to reflect updated remotely sensed imagery.

4.2.1 Shortcomings of initial land cover datasets

The initial watershed characterization and modeling work was based on the 2001 National Cover Dataset data updated and estimated to 2006 conditions. These data are reliable, but have some shortcomings. With Northern Kentucky land cover rapidly changing, even six-year-old data is quickly aging. The region is experiencing much new land development including suburban residential subdivisions, new streets, and expansion of runways and related pavement at the international airport near Florence.

The 2006 update relied on typical residential parcel sizes to estimate the extent of new suburban construction. That method seemed to estimate residential development well, but was not as successful for estimating other kinds of new development, such as the international airport expansion, office parks, and roads. Further, the 2006 update provided good estimates of the quantity of land cover classes within subwatersheds, but the results lacked spatial specificity and could not be accurately mapped.

An evaluation of the more recent 2005 land cover dataset determined that while it provides an accurate picture of recent conditions on a statewide level, it needed improvement for the finer scale application of a Northern Kentucky focus. The 2005 dataset is a clear improvement from the 2001 dataset, but it is still not current enough and some land cover classifications do not accurately reflect actual conditions to best meet watershed management needs.

Some of the new development is not captured in the 2005 dataset.

The land cover was compared to other datasets, including the following:

- Aerial photography taken in 2006, obtained from the Natural Resources Conservation Service, U.S. Department of Agriculture;
- Open space lands obtained in 2007 from the Ohio-Kentucky-Indiana Council of Governments (OKI);
- Building footprints and pavement provided by SD1 in December 2007; datasets were originally based on 2004 aerial photography; the datasets were constructed, maintained, updated, and shared by Boone County, Kenton County, and Campbell County; parts of the datasets were also updated and shared by Northern Kentucky Area Planning Commission's LINK-GIS;

- Detailed surface waters provided by SD1 in September 2006; datasets were originally based on 2004 aerial photography; the datasets were constructed, maintained, updated, and shared by Boone County, Kenton County, and Campbell County; portions of the datasets were also updated and shared by Northern Kentucky Area Planning Commission's LINK-GIS.

The comparisons revealed that a large amount of land cover could be categorized more accurately. The pasture/hay category in particular was over-represented. For example, even in long developed areas, large tracts of land were categorized as pasture/hay, when the landscape is actually dominated by turf lawns surrounding buildings. Many golf courses, cemeteries, and school yards were categorized as pasture/hay while much of the land cover is actually highly-managed turf.

4.2.2 Enhancing 2005 land cover data to represent current conditions

Using GIS tools, a series of data layers were merged to create an enhanced land cover dataset that better approximates 2007 Northern Kentucky landscape conditions. The series included the following land cover classification conversions:

- 100-ft buffers were created around every polygon in the building footprint datasets. All lands within the buffers that were classified as pasture/hay, grassland/herbaceous, cultivated crops, or barren were converted to developed open.

- In highly managed open spaces such as golf courses, cemeteries, and school yards, all lands classified as pasture/hay, grassland/herbaceous, cultivated crops, or barren were converted to developed open.

- In other, less managed open spaces such as nature preserves and hunting clubs, all lands classified as pasture/hay, cultivated crops, or barren were converted to grassland/herbaceous.

- 20-ft buffers were created around road and parking lot pavement polygons and around railroad lines. All lands within the buffers not already classified as highly developed were converted to developed low intensity.

- Very detailed polygons representing open waters were used to convert other land classes to open water.

- All areas within detailed building footprint and pavement polygons were converted to the developed high intensity class.

After the creation of raster grids representing the conversions listed above, the results were merged into a base of the 2005 land cover. A large amount of land was converted to a more accurate representation of current conditions.

4.2.3 Results: improved representation of current landscape conditions

The work to estimate current land cover conditions resulted in a more detailed raster grid that is better suited for watershed modeling and characterization. It provides a better understanding of how the land influences conditions in local creeks and in the Licking and Ohio Rivers. It is a more accurate representation of a landscape that is quickly changing from agriculture and open lands to suburban development. Further, it is a data layer that both provides values for more accurate watershed characterization and modeling, and can be mapped, allowing better visualization of current landscape conditions.

Table 3 shows the land cover classes appearing in the latest revised dataset, as well as those seen in the previous attempt to estimate current conditions.

Table 3. Comparison of Original and Currently Estimated Land Cover Distributions

	Earlier land cover estimate: NLCD 2001 upated to 2006 conditions (acres)	Latest land cover estimate: NLCD 2005 upated to 2007 conditions (acres)
Open water	2,915	6,763
Developed, open space	40,558	47,535
Developed, low intensity	23,406	29,578
Developed, medium intensity	12,854	6,422
Developed, high intensity	4,566	25,544
Barren land	454	620
Deciduous forest	167,931	153,709
Evergreen forest	10,075	10,765
Mixed forest	807	1,971
Shrub/scrub	3,942	9,314
Grassland/herbaceous	8,628	7,380
Pasture/hay	94,305	71,642
Cultivated crops	7,059	5,422
Woody wetlands	878	1,530
Emergent herbaceous wetlands	241	423

4.3 STREAMS AND WATER BODIES – PROXIMITY SCALAR

WAT! uses information about hydrologic features such as streams and water bodies to define proximity to receiving waters. The hydrologic features are based on the USGS National Hydrologic Data (NHD) high-resolution datasets, modified to reflect confirmed physical modifications to stream channels and to match local usage for stream names.

Proximity to waterways is used as a scalar to modify impacts from septic systems and from sanitary sewer overflows. Impact values from these sources are multiplied by a

proximity scalar defined as shown in Table 4. Other point sources are assumed to discharge directly to a waterway, and therefore are not scaled.

Table 4. Values for WAT! Proximity Scalar

Distance from hydrologic feature	Value of proximity scalar
Less than 100 ft	1.0
100 ft to 300 ft	0.5
More than 300 ft	0.1

Additional detail about the hydrologic features GIS layer is included in Attachment C.

4.4 ELEVATION: SLOPE SCALAR

Slope is used as a scalar in WAT! to reflect the higher impact expected from nonpoint sources that originate on steeper slopes as compared to sources on less steep slopes. Slope is calculated using USGS National Elevation Data (NED) 1 foot data, and the slope scalar then determined from the formula:

$$S_{Slope} = \frac{Slope^{0.15}}{mean\left(Slope^{0.15}\right)}$$

Slope = Slope of an individual cell
S_{Slope} = Slope scalar at each 100 ft x 100 ft cell in study area.

This calculation gives the distribution of scalar values across the study area a mean value of 1.0 that minimizes bias in risk estimation.

4.5 SOILS: RUNOFF AND ERODIBILITY SCALARS

Soil characteristics, including hydrologic soil group and erodibility, are used as scalars in WAT! to reflect differences in runoff potential from nonpoint sources with different soil characteristics. The U.S. Department of Agriculture's Soil Survey Geographic (SSURGO) Database is used to define hydrologic soil group and whole-soil erosion factor across the study area. Two scalars are calculated from these data:

First, the whole soil erosion factor, Kw, indicates the susceptibility of a soil to sheet and rill erosion by water[2]. The higher the value, the more susceptible the soil is to this type of erosion.

$$S_{Kw} = Kw\ (whole\_soil\_erosion\_factor)$$

[2] Sheet erosion is when water removes even layers of soil. Rill erosion is when water makes channels up to 30 centimeters deep.

Second, the SCS Curve Number approach (USDA, 1986) is applied across the entire study area for each combination of land cover classification and hydrologic soil group (Table 5). A design rainfall of 2.53", which is the typical 24-hour rainfall amount for the once-a-year storm in the study area, is used in the calculation. The scalar values are normalized (divided by the mean value for the entire study area) to give a mean value of 1.0 to minimize bias in risk estimation.

$$S_{Runoff} \approx SCS\ CN\ runoff\ (\ function\ \ of\ land\ and\ soil\ group)$$

$$CN = f\,(land\,, soil\ group)$$

$$I_a = \frac{20000}{CN} - 2$$

$$R = \frac{\left(2.53 - I_a\right)^2}{2.53 + 4 \times I_a}$$

$$S_{Runoff} = \frac{R^{0.3}}{mean\left(R^{0.3}\right)}$$

Table 5. Curve Numbers Used In WAT! - Adapted from (USDA, 1986)

	Hydrologic Soil Group			
Land cover	**A**	**B**	**C**	**D**
Developed, low intensity	46	65	77	82
Developed, medium intensity	49	69	79	84
Developed, high intensity	89	92	94	95
Developed, open space	39	61	74	80
Buildings	100	100	100	100
Roads	100	100	100	100
Pasture/hay	60	71	81	89
Grassland/herbaceous	39	61	74	80
Cultivated crops	67	78	85	89
Deciduous forest	57	73	82	86
Evergreen forest	57	73	82	86
Mixed forest	57	73	82	86
Shrub/scrub	57	73	82	86
Open water	100	100	100	100
Barren land (rock/sand/clay)	75	80	85	90
Woody wetlands	100	100	100	100

Larger curve numbers in Table 5 correspond to combinations of land cover and hydrologic soil group with higher expected runoff.

4.6 IMPERVIOUS AREAS – PAVED SURFACES AND BUILDING FOOTPRINTS

In the WAT!, impact values from building and paved surfaces (impervious areas) are assumed to be unaffected by local conditions such as steep slopes or permeable soils. The associated scalars for slope, runoff and soil erodibility that are documented in Sections 4.4 and 4.5 are therefore not applied to impact values for impervious areas.

The WAT! uses building footprint and paved surface GIS layers to mask out impervious areas in the study area and set the associated scalar values to 1.0.

4.7 POINT SOURCES

The WAT! assigns impact values to a number of point source categories as shown in Table 6. Additional detail about the contents of the point source GIS layer are included in Attachment D. KPDES point source discharge information was last updated in 2008, and SD1 overflow information in 2009.

Table 6. Point Source Categories

1. Sewer overflows (SD1)

   Combined Sewer Overflows (CSOs)

   Sanitary Sewer Overflows (SSOs)

   - Recurring – Manhole Locations
   - Pump Stations
   - Model-predicted Overflow Locations (discharge points in the sewer system model that have not yet been confirmed as recurring)

2. Kentucky Point Source Discharge Elimination System (KPDES) dischargers (non-CSO)

   - KPDES facilities administered by SD1
   - KPDES sanitary facilities (“package plants”)
   - KPDES residential General Permit holders
   - KPDES construction General Permit holders
   - KPDES storm water discharges
   - Other KPDES-permitted discharges (industrial facilities)

3. Septic systems

4.8 SEPTIC FOCUS AREAS – SEPTIC SCALAR

Certain areas within Northern Kentucky have been identified as having higher-than-normal septic system failure rates – whether due to poor design, improper implementation or operation, or lack of maintenance. These are represented in the WAT! as septic focus polygons. Septic scores from sources outside of the septic focus areas are unscaled (multiplied by 1.0), while septic scores inside of the septic focus areas are scaled upwards by a user-specified factor.

Septic focus areas and the value of the associated scaling factors, which increase the septic scores to reflect assumed increases in failure rates, should be based on specific studies that identify the extent and magnitude of problematic onsite treatment systems.

Septic focus areas were added based on areas of concern provided by the Northern Kentucky Health Department. The septic focus area scalar was set to 5.0, reflecting professional judgment that failure rates are about five times higher in these areas than the 10% failure rate assumed for Northern Kentucky as a whole. The septic focus areas were added for the following:

- Gunpowder Creek watershed: Sherwood Lakes
- Decoursey Creek subwatershed: Latonia Lakes and Garner Drive
- Fowler Creek subwatershed: Walnut Hall
- Big Bone Creek watershed: Twin Lakes
- Fourmile Creek watershed: Blossom Drive, Ripple Creek, Backus

4.9 SEWER AREAS

GIS layers delineating the combined sewer and separate sanitary sewer system areas were used by WAT! to identify areas contributing to CSO locations. In these areas, impact values for runoff sources are set to zero to prevent double-counting of impacts that are already associated with overflows simulated by the hydraulic sewer system models at these locations. In some portions of the study area where contributing areas are not delineated for particular CSOs, best professional judgment was used to assign a fraction of runoff impacts to be masked out under the assumption that that fraction is being routed directly to the CSO and is already being accounted for in the WAT! as a point source input.

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5 Variable-Specific Inputs

This section describes the inputs that are used to calculate variable-specific scores. WAT! calculates scores for the following variables: fecal coliforms, total suspended solids, and nutrients (total phosphorus and total nitrogen). Greater emphasis was put on characterizing sources of fecal coliform for the first set of Watershed Plans. An uncertainty analysis was therefore performed to test the effect of different choices of unit area loads for fecal coliform (see Section 7.2). Assumptions for the total suspended solids and nutrients will be evaluated for future plans as part of the watershed management approach.

5.1 BACTERIA

WAT! bacteria scores are currently based on calculations for fecal coliform bacteria, a commonly-used indicator for pathogens. The bacteria scores will be updated to use *E. coli* when sufficient information on *E. coli* densities in point source discharges and unit area loads for different land cover classifications is available.

Bacteria scores are currently calculated in WAT! for point sources, septic systems and runoff.

5.1.1 Point sources

Point source impact scores for fecal coliform are calculated from an impact value that is based on the estimated annual load from the point source in total colony forming units (cfu). This estimated load may be based on modeled overflow volumes and literature or measured densities, or flows and densities reported in discharge monitoring reports (DMRs). If information is not available to calculate a fecal coliform load for a point source, then its contribution can either be user-specified or remain undefined in WAT!. WAT! tracks the number and type of undefined sources in each subwatershed so that the user can take them into consideration when evaluating results.

SD1 sanitary sources that can be specified in WAT! include CSOs, recurring SSOs at manhole locations, SSOs at pump stations, and SSOs at model-predicted overflow locations. The loads for these sources are defined using overflow volume results from SD1's sewer system models in combination with user-specified event mean concentrations.

Bacteria densities assigned to the SSOs are 1.87×10^6 cfu/100 ml, and 6.82×10^5 cfu/100 ml for CSOs based on sampling data collected during the infrastructure characterization phase. Impact values for SSOs are scaled by the proximity scalar defined in Section 3.3 that reflects distance to the waterways. Impact values for CSOs are multiplied by a proximity scalar of one or 1.0 (i.e., neither scaled up nor down), as CSOs are considered to discharge directly to the waterways. Non-CSO KPDES dischargers include KPDES facilities administered by SD1 (wastewater treatment and water reclamation facilities); KPDES sanitary facilities ("package plants"); KPDES

residential General Permit holders; KPDES construction General Permit holders; individual industrial KPDES storm water discharges; and other KPDES discharges. Loads associated with the storm water dischargers considered runoff loads rather than point source contributions, and are therefore calculated as part of runoff (Section 5.1.3). For the other non-CSO KPDES sources, the load estimate is based, where available, on averages of measured flows and densities in monthly discharge monitoring reports (DMRs) from the Kentucky Division of Water (KDOW). These loads do not reflect periods where performance of individual treatment plants may have been compromised due to washouts from wet weather flows, etc. Where DMRs are not available, a load is estimated from permit information (e.g., allowable load or density times design flow), with the exception of point source discharges permitted under the Residential General Permit. These are treated in the same fashion as septic systems, which are discussed below.

5.1.2 Septic systems

The onsite wastewater treatment systems common in parts of the study area include both surface and underground discharges. Currently, WAT! tracks about 250 surface-water discharges administered under the KDOW Residential General Permit and about 15,000 parcels identified as likely locations for groundwater discharge septic systems. For simplicity, surface and underground discharges are treated identically in WAT! because the potential impacts from both types of systems are generally similar.

The impact value of 2.5 x 10^{11} cfu/year (corresponding to an assumed density of 10^6 cfu/100 ml in effluent) selected for use in the WAT! was calculated as follows:

$$W_{septic} = Failure \times daily\ volume \times \frac{365\,days}{year} \times density\ x\ conversion\ factor$$

$$= 10\% \times \frac{680\,L}{day} \times \frac{365\,day}{year} \times \frac{10^6\ cfu}{100\,mL} \times \frac{10 \times 100\,mL}{L}$$

= 2.5 x 10^{11} cfu/year/septic system

Further details about this calculation are presented in (LimnoTech, 2007).

5.1.3 Runoff

Nonpoint source runoff impact scores for fecal coliform are calculated from impact values that are based on annual land-use specific unit area loads. The unit area loads are derived from the Banklick Creek Hydrologic Simulation Program-Fortran (HSPF) model application (LimnoTech, 2004), and as such reflect site-specific loading rates for the study area. This HSPF model was developed in 2004 as part of a larger project to establish a Watershed Assessment Protocol, which has served as a foundation for SD1's Watershed Management concept. The model was calibrated to instream dry and wet weather sampling data collected during 2002-2003. The model calibration was updated in 2008 to reflect the updates to land cover, hydraulic model results and recent wet weather source and instream data (LimnoTech, 2008).

HSPF model reports of total long-term export of fecal coliforms from each land cover type were then used to calculate unit area loads in terms of cfu/acre/year. Table 7 shows the calculated impact values based on the updated 2008 application of HSPF to Banklick Creek. Runoff impact values for fecal coliform are scaled by the slope and erodibility scalars described in Sections 4.4 and 4.5.

Table 7. WAT! Impact Values for Fecal Coliform

Land Cover	Impact Value / UAL (cfu/acre/yr)
Emergent herbaceous wetlands	0.00E+00
Open water	0.00E+00
Woody wetlands	0.00E+00
Deciduous Forest	3.15E+09
Evergreen Forest	3.15E+09
Mixed Forest	3.15E+09
Barren land	1.22E+10
Developed - open space	1.67E+10
Developed - high density (new)	2.58E+11
Developed - medium density (new)	2.73E+11
Cultivated Crops	2.86E+11
Developed - low density (new)	3.01E+11
Grassland/herbaceous	5.79E+11
Pasture/hay	5.79E+11
Shrub/scrub	5.79E+11
Developed - medium density (old)	1.45E+12
Developed - high density (old)	1.60E+12
Developed - low density (old)	1.72E+12

As noted in the updated calibration memorandum for the HSPF application to Banklick Creek (LimnoTech, 2008), the HSPF model was configured so that bacteria densities in runoff from built-up subwatersheds with older development were higher than densities in runoff from subwatersheds with newer development. Built-up subwatersheds were defined as those with more than 25% of their area in developed land cover classes, and "older" areas were defined as areas with more than 50% of Census-counted dwellings built before 1980. These differentiations were included in the WAT! impact scores and land cover information.

5.1.4 Construction

The impact score for fecal coliform from construction activities is set to 0; no added impact is expected for fecal coliform which is attributable to construction activities.

5.1.5 Streambank erosion

The impact score for fecal coliform from streambank erosion is set to 0.

5.2 SOLIDS

Total suspended solids (solids) scores are currently calculated in WAT! for point sources, runoff, construction and streambank erosion. However, these results are still subject to refinement and are not currently used.

5.3 NUTRIENTS

Nutrient scores are currently calculated in WAT! for point sources, septic systems, runoff and construction. Total phosphorus and total nitrogen are currently simulated in WAT!. Nutrient scores may provide an additional basis for focusing controls in watersheds identified by KDOW as impaired due to nutrients. Although nutrient results are still subject to refinement as detailed modeling of nutrients is undertaken, the scores may be used provisionally to provide insight into ancillary benefits from a nutrient standpoint that are associated with different bacteria control strategies for bacteria.

5.3.1 Point sources

As with bacteria, point source impact scores for nutrients are calculated from an impact value that is based on the estimated annual load from the point source expressed in kg. This estimated load may be based on modeled overflow volumes and literature or measured concentrations, or flows and concentrations – or loads - reported in discharge monitoring reports (DMRs). If information is not available to calculate a nutrient load for a point source, its contribution can either be user-specified or remain undefined in WAT!. WAT! tracks the number and type of undefined sources in each subwatershed so that the user can take them into consideration when evaluating results.

SD1 sanitary sources that can be specified in WAT! are the same as for bacteria, and include CSOs, recurring SSOs at manhole locations, SSOs at pump stations, and SSOs at model-predicted overflow locations. The loads for these sources are defined using overflow volume results from SD1's sewer system models in combination with user-specified event mean concentrations.

Nutrient impact values in the WAT! for CSOs and SSOs are based on concentrations measured during the infrastructure characterization phase of 1.2 mg TP/l or 3.9 mg TN/l for SSOs, and 1.0 mg TP/l or 4.1 mg TN/l for CSOs. Impact values for SSOs are scaled by the proximity scalar defined in Section 4.3 that reflects distance to the waterways. Impact values for CSOs are multiplied by a proximity scalar of one or 1.0 (i.e., neither scaled up nor down), as CSOs are considered to discharge directly to the waterways.

Non-CSO KPDES dischargers of nutrients include KPDES facilities administered by SD1 (wastewater treatment and water reclamation facilities); KPDES sanitary facilities ("package plants"); KPDES residential General Permit holders; KPDES construction General Permit holders; individual industrial KPDES storm water

discharges; and other KPDES discharges. Loads associated with the storm water dischargers are considered runoff loads rather than point source contributions, and are therefore calculated as part of runoff (Section 5.3.3). For the other non-CSO KPDES sources, the load estimate is based, where available, on averages of measured flows and concentrations in monthly DMRs from KDOW. These loads do not reflect periods where performance of individual treatment plants may have been compromised due to washouts from wet weather flows, etc. Where DMRs are not available, a load is estimated from permit information (e.g., allowable load or density times design flow), with the exception of point source discharges permitted under the Residential General Permit. These are treated in the same fashion as septic systems, which are discussed below.

5.3.2 Septic systems

The onsite wastewater treatment systems common in parts of the study area include both surface and underground discharges. Currently, WAT! tracks about 250 surface-water discharges administered under the KDOW Residential General Permit and about 15,000 parcels identified as likely locations for groundwater discharge septic systems.

For both nitrogen and phosphorus, properly operating systems are assumed to remove 50% of the system load through treatment. Passage of the septic system effluent through the region's generally fine-textured soils are assumed to remove 90% of the effluent nutrient load (Karathanasis, 2006), so the net removal for properly operating septic systems is assumed to be 95%. About 150 (1%) of the systems are assumed to be "straight-pipe" discharges that deliver household nutrient loads to the waterway without any removal, and about 1,100 (7.3%) of the systems are assumed to be ponding (discharging the treated effluent to the surface for a net removal of only 50%). Discharges from the 250 KDOW Residential General Permit Holders (1.7% of the total number of onsite disposal systems) are similarly assumed to have treated 50% of the household nutrient load.

Combining these assumptions leads to an estimated average removal efficiency of 90%:

$$\begin{aligned} Efficiency &= Fraction\ properly\ operating \times 95\% \\ &+ Fraction\ straight\ pipe \times 0\% \\ &+ Fraction\ ponding\ or\ RGP \times 50\% \\ &= 90\% \times 95\% + 1\% \times 0\% + 9\% \times 50\% \\ &= 90\% \end{aligned}$$

Households with septic systems are assumed to consist of 2.5 individuals, with each individual contributing 4 kg TN/yr and 0.5 kg TP/yr to the effluent entering the septic system (Baumann and Schafer, 1985; USEPA, 2002), leading to the TN impact score of 1.0 and the TP impact score of 0.125:

Impact = per capita load x individuals/hh x (1-removal)
$Impact_{TN}$ = 4.0 x 2.5 x 0.1 = 1.0
$Impact_{TP}$ = 0.5 x 2.5 x 0.1 = 0.125

5.3.3 Runoff

As with bacteria, nutrient nonpoint source runoff impact scores are calculated from impact values that are based on annual land-use specific unit area loads derived from the Banklick Creek HSPF model application (LimnoTech,2010), that reflect site-specific loading rates for the study area.

HSPF model reports of total long-term export of nutrients by land cover type were used to calculate unit area loads in terms of kg nutrients/acre/year. Table 8 shows the calculated impact values based on the updated 2008 application of HSPF to Banklick Creek. Runoff impact values are scaled by the slope and erodibility scalars described in Sections 4.4 and 4.5.

Table 8. WAT! Impact Values for Nutrients

Land Cover	TN Impact Value / UAL (kg/ha/yr)	TP Impact Value / UAL (kg/ha/yr)
Open water	0.00	0.00
Developed, open space	11.61	9.90
Developed, low intensity	15.81	4.80
Developed, medium intensity	18.29	3.00
Developed, high intensity	19.52	3.25
Barren land (rock/sand/clay)	17.79	25.60
Deciduous forest	5.93	0.80
Evergreen forest	5.93	0.80
Mixed forest	5.93	0.80
Shrub/scrub	10.13	4.60
Grassland/herbaceous	10.13	4.60
Pasture/hay	10.13	4.60
Cultivated crops	19.03	13.10
Woody wetlands	0.00	0.00
Emergent herbaceous wetlands	0.00	0.00
Buildings	15.81	3.70
Roads	15.81	3.70

5.3.4 Construction

The WAT! compares current and future land cover to identify areas where land cover is anticipated to change, and assumes that these areas will contribute an elevated nutrient runoff impact during construction-related disturbance. TN and TP impact values are both set to 24 kg/ha/yr for the areas to undergo construction, but the score is multiplied by a factor of 0.05 to represent the distribution of construction activities over an assumed 20-year period.

5.3.5 Streambank erosion

The impact score for fecal coliform from streambank erosion is set to 0.

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6 WAT! Output

In developing WAT!, a user-interface and viewer were constructed so that results can be viewed in tabular or graphical format. This section presents some of the different formats in which WAT! results can be viewed by the user. These are:

- **Study area-wide summary:** Summarizes pollutant scores by source for the entire study area. Scores can be examined under current and build-out conditions.
- **Watershed summary:** Summarizes pollutant scores by source for each watershed. Results are presented for a user-specified land cover scenario (e.g., current conditions) and pollutant of interest.
- **Watershed maps:** Presents pollutant scores on a map, using pie charts to reflect watershed rankings and sources. Watersheds are color-coded according to their relative rank.
- **Watershed pie charts:** Presents pollutant scores using pie charts to reflect source contributions by watershed and relative differences in scores between watersheds.
- **Watershed sources:** Lists sources ordered by pollutant scores within a user-selected watershed.
- **Subwatershed pie charts:** Presents pollutant scores using pie charts to reflect source contributions for all subwatersheds within a given watershed and relative differences in scores between subwatersheds.
- **Subwatershed sources:** Lists sources ordered by pollutant scores within a user-selected subwatershed.

6.1 STUDY-AREA WIDE SUMMARY

The study area-wide summary output summarizes pollutant scores by source for the entire study area. As shown in Tables 9-11, scores can be examined under different land cover scenarios to help understand how changes in land cover alone may affect the relative contributions of different sources to water quality impacts. In this example, runoff calculations were modified to reflect build-out conditions and associated construction. Fecal coliform scores within the three-county area increase slightly from 1.62×10^{17} to 1.73×10^{17} (about 7%). These changes are consistent with the development simulated in synthesized 2030 land cover layer, which changes forest and open land to urban developed areas. Runoff from urban areas has lower fecal coliform impact values, but overflows are calculated to increase in the build-out infrastructure results (which in this scenario assumes minimal additional construction of controls). Similar trends are seen in results for total nitrogen and total phosphorus.

Table 9. Study Area-Wide Summary of WAT! Scores for Fecal Coliform under Current and Build-out Conditions

	Current		Build-out	
SD1-SSO	7.83E+15	(5%)	6.49E+15	(4%)
SD1-CSO	5.28E+16	(33%)	5.76E+16	(33%)
SD1-MPOL	9.20E+15	(6%)	2.10E+16	(12%)
SD1-KPDES	7.65E+13	(0%)	7.65E+13	(0%)
SD1-PS	9.22E+14	(1%)	2.48E+14	(0%)
Total SD1	**7.09E+16**	**(44%)**	**8.54E+16**	**(49%)**
Runoff	8.90E+16	(55%)	8.63E+16	(50%)
Total Runoff	**8.90E+16**	**(55%)**	**8.63E+16**	**(50%)**
KPDES-RGP	6.32E+11	(0%)	6.32E+11	(0%)
KPDES-PP	8.79E+12	(0%)	8.79E+12	(0%)
KPDES-SW	1.80E+13	(0%)	1.80E+13	(0%)
KPDES-Other	6.58E+13	(0%)	6.58E+13	(0%)
Septic Systems	2.18E+15	(1%)	2.18E+15	(1%)
Total Point	**2.28E+15**	**(1%)**	**2.28E+15**	**(1%)**
Construction	0.00E+00	(0%)	0.00E+00	(0%)
Streambank Erosion	0.00E+00	(0%)	0.00E+00	(0%)
Total Other	**0.00E+00**	**(0%)**	**0.00E+00**	**(0%)**
TOTAL	**1.62E+17**		**1.74E+17**	

SD1-MPOL = Model-predicted Overflow Location
SD1-KPDES = Permitted non-CSO discharge from SD1 sanitary facilities
SD1-PS = SSO at Pump Station Location

KPDES-RGP = KPDES Residential General Permit
KPDES-PP = KPDES discharge from non-SD1 sanitary facilities
KPDES-SW = KPDES-permitted storm water discharge
KPDES-Other = All other KPDES-permitted discharges

Table 10. Study Area-Wide Summary of Initial WAT! Scores for Total Nitrogen under Current and Build-out Conditions

	Current		Build-out	
SD1-SSO	1.48E+03	(0%)	1.64E+03	(0%)
SD1-CSO	3.18E+04	(2%)	3.46E+04	(2%)
SD1-MPOL	1.95E+03	(0%)	2.65E+03	(0%)
SD1-KPDES	2.56E+05	(13%)	2.56E+05	(13%)
SD1-PS	1.92E+02	(0%)	5.16E+01	(0%)
Total SD1	**2.92E+05**	**(15%)**	**2.95E+05**	**(15%)**
Runoff	1.40E+06	(72%)	1.51E+06	(76%)
Total Runoff	**1.40E+06**	**(72%)**	**1.51E+06**	**(76%)**
KPDES-RGP	2.28E+01	(0%)	2.28E+01	(0%)
KPDES-PP	2.03E+04	(1%)	2.03E+04	(1%)
KPDES-SW	3.45E+04	(2%)	3.45E+04	(2%)
KPDES-Other	1.35E+05	(7%)	1.35E+05	(7%)
Septic Systems	2.18E+03	(0%)	2.18E+03	(0%)
Total Point	**1.92E+05**	**(10%)**	**1.92E+05**	**(10%)**
Construction	4.97E+04	(3%)	0.00E+00	(0%)
Streambank Erosion	0.00E+00	(0%)	0.00E+00	(0%)
Total Other	**4.97E+04**	**(3%)**	**0.00E+00**	**(0%)**
TOTAL	**1.94E+06**		**2.00E+06**	

SD1-MPOL = Model-predicted Overflow Location
SD1-KPDES = Permitted non-CSO discharge from SD1 sanitary facilities
SD1-PS = SSO at Pump Station Location

KPDES-RGP = KPDES Residential General Permit
KPDES-PP = KPDES discharge from non-SD1 sanitary facilities
KPDES-SW = KPDES-permitted storm water discharge
KPDES-Other = All other KPDES-permitted discharges

Table 11. Study Area-Wide Summary of Initial WAT! Scores for Total Phosphorus under Current and Build-out Conditions

	Current		Build-out	
SD1-SSO	5.03E+02	(0%)	5.52+.02	(0%)
SD1-CSO	7.75+03	(1%)	8.44+03	(1%)
SD1-MPOL	5.98E+02	(0%)	5.61E+02	(0%)
SD1-KPDES	8.94E+04	(13%)	8.94E+04	(13%)
SD1-PS	5.91E+01	(0%)	1.59E+01	(0%)
Total SD1	**9.83E+04**	**(14%)**	**9.90E+04**	**(15%)**
Runoff	4.99E+05	(72%)	5.28E+05	(78%)
Total Runoff	**4.99E+05**	**(72%)**	**5.28E+05**	**(78%)**
KPDES-RGP	7.01E+00	(0%)	7.01E+00	(0%)
KPDES-PP	5.02E+03	(1%)	5.02E+03	(1%)
KPDES-SW	8.43E+03	(1%)	8.43E+03	(1%)
KPDES-Other	3.29E+04	(5%)	3.29E+04	(5%)
Septic Systems	2.73E+02	(0%)	2.73E+02	(0%)
Total Point	**4.66E+04**	**(7%)**	**4.66E+04**	**(7%)**
Construction	4.97E+04	(7%)	0.00E+00	(0%)
Streambank Erosion	0.00E+00	(0%)	0.00E+00	(0%)
Total Other	**4.97E+04**	**(7%)**	**0.00E+00**	**(0%)**
TOTAL	**6.94E+05**		**6.74E+05**	

SD1-MPOL = Model-predicted Overflow Location
SD1-KPDES = Permitted non-CSO discharge from SD1 sanitary facilities
SD1-PS = SSO at Pump Station Location

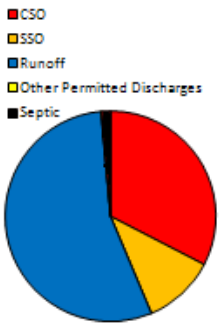
KPDES-RGP = KPDES Residential General Permit
KPDES-PP = KPDES discharge from non-SD1 sanitary facilities
KPDES-SW = KPDES-permitted storm water discharge
KPDES-Other = All other KPDES-permitted discharges

6.2 WATERSHED SUMMARY

The watershed summary output format summarizes pollutant scores by source for each watershed. Results are presented for a user-specified land cover scenario and pollutant of interest. Figure 2 shows the watershed summaries for fecal coliform under current conditions for the cumulative score ("Loading Score") and the normalized score ("Area-Normalized Loading Score").

The watershed summary identifies which of the 16 study watersheds have the highest scores in WAT!, and displays (in parentheses) the rank of each watershed's score, with the rank of 1 corresponding to the highest score. The summary also presents information about the relative contribution of different sources to the scores (percentages shown as 0% indicate that a particular source is present for that watershed, but its relative contribution is less than 1% of the total). In addition, total scores and relative contributions by source for the entire study area are tabulated, and a pie chart graphically depicts major contributors of pollutants across the study area.

Fecal Coliforms, Current Conditions



	Loading Score		Area-Normalized Loading Score		SD1-CSO	SD1-SSO	Runoff	SD1-KPDES	Septic Systems
TOTAL	1.62E+17		9.83E+06		33%	10%	55%	0%	1%
01: Big Bone Creek	1.18E+16	(5)	5.11E+06	(12)			97%	0%	3%
02: Gunpowder Creek	7.33E+15	(6)	4.52E+06	(13)		12%	84%	0%	4%
03: Woolper Creek	3.89E+15	(10)	4.22E+06	(14)		0%	96%	0%	4%
04: Sand Run	4.91E+14	(16)	3.55E+06	(15)			98%	0%	2%
05: Eliljahs Creek	2.00E+15	(15)	1.07E+07	(8)		3%	96%	0%	0%
06: Dry Creek	7.12E+15	(8)	2.06E+07	(5)		5%	95%	0%	0%
07: Pleasant Run Creek	3.08E+15	(12)	1.69E+07	(6)	2%	3%	94%	0%	0%
08: Banklick Creek	2.12E+16	(3)	1.31E+07	(7)	8%	29%	56%	0%	1%
09: Licking River	**4.84E+16**	**(1)**	1.02E+07	(9)	46%	8%	45%	0%	1%
10: Threemile Creek	3.37E+15	(11)	2.07E+07	(4)		11%	85%	0%	0%
11: Taylor Creek	2.81E+15	(14)	2.38E+07	(2)	8%	18%	70%	0%	0%
12: Fourmile Creek	4.24E+15	(9)	8.56E+06	(10)	2%	55%	41%	0%	2%
13: Twelvemile Creek	7.17E+15	(7)	5.58E+06	(11)			97%	0%	2%
14E: Ohio River tribs- East	1.29E+16	(4)	2.32E+07	(3)	61%	14%	24%	0%	0%
14N: Ohio River tribs - North	2.34E+16	(2)	**2.63E+07**	**(1)**	89%	0%	10%	0%	0%
14W: Ohio River tribs - West	2.99E+15	(13)	3.25E+06	(16)			94%	2%	4%

Figure 2. Watershed Summary of Fecal Coliform Scores

The WAT! results in Figure 2 indicate that the Ohio River North watershed currently has the highest area-normalized loading score for fecal coliforms and that the most significant source of bacteria in this watershed is CSOs.

6.3 WATERSHED MAPS

Figure 3 shows a map of the system with pie charts showing each watershed's loadings. The pie charts superimposed on the map are sized to be proportional to each watershed's total score, and depict the relative contribution of different types of sources to that watershed's score.

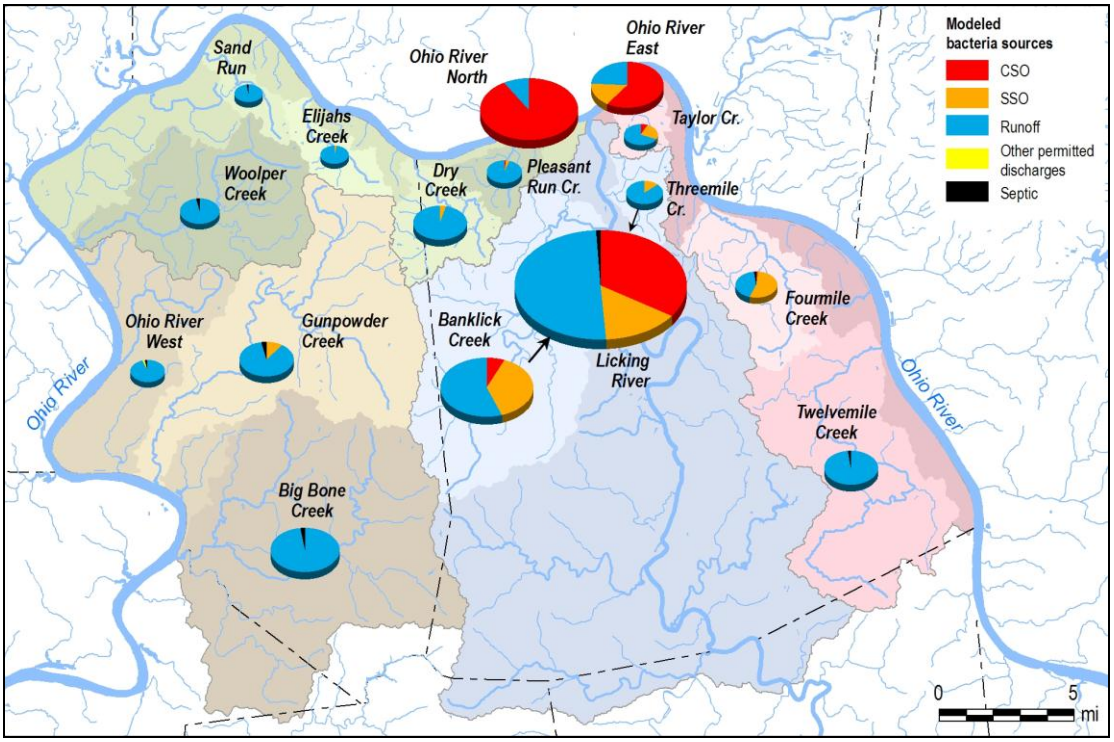


Figure 3. Study Area Map with Watershed Pie Charts Showing Relative Contributions to Fecal Coliform Loading Scores (Licking River Pie includes Banklick and Threemile Creek contributions)

6.4 WATERSHED AND SUBWATERSHED PIE CHARTS

WAT! results can be output as pie charts without a map backdrop. The pie charts can be sized to be proportional to each watershed's total loading or area-normalized score. Figure 4 below shows the relative contributions of major source categories to the WAT! fecal coliform loading scores for each of the 16 study watersheds. The charts are sized to be proportional to watershed loading scores. The largest pie (09: Licking River) corresponds to the watershed with the largest fecal coliform loading score.

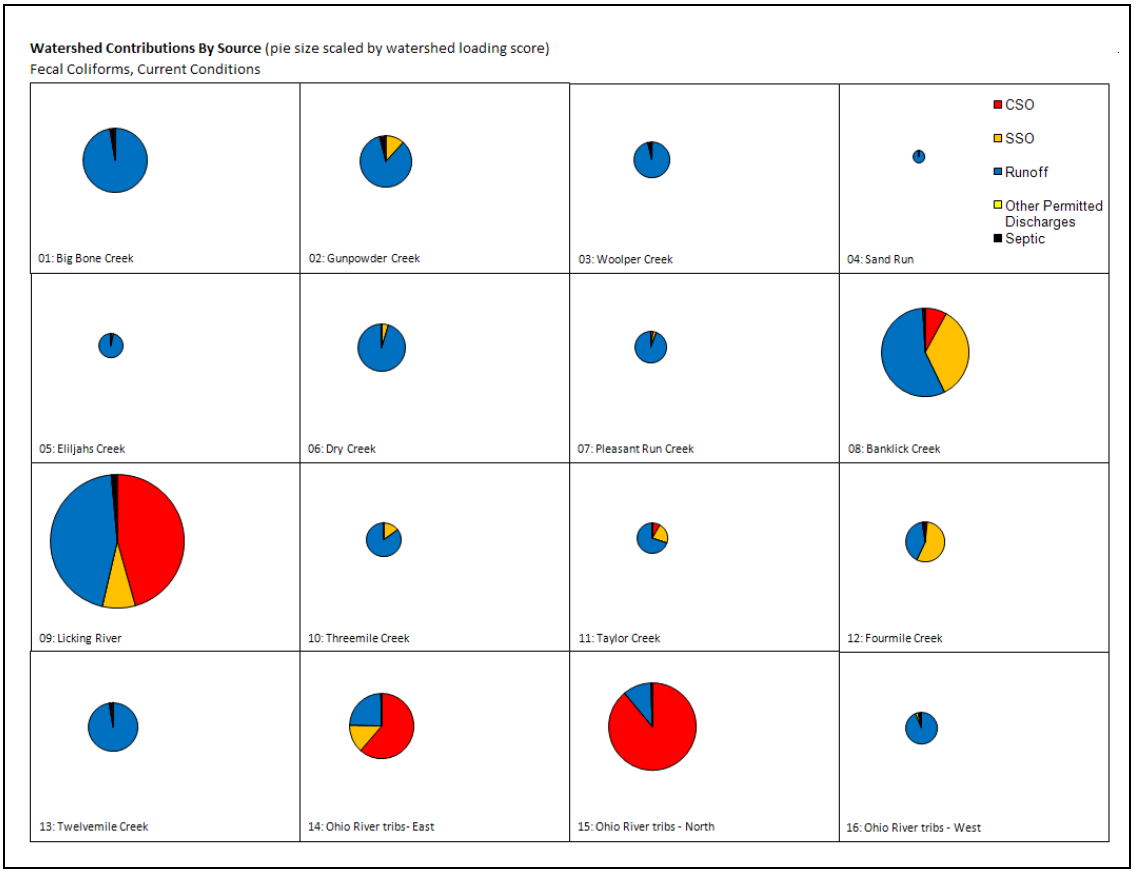


Figure 4. Pie Charts Showing Relative Contributions of Different Sources to Watershed Loading Score, with Pie Areas Proportional to Each Watershed's Fecal Coliform Loading Score

Figure 5 also shows the relative contributions of different sources to each watershed's loading score, but with the pie areas proportional to the area-normalized loading scores. The largest pie (14N: Ohio River North) in Figure 5 corresponds to the watershed with the highest area-normalized score for fecal coliform. The area-normalized scores are more closely related to water quality impact.

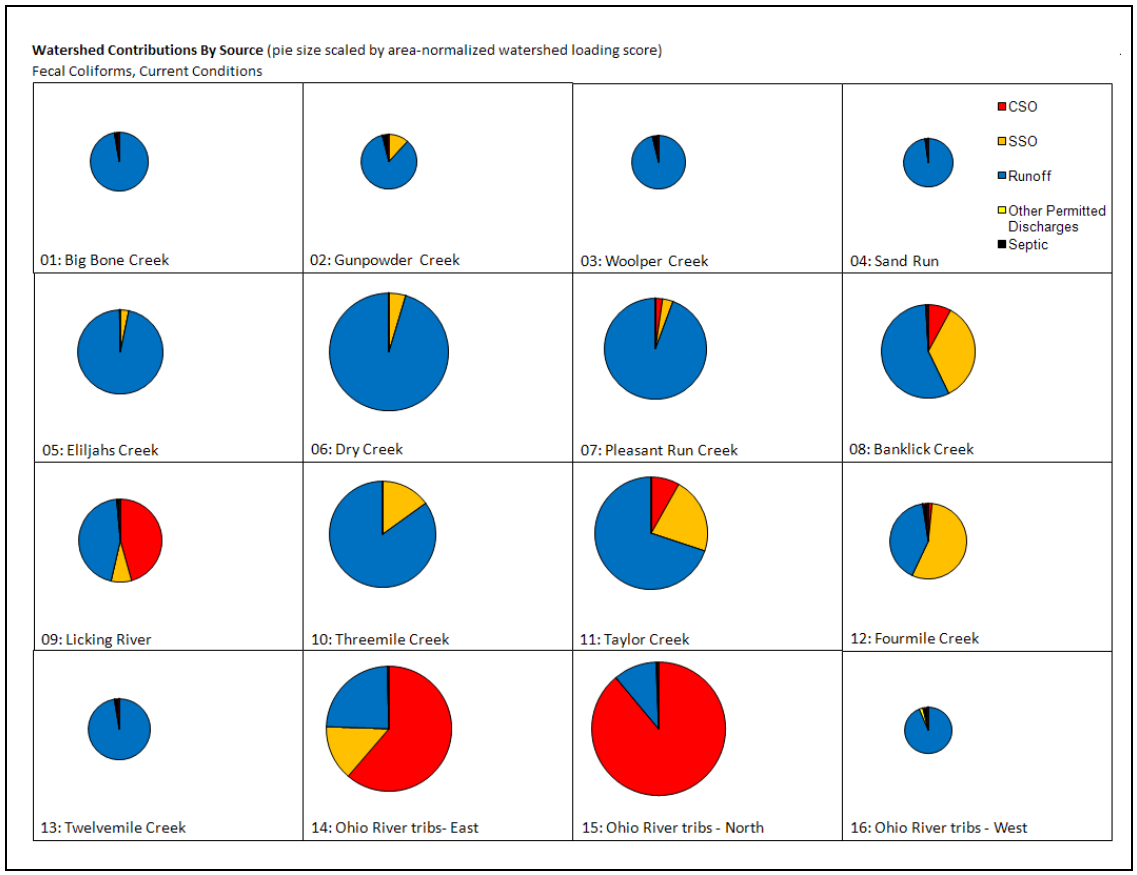


Figure 5. Pie Charts Showing Relative Contributions of Different Sources to Watershed Loading Score, with Pie Areas Proportional to Each Watershed's Area-Normalized Fecal Coliform Loading Score

WAT! results can also be viewed by subwatershed, as seen in Figure 6. The WAT! viewer allows the user to specify a watershed of interest for which subwatershed scores will be displayed. In this figure, the largest pie (08-05) corresponds to the subwatershed of the 08 watershed (Banklick Creek) with the largest area-normalized score.

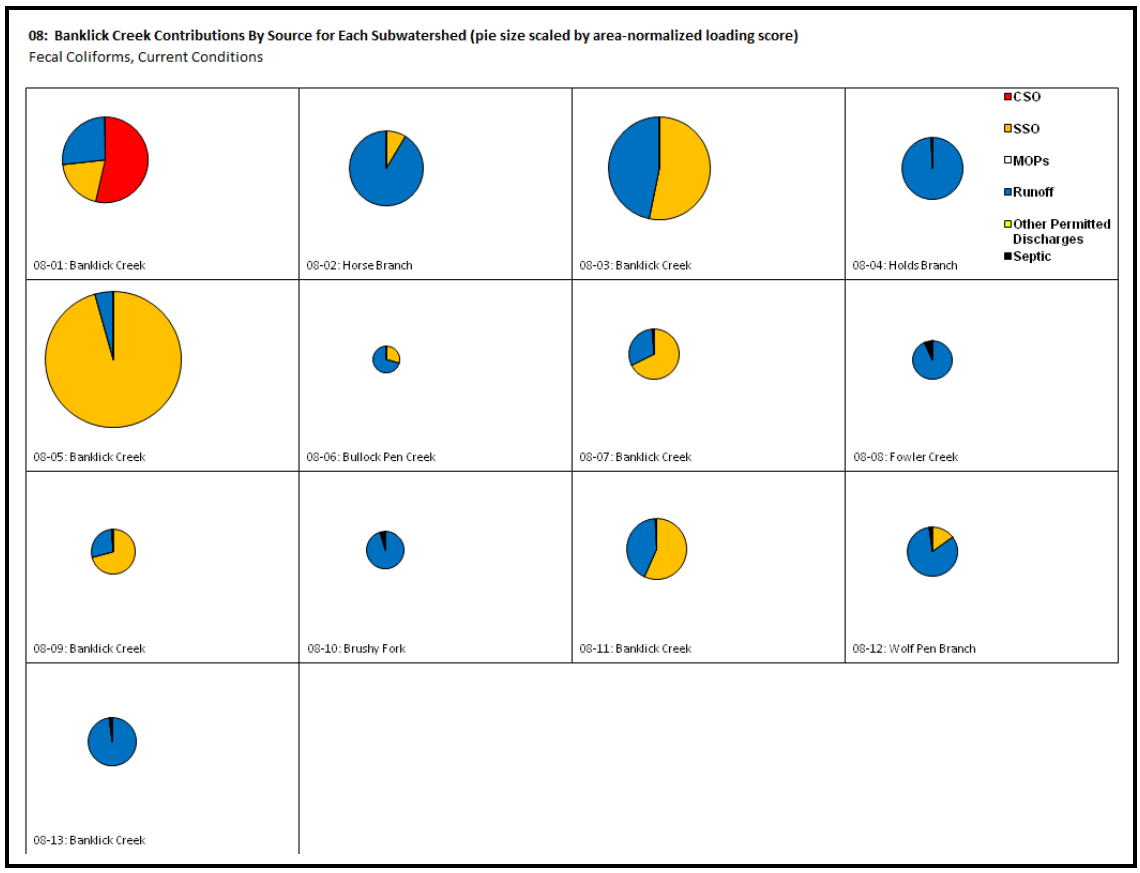
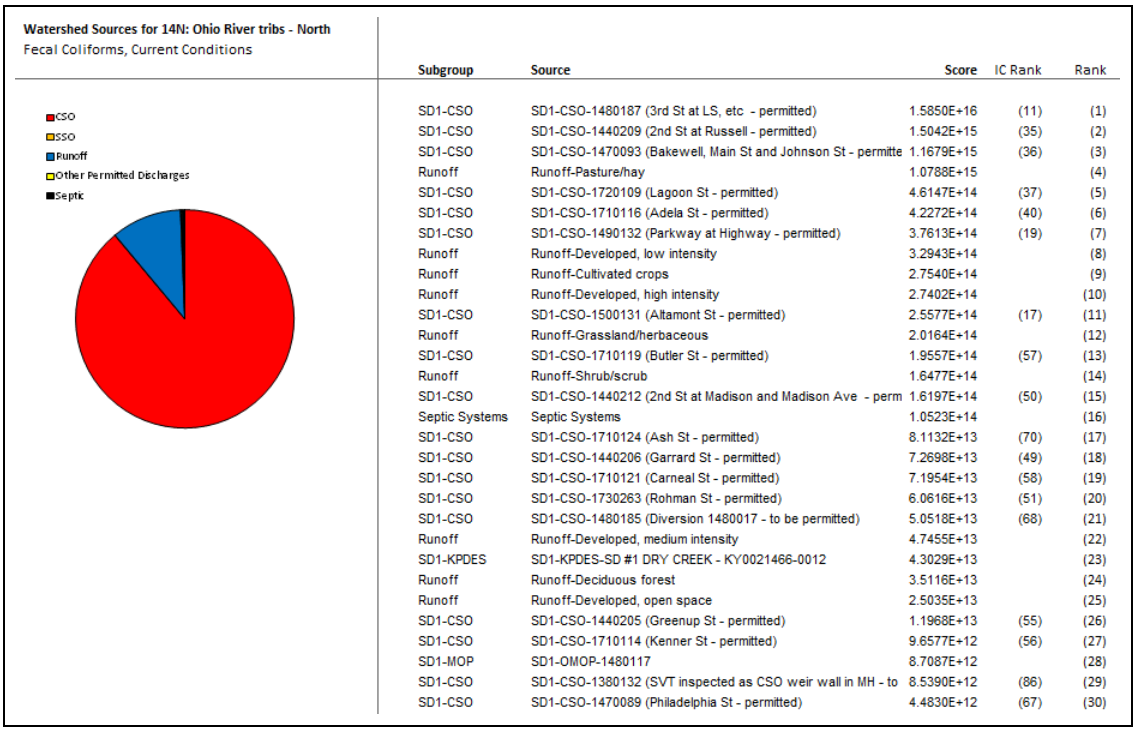


Figure 6. Pie Charts Showing Relative Contributions of Different Sources to Subwatershed Loading Score, with Pie Areas Proportional to Each Subwatershed's Area-Normalized Fecal Coliform Loading Score

6.5 WATERSHED AND SUBWATERSHED SOURCES

WAT! scores can be examined by watershed or subwatershed to identify predominant sources within an area of interest. In Figure 7, WAT! tracks scores for individual sources within a watershed, so that a detailed analysis can be made of source contributions. Sources are listed in descending order of scores and assigned a rank, with the largest score receiving a rank of 1. Scores can also be examined for an individual subwatershed.



Subgroup	Source	Score	IC Rank	Rank
SD1-CSO	SD1-CSO-1480187 (3rd St at LS, etc - permitted)	1.5850E+16	(11)	(1)
SD1-CSO	SD1-CSO-1440209 (2nd St at Russell - permitted)	1.5042E+15	(35)	(2)
SD1-CSO	SD1-CSO-1470093 (Bakewell, Main St and Johnson St - permitte	1.1679E+15	(36)	(3)
Runoff	Runoff-Pasture/hay	1.0788E+15		(4)
SD1-CSO	SD1-CSO-1720109 (Lagoon St - permitted)	4.6147E+14	(37)	(5)
SD1-CSO	SD1-CSO-1710116 (Adela St - permitted)	4.2272E+14	(40)	(6)
SD1-CSO	SD1-CSO-1490132 (Parkway at Highway - permitted)	3.7613E+14	(19)	(7)
Runoff	Runoff-Developed, low intensity	3.2943E+14		(8)
Runoff	Runoff-Cultivated crops	2.7540E+14		(9)
Runoff	Runoff-Developed, high intensity	2.7402E+14		(10)
SD1-CSO	SD1-CSO-1500131 (Altamont St - permitted)	2.5577E+14	(17)	(11)
Runoff	Runoff-Grassland/herbaceous	2.0164E+14		(12)
SD1-CSO	SD1-CSO-1710119 (Butler St - permitted)	1.9557E+14	(57)	(13)
Runoff	Runoff-Shrub/scrub	1.6477E+14		(14)
SD1-CSO	SD1-CSO-1440212 (2nd St at Madison and Madison Ave - perm	1.6197E+14	(50)	(15)
Septic Systems	Septic Systems	1.0523E+14		(16)
SD1-CSO	SD1-CSO-1710124 (Ash St - permitted)	8.1132E+13	(70)	(17)
SD1-CSO	SD1-CSO-1440206 (Garrard St - permitted)	7.2698E+13	(49)	(18)
SD1-CSO	SD1-CSO-1710121 (Carneal St - permitted)	7.1954E+13	(58)	(19)
SD1-CSO	SD1-CSO-1730263 (Rohman St - permitted)	6.0616E+13	(51)	(20)
SD1-CSO	SD1-CSO-1480185 (Diversion 1480017 - to be permitted)	5.0518E+13	(68)	(21)
Runoff	Runoff-Developed, medium intensity	4.7455E+13		(22)
SD1-KPDES	SD1-KPDES-SD #1 DRY CREEK - KY0021466-0012	4.3029E+13		(23)
Runoff	Runoff-Deciduous forest	3.5116E+13		(24)
Runoff	Runoff-Developed, open space	2.5035E+13		(25)
SD1-CSO	SD1-CSO-1440205 (Greenup St - permitted)	1.1968E+13	(55)	(26)
SD1-CSO	SD1-CSO-1710114 (Kenner St - permitted)	9.6577E+12	(56)	(27)
SD1-MOP	SD1-OMOP-1480117	8.7087E+12		(28)
SD1-CSO	SD1-CSO-1380132 (SVT inspected as CSO weir wall in MH - to	8.5390E+12	(86)	(29)
SD1-CSO	SD1-CSO-1470089 (Philadelphia St - permitted)	4.4830E+12	(67)	(30)

Figure 7. WAT! Watershed Source View (Fecal Coliform)

Figure 7 also illustrates the flexibility of WAT! to incorporate additional information for viewing. For example, in this figure a second rank (IC Rank) is presented for illustration for each source. This ranking can be conducted independent of WAT! to reflect a separate priority ranking of sources (in this example, CSOs and SSOs). The user can compare these rankings to WAT!'s ranking of individual sources within a subwatershed. In this illustrative example showing sources in the Ohio River North watershed, the largest WAT! source scores include CSOs, runoff, and septic systems. Plans to reduce water quality impacts in this watershed might therefore best be based on point source controls as well as septic system maintenance and improved runoff management practices.

7 Analysis of Results

This section presents a comparison of WAT! output to various available data. WAT! results were not directly calibrated to instream water quality data because the annual basis of WAT! outputs cannot be readily compared to existing collections of data. However, studies in other locations as well as detailed models of SD1 watersheds provide a basis for qualitative evaluation of WAT! fecal coliform results.

WAT! nutrient results are also compared here to estimated annual loads at several locations in the study area.

7.1 COMPARISON TO OTHER BACTERIA STUDIES

As previously discussed, the bacteria scores calculated in WAT! are analogous to a fecal coliform load. As such, the current WAT! scores can be compared to other studies to assess consistency of results. WAT! results for runoff impacts were compared to results from a recent study performed by the Southeastern Wisconsin Regional Planning Commission (SWRPC, 2007). This study reported that unit area loads of fecal coliforms delivered to modeled stream reaches in 21 Milwaukee River watersheds between 5,000 and 50,000 acres in size ranged from 0.03×10^{12} to 0.33×10^{12} cells/acre/year, with a median of 0.07×10^{12} cells/acre/year. The studied watersheds encompassed a diverse mix of predominant land uses.

Study area-wide unit area loads were estimated from the total WAT! runoff impact scores. The total runoff impact score of 8.9×10^{16} for fecal coliforms under current conditions corresponds to a unit area load of 0.24×10^{12} cells/acre/year for the 378,618-acre study area. Although WAT! bacteria results are at the higher end of the reported range for Milwaukee River watersheds, other studies, such as Benham et al. (2005) show unit area loads as high as 1.9×10^{12} cfu/acre/year for heavily agricultural areas.

The possibility that WAT! estimates of runoff impacts are somewhat on the high side for non-agricultural areas is consistent with WAT! assumptions as the methodology does not incorporate loss processes such as die-off and losses during overland transport.

7.2 COMPARISON TO DETAILED SD1 BACTERIA MODELS

WAT! scores for annual runoff bacteria were compared to average annual loads calculated in five-year baseline runs of detailed models of Banklick Creek (HSPF) and Taylor Creek (SWMM) (Figure 8).

As shown in Figure 8, the WAT! scores by subwatershed using impact values based on the Banklick HSPF model are generally within 10% of the loads calculated by the detailed models for Banklick and Taylor Creeks. The variation is attributed to spatial

heterogeneity of the subwatersheds that is incorporated into the WAT! results through the WAT! slope and soil scalars. Three results show a larger variation:

- **08-01.** The WAT! result for this Banklick Creek subwatershed is 13% greater than the HSPF result because the subwatershed corresponds to three HSPF reaches, one of which is designated as "new development" for runoff calculation purposes in HSPF. Because of the difference in model spatial resolution, the entire subwatershed is designated as "old" in WAT!, so the developed areas from the "new" HSPF reach are treated as "old" in WAT!.

- **08-09.** The WAT! result for this Banklick Creek subwatershed is 22% greater than the HSPF result because the delineations for the corresponding HSPF reach and WAT! subwatershed are not identical.

- **11-01**. The WAT! result for the Taylor Creek watershed is 31% lower than the SWMM result. This was judged an acceptable variation because of the limited availability of data for the hydrologic calibration of the SWMM model.

Overall, the WAT! scores by subwatershed are considered consistent with results from the detailed models of Banklick and Taylor Creeks.

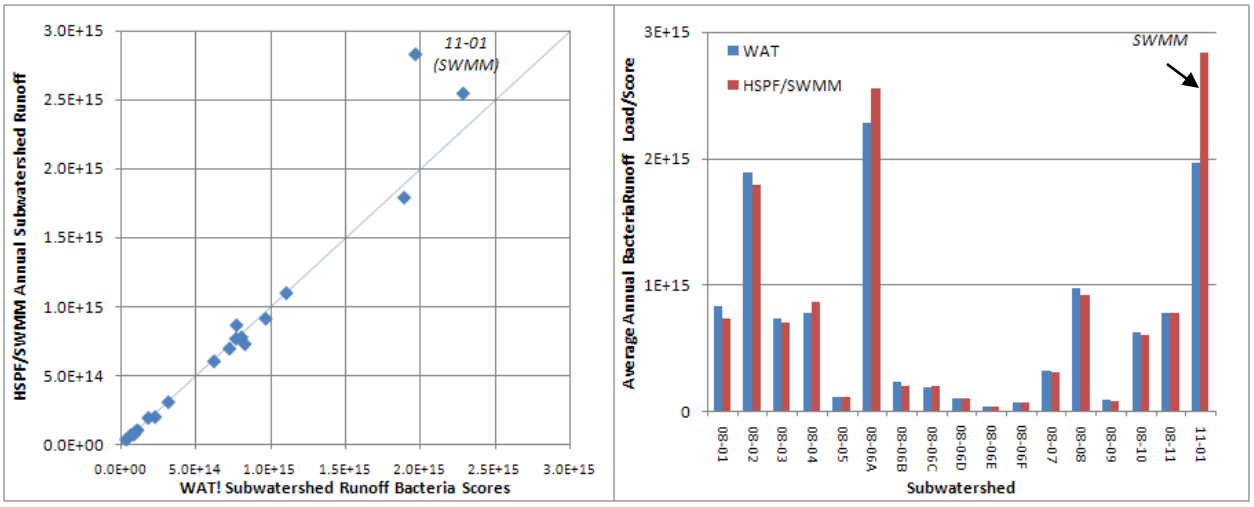


Figure 8. Comparison of WAT!, HSPF, and SWMM results for annual average runoff bacteria loads (current conditions) for Banklick Creek subwatersheds and Taylor Creek

7.3 COMPARISON TO NUTRIENT LOADS ESTIMATED FROM DATA

Initial WAT! scores for annual runoff TP and TN were compared to average annual loads estimated at SD1 sampling stations where both dry and wet-weather event samples were collected across multiple years. The estimates were made using Beale's Ratio Estimator (Beale, 1962) applied using nutrient concentration data collected by SD1 from 2007 to 2009 and daily flows synthesized for the 2001-2010 period using

the USGS Water Availability Tool for Environmental Resources (WATER) (Williamson et al., 2009).

Figure 9 shows that the WAT! results for TN are well-correlated with the mean load estimates derived from sampling data. Correlation for TP, shown in Figure 10, is also good, but WAT! scores are roughly twice as large as the estimated loads. This may be attributable to the current lack in the WAT! of a delivery ratio to account for loss processes in overland and instream transport.

Table 12 lists the WAT! results and mean load estimates for the stations used in this comparison.

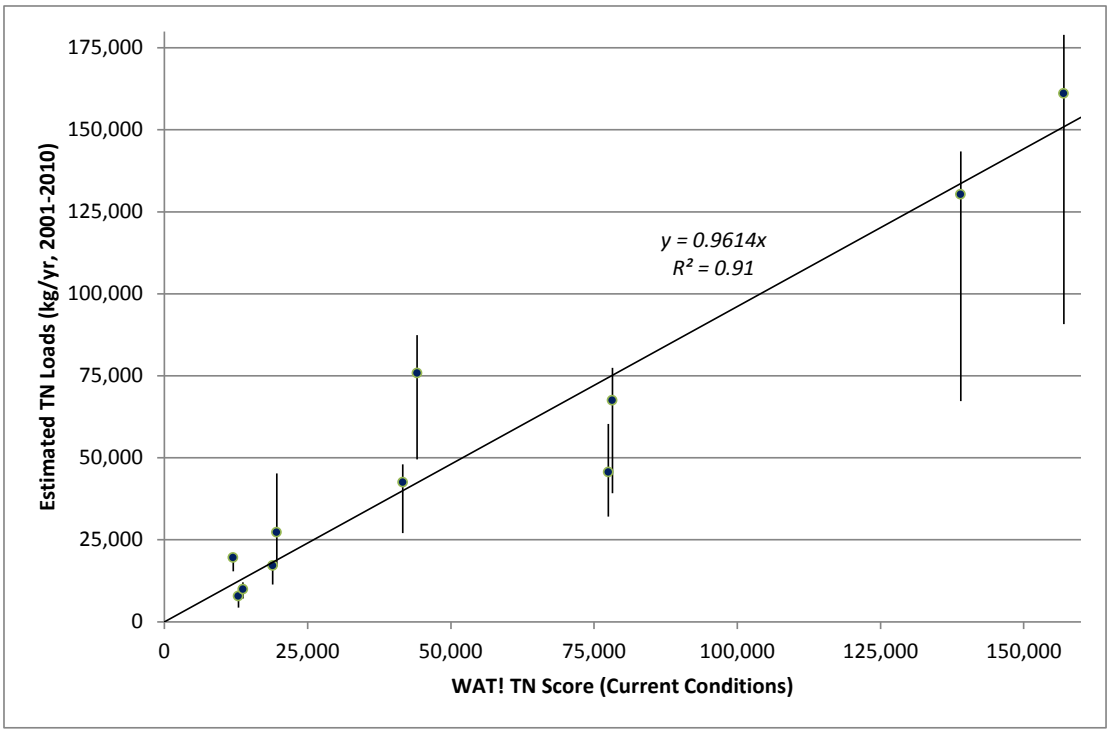


Figure 9. Comparison of Initial WAT! TN Results to Annual Loads Estimated at 11 SD1 Monitoring Stations (with 95% Confidence Limits for Estimates)

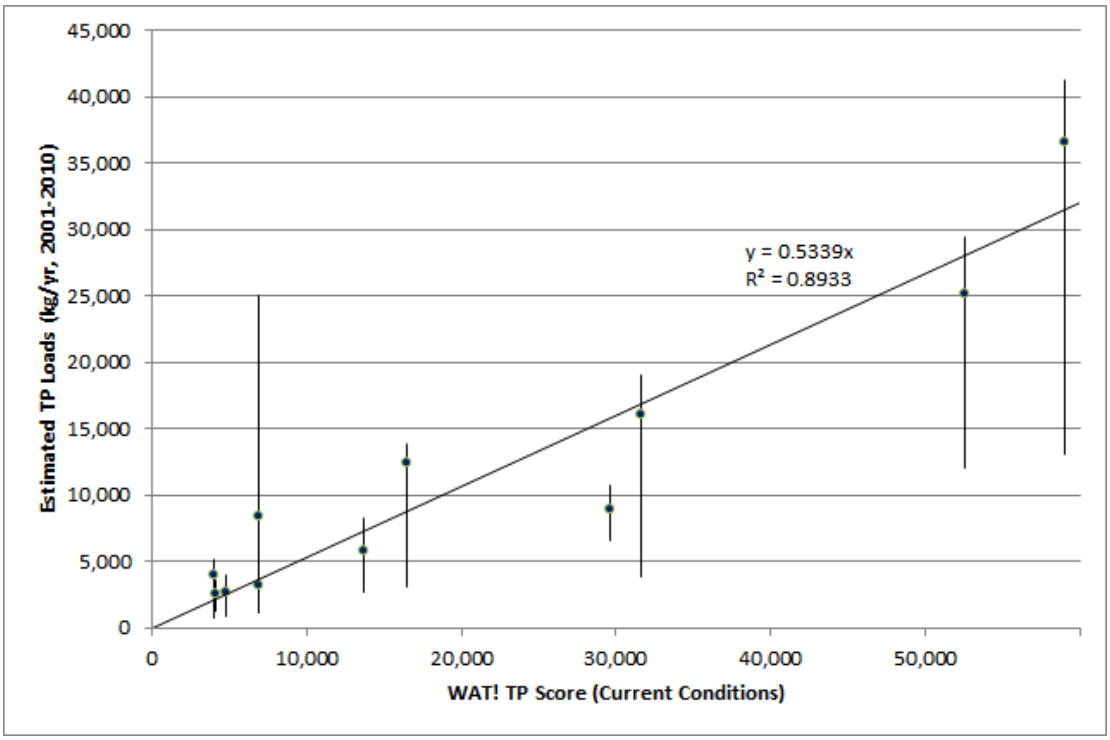


Figure 10. Comparison of Initial WAT! TP Results to Annual Loads Estimated at 11 SD1 Monitoring Stations (with 95% Confidence Limits for Estimates)

Table 12. Comparison of Initial WAT! Nutrient Results to Annual Loads Estimated at 11 SD1 Monitoring Stations

	Total Nitrogen		Total Phosphorus	
	WAT! Score	Estimate (kg/yr)	WAT! Score	Estimate (kg/yr)
BLC0.3	*Excluded - incomplete flow synthesis from WATER*			
BLC1.2	157,000	161,070	59,015	36,620
BLC3.9	139,000	130,311	52,554	25,205
BLC8.1	78,200	67,529	31,635	16,020
DRC1.0	41,600	42,470	13,742	5,835
EJC0.3	13,700	9,923	4,850	2,668
FMC0.5	44,100	75,763	16,463	12,445
LIR0.5-MID	*Excluded - contributing area extends beyond WAT!*			
PRC0.3	19,600	27,219	6,937	8,471
SDR0.6	12,900	7,787	4,086	2,615
THC0.4	18,900	17,078	6,930	3,274
TMC0.4	*Excluded - incomplete flow synthesis from WATER*			
TYC0.6	12,000	19,518	3,960	4,031
WPC1.4	77,500	45,608	29,642	8,956

8 Summary and Anticipated Next Steps

The Watershed Assessment Tool developed for the SD1 study area calculates scores that represent annual loads of fecal coliform bacteria and of nutrients based on source characteristics, including loading potential, slope, and proximity to streams. The WAT! scores provide a consistent area-wide screening basis for evaluating the relative impacts of pollutants on water quality and for examining source contributions at subwatershed, watershed, and regional scales. WAT! results are consistent with observed data and with the calibrated results from the Banklick Creek watershed model.

The WAT! has already been used to prioritize watersheds for development of detailed models, to evaluate watershed control opportunities, and to provide a relative assessment of the benefits of the Five-year Improvement Program and Full System Bounding Analysis across all watersheds. SD1 anticipates that the WAT! will continue to be refined and developed to:

(1) Evaluate solids in addition to fecal coliform bacteria and nutrients;

(2) Incorporate updated infrastructure model results to characterize CSO and SSO contributions as new management alternatives are developed and considered;

(3) Reflect KPDES and SD1 monitoring data to characterize present and future loads from point sources in the study area;

(4) Compare WAT! results to new instream monitoring data; and

(5) Update WAT! impact scores for runoff to reflect results from the extension of detailed models beyond Banklick Creek.

In addition, the WAT! framework allows for its modification to simulate *E. coli* should KDOW elect to adopt an *E. coli*-based water quality standard. This modification would require the calibration of the detailed watershed/water quality models to *E. coli*.

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ATTACHMENT A - SUBWATERSHED GIS LAYER

SUMMARY

A GIS dataset has been created to represent the subwatersheds to be modeled using the Watershed Assessment Tool (WAT!). The dataset, a GIS shapefile named "WAT_Subwatersheds", was edited to include only areas to be modeled and characterized and to provide a consistent, correct data layer for watershed planning efforts. This dataset contains key attributes for the 128 subwatersheds that make up Northern Kentucky's sixteen watersheds in Boone, Campbell, and Kenton Counties.

Two other GIS shapefiles were derived from the subwatershed dataset. The shapefile named "WAT_Watersheds" contains polygons representing the broader study area watersheds. In that dataset, the subwatershed boundaries have been dissolved within watersheds. The shapefile named "WAT_Basins" contains polygons representing the four large basins that encompass the Northern Kentucky study area. In that dataset, the subwatershed and watershed boundaries have been dissolved within basins.

SUBWATERSHED DATASET DESCRIPTION

The subwatershed shapefile is a modified version of a dataset showing Kentucky's 14-digit hydrologic units. It covers sixteen watersheds that will be modeled and described:

- Banklick Creek
- Big Bone Creek
- Dry Creek
- Elijahs Creek
- Fourmile Creek
- Gunpowder Creek
- Licking River
- Pleasant Run Creek
- Sand Run
- Taylor Creek (formerly Woodlawn Creek)
- Threemile Creek (the Licking River tributary, not the Ohio River tributary)
- Twelvemile Creek
- Woolper Creek
- Ohio River Direct Drainage - East
- Ohio River Direct Drainage - North
- Ohio River Direct Drainage - West

Most of the watersheds have subwatersheds that provide the foundation units of modeling and planning. Most subwatersheds are named after the main tributary in them. Others, such as many direct-drainage subwatersheds, share the same name. A unique identifier, called REGCODE, has been assigned to each of the 128 subwatersheds.

Attributes

Attributes of the subwatershed polygons include:

- AREA – Subwatershed area in square feet. Calculated in the GIS after boundary edits were made.

- PERIMETER – Subwatershed perimeter in feet. Calculated in the GIS after boundary edits were made.
- SUBSHED – Name of subwatershed, which may not be unique within a watershed. For example, several of the subwatersheds along the main stem of Banklick Creek are named "Banklick Creek". They are distinguishable by the unique REGCODE attribute.
- WATERSHED – Name of watershed containing the subwatershed.
- BASIN – Name of study basin containing the subwatershed.
- HUC14, HUC11, HUC8, and HUC6 – The hydrologic units containing the subwatershed. The hydrologic unit codes (HUCs) represent fine-scale (14-digit and 11-digit) to broad-scale (8-digit and 6-digit) watersheds. The WAT! subwatersheds were originally based on the 14-digit hydrologic units, but they were modified to fit Consent Decree requirements and watershed modeling needs. Modifications are described below.
- REC_WATER – Name of stream to which the subwatershed delivers flow.
- ABBREV – SD1 three-letter stream and subwatershed abbreviation, where applicable.
- REGCODE – Unique subwatershed identifier of the form WWW-SSS, or WW-SSS, where WWW is a two or three alphanumeric character watershed identifier and SSS is a two or three alphanumeric character subwatershed identifier. For example, 08-03 is subwatershed 03 of the Banklick Creek (08) watershed. The REGCODE is used by WAT! for aggregation of results.
- REC_SHED – The unique REGCODE for the subwatershed downstream of the subwatershed. Used for accumulation of results by watershed.

The shapefile projection/coordinate system is Kentucky State Plane Coordinate System (SPCS), north zone (FIPS 1601), horizontal datum NAD83 HARN, with units of measurement in U.S. survey feet.

Dataset Edits

A number of edits were performed on the original 14-digit watershed shapefile in order to meet the needs of the watershed modeling and planning efforts. The edits included the following.

- **Elimination of areas outside the study area.** Nearly all of Boone, Kenton, and Campbell Counties are included in the study area. Watershed areas that extend over county lines into Gallatin, Grant, and Pendleton Counties are also in the study area. Some exceptions help limit the study area.
  - A small portion of Ohio River direct drainage was excluded near the mouth of Big Bone Creek in Gallatin County. The 14-digit hydrologic unit extends south of that confluence. The subwatershed from Big Bone Creek to the south end of the hydrologic unit is completely outside of Boone County.

  - Portions of Gallatin, Boone, and Grant Counties in the Tenmile Creek watershed are not included. This Tenmile Creek (different from the Tenmile Creek that is a small tributary of the Ohio River in Campbell County) drains to the southwest and is part of the Kentucky River basin.
  - The majority of the Licking River watershed is not included in the study area. The upstream limit of the Licking River watershed is the mouth of Willow Creek near Butler, Kentucky.
  - Only a small portion of the Grassy Creek subwatershed is included to include the mouth of North Fork Grassy Creek, which straddles the Kenton/Grant/Pendleton county lines.
  - The Stepstone Creek watershed is not included. Only a tiny portion of its headwaters are in Campbell County.
  - A small portion of Campbell County that drains to Goose Creek in the far northeastern corner of Pendleton County is excluded.

- **Watershed and subwatershed boundary edits.** The linework for several boundaries was edited to more accurately define drainage areas on the landscape.
  - Some study watersheds are not delineated in the 14-digit hydrologic unit data. Detailed polygons for the Dry Creek, Pleasant Run Creek, Taylor Creek, and Threemile Creek watersheds were delineated using detailed topography.
  - Polygons along the Ohio River extended far out into the river and appeared to arbitrarily end at the county/state line. All of these polygons were edited to end at the shoreline of the Ohio River. The shoreline was taken from detailed hydrography.
  - Watershed delineations at the mouths of most Ohio River tributaries did not match well with detailed hydrography of the streams, the Ohio River shoreline, or detailed topography. Several watersheds did not reach the river shoreline. These watershed lines were edited based mainly on detailed hydrography and elevation contours.
  - Other minor edits were performed on interior watershed lines.

- **Watershed names.** Extensive research was conducted to identify stream names in order to create consistent and correct naming conventions for watersheds. Research was conducted on the following names that are now being used:
  - Big Bone Creek
  - Elijahs Creek

- Fourmile Creek
- Pleasant Run Creek
- Taylor Creek
- Threemile Creek
- Twelvemile Creek

WATERSHED DATASET DESCRIPTION

The watershed shapefile, called WAT_Watersheds, is derived directly from the subwatershed dataset. The polygons in the subwatershed shapefile were dissolved using the WATERSHED attribute field. Attributes include watershed name, study basin name, area in square feet, perimeter in feet, and the alphanumeric watershed code.

BASIN DATASET DESCRIPTION

The basin shapefile, called WAT_Basins, is derived directly from the subwatershed dataset. The polygons in the subwatershed shapefile were dissolved using the BASIN attribute field. Attributes include study basin name, area in square feet, and perimeter in feet.

ATTACHMENT B - LAND COVER GIS LAYER

An accurate, up-to-date, and appropriate GIS data layer depicting land cover is needed to correctly model runoff and pollutant loadings in Northern Kentucky watersheds. Several datasets were acquired that represent land use and land cover conditions. Most were found to be inadequate for use in the Watershed Assessment Tool (WAT!). To represent a current landscape condition, a GIS layer from the National Land Cover Dataset (NLCD was modified). To represent future landscape conditions, the current land cover was modified based on several datasets that indicated either the addition of new development or limitations on development.

AVAILABLE CURRENT LAND USE DATASETS ARE INADEQUATE

The land use datasets acquired were not adequate for watershed modeling needs to varying degrees:

- Inconsistent – The land use datasets have different information for each of the three northern counties (Boone, Campbell, and Kenton). Some datasets show land use, some show a combination of land use and land cover. Some are parcel based, some are not.
- Incomplete – Some parts of counties have no information. The modeling requires datasets that blanket the study area land surface. There is no land use information at all for the three southern counties (Gallatin, Grant, and Pendleton).
- Out of date – The datasets have not been updated to reflect recent land development in the region.

LAND COVER MATTERS FOR WATERSHED MODELING

Land use data is important for local and regional planners and tax assessors. They care most about the uses of land by humans and the demographic and economic impacts of those uses. For watershed modeling, land use tends to be a surrogate for what is actually happening on the land. If, for example, we know that a piece of land is converting from woods and fields to single-family residences, the model should be reacting to the decrease in vegetative cover, the increase in imperviousness, the increased runoff, the likely increase in fertilizer and pesticide use, the possible increase in pet waste, and the presence or absence of Best Management Practices (BMPs). This information is not contained in the land use data that the planners and assessors need.

Land cover can be seen in remotely sensed imagery. A single satellite image or aerial photograph mosaic can provide a snapshot of the land cover in a large portion of the study area. Imagery that is periodically captured can be used to see landscape changes and to update land cover datasets. Remotely-sensed land cover data most closely resembles what a rain drop is falling on and the landscape that precipitation runs off.

LAND COVER CHANGES WITHIN PARCELS

Land ownership parcels provide the best blocks to use to model land cover change. Parcels might get subdivided into a pattern of smaller parcels that cannot be calculated. But the pattern of the parcels is not as significant in the model as the actual presence or absence of development.

The land ownership parcels should be used in the modeling, but not the land use categories to which they have been assigned. Those assignments will not work for watershed modeling. The polygons can be used in association with land cover to provide the information needed to model watersheds.

LAND COVER DATASET IS NOT CURRENT

The best dataset showing consistent land cover information across the entire study is the 2001 NLCD data acquired from the State of Kentucky's Kentucky Landscape Snapshot. It was developed by a team that included the Kentucky Department of Natural Resources and the U.S. Geological Survey.

The latest NLCD data is from 2001 and the satellite imagery on which it is based might even be a year or two older than that. That is well over half a decade, and that is not adequate for modeling the landscape of a region that is seeing rapid suburban development.

PROCEDURE TO SYNTHESIZE CURRENT (2006) LAND COVER FOR WATERSHED MODELING

A comparison of 2001 NLCD data, parcels, and recent aerial photography that was obtained from the National Resources Conservation Service was conducted. Some new construction was evident in places that were still shown as forest or other open lands in the land cover dataset. The parcel dataset usually showed smaller, subdivided residential lots in these areas.

Small parcels were isolated that likely represent single-family residential areas. Some of those parcels overlay land cover classes that indicate development already in place. Those parcels were omitted to focus only on small lots that contain land cover classes that represent only non-developed areas. These parcels were used to outline areas where the land cover data needed to be updated.

A determination of dominant land cover classes within already developed portions of each watershed was conducted. Those classes were then assigned to areas contained by the polygons isolated in the process described above. The newly assigned land cover classes were then superimposed on the NLCD 2001 data to create a unified, complete, and updated land cover dataset to model current conditions in the Northern Kentucky watersheds.

PROCEDURE TO SYNTHESIZE FUTURE LAND COVER FOR WATERSHED MODELING

In order to model future conditions in the study area, GIS data layer was created that represents land cover under a build-out scenario. The future land cover is based on

modifications of the current land cover dataset described above. The modifications are based on datasets that indicate the potential character and location of future development in Northern Kentucky. The modifications are also based on a variety of datasets that limit potential future development and indicate locations where the land cover is not expected to change substantially.

A land use dataset showing future build-out conditions was obtained from a previous project based on data supplied from the Boone County Planning Commission, Campbell County Planning Commission and the Northern Kentucky Area Planning Commission. The data layer contained polygons showing types of future land uses. Some of these land use polygons, such as residential, commercial, and industrial, were used to delineate areas where new development would occur in the modeled future scenario.

Within the to-be-developed areas, NLCD land cover categories were applied. The land cover categories were based on a translation of the land use classes in the input dataset. The proportions of land cover types within residential areas were used to update the current land cover. Those same proportions were applied for future residential areas.

A data layer depicting highway projects under a six-year plan was obtained from the Kentucky Transportation Cabinet. New routes, relocations, and major widening projects were used to further apply new development in the future scenario.

Some information was used to limit future development. The build-out land use dataset contained some polygons, such as open or agriculture, that were used to delineate areas where current land cover conditions would carry over into the future. The current land cover conditions dataset contains several categories that were left as-is in the future land cover dataset. These included open water, wetlands, and already developed areas.

A data layer depicting open lands in Northern Kentucky was obtained from the Ohio-Kentucky-Indiana Regional Council of Governments. Polygons in that dataset were used to delineate areas where new development would not occur.

Areas very near streams and on very steep slopes were isolated. Land cover within these zones was left unchanged from current conditions to the future timeframe.

The sets of new-development and no-development areas were merged to create the future land cover conditions to be modeled in the WAT!. This modeled future is not meant to represent desired conditions, but rather potential conditions that accurately reflect current knowledge about the direction and character of land cover change in the region.

DATASETS GENERATED

As a result of the above-described methodology, two raster datasets were generated. The raster grid named "nlcd01dev06" contains 2001 National Land Cover Dataset data that has been updated for modeling purposes through 2006. The raster grid is limited to the study watersheds and a small buffer around them. The raster grid named "ultdev2" depicts future land conditions under a modeled ultimate build-out scenario. It, too, has been limited to an area encompassing the study watersheds. Both raster grids are appropriate only for watershed assessment modeling and are not appropriate for mapping and other purposes. Table B-1 lists the land cover classes observed in the study area.

Table B-1 – Descriptions of NLCD Land Cover Classes in Study Area

21. **Developed, Open Space** - Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

22. **Developed, Low Intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

23. **Developed, Medium Intensity** - Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of the total cover. These areas most commonly include single-family housing units.

24. **Developed, High Intensity** - Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover.

31. **Barren Land (Rock/Sand/Clay)** - Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Table B-1 – Descriptions of NLCD Land Cover Classes in Study Area (continued)

41. **Deciduous Forest** - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

42. **Evergreen Forest** - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

43. **Mixed Forest** - Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75 percent of total tree cover.

52. **Shrub/Scrub** - Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

71. **Grassland/Herbaceous** - Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

81. **Pasture/Hay** - Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20 percent of total vegetation.

82. **Cultivated Crops** - Areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20 percent of total vegetation. This class also includes all land being actively tilled.

90. **Woody Wetlands** - Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

95. **Emergent Herbaceous Wetland.** Areas where perennial vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Table B-2 – Distribution by Watershed of Different Land Cover Classifications for Synthesized 2006 Land Cover (Areas in Acres)

NLCD land cover class descriptions	Fourmile Creek	Banklick Creek	Threemile Creek	Twelvemile Creek	Taylor Creek	Pleasant Run Creeek	Dry Creek	Licking River	Gunpowder Creek	Elijahs Creek	Woolper Creek	Big Bone Creek	Sand Run	Ohio River east	Ohio River north	Ohio River west	TOTAL
11 Open water	23	132	18	34	7	7	42	1,294	205	20	93	285	3	194	339	219	2,915
21 Developed, open space	1,896	6,375	863	2,770	640	1,294	1,905	8,627	5,515	589	2,163	3,782	242	1,608	1,478	811	40,558
22 Developed, low intensity	885	5,392	945	423	768	1,061	2,118	2,675	4,270	466	924	1,215	408	918	857	83	23,406
23 Developed, medium intensity	295	1,927	504	236	488	368	1,096	2,409	2,288	451	438	605	144	703	884	17	12,854
24 Developed, high intensity	85	554	78	19	97	82	487	828	1,052	482	49	92	76	218	367		4,566
31 Barren land (rock/sand/clay)	1	26	3	5			2	31	3	1	6	274	11	2	32	57	454
41 Deciduous forest	4,993	13,527	962	11,601	631	1,255	1,675	51,818	13,714	1,427	10,090	24,108	1,563	6,198	11,206	13,165	167,931
42 Evergreen forest	870	91	50	2,043	22	57	20	5,145	124	7	16	965	2	293	97	276	10,075
43 Mixed forest	22	9		131	1	4	1	461	11		0	123		17	9	16	807
52 Shrub/scrub	112	232	18	797	4	6	16	1,751	158	20	146	369	8	127	84	94	3,942
71 Grassland/herbaceous	151	201	1	574		1	33	2,857	916	47	1,077	1,112	39	134	459	1,026	8,628
81 Pasture/hay	1,970	8,350	301	10,683	49	36	472	30,206	7,935	781	5,370	19,365	458	1,894	3,059	3,376	94,305
82 Cultivated crops	40	404	7	172		2	56	469	922	13	735	327	191	383	1,444	1,893	7,059
90 Woody wetlands	19	7		18		1		340	63	1	27	180	27	77	42	75	878
95 Emergent herbaceous wetlands	7	22	1	10	1	5	6	61	40		12	41	1	9	12	12	241
	11,368	37,249	3,750	29,515	2,709	4,180	7,929	108,972	37,218	4,304	21,147	52,843	3,172	12,773	20,370	21,121	378,620

ATTACHMENT C - HYDROLOGIC FEATURES GIS LAYER

Accurate and complete GIS data layers are essential for modeling watersheds and displaying information on maps. GIS datasets depicting surface waters are particularly important. For watershed modeling and watershed characterization efforts, datasets were used that originated in the National Hydrography Dataset (NHD). Further, datasets that included the results of feature name research were also included.

This Attachment describes two GIS shapefiles showing surface waters in the Northern Kentucky region. WAT_Streams.shp, contains lines showing streams and river centerlines. WAT_Water bodies.shp contains polygons showing lakes, ponds, rivers, and wide creeks.

The shapefile projection/coordinate system is Kentucky State Plane Coordinate System (SPCS), north zone (FIPS 1601), horizontal datum NAD83 HARN, with units of measurement in U.S. survey feet.

STREAM LINES

The basis of the detailed stream linework is flowlines in high resolution NHD data obtained from the U.S. Geological Survey (USGS). Nearly all line features are exactly as they appear in the original dataset. A few lines were added in some watersheds where streams are buried under development. Lines were added in the following watersheds: Taylor Creek, Threemile Creek, Licking River, and Gunpowder Creek. For example, the mainstem of Threemile Creek was buried under the large interstate highway interchange that dominates that area. A line was added to the streams dataset based on SD1's detailed storm water inventory data.

Most of the edits of the streams dataset involved the attributes attached to the streams, especially names. Newly added attribute fields include the following:

Attribute field	Domain	Description
hasDistrictname	1 or 0	The "1" flags stream lines with known names
District_name	Text	Most names originate from the NHD data; corrections and additions came from research
District_abbrev	Three-letter text string	District stream name abbreviation; some named streams do not have abbreviations

Corrected and additional stream names came from USGS topographic maps, SD1 GIS data, SD1 research, and the Campbell County Historical Society. Names on nearly all streams outside of Boone, Campbell and Kenton Counties are based only on the names in the NHD dataset.

Names added to lines that did not have a name in the NHD data included the following:

Name added to lines that had no name in the NHD data	SD1 abbreviation
Balls Run	
Beaver Branch	BVB
Chadwick Branch	
Cliffs Run	
Constance Branch	
Covert Run	
Eightmile Creek	
Fox Branch	
Goose Creek	
Herringers Run	
Kinneys Run	
Loders Creek	
McPherson Branch	MPB
Moores Run	
Mosers Branch	
North Branch	
Painter Run	
Parks Branch	
Pleasant Run	
Ranty Creek	
Sevenmile Creek	
Steep Gut Creek	
Taylor Creek	TAC
Taylor Creek	TYC
Tenmile Creek	TEC
Terrilis Branch	
Threemile Creek	
Threemile Creek	THC
Uhl Creek	
Wilsons Creek	
Woodlawn Creek	
Worlds Creek	
Youdseys Creek	

Names that were in the NHD data but were removed included the following. Some of these streams had their name applied to a different course. Others had their names originally applied to reaches in reservoirs:

Name in NHD data that was removed from some lines
Beaver Branch
Bullock Pen Creek
Cruises Creek
Gunpowder Creek
McPherson Branch
Phillips Creek
Steep Creek
Taylor Creek
Uhl Creek

Portions of some creeks had a name in the NHD data that was corrected:

Name in NHD data that was edited	Name after correction
Big South Fork	Big Bone Creek
Bullock Pen Creek	Doe Run Creek
North Fork Ten Mile Creek	North Fork Tenmile Creek
Steep Creek	Steep Gut Creek
Ten Mile Creek	Tenmile Creek

WATER POLYGONS

A surface water polygon GIS dataset was assembled from water bodies and areas in high resolution NHD datasets. The set of attributes attached to each polygon include the following:

Attribute field	Domain	Description
NHD_source	NHDarea or NHDwaterway	NHD data makes a distinction between different kinds of water polygons
Feature	Text	Feature type, such as lake/pond, stream/river, or reservoir
NHD_desc	Text	NHD description of feature
SD_name	Text	Name of feature; very few polygons have a name attached

One lake in western Boone County now has a different name. NHD data called it Lake Jeanclia, but SD1 research resulted in the corrected name of Treasure Lake.

USE OF WATER GIS DATASETS

The modified high resolution NHD datasets do not replace the very detailed hydrography that Northern Kentucky has for Boone, Campbell and Kenton Counties. The NHD data is appropriate for maps and analysis on a regional and watershed level. The detailed hydrography is better suited for field work, for maps of small parts of the study area, and for detailed analysis of surface drainage.

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ATTACHMENT D - POINT SOURCE GIS LAYER

The accurate location and characterization of point sources that discharge non-runoff waste into streams, ponds, and rivers within Northern Kentucky is necessary for the development of watershed management plans. This Attachment describes the organization for point sources used in the Watershed Assessment Tool (WAT!). These point sources, which come from multiple sources, are combined into a single attributed ArcView shapefile for use in the WAT!. The creation of a consolidated collection of tracked point sources makes WAT! calculations more efficient to code and perform.

TYPES AND SOURCES

The following sets of point sources have been identified for tracking in the WAT!:

- SD1 Combined Sewer Overflows
- SD1 Sanitary Sewer Overflows: Recurring Manhole Locations
- SD1 Sanitary Sewer Overflows: Model-predicted Overflow Locations
- SD1 Sanitary Sewer Overflows: Pump Stations
- SD1-administered KPDES (Kentucky Permit Discharge Elimination System) dischargers
- KPDES Residential GP dischargers
- KPDES Construction GP dischargers
- KPDES Storm water facilities
- Other KPDES facilities
- Septic systems

ORGANIZATION

As shown in Table D-1, the different point sources are grouped into three broad categories – sewer overflows, KPDES, and septic systems – and several sub-categories. These categories reflect some preliminary assumptions about what actions may be used to mitigate impacts from these point sources and who might bear responsibility for those actions.

Table D-1 – Point Source Categories

1. Sewer overflows (SD1)

   Combined Sewer Overflows (CSOs)

   Sanitary Sewer Overflows (SSOs)

   Recurring – Manhole Locations
   Pump Stations
   Model-predicted Overflow Locations (discharge points in the sewer system model that have not yet been confirmed as reoccurring)

2. Kentucky Point Source Discharge Elimination System (KPDES) dischargers (non-CSO)

   KPDES facilities administered by SD1
   KPDES sanitary facilities ("package plants")
   KPDES residential General Permit holders
   KPDES construction General Permit holders
   KPDES storm water discharges
   Other KPDES-permitted discharges

3. Septic systems

ATTRIBUTES

Point sources included in the WAT! will have the following common attributes:

- IDENTIFIER – a unique identifier based on KPDES permit number and outfall number where available, otherwise assigned based on tracking category and manhole number or record number in source dataset.
- TRACKING CATEGORY – applicable category from previous section
- DATA SOURCE NAME – name of source dataset.
- DATA SOURCE DATE – last change date for source dataset at time of incorporation into WAT! point source list.
- NAME –From attributes in source dataset.
- DESCRIPTION – Brief description taken from source dataset.
- DISCHARGE TYPE CATEGORY – indicates whether the discharge is considered a CSO, SSO, Pump Station, or Model-predicted Overflow Location. The discharge type category is used to assign a concentration/density if no concentration/density data are available, or to override the specified data.

- FLOW – Annual flow from tracked point source.
- CONCENTRATION – mean annual bacteria density from tracked point source.
- LOAD – Annual bacteria load from tracked point source
- SUBWATERSHED – Subwatershed into which point source discharges.

Additional attributes from the original source datasets may also be included as described below.

CREATION

The creation of the WAT! point source shapefile is based on the following steps:

1) Import of SD1 overflow points.
2) Import of KPDES layers, mapping of attributes, and reconciliation with SD1 point sources.
3) Import of septic system layer.

SD1 Overflow Points

SD1 has implemented a consolidated Release Point Inventory that tracks the status of CSOs and SSOs, and provides a single, consistent point shapefile that uniquely identifies current overflow points with manhole IDs. These points are then linked to additional data records provided that include annual overflow volume and other characterizations of overflows. The inventory is integrated with SD1's comprehensive infrastructure geodatabase.

KPDES dischargers

KPDES discharge locations and attributes are primarily based on data retrievals performed by KDOW staff and provided in Excel spreadsheet format. The data retrieval consists of records showing facility information and where available, outfall information. All KPDES dischargers within the watershed are included in the tracked point source layer and put into one of the following categories:

- SD1 KPDES tracked point sources, including all outfalls from treatment facilities operated by SD1, but not including permitted CSOs that are in the SD1 CSO category.
- KPDES Residential General Permit discharges.
- KPDES Construction General Permit discharges.
- KPDES storm water discharges.
- Other KPDES discharges.

All KPDES records are subjected to common processing:

- Locations for all SD1 KPDES dischargers are based on detailed information provided by SD1.
- A discharge location is added to the attributes for each record. This is the outfall location if an outfall has been entered for the referenced facility. The facility location is used if there is no outfall associated with the facility.
- All records are checked to confirm that their locations fall in the study area. Corrections of gross errors are made where appropriate.
- For residential discharges, locations may be checked to confirm that the discharge is in the correct subwatershed, and corrected if deemed necessary.
- All locations adjusted during reconciliation with SD1 records and general consistency checking will be transmitted to KDOW, who will consider updating their master records appropriately.
- Where available, DMR data are used to provide estimates of annual flows, concentrations/densities, and loads. If no data are available, loads are set to zero.

Septic systems

A point shapefile of locations believed to have onsite wastewater treatment systems with subsurface discharges was created using a set of shapefiles containing parcels tentatively identified as serviced by septic systems. This analysis was based on indicated land use in the parcel, presence or absence of buildings, and distance from sewer lines and/or sewer service areas. The parcels were checked against the KPDES Residential General Permit discharges to ensure that no duplicate entries were made, and then converted to a point representation using polygon centroids.

Appendix 2-C

Infrastructure Characterization and Current System Conditions

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This appendix contains additional detail that is not included in Section 2 of the Watershed Plans. The sections that follow describe:

- the prioritization of overflow locations for sampling,
- the QA/QC of flow and rain data,
- the identification and characterization of model-calculated overflow locations,
- tables and maps that characterize SD1 CSOs and SSOs.

Overflow Prioritization Program Criteria:

SD1 overflow locations were prioritized to identify locations for monitoring and sampling. The general approach for prioritizing these overflows is described in Section 2.1.2, and additional detail is provided below on the quantitative and qualitative measures used to identify overflows for more comprehensive characterization. The criteria were used to rank the overflows:

Quantitative Measures

To assist with overflow prioritization for monitoring, SD1 updated three of their existing hydraulic model networks (Dry Creek, Bromley, Taylorsport) to reflect changes to the sewer system over the past several years. The updated model provided the most accurate current representation of SD1's collection system for prioritizing overflows for monitoring. The model was run with typical year rainfall from 1970 and activation statistics were collated. The following criteria were used with output from the model to rank the overflows:

1. **Frequency of Overflow** - The number of activations predicted by the model to occur in a typical year. Each overflow was given a score between 0 (no activations) and 1 (highly active).
2. **Volume of Overflow** - The total volume spilled from the overflow within a typical year. Each overflow was scored between 0 (no overflow volume) and 1 (high overflow volume).
3. **Public Health Impacts** – The likelihood of public contact to the overflow. The potential risk to public health was considered to be the highest priority. Therefore, criteria and resulting scoring were developed to assess the risk of a public health impact from an overflow based on the likelihood of public contact to the overflow. Each overflow was scored between 0 (no public health risk) and 1 (possible public health risk).
4. **Water Quality Impacts** – Overflows that discharge to streams on the 303(d) list of impaired waters. Limited data were available to evaluate the current water quality impacts of each overflow. The 303(d) list documents impaired stream segments that are not supporting their designated use(s). Each overflow was given a score if it could reach a waterway or an impaired waterway.

Qualitative Measures

In addition to the quantitative criteria, SD1 determined that there were a number of factors that should be considered in the prioritization, but were difficult to express using a quantitative scale. Additional data were gathered to ensure that the prioritization would account for these qualitative factors:

1. Consent Decree Deadline (Exhibit E)
2. Current CIP Plan and Projected Improvements that would address the overflow
3. Additional Water Quality Criteria
4. District Maintenance & Trouble Call History
5. Potential for Inline Storage (CSO)
6. Regulator Optimization (CSO) potential to reduce overflow volume and frequency
7. Related or Clustered Overflows

This information was compiled into two separate spreadsheets to develop the final prioritization for SSOs and CSOs. The final prioritization of overflows was based on individual criteria and an overall score, and was used to guide the infrastructure characterization efforts.

Flow and Rain Data QA/QC:

Throughout the flow monitoring program, the flow and rain data described in Section 2.1.2 were continuously reviewed and analyzed to assess their suitability for use in model calibration and validation. Two levels of review were performed:

Quality Assurance / Quality Control Analysis – Flow and rain data were reviewed as they were downloaded to identify non-operational rain gauges and flow monitors, and to provide maintenance recommendations to field staff. This served as a quick check to make sure the equipment was operating normally and helped ensure that future rainfall events were not missed because of faulty equipment.

Hydraulic and Model Analysis –The models were run using the measured rain data and the model calculations were compared to the measured flow data while the flow monitors and rain gauges were in-place to check for any system or equipment issues that could be corrected as the program progressed. This information was reviewed for both dry weather and wet weather flows. Rain gages and flow monitors that were identified as having data quality issues were not used.

Typical Year Model-calculated SSO Locations

Within the Watershed Plans, a total of 126 locations are listed as SSOs. These 126 locations include 96 recurring SSOs (at manholes) and 30 pump stations that are listed within this Appendix in the individual basin tables.

In addition to the 126 confirmed recurring SSOs that have been identified, SD1 has also identified 214 model-calculated overflow locations in the separate sewer system that have not yet been confirmed as recurring SSOs. These model-calculated overflow locations are manhole locations that have been shown using the calibrated hydraulic model to overflow during the 1970 typical year model simulation. As part of the ongoing characterization work and model updates, SD1 has developed a prioritized field inspection program by watershed for field inspection staff to visit model-calculated and recurring overflow locations in the sewer system to assess activity during and after rain events to compare against the model results. This program is in addition to the ongoing Sewer Overflow Response Plan (SORP) for overflow clean-up that SD1 currently employs. However, the coordinated field investigations to confirm the model predictions have not yet gathered sufficient data to consider these model-calculated overflow locations as recurring SSOs, as stated in the SD1 SORP.

- Recurring SSO - Overflows will be classified as a recurring SSO if they have been observed to have occurred more than once in a twelve month period.

SD1 is committed to updating the recurring SSO list through its field investigation program and will update the SSO list annually as part of its Quarterly Report submittals and in future Watershed Plans. This may involve the addition of locations as they are confirmed in the field or the removal of locations if they are found to be inactive due to system changes or improvements. The field inspection work will be a continuous process to confirm and update the list of recurring SSO locations.

In discussing the model-calculated SSO volume within the Watershed Plans, SD1 decided that the overflow volume from all model-calculated overflow locations, including the known recurring SSOs, should be included to conservatively estimate the impact of the separate system overflows on water quality. Thus, a total of 242.1 MG was included as the estimated typical year overflow volume from SSOs within the SD1 system. This includes volume from not only the 126 confirmed recurring SSO locations, but also the 214 model-calculated overflow locations. The total of 242.1 MG also includes the 8 MG of overflow volume attributed to the existing Eastern Regional Collection System before the Eastern Regional Initial Watershed Projects and WRF improvements are completed. The 8 MG will be eliminated with the completion of the Eastern Regional improvements.

Table 2-C.1 shows a breakdown of the model-calculated SSO volume by type for the 1970 typical year model simulation.

Table 2-C.1 Summary of Model-calculated SSO Locations & Volume for the 1970 Typical Year

Basin	No. of Recurring SSOs – Manhole Locations	Recurring SSOs – Manhole Locations Volume (MG)	No. of SSO-Pump Stations	SSO-Pump Stations Volume (MG)	No. of Model - Predicted Overflow Locations	Model - Predicted Overflow Locations Volume (MG)	Total No. of Overflow Locations	Total Volume (MG)
Central	41	61.3	10	10.8	129	86.5	180	158.6
East	14	33.8[1]	7	17	63	22.6	84	73.4
North	40	2.1	5	0	13	5.4	58	7.5
West	1	0.4	8	1.2	9	1	18	2.6
Total	96[2]	97.6	30	29	214	115.5	340	242.1[1]

Notes

1. The total of 242.1 MG also includes the 8 MG of overflow volume attributed to the existing Eastern Regional Collection System before the Eastern Regional Initial Watershed Projects and WRF improvements are completed. The 8 MG will be eliminated with the completion of the Eastern Regional improvements.
2. The 96 recurring SSO locations represent updated information when compared to the December 2008 Quarterly Report. There are several differences between the 96 locations and the 99 SSO locations in the December 2008 Quarterly Report due to the updated information.
    a. 5 locations were removed - 0650098, 0650025, 0650053 (now listed as CSOs) and 1900028 and 1950PS1 (transferred to PS Overflow list)
    b. 2 locations were added 2280010, 0020005 (field confirmed recurring SSOs)
    c. Changes between the Watershed Plans and the December 2008 Quarterly Report listing do not impact the total SSO volume listed in Table 2-C.1

Additional changes in the recurring SSO list will continue to be documented in Quarterly Report submittals.

CSO Locations

The SD1 list of active CSO locations provided in the Watershed Plans was current as of November 21, 2008. There were several adjustments to the CSO location list that was provided in the December 2008 Quarterly Report due to field inspections and recent construction. A total of 97 CSO locations are listed in the Watershed Plans while a total of 94 CSO locations are included in the December 2008 Quarterly Report. The changes made for the December 2008 Quarterly Report are described below:

Table 2-C.2 December 2008 Quarterly Report CSO Comparison

CSO ID	December 2008 Quarterly Report Status
0530110	Listed as a CSO in December Quarterly Report
0650008	Determined not to be an active CSO
0660085	Determined not to be an active CSO
1730261	Determined not to be an active CSO
1310106	Determined not to be an active CSO
1440212	Determined not to be an active CSO
0530117	Listed as a CSO in December Quarterly Report

A total of 5 CSO locations were removed from the list and 2 CSO locations were added to the list, comprising the 94 total CSO locations. A number of additional locations have also had several IDs based on historical conventions but have recently been updated within the SD1 geodatabase and for reporting purposes.

Table 2-C.3 CSO Historical IDs

CSO ID	Historical CSO ID
0010220	0010001
0550134	0550024
0690059	0690008
1320112	1320093
1380132	1380054
1380146	1380083
1510245	1510098

Changes between the Watershed Plans and the December 2008 Quarterly Report listing do not impact the total typical year CSO volume predicted with the hydraulic model. Additional changes to the CSO list will continue to be documented in Quarterly Report submittals.

Appendix 2-C: Central Basin - Combined Sewer Overflow Location Data

Manhole ID	Common Name/ Description	To-be Permitted CSO?	Direct Discharge to Waterbody	Watershed	Basin	Typical Year Spill Frequency (No.)[1,2]	Typical Year Overflow Volume (MG)[1,2]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk
0790086	4th St	No	Licking River	Licking River	Central	63	164.88	CSO	Outfall	Located on Licking River by public landing and outfall for Fourth Street PS	Recreation
0840116	12th St.	No	Licking River	Licking River	Central	81	8.31	CSO	Outfall	Located on Licking River by barge loading dock	Recreation
0870078	Park Dr	No	Licking River	Licking River	Central	4	0.48	CSO	Outfall	Located on Licking River bank by golf course	Recreation
0870079	Southern Ave	No	Licking River	Licking River	Central	67	29.49	CSO	Outfall	Located on Licking River bank by golf course	Recreation
0880081	34th St	No	Licking River	Licking River	Central	65	21.91	CSO	Outfall	Located on Licking River bank	Recreation
0880082	33rd St	No	Licking River	Licking River	Central	12	0.78	CSO	Outfall	Located on Licking River bank	Recreation
0910065	James Ave	No	Licking River	Licking River	Central	93	223.18	CSO	Outfall	Located in Licking River by public parking lot	Recreation
0910068	Eastern Ave	No	Licking River	Licking River	Central	47	49.30	CSO	Outfall	Located in Licking River and outfall for Eastern Avenue PS	Recreation
0930102	Glenway Ave	No	Licking River	Licking River	Central	0	0.00	CSO	Outfall	Located in Licking River	Recreation
0930103	20th St	No	Licking River	Licking River	Central	3	0.09	CSO	Outfall	Located in Licking River and outfall for Newport Steel Mill PS	Recreation
0930104	17th St	No	Licking River	Licking River	Central	2	0.10	CSO	Outfall	Located on Licking River bank and next to commercial yard	Recreation
0930105	19th St	No	Licking River	Licking River	Central	66	30.94	CSO	Outfall	Located on Licking River bank and outfall for Nineteenth Street PS	Recreation
0930106	16th St	No	Licking River	Licking River	Central	4	0.04	CSO	Outfall	Located in Licking River and next to commercial parking lot	Recreation
0960063	Patton St	No	Licking River	Licking River	Central	23	5.58	CSO	Outfall	Located in Licking River and outfall for Patton Street PS	Recreation
0960064	15th St	No	Licking River	Licking River	Central	2	0.02	CSO	Outfall	Located on Licking River bank	Recreation
0980073	12th St (Covington)	No	Licking River	Licking River	Central	12	0.17	CSO	Outfall	Located in Licking River by 12th Street	Recreation
0980080	13th St	No	Licking River	Licking River	Central	3	0.04	CSO	Outfall	Located in Licking River by 13th Street	Recreation
0980081	Pleasant St	No	Licking River	Licking River	Central	75	56.04	CSO	Outfall	Located in Licking River and outfall for Pleasant Street PS	Recreation
1420141	6th St	No	Licking River	Licking River	Central	32	0.74	CSO	Outfall	Located in Licking River next to residences	Recreation
1420142	8th St	No	Licking River	Licking River	Central	70	104.66	CSO	Outfall	Located in Licking River and outfall for 8th Street PS	Recreation
1420144	9th St	No	Licking River	Licking River	Central	0	0.00	CSO	Outfall	Located in Licking River	Recreation
1420145	10th St	No	Licking River	Licking River	Central	0	0.00	CSO	Outfall	Located in Licking River	Recreation

Appendix 2-C: Central Basin - Combined Sewer Overflow Location Data

Manhole ID	Common Name/ Description	To-be Permitted CSO?	Direct Discharge to Waterbody	Watershed	Basin	Typical Year Spill Frequency (No.)[1,2]	Typical Year Overflow Volume (MG)[1,2]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk
1420146	Robbins St	No	Licking River	Licking River	Central	0	0.00	CSO	Outfall	Located in Licking River	Recreation
1420147	11th St	No	Licking River	Licking River	Central	3	0.23	CSO	Outfall	Located in Licking River	Recreation
1850158	Church Street	No	Banklick Creek	Banklick Creek	Central	74	56.20	CSO	Outfall	Located in Banklick Creek next to backyard of residence	Residential
1870193	Decoursey Ave.	No	Banklick Creek	Banklick Creek	Central	23	1.29	CSO	Outfall	Located in Banklick Creek	Recreation
1870194	47th Street	No	Banklick Creek	Banklick Creek	Central	4	0.20	CSO	Outfall	Located in Banklick Creek	Recreation
1880090	45th St	No	Licking River	Licking River	Central	20	2.11	CSO	Outfall	Located in Licking River	Recreation
1880091	44th St	No	Licking River	Licking River	Central	5	2.18	CSO	Outfall	Located in Licking River	Recreation
0730129	Fitzsimmons St.	Yes	Licking River	Licking River	Central	75	2.44	CSO	Outfall	Located in Licking River	Commercial/ Industrial
0840111	9th St.	Yes	Licking River	Licking River	Central	65	25.68	CSO	Outfall	Located in Licking River at 9th Street	Commercial/ Industrial
0840112	10th St.	Yes	Licking River	Licking River	Central	52	2.03	CSO	Outfall	Located in Licking River at 10th Street	Commercial/ Industrial
0910066	Adams St	Yes	Licking River	Licking River	Central	0	0.00	CSO	Outfall	Located in Licking River 130' from residences	Residential
1310100	Augustine St.	Yes	Storm Drainage to CSO 0910068	Licking River	Central	0	0.00	CSO	Bypass	Located by warehouse at W 23rd Street and Herman Street	Commercial/ Industrial
1310106	Augustine St.	Yes	Storm Drainage to CSO 0910068	Licking River	Central	NA	NA	CSO	Bypass	Located by warehouse at W 23rd Street and Herman Street	Commercial/ Industrial
1440207	Kennedy St	Yes	Licking River	Licking River	Central	0	0.00	CSO	Outfall	Located on Licking River bank between 2nd and 3rd Street	Recreation
1510133	Marcella Dr	Yes	Storm Drainage to CSO 1480198	Licking River	Central	0	0.00	CSO	Bypass	Located in frontyard of residence	Residential
1510245	Henry Clay	Yes	Tributary to Banklick Creek	Banklick Creek	Central	0	0.00	CSO	Bypass	Located at Henry Clay Avenue and Bluegrass Avenue	Residential
1840130	Latonia	Yes	Tributary to Banklick Creek	Banklick Creek	Central	25	1.12	CSO	Outfall	Located on bank of Banklick Creek	Residential
						Central Basin - Total Model-Predicted CSO Volume	790.2				

Notes:

1. The presented results were generated by planning-level models based on SD1's current understanding of the CSS (November 2008). These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the collection system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. These results are subject to change, and should not be considered definitive. Annual simulations with SD1's 2008 refined calibrated system-wide model use SD1's selected typical year of 1970 and include river influence. Overflow statistics also based on 5-min output, 7-hr inter-event period; 0.01 MGD peak flow and 0.001 MG volume thresholds.
2. "NA" indicates that model output is not available.

Appendix 2-C: Central Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
0090009	Tributary to Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located in Southeast area of I-275 and I-471 interchange in rear of residences	Residential	Licking River Sewer Crossing Study	
0100001	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located in Southwest area of I-275 and I-471 interchange	Commercial/ Industrial	Licking River Sewer Crossing Study	
0100002	Threemile Creek	Threemile Creek	Central	9	0.70	SSO	Manhole	Located in Southwest area of I-275 and I-471 interchange	Commercial/ Industrial	Licking River Sewer Crossing Study	
0110010	Threemile Creek	Threemile Creek	Central	10	0.63	SSO	Bypass Pipe	Located in frontyard of residence at Water Street	Residential	Licking River Sewer Crossing Study	
0150023	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located nearby apartments on Moock Road	Residential	Licking River Sewer Crossing Study	
0150058	Threemile Creek	Threemile Creek	Central	16	1.96	SSO	Manhole	Located on Three Mile Road	Residential	Licking River Sewer Crossing Study	
0150063	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located on Three Mile Road	Residential	Licking River Sewer Crossing Study	
0150064	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located on Three Mile Road	Residential	Licking River Sewer Crossing Study	
0150065	Threemile Creek	Threemile Creek	Central	9	0.22	SSO	Manhole	Located on Three Mile Road	Residential	Licking River Sewer Crossing Study	
0150069	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located on Three Mile Road	Residential	Licking River Sewer Crossing Study	
0150351	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located on Moock Road	Residential	Licking River Sewer Crossing Study	
0150356	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located nearby apartments on Moock Road	Residential	Licking River Sewer Crossing Study	
0860001 (Licking River Siphon)	Licking River	Licking River	Central	77	48.99	SSO	Bypass Pipe	Wooded area along the bank of the Licking River	Recreation Area	Licking River Sewer Crossing Study	Vernon Lane SSES
0860003	Licking River	Licking River	Central	0	0.00	SSO	Manhole	Located on bank of Licking River	Commercial/ Industrial	Licking River Sewer Crossing Study	
0860016	Threemile Creek	Threemile Creek	Central	0	0.00	SSO	Manhole	Located near to apartment complex on Moock Rd	Residential	Licking River Sewer Crossing Study	
1040060	Tributary to Bullock Pen Creek	Banklick Creek	Central	3	0.09	SSO	Manhole	Located on Industrial Raod	Commercial/ Industrial	Southern Kenton Drainage Study	Western Regional Conveyance System and Water Reclamation Facility
1090069	Tributary to Bullock Pen Creek	Banklick Creek	Central	0	0.00	SSO	Bypass Pipe	Located along Madonna Drive	Residential	Southern Kenton Drainage Study	
1110025	Tributary to Bullock Pen Creek	Banklick Creek	Central	4	0.16	SSO	Manhole	Located along Stevenson Road	Residential	Southern Kenton Drainage Study	Stevenson Road Relief Sewer Project- Phase II
1110067	Tributary to Bullock Pen Creek	Banklick Creek	Central	5	0.43	SSO	Bypass Pipe	Located along Stevenson Road	Residential	Southern Kenton Drainage Study	Stevenson Road Relief Sewer Project- Phase II
1110161	Tributary to Bullock Pen Creek	Banklick Creek	Central	2	0.13	SSO	Manhole	Located along Stevenson Road	Residential	Southern Kenton Drainage Study	Stevenson Road Relief Sewer Project- Phase II
1110294	Tributary to Bullock Pen Creek	Banklick Creek	Central	5	0.09	SSO	Manhole	Located along Stevenson Road	Residential	Southern Kenton Drainage Study	Stevenson Road Relief Sewer Project- Phase II

Appendix 2-C: Central Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
1570100	Tributary to Horse Branch	Banklick Creek	Central	7	0.19	SSO	Bypass Pipe	Located next to Leathers Road PS in backyard of residence and 165' from lake	Residential	Southern Kenton Drainage Study	
1760047	Tributary to Bullock Pen Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located in backyard of Magnolia Court	Residential	Southern Kenton Drainage Study	
1760048	Tributary to Bullock Pen Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located in backyard of Poinsettia Court	Residential	Southern Kenton Drainage Study	
1860108	Banklick Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located at Grand Avenue and Kollman Avenue	Residential	Southern Kenton Drainage Study	
1870013	Banklick Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located near intersection of Grand Avenue and Howard Avenue	Residential	Southern Kenton Drainage Study	
1920163	Tributary to Riffle Creek	Licking River	Central	0	0.00	SSO	Bypass Pipe	Located in backyard of residence on Spring Place	Residential	Southern Kenton Drainage Study	
1950199	Tributary to Banklick Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located in backyard of Kyles Lane	Residential	Southern Kenton Drainage Study	
1960012	Horse Branch	Banklick Creek	Central	0	0.00	SSO	Manhole	Located in frontyard of Horse Branch Road and 110' from Horse Branch	Residential	Southern Kenton Drainage Study	
2030097	Tributary to Bullock Pen Creek	Banklick Creek	Central	0	0.00	SSO	Bypass Pipe	Located in frontyard of Stoneridge Drive	Residential	Southern Kenton Drainage Study	
2090001	Bullock Pen Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located in backyard of Grouse Court	Residential	Southern Kenton Drainage Study	
2090026	Bullock Pen Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located along bank of Bullock Pen Creek	Residential	Southern Kenton Drainage Study	
2110002	Tributary to Bullock Pen Creek	Banklick Creek	Central	10	0.95	SSO	Manhole	Located in backyard of Lytle Avenue	Residential	Southern Kenton Drainage Study	
2120001	Tributary to Bullock Pen Creek	Banklick Creek	Central	5	0.18	SSO	Manhole	Located in backyard of Lytle Avenue	Residential	Southern Kenton Drainage Study	
2120002	Tributary to Bullock Pen Creek	Banklick Creek	Central	0	0.00	SSO	Manhole	Located in backyard of Lytle Avenue and 215' from stream	Residential	Southern Kenton Drainage Study	
2120041	Tributary to Bullock Pen Creek	Banklick Creek	Central	4	0.07	SSO	Manhole	Located in backyard of Spring Street	Residential	Southern Kenton Drainage Study	
2160036	Tributary to Horse Branch	Banklick Creek	Central	0	0.00	SSO	Bypass Pipe	Located in backyard of Requardt Lane	Residential	Southern Kenton Drainage Study	
2280010	Wolf Pen Branch	Banklick Creek	Central	0	0.00	SSO	Manhole	Located along bank of Wolfpen Branch	Residential	Southern Kenton Drainage Study	Western Regional Conveyance System and Water Reclamation Fac ility
2280011	Wolf Pen Branch	Banklick Creek	Central	10	0.37	SSO	Manhole	Located along bank of Wolfpen Branch	Residential	Southern Kenton Drainage Study	Western Regional Conveyance System and Water Reclamation Fac ility
2280012	Wolf Pen Branch	Banklick Creek	Central	0	0.00	SSO	Manhole	Located along bank of Wolfpen Branch	Residential	Southern Kenton Drainage Study	Western Regional Conveyance System and Water Reclamation Fac ility
2300123	Banklick Creek	Banklick Creek	Central	27	6.15	SSO	Manhole	Located along Bristow Road	Residential	Southern Kenton Drainage Study	Western Regional Conveyance System and Water Reclamation Fac ility

Appendix 2-C: Central Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
1900PS3 (Ripple Creek PS)	Tributary to Riffle Creek	Licking River	Central	11	0.17	SSO - pump station	Bypass Pipe	Located 150' from Ripple Creek at Ripple Creek PS	Residential	Pump Station Overflow Elimination; Pump Station Plan for Backup Power	Ripple Creek PS Overflow Elimination
1950PS1	Banklick Creek	Banklick Creek	Central	17	10.60	SSO-Pump Station	Bypass Pipe	Vicinity of Industrial Public Service Park	Recreation	Pump Station Overflow Elimination; Pump Station Plan for Backup Power; Southern Kenton Drainage Study	Western Regional Conveyance System and Water Reclamation Facility; South Hills Outfall Sewer; Fort Wright Sanitary Sewer Rehabilitation; Brookwood I/I Study
2010PS1 (Keavy Rd PS)	Tributary of Licking River	Licking River	Central	NA	NA	SSO - pump station	Bypass Pipe	Located in rear of homes in residential neighborhood	Residential	Pump Station Plan for Backup Power; Southern Kenton Drainage Study	
2010PS2 (Meadow Lane PS)	Tributary of Licking River	Licking River	Central	NA	NA	SSO - pump station	Bypass Pipe	Located in rear of homes in residential neighborhood	Residential	Pump Station Plan for Backup Power; Southern Kenton Drainage Study	
2010PS3 (Ridgeway PS)	Tributary of Decoursey Creek	Licking River	Central	NA	NA	SSO - pump station	Bypass Pipe	Located in rear of homes in residential neighborhood	Residential	Pump Station Plan for Backup Power; Southern Kenton Drainage Study	
2010PS4 (Mafred PS)	Tributary of Decoursey Creek	Licking River	Central	NA	NA	SSO - pump station	Bypass Pipe	Located near homes at end of residential street	Residential	Pump Station Plan for Backup Power; Southern Kenton Drainage Study	
2020PS2 (Meadow Hill PS)	Tributary to Banklick Creek	Banklick Creek	Central	NA	NA	SSO - pump station	Bypass Pipe	Located in rear of homes in residential neighborhood	Residential	Pump Station Plan for Backup Power; Southern Kenton Drainage Study	
2020PS7 (Twin Lakes PS)	Tributary of Decoursey Creek	Licking River	Central	NA	NA	SSO - pump station	Pump Station wet well	Located in residential development	Residential	Pump Station Plan for Backup Power; Southern Kenton Drainage Study	
2200PS1 (Alex-Licking PS)	Tributary to Riffle Creek	Licking River	Central	NA	NA	SSO - pump station	Pump Station wet well	Located between roadway and Riffle Creek at Alex-Licking PS	Residential	Pump Station Overflow Elimination; Pump Station Plan for Backup Power	Eastern Regional - Alex-Licking and Sunset Pump Stations
2450PS2 (Sunset PS)	Tributary to Riffle Creek	Licking River	Central	NA	NA	SSO - pump station	Bypass Pipe	Located at end of residential street	Residential	Pump Station Overflow Elimination; Pump Station Plan for Backup Power	Eastern Regional - Alex-Licking and Sunset Pump Stations
					Total for Individual Overflow Locations	72.1					
					Other Potential Overflows	86.5					
					Central Basin - Total Model-Predicted SSO Volume	158.6					

Notes

1. Any locations with value of "No" are greather than 50 feet from a waterbody.

2. The presented results were generated by planning-level models based on SD1's current understanding of the collection system infrastructure (November 2008). These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the collection system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. These results are subject to change, and should not be considered definitive. Annual simulations with SD1's 2008 refined calibrated system-wide model use SD1's selected typical year of 1970 and include river influence. Overflow statistics also based on peak hourly flows from a rolling average of 5-minute output, 7-hr inter-event period, and 0.01 MGD peak flow threshold.

3. "NA" indicates that model output is not available.

4. "Other Potential Overflows" are locations that have been predicted by the model to occur in the typical year but have not yet been field verified.

Appendix 2-C: East Basin - Combined Sewer Overflow Location Data

Manhole ID	Common Name/ Description	To-be Permitted CSO?	Direct Discharge to Waterbody	Watershed	Basin	Typical Year Spill Frequency (No.)[1,2]	Typical Year Overflow Volume (MG)[1,2]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk
0030031	Carmel Manor Road	No	Ohio River Tributary	Ohio River East	East	0	0	CSO	Outfall	Located in channel that drains to Ohio River	Recreation
0200069	Mary Ingles Highway	No	Ohio River Tributary	Ohio River East	East	25	0.23	CSO	Outfall	Located in channel that drains to Ohio River	Recreation
0330100	Mary Ingles Highway & Tower Hill Road	No	Ohio River Tributary	Ohio River East	East	6	0.15	CSO	Outfall	Located in channel that drains to Ohio River	Recreation
0340050	Mary Ingles Highway & Lester Lane	No	Ohio River Tributary	Ohio River East	East	20	0.50	CSO	Outfall	Located in channel that drains to Ohio River	Recreation
0340051	Mary Ingles Highway	No	Ohio River Tributary	Ohio River East	East	33	1.04	CSO	Outfall	Located in channel that drains to Ohio River	Recreation
0570089	McKinney Avenue	No	Ohio River	Ohio River East	East	62	50.01	CSO	Outfall	Located in Ohio River	Recreation
0570090	Main Street	No	Ohio River	Ohio River East	East	56	36.15	CSO	Outfall	Located in Ohio River	Recreation
0600094	Foote Avenue	No	Ohio River	Ohio River East	East	27	1.62	CSO	Outfall	Located in Ohio River	Recreation
0600097	Ward Avenue	No	Ohio River	Ohio River East	East	36	4.54	CSO	Outfall	Located in Ohio River	Recreation
0610071	Taylor Avenue	No	Ohio River	Ohio River East	East	69	14.11	CSO	Outfall	Located in Ohio River	Recreation
0610072		No	Ohio River	Ohio River East	East	25	0.63	CSO	Outfall	Located in Ohio River	Recreation
0620075	Patchen Avenue	No	Ohio River	Ohio River East	East	59	9.96	CSO	Outfall	Located in Ohio River	Recreation
0620077	Lafayette Avenue	No	Ohio River	Ohio River East	East	25	0.32	CSO	Outfall	Located in Ohio River	Recreation
0630061	Linden Avenue	No	Ohio River	Ohio River East	East	25	1.90	CSO	Outfall	Located in Ohio River	Recreation
0640090	Washington Avenue	No	Ohio River	Ohio River East	East	62	128.99	CSO	Outfall	Located in Ohio River	Recreation
0650090	Riviera Drive	No	No	Ohio River East	East	29	3.54	CSO	Outfall	Located at Riviera Drive & Dave Cowens Drive	Commercial/ Industrial
0650100	Geiger Avenue	No	No	Taylor Creek	East	4	0.14	CSO	Outfall	Located at Geiger Avenue	Residential
0770096	Saratoga Street	No	Ohio River	Ohio River East	East	65	6.55	CSO	Outfall	Located in Ohio River	Recreation
0790084	Columbia Street	No	Ohio River	Ohio River East	East	74	14.35	CSO	Outfall	Located in Ohio River	Recreation
0010220	Johnny Drive	Yes	Ohio River Tributary	Fourmile Creek	East	29	2.43	CSO	Outfall	Located in woods at Johnny Drive and Ash Street	Recreation

Appendix 2-C: East Basin - Combined Sewer Overflow Location Data

Manhole ID	Common Name/ Description	To-be Permitted CSO?	Direct Discharge to Waterbody	Watershed	Basin	Typical Year Spill Frequency (No.)[1,2]	Typical Year Overflow Volume (MG)[1,2]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk
0010228	Maple Street	Yes	Ohio River Tributary	Ohio River East	East	0	0	CSO	Outfall	Located in woods at Maple Street and Mary Ingles Highway	Recreation
0360079	Marina on Mary Ingles Highway	Yes	Ohio River Tributary	Ohio River East	East	46	0.73	CSO	Outfall	Located in Marina along Ohio River	Recreation
0540009	Berry Avenue	Yes	No	Taylor Creek	East	32	1.35	CSO	Outfall	Located at Berry Avenue and Donnermyer Boulevard	Residential
0540044	Lafayette Avenue at Donnermyer Avenue	Yes	No	Taylor Creek	East	33	2.27	CSO	Outfall	Located at Lafayette Avenue and Donnermyer Boulevard	Commercial/ Industrial
0550134	Pike Avenue	Yes	Covert Run	Taylor Creek	East	4	0.08	CSO	Outfall	Located at Covert Run Pike and Pike Avenue	Recreation
0600096	O'Fallon Avenue	Yes	Ohio River	Ohio River East	East	8	0.14	CSO	Outfall	Located at O'Fallon Avenue and Dodd Drive	Commercial/ Industrial
0600104	Van Voast Avenue	Yes	No	Ohio River East	East	3	0.12	CSO	Outfall	Located at Van Voast Avenue and Frank Banke Way	Recreation
0650008	I-471 & KY-8	Yes	No	Taylor Creek	East	0	0	CSO	Outfall	Located at I-471 & KY-8 interchange	Commercial/ Industrial
0650054	Glazier Avenue	Yes	Ohio River Tributary	Taylor Creek	East	0	0	CSO	Outfall	Located near residences on Glazier Avenue	Residential
0650098	Tiger Lane	Yes	No	Taylor Creek	East	16	4.41	CSO	Outfall	Located near school on Tiger Lane	School
0660085	I-471 & Memorial Parkway	Yes	No	Taylor Creek	East	0	0	CSO	Outfall	Located east of I-471 near railroad tracks	Commercial/ Industrial
0690059	Monmouth Street	Yes	No	Taylor Creek	East	4	0.11	CSO	Outfall	Located at Monmouth Street & 18th Street	Commercial/ Industrial
						East Basin - Total Model-Predicted CSO Volume	286.4				

Notes:

1. The presented results were generated by planning-level models based on SD1's current understanding of the CSS (November 2008). These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the collection system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. These results are subject to change, and should not b considered definitive. Annual simulations with SD1's 2008 refined calibrated system-wide model use SD1's selected typical year of 1970 and include river influence. Overflow statistics also based on 5-min output, 7-hr inter-event period; 0.01 MGD peak flow and 0.001 MG volume thresholds.

2. "NA" indicates that model output is not available.

Appendix 2-C: East Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
0020005	No	Fourmile Creek	East	32	22.80	SSO	Manhole	Located at Mary Ingles Highway & Industrial Road	Recreation	Highland Heights-Silver Grove Area Phase II Study	Ash St Pump Station
0020014	No	Fourmile Creek	East	1	0.00	SSO	Manhole	Located at Mary Ingles Highway & Tiemeier Lane	Commercial/ Industrial	Highland Heights-Silver Grove Area Phase II Study	Ash St Pump Station
0050022	No	Ohio River East	East	8	0.36	SSO	Manhole	Located at residence on River Road	Residential	Highland Heights-Silver Grove Area Phase II Study	Ash St Pump Station
0060001	No	Ohio River East	East	6	0.34	SSO	Manhole	Located on Blangey Road	Residential	Highland Heights-Silver Grove Area Phase II Study	Ash St Pump Station
0060002	No	Ohio River East	East	4	0.03	SSO	Manhole	Located at residence on Blangey Road	Residential	Highland Heights-Silver Grove Area Phase II Study	Ash St Pump Station
0300008	No	Ohio River East	East	NA	NA	SSO	Manhole	Located in subdivision on Woodside Road	Residential		
0410010	No	Taylor Creek	East	12	0.23	SSO	Manhole	Located near residences on Maine Avenue	Residential	Wilson/Waterworks Rd Study	
0410011	No	Taylor Creek	East	0	0.00	SSO	Manhole	Located at Maine Avenue and Taylor Mill Road near residences	Residential	Wilson/Waterworks Rd Study	
0410019	No	Taylor Creek	East	11	0.28	SSO	Manhole	Located in woods off Maine Avenue	Residential	Wilson/Waterworks Rd Study	
0410036	No	Taylor Creek	East	1	0.00	SSO	Manhole	Located on Waterworks Road	Residential	Wilson/Waterworks Rd Study	
0410068	No	Taylor Creek	East	0	0.00	SSO	Manhole	Located at Waterworks Road and London Acres Drive	Residential	Wilson/Waterworks Rd Study	
0440074	No	Taylor Creek	East	3	0.03	SSO	Manhole	Located near residence on Covert Place	Residential	Wilson/Waterworks Rd Study	
0530083	No	Taylor Creek	East	23	1.75	SSO	Manhole	Located near Residence on Waterworks Road	Residential	Wilson/Waterworks Rd Study	Wilson/Waterworks Rd. Improvements
2150050	No	Fourmile Creek	East	1	0.00	SSO	Bypass Pipe	Located near Skyview & Pine Hill Drive	Residential		Crestiview SSES and I/I Reduction
0010PS5 - Harrison Harbor (Anderson)	No	Ohio River East	East	NA	NA	SSO - Pump Station	Pump Station Wet Well	Located near residences near Ohio River	Residential	Pump Station Overflow Elimination Plan	
0020PS1 - Silver Grove	No	Fourmile Creek	East	0	0.00	SSO - Pump Station	Bypass Pipe	Located at Mary Ingles Highway & Industrial Road	Recreation	Highland Heights-Silver Grove Area Phase II Study	Ash St Pump Station
0050PS1 - Highland Heights	No	Ohio River East	East	46	17.00	SSO - Pump Station	Bypass Pipe	Located near residences at River Rd.	Residential	Highland Heights-Silver Grove Area Phase II Study	Ash St Pump Station

Appendix 2-C: East Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
1920PS3 - Winters Ln No. 2	No	Ohio River East	East	NA	NA	SSO - Pump Station	Bypass Pipe	Located near residences on Winters Ln. 2	Residential	Pump Station Plan for Backup Power	
2150PS1 - Crestview	No	Fourmile Creek	East	NA	NA	SSO - Pump Station	Bypass Pipe	Located near Skyview & Pine Hill Drive	Residential	Pump Station Overflow Elimination Plan	Crestiview SSES and I/I Reduction
2210PS2 - Enzweiller	No	Fourmile Creek	East	NA	NA	SSO - Pump Station	Pump Station Wet Well	Located near residences on Enzweiler Rd	Residential	Pump Station Plan for Backup Power	
2230PS3 - Riley Rd	No	Fourmile Creek	East	NA	NA	SSO - Pump Station	Bypass Pipe	Located off Riley Rd. near creek	Commercial	Pump Station Overflow Elimination Plan	Eastern Regional Riley Rd Pump Station
					Total for Individual Overflow Locations	42.8					
					Total for Eastern Regional Collection System	8.0					
					Other Potential Overflows	22.6					
					East Basin - Total Model-Predicted SSO Volume	73.4					

Notes:

1. Any locations with value of "No" are greather than 50 feet from a waterbody.

2. The presented results were generated by planning-level models based on SD1's current understanding of the collection system infrastructure (August 2008). These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the collection system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. These results are subject to change, and should not be considered definitive. Annual simulations with SD1's 2008 refined calibrated system-wide model use SD1's selected typical year of 1970 and include river influence. Overflow statistics also based on peak hourly flows from a rolling average of 5-minute output, 7-hr inter-event period, and 0.01 MGD peak flow threshold.

3. "NA" indicates that model output is not available.

4. "Other Potential Overflows" are locations that have been predicted by the model to occur in the typical year but have not yet been field verified. SD

Appendix 2-C: North Basin - Combined Sewer Overflow Location Data

Manhole ID	Common Name/ Description	To-be Permitted CSO?	Direct Discharge to Waterbody	Watershed	Basin	Typical Year Spill Frequency (No.)[1,2]	Typical Year Overflow Volume (MG)[1,2]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk
1320112	Dixie Hwy/S. Arlington	Yes	No	Ohio River North	North	0	0	CSO	Outfall	Located at Dixie Highway and Arlington Road	Residential
1350155	Park Hills/Dixie Hwy.	No	No	Ohio River North	North	4	0.13	CSO	Outfall	Located across street from commercial facility	Recreation
1380132	Amsterdam/ Parkvale	Yes	No	Ohio River North	North	3	0.24	CSO	Outfall	Located at Amsterdam Road and Parkvale Court	Residential
1380146	Amsterdam/ Arlington	Yes	No	Ohio River North	North	2	0.01	CSO	Outfall	Located between Amsterdam Road and Arlington Road	Residential
1440204	Scott St.	No	Ohio River	Ohio River North	North	0	0	CSO	Outfall	Located in Ohio River next to boat loading dock	Recreation
1440205	Greenup St.	No	Ohio River	Ohio River North	North	19	0.62	CSO	Outfall	Located in Ohio River next to boat loading dock	Recreation
1440206	Garrard St.	No	Ohio River	Ohio River North	North	33	3.30	CSO	Outfall	Located in Ohio River next to boat landing	Recreation
1440209	2nd St. at Russell	No	Ohio River	Ohio River North	North	92	56.08	CSO	Outfall	Located on bank of Ohio River and outfall for Russell Street PS	Recreation
1440212	2nd St. at Madison and Madison Ave.	No	Ohio River	Ohio River North	North	54	5.66	CSO	Outfall	Located in Ohio River under boat loading next to public landing	Recreation
1470089	Philadelphia St.	No	Ohio River	Ohio River North	North	3	0.23	CSO	Outfall	Located on bank of Ohio River	Recreation
1470093	Bakewell, Main St. and Johnson St.	No	Ohio River	Ohio River North	North	60	42.66	CSO	Outfall	Located in Ohio River next to public parking	Recreation
1480185	Wright St.	Yes	Ohio River	Ohio River North	North	28	1.85	CSO	Outfall	Located in Ohio River	Recreation
1480187	Willow Run	No	Ohio River	Ohio River North	North	77	614.00	CSO	Outfall	Located in Ohio River and outfall for Willow Run PS	Recreation
1490132	Parkway at Highway	No	Ohio River	Ohio River North	North	36	12.56	CSO	Outfall	Located in Ohio River	Recreation
1490172	Swain Ct.	No	Ohio River	Ohio River North	North	0	0.00	CSO	Outfall	Located in Ohio River and next to residences	Recreation
1500131	Altamont St.	No	Ohio River	Ohio River North	North	47	9.09	CSO	Outfall	Located in Ohio River	Recreation
1710114	Kenner St.	No	Ohio River	Ohio River North	North	10	0.47	CSO	Outfall	Located in Ohio River	Recreation
1710116	Adela St.	No	Ohio River	Ohio River North	North	58	15.27	CSO	Outfall	Located in Ohio River next to boat landing	Recreation
1710119	Butler St.	No	Ohio River	Ohio River North	North	39	6.42	CSO	Outfall	Located in Ohio River	Recreation
1710121	Carneal St.	No	Ohio River	Ohio River North	North	23	2.58	CSO	Outfall	Located in Ohio River	Recreation
1710124	Ash St.	No	Ohio River	Ohio River North	North	22	3.05	CSO	Outfall	Located in Ohio River	Recreation
1720109	Lagoon St.	No	Ohio River	Ohio River North	North	43	17.11	CSO	Outfall	Located in Ohio River	Recreation

Appendix 2-C: North Basin - Combined Sewer Overflow Location Data

Manhole ID	Common Name/ Description	To-be Permitted CSO?	Direct Discharge to Waterbody	Watershed	Basin	Typical Year Spill Frequency (No.)[1,2]	Typical Year Overflow Volume (MG)[1,2]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk
1730259	Pleasant St	No	Pleasant Run Creek	Pleasant Run	North	31	2.66	CSO	Outfall	Located in Pleasant Run Creek	Recreation
1730261	Bromley	Yes	Ohio River	Ohio River North	North	NA	NA	CSO	Outfall	Located in Ohio River and outfall for Bromley PS	Recreation
1730262	Steve Tanner St	Yes	Pleasant Run Creek	Pleasant Run	North	0	0	CSO	Outfall	Located at Highwater Road and Main Street near residences	Residential
1730263	Rohman St.	No	Ohio River	Ohio River North	North	37	2.26	CSO	Outfall	Located in Ohio River	Recreation
					North Basin - Total Model-Predicted CSO Volume		796.2				

Notes:

1. The presented results were generated by planning-level models based on SD1's current understanding of the CSS (November 2008). These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the collection system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. These results are subject to change, and should not be considered definitive. Annual simulations with SD1's 2008 refined calibrated system-wide model use SD1's selected typical year of 1970 and include river influence. Overflow statistics also based on 5-min output, 7-hr inter-event period; 0.01 MGD peak flow and 0.001 MG volume thresholds.
2. "NA" indicates that model output is not available.

Appendix 2-C: North Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
1160004	Dry Creek Tributary	Dry Creek	North	0	0	SSO	Manhole	Located along Campus Drive	Residential		
1190007	Dry Creek Tributary	Dry Creek	North	0	0	SSO	Manhole	Located at end of Linwood Avenue	Recreation		
1220029	Dry Creek Tributary	Dry Creek	North	0	0	SSO	Bypass Pipe	Located in frontyard of residence along Birch Drive	Residential		
1240008	Dry Creek Tributary	Dry Creek	North	17	0.68	SSO	Bypass Pipe	Located in backyard of residence along Lafayette Court	Residential		
1280008	Dry Creek Tributary	Dry Creek	North	0	0	SSO	Bypass Pipe	Located in parking lot along apartments on Rosary Court	Residential		
1590006	No	Dry Creek	North	0	0	SSO	Manhole	Located in front yard of residence on Hudson Ave southeast of Evergreen Ct	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1600005	No	Dry Creek	North	0	0	SSO	Manhole	Located in front yard of residence on Marlo southwest of Locust Ave	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1600009	No	Dry Creek	North	3	0.29	SSO	Manhole	Located in backyard of residence on Brittany Court	Residential	Lakeside Park I/I Investigation	Van Deren Sanitary Sewer Improvements; Lakeside Park Public Sewer Rehab and Private Source Removal
1600029	No	Dry Creek	North	0	0	SSO	Manhole	Located at upper end of Hudson Ave cul-de-sac next to the road	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1600049	No	Dry Creek	North	0	0	SSO	Manhole	Located in front yard of residence on Locust Ave and Marlo	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1600050	No	Dry Creek	North	4	0.06	SSO	Manhole	Located in front yard of residence on Shaker Rd and Penwood Ave	Residential	Lakeside Park I/I Investigation	Van Deren Sanitary Sewer Improvements; Lakeside Park Public Sewer Rehab and Private Source Removal
1600059	No	Dry Creek	North	0	0	SSO	Manhole	Located behind residence on Arcadia Ave	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1600110	No	Dry Creek	North	0	0	SSO	Manhole	Located in front yard of residence on Locust Ave and Marlo	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1610102	No	Dry Creek	North	0	0	SSO	Manhole	Located southwest of apartment building (>100 ft away) on Quincy Ct	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1610114	No	Dry Creek	North	0	0	SSO	Manhole	Located in front yard of residence on Avon Dr	Residential	Lakeside Park I/I Investigation	Avon Drive Sanitary Sewer Improvements; Lakeside Park Public Sewer Rehab and Private Source Removal
1610115	No	Dry Creek	North	0	0	SSO	Manhole	Located in front yard of residence on Avon Dr	Residential	Lakeside Park I/I Investigation	Avon Drive Sanitary Sewer Improvements; Lakeside Park Public Sewer Rehab and Private Source Removal

Appendix 2-C: North Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
1630012	Dry Creek	Dry Creek	North	0	0	SSO	Bypass Pipe	Located along Eubanks Road and 185' from residence	Residential		
1820014	Dry Creek Tributary	Dry Creek	North	0	0	SSO	Manhole	Located in yard of residence on Buttermilk Pike and 100' from lake	Residential		
1830017	No	Dry Creek	North	0	0	SSO	Manhole	Located in frontyard along Peach Tree Lane	Residential		
1830020	No	Dry Creek	North	0	0	SSO	Bypass Pipe	Located at corner residence on Cherry Tree Lane and Maple Tree Lane	Residential		
1830067	No	Dry Creek	North	0	0	SSO	Bypass Pipe	Located on Maple Tree Lane	Residential		
1890001	No	Dry Creek	North	0	0	SSO	Manhole	Located on Hudson Avenue	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1890010	No	Dry Creek	North	0	0	SSO	Manhole	Located near a pond at Dixie Highway and Hudson Avenue	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
1890011	No	Dry Creek	North	0	0	SSO	Manhole	Located near a pond at Dixie Highway and Hudson Avenue	Residential	Lakeside Park I/I Investigation	Lakeside Park Public Sewer Rehab and Private Source Removal
2130022	No	Dry Creek	North	3	0.16	SSO	Manhole	Upstream of wastewater treatment plant along Dry Creek	Recreation		
1560016	No	Pleasant Run	North	0	0	SSO	Bypass Pipe	Located in empty lot on Thompson Avenue and 300' from Pleasant Run Creek	Residential		
1560019	No	Pleasant Run	North	0	0	SSO	Bypass Pipe	Located along Burdsall Avenue	Residential		
1560074	No	Pleasant Run	North	0	0	SSO	Bypass Pipe	Located in backyards between Burdsall Avenue and Pleasant Ridge Avenue	Residential		
1600113	No	Pleasant Run	North	0	0	SSO	Manhole	Located in front yard of residence on Kearne Ct	Residential		
1620001	Pleasant Run Creek	Pleasant Run	North	0	0	SSO	Manhole	Located along Beechwood Road underneath I-71/75	Residential		
1680001	Pleasant Run Creek	Pleasant Run	North	6	0.79	SSO	Manhole	Located along bank of Pleasant Run Creek	Residential		
1690043	Pleasant Run Creek	Pleasant Run	North	2	<0.01	SSO	Bypass Pipe	Located in front of residence along Amsterdam Road and 190' from Pleasant Run Creek Tributary	Residential		
1700025	No	Pleasant Run	North	0	0	SSO	Bypass Pipe	Located in frontyard of residence along Sleepy Hollow Road and 135' from Pleasant Run Creek Tributary	Residential		

Appendix 2-C: North Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody[1]	Watershed	Basin	Typical Year Spill Frequency (No.)[2,3]	Typical Year Overflow Volume (MG)[2,3]	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
1730104	Pleasant Run Creek	Pleasant Run	North	1	0.01	SSO	Manhole	Located on St John's Road	Residential		
1730110	No	Pleasant Run	North	0	0	SSO	Manhole	Located in frontyard of Bromley-Cresent Springs Road and 200' from Pleasant Run Creek	Residential		
2290001	Pleasant Run Creek	Pleasant Run	North	1	0.02	SSO	Manhole	Located on Bromley-Cresent Springs Road & St John's Road	Residential		
2390002	Allen Fork	Woolper Creek	North	0	0	SSO	Manhole	Located along Belleview Rd next to road in the woods	Residential		Allen Fork Phase I Improvements; Allen Fork PS Overflow Elimination
2390006	Allen Fork	Woolper Creek	North	0	0	SSO	Manhole	Located along Belleview Rd next to road in low-density residential neighborhood	Residential		Allen Fork Phase I Improvements; Allen Fork PS Overflow Elimination
2390008	Allen Fork	Woolper Creek	North	0	0	SSO	Manhole	Located at Burlington Pike and Lakeview Drive	Residential		Allen Fork Phase I Improvements; Allen Fork PS Overflow Elimination
2390762	Allen Fork	Woolper Creek	North	3	0.06	SSO	Manhole	Located at Burlington Pike and Caroline Williams Way	Residential		Allen Fork Phase I Improvements; Allen Fork PS Overflow Elimination
2360PS1 (Taylorsport PS)	Elijahs Creek	Elijahs Creek	North	0	0	SSO – Pump Station	Pump Station Wet Well	Located near to residences along Tanner Rd	Residential	Allen Fork Collection System Phase I Improvements: Modeling Summary	Western Regional Conveyance and Water Reclamation Facility; Taylorsport PS Upgrade (2004)
2360PS2 (Cardinal Cove PS	Tributary to Elijahs Creek	Elijahs Creek	North	0	0	SSO – Pump Station	Pump Station Wet Well	Located behind residences on Cardinal Way	Residential	Category 5 Pump Station	
2360PS3 (South Park Industrial PS)	Tributary to Elijahs Creek	Elijahs Creek	North	0	0	SSO – Pump Station	Pump Station Wet Well	Located in industrial park	Comercial/Industrial	South Park SSES Investigation	Backup Power Project 5
2370PS1 (Bullitsville PS)	Tributary of Woolper Creek	Woolper Creek	North	0	0	SSO – Pump Station	Pump Station Wet Well	Located near residences by Petersburg and Graves Rd.	Residential		
2390PS1 (Allen Fork PS)	Allen Fork	Woolper Creek	North	0	0	SSO – Pump Station	Pump Station Wet Well	Located near Burlington Pike, off road, near creek	Residential	Western Regional Capacity Analysis	Allen Fork Phase I Improvements; Western Regional Conveyance and Water Reclamation Facility; Allen Fork PS Overflow Elimination
Total for Individual Overflow Locations					2.1						
Other Potential Overflows					5.4						
North Basin - Total Model-Predicted SSO Volume					7.5						

Notes:

1. Any locations with value of "No" are greather than 50 feet from a waterbody.

2. The presented results were generated by planning-level models based on SD1's current understanding of the collection system infrastructure (August 2008). These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the collection system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. These results are subject to change, and should not be considered definitive. Annual simulations with SD1's 2008 refined calibrated system-wide model use SD1's selected typical year of 1970 and include river influence. Overflow statistics also based on peak hourly flows from a rolling average of 5-minute output, 7-hr inter-event period, and 0.01 MGD peak flow threshold.

3. "NA" indicates that model output is not available.

4. "Other Potential Overflows" are locations that have been predicted by the model to occur in the typical year but have not yet been field verified. SD1 is conducting ongoing investigation to confirm if these model predicted locations are occurring in the field.

Appendix 2-C: West Basin - Sanitary Sewer Overflow Location Data

Manhole ID	Direct Discharge to Waterbody1	Watershed	Basin	Typical Year Spill Frequency (No.)2,3	Typical Year Overflow Volume (MG)2,3	Overflow Point Type	Discharge Location	Description of Immediate Area Land Use	Potential Public Health Risk	Applicable Studies	Applicable Rehab or Construction Work
2380001	Gunpowder Creek	Gunpowder Creek	West	4	0.37	SSO	Manhole	Located in woods along Gunpowder Creek near Gunpowder PS	Recreation	Western Regional Capacity Analysis	Western Regional Conveyance System and Water Reclamation Facility
2280PS2 (Ky Aire PS)	Tributary to South Fork Gunpowder Creek	Gunpowder Creek	West	8	1.11	SSO – Pump Station	Bypass Pipe	Located next to creek by residential homes	Residential	Pump Station Overflow Elimination Plan; Southern Kenton Drainage Study; Western Regional Capacity Analysis	Kentucky Aire PS Overflow Elimination
2420PS6 (South Hampton PS)	South Fork Gunpowder Creek	Gunpowder Creek	West	4	0.06	SSO – Pump Station	Bypass Pipe	Located next to South Fork Gunpowder Creek in wooded area	Residential	Pump Station Overflow Elimination Plan; Southern Kenton Drainage Study; Western Regional Capacity Analysis	Western Regional Conveyance System and Water Reclamation Facility
2280PS1 (Highland Acres PS	Tributary to South Fork Gunpowder Creek	Gunpowder Creek	West	0	0	SSO – Pump Station	Bypass Pipe	Located next to stream at end of residential street	Residential	Pump Station Overflow Elimination Plan; Southern Kenton Drainage Study; Western Regional Capacity Analysis	Highland Acres PS Overflow Elimination
2420PS3 (Union PS)	Fowlers Fork	Gunpowder Creek	West	0	0	SSO – Pump Station	Bypass Pipe	Located next to Fowlers Fork near roadway	Recreation	Pump Station Overflow Elimination Plan; Southern Kenton Drainage Study; Western Regional Capacity Analysis	Western Regional Conveyance System and Water Reclamation Facility
1030PS1 (Gammon Calmet PS)	Tributary to South Fork Gunpowder Creek	Gunpowder Creek	West	0	0	SSO – Pump Station	Bypass Pipe	Located in wooded area in close proximity to industral area	Commercial/ Industrial	Pump Station Backup Power Plan; Southern Kenton Drainage Study; Western Regional Capacity Analysis	Western Regional Conveyance System and Water Reclamation Facility
2380PS1 (Gunpowder PS)	Gunpowder Creek	Gunpowder Creek	West	0	0	SSO – Pump Station	Manhole	Located in woods along Gunpowder Creek	NA	Pump Station Backup Power Plan; Western Regional Capacity Analysis	Western Regional Conveyance System and Water Reclamation Facility
1030PS2 (Levi PS)	Tributary to South Fork Gunpowder Creek	Gunpowder Creek	West	0	0	SSO – Pump Station	Pump Station Wet Well	Located near industrial buildings and parking lot	Commercial/ Industrial	Pump Station Backup Power Plan; Southern Kenton Drainage Study; Western Regional Capacity Analysis	American Sign Pump Station Rehabilitation
2320PS3 (Richwood PS)	Mud Lick Creek	Big Bone Lick	West	0	0	SSO – Pump Station	Bypass Pipe	Located along roadway near Mud Lick Creek	Recreation	Pump Station Backup Power Plan; Southern Kenton Drainage Study; Western Regional Capacity Analysis	Richwood Pump Station Improvements
					Total for Individual Overflow Locations	1.6					
					Other Potential Overflows	1.0					
					West Basin - Total Model-Predicted SSO Volume	2.6					

Notes:

1. Any locations with value of "No" are greather than 50 feet from a waterbody.

2. The presented results were generated by planning-level models based on SD1's current understanding of the collection system infrastructure (August 2008). These models are predictive tools and are based on numerous variables and assumptions on the characteristics of the collection system, and may differ from actual measured field conditions. These models are subject to change based on improved knowledge of the system, improvements to the system, and changes in land use and development. These results are subject to change, and should not be considered definitive. Annual simulations with SD1's 2008 refined calibrated system-wide model use SD1's selected typical year of 1970 and include river influence. Overflow statistics also based on peak hourly flows from a rolling average of 5-minute output, 7-hr inter-event period, and 0.01 MGD peak flow threshold.

3. "NA" indicates that model output is not available.

4. "Other Potential Overflows" are locations that have been predicted by the model to occur in the typical year but have not yet been field verified. SD1

Appendix 2-C: West Basin - Sanitary Sewer Overflow Location Data

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Sewer Overflows and Sanitary Sewer Service Area

Overflows
- CSO
- SSO

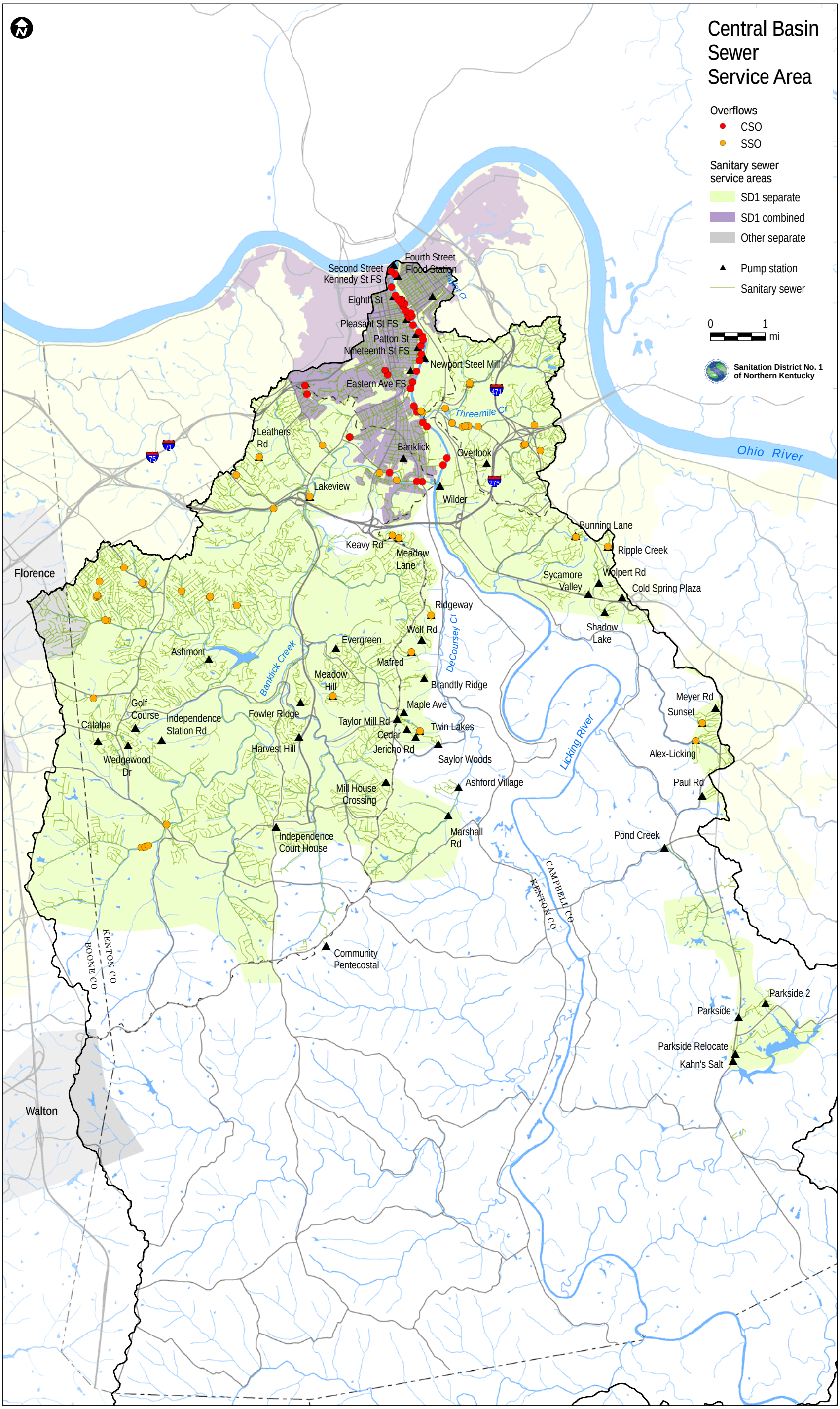
Sanitary sewer service areas
- SD1 separate
- SD1 combined
- Other separate

Pump station

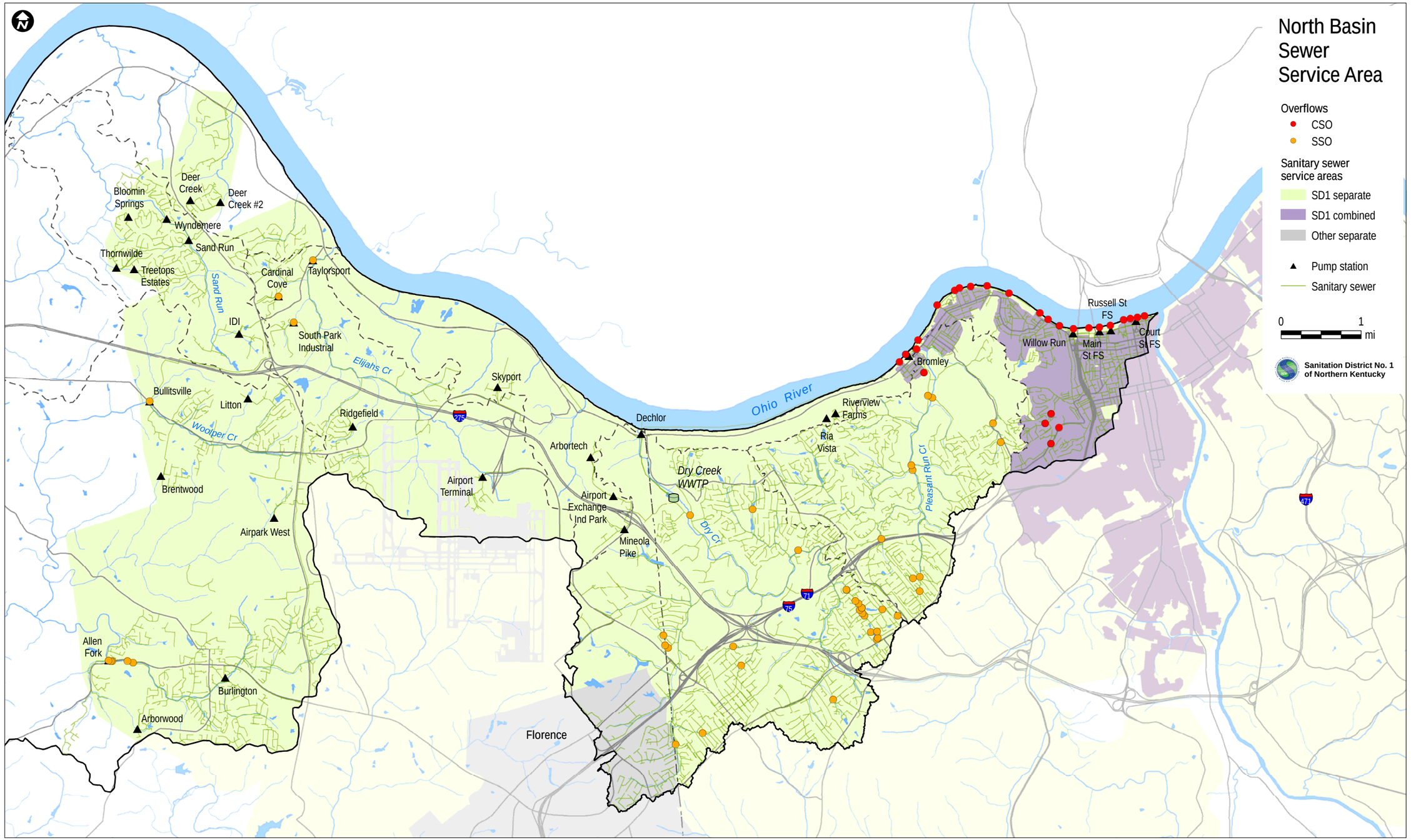
0 1 2 mi

Sanitation District No. 1 of Northern Kentucky

INDIANA
OHIO
Ohio River
Dry Creek WWTP
Future Western Region WRF
Florence
Walton
Licking River
Eastern Regional WRF
KENTON CO
BOONE CO
CAMPBELL CO
KENTON CO
275
71
75
471
74


Central Basin Sewer Service Area
Overflows
CSO
SSO
Sanitary sewer service areas
SD1 separate
SD1 combined
Other separate
Pump station
Sanitary sewer
0
1
mi
Sanitation District No. 1 of Northern Kentucky
Fourth Street Flood Station
Second Street
Kennedy St FS
Eighth St
Pleasant St FS
Patton St
Nineteenth St FS
Eastern Ave FS
Newport Steel Mill
Threemile Cr
Ohio River
Leathers Rd
Banklick
Lakeview
Wilder
Overlook
Bunning Lane
Ripple Creek
Wolpert Rd
Cold Spring Plaza
Shadow Lake
Sycamore Valley
Keavy Rd
Meadow Lane
Ridgeway
Wolf Rd
Evergreen
Mafred
Brandtly Ridge
Maple Ave
Twin Lakes
Cedar
Jericho Rd
Saylor Woods
Ashford Village
Marshall Rd
Pond Creek
Meyer Rd
Sunset
Alex-Licking
Paul Rd
Licking River
DeCoursey Cr
Banklick Creek
Florence
Ashmont
Golf Course
Independence Station Rd
Catalpa
Wedgewood Dr
Fowler Ridge
Harvest Hill
Meadow Hill
Taylor Mill Rd
Mill House Crossing
Independence Court House
Community Pentecostal
KENTON CO
BOONE CO
CAMPBELL CO
KENTON CO
Walton
Parkside 2
Parkside
Parkside Relocate
Kahn's Salt

East Basin Sewer Service Area
Overflows
CSO
SSO
Sanitary sewer service areas
SD1 separate
SD1 combined
Other separate
Pump station
Sanitary sewer
0
1
mi
Sanitation District No. 1 of Northern Kentucky
Main St FS
McKinney St FS
Washington St FS
Columbia St FS
Taylor Cr
Rosewood Lane
Army Reserve
Highland Heights
Lamphill
Silver Grove
Ohio River
Harrison Harbor (Anderson)
Gerrard Ave
Ohio Ave
Neace Subdivision
Carlisle Ave
Jefferson Ave
St Annes
Winters Ln No. 2
Cedar Point
Crestview
Darma Ct
Licking River
Fourmile Creek
Cold Spring Crossing
Centerplex
Douglas & James
Enzweiller
Riley Rd #2
Macke
Kees
Riley Rd
Stillwater
Brookwood
Ridgewood
Eastern Regional WRF
Twelvemile Cr
Barrs Branch
CAMPBELL CO
KENTON CO
471
275


North Basin Sewer Service Area
Overflows
CSO
SSO
Sanitary sewer service areas
SD1 separate
SD1 combined
Other separate
Pump station
Sanitary sewer
0
1
mi
Sanitation District No. 1 of Northern Kentucky
Ohio River
Deer Creek
Deer Creek #2
Bloomin Springs
Wyndemere
Sand Run
Thornwilde
Treetops Estates
Cardinal Cove
Taylorsport
Sand Run
IDI
South Park Industrial
Elijahs Cr
Bullitsville
Litton
Woolper Cr
Ridgefield
Skyport
Dechlor
Arbortech
Airport Terminal
Airport Exchange Ind Park
Mineola Pike
Dry Creek WWTP
Dry Cr
Riverview Farms
Ria Vista
Pleasant Run Cr
Bromley
Willow Run
Russell St FS
Main St FS
Court St FS
Brentwood
Airpark West
Allen Fork
Burlington
Arborwood
Florence
71
75
275
471

West Basin Sewer Service Area

Overflows
- CSO
- SSO

Sanitary sewer service areas
- SD1 separate
- SD1 combined
- Other separate

- Pump station
- Sanitary sewer

0 1 mi

Sanitation District No. 1 of Northern Kentucky

Orchard Estates
Jonathan
Youell Rd
Airport Tower
Saturn
Hazel Rd
Woodspoint Dr
Florence
Willow Bend #2
Lantern Way
Cinnamon Ridge
Hampton Ridge
Blackstone
Gunpowder
Blackstone (Florence)
Stonegate
Pheasant Run
Levi
Rosetta
Fowler Creek (Florence)
Fowler Creek
Farmview
Gunpowder Creek
S Fork Gunpowder Cr
Eagles Landing
American Sign
Gammon Calmet
Anchor Storage
Sycamore
Hempsteade
Highland Acres
Dublin Green No. 1
Ky Aire
Union
South Hampton
Dublin Green No. 2
Lassing Green
Brushup Lane
Red Stone Village
War Admiral
Richwood
Big Bone Creek
KENTON CO
BOONE CO
Mud Lick Creek
Walton
71
75

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Appendix 2-D

Green Infrastructure Characterization Inventory and Analysis Completed for the Northern Kentucky Region and the Combined Sewer System

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Appendix 2-D

Green Infrastructure Characterization Inventory and Analysis Completed for the Northern Kentucky Region And the Combined Sewer System

The process for identifying green infrastructure opportunities was founded upon a detailed inventory and analysis using geographic information systems (GIS) data. The GIS-based inventory and analysis were completed for both the combined sewer system (CSS) and the three-county Northern Kentucky region. The GIS inventory process involved combining multiple data sources to determine the current conditions in regard to natural and built systems. Natural systems can include hydrology (e.g., rivers and streams, lakes, wetlands, watersheds, and flood information), geology, soils, and tree canopy cover, while built systems can include impervious surfaces, transportation corridors, infrastructure (e.g., utility structures, pipes, pump stations, locations of combined sewer overflows, and sewersheds), land use information, and land cover information.

Multiple data sources were combined using geographic information systems (GIS) to determine and assess current conditions in regard to natural and built systems. GIS data was obtained from the following sources:

National-Level Data Sources

- National Land Cover Database (NLCD)
- US Dept. of Agriculture (USDA)
- US Geologic Survey (USGS)
- National Resource Conservation Service (NRCS)
- US Environmental Protection Agency (EPA)

State-Level Data Sources

- Kentucky Division of Water (KDOW)
- Kentucky Transportation Cabinet (KYTC)
- Kentucky Geography Network (KYGEONET)
- Kentucky Geological Survey (KGS)
- Kentucky Energy and Environment Cabinet (KYEEC)
- Kentucky Resource Conservation Service (KRCS)

Local-Level Data Sources

- Northern Kentucky Sanitation District No.1 (SD1)
- Northern Kentucky Area Planning Commission (NKAPC)
- Boone County
- Kenton County
- Campbell County
- Kentucky Division of Geographic Information
- Ohio-Kentucky-Indiana Regional Council of Governments (OKI)
- Northern Kentucky Urban and Community Forestry Council
- Ohio River Sanitation Commission (ORSANCO)
- Kentucky Property Valuation Administrator (PVA) for each county

The following series of maps highlight the inventory and analysis of the natural and built systems within the Northern Kentucky three county region and SD1's combined system.

Inventory and Analysis Maps	Page
Three County Region Inventory	
Hydrology	4
Tree Canopy Cover	5
Slopes	6
Detailed Geology	7
Impervious Surfaces	8
Road Right-of-Way	9
Potential Strategic Partners	10
Existing Land Use	11
Future Land Use	12
Three County Region Analysis	
303 (d) Impaired Waters	13
Infiltration Rate Potential	14
Sewer Lines Within Stream Buffer	15
Stream Level	16
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Conservations Areas and High Quality Streams	19
Drywell Opportunities	20
Tree Deficiency	21
Landslide-Prone Areas and Tree Canopy Cover	22
Road Right-of-Way and Tree Canopy Cover	23
Stream Buffer With/Without Tree Cover	24
Physically-Restricted Development Areas	25
Combined System Inventory	
Detailed Geology	26
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Slopes	28
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Existing Land Use	30
Future Land Use	31
Potential Strategic Partners	32
Combined System Analysis	
Combined Sewer Overflows – Annual Activations	33
Historic Geology	34
Drywell Opportunities	35

Upon completion of the inventory and analysis portion of the green infrastructure evaluation, four themes or recommendations were identified for the Northern Kentucky region and have been outlined below.

Protect and Restore Water Resources

Based on the inventory and analysis it is apparent that Northern Kentucky possesses a valuable stock of rivers, streams, creeks, and aquatic habitat that are vital to the health of the watersheds in the region. Three approaches to consider for maintaining and restoring this hydrologic network include conservation and restoration, reduced hydromodification, and creation and enhancement of stream buffers.

Protect, Enhance and Connect Forests

In addition to protecting the freshwater resources as part of riparian buffers, reforestation techniques in road right-of-ways and along steep slopes can have significant impacts. A reforestation strategy can help reduce urban heat island effect, improve slope stability, reduce stormwater runoff, improve air quality, and provide water quality benefits.

Promote Transportation Corridors as Greenway Connections

While an important asset, transportation corridors that connect Northern Kentucky to surrounding regions contribute a significant amount of impervious surface and storm water runoff to the separate and combined system. Implementing green infrastructure along these corridors provides opportunities for improving water quality, reducing storm water runoff, improving air quality, and reducing noise pollution.

Regional Planning and Smart Growth

Green infrastructure planning can help Northern Kentucky communities determine where to direct growth and development, and how to prioritize conservation needs. When green infrastructure solutions are considered in the context of existing land use and future growth, multiple benefits, beyond those described above, are realized by the community.

The following series of graphics combine the above inventory and analysis of the natural and built systems within the Northern Kentucky three county region and SD1's combined system.

Green Infrastructure Graphics	Page
Regional Green Infrastructure Reforestation Strategies	36
Protecting Water Resources: Conservation and Restoration	37
Regional Green Infrastructure Stream Buffers	38
Anatomy of a Regional Green Infrastructure Plan	39
Combined Sewer System Reforestation Strategies Combined	40
Sewer System Green Urban Core	41

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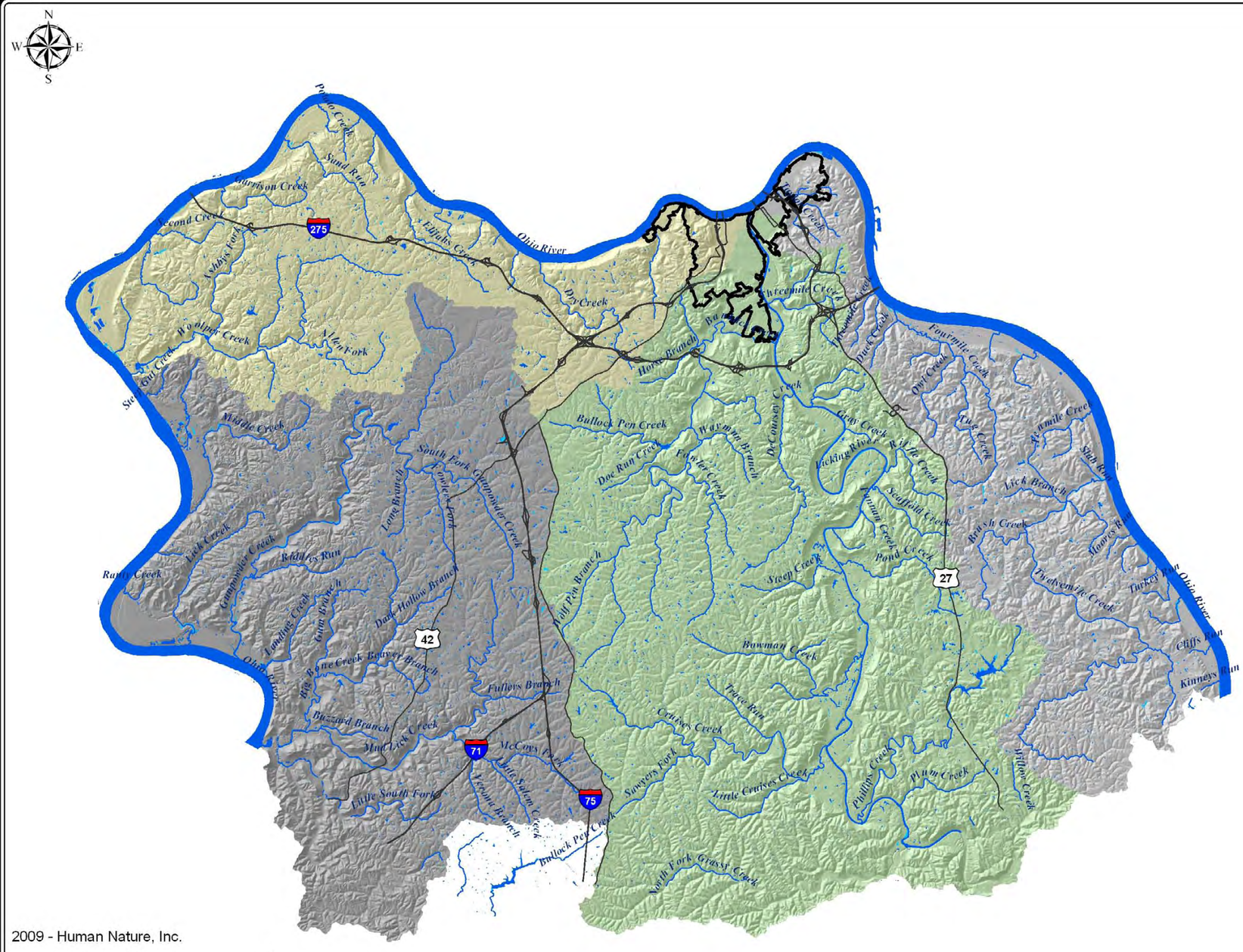

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Miles

Legend

- Major Roads
- River and Major Streams
- Combined Sewer System Boundary
- Lakes
- Wetlands
- North Basin
- East Basin
- Central Basin
- West Basin

Features	Acres	Miles
Major Streams	2,165	459
Major Streams (CSS)	14	-
Lakes	3,410	-
Lakes (CSS)	25	-

- The three-county Northern Kentucky region contains over 460 miles of major streams, covering over 2,000 acres of land area
- The North Basin has the largest number of watersheds, while the Central and West basins cover the greatest area
- The Combined Sewer System (CSS) contains three basins: the North, Central and East basins

Recommendation:
- Green infrastructure strategies should focus on maximizing benefits in both the CSS and within the largest basins

Source:
Wetlands and Detailed Streams layer are from National Hydrography Dataset by USGS

HYDROLOGY

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

HUMAN NATURE
900 St. Paul Place
Cincinnati, OH 45206
T: 513.281.7211
F: 513.281.2243
www.humannature.cc

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0 1 2 4
Miles

Legend

Major Roads

Combined Sewer System Boundary

Canopy Crown Size

Large Crown

Medium Crown

Small Crown

- 38 percent of the land in Northern Kentucky is covered by tree canopy
- There are considerable areas along the interstates (71, 75, and 275) and major state routes (42 and 26) that are devoid of forest canopy

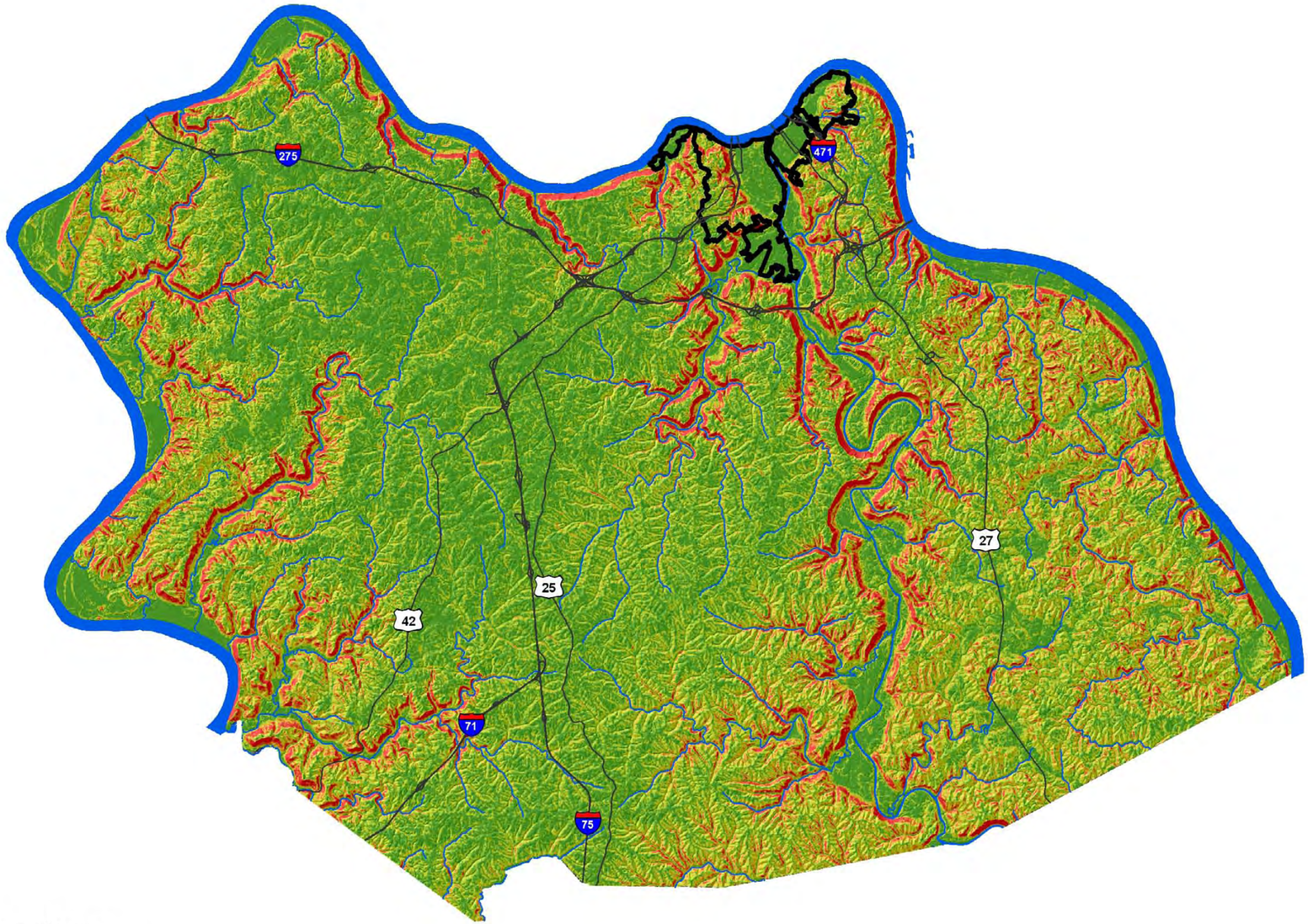
Recommendations:
- Increased forest cover may help reduce the volume of stormwater runoff reaching and within the SD1 service area.

Source:
County canopy layers are from
Northern Kentucky Urban & Community Forestry Council

TREE CANOPY COVER

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

HUMAN NATURE
900 St. Paul Place
Cincinnati, OH 45206
T: 513.281.7211
F: 513.281.2243
www.humannature.cc



2009 - Human Nature, Inc.

0 1 2 4
Miles

Legend

- Major Roads
- River and Major Streams
- Combined Sewer System Boundary

Slope (Percent)

- 0 - 5
- 5 - 8
- 8 - 15
- 15 - 20
- 20 - 25
- 25 +

Features	Acres	Percent
Total Area	371,715	-
Slopes over 15%	58,585	15.8%
Slope over 20%	36,975	10.0%

- Three-fourths of the region has slopes less than 15 percent
- Areas with steep slopes (over 15 percent) correspond to major waterways and major tributaries (e.g., the Ohio and Licking Rivers, Banklick Creek, Gunpowder Creek, Big Bone Creek)

Recommendation:
- Slopes can greatly influence the volume of stormwater runoff, reduce opportunities for infiltration, and contribute to sedimentation (through erosion)

SLOPES

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

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990 St. Paul Place
Cincinnati, OH 45206
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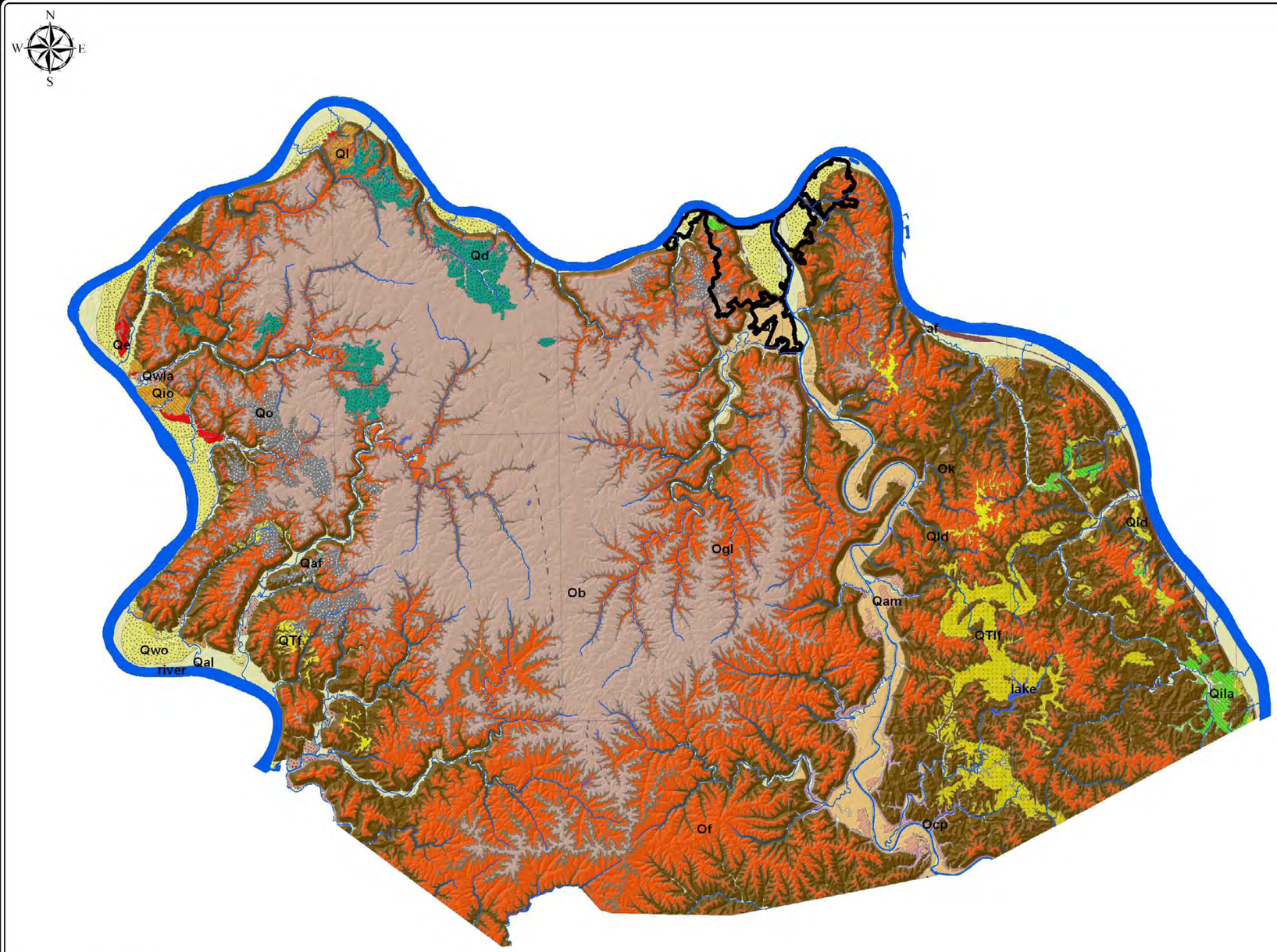
F: 513.281.2242
www.humannature.cc



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Miles

Legend

River and Major Streams

Major Roads

Combined Sewer System Boundary

KGS Detailed Geology

- Qaf - Alluvial Fan Deposits
- Qal - Alluvium
- Qam - Alluvium of valley sides, etc.
- af - Artificial fill
- Ob - Bull Fork Formation
- Qe - Eolian sand, dune sand
- Of - Fairview Formation
- Qid - Glacial drift (Illinoian)
- Qd - Glacial drift (pre-Illinoian)
- Qio - Glacial outwash (Illinoian)
- Qwo - Glacial outwash (Wisconsinan)
- Qgl - Grant Lake Limestone
- QTf - High-level fluvial deposits
- Ok - Kope Formation
- QTlf - Lacustrine and fluvial deposits (pre-Illinoian)
- Qila - Lacustrine deposits (Illinoian)
- Qwla - Lacustrine deposits (Wisconsinan)
- Lake - Lake area
- Qld - Landslide and alluvial fan deposits
- Ql - Loess
- Qo - Outwash deposits (pre-Illinoian)
- Ocp - Point Pleasant Tongue of Clays Ferry Formation
- River - River area
- Qt - Terrace deposits

Source:
Geology layer is from Kentucky Geological Survey (KGS)

DETAILED GEOLOGY

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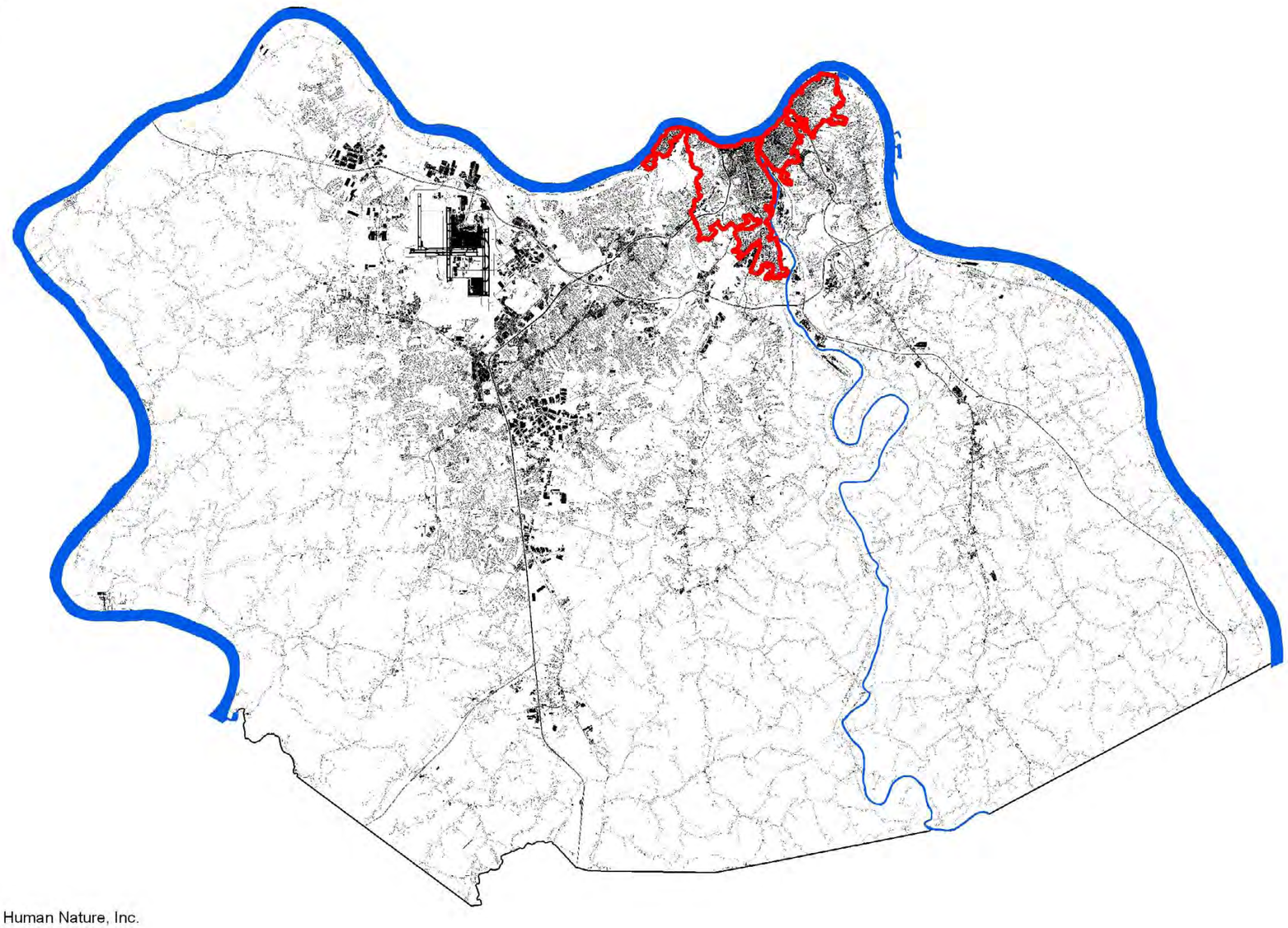

Legend

- Combined Sewer System Boundary
- Rivers
- Impervious Surfaces

Feature	Acres	Percent
Total Area	371,715	-
Impervious Surfaces	23,850	6.4%

- Impervious surfaces include buildings, pavement, roadways and highways, and bridges.
- Semi-Impervious surfaces include bridges, unpaved roads and parking lots, and railroads.

Recommendation:
- Impervious surfaces greatly reduce infiltration and evaporation and, therefore, contribute to increased volumes of stormwater runoff entering the Licking and Ohio rivers

IMPERVIOUS SURFACES

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900 St. Paul Place
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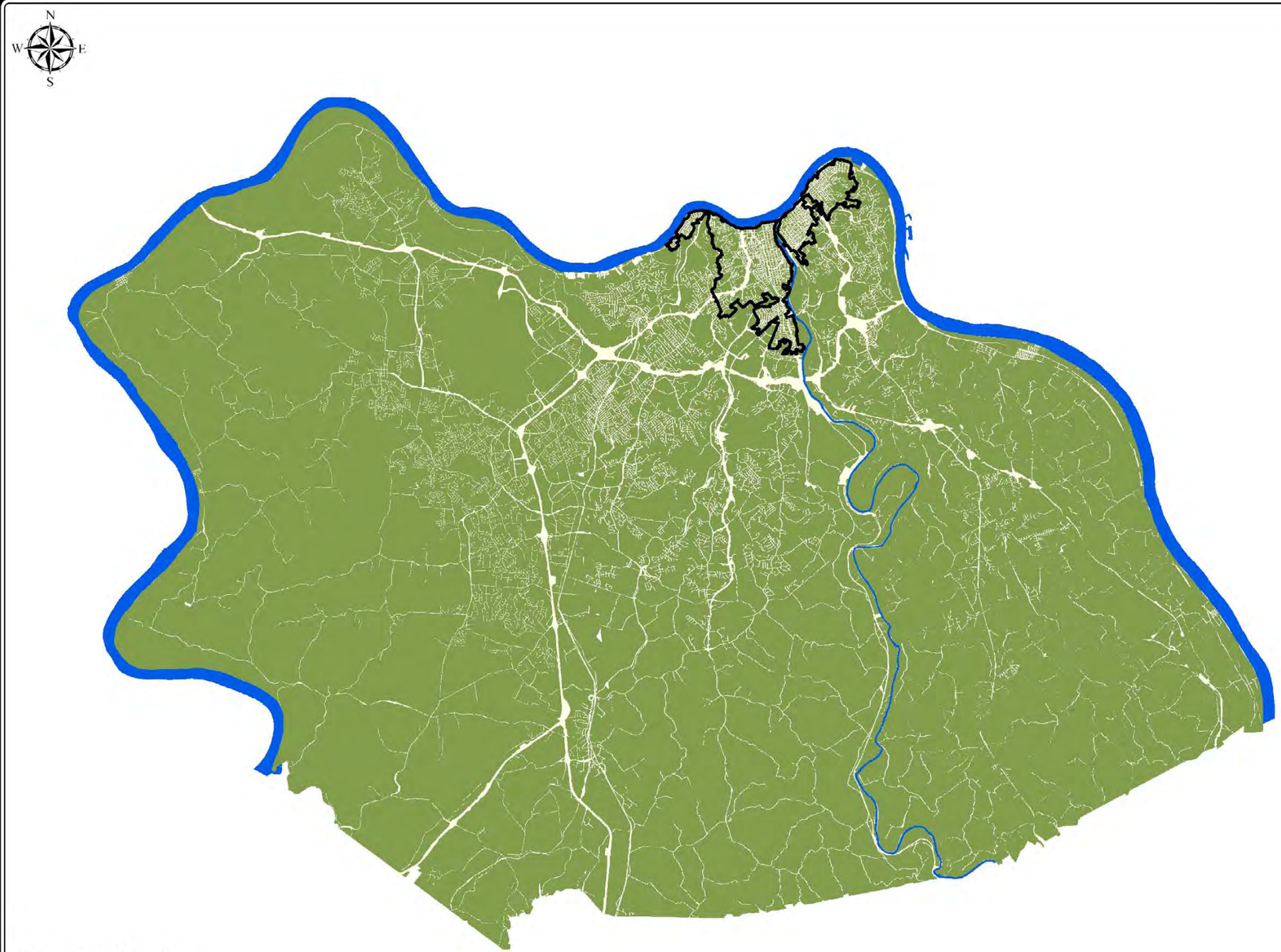

Legend

- Combined Sewer System Boundary
- Rivers
- Road Right-of-Way (12,539 Acres)
- Parcels

Feature	Acres	Percent
Right-of-Way	14,025	-
Without Tree Cover	2,195	15.7%
With Tree Cover	11,830	84.3%

- The road right-of-way shows the extent of transportation infrastructure in Northern Kentucky

Recommendation:
- Road right-of-way, specifically along the interstates, can represent the major arteries of a regional green infrastructure network

ROAD RIGHT OF WAY

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Cincinnati, OH 45206
T: 513.281.2211
F: 513.281.2242
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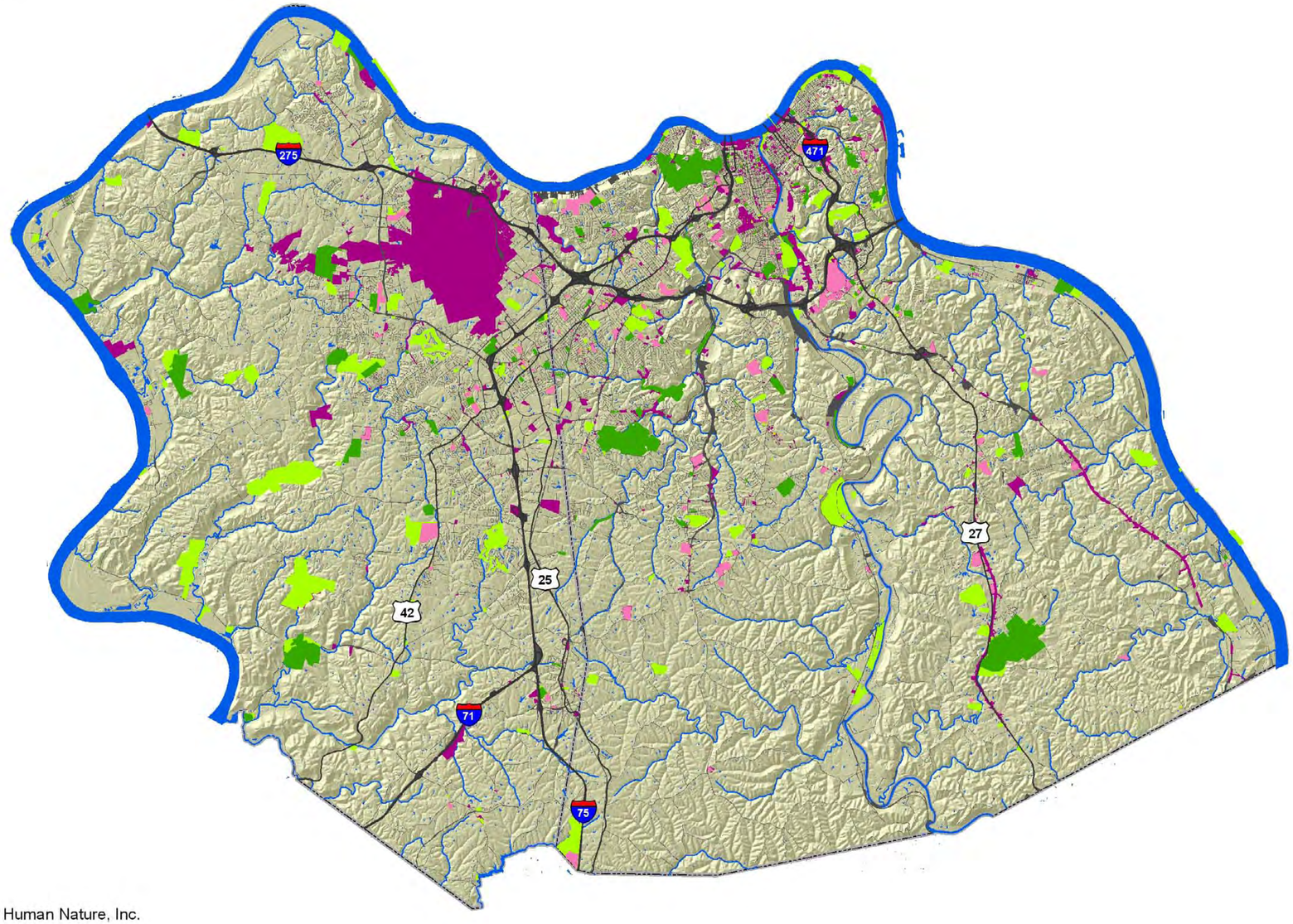

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0 1 2 4
Miles

Legend

- Major Roads
- Parks
- Schools
- Greenspace
- PublicProps
- Road Right-of-Way

- Public properties consist of parks, schools, cemeteries, streams and rivers, and right-of-way
- Public properties are concentrated mostly within the I-275 loop and adjacent to the interstates and major roadways
- The Greater Cincinnati/Northern Kentucky Airport is the largest piece of public property in the region

Recommendation:
- Connecting public and institutional properties, as well as open spaces, provides a foundation for a regional green infrastructure network

POTENTIAL STRATEGIC PARTNERS

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SANITATION DISTRICT NO.1 OF NORTHERN KY
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HUMAN NATURE
990 St. Paul Place
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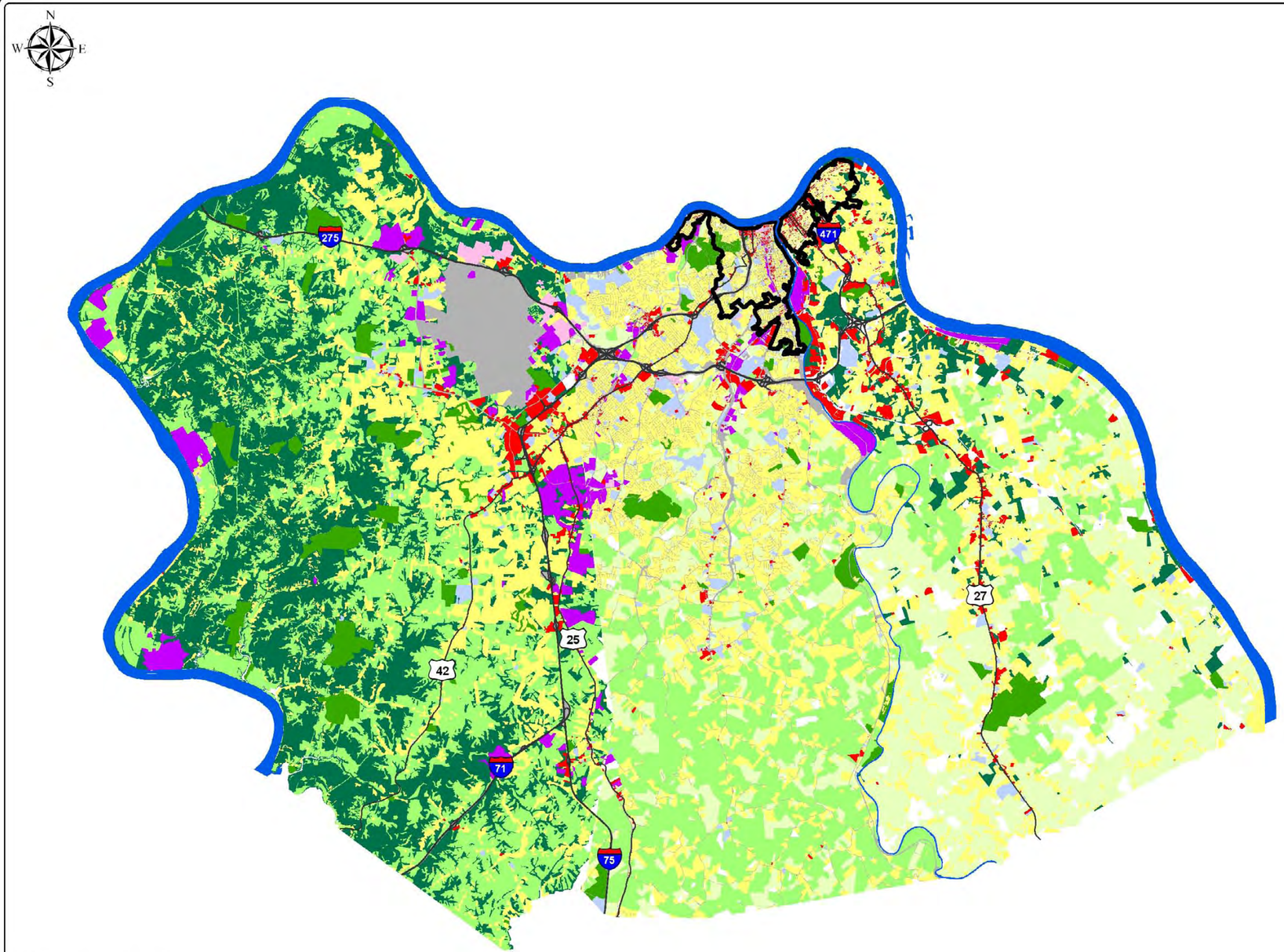
T: 513.281.2241
F: 513.281.2242
www.humannature.cc



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Legend

- Major Roads
- Combined Sewer System Boundary

Land Use Type

- Road Right-of-Way
- Agricultural
- Commercial
- Industrial
- Mixed-use
- Office
- Public/Semi-public/Institutional
- Residential
- Recreational
- Airport/ROW/Railroad
- Undeveloped
- Woodland

Note:
Land uses are not verified by field survey for the following cities: Bellevue, Newport, Wilder, Fort Thomas, Highland Heights, Cold Spring, Alexandria, California, and Mentor.

EXISTING LAND USE

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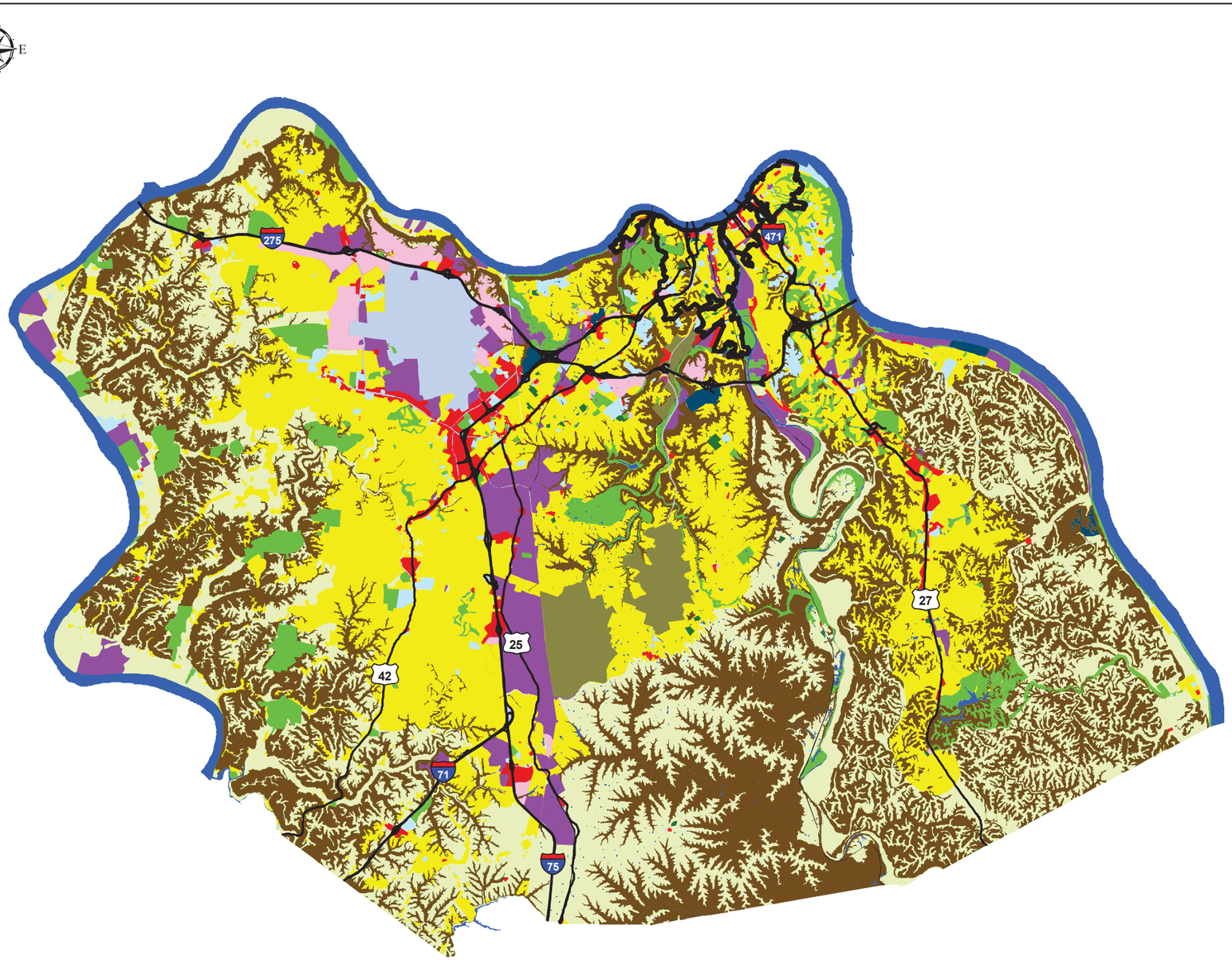
T: 513.281.7211
F: 513.281.2243
www.humannature.cc



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Miles

Legend

- Combined Sewer System Boundary
- Agricultural
- Commercial
- Industrial
- Institutional
- Mixed Use
- Office
- Openspace/Recreational
- PRDA
- Public
- Railroad
- Residential
- Right of Way
- School/Parks
- Small Study Areas
- Special Development Area
- Water

- Based on current zoning regulations, residential land uses will take over agricultural, woodland, and undeveloped areas in NKY
- Hillsides, which are represented by dendritic patterns, will remain as physically-restricted development areas (PRDA)

Recommendation:
- Watershed planning efforts should consider the effects of expanded development and changes in land use
- Converting agricultural, woodland, and undeveloped land uses will have significant impacts on stormwater quality and quantity

Data Source:
For Campbell and Kenton counties, future land use data was obtained from the 2009 NKAPC database.

For Boone County, future land use data was obtained from the Boone County Comprehensive Plan.

FUTURE LAND USE

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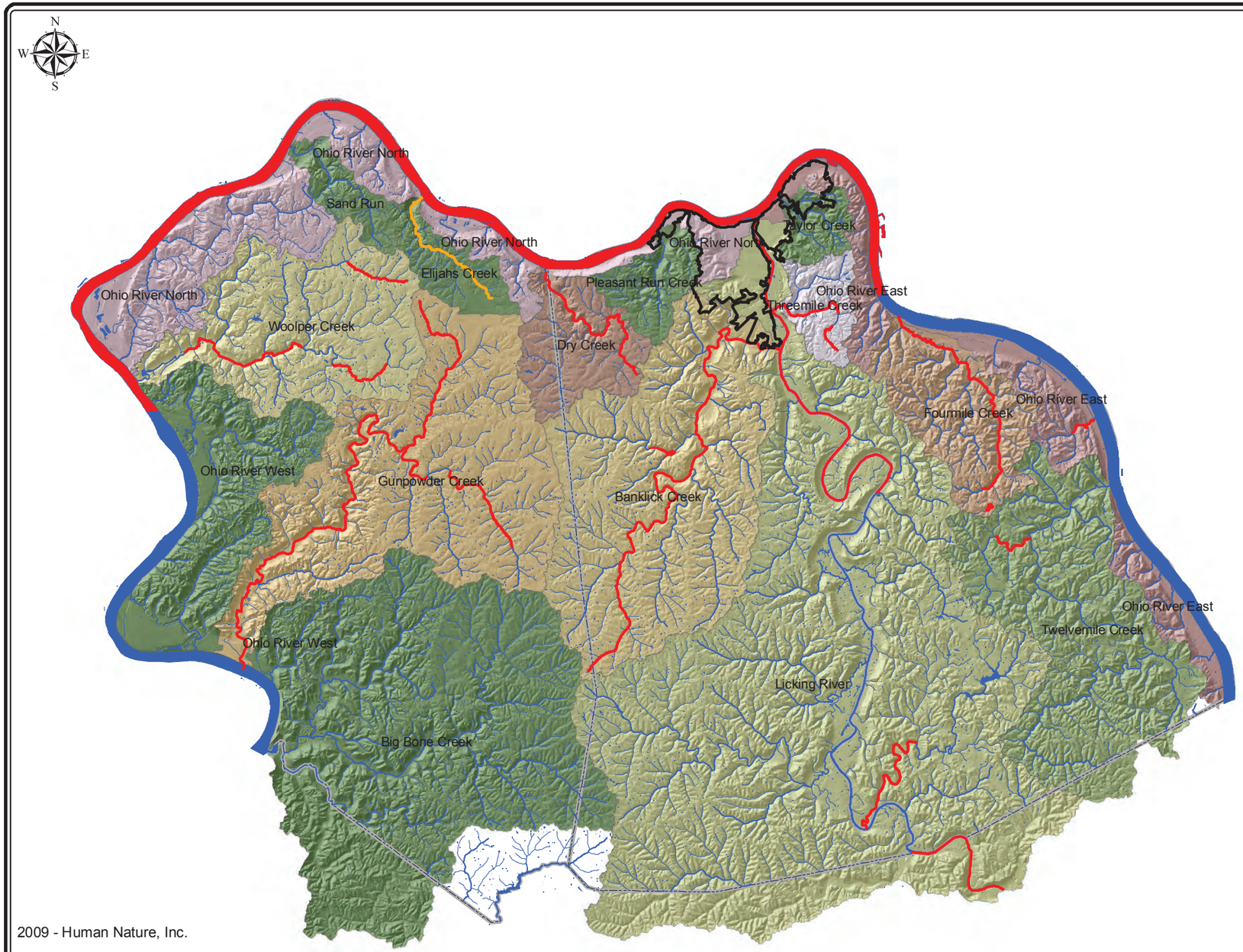
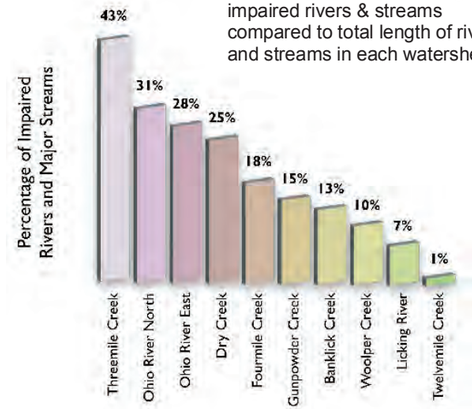


*Bar Chart shows percentage of impaired rivers & streams compared to total length of rivers and streams in each watershed



- The 303(d) Report has particular importance for water quality in Northern Kentucky. Specifically, this report identifies impaired surface waters, those with and without approved TMDLs; classifies impaired uses; and identifies potential causes of impairment.
- Four watersheds have more than 20 percent of rivers and streams listed as “impaired”; these include Threemile Creek (43 percent), Ohio River North (31 percent), Ohio River East (28 percent), and Dry Creek (25 percent)
- Less than 10 percent of the rivers and streams in the Licking River and Twelvemile Creek watersheds are listed as impaired

Legend

- Combined Sewer System Boundary

Impaired Streams

- TMDL Approved
- TMDL Required

Impaired Lakes

- TMDL Required
- NHD Streams
- Lakes
- County Boundary

Source:
KY Environmental and Public Protection Cabinet. 2008. The 2008 Integrated Report to Congress on the Condition of Water Resources in Kentucky, Volume II. Division of Water. Impaired Streams/lakes shapefiles are from KY Division of Water: 305 (b) 2003-2007

303(d)
IMPAIRED WATERS

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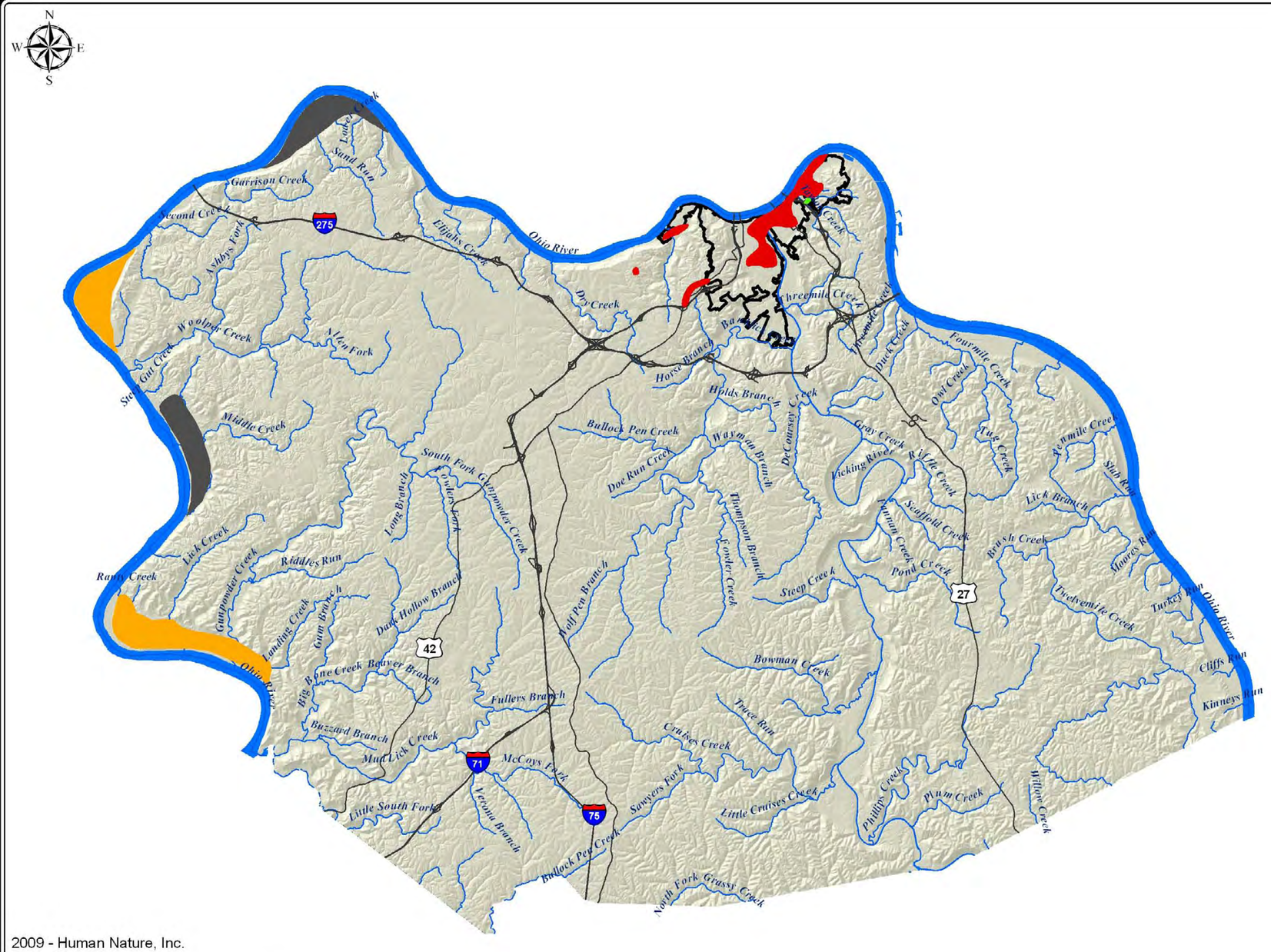

Legend

- Major Roads
- River and Major Streams
- Combined Sewer System Boundary

Infiltration Rate Potential

- High (18 acres)
- Medium to High (3,863 acres)
- Medium (2,919 acres)
- Low w/ Occasional Medium (1,645 acres)

Source: Infiltration rate layer is digitized from drawings by Thelen Associates, Inc.

INFILTRATION RATE POTENTIAL

(from 0' to 6')

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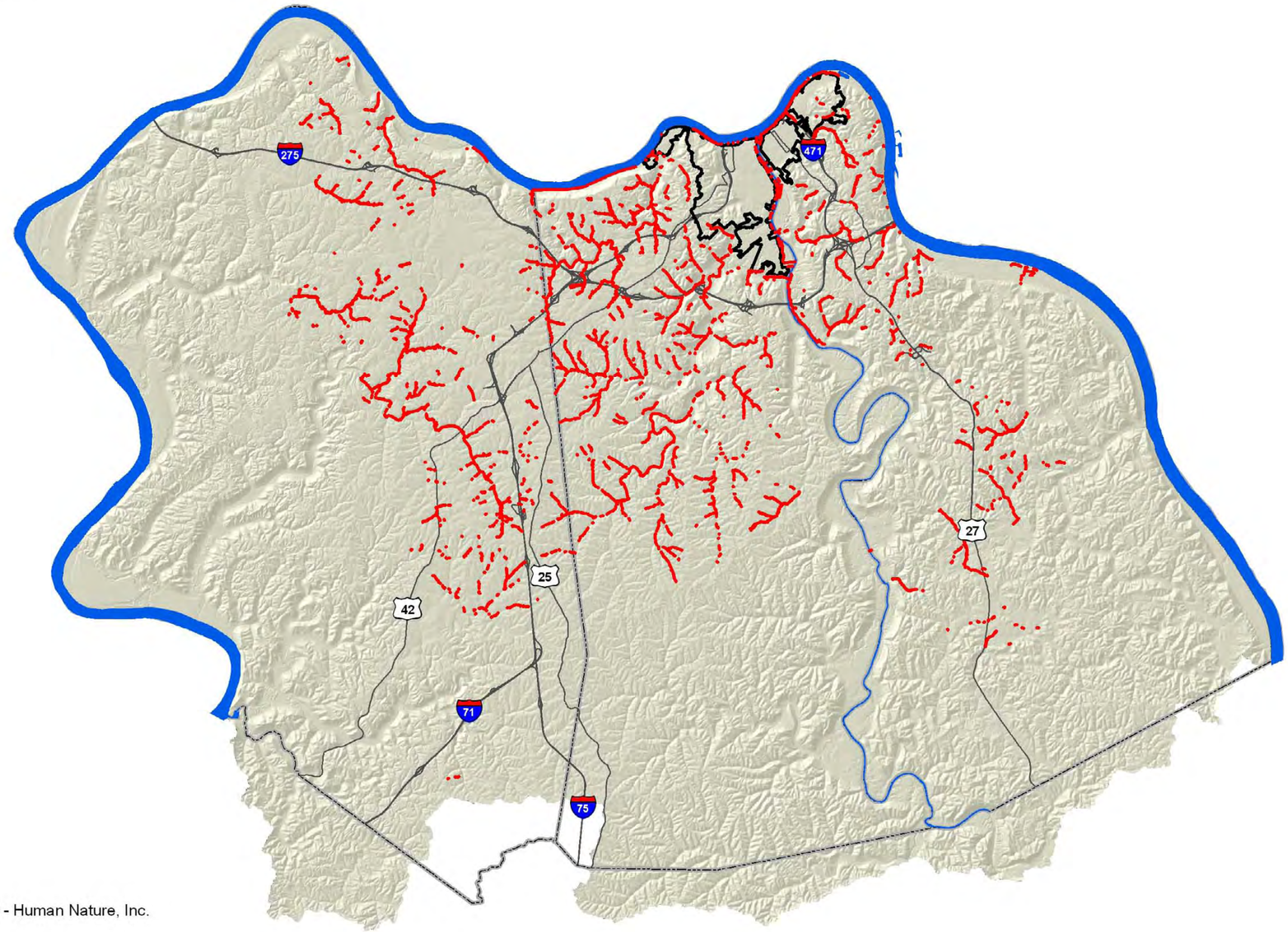
HUMAN NATURE
980 St. Paul Place
Cincinnati, OH 45206
T: 513.281.7211
F: 513.281.2243
www.humannature.cc



Legend

- Major Roads
- Sanitary and Combined Sewers
- Combined Sewer System Boundary
- County Boundary
- Rivers

Feature	Length (ft)	Length (miles)
Utility Type		-
Sanitary	1,069,154	202
Combined	29,145	6

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0 1 2 4
Miles

SEWERLINE WITHIN STREAM BUFFER

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990 St. Paul Place
Cincinnati, OH 45206
T: 513.281.2211
F: 513.281.2243
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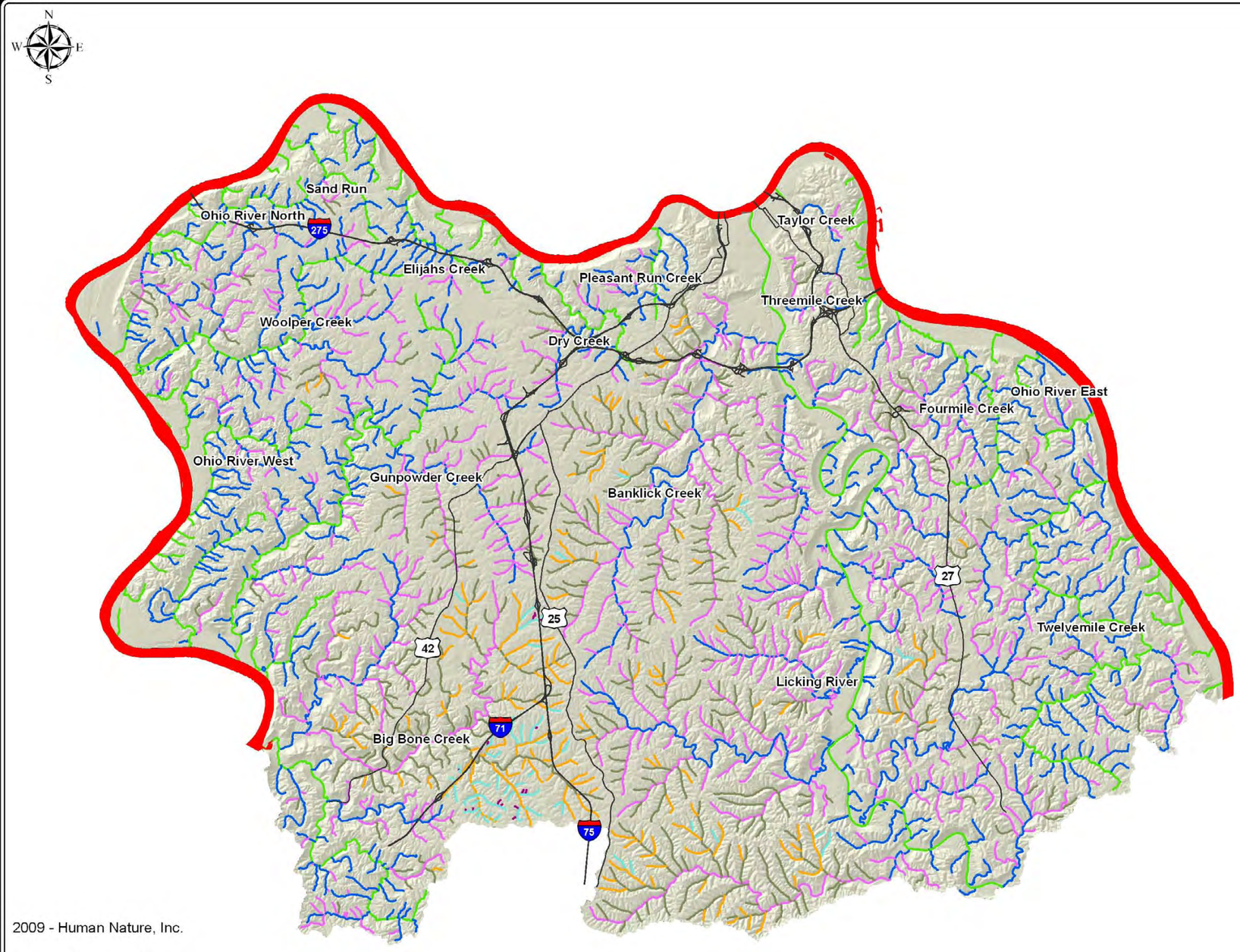


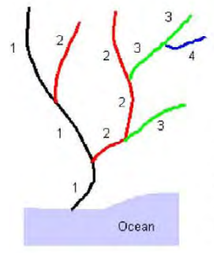
Legend

- Major Roads
- Ohio River (level 2)

Stream Level

- 3
- 4
- 5
- 6
- 7
- 8
- 9

- Stream order is a classification for measuring the relative size of streams. Stream sizes range from the largest, first-order, to the smallest, ninth-order. For example, the Ohio River is a second-order waterway. The Licking River flows into the Ohio River, and is classified as a third-order waterway. The Banklick Creek, which flows into the Licking River, is classified as a fourth-order waterway.



Source: NHD Stream Levels are categorized by USGS. Left image is from The Report of National Hydrography Dataset Concepts and Contents.

STREAM LEVEL

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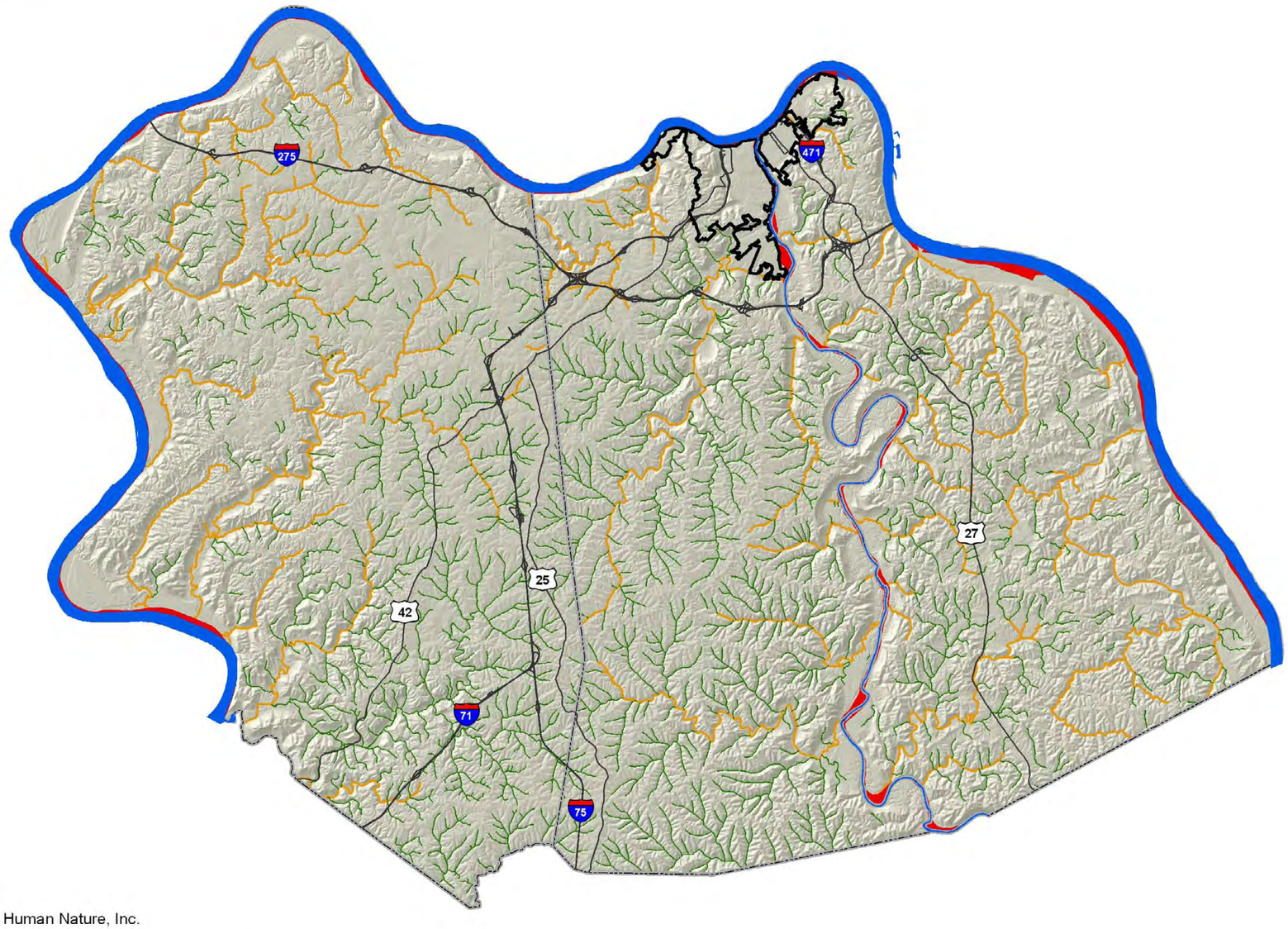

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0 2 4 8
Miles

Legend

- Major Roads
- Rivers and Streams
- Combined Sewer System Boundary
- County Boundary
- Group A Buffer
- Group B Buffer
- Group C Buffer

The following buffers were applied to all ranked streams in Northern Kentucky:

Group A
- Riparian buffer for both the Ohio and Licking rivers is recommended as the floodway boundaries plus an additional 50 feet on each side

Group B
- Riparian buffer for SD1 'Major Creeks' (those that are NHD level 3 and 4 streams) is recommended as 125 feet on each side, measured from the centerline

Group C
- Riparian buffer for all remaining streams (NHD levels 3 and 4 that are not SD1 'Major Creeks', and NHD levels 5 through 9) is recommended as 50 feet on each side, measured from the centerline

Recommendations:
- Riparian buffers can filter sediment from surface runoff, reduce nutrient concentrations, and even stabilize stream banks
- These systems provide a mechanism for connecting waterways and linking watersheds

STREAM BUFFER

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SANITATION DISTRICT NO.1 OF NORTHERN KY
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990 St. Paul Place
Cincinnati, OH 45206
T: 513.281.2211
F: 513.281.2243
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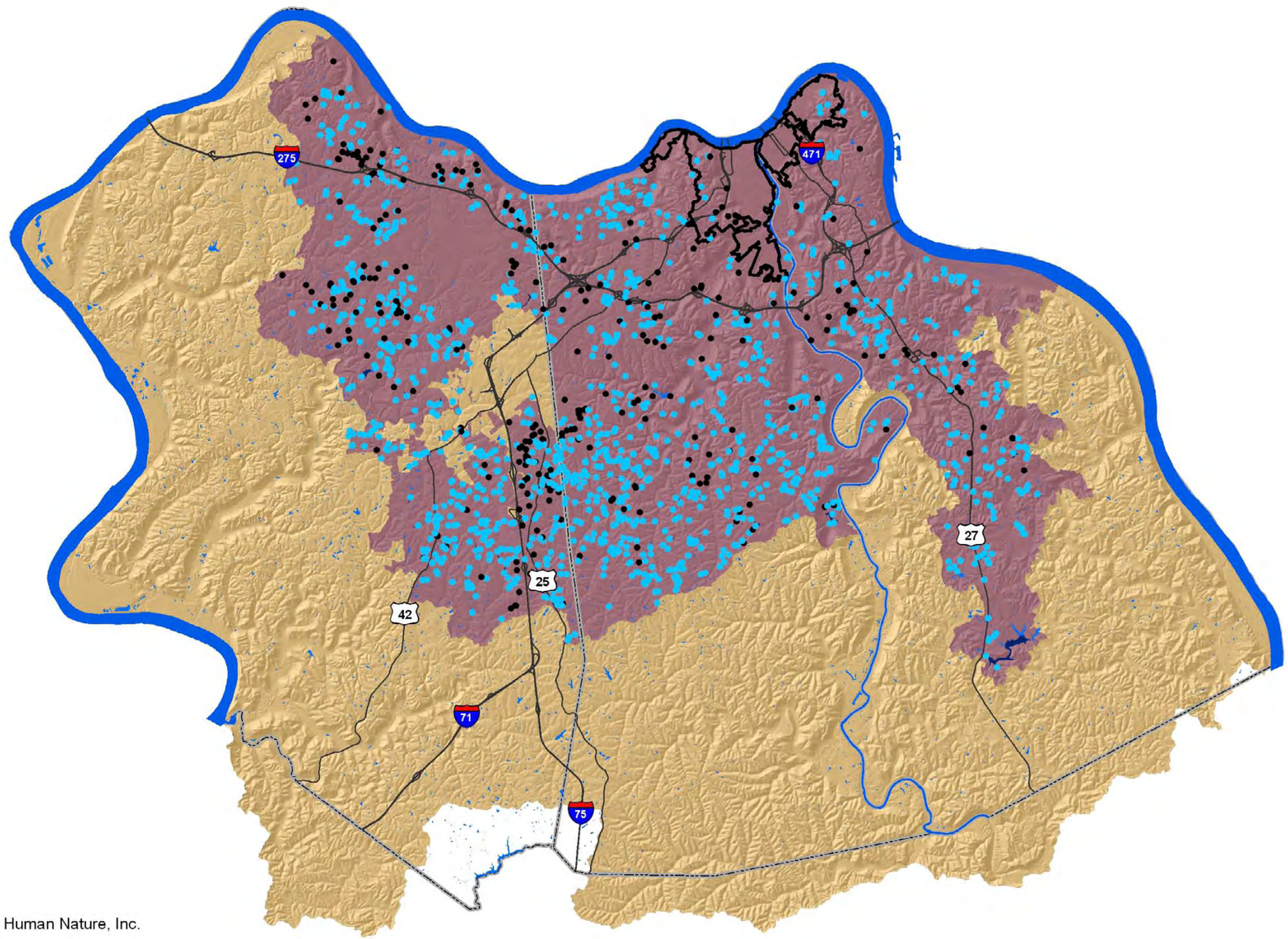

Legend

- Dry Ponds (284)
- Wet Ponds (1289)
- Major Roads
- Combined Sewer System Boundary
- wet Ponds (977 acres)
- Lakes
- County Boundary
- SD1 Storm Water Service Area

Note: There are 1,573 detention/retention points, 32 of them are within CSO service area.

DETENTION/RETENTION STRUCTURES

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T: 513.281.2211
F: 513.281.2242
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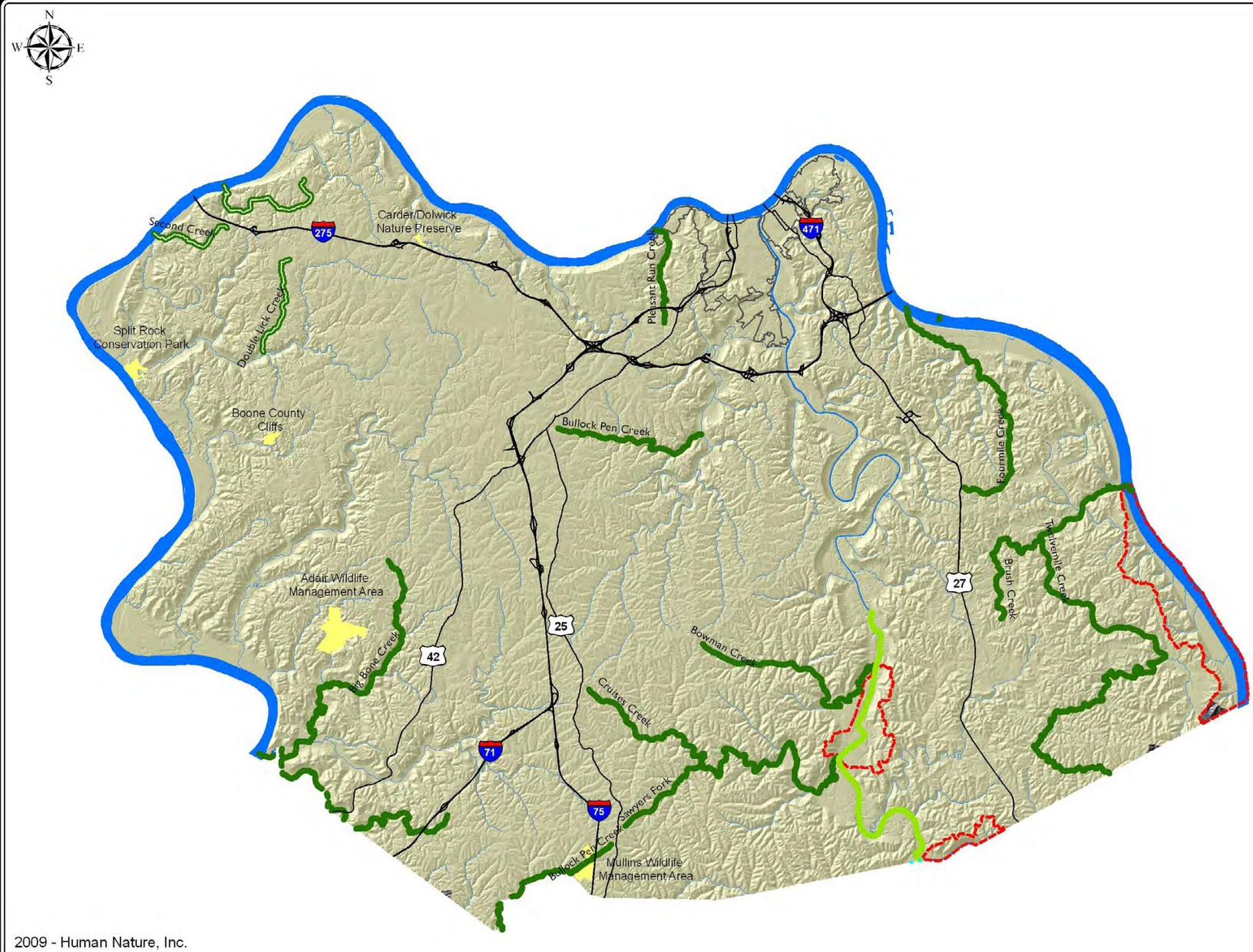

Legend

- Major Roads
- Rivers and Major Streams
- Kentucky Exceptional Waters*
- Outstanding State Resource Waters*
- Fully-Supporting Streams**
- Combined Sewer System Boundary
- Mussel Conservation Areas
- Wildlife Preserves

** Division of Water, Department for Environmental Protection, Kentucky Environmental and Public Protection Cabinet. 401 KAR 10:030. Antidegradation Policy Implementation Methodology. 2008.

* Kentucky Environmental and Public Protection Cabinet. 2008. The 2008 Integrated Report to Congress on the Condition of Water Resources in Kentucky, Volume I. Frankfort, KY: Division of Water.

CONSERVATION AREAS AND HIGH-QUALITY STREAMS

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T: 513.281.2211
F: 513.281.2242
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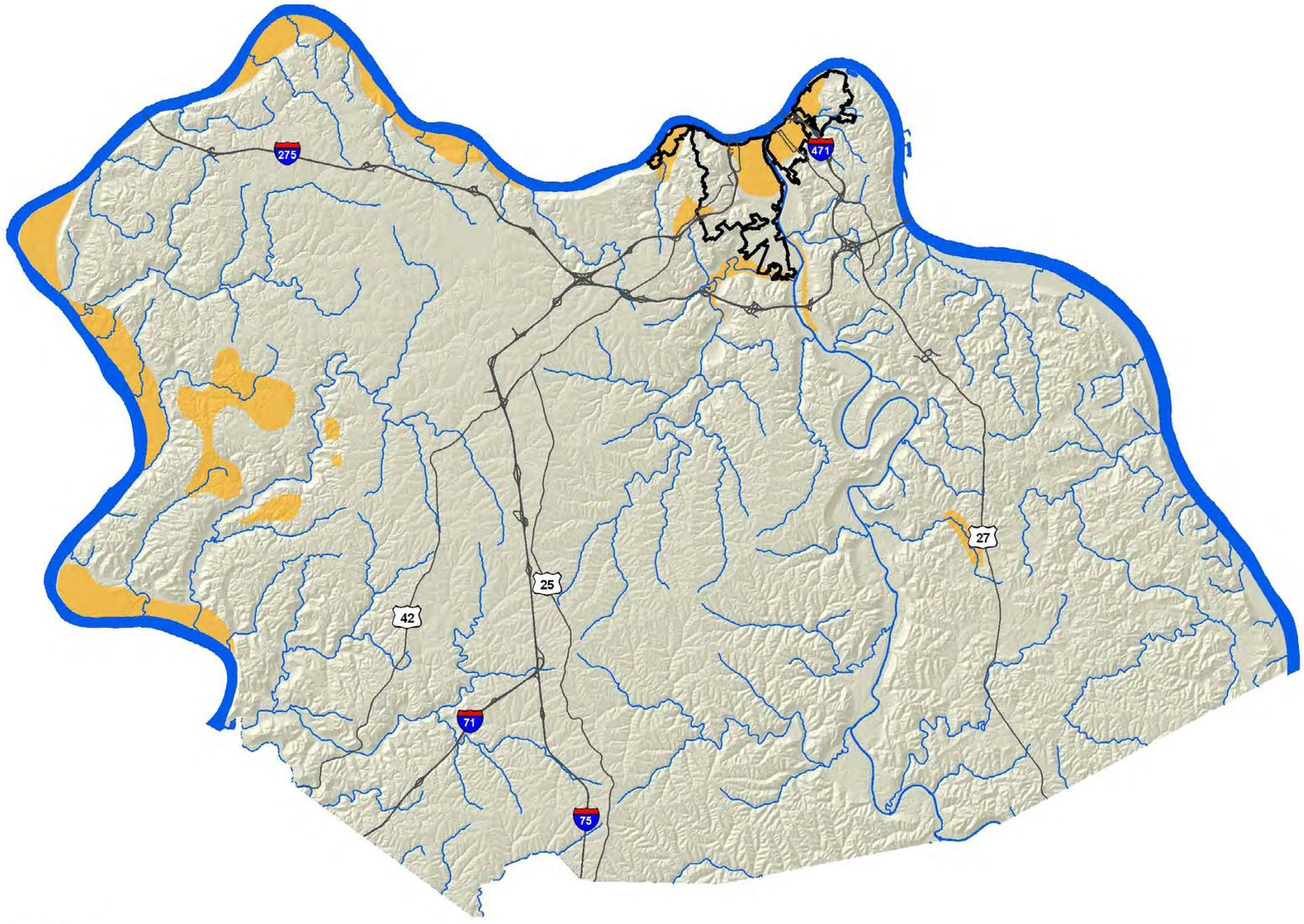

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0 1 2 4
Miles

Legend

- Major Roads
- River and Major Streams
- Combined Sewer System Boundary
- Drywell Opportunities (opportunity exists and needs to be further evaluated)

Source:
Drywell opportunities layer is digitized from drawings by Thelen Associates, Inc.

DRYWELL OPPORTUNITIES

(from depths of 6 feet to the top of the highly-permeable stratum or bedrock)

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F: 513.281.2243
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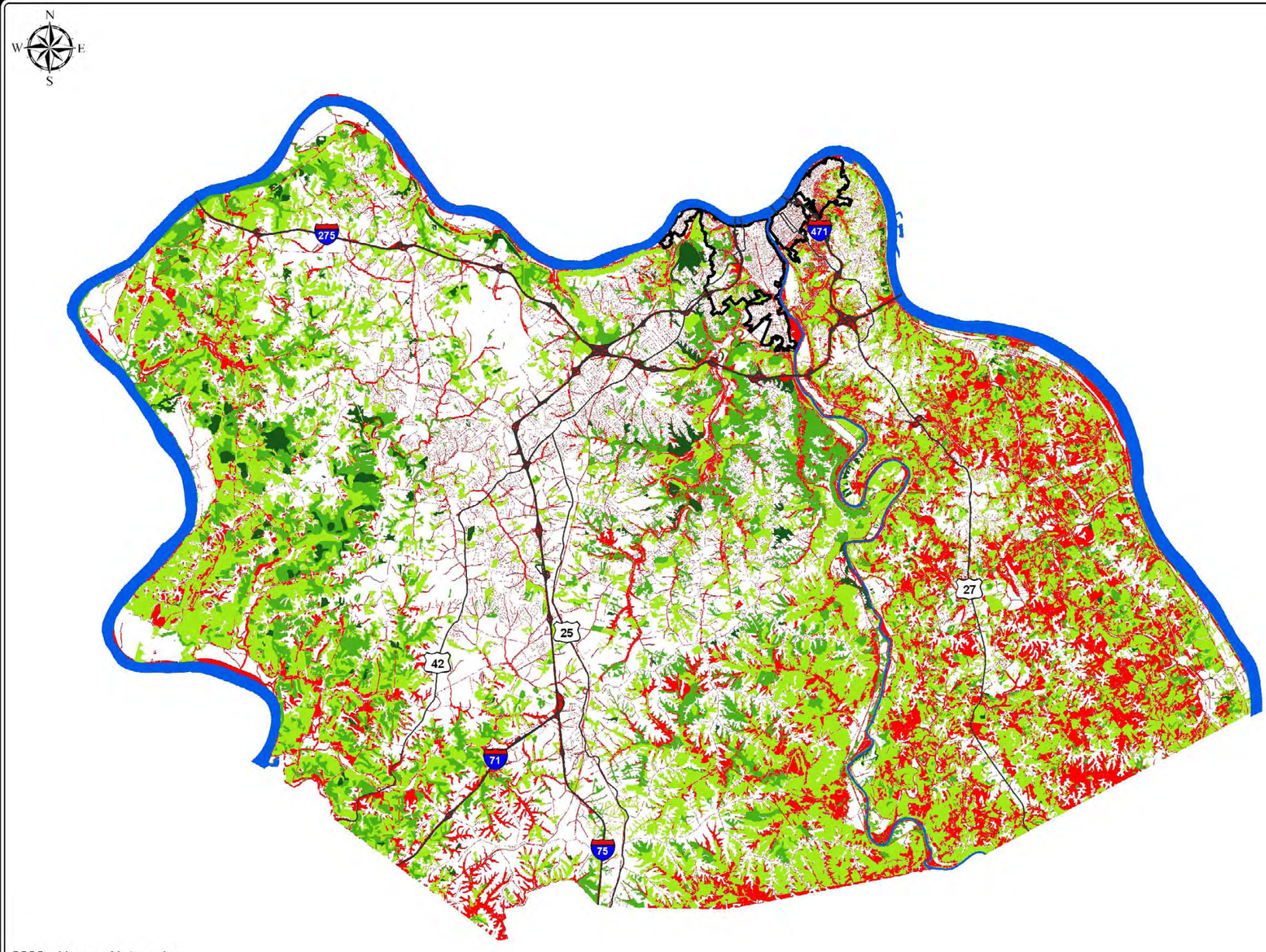

Legend

Canopy Crown Size

- Large Crown
- Medium Crown
- Small Crown
- Major Roads
- Combined Sewer System Boundary
- Canopy-Deficient Areas (62,193 acres)

Feature	Acres	Percent
Canopy	142,510	-
Large Crown	5,296	4%
Medium Crown	36,626	26%
Small Crown	100,588	71%
Right-of-Way	14,025	-
Without Tree Cover	2,195	16%
With Tree Cover	11,830	84%
LSPA	140,909	-
Without Tree Cover	92,505	66%
With Tree Cover	48,404	34%
Stream Buffer	22,046	-
Without Tree Cover	13,749	62%
With Tree Cover	8,297	38%

Source: Tree canopy layers are from Northern Kentucky Urban & Community Forestry Council

TREE DEFICIENCY

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HUMAN NATURE
950 St. Paul Place
Cincinnati, OH 45206
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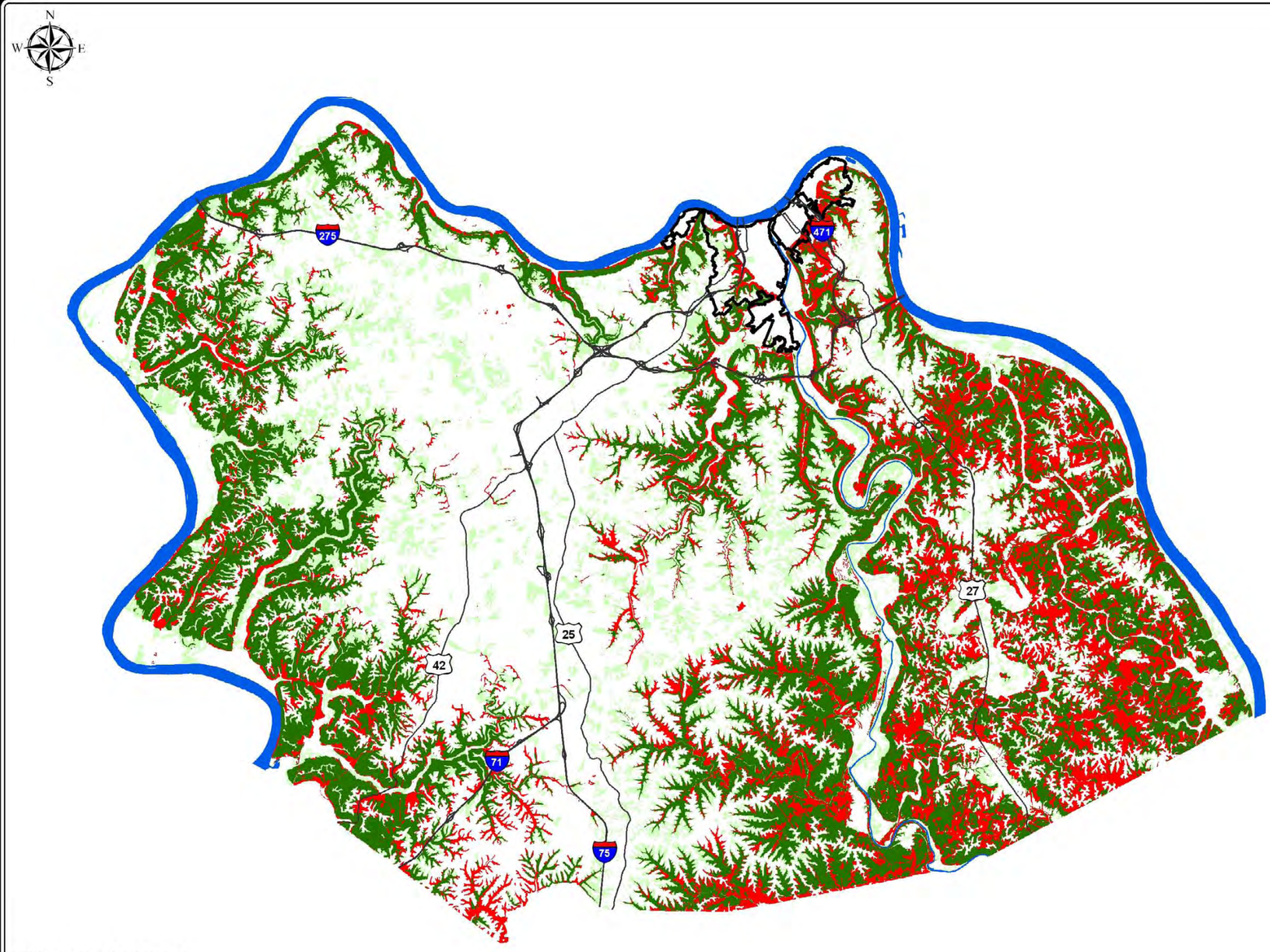

Legend

- Major Roads
- Combined Sewer System Boundary
- Rivers
- Existing Tree Canopy
- Landslide-Prone Area with Tree Cover
- Landslide-Prone Area without Tree Cover

Feature	Acres	Percent
Landslide-Prone Area	140,909	-
Without Tree Cover	92,505	65.6%
With Tree Cover	48,404	34.4%

- There are almost 141,000 acres of landslide-prone areas (LSPA) in Northern Kentucky
- 34 percent of LSPAs do not have significant tree cover
- LSPAs along the upper reaches of the Licking River and its tributaries do not have tree cover
- Campbell County has the most LSPAs without tree cover

Recommendation:
- Trees and forests greatly improve slope stability, and also help slow the velocity and reduce the volume of stormwater

Note:
Landslide-Prone Areas include areas with slopes of 20% and greater and/or areas which contain known soil/geologic fomation problems (e.g., kope formation).

LANDSLIDE-PRONE AREA AND TREE CANOPY COVER

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F: 513.281.2243
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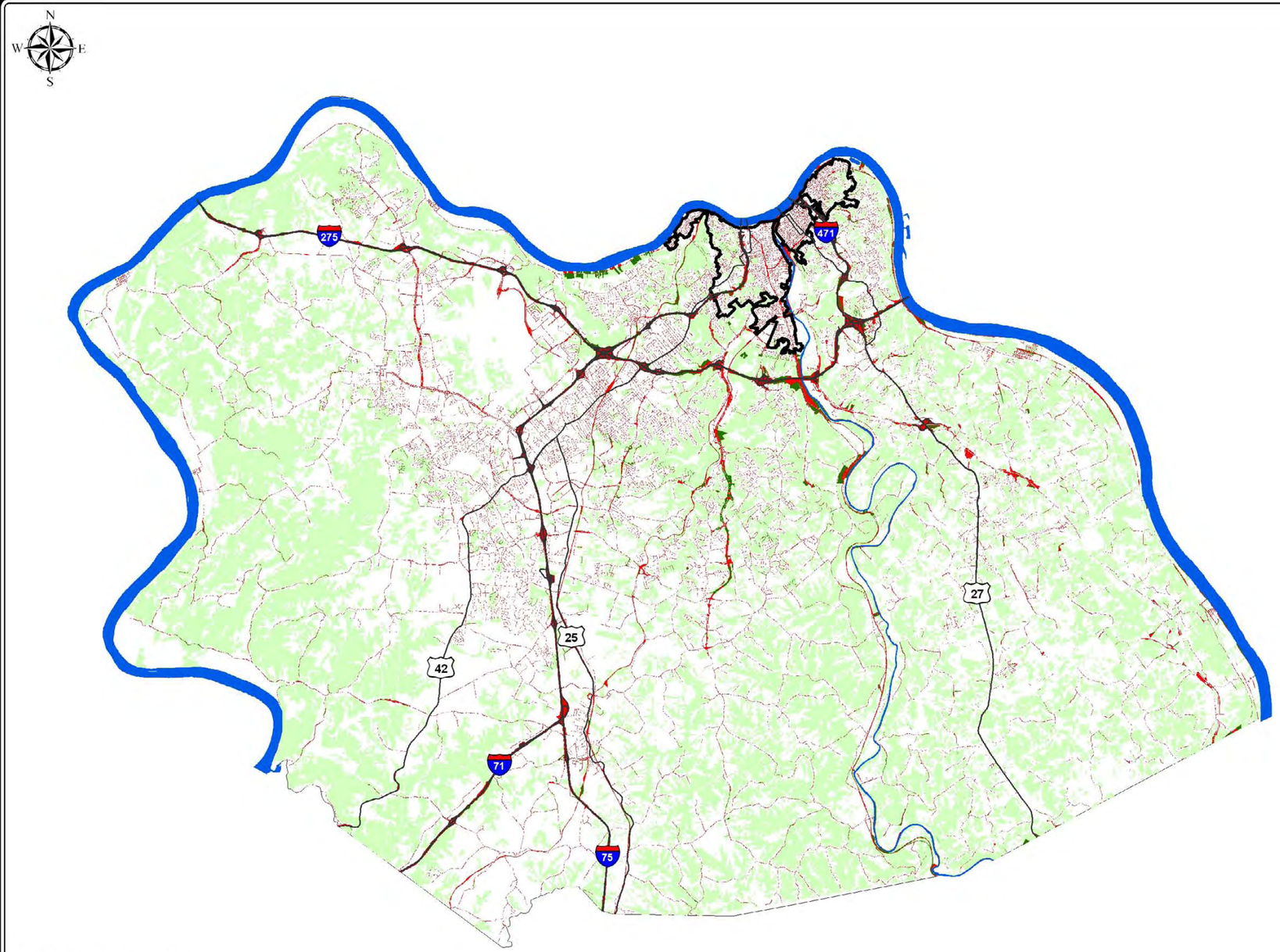

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0 2 4 8
Miles

Legend

- Major Roads
- Combined Sewer System Boundary
- Rivers
- Right-of-Way with Tree Cover
- Right-of-Way without Tree Cover
- Existing Tree Canopy

Feature	Acres	Percent
Right-of-Way	14,025	-
Without Tree Cover	2,195	15.7%
With Tree Cover	11,830	84.3%

- There are over 14,000 acres of right-of-way in Northern Kentucky
- Almost 85 percent of right-of-way does not have tree cover
- Tree cover is almost completely absent in right-of-way along the major interstates

Recommendations:
- In addition to reducing the volume of stormwater runoff, reforestation within right-of-way acts as an effective sound barrier, helps improve air quality, and can lessen the urban heat island effect

ROAD RIGHT-OF-WAY AND TREE CANOPY COVER

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950 St. Paul Place
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F: 513.281.2247
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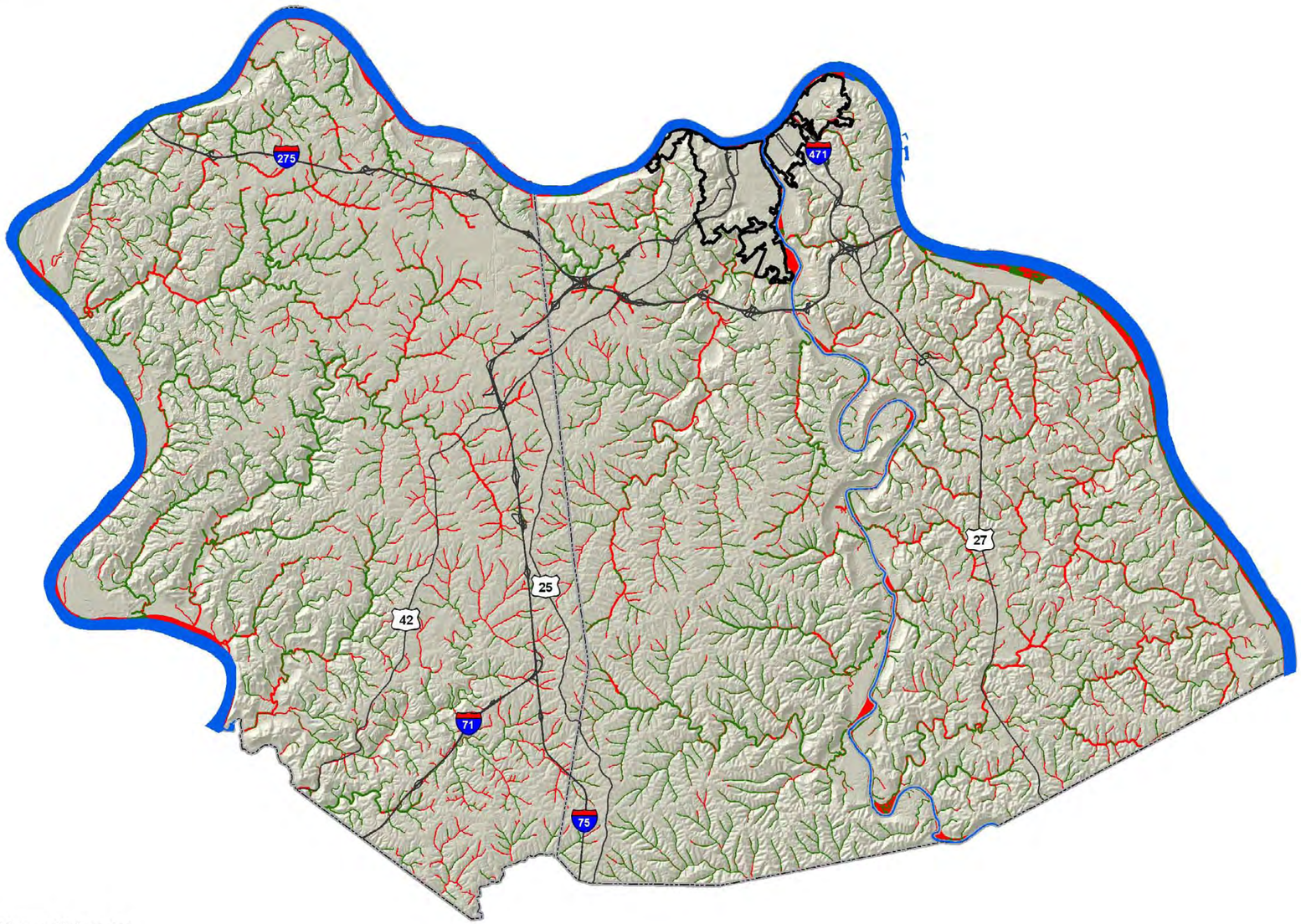

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0 2 4 8
Miles

Legend

- Major Roads
- Rivers and Streams
- Combined Sewer System Boundary
- County Boundary
- Buffer Area with Tree Cover
- Buffer Area without Tree Cover

Feature	Acres	Percent
Stream Buffer	22,046	-
Without Tree Cover	13,749	62.4%
With Tree Cover	8,297	37.6%

Riparian Buffer
The following buffers were applied to all ranked streams in Northern Kentucky:
Group A Buffer
- Riparian buffer for both the Ohio and Licking rivers is recommended as the floodway boundaries plus an additional 50 feet on each side
Group B Buffer
- Riparian buffer for SD1 'Major Creeks' (those that are NHD level 3 and 4 streams) is recommended as 125 feet on each side, measured from the centerline
Group C Buffer
- Riparian buffer for all remaining streams (NHD levels 3 and 4 that are not SD1 'Major Creeks', and NHD levels 5 through 9) is recommended as 50 feet on each side, measured from the centerline

The recommended buffers cover almost 22,000 acres, and based on this area:
- Almost 38 percent does not contain significant tree cover
- Almost 58 percent contains landslide-prone areas
- Almost 24 percent of the land use is agricultural
- 62 percent contains potential strategic partners (e.g., public lands, institutional properties, open space, etc.)

Recommendations:
- Riparian buffers can filter sediment from surface runoff, reduce nutrient concentrations, and even stabilize stream banks
- These systems provide a mechanism for connecting waterways and linking watersheds

STREAM BUFFER WITH/WITHOUT TREE COVER

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

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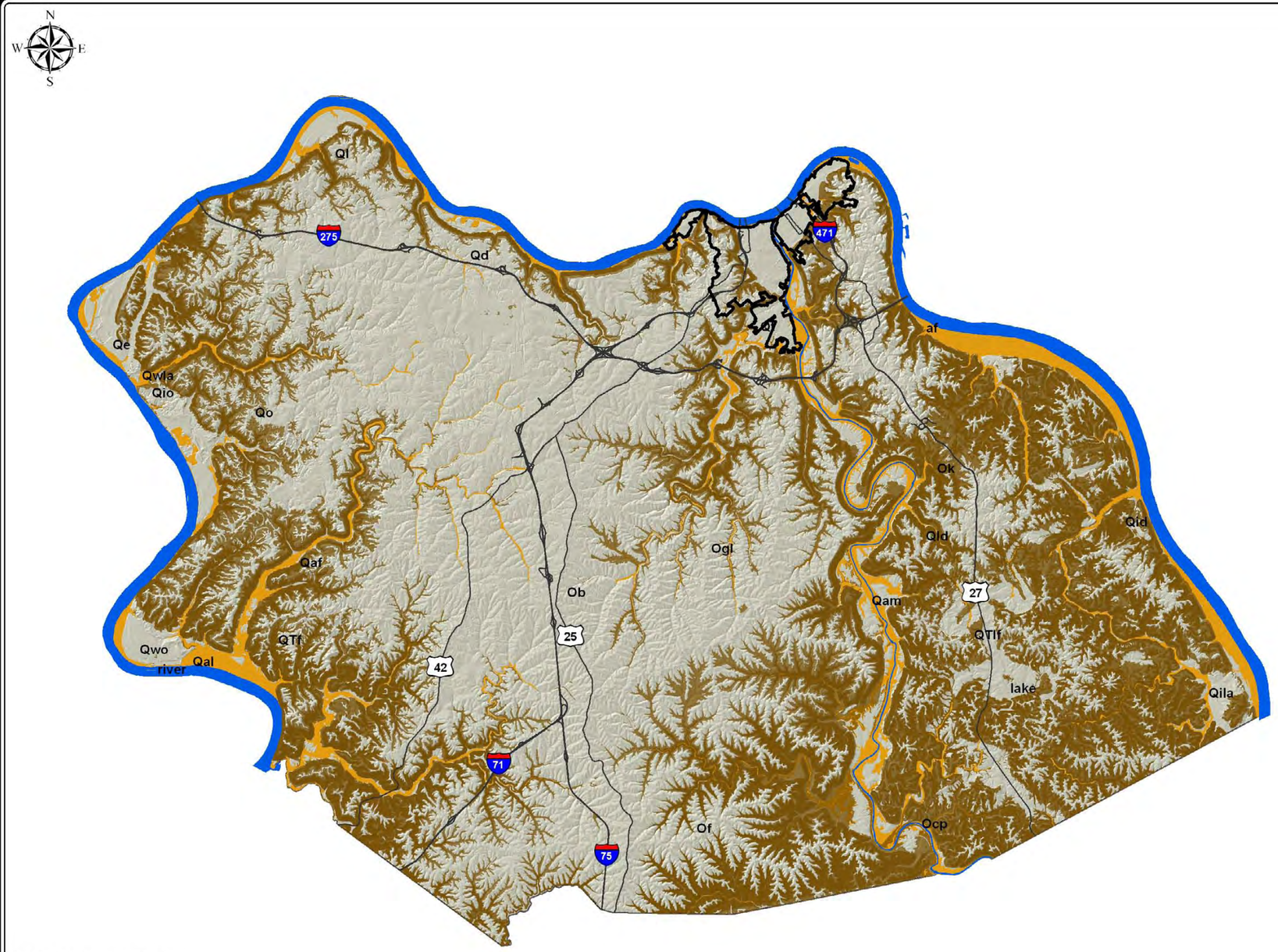
900 St. Paul Place
Cincinnati, OH 45206
T: 513.281.2211
F: 513.281.2243
www.humannature.cc



Legend

- Major Roads
- Combined Sewer System Boundary
- Rivers

Physically-Restricted Development Areas (PRDA)

- Landslide-Prone Areas/Kope Formation
- Flood-Prone Areas

Feature	Acres	Percent
Physically-Restricted Development Areas	182,738	-
Landslide-Prone Areas	146,416	80%
Flood-Prone Areas	36,322	20%

Note: Physically-Restricted Development Areas are areas which are flood-prone (within the 100-year flood plain) and/or landslide prone (slopes of 20% and greater) and/or areas which contain known soil/geologic fomation problems like kope formation.

PHYSICALLY-RESTRICTED DEVELOPMENT AREAS

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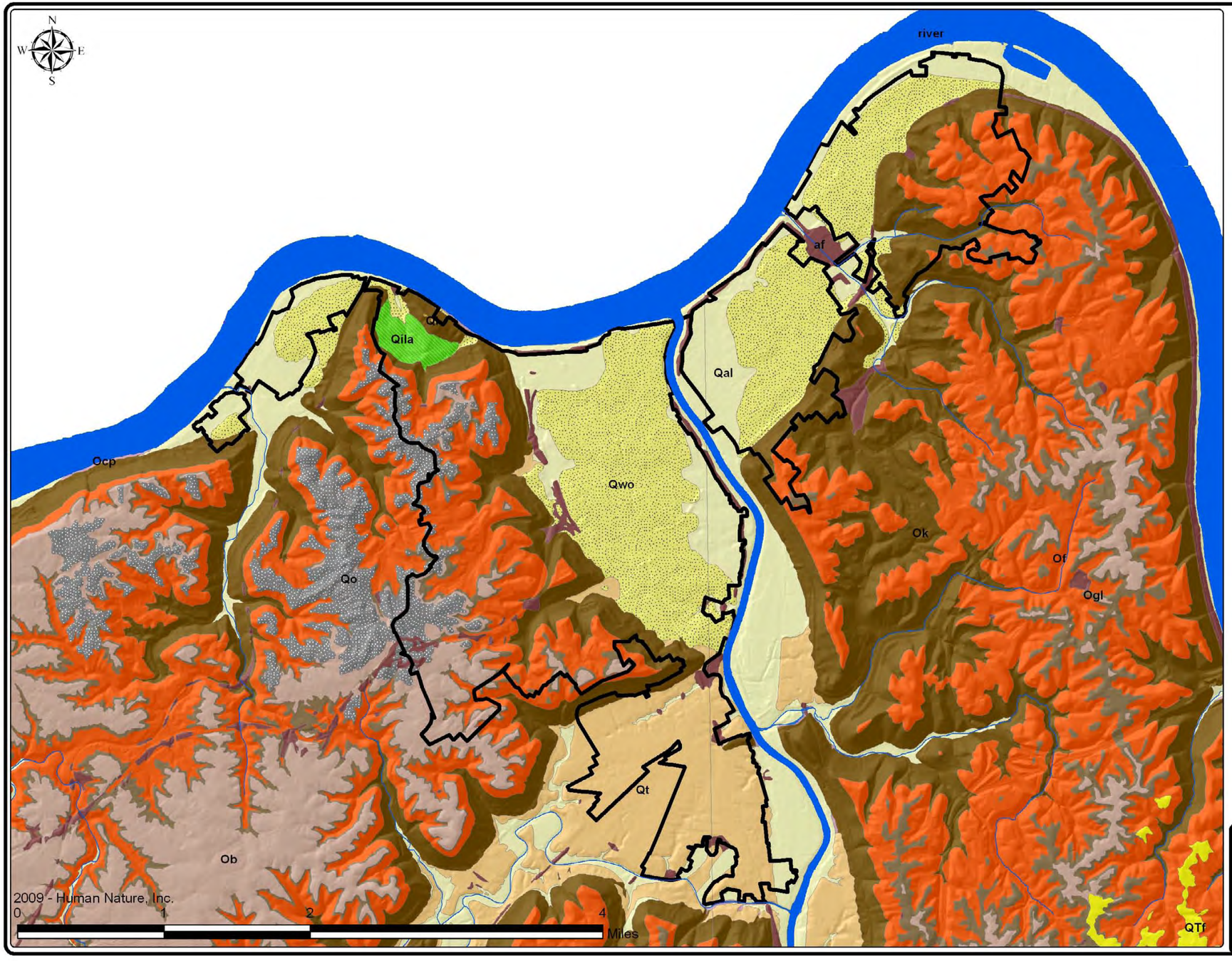

Legend

- River and Major Streams
- Major Roads
- Combined Sewer System Boundary

KGS Detailed Geology

- Qaf - Alluvial Fan Deposits
- Qal - Alluvium
- Qam - Alluvium of valley sides, etc.
- af - Artificial fill
- Ob - Bull Fork Formation
- Qe - Eolian sand, dune sand
- Of - Fairview Formation
- Qid - Glacial drift (Illinoian)
- Qd - Glacial drift (pre-Illinoian)
- Qio - Glacial outwash (Illinoian)
- Qwo - Glacial outwash (Wisconsinan)
- Qgl - Grant Lake Limestone
- QTf - High-level fluvial deposits
- Ok - Kope Formation
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- Qila - Lacustrine deposits (Illinoian)
- Qwla - Lacustrine deposits (Wisconsinan)
- Lake - Lake area
- Qld - Landslide and alluvial fan deposits
- Ql - Loess
- Qo - Outwash deposits (pre-Illinoian)
- Ocp - Point Pleasant Tongue of Clays Ferry Formation
- River - River area
- Qt - Terrace deposits

Source:
Geology layer is from Kentucky Geological Survey (KGS)

DETAILED GEOLOGY

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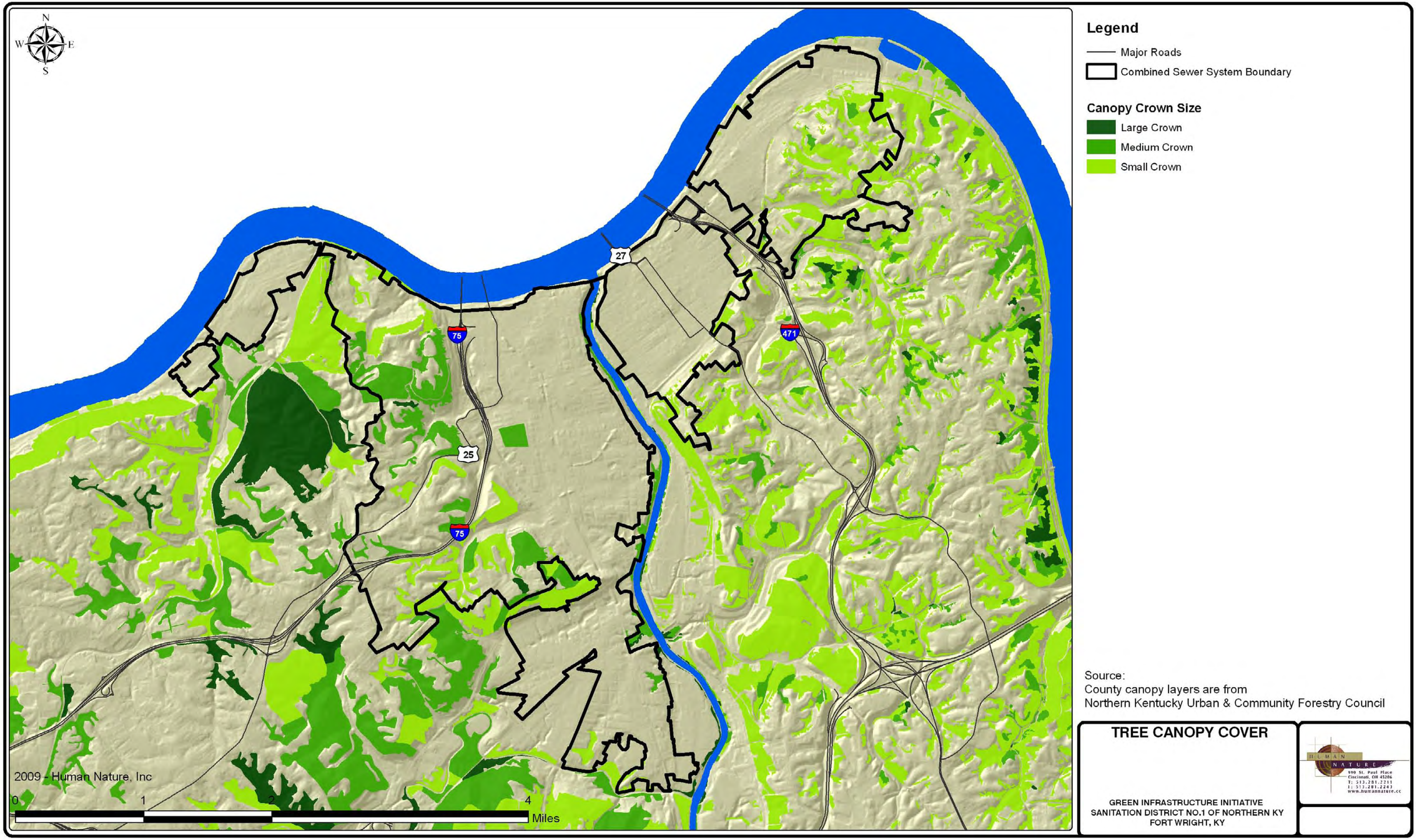

Legend

- Major Roads
- Combined Sewer System Boundary

Canopy Crown Size

- Large Crown
- Medium Crown
- Small Crown

Source:
County canopy layers are from
Northern Kentucky Urban & Community Forestry Council

TREE CANOPY COVER

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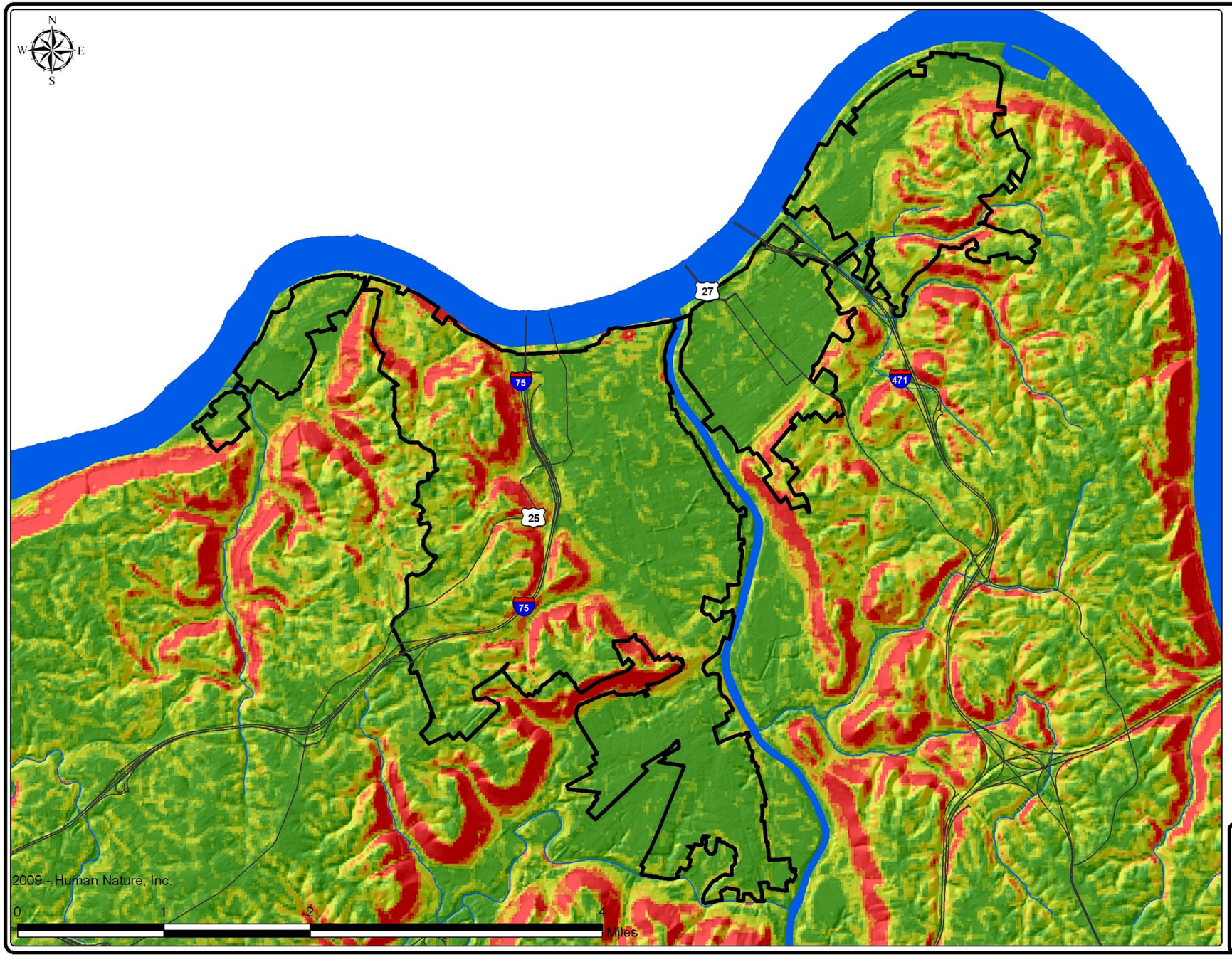

Legend

- Major Roads
- River and Major Streams
- Combined Sewer System Boundary

Slope (Percent)

- 0 - 5
- 5 - 8
- 8 - 15
- 15 - 20
- 20 - 25
- 25 +

Features	Acres	Percent
Total Area	6,036	-
Slope over 20%	922	15.3%

SLOPES

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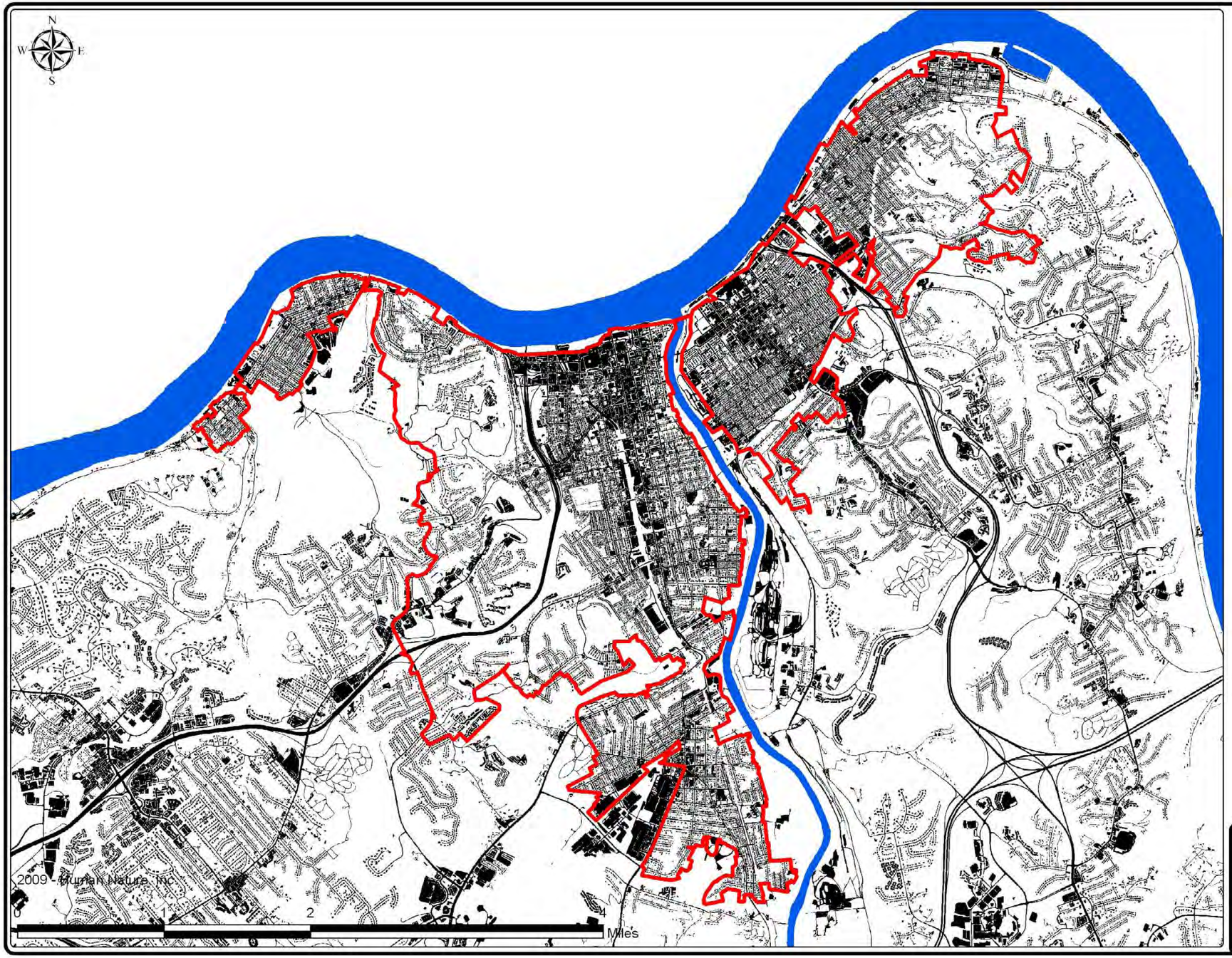

Legend

- Combined Sewer System Boundary
- Rivers
- Impervious Surfaces

Feature	Acres	Percent
Combined Sewer System (CSS)	6,036	-
Impervious Surfaces	2,155	35.7%

- Impervious surfaces include buildings, pavement, roadways and highways, and bridges.
- Semi-Impervious surfaces include bridges, unpaved roads and parking lots, and railroads.
- The Combined Sewer System has 2,155 acres of impervious surfaces, representing 36% of total area.

Recommendation:
- Impervious surfaces greatly reduce infiltration and evaporation and, therefore, contribute to increased volumes of stormwater runoff entering the Licking and Ohio rivers

IMPERVIOUS SURFACES

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SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

MUMIAN NATURE
990 St. Paul Place
Cincinnati, OH 45206
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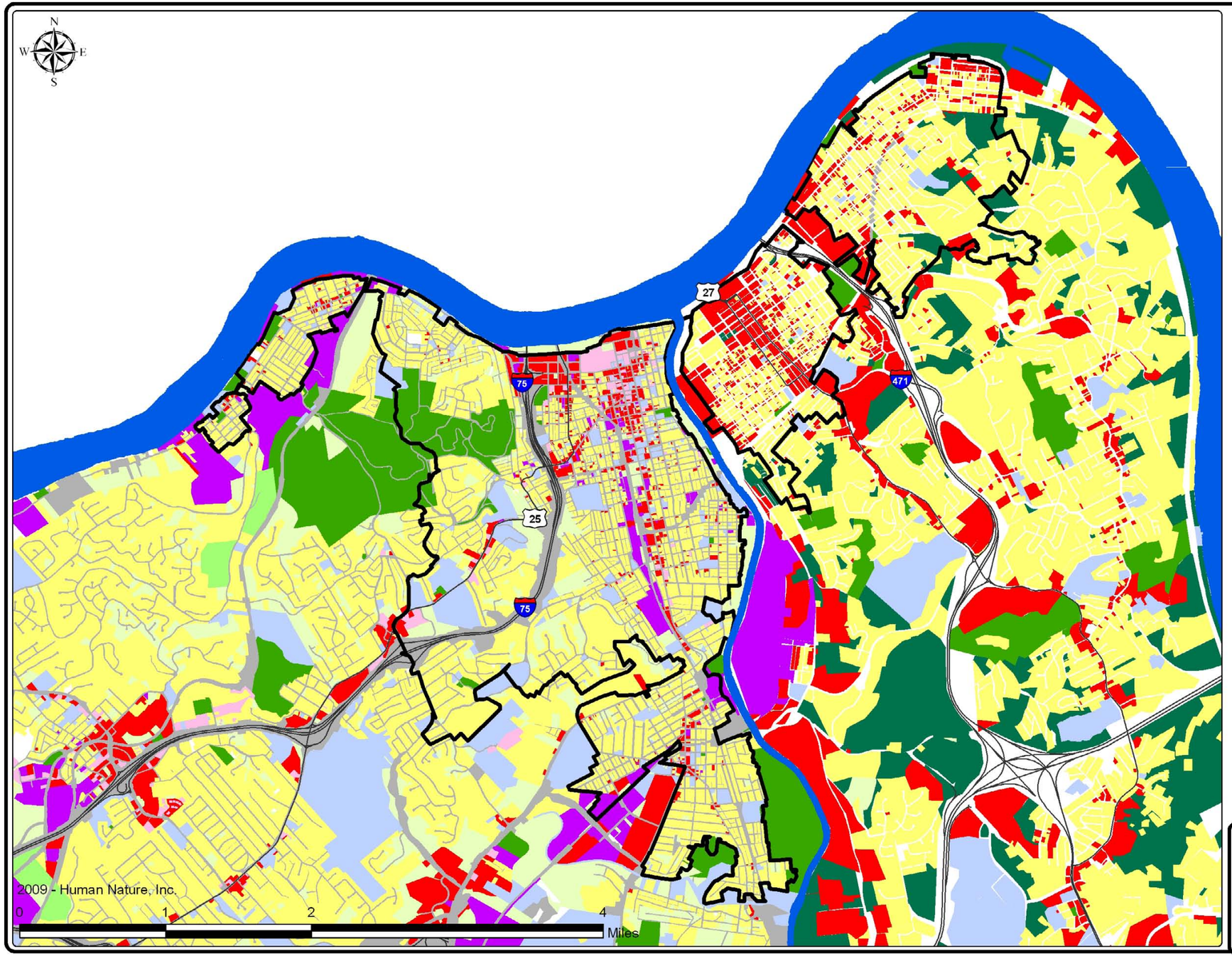
www.mumiannature.com



Legend

- Major Roads
- Combined Sewer System Boundary

Land Use Type

- Road Right-of-Way
- Agricultural
- Commercial
- Industrial
- Mixed-use
- Office
- Public/Semi-public/Institutional
- Residential
- Recreational
- Airport/ROW/Railroad
- Undeveloped
- Woodland

Note:
Land uses are not verified by field survey for the following cities: Bellevue, Newport, Wilder, Fort Thomas, Highland Heights, Cold Spring, Alexandria, California, and Mentor.

EXISTING LAND USE

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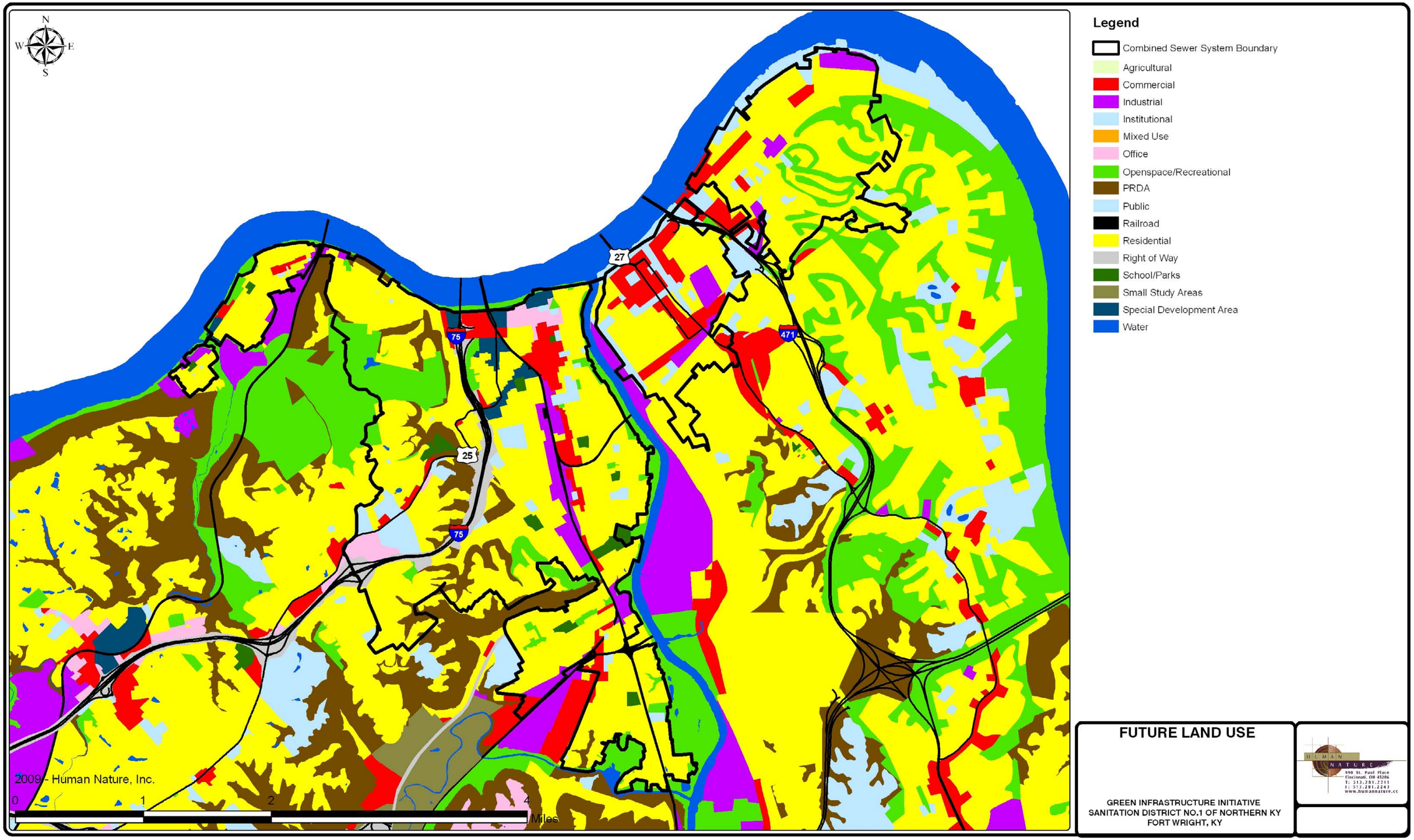

FUTURE LAND USE

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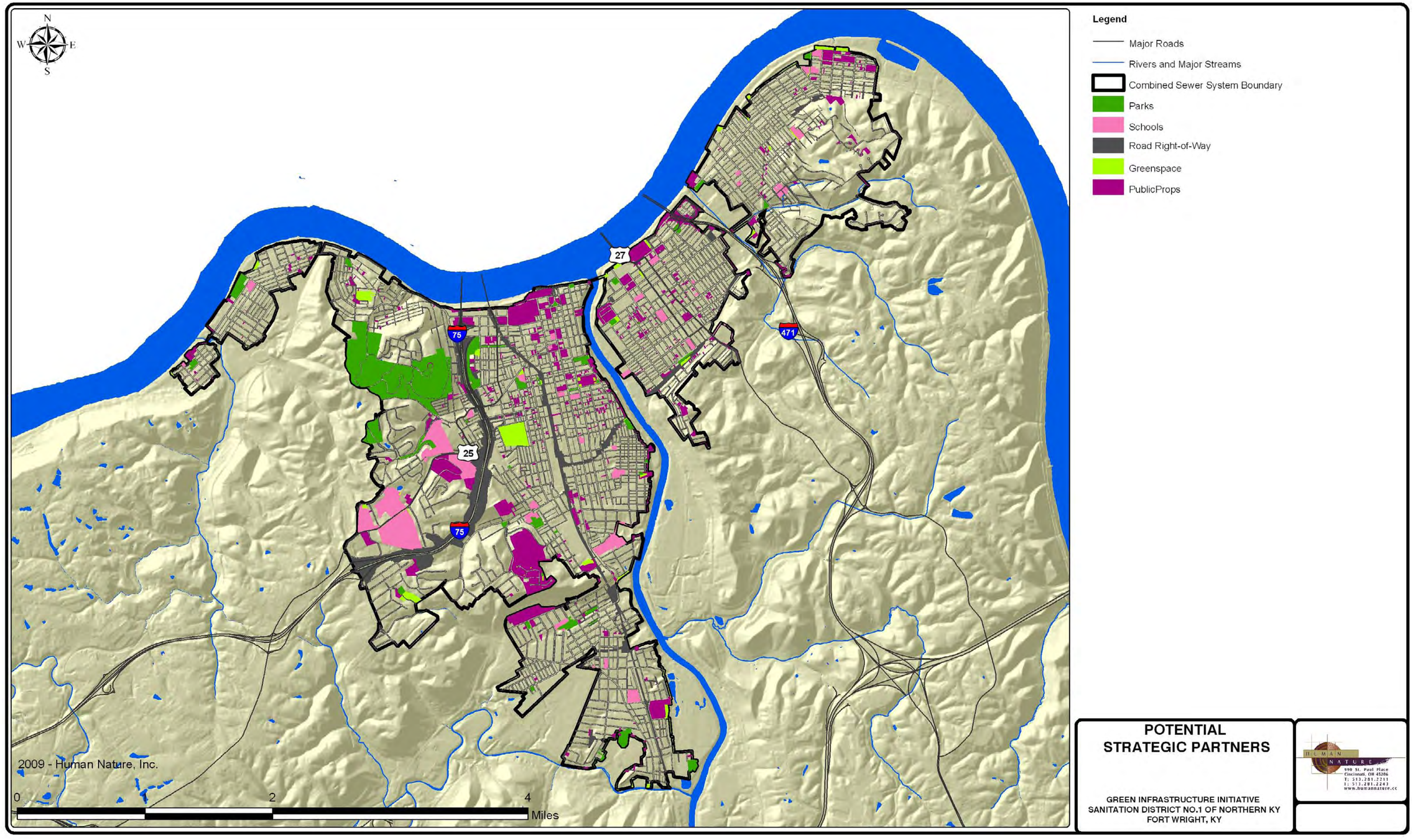

POTENTIAL STRATEGIC PARTNERS

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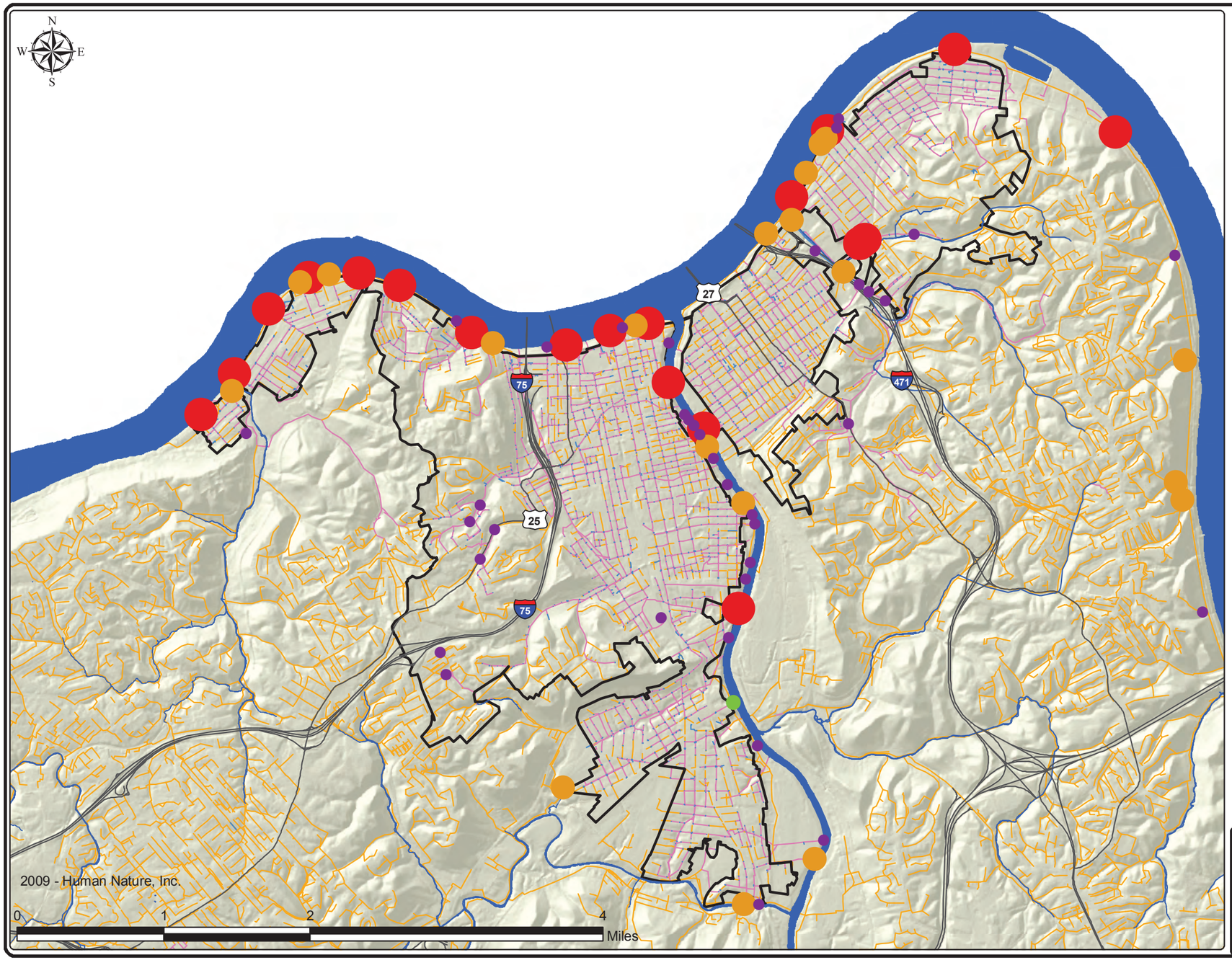

Legend

Combined Sewer System Boundary

Activations of CSO Points

- 0-10 per year (36 total)
- 11-30 per year (22 total)
- 31-60 per year (21 total)
- Greater than 60 (18 total)

Major Roads

River and Major Streams

Utility Flow Type

Combined

Separate Sanitary

Separate Storm

Data for the number of CSO activations is based on annual simulations with SD1's 2008 refined calibrated system-wide model using SD1's selected typical year of 1970.

COMBINED SEWER OVERFLOWS - ANNUAL ACTIVATIONS

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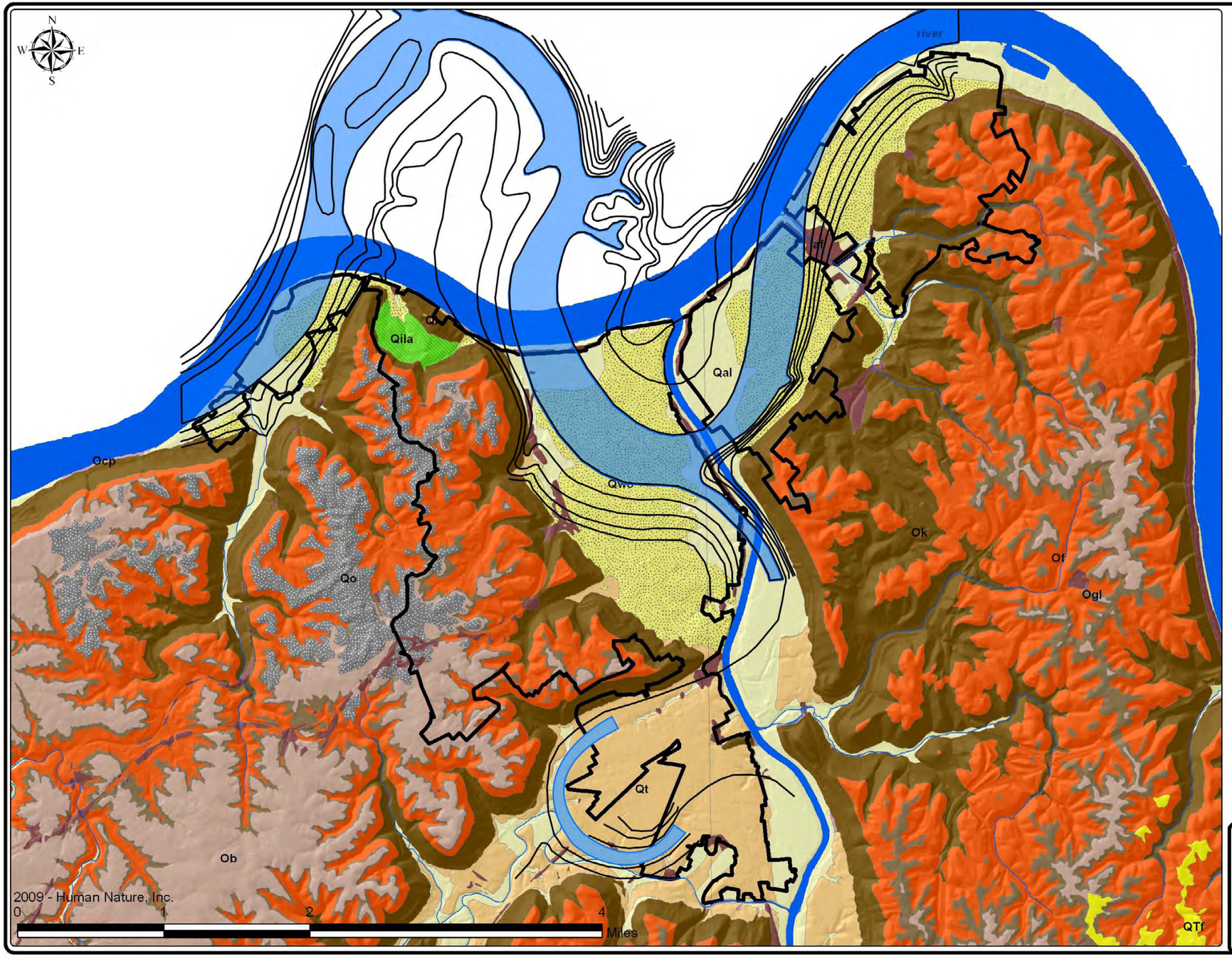
550 St. Paul Place
Cincinnati, OH 45206
T: 513.281.2241
F: 513.281.2245
www.humannature.cc



Legend

- River and Major Streams
- Major Roads
- Combined Sewer System Boundary

KGS Detailed Geology

- Qaf - Alluvial Fan Deposits
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- Ocp - Point Pleasant Tongue of Clays Ferry Formation
- River - River area
- Qt - Terrace deposits

Source:
Geology layer is from Kentucky Geological Survey (KGS)

HISTORIC GEOLOGY

GREEN INFRASTRUCTURE INITIATIVE
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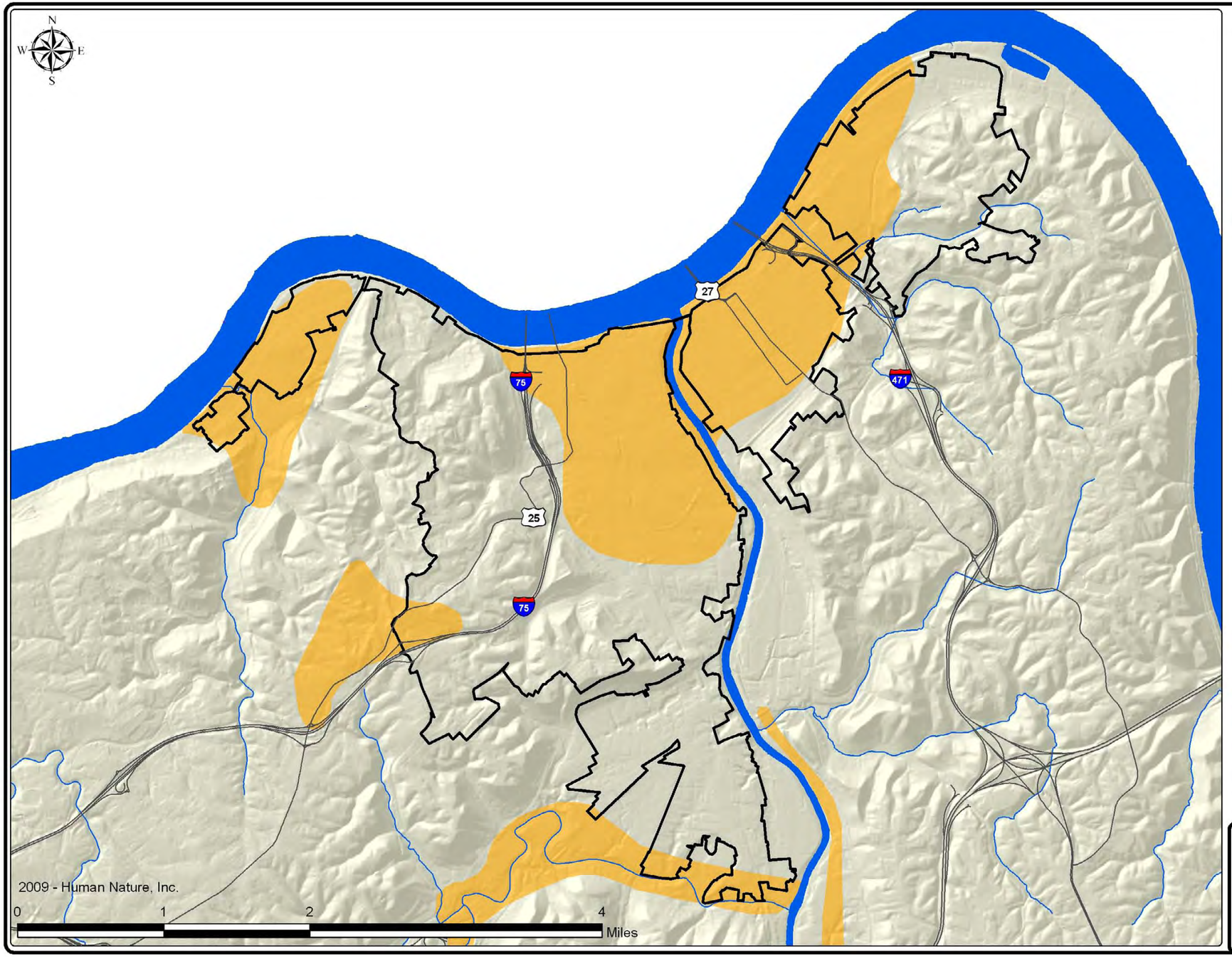

Legend

- Major Roads
- River and Major Streams
- Combined Sewer System Boundary
- Drywell Opportunities (opportunity exists and needs to be further evaluated)

Source:
Drywell opportunities layer is digitized from drawings by Thelen Associates, Inc.

DRYWELL OPPORTUNITIES

(from depths of 6 feet to the top of the highly-permeable stratum or bedrock)

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HUMAN NATURE
980 St. Paul Place
Cincinnati, OH 45206
T: 513.281.7211
F: 513.281.2243
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REGIONAL GREEN INFRASTRUCTURE reforestation strategies

legend

- Reforestation of riparian forests
- Reforestation along major rivers
- Reforestation along right-of-way
- Reforestation of landslide-prone areas
- Strategic partner properties
- Existing forest canopy cover

AN miles 0 2 4

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	Riparian Forests		Right-of-Way		Steep Slopes	
Additional Storage Volume	**85.1**	million gallons	**60.2**	million gallons	**398**	million gallons
Potential Stormwater Benefit	**$22.7**	million	**$16.1**	million	**$106**	million

* All values based on CITYgreen analysis of land cover and 2-year, 24-hour rainfall of 2.75 inches

recommendations

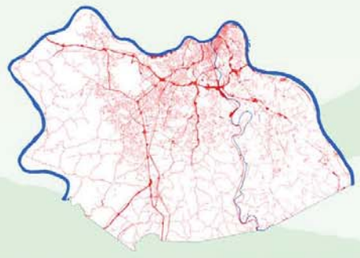
1. FILL GAPS IN RIPARIAN FORESTS

In addition to protecting the region's valuable stock of freshwater resources, riparian buffers can filter sediment from surface runoff, reduce nutrient concentrations, and even stabilize stream banks. The recommended stream buffers cover almost 22,000 acres in Northern Kentucky.

- 38 percent does not contain significant tree cover

2. REFOREST ROAD RIGHT-OF-WAY

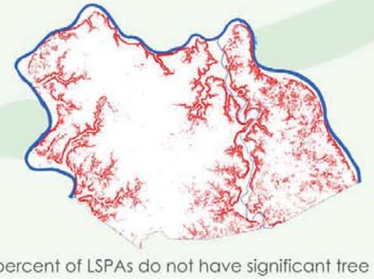
In addition to reducing the volume of stormwater runoff, reforestation within right-of-way acts as an effective sound barrier, helps improve air quality, and can lessen the urban heat island effect. There are over 14,000 acres of right-of-way in Northern Kentucky.



- 85 percent of right-of-way does not have tree cover

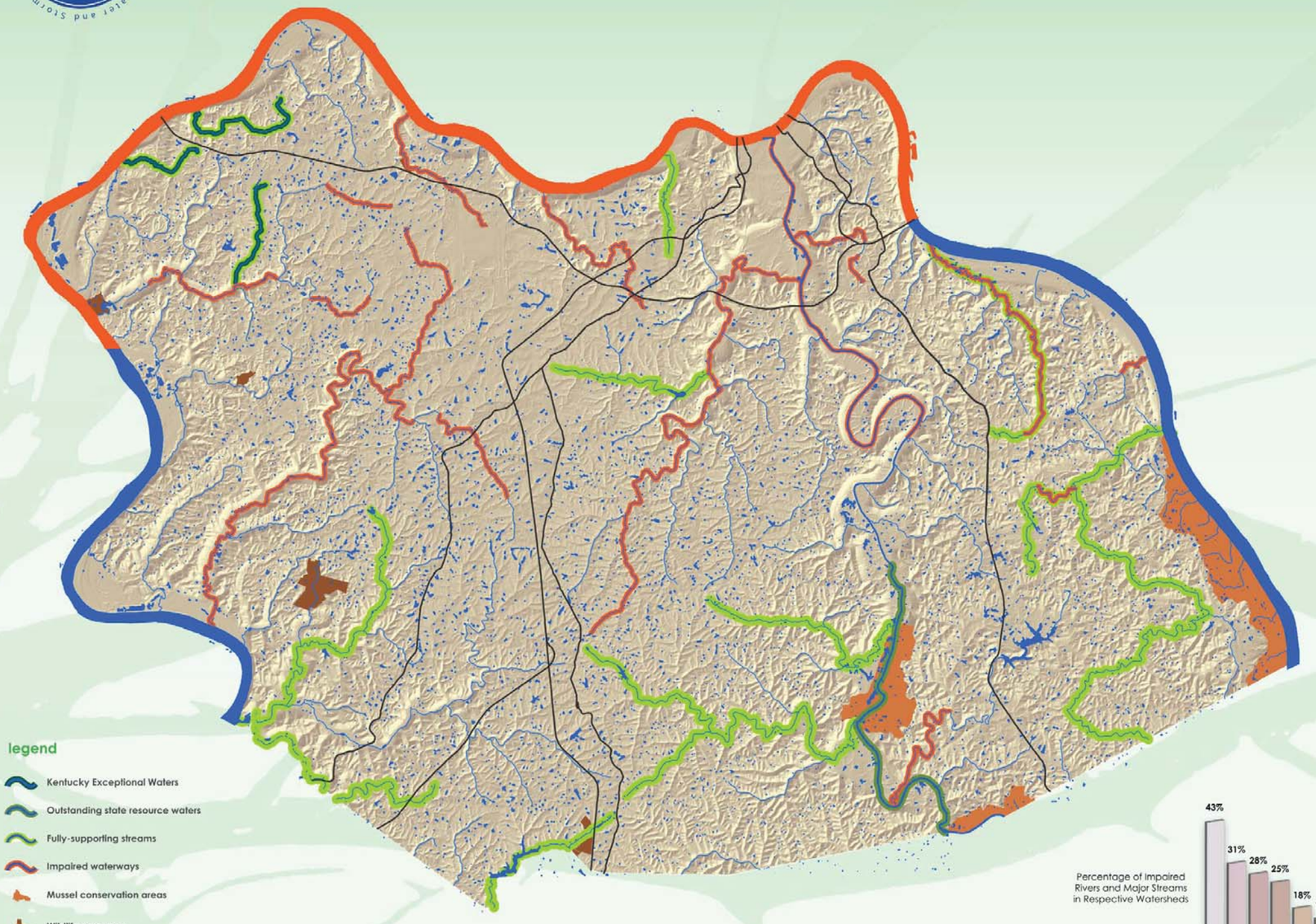
3. REFOREST STEEP SLOPES

Landslide-prone areas (LSPA) include areas with slopes greater than 20 percent and/or areas with known geologic instability. Trees and forests greatly improve slope stability, and also help slow the velocity and reduce the volume of stormwater. There are almost 141,000 acres of LSPA in Northern Kentucky.



- 34 percent of LSPAs do not have significant tree cover

PROTECTING WATER RESOURCES: conservation & restoration



The State of Kentucky establishes water quality standards in order to comply with regulations within the Clean Water Act. The Kentucky Division of Water (KDOW), a branch within the state's Natural Resources and Environmental Protection Cabinet, maintains water quality standards in Chapter 10 of the *Kentucky Administrative Regulations* (KAR).

conservation

Northern Kentucky possesses a valuable stock of rivers, streams, creeks, and aquatic habitat. These water resources are vital to the health of the watersheds in the region. There are almost 130 total miles of streams and rivers that are recognized in the state's antidegradation policy[1].

7.9 miles
of Kentucky Exceptional Waters

- Double Lick Creek
- Second Creek
- Garrison Creek

16.7 miles
of Outstanding State Resource Waters

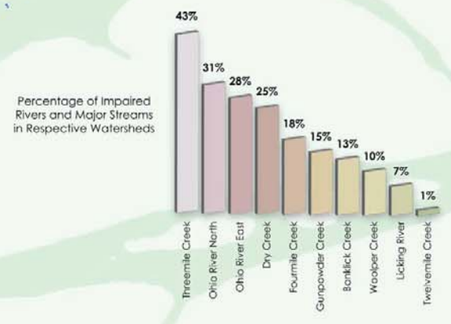
- Licking River

104 miles
of streams fully supporting warm aquatic habitat

3,410 acres
of existing surface waters

restoration

KDOW also identifies and prioritizes all of the state's impaired waters, or those that do not meet state water quality standards. Impaired waters are summarized in a biannual report titled Kentucky Report to Congress on Water Quality, or the 305(b) Report[2,3]. In the 2008 version of the report, there were 183 miles of streams and rivers in Northern Kentucky that were listed as impaired. The corresponding bar chart shows the percentage of impaired rivers and streams compared to the total length of rivers and streams in each watershed.



183 miles
of impaired streams and rivers

[1] Division of Water, Department for Environmental Protection, Kentucky Environmental and Public Protection Cabinet. 401 KAR 10:030. *Antidegradation Policy Implementation Methodology*. 2008.

[2] Kentucky Environmental and Public Protection Cabinet. 2008. *The 2008 Integrated Report to Congress on the Condition of Water Resources in Kentucky*, Volume I. Frankfort, KY: Division of Water.

[3] Kentucky Environmental and Public Protection Cabinet. 2008. *The 2008 Integrated Report to Congress on the Condition of Water Resources in Kentucky*, Volume II. Division of Water.

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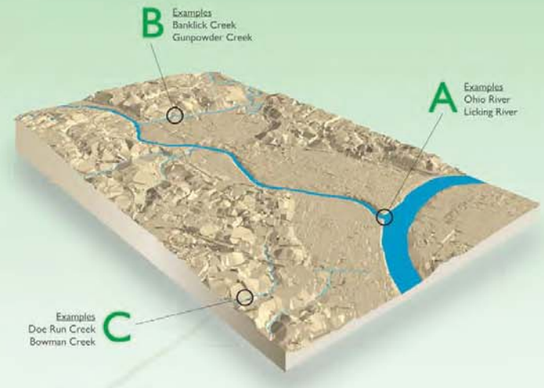
REGIONAL GREEN INFRASTRUCTURE **stream buffers**

Stream order is a classification for measuring the relative size of streams. Stream sizes range from the largest (*i.e.*, first-order) to the smallest (*i.e.*, ninth-order). For example, the Ohio River is a second-order waterway. The Licking River flows into the Ohio River, and is classified as a third-order waterway. The Banklick Creek, which flows into the Licking River, is classified as a fourth-order waterway. Using this categorization, the following buffers are recommended for all ranked streams[1] in Northern Kentucky:



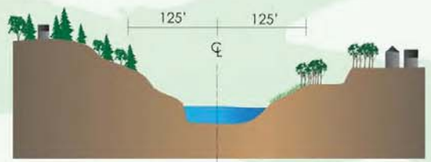
group A

Stream buffer for both the Ohio and Licking rivers is recommended as the floodway boundaries plus an additional 50 feet on each side.

*Based on: Northern Kentucky Area Planning Commission (NKAPC). "Article X: Zones". In *The Official Zoning Ordinance: Fort Wright, Kentucky*, 10-128 – 129.

group B

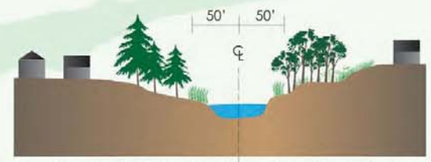
Stream buffer for SD1 'Major Creeks' (those that are level 3 and 4 streams) is recommended as 125 feet on each side, measured from the centerline.



*Based on: U.S. Army Corps of Engineers (USACE). *Banklick Creek Watershed, Section 905(b) (WRDA 1986) Analysis*. Prepared by the USACE Louisville District Office. September 2000.

group C

Stream buffer for all remaining streams (levels 3 and 4 that are not SD1 'Major Creeks', and levels 5 through 9) is recommended as 50 feet on each side, measured from the centerline.



*Based on: City of Louisville, Kentucky. *Land Development Code for All of Jefferson County, Kentucky*. Prepared by Louisville - Jefferson County Metro Goverment. March 2006.

[1]Stream Levels were classified according to the National Hydrography Dataset (NHD), provided by the United States Geologic Survey (USGS).

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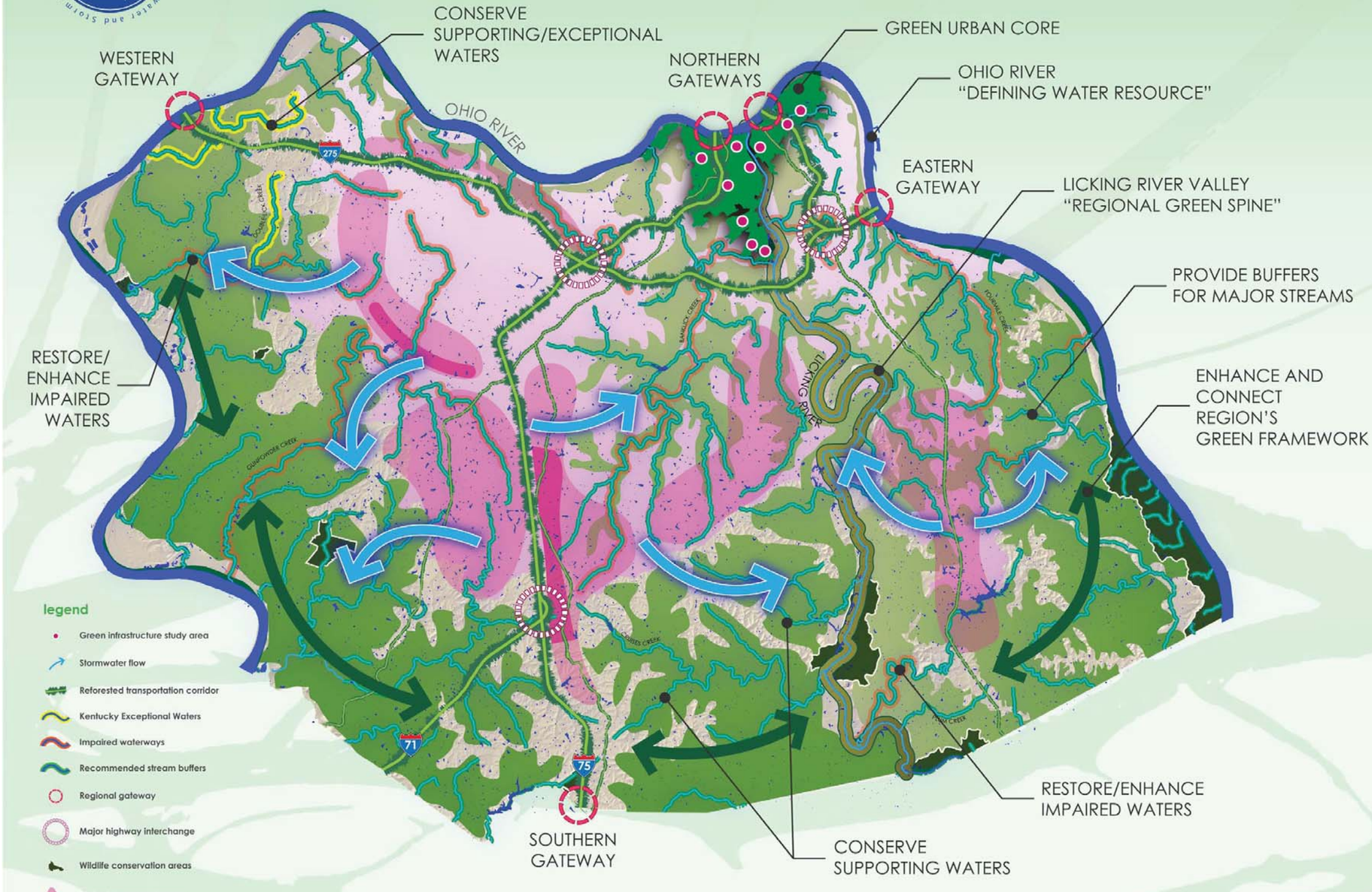
THE ANATOMY OF A REGIONAL GREEN INFRASTRUCTURE PLAN



legend

- Green infrastructure study area
- Stormwater flow
- Reforested transportation corridor
- Kentucky Exceptional Waters
- Impaired waterways
- Recommended stream buffers
- Regional gateway
- Major highway interchange
- Wildlife conservation areas
- Major future growth areas

AN miles 0 2 4

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green infrastructure

Northern Kentucky's green infrastructure is an interconnected network of natural and built systems that conserves natural ecosystem values and functions, sustains clear air and water, and provides a wide array of benefits to people and wildlife. The green infrastructure offers a framework for new development, for enhancing existing infrastructure, and for encouraging low-impact development in our communities.

goals

PROTECT & RESTORE WATER RESOURCES
Northern Kentucky possesses a valuable stock of rivers, streams, creeks, and aquatic habitat. These water resources are vital to the health of the watersheds in the region. The green infrastructure plan proposes a three-part approach to restoring a hydrologic network that mimics the natural water balance:

- **CONSERVATION AND RESTORATION**
- **REDUCED HYDROMODIFICATION**
- **STREAM BUFFERS**

PROTECT, ENHANCE & CONNECT FORESTS
Nature's systems provide exceptional healing powers. Through strategic and adaptive reforestation, the natural fabric of the region can be both restored and connected.

PROMOTE TRANSPORTATION CORRIDORS AS GREENWAY CONNECTIONS
Transportation corridors like the interstate systems and major highways connect Northern Kentucky to surrounding regions. Implementing green infrastructure along these corridors provides opportunities for improving water quality, air quality, and reducing noise pollution.

REGIONAL PLANNING & SMART GROWTH
Green infrastructure planning can help Northern Kentucky communities determine where to direct growth and development, and how to prioritize conservation needs. Through a strategic framework, green infrastructure solutions are considered in the context of existing land use and future growth.

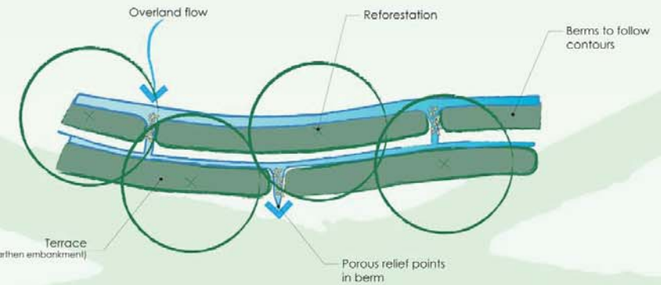
COMBINED SEWER SYSTEM reforestation strategies

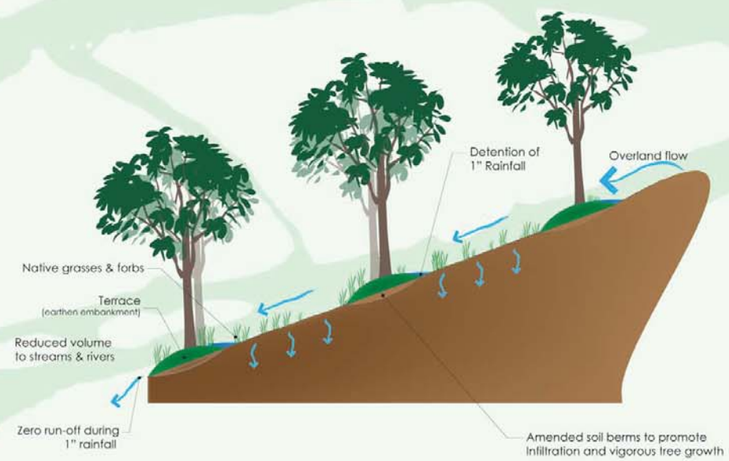
recommendations

American Forests, Inc. estimates a deficit of 634 million trees in US urban areas. They base their findings on changes to urban landscapes over the past twenty years. As a way to decrease this tree deficit, American Forests recommends the following tree canopy guidelines (given as a percentage of land area):

These coverage standards serve as a starting point, as each community must measure their current canopy cover and then develop tree cover targets based on their unique mix of climate, geography, land cover, and land use patterns.

terraced reforestation





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COMBINED SEWER SYSTEM green urban core

The combined sewer system (CSS) is an area in which all sanitary sewage and stormwater runoff flows through the same pipe network. During certain rain storms, pipes are overloaded and stormwater and sanitary sewage combine and overflow into streams and rivers. This is called a combined sewer overflow, or CSO. Unfunded federal mandates require controls to reduce CSO discharges. Conventional engineering solutions such as sewer pipe upgrades and overflow storage facilities are often used to comply with theses mandates. Green infrastructure offers an alternative approach to reducing CSO discharges while also providing additional community benefits.

Green infrastructure is not only a cost-effective and sustainable approach to stormwater management, but also provides possibilities for improving the quality of life in Northern Kentucky. Along with reducing the frequency and volume of CSOs, green infrastructure can help restore natural systems in highly-urbanized areas such as combined sewer system.

strategies

FACILITATE LOW-IMPACT DEVELOPMENT

- Optimize site design to reduce impervious areas
- Optimize site design for functional green space
- Capture, infiltrate and treat stormwater
- Optimize landscaping for stormwater management
  - Bioinfiltration (e.g., bioswales)
  - Retrofit existing detention/retention basins
  - Infiltration wells and basins

IMPLEMENT MULTI-COMPONENT GREEN STUDY AREAS

Twelve study areas were identified for maximizing the reduction of stormwater volume and reducing the frequency of combined sewer overflows.

OFFLOAD STORMWATER TO NATURAL SYSTEMS

- Identify and limit natural drainage into combined sewers
- Reduce/eliminate stormwater at the headwaters
- Beginning-of-pipe best management practices
- Site-by-site recommendations

REDUCE DIRECT STORMWATER INFLOW POINTS

- Separate piped storm connections from combined sewers
- Identify conditions and direct stormwater to natural systems where possible

INCREASE TREE CANOPY COVER

- Reforest physically-restricted development areas ('Hillside Greenbelt')
- Reforest road right-of-way
- Promote street trees in the urban core
- Reforest with "Strategic Partners"
- Use adaptive reforestation techniques (e.g., terraced reforestation, bio-log enhancement of steep slopes)

Appendix 2-E

Water Quality Criteria Associated with Designated Uses

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Water Quality Standards
Kentucky Division of Water
(As of June 30, 2009)

401 KAR 10:026 Designated Uses

All surface waters within the study area are designated for the uses of warm water aquatic habitat, primary contact recreation, secondary contact recreation and domestic water supply. In addition, the outstanding state resource water (OSRW) use applies to the following segment:

Licking River watershed

Licking River from RM 18.9 - 115 (only a portion of this is in the study area (RM 18.9 - 35.6))

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401 KAR 10:031 Surface Water Standards

Parameter	Human Health		Aquatic Life	Recreational Waters		**Main Stem Ohio River** (River Mile 317.1 to confluence with the Mississippi River)
	Drinking Water Supply	*Fish*	*Warm Water Aquatic Habitat*	*Primary Contact (May 1 to October 31)*	*Secondary Contact (November 1 to April 30)*	
E. coli				130 colonies/100mL 30-day geometric mean[1]; 240 colonies/100mL in 20% or less of all samples in a 30-day period		
Fecal coliform				200 colonies/100mL 30-day geometric mean[1]; 400 colonies/100mL in 20% or less of all samples in a 30-day period	1,000 colonies/100mL 30-day geometric mean[1]; 2,000 colonies/100mL in 20% or less of all samples in a 30-day period	
Dissolved oxygen			5.0 mg/L as a 24-hr average; 4.0 instantaneous minimum			5.0 mg/L average per calendar day; 4.0 mg/L minimum except during the April 15 - June 15 spawning season when a minimum of 5.1 mg/l shall be maintained
Ammonia (unionized)			Shall not be greater than 0.05 mg/L at any time after mixing; Y = 1.2 (Total ammonia-N)/(1 + 10pKa-pH) pka = 0.0902 + (2730/(273.2 + Tc)) Where: Tc = temperature, ^{o}C Y = un-ionized ammonia (mg/l)			
Oil and grease	Surface waters shall not be aesthetically or otherwise degraded by substances that float as debris, scum, oil, or other matter to form a nuisance					
Nitrate (as N)	10 mg/L					
Nitrite (as N)						1.0 mg/L maximum for protection of human health
pH			pH > 6.0 and < 9.0; fluctuations must be less than 1.0 s.u. over 24 hours			

401 KAR 10:031 Surface Water Standards - Continued

Parameter	Human Health		Aquatic Life		Recreational Waters		Main Stem Ohio River (River Mile 317.1 to confluence with the Mississippi River)
	Drinking Water Supply	*Fish*	*Warm Water Aquatic Habitat*		*Primary Contact (May 1 to October 31)*	*Secondary Contact (November 1 to April 30)*	
Specific conductance			Shall not be changed to the extent that the indigenous aquatic community is adversely affected				
Sulfate	250,000 ug/L						
Temperature[2,3]			< 31.7 °C				
Total dissolved solids	750,000 ug/L		Shall not be changed to the extent that the indigenous aquatic community is adversely affected				
Total suspended solids			Shall not be changed to the extent that the indigenous aquatic community is adversely affected				
Metals			**Acute**	**Chronic**			
Cadmium	5 ug/L		e(1.0166 (ln Hard*)-3.924) ug/L	e(0.7409 (ln Hard*)-4.719) ug/L			
Chromium	100 ug/L						
Chromium (III)			e(0.8190 (ln Hard*)+3.7256) ug/L	e(0.8190 (ln Hard*)+0.6848) ug/L			
Chromium (VI)			16 ug/L	11 ug/L			
Copper	1,300 ug/L		e(0.9422 (ln Hard*)-1.700) ug/L	e(0.8545 (ln Hard*)-1.702) ug/L			
Cyanide, free	700 ug/L	220,000 ug/L	22 ug/L	5.2 ug/L			
Lead	15 ug/L		e(1.273 (ln Hard*)-1.460) ug/L	e(1.273 (ln Hard*)-4.705) ug/L			
Mercury	2.0 ug/L	0.051 ug/L	1.7 ug/L	0..91 ug/L			
Nickel	610 ug/L	4,600 ug/L	e(0.8460(ln Hard*)+2.255) ug/L	e(0.8460(ln Hard*)+0.0584) ug/L			

401 KAR 10:031 Surface Water Standards - Continued

Parameter	Human Health		Aquatic Life		Recreational Waters		Main Stem Ohio River (River Mile 317.1 to confluence with the Mississippi River)
	Drinking Water Supply	*Fish*	*Warm Water Aquatic Habitat*		*Primary Contact (May 1 to October 31)*	*Secondary Contact (November 1 to April 30)*	
Metals			**Acute**	**Chronic**			
Selenium	170 ug/L	4,200 ug/L	20 ug/L	5.0 ug/L			
Silver			e(1.72(ln Hard*)-6.59) ug/L				
Zinc	7,400 ug/L	26,000 ug/L	e(0.8473(ln Hard*)+0.884) ug/L	e(0.8473 (ln Hard*)+0.884) ug/L			

Hard = Hardness as mg/l CaCO3.

1. Based on not less than five samples
2. The normal daily and seasonal temperature fluctuations that existed before the addition of heat due to other than natural causes shall be maintained.
3. The Cabinet may determine allowable surface water temperatures on a site-specific basis utilizing available data that shall be based on the effects of temperature on the aquatic biota that utilize specific surface waters of the Commonwealth and that may be affected by person-induced temperature changes.

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Appendix 3-A

Full System Bounding Analysis

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SECTION 1. INTRODUCTION

SD1's June 2009 Watershed Plans included a section call the Full System Analysis, which provided an analysis of a suite of full system gray and/or integrated solution concepts that addressed all sewer overflows. This analysis identified several types of solution 'concepts' and considered combinations of gray, green, and watershed controls at varying levels of control. This sensitivity analysis enabled SD1 to determine the most cost-effective and relative benefits of the solutions.

Based on these conclusions, SD1 developed a detailed Five-year Improvement Program, but did not indicate a preferred system-wide solution set. EPA's feedback on the June 2009 document indicated a need for identifying a preferred system-wide solution set to address all overflows, so SD1 conducted further analysis and updated the Watershed Plans (March 2011) to include a preferred Integrated Plan for 2025 (Section 3). The Full System Analysis originally presented in Section 3, is now included in this Appendix and is referred to as the Full System Bounding Analysis.

1.1 Approach

SD1's solutions to address sewer overflows and improve water quality were evaluated using a Full System Bounding Analysis for the 2025 planning horizon. This analysis differed from traditional approaches by including a comprehensive evaluation of green infrastructure and large-scale watershed controls with the analysis of traditional gray controls. The Full System Bounding Analysis assessed the relative benefit of different levels of control and different combinations of control types (i.e. gray infrastructure controls alone vs. a combination of gray, green and/or watershed controls). These sensitivity analyses furthered SD1's understanding of the cost-effectiveness of the various levels and combination of control types. These important conclusions were used in SD1's selection of the preferred Integrated Plan for 2025 and the projects and control levels for the Five-year Improvement Program.

The Bounding Analysis includes an analysis of traditional (gray infrastructure) alternatives to reduce CSO discharges (Section 3.1), consistent with the CSO Control Policy and the elements of a Long-Term Control Plan. The analysis includes cost/performance evaluations of the preliminary solutions at different levels of control using the "knee of the curve" analysis discussed in the CSO Control Policy (Section 4). In addition, all SSOs were evaluated with preliminary system-wide infrastructure solutions, as required by the Consent Decree.

1.2 Evaluation Metrics

SD1 developed a suite of metrics to assess the benefits (both water-quality and other associated benefits) provided by the various control scenarios. These include traditional metrics to assess improvements in system performance and bacteria reductions, and other metrics to assess the additional benefits of a control (i.e. reduce flooding, improve conditions for aquatic life, and improve the quality of life for residents

of Northern Kentucky). Specific metrics used to evaluate controls are categorized in Table 1.

Table 1 Evaluation Metrics

Evaluation of	Factor[1]	Metric
System performance	3	Maximization of existing treatment capacity
	4	Reduction in surface runoff contribution to the combined system
	3	Reduction in number of overflow events[3]
	3	Reduction in overflow volume
	3	Enhancement of Nine Minimum Controls program
Bacteria reduction	4	Overall watershed reduction of instream bacteria densities
	3	Increased attainment of bacteria water quality criteria
	4	Percent bacteria load reduction
	4	Length of stream reach with reduced bacteria densities
Cost	6	Construction cost vs. water quality improvement[2]
	6	Construction cost vs. all benefits
	6	Capital cost
	6	Annual operations and maintenance cost
Ecological, human health and other additional benefits	2	Reduction in public health risk[3]
	1	Reduction in flooding and increase in infiltration
	1	Improvements in aquatic habitat and biological index scores
	1	Stabilization of streambanks to reduce erosion
	1	Reductions in other pollutants or water quality violations
	1	Preservation of green space
	1	Opportunities to connect public lands/greenways
	5	Opportunities for community involvement and partnering

[1] The Factors in Table 1 were developed to implement the factors from the Consent Decree (IV.D.39) defined as follows:

1 Environmental impact
2 Public risk
3 Regulatory requirements
4 Degree of water quality improvement expected to be achieved
5 Public input
6 Cost-effectiveness

[2] This metric reflects the "knee of the curve" analysis discussed in the CSO Control Policy.

[3] This is a key metric for assessing level of service and schedule for SSO elimination.

This section summarizes the solution concepts (Section 2) and describes the evaluation of system-wide controls and their benefits (Sections 3 and 4). Important conclusions from the sensitivity analyses are provided in Section 5.

SECTION 2. SOLUTION CONCEPTS

The solution concepts used in the Bounding Analysis are control programs that address all overflows in SD1's system under 2030 future build-out conditions. These alternatives included a typical range of gray only solution concepts for CSO and SSO controls. For the purpose of SD1's watershed planning, the range was defined as 18 to 0 overflows per year level of control for CSOs and a 6-month to 10-year level of service for SSOs. These scenarios were developed as components of the Long-term Control Plan and the Sanitary Sewer Overflow Plan, and to provide information on the alternative solutions' extent, costs, and benefits in order to support decision-making under SD1's watershed approach.

The CSO Control Policy states that "EPA expects the long-term CSO control plan to consider a reasonable range of alternatives" and "the analysis of alternatives should be sufficient to make a reasonable assessment of cost and performance" (EPA, 1994). While the analysis of full system solutions is a required part of the decision process, the selection of controls is ultimately impacted by cost- benefit considerations – the Full System Bounding Analysis does not infer a commitment to any full system solution.

SD1's Bounding Analysis included gray infrastructure concepts and integrated solution concepts that include green infrastructure and/or watershed controls, analyzed under 2030 future build-out conditions. The purpose of evaluating these future build-out alternatives was to assess the relative cost-benefit of increasing levels of control, and the relative benefit of blending watershed and green controls with a gray infrastructure solution under typical conditions. The gray infrastructure solution concepts have wide applicability (although cost varies with site conditions) and they are also scalable (meaning control of overflows can be examined across a wide range of control levels). The green infrastructure and watershed control solutions are more dependent on site characteristics and coordination with partners. Because the extent of the green and watershed solutions is difficult to predict, they are not easily scalable. When the opportunity for green or watershed controls does exist, these controls are often highly cost-effective and eco-friendly. For example, the green and watershed controls can also address dry weather pollution sources whereas gray solutions to overflows do not address dry weather sources.

The solution concepts in the Bounding Analysis were configured to accommodate the projected 2030 future conditions presented in Section 2 of the Watershed Plans. This allowed simulation of potential benefits relative to a "no control" scenario based on estimated 2030 land cover and infrastructure conditions, using the detailed water quality models (Banklick, Licking and Taylor Creek). As described in Section 2.3.6 of the Watershed Plans, the Ohio River model was applied with inputs from all SD1 overflows and watershed loads from the detailed models. Because the Ohio River water quality shows little impact from these sources, which are comprised primarily of SD1 overflows (>90% compliance with fecal coliform standards), simulations of the solution concepts were not conducted with the Ohio River model.

2.1 Gray Infrastructure Concepts

The gray infrastructure concepts consist of infrastructure-based facilities that could control all of SD1's CSOs and SSOs to a range of targeted levels. The objectives used in developing the gray infrastructure concepts were as follows:

- Scalable across a range of control levels;
- Phased to enable costs to be spread over multiple years;
- Technologically varied;
- Technically feasible to implement;
- Cost-effective; and
- Compatible with SD1 preferences and operations.

These gray infrastructure concepts were developed to provide an understanding of the facilities, costs and benefits associated with gray infrastructure controls over a typical range of control levels for the 2025 planning horizon. These solutions were developed to a high level of detail, but are considered preliminary because they were developed as a boundary point for the sensitivity analysis for the watershed planning process.

In particular, the gray infrastructure concepts allowed SD1 to assess the cost-benefit relationships of a traditional "gray-only" solution, provided information for the cost-benefit assessment (Section 4), and provided a point of comparison for control alternatives that include watershed and green infrastructure approaches. While SD1 is committed to an affordable program to improve water quality, protect public health, eliminate recurring SSOs, and ensure CSOs conform to the CSO Control Policy as provided in the Consent Decree, the level of detail presented here does not imply an assumed commitment to gray only solution concept. The detail helps inform what parts of a traditional gray solution may be warranted in SD1's watershed management program.

The gray infrastructure concepts were developed using a systematic process beginning with the identification of and screening out of any technologies incapable of meeting SD1's goals and objectives. Technologies passing the initial screening were applied to the combined and separate sanitary sewer systems, producing a list of all potential technologies and control options. These options were then consolidated based on perceived levels of cost-effectiveness and performance to develop a short-list of six gray-only solution sets. The six solution sets were sized and costs developed for two levels of control to provide a framework for understanding the scalability and costs over a range of control levels. From the six solution sets, one set was selected as the gray-only solution concept alternative. This concept was then sized and costs developed across a full range of CSO and SSO control levels for use in comparative analyses.

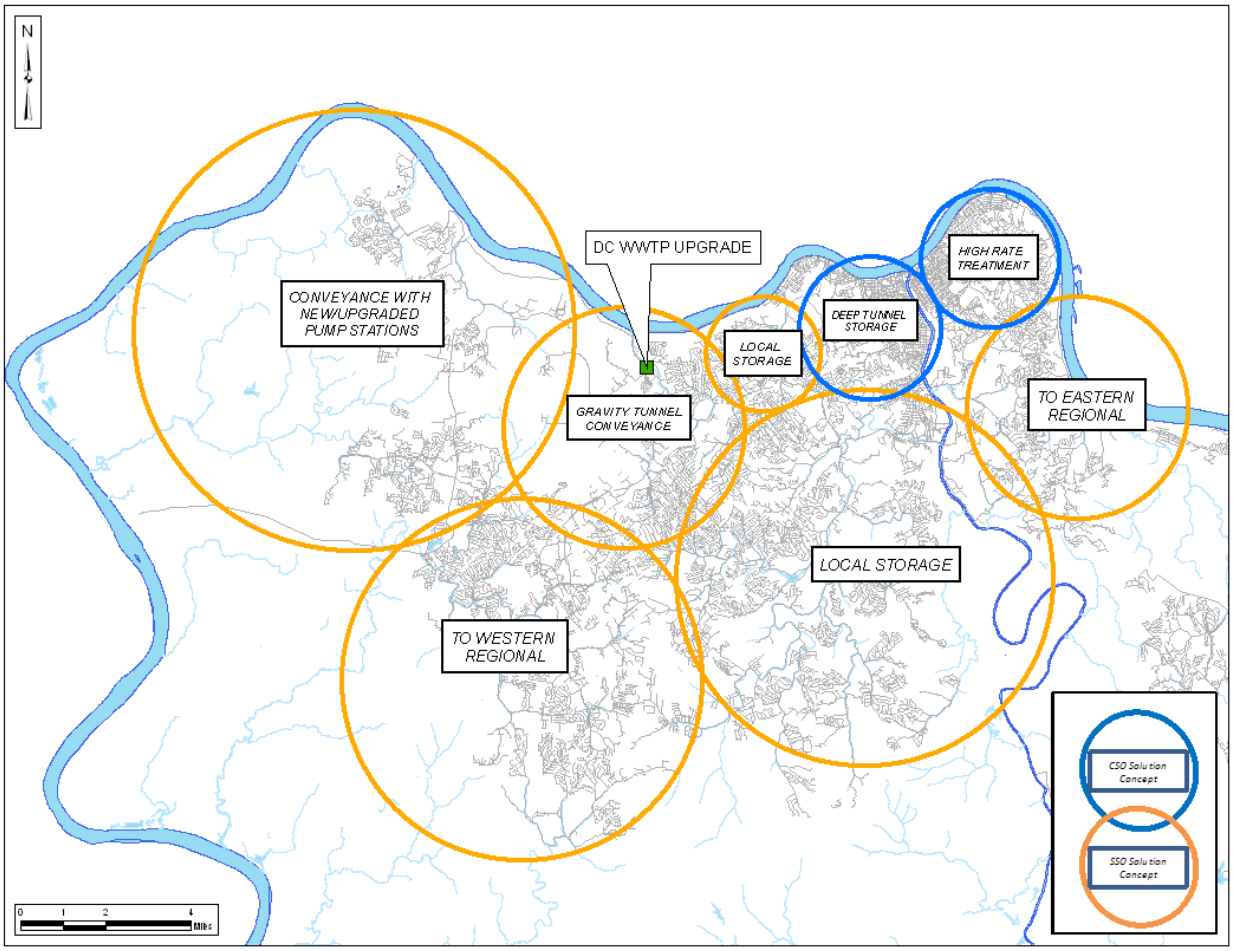
The following technologies and facilities were included in the gray-only solution concept:

- Primary and secondary treatment expansion;
- High-rate treatment;
- Deep tunnel for storage and/or conveyance;
- Storage tanks;

- Pump station: new construction, replacement and/or capacity upgrades; and
- Conveyance piping for increased capacity.

Technologies and facilities within the gray-only solution concept were divided into three components: Dry Creek WWTP Upgrade, CSO Control, and SSO Control. The geographic extent of these solution concepts is shown in Figure 1, and a narrative summary of each of the components is provided in the following sections.

Figure 1 Gray-Only Solution Concept



2.1.1 Dry Creek WWTP Upgrade Component

The Dry Creek WWTP upgrade component consisted of primary and secondary treatment expansion with the goals of 1) prioritizing and maximizing treatment of flows from the separate sanitary sewer system, and 2) maximizing secondary and primary treatment of flows from the combined sewer system. The upgrade assumes modification of existing facilities to increase peak wet weather treatment rates to match the 160 MGD capacity of the WWTP outfall pipe. This includes increasing the peak wet weather primary/disinfection treatment capacity to 160 MGD and the peak sustained

secondary treatment capacity to 100 MGD. See Section 2.4 of the Watershed Plans for a detailed discussion of the capacity upgrades evaluated.

2.1.2 CSO Control Component

The CSO control component uses a high-rate treatment (HRT) facility for the Taylor Creek CSOs, deep tunnel storage for the balance of the CSOs along the Ohio River and those along the Licking River, local storage control at the Banklick Creek CSOs, and re-direction of the Highland Heights / Silver Grove CSOs to the Eastern Regional WRF.

The deep tunnel concept is designed to store wet weather flows for subsequent conveyance to the Dry Creek WWTP. The facility was laid out as an approximate 31,000-foot long deep-rock tunnel. The facility begins at the James Avenue CSO and ends at the Bromley PS site. The tunnel includes drop shafts to intercept flows at Patton Street, Eighth Street, Fourth Street, Willow Run and Livingston Avenue. Each of the drop shaft locations are fed by one or more diversion structures. A tunnel dewatering pump station is located at the downstream end of the tunnel, on the Bromley PS site. The pump station uses the existing Bromley PS forcemain, capping the pumping capacity at 60 MGD.

The Taylor Creek HRT facility concept uses a treatment technology to provide equivalent primary treatment for wet weather overflows originating in the Taylor Creek basin and the eastern portion of SD1's combined system. The Taylor Creek HRT facility would be located near the confluence of Taylor Creek with the Ohio River. The facility includes an equalization basin, HRT tanks and equipment, fine screens and a disinfection system. The facility would be supported by a system of gravity pipes that convey wet weather overflows from the tributary sewer system to the HRT facility.

The Banklick Creek local storage concept includes an end-of-pipe storage tank to capture overflows from Banklick Creek CSOs. This storage tank would consolidate overflows from three CSOs and reduce overflows to Banklick Creek. The facility would be supported by a system of gravity pipes that convey wet weather overflows from the CSOs to the storage facility.

The Highland Heights / Silver Grove concept is made up of a suite of new and upgraded pump stations and connecting conveyance pipes. This concept would re-direct flow from the Dry Creek WWTP service area to the Eastern Regional WRF.

Each of these facilities would be supported by a piping network with the hydraulic capacity to carry the future wet weather flows. The design of this CSO control component ranges from 0 overflows per typical year to 18 overflows per year. Therefore, the analysis allows for a comparison of benefit in terms of end-of-pipe metrics (activations and overflow volume), along with the relative water quality benefits across this range of control levels (as presented below in Section 3).

2.1.3 SSO Control Component

The SSO control component consists of a series of smaller facilities that are more localized than the CSO component, because the SSOs are spread out across SD1's service area. This concept consists of:

- Deep tunnel conveyance for the Dry Creek separate sanitary sewershed;
- Storage tank at the Lakeview PS;
- Storage tank at the Licking River Siphon;
- Conveyance improvements in the Taylor Creek service area;
- Storage tank for the Bromley-Crescent Springs sewershed;
- Pump station upgrading and upsizing throughout the separate sanitary sewer system; and
- The Western Regional Tunnel and Water Reclamation Facility improvements, which are Initial Watershed Projects.

Each of these facilities is supported by a network of pipes with the capacity needed to carry peak wet weather flows. To maintain an appropriate level of conservatism, the reduction of I/I is not part of the gray-only solution concept. While cost-effective I/I reduction is a key component of SD1's wet weather control program, the gray-only solution concept only assumed use of scalable gray infrastructure technologies with a predictable ability to control overflows.

The Dry Creek conveyance tunnel concept consists of a deep tunnel to provide conveyance for dry and wet weather flows from the Dry Creek Interceptor sewershed to the Dry Creek WWTP. The approximate 17,000-foot rock tunnel replaces the existing Dry Creek Interceptor. The tunnel begins near the current discharge point of the Lakeview Pump Station forcemain and ends at the Dry Creek WWTP. Because of the variation in elevation, the tunnel concept can discharge to the WWTP by gravity. The capacity of the tunnel would match the planned secondary capacity of the WWTP. Consequently, no mechanical structures would be required for throttling of flows.

The Lakeview storage tank and conveyance system concept consists of a storage tank with ancillary support systems and conveyance piping. The storage tank is designed to attenuate and store excess wet weather flows for subsequent treatment at the Dry Creek WWTP. This tank would be a covered storage tank located near the Lakeview Pump Station, and would fill by gravity and have a pumped discharge. The discharge pumping uses the existing Lakeview Pump Station and forcemain. The facility is supported by a gravity piping network that conveys flows up to the selected control level to the pump station and storage tank.

The Licking River Siphon storage tank concept consists of a surface storage tank with ancillary facilities, including a pump station and conveyance piping. The storage tank will attenuate and store flows above 3 MGD for subsequent treatment at the Dry Creek WWTP. Smaller storage tank concepts are evaluated for the Bromley-Crescent Springs sewershed and to supplement upgrades to the Wilder Pump Station.

The Taylor Creek area includes both separate and combined sewers that discharge into the Ohio River Interceptor via the Bellevue Trunk Sewer. For the separate sewer areas and the trunk sewers in the service area, including the Bellevue Trunk Sewer, the solutions were sized to convey peak design storm flows without surcharge. For the combined area, conveyance was sized to convey peak flows from the 1970 typical year. In the gray-only solution concept, the Bellevue Trunk Sewer is used to convey all flows from the Taylor Creek service area to the Taylor Creek HRT.

Pump stations throughout the system require upgrading to meet the demand anticipated in 2030. These pump stations include:

- Taylorsport
- Bullitsville
- Sand Run
- Allen Fork
- Wilder

Each of these facilities would be supported by a piping network with the hydraulic capacity to carry the future wet weather flows.

The Western Regional improvement component consists of the Western Regional Tunnel and the Western Regional WRF, supported by local conveyance improvements to bring flows to the tunnel. These improvements are currently underway and reduce the load on the Dry Creek WWTP and tributary conveyance systems. These improvements were approved as necessary components of a regional facility plan to provide treatment capacity to the rapidly growing areas of Boone County.

2.2 Integrated Solution Concepts

The assessment of current conditions described in Section 2 of the Watershed Plans indicates that water quality in some creeks, such as Banklick Creek and Taylor Creek, is impaired in reaches where there are no SD1 overflows. A “gray-only” solution will not improve water quality in these reaches. The purpose of evaluating integrated solution concepts that include other, non-infrastructure-based controls (such as green infrastructure and watershed controls) was to evaluate whether more effective solutions can be achieved using a combination of controls that benefit local waterways. This section describes the development of green and watershed controls and the modeling approach used to simulate potential improvements in water quality as a result of these integrated solution concepts. This analysis of green and watershed concepts for the Bounding Analysis provided a starting point for SD1’s green and watershed planning. With the March 2011 update of the Watershed Plans, a more extensive analysis and EPA feedback were included for a more refined estimate of the types and benefits of potential controls. This more detailed analysis is provided as part of the new Section 3 of the Watershed Plans.

As with the gray-only solution concept, the integrated solution alternatives are preliminary configurations that were developed as alternatives in the planning process that could meet the remedial obligations of the Consent Decree rather than an assumed

endpoint. These solutions allow SD1 to assess the cost-benefit relationships of the watershed approach in comparison to the traditional approach that relies solely on gray infrastructure controls.

As noted in the Characterization section of the Watershed Plans, the future build-out scenario was developed using information, trends and assumptions about when and where future development occurs. There is uncertainty about what the future condition will be and how successfully the green and watershed strategies can be implemented given the need for suitable site characteristics and partner involvement. Therefore, two approaches for watershed controls were considered for the bounding analysis:

1. A dispersed approach in which watershed and green controls or best management practices (BMPs) are implemented largely on an individual or clustered parcel basis; and,
2. A regional approach in which watershed and green controls are centralized as relatively large-scale controls located in the stream or as an adjacent side stream.

The first approach was applied with the Banklick and Taylor Creek watershed models, while the second regional control approach was evaluated with the Banklick Creek model. The dispersed BMP approach offers an opportunity to reduce bacteria loads in runoff before it reaches the stream; however, because the controls are implemented at a local level (e.g. individual homeowner or small subdivisions), they can be relatively expensive due to the large number of BMPs needed at this level. The regional approach offers the benefit of being relatively cheaper than the dispersed BMP approach because the controls are large and centralized at strategic locations within the watershed. They can also be constructed so that flows from sources other than runoff are treated with these controls. However, finding suitable locations for such large controls can be challenging and their feasibility (and total benefit) may be more tenuous than the localized BMP approach. The spatial extent of instream benefits is limited to the portion of the stream downstream of the regional controls whereas the dispersed BMP approach can offer the potential for improvement along the entire stream length.

For the dispersed BMP approach, watershed and green controls were simulated using a cumulative benefit approach for the Full System Bounding Analysis, rather than estimating the benefits of individual controls or green practices identified as near term (e.g. Five-year Improvement Program) opportunities. This approach was appropriate because the purpose of these simulations was to provide a sensitivity analysis (i.e., to evaluate the potential benefits from watershed controls compared to the gray-only solution concept), rather than to simulate a very specific future watershed control configuration with these controls. As the Five-year Improvement Program is implemented, SD1 will have opportunities to refine the analysis of water quality benefits using specific integrated solutions that reflect the priorities of potential teaming partners, actual conditions in the watershed and interest from the public (for example, the public may be more interested in doing rain gardens than green roofs).

Green and watershed controls were evaluated using the dispersed BMP approach in the detailed water quality models by characterizing the watershed features as follows:

1. Current development was identified as areas with potential retrofit opportunities, such as green roofs, rain gardens and on-site detention. Different levels of control were simulated by varying the assumption of the percentage of existing development area retrofitted with a green or watershed control.
2. Additional development between 2007 and 2030 was considered as providing opportunities for low impact development and having more rigorous storm water control requirements than current development. It was assumed that 100% of the new development required storm water control, but different levels of control were simulated by varying the storm size requiring control.
3. Existing pasture, row crop and developed open space (e.g. parks, golf courses) adjacent to streams were considered riparian buffer opportunities. Different levels of control were simulated by varying the length of stream buffered and the width of the buffer.

Literature indicates that the ability of the different watershed and green control practices to remove bacteria varies widely, with the average for most controls ranging from 40 to 60%. A removal efficiency of 50% was assumed for the area "treated" with watershed/green controls.

Using the above assumptions, three levels of watershed/green controls were developed and evaluated: moderate, aggressive and extreme. Each of these control levels was blended with a gray solution at a given level of control, creating three integrated solution concepts. The characteristics of each of these integrated alternatives, or solutions, including assumptions about watershed/green control implementation, are shown in Table .2. Benefits from these alternatives are described in Section 3

Table 2 Integrated Control Alternatives - Assumptions

Watershed/Green Control Level	New Development[1]	Existing Development[2]	Riparian Buffers[3]	CSO LOC[4]	SSO LOS[5]	Dry Weather Sources[6]
Moderate	0.50"	Implementation area = 20%	50 ft buffer	18	6-mo	Current
Aggressive	1.00"	Implementation area = 50%	100 ft buffer	18	6-mo	Current
Extreme	1.50"	Implementation area = 100%	Variable buffer (EPA guidance)	0	5-yr	10% of Current

[1]It is assumed that runoff up to the storm size indicated will be controlled over 100% of the new development area (e.g. in the Moderate scenario, new development will be required to control the first 0.50" of rainfall in each storm).

[2]It is assumed that retrofits will be used to control runoff up to 1.20" in the percentage of the existing development area indicated (e.g. in the Moderate scenario, the first 1.20" of rainfall in each storm will be treated in 20% of the existing developed area). Approximately 90% of the storms have total rainfall less than 1.20", so this value was used as the water quality volume target for sizing retrofits in existing development.

[3]"Convertible" land is defined as pasture, crop and urban open space land covers that are adjacent to a major stream. In all scenarios, the assumption is that 20% of the identified convertible land will have riparian buffers. The variable buffer is consistent with EPA's model ordinances for forest buffers (http://www.epa.gov/nps/ordinance/mol1.htm).

[4]LOC = Level of control

[5]LOS = Level of service

[6]Dry weather sources were maintained at current (2007) loads unless otherwise noted.

The regional control approach was analyzed with the Banklick Creek model for two large-scale types of watershed controls: retention basins and low-flow wetlands. These controls were considered for Banklick Creek because of their potential to improve water quality through "treatment" of other sources, which are important in this watershed. Potential locations for these controls were tentatively identified using topography and soils information.

Note that although the regional control approach requires significant analysis to identify potentially feasible specific locations for the controls, the regional controls evaluated in this analysis can only be considered preliminary given that the Full System Bounding Analysis is based on a projected future build-out scenario. The purpose of this analysis was to evaluate the range of instream benefits that can be obtained using a combination of controls. As described in Section 3, the comparison of all approaches (gray, BMP green/watershed controls, regional green/watershed controls) includes the full range of quantitative and non-quantitative benefits shown in Table 1.

SECTION 3. WATER QUALITY EVALUATION AND SENSITIVITY ANALYSIS

Potential benefits from the Full System Bounding Analysis scenarios were evaluated using a variety of tools, including the infrastructure hydraulic model and the detailed water quality models. The hydraulic model results were used to evaluate end-of-pipe characteristics of the remaining overflows, such as number of activations, total volume and hours of overflow (e.g. system performance metrics in Table 1) under the various alternatives. The detailed water quality models were used to evaluate compliance with water quality standards (e.g., bacteria reduction metrics in Table 1) and to characterize benefits in more spatial and temporal detail in the Banklick Creek, Licking River and Taylor Creek watersheds.

An evaluation of the water quality benefits of the gray-only solution concept generally showed that there is a threshold where increased levels of overflow control provide diminishing returns. In addition, based on insight gained during the characterization effort, the benefit of controlling a given overflow is highly variable and may include non-water quality based considerations such as reducing risk to public health. Based on these and similar determinations regarding benefit, the 'watershed approach' provides significant value in the long-term plan of improving water quality. SD1, through its evaluation of both gray and green infrastructure features as well as characterization of overflow impacts on each watershed, has developed valuable insight into the relative significance of different overflows based on the suite of metrics in Table 1. As the following section details, use of green and watershed controls can provide a greater water quality benefit for a given investment than using gray infrastructure controls that only address overflows. For example, in Taylor Creek, reducing dry weather sources could provide more benefit than controlling overflows in terms of number of days that a stream could be used for recreation while in Banklick Creek, managing runoff could result in more stream miles that could be used for recreation.

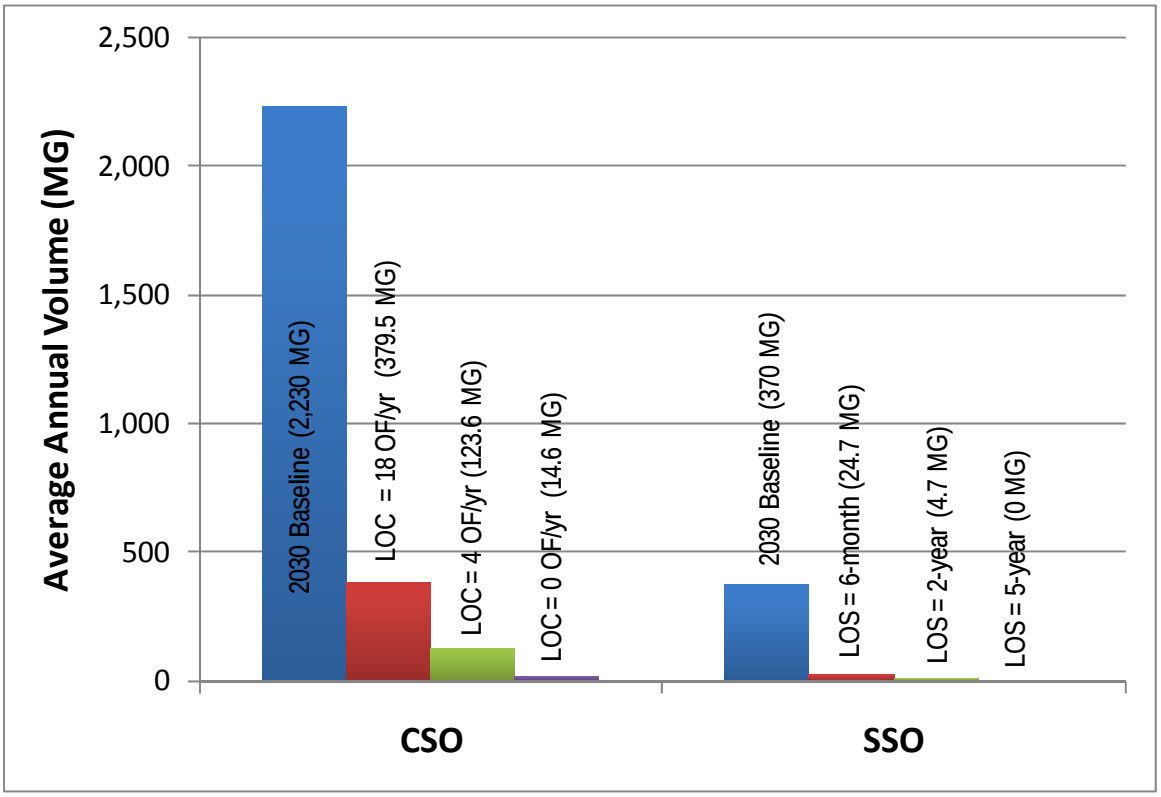
To assess the sensitivity of instream water quality benefit to different control approaches, three alternative solution concepts were evaluated with the water quality models, as detailed in the following sections:

- Gray-only solution concept;
- Integrated solution concepts incorporating a combination of gray, green, and watershed controls using dispersed BMP (all modeled watersheds) and regional green/watershed control (Banklick Creek only) approaches; and
- A solution concept that assumes an extreme level of implementation for all controls. This analysis provides a hypothetical boundary point to inform decisions on reasonable endpoints for future Watershed Plans.

3.1 Potential Water Quality Benefits with the Gray-Only Solution Concept

Three levels of CSO control (18 overflows (OF)/yr, 4 OF/yr, and 0 OF/yr) and three levels of service of SSO control (6-month level of service (LOS), 2-year LOS, and 5-year LOS) were sized with the infrastructure model based on a combination of design storms, the typical rainfall year (1970), and the typical five-year period (1992-1996). These controls were carried forward for additional evaluation using the detailed water quality models. Each level of control was simulated with the sewer system hydraulic model for the five-year typical period (1992-1996) and the hourly results for each overflow point were provided as input to the water quality models. Note that the descriptors of the CSO control scenarios (e.g., "CSO control at 4 OF/yr") describe the maximum number of activations at one or more overflow locations during the typical year of rainfall (1970). Within a given watershed and/or five-year period, the number of activations per year may be nominally different than the general descriptor. The descriptors of the SSO level of service describe the return period of the overflow during the five-year typical period (e.g. a 6-month LOS means that a storm causing an SSO occurs approximately every six months in the simulated period). The resulting sewer system and water quality model results were compared to the 2030 baseline (no control) scenario. Figure 2 shows this comparison in terms of annual average overflow volume predicted by the infrastructure hydraulic model using the 1992-1996 typical five-year period.

Figure 2 Average Annual Overflow Volumes Predicted for Each Level of CSO and SSO Control



The overflow volumes by watershed for each of the CSO and SSO control levels are summarized in Table 3. Each combination of CSO and SSO control levels was run through the water quality models, for a total of nine scenarios.

Table 3 Annual Average Overflow Volumes (MG) Used in Detailed Water Quality Models

	CSO[1]				SSO[1]			
Watershed	2030 Base	18 OF/yr	4 OF/yr	0 OF/yr	2030 Base	6-mo LOS	2-yr LOS	5-yr LOS
Banklick Creek	73.7	10.6	10.2	1.1	87.7	14.5	2.7	0.0
Licking River	885.5	128.9	44.1	3.9	57.2	4.6	0.5	0.0
Taylor Creek	12.2	0.2	0.2	0.2	10.1	0.1	0.0	0.0
Other Watersheds[2]	1,258.9	239.8	69.1	9.4	215.3	5.5	1.5	0.0

Note:

[1] The scenario descriptors (e.g., "4 OF/yr" for CSOs or "6-mo LOS" for SSOs) refer to the maximum number of activations at any given location during a typical year of rainfall (1970). During the five-year typical period (1992-1996) simulated with the water quality models, some overflow locations will activate more (or less) frequently than the scenario descriptor implies, but the difference is nominal.

[2] The "Other Watersheds" include Fourmile Creek, Threemile Creek, Dry Creek, Pleasant Run, Ohio River East, Ohio River North, Elijahs Creek, Sand Run, Woolper Creek, and Gunpowder Creek.

The water quality model results were compared to current bacteria water quality standards to determine compliance rates, and to the 2007 and 2030 no control

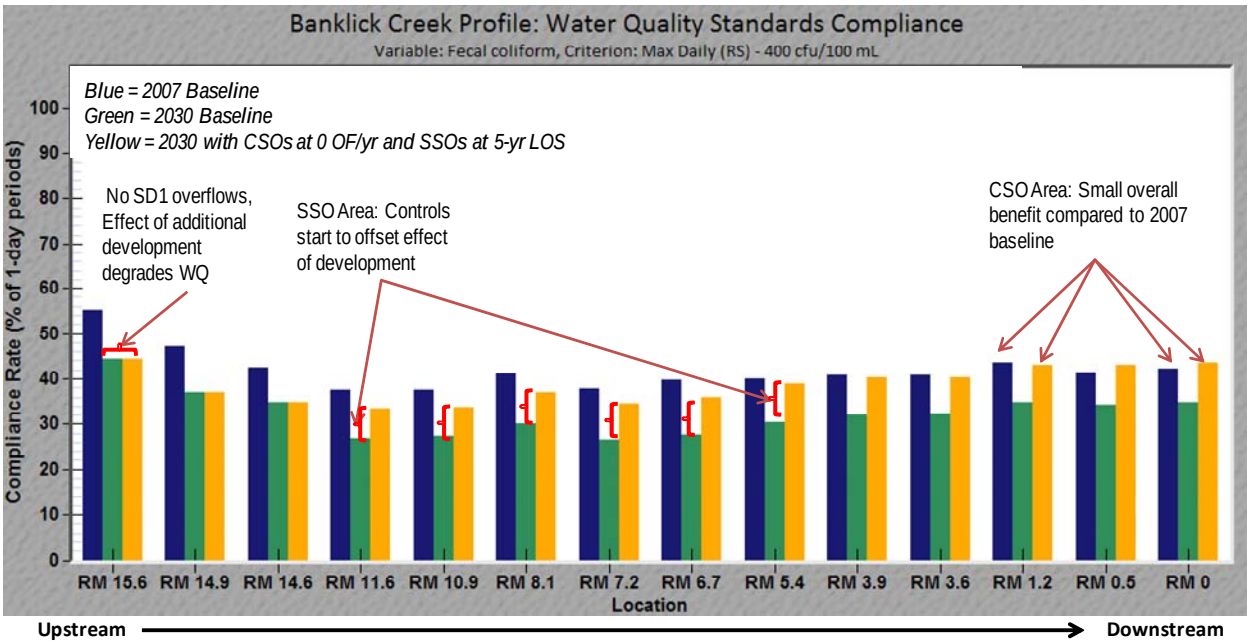
baselines to evaluate improvements in water quality. Four bacteria density measures were used to compare scenarios, depending on the characteristics of the waterway and the purpose of the comparison. These bacteria density measures are as follows:

- Measure #1: The first measure consists of counting the number of days in the five recreation seasons (i.e., all recreation seasons in the five-year simulation period) where the maximum bacteria densities were less than 400 colony forming units per 100 milliliters (cfu/100 ml). This measure is conservative, because Kentucky's water quality standards allow 20 percent of the fecal coliform measurements in a 30-day period to exceed 400 cfu/100 ml.
- Measure #2: The second measure consists of calculating the percent of 30-day periods in the five recreation seasons where 80 percent or more of the hourly values were less than 400 cfu/100 ml; this provides a more direct comparison to the current Kentucky water quality standard.
- Measure #3: The third measure consists of calculating the percent of 30-day periods in the five recreation seasons where the geometric mean of the hourly values was less than 200 cfu/100 ml; this again provides a more direct comparison to the current Kentucky water quality standard.
- Measure #4: The fourth measure consists of calculating a geometric mean of the hourly fecal coliform densities calculated by the model across the five recreation seasons. This measure is not directly related to a current water quality standard, but provides a concise indication of average conditions across the five-year period.

3.1.1 Banklick Creek

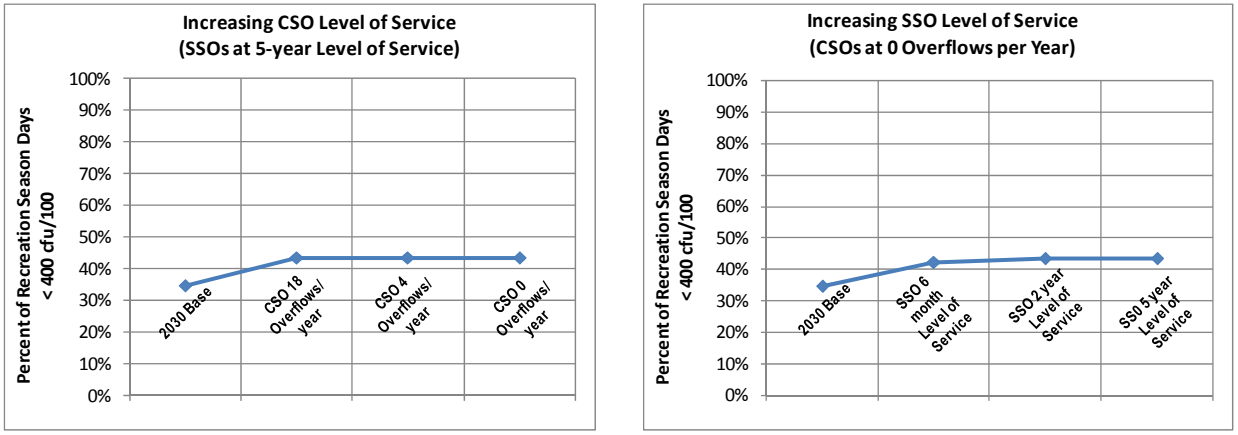
In Banklick Creek, although water quality improves relative to the 2030 baseline, there is little improvement in compliance with water quality standards (Measure #1) relative to the 2007 baseline (Figure 3). This suggests that gray overflow control measures will merely offset the effect of future development rather than improve water quality. Furthermore, increasing the level of control of SD1 overflows does not provide a corresponding increase in water quality benefit in terms of instream compliance with water quality standards (Measure #1) relative to baseline conditions (Figure 4). These results are not surprising, as much of the bacteria load in Banklick Creek originates from runoff and dry weather sources. As discussed in the next section, controls that target these sources are likely to provide more improvement in water quality (e.g. higher compliance with water quality standards, more stream length improved) than solutions based on SD1 overflow control alone through traditional gray infrastructure.

Figure 3 Banklick Creek: Comparison of Number of Days That Fecal Coliform Densities are Less than 400 cfu/100 ml for Baseline Scenarios and a High Level of Point Source Control



Note: The sizing indicated in the model scenario descriptor for the level of CSO and SSO control reflects a basin-wide maximum number of activations based on the typical year of rainfall (1970). The number of activations for the CSOs and SSOs in this watershed for the five-year period may be higher or lower than the descriptor, but the difference is nominal.

Figure 4 Water Quality Benefits of Increasing the Level of CSO and SSO Control in Banklick Creek



Note: Results summarized at the mouth of Banklick Creek (downstream of all SD1 CSOs and SSOs)

3.1.2 Licking River

As described in the characterization section of the Watershed Plans (Section 2.2.6), sources of bacteria in the Licking River are spatially distributed, with loads from SD1 CSOs discharging to the river largely in the lower two miles of the river (~45% of the CSO volume is discharged in the last mile of the river). Watershed sources, such as

runoff, dominate the upper portion of the modeled river (between RM 5.5 and RM 3.0). Current conditions in the Licking River are affected by both SD1 overflows and other upstream sources (see Figure 2.38 of the Watershed Plans). This suggests that a watershed-based approach that addresses the multiple sources of pollution contributing to water quality impairment is needed for the Licking River.

In the lower portion near the mouth of the Licking River, controlling SD1 overflows to an 18 OF/yr level of control for CSOs and a 6-month level of service for SSOs increases compliance with the State's 30-day maximum fecal coliform criterion (Measure #2) from 20-30 percent in the 2030 baseline to nearly 100% (Figure 5). These benefits are due not only to reduced overflow frequency and volume but also to instream conditions, in which the low velocities in the Licking River (due to Ohio River stage effects) increase the travel time of the upstream bacteria load, allowing more die-off and an overall decrease in densities near the mouth. The instream fate and transport effects are described in more detail in the Characterization section (Section 2.2.6) of the Watershed Plans. However, it is important to note that the benefit is limited to the lower portion of the Licking River near the mouth and does not result in full compliance in the upper reaches of the river. Figure 6 shows, as with Banklick Creek, little additional benefit in instream water quality relative to attainment of water quality standards (Measure #2) is observed when comparing results for scenarios with higher levels of SD1 overflow control. This provides additional support for a strategy addresses multiple sources rather than using an approach that simply reduces SD1 overflows alone.

The Licking River analysis provides a very important result. Given the relative distribution of bacteria sources along the lower Licking River, it is to be expected that controlling SD1 CSOs and SSOs will provide an increased water quality benefit compared to other CSO-impacted waterways. However, this benefit is limited to the lower portion of the Licking River. Under the watershed approach, the important question is whether a given level of overflow control can be achieved more cost-effectively with a combination of control types (gray/green/watershed), with the added benefit of improving all stretches of the river, rather than potentially cost-prohibitive controls based solely on gray infrastructure solution concepts. This question is examined further in Section 3.2.

Figure 5 Improvement in Water Quality in the Lower Licking River With SD1 Overflow Control Compared to the 2030 Baseline (Based on State's Recreation Season 30-day Maximum Fecal Coliform Criterion)

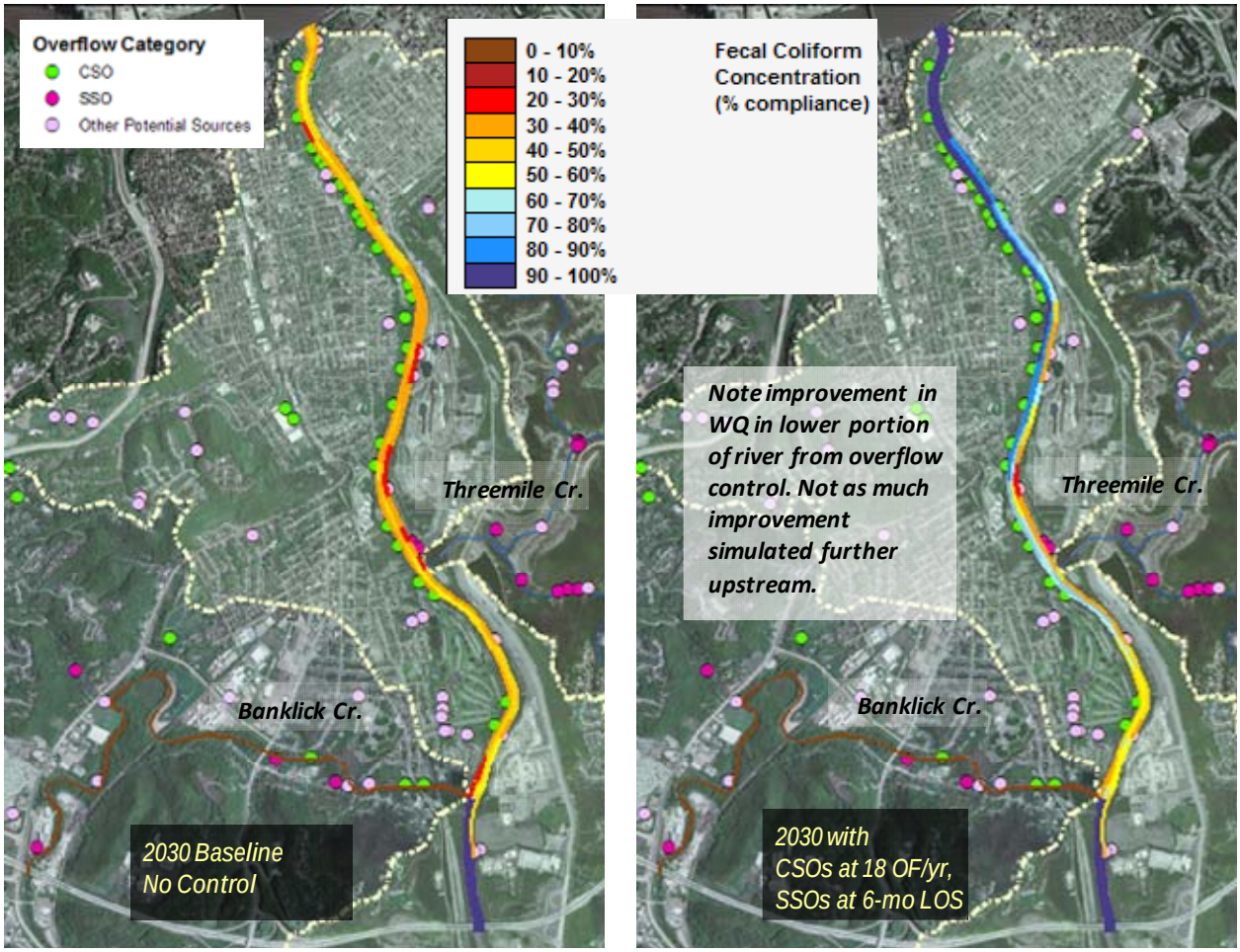
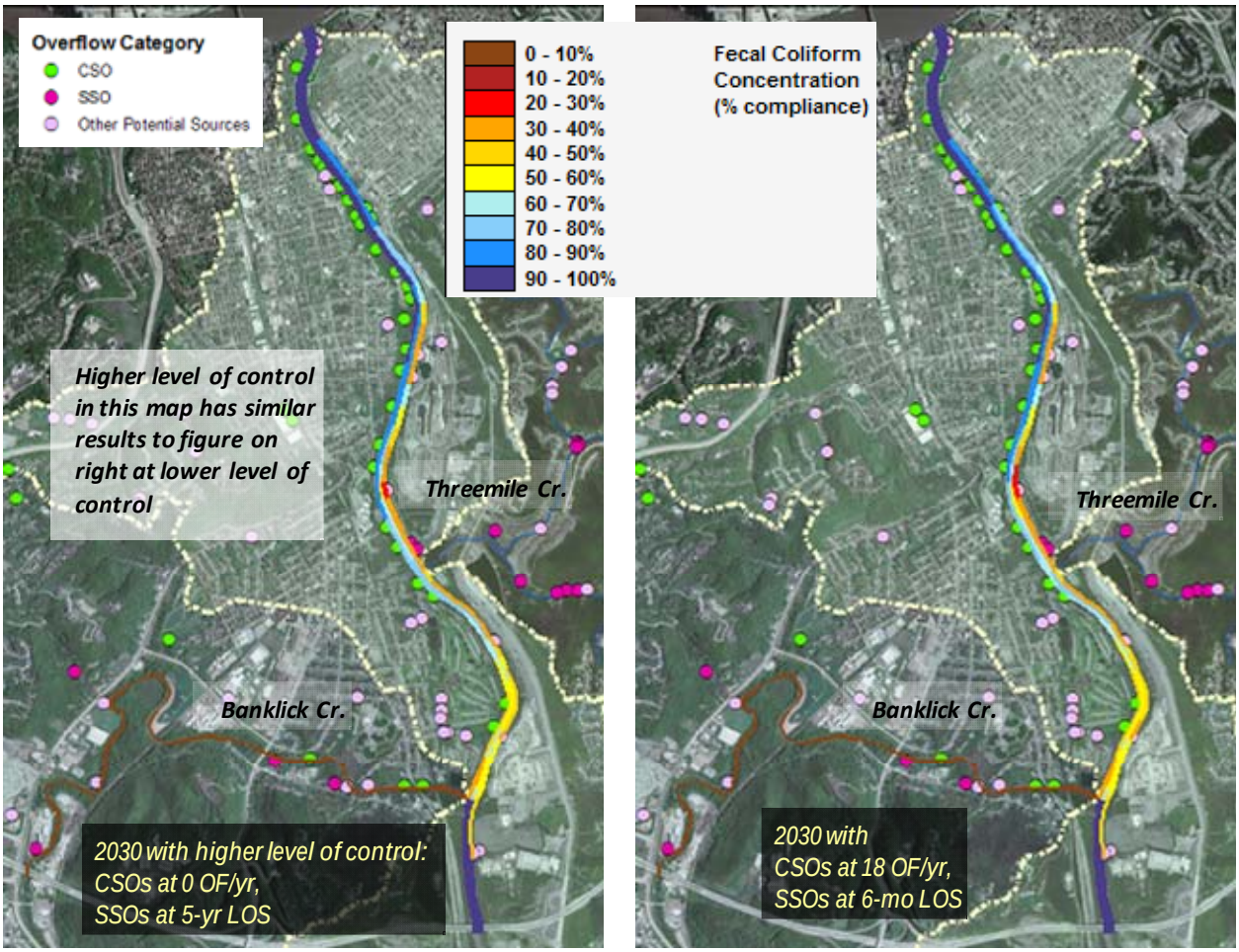


Figure 6 Similar Water Quality Benefit in the Lower Licking River With Increasing Levels of CSO and SSO Control (Comparison to State's Recreation Season 30-day Maximum Fecal Coliform Criterion)

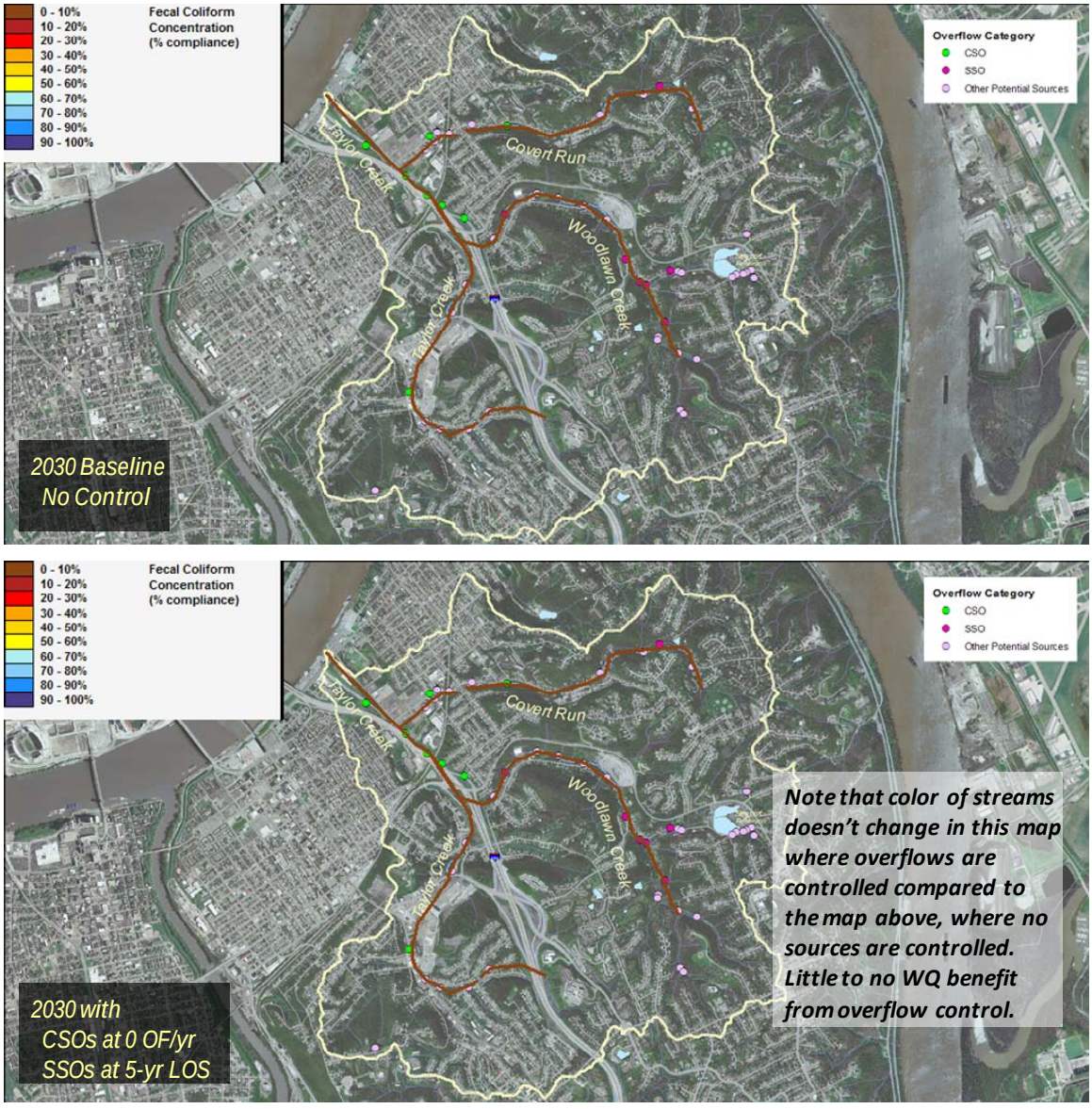


3.1.3 Taylor Creek

Like Banklick Creek, bacteria densities in Taylor Creek are dominated by dry weather and runoff sources rather than by CSOs and SSOs. In all of the Bounding Analyses CSO control scenarios, two of the CSOs in Taylor Creek are eliminated due to the impact of conveyance improvements. The remaining CSOs were controlled to convey the typical year peak flow under all CSO control scenarios. As a result, all 1992-1996 continuous simulations predicted a total CSO volume of ~0.2 MG/yr in the Taylor Creek area. In addition, the 2-year design storm level of control sizing in the separate sanitary area resulted in 0 overflows in the 1992-1996 continuous simulation. This is due to the conservative sizing of the CSO component of the trunk sewers as well as the fact that the design storms were run assuming very wet antecedent conditions. As a result, the overflow volumes in Taylor Creek are the same for all CSO and SSO control combinations except where a 6-month SSO control level was used.

Even when controlling CSOs and SSOs at these very high levels, little improvement in compliance with water quality standards is predicted in terms of Measure #2, the recreation season 30-day maximum fecal coliform criterion (Figure 7). As discussed in the next section, controls that target dry weather and runoff sources appear to provide more improvement in water quality than solutions based on SD1 overflow control alone.

Figure 7 Limited Water Quality Benefit in the Taylor Creek With CSO and SSO Control (Comparison to State's Recreation Season 30-day Maximum Fecal Coliform Criterion)



3.2 Potential Water Quality Benefits with a Combination of Control Types (Integrated Solution Concepts)

After establishing measures of the water quality benefits from the gray-only solution concept, SD1 examined the benefit of including green and watershed controls. The detailed water quality models for Banklick Creek, the Licking River and Taylor Creek were applied using a combination of control types (gray, green, and/or watershed) to evaluate two questions:

1. Can a combination of gray and other watershed/green controls provide equivalent (or better) improvements in water quality than the improvements obtained by implementing gray-only solution concepts at a higher level of control? For this question, the definition of "benefit" is critical – while improvement relative to attainment of bacteria water quality standards is relevant, the broader benefits of integrated solution concepts must also be considered.
2. Having identified that gray infrastructure concepts do not improve impaired streams where there are no SD1 overflows, can current water quality standards be achieved instream if the combination of control types are simulated at an extreme level of implementation?

The answer to the first question will inform the usefulness and viability of pursuing a strategy of integrated solutions containing a combination of control types (e.g. the watershed approach). The answer to the second question, which assumes no budgetary constraints and full commitment by other stakeholders to invest in improving water quality, will start to inform and identify reasonable endpoints for the bounding analysis.

The results from each of the detailed models are presented below. **In summary, the results indicate that combining CSO and SSO control at the lowest level of the range considered (18 OF/yr and 6-month level of service, respectively) with moderate watershed controls yields similar water quality improvements (in terms of bacteria densities) as controlling CSO and SSO alone at a higher level of control (4 OF/yr and 2-year level of service, respectively). The integrated solution results also illustrate that water quality benefits occur along more stream miles and address sources (such as dry weather) that gray-only solution concept cannot address. Finally, while not quantifiable with bacteria water quality models, the integrated solutions provide inherent benefits that cannot be achieved with a gray-only solution concept – e.g., habitat improvements, preservation of green space, opportunities for public involvement, and other qualitative benefits listed in Table 1.**

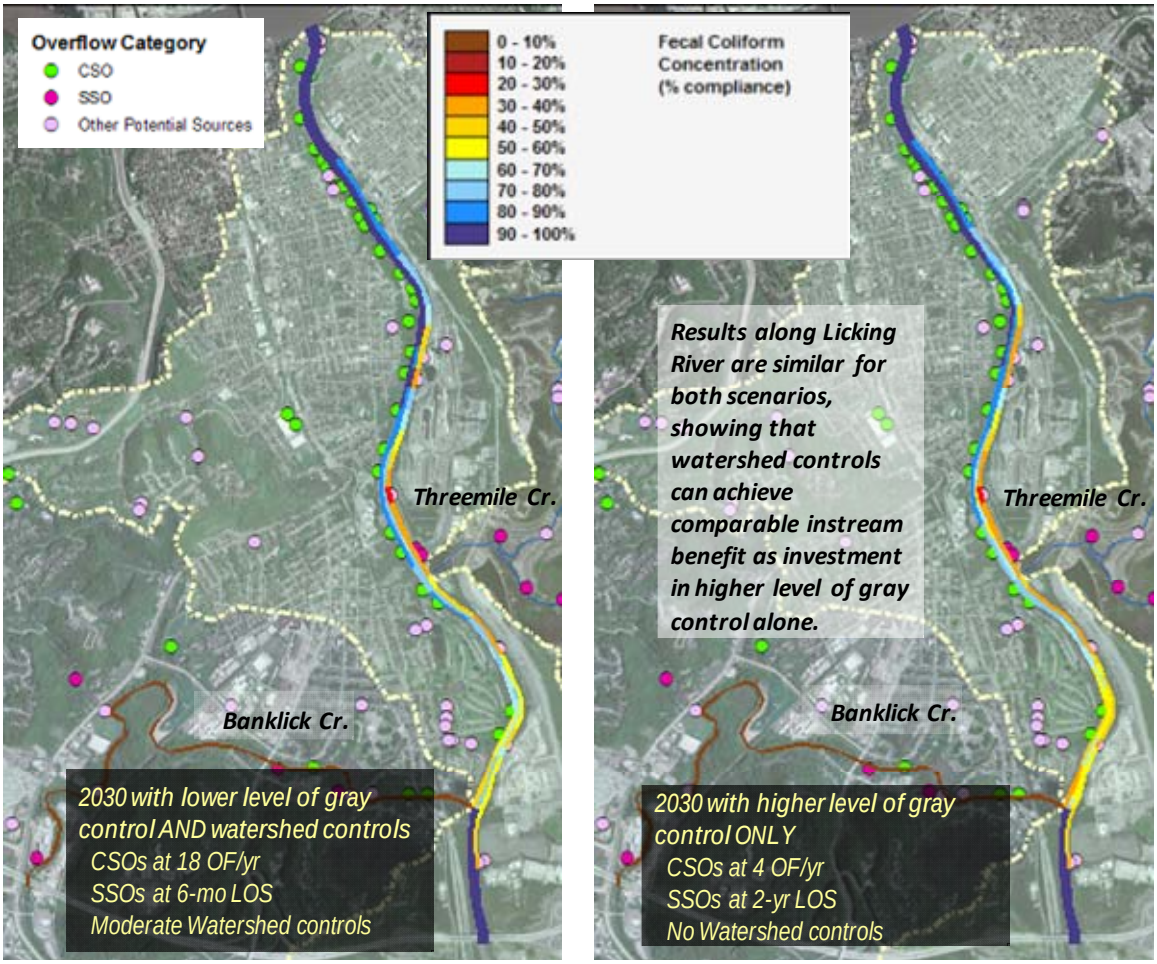
These results and comparisons show that use of green and watershed controls can be a more effective approach to improving water quality than using gray infrastructure alone to control only overflows. As discussed below in Section 5, the use of green and watershed controls can also be more cost-effective than using gray infrastructure controls alone.

3.2.1 Licking River

Integrated solutions in the Licking River were evaluated using the dispersed BMP approach. In the Licking River (Figure 8), model results for the moderate integrated solution (controlling CSOs to 18 OF/yr and SSOs to a 6-month level of service and adding in moderate watershed/green controls) calculate similar compliance rates (for Measure #2) as a gray-only solution concept at a higher level of CSO and SSO control (controlling CSOs to 4 OF/yr and SSOs to a 2-year level of service). The integrated solution includes assumptions about BMPs that are typically associated with green infrastructure, such as rain gardens and green roofs, at a preliminary level. These controls were applied to the portion of the watershed outside the combined sewer service area. The overall benefit observed from the integrated solution model results suggest that a higher level of CSO and SSO control is not warranted if these types of BMPs can be implemented outside of the combined sewer service area.

While not simulated specifically, it is reasonable to extrapolate that additional benefits can be achieved in the combined sewer service area if these BMPs were extended into this portion of the study area. **At minimum, the integrated solution results support an approach that pursues green/watershed BMPs in the combined area before investing in significant gray infrastructure as the sole overflow control technology on the Licking River.** This approach will provide immediate qualitative benefit - habitat improvements, preservation of green space, opportunities for public involvement, etc. - and demonstrate whether green infrastructure applied in the combined system can sufficiently reduce the instream impact from CSOs to offset a higher overflow control level.

Figure 8 Similarity in Compliance with State's 30-day Maximum Criterion in Lower Licking River for Moderate Integrated Solution Scenario and High Level of CSO and SSO Control



Note: 30-day evaluations, such as the figure shown above, do not capture water quality benefits in Banklick Creek. This is because the frequency of rainfall and associated runoff in the typical period result in very few 30-day periods of compliance. A more useful evaluation tool for Banklick Creek is the number of days less than 400 cfu/100 ml, which is used in discussions on Banklick Creek (see next section as an example).

3.2.2 Banklick Creek

Integrated solutions were evaluated in Banklick Creek using both the dispersed BMP and the regional approaches. Both integrated solution approaches included CSO control at 18 OF/yr and SSO control at 6-month level of service. The dispersed BMP approach was evaluated at the moderate, aggressive and extreme levels of control. The regional approach was evaluated with two scenarios: the first scenario includes several regional retention basins, and the second scenario includes the retention basins from the first scenario and two low-flow treatment wetlands, each approximately 5 acres in size. One wetland was located just upstream of Bullock Pen confluence (near RM 6.5) and the other wetland was located downstream of this confluence.

Results show that both of the integrated solution approaches provide benefit along more stream length and provide a greater benefit than gray controls alone (Figure 9 and Figure 10). Figure 9 provides a comparison of the dispersed BMP integrated solution to a gray-only solution in terms of bacteria Measure #1, the number of days where the maximum bacteria densities were less than 400 cfu/100ml. Note that the integrated solution assumes a lower level of CSO and SSO control than the gray-only solution shown in this figure, yet the water quality benefit is greater throughout the entire stream length. This shows that integrated solutions offer potentially greater benefit than gray-only solutions in this watershed.

Figure 10 shows the results for the second regional control approach scenario, again in terms of bacteria Measure #1. The potential water quality benefit is even greater using a regional control than a dispersed control approach. By strategically locating the wetland just upstream of Pioneer Park, a potential recreation area, the greatest increase in the number of days meeting the recreation bacteria density threshold (400 cfu/100 ml) is simulated at this location.

Figure 9 Benefit of Integrated Solution Approaches Along Entire Banklick Creek Mainstem for Moderate Integrated Solution (Dispersed BMP) and Solution Using Only Gray Infrastructure Controls.

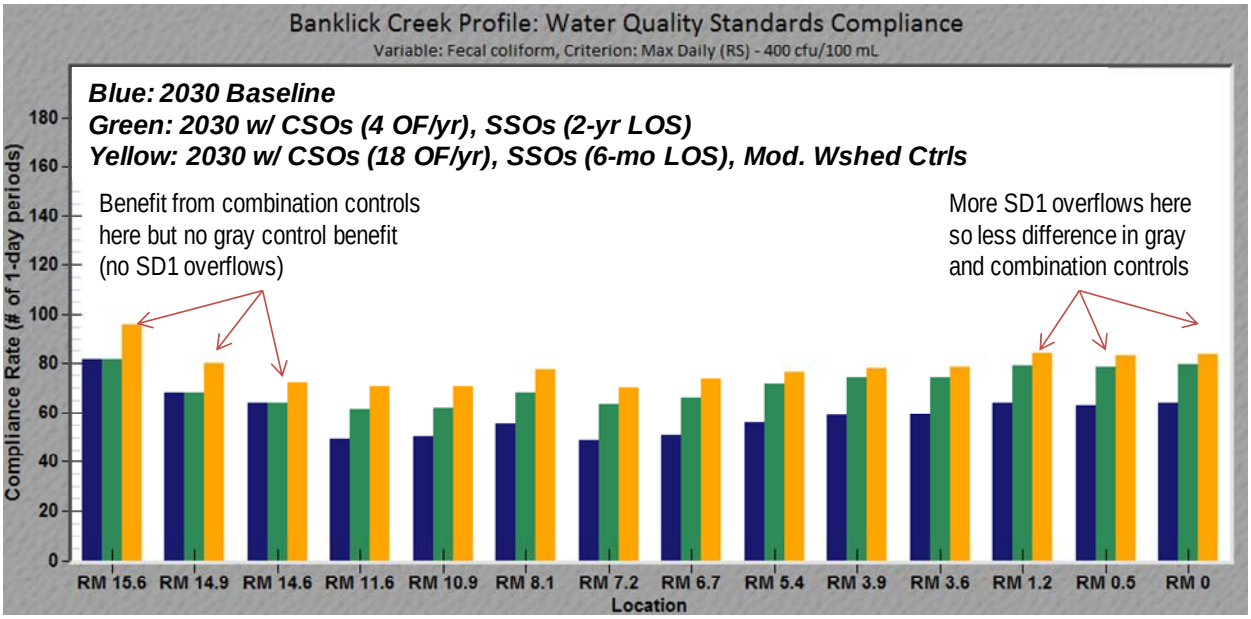
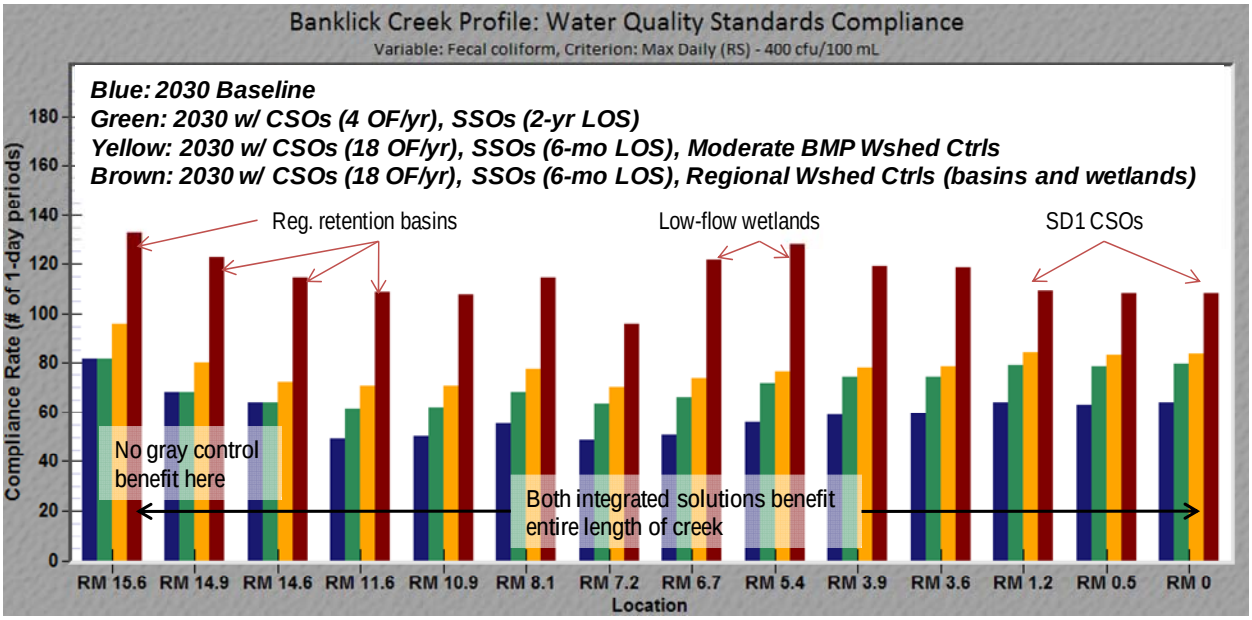


Figure 10 Comparison of Number of Days Density is Less than 400 cfu/100 ml Throughout Banklick Creek for Integrated Solutions (Dispersed BMP and Regional) and Solution Using Only Gray Infrastructure Controls.



The results presented for Banklick Creek are based on modeling bacteria and evaluating compliance with water quality standard thresholds. However, it is important to note that while compliance with bacteria water quality standards is a relevant measure, it is not a complete indicator of benefit - watershed controls offer other benefits that improve water quality in non-quantitative ways. Both types of integrated solution approaches can, for example, reduce flooding in the creek. The storage that regional retention basins provide is likely to reduce the frequency of bank-scouring events, improving habitat for aquatic life. Dispersed BMPs can be used to improve infiltration, preserve green space and connect greenways.

Section 4 below describes the costs associated with each of these alternatives and illustrates that in addition to providing greater compliance with water quality standards over a longer stream reach, the integrated solutions can also be more cost-effective than the gray-only solution concept.

3.2.3 Taylor Creek

Model results for Taylor Creek (Figure 11) for the moderate integrated alternative scenario suggest that watershed controls provide limited benefit in terms of bacteria Measure #4, the recreational season geometric mean. Note that specific to Taylor Creek, the moderate integrated solution includes CSO control at 0 OF/yr and SSO control at the 6-month level of service. However, when the moderate integrated alternative is coupled with dry weather source reduction (to 10% of current levels), significant improvement in water quality is predicted in terms of the recreational season geometric mean (Figure 12). When combined with the wider range of benefits achieved with green/watershed controls, this finding illustrates how well the holistic, watershed

management approach described in the Consent Decree suits this area to achieve the goals of improving water quality and public health.

Figure 11 Similarities in Water Quality in Taylor Creek - Gray-Only and Moderate Integrated Solution Scenarios (Recreation Season Geometric Mean Density)

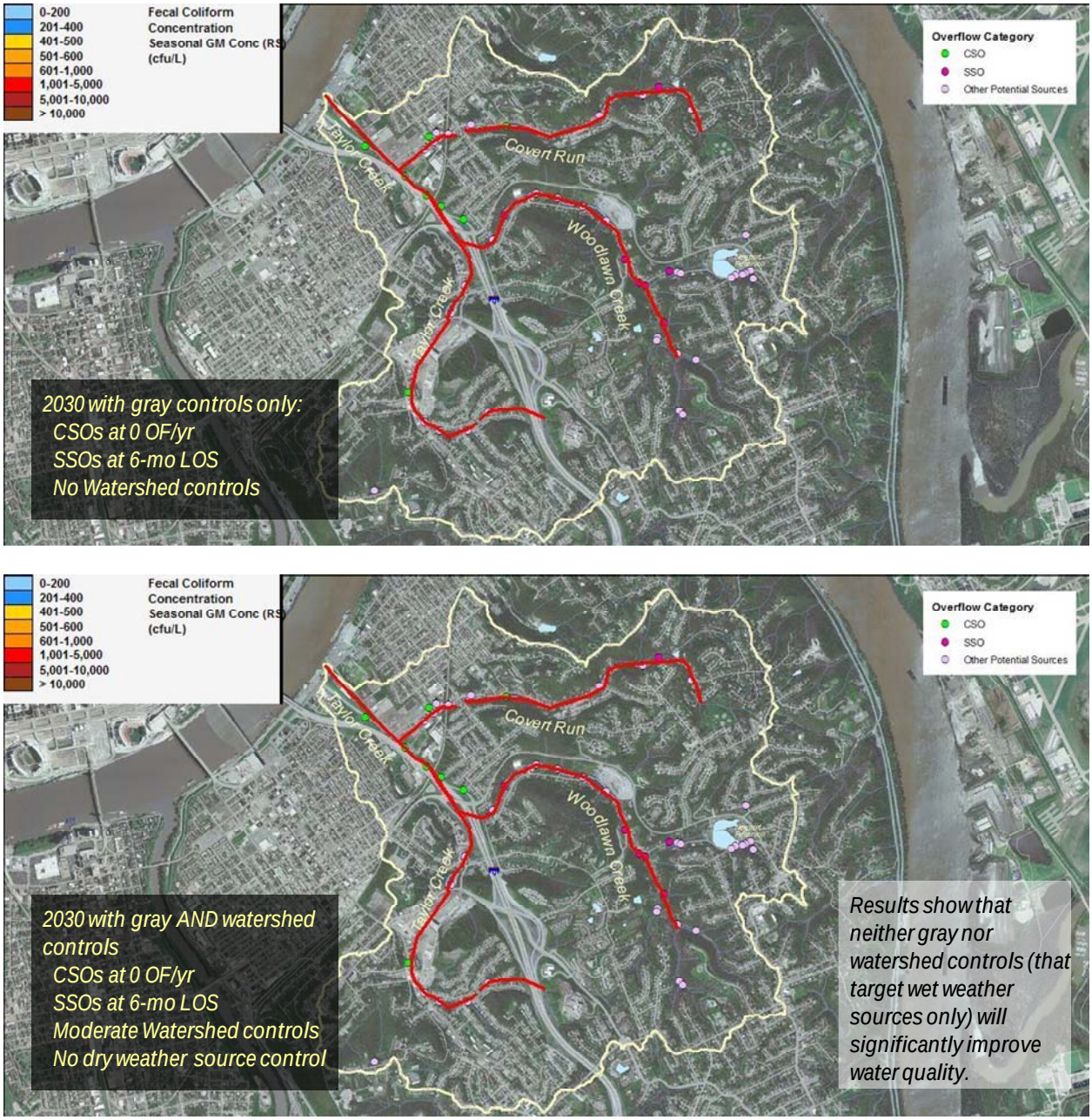
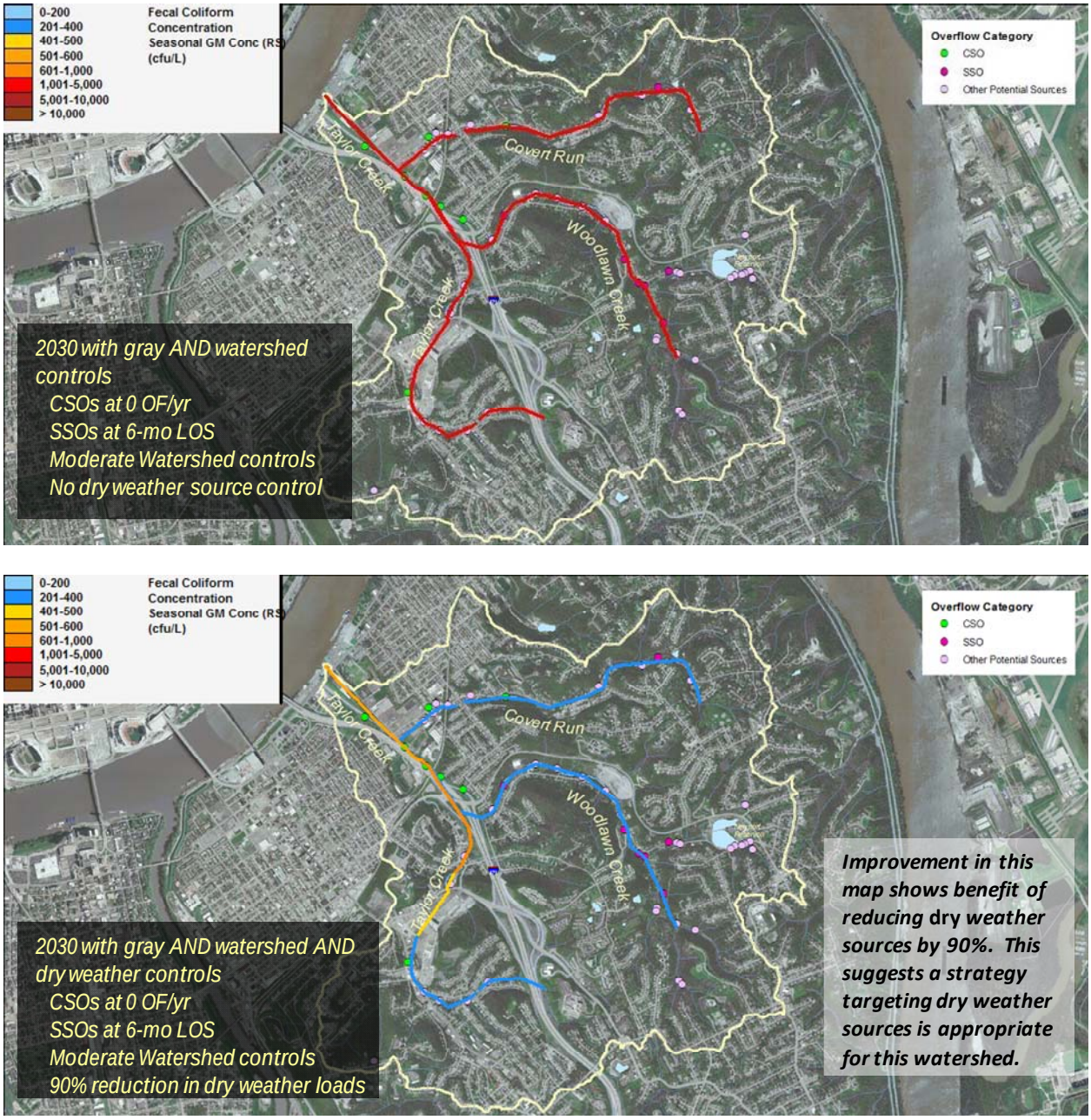


Figure 12 Additional Water Quality Benefit in Moderate Integrated Solution Scenario with Dry Weather Source Control Included (Recreation Season Geometric Mean Density)



3.3 Boundary Point Analysis – Potential Water Quality Benefits with Extreme Implementation of All Control Types

As a final step in the sensitivity analysis, SD1 evaluated an alternative that assumes extreme implementation of watershed/green controls in combination with a high level of CSO/SSO control to determine if water quality standards could be met at all times if every control measure was implemented at the most extreme level. The assumptions associated with this "extreme integrated alternative" scenario were presented previously in Table 2. A second "extreme" scenario was developed specifically for Banklick Creek that includes all of the regional controls plus the BMP approach in subwatersheds that were not "treated" with the regional controls. In all "Extreme" scenarios, the CSOs were controlled to 0 OF/yr and SSOs were controlled to a five-year level of service.

Given its purpose, this scenario assumes unrealistic levels of implementation, such as 100% participation by homeowners to retain storm water on site. By necessity then, this scenario intentionally ignores the budget constraints that factor into every decision and becomes, by definition, an "extreme" scenario that is impractical. However, the outcome of this scenario may be useful as a hypothetical boundary point to inform decisions on reasonable endpoints and achieving the 2025 compliance objectives

Results from the simulation of the extreme scenario indicate that although water quality improves, current water quality standards cannot be met at all times and at all locations.

3.3.1 Banklick Creek

The Banklick Creek model results from this scenario were compared to the current Kentucky water quality standards, i.e. bacteria Measures #2 and #3. Note that the previous results (Figure 9 and Figure 10) were compared to a similar but more illustrative metric of the number of days less than 400 cfu/100 ml, i.e. bacteria Measure #1. Compliance is higher for the 30-day geometric mean criterion than for the 30-day maximum criterion (Figures 13 and 14 for Banklick Creek, respectively). Note that the BMP-based controls in these integrated solutions assume a literature-based bacteria removal efficiency in runoff of 50%. The results suggest that the remaining bacteria load in the runoff, along with loads from other sources, is sufficient to cause the creek to not meet either water quality standard all the time.

Figure 13 Extreme Control Levels (Including Dispersed BMP Watershed Controls) Does Not Ensure Compliance in Banklick Creek with 30-day Geometric Mean Criterion (200 cfu/100 ml)

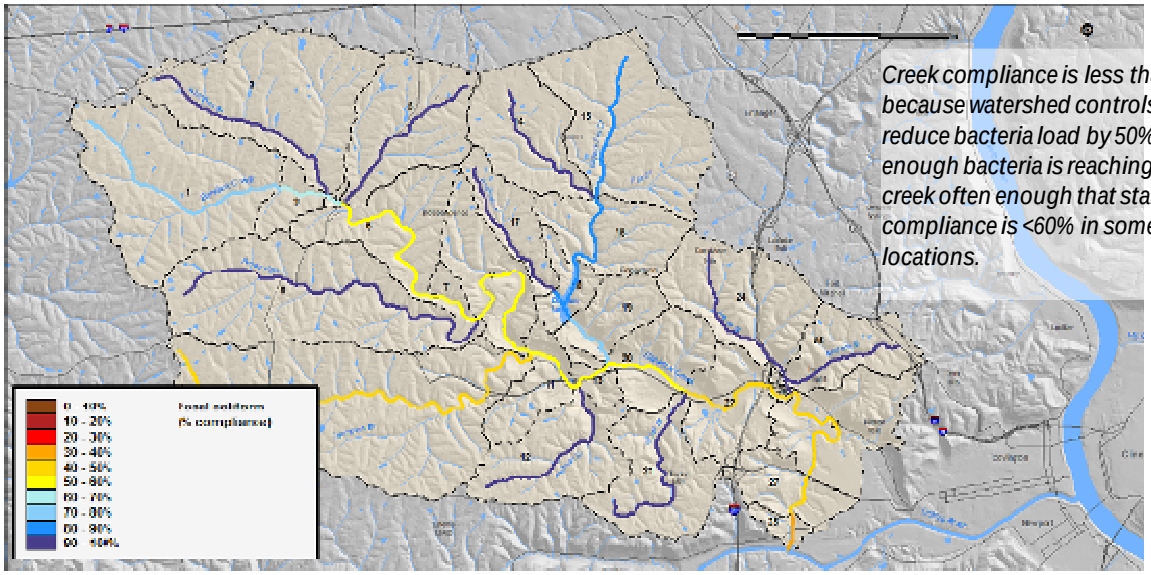
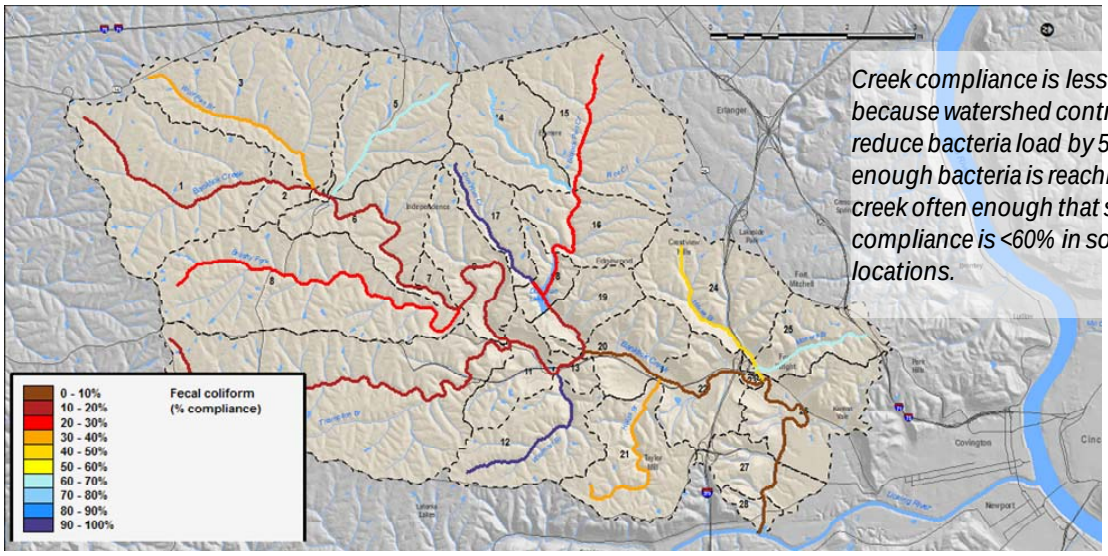


Figure 14 Extreme Control Level (Including Dispersed BMP Watershed Controls) Does Not Ensure Compliance in Banklick Creek with 30-day Maximum Criterion (400 cfu/100 ml)

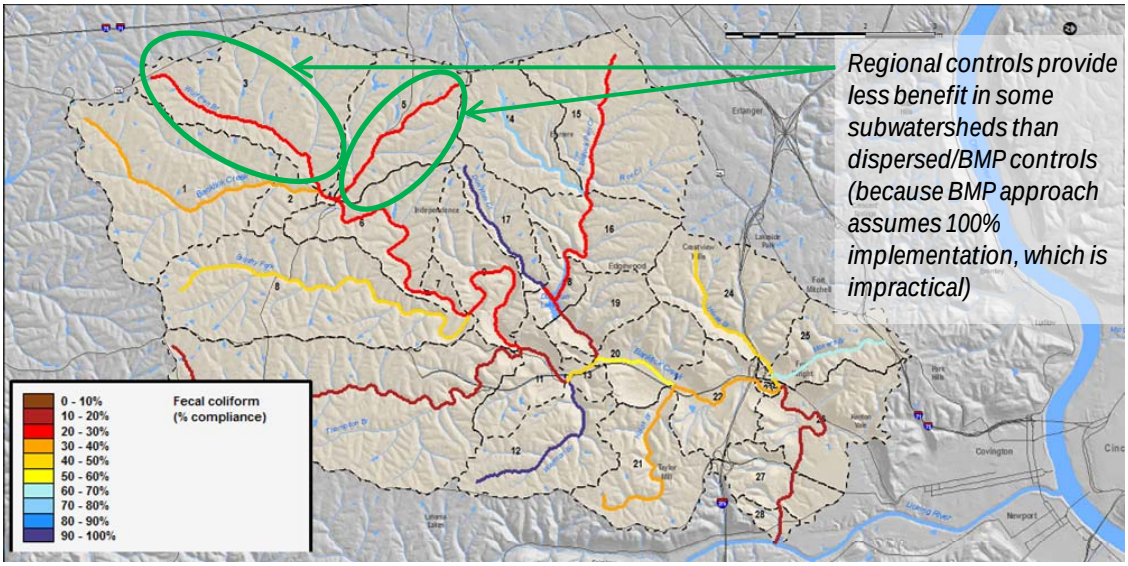


Note: Results comparing control alternative scenarios in Section 3.1 and 3.2 used the number of days < 400 cfu/100 ml as the comparison metric. The evaluation presented in this section relies on comparison to the actual water quality standards so results will differ, and in some cases, show lower compliance rates than the results presented in previous sections.

Similar results are observed with the "Extreme" integrated solution scenario using regional watershed controls, relative to bacteria Measure #2 (Figure 15). (Note that this scenario includes dispersed BMP watershed controls in subwatersheds that are not

"treated" by the regional controls. Regional controls include retention basins at the outlet of subwatersheds 1, 3, 5 and 8, and low flow wetlands in subwatersheds 13 and 20.) This scenario is an example where the dispersed green/watershed controls provide more benefit than the regional controls in terms of compliance with current bacteria water quality standards. In subwatersheds with regional controls, compliance with the State's 30-day maximum criterion is worse than with dispersed controls.

Figure 15 Extreme Regional Control Level (Including Regional Watershed Controls) Does Not Ensure Compliance in Banklick Creek with 30-day Maximum Criterion (400 cfu/100 ml)



3.3.2 Licking River

The Licking River, which currently has the best compliance with existing water quality standards, nevertheless fails to meet both of the State's 30-day criteria at all times (Figure 16 for geometric mean criterion (200 cfu/100 ml) Measure #3 and Figure 17 for maximum criterion (400 cfu/100 ml) Measure #2) under the extreme implementation scenario. This result is important to recognize in the context of the results presented in Section 3.1, where control of SD1 overflows with gray-only solution concepts resulted in an increased water quality benefit in the lower Licking River compared to other CSO-impacted waterways. Despite that relative benefit, current water quality standards could not be met at all times instream of the lower Licking River even with a hypothetical extreme implementation of all control types.

Figure 16 Extreme Control Level Does Not Ensure Compliance in Lower Licking River Mid-channel with 30-day Geometric Mean Criterion (200 cfu/100 ml) (Measure #3)

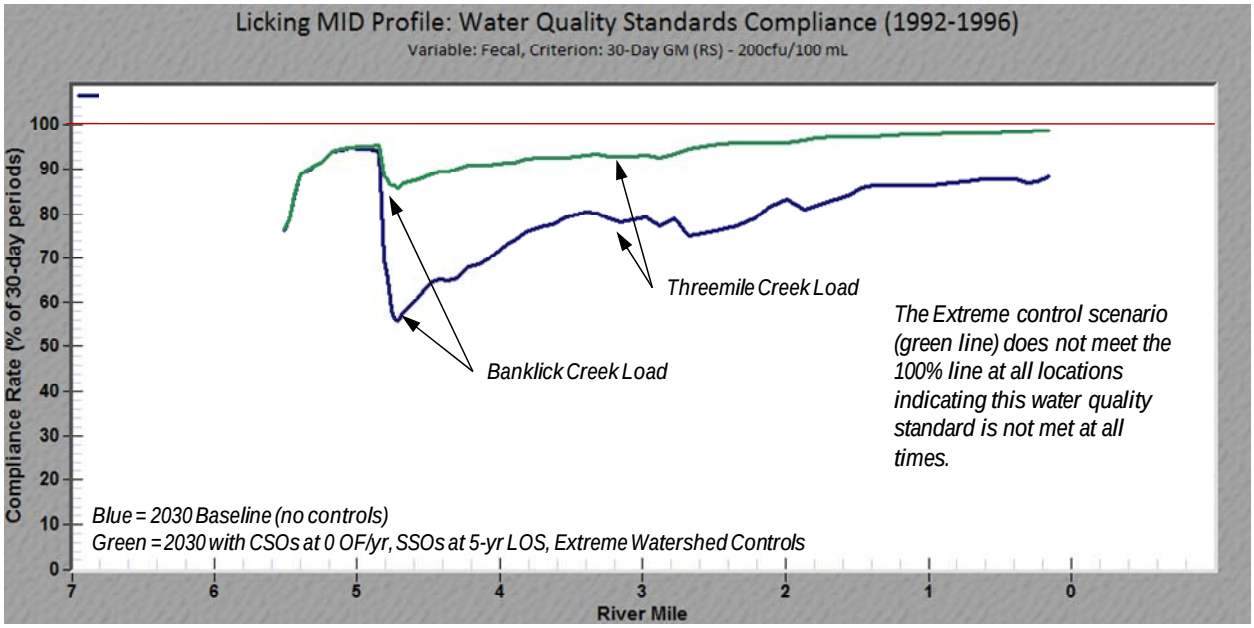
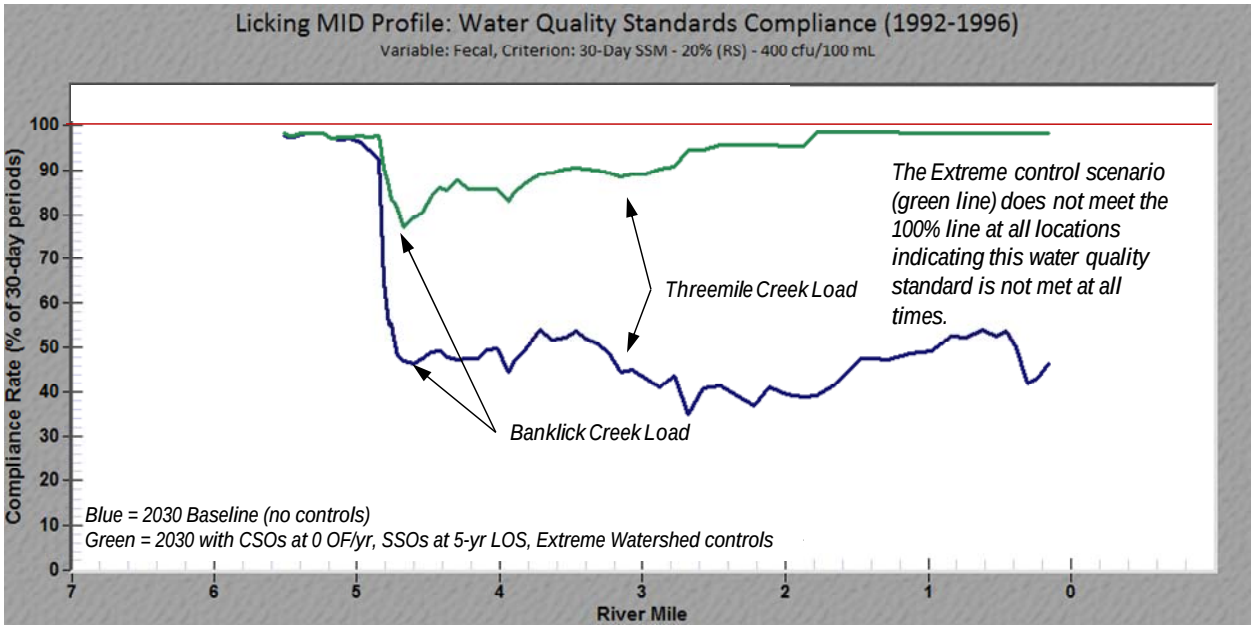


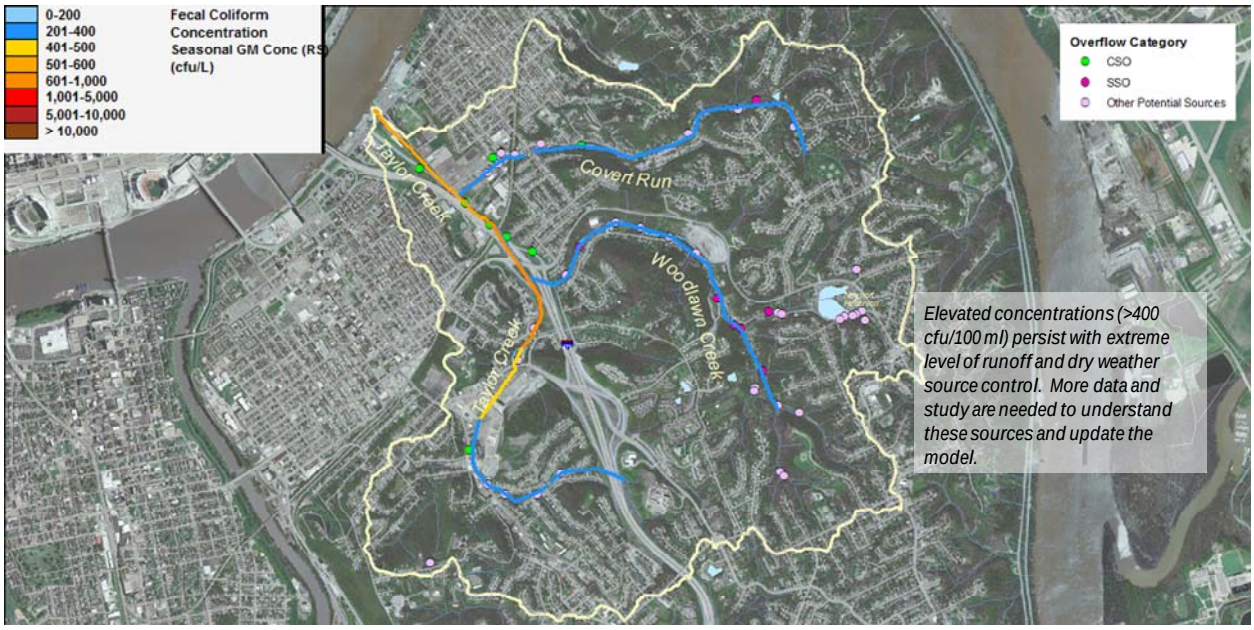
Figure 17 Extreme Control Level Does Not Ensure Compliance in Lower Licking River Mid-channel with 30-day Maximum Criterion (400 cfu/100 ml) (Measure #2)



3.3.3 Taylor Creek

Results for Taylor Creek, which is dominated by runoff and dry weather sources, shows that, as with other streams, water quality improves under the extreme implementation scenario but current water quality standards are not met at all times nor at all locations. However, both of these dominant source types are not well understood in Taylor Creek and more investigation is needed to better inform the model and evaluate control options. Figure 18 illustrates the impact of the Extreme scenario in terms of bacteria Measure #4 (recreational season geometric mean). While water quality improves (compared to results presented in Figure 11 for lower levels of control), the magnitude of the geometric mean densities shows that the instream density is greater than 400 cfu/100 ml (Measure #2) and unlikely to meet either bacteria water quality standard (Measure #2 or Measure #3) more than half of the time.

Figure 18 High Recreation Season Geometric Mean Densities Simulated in Extreme Control Level Scenario in Taylor Creek



The results of the extreme, integrated alternative scenario, assuming maximum implementation of all control types, indicate that meeting current water quality standards at all times and at all locations is not possible. Nevertheless, the integrated solution alternatives indicate that green and watershed technologies show significant potential for improving water quality, increasing the recreational use of the streams, and achieving important qualitative benefits such as habitat improvement and green space enhancement. The cost-benefit relationships and the potential for integrated solutions to provide greater benefit than solutions targeting overflows alone with gray infrastructure controls for a given investment are examined in the next section.

SECTION 4. COST-BENEFIT ASSESSMENT

The previous sections illustrated the benefits of overflow reduction and instream water quality predicted with SD1's models for two types of solutions - infrastructure controls only (gray-only solution concept) and a combination of infrastructure, green and watershed controls (integrated solutions). These analyses indicated that the watershed approach, which includes a combination of control types, can provide as much or more improvement in water quality (in terms of compliance with bacteria standards) along more stream miles as compared to a traditional solution that only controls overflows with gray infrastructure. None of the alternatives, however, ensure that the streams will achieve full compliance with Kentucky's current bacteria water quality standards. Further, the comparison must recognize that while assessment of compliance with bacteria water quality standards is an important metric, the integrated solutions associated with the watershed approach also provide a wider range of benefits, beyond bacteria reduction, than the gray only solution concepts. This section presents a cost-benefit analysis of the gray-only solution concept and the integrated solution alternatives.

SD1 has invested in a sophisticated cost estimation tool to estimate the costs associated with the gray infrastructure concepts and the gray-only solution concept. Using a planning horizon of 2025, however, presents difficult challenges in determining cost-performance of integrated solutions with a combination of control types. There are three difficulties:

1. Future development is difficult to predict; therefore, the extent of watershed controls that can be actually implemented may be substantially different than the levels used for the water quality modeling and costed as part of the alternative.
2. The opportunities that arise from SD1's goal of working in partnerships with other governmental entities and non-profits are difficult to predict and even more difficult to cost, even at the preliminary estimate level.
3. Any costs developed must include large contingencies to account for site-specific considerations and additional engineering, legal and permitting needs that cannot be quantified until control projects are taken to a more detailed design phase.

Despite these challenges, SD1 has developed cost estimates for the Full System Bounding Analysis that are appropriate for the current level of watershed planning using industry-accepted methods and standards. This section first presents the cost estimating methodologies for gray infrastructure concepts and green/watershed controls, and then develops a number of representative cost-benefit comparisons to inform decisions on the relative cost-effectiveness of different control options. Finally, the benefit evaluation is expanded to include all of the metrics, both cost-based and non cost-based, important to the decision process. The full range of metrics was provided previously in Table 1.

4.1 Gray Infrastructure Cost Estimation Methods

At the onset of the watershed planning effort, it was determined that a consistent and credible basis for establishing costs was essential to the Watershed Plan decision-making process. Therefore, SD1 developed a costing tool to assure that consistent and justifiable planning-level costs could be applied to numerous wet weather control technologies and Watershed Plan alternatives.

A Microsoft Access-based costing tool was used to develop and compare costs for hundreds of facilities and multiple gray infrastructure solution concepts for consideration in the Full System Bounding Analysis and for developing the concept plan for the gray infrastructure portion of the Integrated Plan for 2025 after the Five-year Improvement Program is implemented.

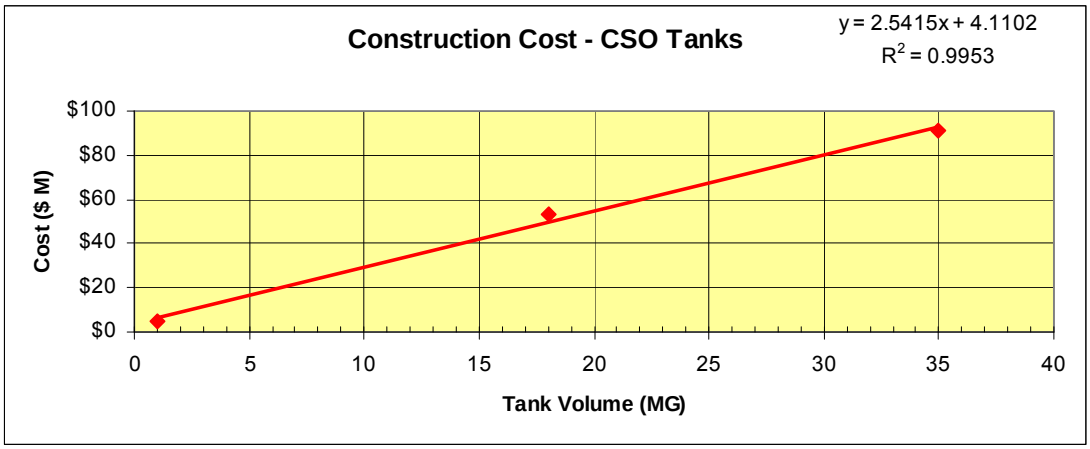
The first step in developing the costing tool was to screen viable technologies based on performance potential and characteristics of SD1's sewer system. This screening process resulted in identification of seven wet weather control technologies as feasible options for the SD1 system - gravity sewer mains, force mains, pumping stations, storage tanks, deep tunnels, mechanical bar screens and ballasted flocculation. For each of these feasible technologies, a detailed list of project and design assumptions were developed for the general cost basis, taking into account local topography, soil characteristics, sewer system configuration, general design parameters, etc. Assumptions that were common to each wet weather control technology are as follows:

- Present worth analysis evaluated over a 75 year time period.
- Constant annual interest rate of 4.875% (Discount Rate).
- Constant annual inflation rate of 3.0%.
- O&M costs are based upon a percentage of the construction cost. The percentages generally range between 1.0% and 3.0%.
- For mechanical facilities/technologies – i.e., screens, pump stations and ballasted flocculation – it was assumed that significant/scheduled maintenance activities will occur every 10 years. These maintenance activities were estimated to be 10% of the capital construction cost.
- There will be no salvage value at the conclusion of the 75 year time period.
- Construction costs are based upon the July 2008 Engineering News-Record Cost Index for the Cincinnati metropolitan area but is considered to reflect "2009" costs since the 2009 fiscal year begins on July 1..
- Estimated values for land/property costs are as follows:
    - Land acquisition = $100,000/acre
    - Subterranean/tunnel easements = $1,000/acre.
    - The cost of pipeline easements was considered to be negligible and was not included in the costing tool.

Using the design assumptions, a "bottom up" estimating approach was used, whereby individual capital cost estimates were developed over a range of capacities/sizes for each type of wet weather control technology. In general, three cost estimates were prepared for each technology covering the anticipated low, mid-range and high

capacity/size. The accuracy of these individual estimates was based upon the Association for the Advancement of Cost Engineering (AACE), Class 4 standards. The contingency applied within the costing tool is customizable and this feature can be used to reflect changes in level of detail available for different analyses. A contingency of 40% was used for the Full System Bounding Analysis. For the more refined Integrated Plan for 2025 analysis, a contingency of 20% was used, reflecting the higher level of detail put into the sizing and location of the facilities. For each type of technology, the individual capital cost estimate values were plotted and used to develop a standard cost curve/equation. An example of the resulting cost curves is shown in Figure 19.

Figure 19 Example of a Cost Curve/Equation (CSO Tanks)



The construction cost estimates and cost curves/equations were then confirmed through a variety of sources including:

- Recent bid information from SD1;
- Planning level cost information developed by the consulting team for other CSO studies; and
- EPA Technology Fact Sheets, Water Environment Research Federation studies and similar reference material.

One of two exceptions to the above was the development of the ballasted flocculation cost curve/equation. Due to the extensive scope that is generally required for the construction of a ballasted flocculation facility (including coarse and fine screens, pump station, storage tanks, disinfection facilities, etc.) it was determined that a cost equation would be developed using data derived from similar projects throughout the United States. For this technology, a cost curve was developed using information gathered from a variety of sources, including a ballasted flocculation manufacturer (US Filter – Actiflo™), published technical papers and data provided by the consulting team. All cost information was normalized to the Cincinnati metropolitan area using the construction cost index (CCI) published monthly in the Engineering News-Record.

The other exception was that the coarse screening cost curve/equation was based upon an earlier effort by AECOM for the Pittsburgh Water and Sewer Authority. The AECOM equation was derived from cost information provided in the EPA's CSO Technical Fact Sheet – Screens (EPA 832-F-99-040). AECOM's Pittsburgh Water and Sewer Authority

screening equation was normalized to the July 2008 Cincinnati metropolitan area using Engineering News-Record's monthly CCI number.

The capital cost equation for each feasible wet weather control technology is presented in Table 4.

Table 4 Capital Cost Equation for Wet Weather Control Technologies

Wet Weather Control Technology	"X" Value	Capital Cost Equation
Gravity Sewer Main (per LF)	Diameter (ft)	$y = 0.0182x^2 + 13.939x - 46.432$
Forcemain (per LF)	Diameter (ft)	$y = 73.468e^{(0.0531x)}$
Storage Tank (≤1.0 MG)	MG	$y = 6.65x$
Storage Tank (≥1.0 MG)	MG	$y = 2.5415x + 4.1102$
Ballasted Flocculation Facility	MG	$y = 0.4382x + 3.7063$
Pump Station	MGD	$y = 0.9054x^{0.7793}$
Tunnel (per LF)	Diameter (ft)	$y = 198.84x + 1739.8$
Tunnel Shaft (per VF)	Diameter (ft)	$y = 8{,}508\ln(x) - 14{,}296$
Coarse Screen	MGD	$y = 0.0453x + 0.4036$

With the these equations forming the cost basis for applicable technologies, site specific alternative facilities were input into the costing tool and grouped into numerous gray infrastructure solution concepts for consideration.

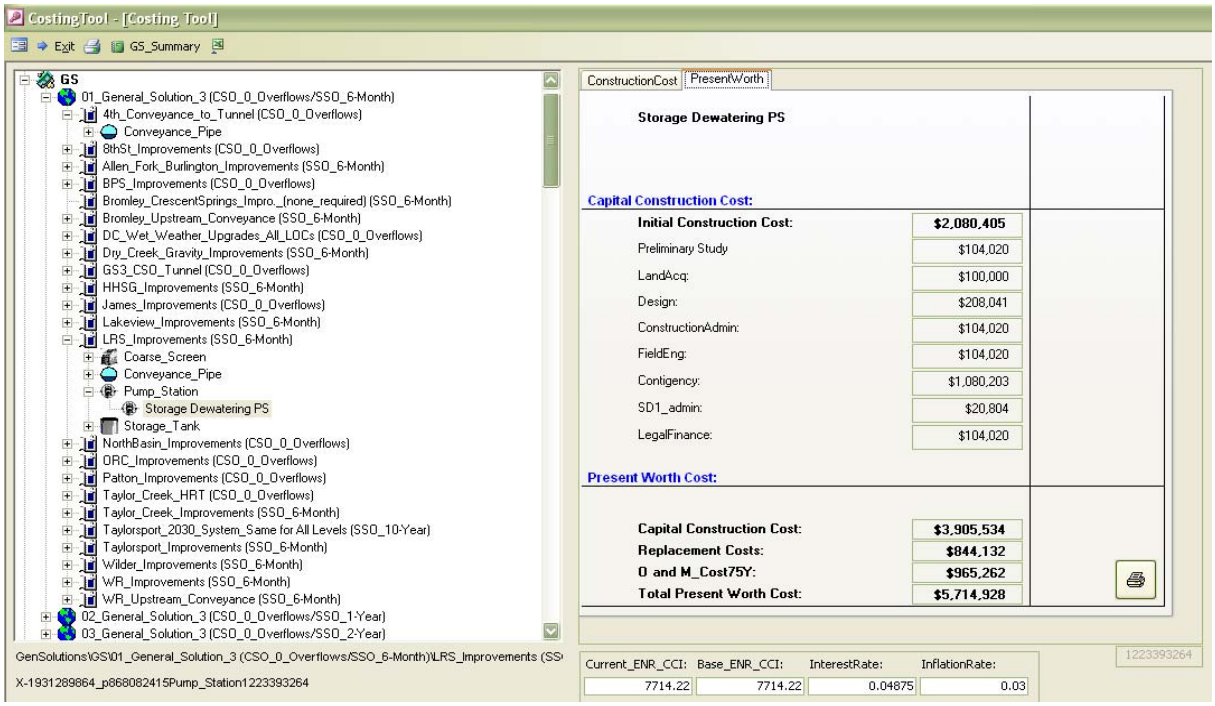
4.1.1 Costing Tool Output

The costing tool develops both a capital construction cost and a present worth (including O&M and capital replacement) for individual facilities, projects, which encompass groups of facilities, and general system-wide solution concepts, which are a roll-up of a particular set of planning project alternatives. The capital construction cost is only one element of SD1's cost to implement its Capital Improvement Program (CIP). To assist in planning for implementation and budgeting, the costing tool also develops anticipated cost values for typical SD1 CIP budget-related cost categories including preliminary study, engineering design, construction administration, field engineering, project contingency, administration and legal/finance. The cost allocated to each of these CIP cost categories was developed using SD1's standard fixed percentage of the capital construction cost for CIP budgeting, with the project contingency set at a level consistent with the level of planning. The costing tool allows SD1 to utilize the capital construction cost, CIP costs, and present worth cost estimates to evaluate alternatives at the individual facility level, or individual facilities can be grouped and rolled up costs evaluated for alternatives to address either specific planning areas or a general system-wide solution.

A screen shot of the project tree starting at the general system-wide solution level is shown in Figure 20. This figure shows that one general solution alternative incorporates groups of projects for numerous areas across the SD1 system. Additionally, each individual project incorporates a number of facilities, such as conveyance piping, pump stations, storage tanks, and screens. In the figure, a storage tank alternative is

highlighted and the cost estimate for that tank is shown on the right. The costs presented include the estimated initial capital construction cost, other CIP implementation related costs, and the present worth estimate.

Figure 20 Costing Tool Screen Shot



The resulting total costs represent full capital costs (in 2009 dollars) for the gray infrastructure concepts.

4.2 Watershed Control Cost Estimation Methods

Watershed control costs are much more difficult to estimate than costs for gray controls for the time horizon because they cannot be developed to the same level of detail as the infrastructure controls. Data from the NRCS and the Center for Watershed Protection (CWP) were used to estimate the costs of the dispersed BMP watershed controls. The NRCS provided data regarding construction costs for buffers expressed on a per acre basis in 2007 dollars (Kentucky NRCS, 2008a). The CWP has developed unit construction cost relationships based on cubic foot treated (retrofits) and impervious acre treated (new development) in 2006 dollars (CWP, 2007).

The CWP methods first estimate the water quality volume requiring control based on the area and imperviousness of the target area. Empirical equations, developed using data for differently sized BMPs around the country, are then used to estimate cost based on water quality volume requiring control. These equations are typically of the form Cost ($) = $a*(WQv)^b$, with WQv being the water quality volume controlled. These unit costs can range by an order of magnitude and include the cost of construction only. They do not account for site-specific considerations, such as site characteristics (topography,

soils, existing cover, ground water characteristics, etc.), land acquisition costs, and complex permitting. Nor do they account for operation and maintenance, design, engineering, permitting (see below), programmatic costs (such as dry weather source control, pet waste management outreach), and ordinance development. They do not scale well linearly (e.g. the cost for treating twice as much runoff is not twice as high as the original cost). Thus, they are very coarse estimates compared to the costs estimated using the infrastructure costing model. In actuality, some controls will cost more and some will cost less than the cost predicted with these equations, but when applied across a large area (as in this analysis), they are expected to reasonably represent the average cost of individual controls and so provide the best available estimate of total cost.

SD1 scaled the unit costs from the CWP and NRCS to reflect the assumptions used in the dispersed BMP watershed control scenarios (Section 3.2) regarding implementation of buffers, retrofits in existing development and runoff control requirements in new development. The costs were adjusted to 2009 dollars using a Northern Kentucky labor and inflation scalar of 8% (Kentucky NRCS, 2008b); this rate is projected to be higher than standard inflation given the uncertainty associated with these rapidly developing watershed technologies.

Because of the significant work needed to identify potential regional watershed controls, their cost was estimated with more certainty than the BMP-based methods. Preliminary cost estimates were developed for planning and project comparison purposes by developing initial designs for each project. At each location identified for a watershed control opportunity, the approximate project size was determined using standard water quality volume and other design calculations. Major project cost elements were identified (earthwork, land acquisition, structures, etc.) and quantities for each element were estimated based on project size. Unit costs were developed from a variety of sources including standard construction cost references (i.e., Means Heavy Construction Cost Data), local cost references (i.e. Kentucky Natural Resource Conservation Service), and experience from other SD1 projects. Capital construction costs were calculated as the sum of subtotals for individual project elements. Additional costs were estimated for other project components such as site evaluation, design, regulatory and permitting, and construction management. Overall contingency factors of 20% to 40% of capital construction costs were then applied to cover unforeseen conditions. Although these preliminary cost estimates may vary as more detailed site evaluations and feasibility assessment are conducted, they provide a reasonable level of detail and rigor at this stage of planning.

Table 5 presents a summary of the costs for the watershed controls for the Banklick Creek and Taylor Creek scenarios. SD1's detailed cost-benefit analysis of different control types focused on these two watersheds, for several reasons:

- Both were identified as important watersheds because they offer an opportunity to evaluate the benefit of controlling sources other than SD1 overflows;
- The analysis of control options in the Banklick Creek watershed is well developed, having started as a pilot analysis in 2007;

- While every watershed is different, the Banklick Creek and Taylor Creek watersheds represent the totality of issues seen in other SD1 watersheds; and
- Pending additional characterization and analysis in other watersheds during future watershed planning cycles, the Banklick Creek and Taylor Creek watersheds are expected to represent reasonable case studies reflecting the likely cost-benefit characteristics of other SD1 watersheds.

Table 5 Watershed Control Cost Estimates

Watershed Control Level	Range in Estimated Costs[1,2] ($ Million)	
	Banklick Creek	Taylor Creek
Moderate	$27.8 - $86.8	$2.7 - $8.9
Aggressive	$65.1 - $180.3	$6.7 - $22.5
Extreme	$134.2 - $406.7	$13.4 - $45.5

[1]These costs do not include costs associated with dry weather source control because the sources and remedies are too variable and uncertain to reasonably estimate. SD1 is implementing a Source Identification Program (described in Appendix 3-D of the Watershed Plans) as part of this first Five-year Improvement Program to obtain more information on dry weather sources that will reduce their uncertainty in future modeling analyses.

[2] Watershed control costs are not site specific and do not include site-specific contingency costs. It is likely that some controls will cost more than the estimated cost and some will cost less. However, when applied across a large area (as in this analysis), they are expected to reasonably represent the average cost of individual controls and so provide the best available estimate of total cost.

4.3 Cost-Benefit Analysis Results

As introduced above, cost-performance analyses were conducted for Banklick Creek and Taylor Creek for the traditional (gray-only solution concepts) and integrated solutions. To represent the gray-only solution concept cost for these two watersheds, the costs of controlling the CSOs and SSOs in Banklick Creek and Taylor Creek at the different control levels were isolated within the Bounding Analysis costs. The integrated solution cost was based on the sum of watershed costs (Table 4) and an associated gray-only solution concept control level cost. Performance was evaluated using the recreation season geometric mean density (bacteria Measure #4) at the mouth of each creek.

4.3.1 Cost-Benefit – Banklick Creek Watershed

Table 6 presents a summary of the costs and performance metrics from Banklick Creek used to generate the curves shown in Figure 21. As described in Section 3.1, the gray-only solution concept for the CSO sources in Banklick Creek include local storage and the majority of the SSO volume is rerouted to the Western Regional WRF. Therefore, it was relatively straightforward to extract the cost for controlling Banklick CSOs and SSOs from the full gray-only solution concepts' costs.

Table 6 Costs and Water Quality Performance for Gray Only and Integrated Solutions in Banklick Creek

Gray Only Solution Cost (Banklick Creek Sources Only)

Description	CSO LOC (OF/yr)	SSO LOS (OF freq)	CSO Cost ($ Million)	SSO Cost ($ Million)	Watershed Control Cost ($ Million)	Total Cost ($ Million)	WQ Benefit (Rec Season Geomean cfu/100ml)
2030 Base	Current	Current	$0	$0	$0	$0	1,058
18 OF/yr (6-mo SSO)	18	6-month	$10.5	$99.4	NA	$109.9	645
4 OF/yr (2-yr SSO)	4	2-year	$18.3	$179.7	NA	$198.1	617
0 OF/yr (5-yr SSO)	0	5-year	$34.3	$223.6	NA	$257.9	616

Integrated Solution (Dispersed BMP Watershed Controls) Cost (Banklick Watershed Only)

Description	CSO LOC (OF/yr)	SSO LOS (OF freq)	CSO Cost ($ Million)	SSO Cost ($ Million)	Watershed Control Cost ($ Million)	Total Cost ($ Million)	WQ Benefit (Rec Season Geomean cfu/100ml)
2030 Base	Current	Current	$0	$0	$0	$0	1,058
Moderate	18	6-month	$10.5	$99.4	$57.2	$167.1	517
Aggressive	18	6-month	$10.5	$99.4	$122.7	$232.5	494
Extreme	0	5-year	$34.3	$223.6	$270.5	$528.3	171

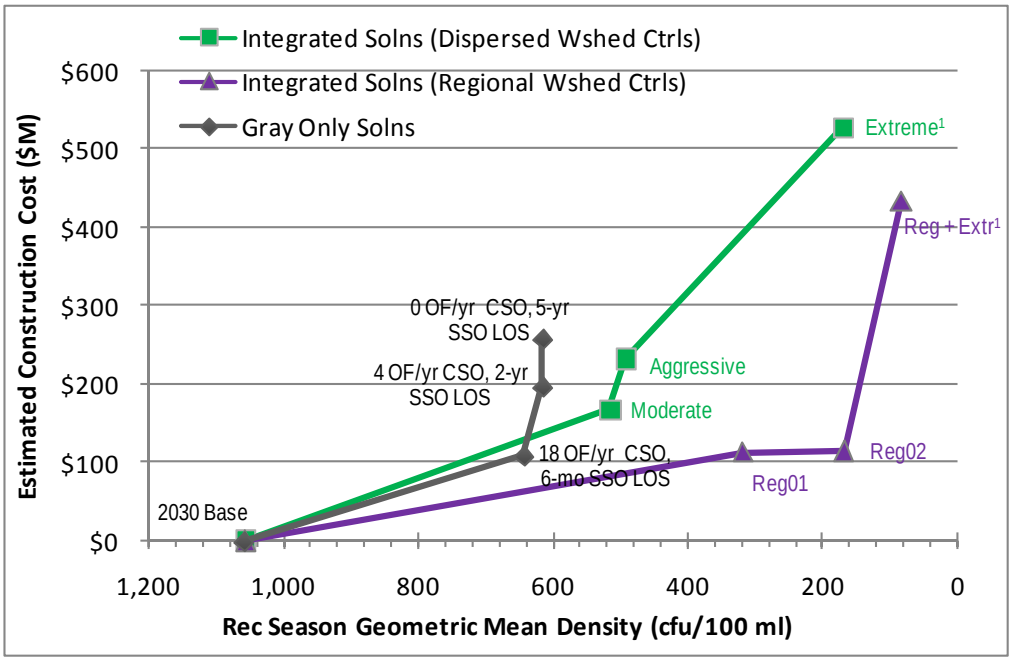
Integrated Solution (Regional Watershed Controls) Cost (Banklick Watershed Only)

Description[1]	CSO LOC (OF/yr)	SSO LOS (OF freq)	CSO Cost ($ Million)	SSO Cost ($ Million)	Watershed Control Cost ($ Million)	Total Cost ($ Million)	WQ Benefit (Rec Season Geomean cfu/100ml)
2030 Base	Current	Current	$0	$0	$0	$0	1,058
Reg01	18	6-month	$10.5	$99.4	$2.4	$112.2	321
Reg02	18	6-month	$10.5	$99.4	$4.2	$114.2	171
Reg-Extr	0	5-year	$34.3	$223.6	$176.2	$434.1	86

Note:

[1] Reg01 = Regional Retention Basins
Reg02 = Regional Retention Basins and Two-Stage Low Flow Wetland
Reg-Extr = Reg02 and Extreme Dispersed BMP controls in watersheds not treated with regional control

Figure 21 Cost-Performance Comparison for Gray-Only and Integrated Solutions in Banklick Creek



Note:

[1] Extreme scenarios simulated 90% reduction in dry weather source loads but does not include that cost in curve (could not be reasonably estimated given uncertainty). SD1 is implementing a Source Identification Program (described in Appendix 3-D of the Watershed Plans) as part of this first Five-year Improvement Program to obtain more information on dry weather sources that will reduce their uncertainty in modeling analyses.

The results shown in Figure 21 for Banklick Creek indicate that integrated solutions at a moderate or aggressive level or regional controls provide more improvement in water quality (e.g. lower geometric mean density) for the same amount of funding compared to gray-only solution concept. This relationship exists wherever the integrated solution curve lies to the right of the gray-only solution concept curve for a given construction cost. Applying a regional approach to watershed controls can be more cost-effective and provide greater instream benefit than applying a dispersed BMP approach. Note, however, that not all watersheds will have feasible opportunities to consider regional controls and so this cost-effective comparison between dispersed and regional controls may not be similar in other watersheds.

The general trend in the curves is apparent – for construction cost investments, the integrated solutions will provide a greater benefit in terms of reduced instream bacteria levels. This is likely true even for the integrated extreme scenarios, despite the fact that they do not currently include the cost of dry weather source controls. Because the gray-only solution concept curve is trending vertically, it is reasonable to assume that it will remain to the left of the integrated solution curves.

Finally, it is important to note that the cost-benefit curve shown in Figure 21 captures the water quality benefit in terms of bacteria reductions alone. Integrated solutions also

offer non-water quality based benefits, including the qualitative advantages described previously. Table 7 presents a more comprehensive analysis of benefits for each of the solution types in the Banklick Creek watershed. This table captures some of the important non-quantitative metrics described in the beginning of this section. As the table illustrates, integrated solutions provide many additional benefits that cannot be attained with the gray solution overflow controls. In particular, more stream length is improved with integrated solutions. These other metrics also allow the controls to be evaluated with respect to aquatic life use. Other benefits shown in this table, such as reducing flooding and erosion, directly benefit aquatic life in the area's creeks and provide a link between the controls and this use. These metrics are important to consider to ensure that the Consent Decree objective of improving water quality is thoroughly evaluated as intended, i.e. including not only bacteria reduction but also the broader environmental impact indicators shown in Table 7. Note that the indicators in Table 7 are the similarly named metrics in Table 1 that correspond to the "environmental impact" factors from the Consent Decree.

Table 7 Range of Benefits for Gray-Only and Integrated Solutions in Banklick Creek

Scenario	Construction Cost ($ Million)	% of Days < 400 cfu/100 ml	Rec season geomean (cfu/100 ml)	Flood Reduction	Erosion Control	Reductions in Other Pollutants	Biological Benefits	Stream Miles Benefited
2030 base (no controls)	$0	32%	1,058					None
Gray-only Level 1[1]	$110	38%	645			X		Lower 4 miles[9]
Gray-only Level 2[2]	$198	39%	617			X		Lower 4 miles[9]
Gray-only Level 3[3]	$258	39%	616			X		Lower 4 miles[9]
Gray + Moderate watershed control[4]	$167	43%	517	X	X	X	X	All
Gray + Aggressive watershed control[4]	$232	44%	494	X	X	X	X	All
Gray + Extreme watershed control[5]	$528[11]	63%	171	X	X	X	X	All
Gray + Regional watershed control level 1[6]	$112	57%	321	X	X	X	X	Lower 15.6 miles[10]
Gray + Regional watershed control level 2[7]	$114	63%	171	X	X	X	X	Lower 15.6 miles[10]
Gray + Regional watershed control level 3[8]	$434[11]	69%	86	X	X	X	X	All

Notes:

[1] Gray-only level 1 includes CSO = 18 OF/yr, SSO = 6-mo LOS

[2] Gray-only level 2 includes CSO = 4 OF/yr, SSO = 2-yr LOS

[3] Gray-only level 3 includes CSO = 0 OF/yr, SSO = 5-yr LOS

[4] Gray level of control was CSO = 18 OF/yr, SSO = 6-mo LOS

[5] Gray level of control was CSO = 0 OF/yr, SSO = 5-yr LOS. Also includes a 90% reduction in dry weather source loads.

[6] Gray level of control was CSO = 18 OF/yr, SSO = 6-mo LOS, Regional control includes retention basins

[7] Gray level of control was CSO = 18 OF/yr, SSO = 6-mo LOS, Regional control includes retention basins and two-stage low flow wetland

[8] Gray level of control was CSO = 0 OF/yr, SSO = 5-yr LOS; Regional control includes retention basins plus Extreme Dispersed BMP controls in watersheds not treated with regional control

[9] SD1 overflows are located largely in lower four miles of watershed but this control level would also reduce smaller upstream SSOs, so limited benefit would be observed throughout the lower 11.6 miles of the creek.

[10] The most upstream regional watershed control is potentially located near this river mile.

[11] Cost does not include the cost associated with reducing dry weather sources. Additional information collected in the next five year planning cycle will be used to update these costs.

4.3.2 Cost-Benefit – Taylor Creek Watershed

The cost-performance analysis for Taylor Creek includes benefits for the integrated solutions with and without dry weather source control. Table 8 presents a summary of the costs and performance metrics from Taylor Creek used to generate the curves shown in Figure 22. As described in Section 3.1, the gray solution in vicinity of Taylor Creek is a high rate treatment facility. However, because this facility is designed to

receive volume from sources outside the Taylor Creek watershed, conveyance and facility costs in Table 8 reflect the costs associated with the solution rather than the costs for controlling Taylor Creek sources alone.

One permutation of the Moderate control scenario for Taylor Creek included reductions in dry weather sources. Although these costs cannot be projected at this time, the analysis confirmed that incorporating dry weather control into the Taylor Creek solution could provide more significant benefit than control of wet weather controls alone. Although specific dry weather control approaches have not been defined (because more information is needed about the relevant sources), percent reductions have been hypothesized for this analysis. Also noteworthy in the cost-benefit analysis is that the benefit of the Extreme scenario, which does not meet water quality standards, still shows approximately a six-fold reduction in the recreation season density, which is a significant reduction.

Table 8 Costs and Water Quality Performance for Gray-Only and Integrated Solutions in Taylor Creek

Gray-only Solution Cost (Taylor Creek Sources)

Description	CSO LOC (OF/yr)	SSO LOS (OF freq)	CSO Cost ($ Million)	SSO Cost ($ Million)	Watershed Control Cost ($ Million)	Total Cost ($ Million)	WQ Benefit (Rec Season Geomean cfu/100ml)
2030 Base	Current	Current	$0	$0		$0	3,056
18 OF/yr (6-mo SSO)	18	6-month	$85.1	$13.2		$98.3	3,014
0 OF/yr (5-yr SSO)	0	5-year	$143.8	$19.1		$162.9	3,014

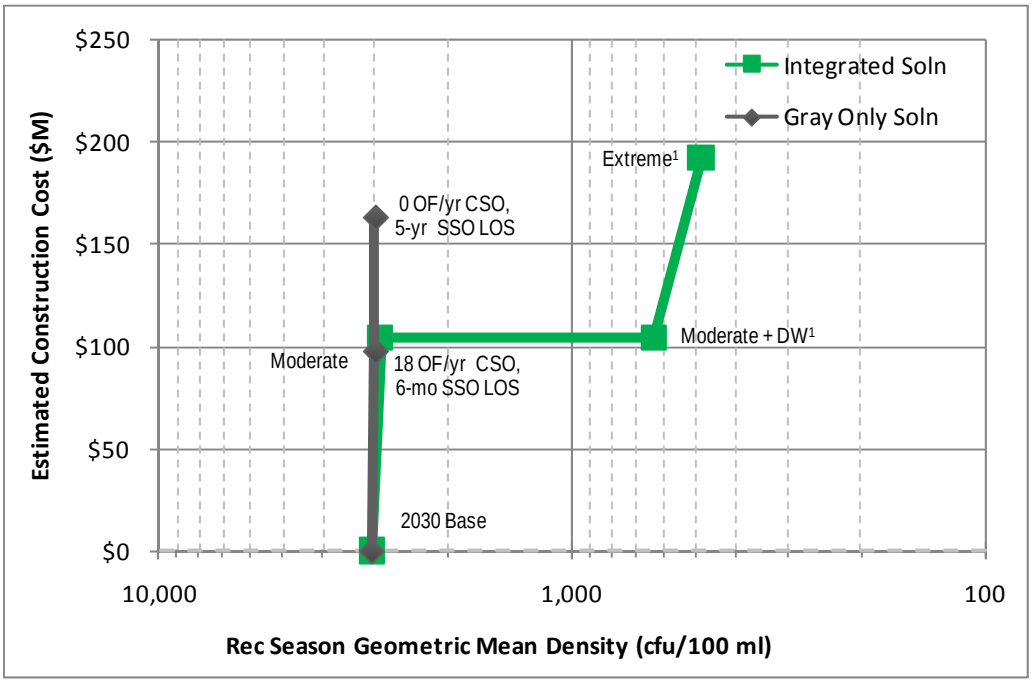
Integrated Solution Cost (Taylor Watershed Only)

Description	CSO LOC (OF/yr)	SSO LOS (OF freq)	CSO Cost ($ Million)	SSO Cost ($ Million)	Watershed Control Cost ($ Million)	Total Cost ($ Million)	WQ Benefit (Rec Season Geomean cfu/100ml)
2030 Base	Current	Current	$0	$0	$0	$0	3,056
Moderate	18	6-month	$85.1	$13.2	$5.8	$104.0	2,892
Moderate + DW[1]	18	6-month	$85.1	$13.2	$5.8	$ 104.0	632
Extreme[1]	0	5-year	$143.8	$19.1	$29.4	$192.3	487

Note:

[1] This scenario simulated 90% reduction in dry weather source loads but does not include that cost in curve (could not be reasonably estimated given uncertainty). SD1 is implementing a Source Identification Program (Appendix 3-D of the Watershed Plans) as part of this first Five-year Improvement Program to obtain more information on dry weather sources that will reduce their uncertainty in future modeling analyses.

Figure 22 Cost-Performance Comparison for Gray-Only and Integrated Solutions in Taylor Creek



Note:

[1] Scenario simulated 90% reduction in dry weather source loads (Extreme and Moderate+DW) but does not include that cost in curve (could not be reasonably estimated given uncertainty). SD1 is implementing a Source Identification Program (Appendix 3-D of the Watershed Plans) as part of this first Five-year Improvement Program to obtain more information on dry weather sources that will reduce their uncertainty in modeling analyses. Cost estimates for dry weather source control can be improved as more information is obtained in the next five years.

The results above show that in the Taylor Creek watershed it is necessary to address and control dry weather sources in addition to other wet weather sources to gain significant improvement in water quality. Simply addressing SD1 overflows and other wet weather sources do not offer significant water quality improvement. By controlling dry weather sources in addition to wet weather sources, the geometric mean bacteria density drops by approximately one-fifth (from ~ 3,000 cfu/100 ml to ~600 cfu/100 ml).

Table 9 provides a summary of the non-quantitative benefits of the gray-only and integrated solution concepts in Taylor Creek. As with Banklick Creek, this comparison indicates that integrated solutions provide many additional benefits that cannot be attained with the overflow controls.

Table 9 Range of Benefits for Gray-Only and Integrated Solution Concepts in Taylor Creek

Scenario	Construction Cost ($ Million)	% of Days < 400 cfu/100 ml	Rec season geomean (cfu/100 ml)	Flood Reduction	Erosion Control	Reductions in Other Pollutants	Biological Benefits	Stream Miles Benefited
2030 base (no controls)	$0	1.3%	3,058					None
Gray-only Level 1[1]	$98	1.3%	3,014			X		Lower 5.3 miles[7]
Gray-only Level 2[2]	$163	1.3%	3,014			X		Lower 5.3 miles[7]
Gray + Moderate watershed control[3]	$104	1.4%	2,892	X	X	X	X	All
Gray + Moderate watershed control + dry weather source reduction[4]	$104[6]	56.5%	632	X	X	X	X	All
Gray + Extreme watershed control[5]	$192[6]	60.0%	487	X	X	X	X	All

Notes:

[1] Gray-only level 1 includes CSO = 18 OF/yr, SSO = 6-mo LOS

[2] Gray-only level 2 includes CSO = 0 OF/yr, SSO = 5-yr LOS

[3] Gray level of control was CSO = 18 OF/yr, SSO = 6-mo LOS

[4] Gray level of control was CSO = 18 OF/yr, SSO = 6-mo LOS. Includes 90% reduction in dry weather loads

[5] Gray level of control was CSO = 0 OF/yr, SSO = 5-yr LOS. Includes 90% reduction in dry weather loads

[6] Cost does not include the cost associated with reducing dry weather sources. Additional information collected in the next five year planning cycle will be used to update this cost.

[7] The Taylor Creek system contains three major branches: Taylor Creek, Covert Run and Woodlawn Creek. The stream miles shown in this table correspond to the sum of the stream length affected by SD1 overflows. The sum of the total lengths of these streams is approximately 6.8 miles

4.4 Summary of Overall Benefits

As shown above, the results illustrate that a holistic, watershed management approach addressing multiple sources of pollution achieves greater benefit to improving water quality and public health as compared to overflow control only. This is true for both the traditional quantitative benefit of instream bacteria reduction, as well as broader benefits reflecting environmental impact, eco-friendliness, and quality of life.

The benefits of the integrated solution concepts in terms of the full range of decision metrics is summarized in Table 10 below. This table further highlights that the benefits of integrated solutions go beyond pure bacteria-based cost-benefit arguments, given the inherent nature of green and watershed controls. The table provides a relative scoring of the benefits of each solution approach with respect to the Table 1 metrics. The metrics were scored with a positive (+) or negative (-) based on their ability to address the associated metric. If both solution types addressed the associated metric but one solution type was more effective than the other, then a double positive (++) was used to indicate the more effective control type. The two cost metrics were not evaluated in this

analysis because the solutions discussed in this section are preliminary and their comparative costs will likely change as additional information and data are collected in each five-year planning cycle. Nevertheless, they are important metrics and should be carried forward into future planning.

Table 10 Comparison of Bounding Analysis Benefits

Evaluation of	Factor[2]	Metric	Full System Bounding Analysis Concepts[1]	
			Gray-only Solution Concepts[3]	Integrated Solution w/ Combination of Control Types[3]
System performance	3	Maximization of existing treatment capacity	++	+
	4	Reduction in surface runoff contribution to the combined system	-	+
	3	Reduction in number of overflow events	++	+
	3	Reduction in overflow volume	++	+
	3	Enhancement of Nine Minimum Controls program	++	+
Bacteria reduction	4	Overall watershed reduction of instream bacteria densities	+	++
	3	Increased attainment of bacteria water quality criteria	+	++
	4	Percent bacteria load reduction by watershed	+	++
	4	Length of stream reach with reduced bacteria densities	+	++
Cost	6	Construction cost vs. water quality improvement	+	++
	6	Construction cost vs. all benefits	+	++
	6	Capital cost	n/a[3]	n/a[3]
	6	Annual operations and maintenance cost	n/a[3]	n/a[3]
Ecological, human health and other additional benefits	2	Reduction in public health risk	+	++
	1	Reduction in flooding and increase in infiltration	-	++
	1	Improvements in aquatic habitat and biological scores	-	+
	1	Stabilization of streambanks to reduce erosion	-	+
	1	Reductions in other pollutants or water quality violations	+	++
	1	Preservation of green space	-	+
	1	Provide opportunities to connect public lands/greenways	-	+
	5	Provide opportunities for community involvement and partnering	-	+

Notes:

[1] The scoring system used in this table was:

+ = the metric is improved by the solution type

++ = in instances where both solution types improve the metric, this score is used to indicate the more effective solution type

- = the metric is not addressed by the solution type

n/a = the metric was not evaluated.

[2] The Factors in Table 1 are matched against the factors from the Consent Decree (IV.D.39) defined as follows:

1 Environmental impact
2 Public risk
3 Regulatory requirements
4 Degree of water quality improvement expected to be achieved
5 Public input
6 Cost-effectiveness

[3] A value of n/a indicates that the metric was not evaluated for the Bounding Analysis concepts due to uncertainty in the value.

SECTION 5. CONCLUSIONS

The analyses and results described above provide an important information base for SD1 decision-making by assessing the sensitivity between control of different types of pollutant sources and compliance with instream water quality bacteria standards under projected future conditions. In addition, the analysis provides a mechanism for assessing the cost and benefit of control programs that addresses all SD1 point sources at the end of the Consent Decree implementation period. This information provided several key conclusions that are important for guiding the configuration of SD1's first Five-year Improvement Program. By incorporating these conclusions in the first Watershed Plans, SD1 is laying the groundwork for consistently expanding effective approaches in subsequent cycles.

Conclusion #1: Targeting dry weather and runoff sources can provide cost-effective improvement in compliance with water quality standards.

A recurring theme in several local streams is that water quality is dominated by dry weather and runoff sources rather than by CSOs and SSOs. Therefore, early action on these sources will typically provide greater water quality standards compliance than global control of overflows.

Conclusion #2: High levels of overflow control provide diminishing instream water quality standards compliance returns.

SD1's detailed water quality modeling has demonstrated that instream compliance with water quality standards is not sensitive to the level of overflow control. That is, controlling CSOs and SSOs to "typical" control levels (e.g., 4 activations per year for CSOs, and 2-year level of service for SSOs) provides little to no additional instream benefit compared to controlling to lower control levels (e.g., 18 activations per year for CSOs, and 6-month level of service for SSOs). Therefore, justification does not exist for investing in high levels of overflow control in pursuit of improving compliance with water quality standards.

Conclusion #3: Decisions on overflow control should first target protection of human health, rather than compliance with water quality standards.

SD1 does not believe that Conclusions #1 and #2 above in any way relieve them of general responsibility for overflow control. Overflow control is clearly warranted to protect human health, and should be targeted first at locations with high risk for public exposure.

Conclusion #4: Use of green and watershed controls can be more cost-effective than gray controls, especially in the early stages of a multi-stage program.

SD1's detailed water quality modeling of integrated solutions has indicated that combining CSO and SSO control at 18 OF/yr and 6-month level of service, respectively with moderate watershed controls yields greater overall water quality improvements

along more stream length as compared to controlling CSO and SSO alone at a higher level (4 OF/yr and 2-year level of service, respectively). Therefore, cost-effective opportunities for green and watershed controls are ideal candidates for the first Five-year Improvement Program, as they provide immediate benefit over a wide range of metrics and can serve as a cost-effective step towards the 2025 control alternatives with integrated solutions.

The ability of green and watershed controls to achieve a wide range of benefits is an important decision factor for SD1. While reduction of instream bacteria densities and attainment of water quality standards are obviously important objectives, bacteria measures are only one indicator of environmental impact. Therefore, in selecting solutions, SD1 will consider the full range of benefits achieved with different controls to properly compare various options and make fully informed cost-benefit decisions.

A prime example of the value of leading with green programs emerges from the lower Licking River analysis. Given the relative distribution of bacteria sources along the lower Licking River, it is to be expected that controlling SD1 CSOs will provide an increased water quality benefit compared to other CSO-impacted waterways. The CSO problem is due to runoff overwhelming the combined system. SD1's strategy is to first use green infrastructure and source control to reduce the runoff volume to the combined system, while also gaining the benefit of incorporating eco-friendly solutions in the urban CSO area. Time is then needed to evaluate the performance of these controls and to refine the understanding of the maximum level of volume reduction that is feasible with these technologies. In future Watershed Plans, alternatives may be reassessed if an appropriate level of control has not been achieved.

Conclusion #5: Because the implementability and performance of green and watershed controls requires further confirmation, the first five-year Watershed Plans should provide for implementation of controls that are important to all alternative solutions.

The analysis herein shows the integrated control approach has the most promise from a broad environmental, instream water quality, and cost standpoint. However, because green and watershed controls must be studied further to confirm cost and benefit, and SD1 must coordinate with other entities to determine full scale implementability, the Five-year Improvement Program should focus remedial efforts on critical projects and programs that are a component of the remedies.

SD1 carried results from the Bounding Analyses, aligned with the above conclusions, into the planning process and the development of the Integrated Plan for 2025 (Section 3) and the Five-year Improvement Program (Section 7) of the Watershed Plans.

Appendix 3-B

Green Opportunities Analysis

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    - Church Street Study Area

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Appendix 3-B.1
Initial Green Infrastructure Opportunities Analysis

Green infrastructure opportunities were identified on a large regional scale (for system-wide application), as well as part of a detailed evaluation of the combined sewer system for more specific project implementation. The system-wide green approaches will help SD1 inform and direct development strategies and help develop key partnerships to further the commitment to the implementation of green infrastructure. The identification of opportunities system-wide and in the combined system expands on the inventory and analysis described in Section 2.1.3 and Appendix 2-D.

System-wide Green Infrastructure Overview

Northern Kentucky possesses a valuable inventory of rivers, streams, creeks, and aquatic habitat. The system-wide green infrastructure opportunities include a continual effort to protect and restore the hydrologic network that mimics the natural water balance in Northern Kentucky. The approach includes:

- Conservation and restoration;
- Implementation of design protocols to reduce the impacts of runoff;
- Protection, enhancement, and connection of forests;
- Promotion of transportation corridors as greenway connections;
- Support of regional planning and low impact development; and,
- Offload of runoff to natural systems.

System-wide Green Infrastructure Approach

The components of the above principles, which represent SD1's guiding philosophy and approach to green infrastructure, are described in more detail below.

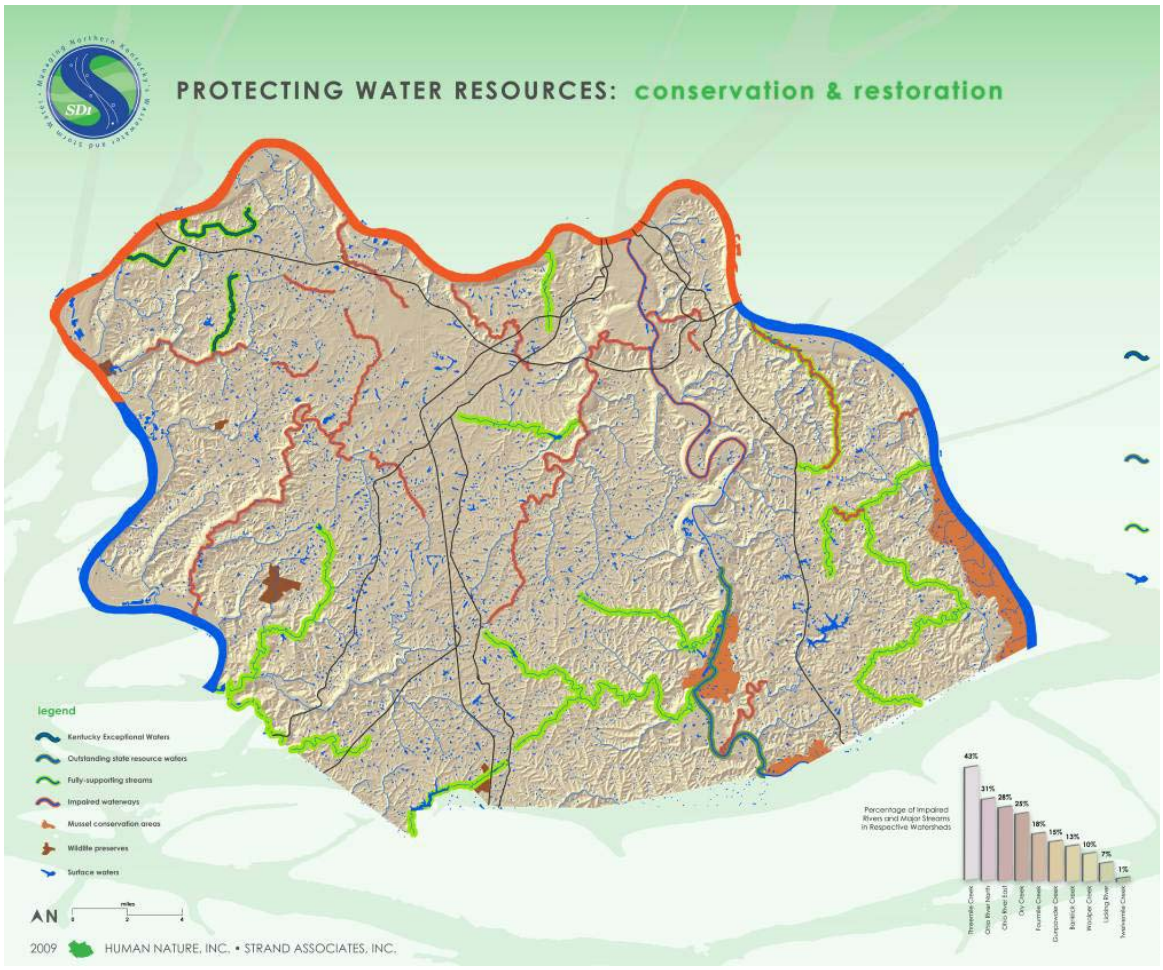
Conservation and Restoration

The Commonwealth of Kentucky has classified several stream segments in the Northern Kentucky area as having very good conditions for supporting aquatic life. These include 7.9 miles of Kentucky Exceptional Waters (Double Lick Creek, Garrison Creek and Second Creek), 16.7 miles of Outstanding State Resource Waters (Licking River), 104 miles of streams fully supporting warm aquatic habitat, and 3,410 acres of existing surface waters.

KDOW also identifies and prioritizes all of the Commonwealth's impaired waters or those that do not meet state water quality standards. Impaired waters are summarized in a biannual report titled Kentucky Report to Congress on Water Quality, or the 305(b) Report. In the 2008 version of the report, there were 104.8 miles of streams and rivers in Northern Kentucky that were listed as impaired.

Figure 1 summarizes recommended streams for both conservation and restoration. For a larger version of the Protecting Water Resources figure please refer to Appendix 2-D page 37.

Figure 1. Protecting Water Resources: Conservation and Restoration (as of June 2009).



Implementation of Design Protocols to Reduce the Impacts of Runoff

Traditional storm water management strategies focus on flood control, with little regard for smaller storms that convey significant pollutant loadings and have the potential to trigger hydromodification impacts. SD1 recognizes the importance of controlling more frequent storm events in terms of improving water quality and reducing stream instability. As part of the ongoing watershed assessment process, SD1 will continue to explore and evaluate opportunities to address water quality and hydromodification issues associated with frequent rainfall and runoff events. SD1 is currently evaluating a number of potential revisions to existing post construction storm water regulations for new and redevelopment projects in both the combined sewer system and the separate storm sewer system.

Opportunities that have been identified to address these issues include:

- Minimize the impact of infrastructure on stream corridors: There are approximately 209 miles of sewer infrastructure adjacent to streams and rivers in SD1's service area. This infrastructure affects the natural flow of streams and rivers, and is also susceptible to inundation during intense rain events.
- Enhance existing detention and retention ponds: These facilities are designed to temporarily detain runoff and to provide peak flow attenuation for flood control purposes. Retrofitting existing ponds to address small storm flows represents an efficient way to reduce the impacts of runoff.

Protection, Enhancement, and Connection of Forests

There are currently 142,510 acres of tree canopy in the region covering 38 percent of the total land area. The regional canopy network provides valuable benefits in regard to natural storm water management and air quality improvement. Based on a CITYgreen model (American Forests, 2006) analysis of the storm water benefits from trees, the existing canopy cover provides approximately 2.44 billion cubic feet of annual storage volume for the three county region. This represents the volume of additional runoff to be managed if trees were removed from the landscape. CITYgreen also reports the construction cost per cubic foot for building a storm water management facility to control this volume of runoff. Using a construction cost of $2 per cubic foot, the estimated annual savings from the existing tree canopy is almost $4.9 Billion.

In addition to protecting existing tree canopy, urban reforestation should focus efforts on opportunities and constraints in regard to:

- Reforestation within the right-of-way of major interstate corridors;
- Reforestation on steep slopes, specifically those adjacent to impaired or exceptional waterways;
- Reforestation requirements for future land uses and new development (e.g., industrial and commercial growth along I-71 and I-75); and
- Reforestation opportunities with strategic partner properties.

In addition to protecting the region's valuable inventory of freshwater resources, riparian buffers can filter sediment from surface runoff, reduce nutrient densities, and stabilize stream banks. The recommended stream buffers cover almost 22,000 acres in Northern Kentucky, 38 percent of which does not contain significant tree cover.

In addition to reducing the volume of runoff, reforestation within right-of-way acts as an effective sound barrier, improves air quality, and lessens the urban heat island effect. There are over 14,000 acres of right-of-way in Northern Kentucky, 85 percent of which does not have tree cover.

Landslide-prone areas include areas with slopes greater than 20 percent and/or areas with known geologic instability. Trees and forests greatly improve slope stability, and also help slow the velocity and reduce the volume of runoff. There are almost 141,000 acres of landslide-prone areas in Northern Kentucky, 34 percent of which do not have significant tree cover.

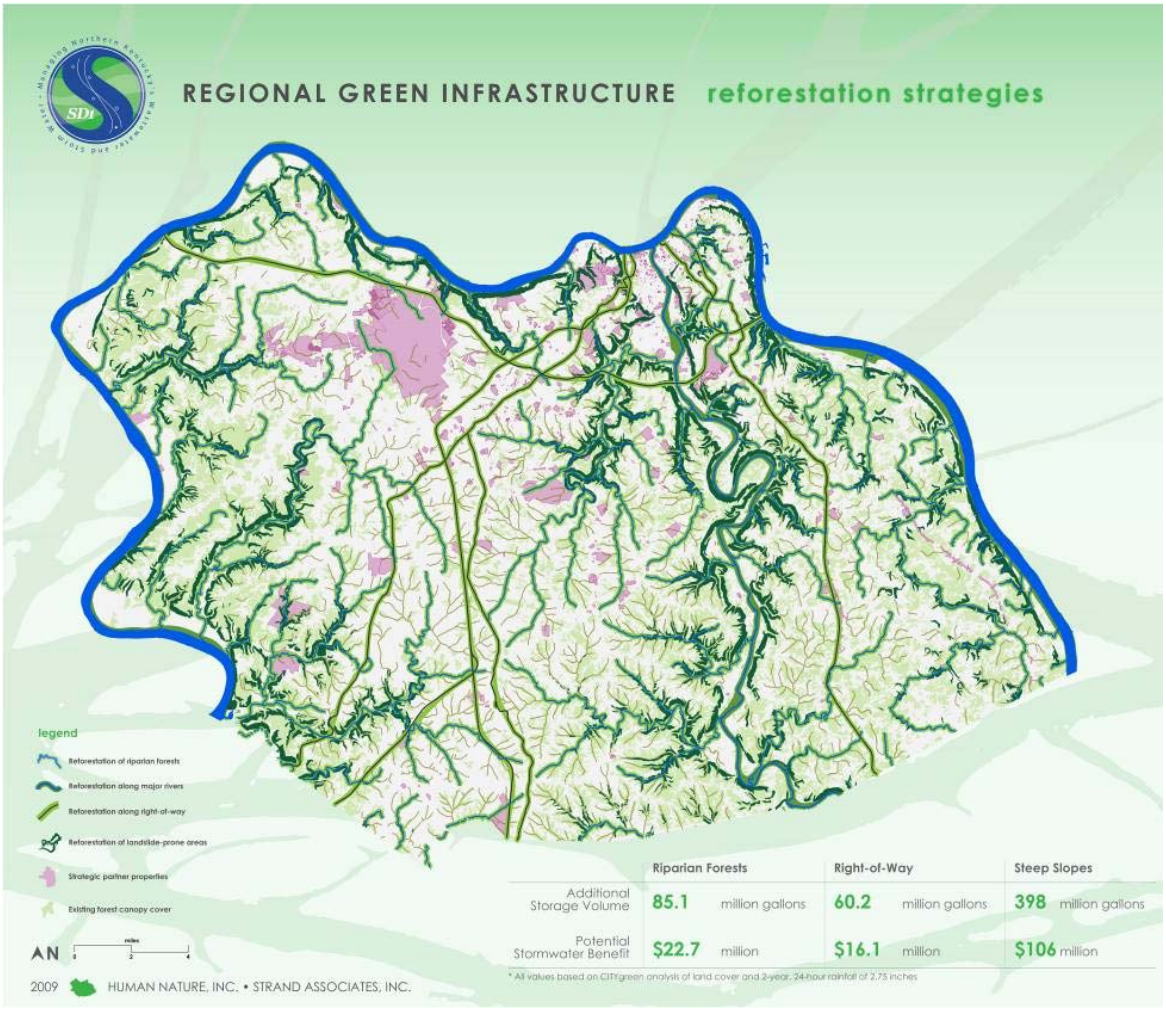
Table 1 summarizes the results of CITYgreen analysis for reforestation within each of the three areas. The results from CITYgreen were based on a 2-year, 24-hour storm of 2.75 inches.

Table 1. Potential Regional Reforestation Benefits.

	Riparian Forests	Right-of-Way	Steep Slopes
Potential Reforestation Area	8,297 acres	11,830 acres	48,404 acres
Additional Storage Volume	85.1 million gallons	60.2 million gallons	398 million gallons
Potential Storm Water Benefit	$22.7 Million	$16.1 Million	$106 Million

Figure 2 shows a potential reforestation strategy for Northern Kentucky. For a larger version of the Protecting Water Resources figure please refer to Appendix 2-D, page 36. The figure shows that, if fully implemented, reforestation could have a significant impact on reducing runoff volume which would directly reduce overflows in the combined sewer system.

Figure 2. Regional Reforestation Strategies.



Promotion of Transportation Corridors as Greenway Connections

Transportation corridors such as the interstate systems and major highways connect Northern Kentucky to surrounding regions. The surfaces of roadways within the right-of-way corridors greatly contribute to the volume of runoff as well as nonpoint source pollution. These corridors are also sources of air pollution, heat island impacts, and noise. Implementing green infrastructure along these corridors provides opportunities for improving water quality, reducing noise pollution, mitigating the heat island effect, and improving air quality.

Support of Regional Planning and Low Impact Development

Green infrastructure planning can help Northern Kentucky communities determine where to direct growth and development and how to prioritize conservation needs. Encouraging regional planning that emphasizes reinvestment in existing communities, compact and mixed land uses, and preservation of critical environmental areas, provides a framework for green infrastructure solutions that are considered in the context of existing land use and future growth. Together, SD1 and local developers and planners may develop ways to optimize site design to reduce impervious areas and maximize functional green space. In addition, site designs should optimize landscaping for managing runoff by incorporating biofiltration, retrofitting existing detention/retention basins, and incorporating infiltration wells and basins where possible to capture, infiltrate and treat runoff.

Combined Sewer System Green Infrastructure Overview

To identify potential green infrastructure opportunities that will reduce combined sewer overflow volume, an initial opportunities evaluation was performed on the combined sewer system. These identified potential green opportunities will complement the green programs proposed for Northern Kentucky.

The identification and evaluation of opportunities was conducted at a small scale, with opportunities evaluated by CSO sewershed. Sixty-two CSO sewersheds have been delineated within the combined sewer system to represent the local drainage areas to all CSO discharge locations. For approximately 70 percent of the CSO service area, a ratio of one-to-one, sewershed-to-CSO association accurately reflects flow routing in the system. However, it is important to note that for the remaining 30 percent of the CSO service area, this one-to-one association is a simplified representation of the sewer system. These delineations are adequate to support the green sewershed evaluation; however, because of the intricacies and unique connections within the existing collection system, they are not fully representative of wet weather flow routing to downstream CSOs. In these more complicated areas, flows have the opportunity to transfer between sewersheds, and/or pass through multiple regulating structures, allowing the flow to be discharged through numerous overflow points depending on the system hydraulics at the time of the overflow. Regardless of the CSO discharge properties, any strategies identified to disconnect impervious surfaces from the combined sewer system and/or reduce the amount of runoff generated by existing impervious surfaces within the sewershed should have a positive impact on the downstream CSO.

Combined System Green Infrastructure Analysis Approach

Each CSO sewershed with an active overflow was reviewed for potential green opportunities to either disconnect or remove storm water runoff from the combined sewer system. For the purpose of consistency, a standard set of information was compiled for each sewershed and served as the basis for identifying candidate green opportunities. Using the combined system collection model outputs and available GIS data from SD1 and other Northern Kentucky sources the following information was collected or generated for each CSO sewershed:

- CSO statistics (number of overflows, average annual overflow volume, duration of overflow, and drainage area);
- Percent imperviousness;
- Land use;
- Properties classified as publicly owned;
- Rooftops greater than 10,000 square feet in area;
- Parking lots greater than 15,000 square feet in area;
- Single family homes;
- Percent tree cover;
- Number of catch basins;
- Direct entry points of streams and drainage channels to the combined sewer system; and,
- Catch basins on SD1's repair list.

This inventory of information influences the appropriate type of green control selected for each identified opportunity. The following summaries highlight the importance of each of these components.

CSO Statistics

The statistics for each of the CSO sewersheds (number of overflows, average annual overflow volume, duration of overflow, and drainage area) provide information on the overall impact of each sewershed on the combined system. The size of the sewershed and total overflow volume can influence the magnitude of potential green infrastructure opportunities needed to eliminate or downsize the proposed gray infrastructure.

Imperviousness

Of the 6,000 acres of land in the combined sewer sytem in SD1's service area, approximately 38 percent (2,155 acres) is impervious surface. Individual sewersheds range in imperviousness from 20 percent to 89 percent.

In general, impervious areas were divided into three major categories - rooftops, roadways, and parking lots and driveways. These three major categories of impervious surfaces within the combined sewer system include:

- Residential land use (44%)
- Transportation (19%)
- Commercial land use (10%)

This information was derived from data in SD1's GIS database and is based on 2007 aerial images. Understanding the distribution of impervious surface helps to inform the green infrastructure components that are suggested for a particular site or sewershed. With this information, SD1 can begin to target particular types or categories of impervious surface and identify effective green techniques to reduce the associated runoff.

Land Use

Land use is important in this evaluation process because the types of impervious surfaces are directly linked to land use types. Parcel information for the portions of Kenton and Campbell Counties within the combined sewer system were used to determine the land use or class of each property. Land use categories for both counties include residential, commercial, and industrial. The parcels without a land use classification were designated "unknown" for the purpose of the land use evaluation. Land use distribution within the combined sewer system is as follows:

- Residential (44%)
- Public property (including roadways) (24%)
- Commercial (18%)

These data also help determine which green infrastructure techniques may be most appropriate for a particular area. For example, in an area comprised predominantly of residential land use, most of the impervious surface is residential rooftops and roadways. Therefore, a recommended green program targeting this area would need to identify techniques that are suitable for these types of impervious surfaces, such as downspout disconnection; it would not be appropriate to anticipate large benefits from a control such as a green roof program for residential areas.

Public Ownership

In order for SD1's green initiatives to be successful, major property owners within the combined sewer system will need to become partners in the implementation of green techniques. Public agencies who own large parcels represent good candidates to fulfill this need. Public property within the combined sewer system represents 24 percent of the total land area and 43 percent of the total impervious area.

Using parcel-level data obtained from Boone, Kenton, and Campbell Counties, all parcels owned by public entities, (e.g., City of Newport, Board of Education, etc.), were identified as potential opportunities for implementing green infrastructure. Recommendations for developed public properties include green roofs, rain gardens, bioswales, etc. Green streets are suggested only in those sewersheds with soils identified as suitable for infiltration or with available right-of-way space for curb extensions, planters or other techniques that don't require high infiltration rates to provide cost effective benefits.

Ohio/Kentucky/Indiana Regional Council of Governments (OKI) GIS data were used to identify public parks, city gardens and other natural or vacant open areas. These areas were identified as opportunities for green infrastructure techniques such as rain gardens, reforestation, or storm water storage locations.

Large Buildings and Parking Lots

Large buildings and parking lots, often associated with commercial and industrial properties, were also identified as potential green opportunities. Appropriate green infrastructure control types are determined based on building size and/or parking lot size. Utilizing the parking lot and building data, any roof over 10,000-square feet in area and any parking lot over 15,000-square feet in area was tagged as a potential opportunity for green infrastructure techniques. Based on the provided building data, buildings over 10,000 square feet make up only one percent of the total number of buildings, but correspond to 20 percent of the associated roof area. In addition parking lots over 15,000-square feet represent only five percent of the total number of parking lots, but account for 16 percent of the total parking lot area in the combined sewer system. Potential green solutions for properties with large buildings and parking lots include green roofs, rain gardens, bioswales, and green parking lots.

Single Family Homes

The number of single family homes and associated rooftop area in each sewershed was calculated in GIS to determine the total single family rooftop area that contributed to the imperviousness of the sewershed. Based on Kenton County parcel data, the percentage of rooftops that belong to single family homes was calculated for each delineated sewershed. However, the parcel data for Campbell County does not distinguish between single family and multi-family properties; therefore, contributing roof area was associated with any building classified as residential. Based on the size of the residential parcels, density of the homes, percentage of the impervious area, and soil characteristics of the area, a ranking of good, fair, or poor was given to each sewershed regarding the potential effectiveness of a downspout disconnect program.

Points of Entry

Points of entry were identified where any surface conveyance systems, such as blue line, intermittent, or ephemeral streams, enter directly into the combined sewer system. These areas may contribute significant amounts of storm water runoff to the combined sewer system and therefore merit evaluation. Opportunities to redirect, separate or reduce storm water volume directly entering the combined sewers through green techniques were identified and evaluated. As part of a further evaluation, drainage areas to these locations will be determined to understand the significance of these locations and the value in addressing these sources.

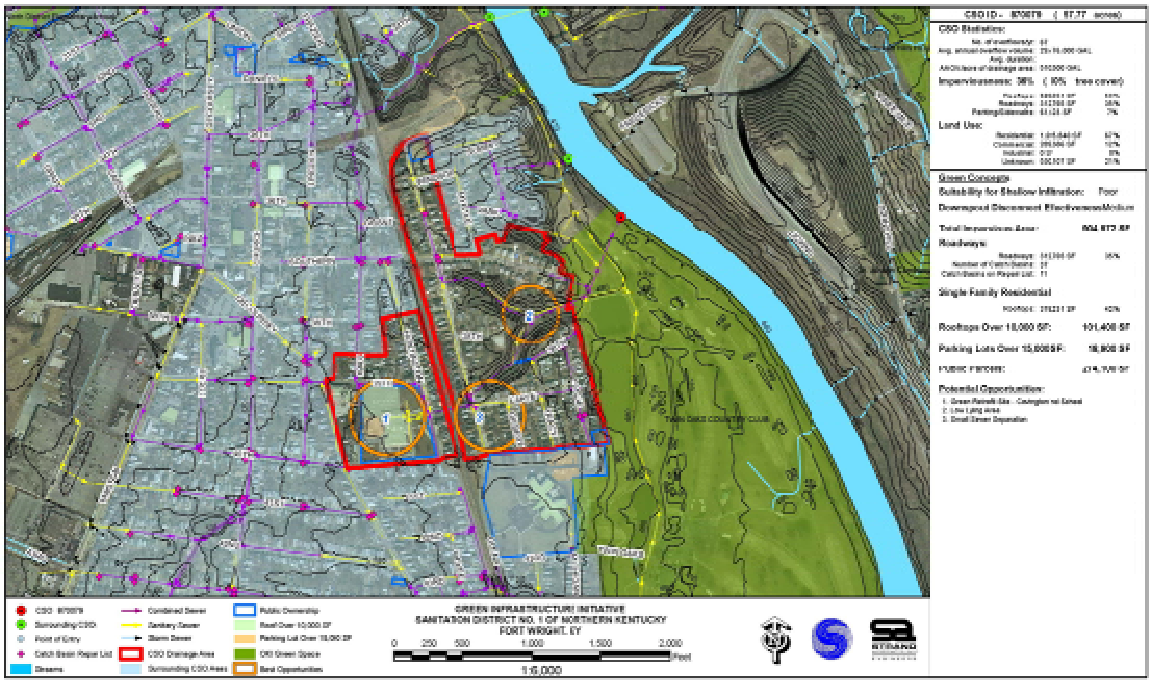
Catch Basin Rehabilitation

Catch basin locations identified in the NMC Compliance Report as needing either additional cleaning or repairs will be denoted on each of the sewershed maps and considered for possible green infrastructure opportunities. The NMC report cited 501 catch basin cleaning needs and 704

repair locations. SD1 intends to investigate green infrastructure to not only reduce runoff volumes entering the combined sewer system, but also address solids and floatable controls. Catch basin points were identified on the green opportunities maps to potentially incorporate green controls in these areas.

Utilizing the above inventory and analysis, green infrastructure opportunity maps were prepared for the combined system, highlighting this information and potential opportunity areas for each CSO sewershed. This effort resulted in the generation of 62 maps of individual sewersheds, each with specific green opportunities identified. The goal of this exercise was to examine each delineated sewershed and present a series of candidate locations/study areas for implementation of green infrastructure. By representing all of the above information in one location, different strategies and potential opportunities to disconnect impervious surfaces from the combined sewer system and/or reduce the amount of runoff generated by existing impervious surfaces within the sewershed can be identified. This assessment was not intended to provide a detailed evaluation of each of the identified opportunities, but rather to understand the magnitude, distribution and types of green solutions across the combined sewer system. The green opportunity maps can be found for each of the evaluated CSO basins in the following section. An example green opportunities map is shown in Figure 3.

Figure 3. Example Green Opportunities Map (CSO 870079)



Combined Sewer System Green Infrastructure Opportunity Results

The combined sewer system has emerged as the focus for green infrastructure techniques during the first five years of the Watershed Plans. The ability to reduce the impacts of impervious surfaces throughout the combined sewer system provides SD1 an opportunity to positively impact combined sewer overflows through reductions in storm water runoff volumes.

There were 62 CSO sewersheds, totaling over 5,700 acres, evaluated as part of the combined sewer area green opportunities mapping. Within these 62 sewersheds, approximately 38 percent of the land area is impervious and the primary land use is residential. During this green

opportunities evaluation, over 197 initial opportunities to incorporate green infrastructure techniques to reduce combined sewer overflow were identified. Table 2 summarizes these opportunities.

Table 2. Green Opportunities Identified in the Combined Sewer System

Opportunity Description	Number of Occurrences
Green Retrofit Site	90
Green Street Opportunity	18
Utilization of Existing Green Space	31
Utilization of Existing Natural System	6
Surface Entry Point	14
Small Sewer Separation	15
Areas Flowing into the Combined System	21
Low Lying Ravine	2
Total	*197*

In addition to the 197 opportunities identified based on open space and land characteristics, large areas of impervious surfaces were targeted for implementing green infrastructure controls. Any opportunity to disconnect impervious surfaces from the combined system will have a positive impact on the downstream CSO. For this reason, all large buildings were called out as an opportunity for a green roof retrofit and large parking lots were called out for a retrofit opportunity to include techniques such as bioswales, green planters, and curb cuts. In addition to large impervious surfaces, all publicly owned properties were identified. Publicly owned properties provide great opportunities to partner in the implementation of green techniques. The following table, Table 3, provides a summary of these additional opportunities within the combined sewer area.

Table 3. Key Areas for Green Retrofit Opportunities

Description	Area (SF)	Quantity
Buildings over 10,000 SF	8,805,705	336
Parking lots over 15,000 SF	2,552,579	81
Publicly Owned Parcels	28,921,582	763

Combining these strategies and identified opportunities will help create a 'green urban core', which will serve not only as an area of optimized infrastructure, but also as the keystone to the regional green infrastructure strategy. In order to successfully and cost effectively develop this green urban core, it is important to capitalize on partnership opportunities for the implementation of these green techniques.

Initial Green Infrastructure Opportunity Analysis Maps

The following series of maps detail the initial green infrastructure opportunity analysis conducted for the:

- Central Basin CSO Sewersheds
- East Basin CSO Sewersheds
- North Basin CSO Sewersheds

A summary table listing the CSOs precedes the series of maps for each basin.

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3-B.1 - Initial Combined Sewer Area

Green Infrastructure Opportunities

Central Basin CSO Sewersheds
870078
870079
880081
880082
910065
910068
930102
930103
930104
930105
930106
960063
960064
980073
980080
980081
1420141
1420142
1420144
1420145
1420146
1420147
1440204
1440205
1440206
1440207
1440209
1440212
1470093

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CSO 870078
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 870078 (13.99 acres)

CSO Statistics:

No. of overflows/yr:	4
Avg. annual overflow volume:	484,000 GAL
AAOV/acre of drainage area:	34,600 GAL

Imperviousness: 25% (3% tree cover)

Rooftops:	96,976 SF	63%
Roadways:	56,982 SF	37%
Parking/Sidewalks:	1,065 SF	1%

Land Use:

Residential:	506,940 SF	83%
Commercial:	4,081 SF	1%
Industrial:	0 SF	0%
Unknown:	98,401 SF	16%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: High

Total Impervious Area: **155,023 SF**

Roadways:

Roadways:	56,982 SF	37%
Number of Catch Basins:	8	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	91,694 SF	59%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **700 SF**

Potential Opportunities:

1. Small Sewer Separation

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CSO ID - 870079 (57.77 acres)

CSO Statistics:

No. of overflows/yr:	67
Avg. annual overflow volume:	29,476,000 GAL
AAOV/acre of drainage area:	510,500 GAL

Imperviousness: 36% (10% tree cover)

Rooftops:	529,884 SF	59%
Roadways:	312,765 SF	35%
Parking/Sidewalks:	61,623 SF	7%

Land Use:

Residential:	1,695,840 SF	67%
Commercial:	289,386 SF	12%
Industrial:	0 SF	0%
Unknown:	530,107 SF	21%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: 904,972 SF

Roadways:

Roadways:	312,765 SF	35%
Number of Catch Basins:	37	
Catch Basins on Repair List:	11	

Single Family Residential:

Rooftops:	378,231 SF	42%

Rooftops Over 10,000 SF: 101,400 SF

Parking Lots Over 15,000 SF: 18,900 SF

Public Parcels: 274,100 SF

Potential Opportunities:

1. Green Retrofit Site - Covington Ind School
2. Low Lying Area
3. Small Sewer Separation

CSO 870079
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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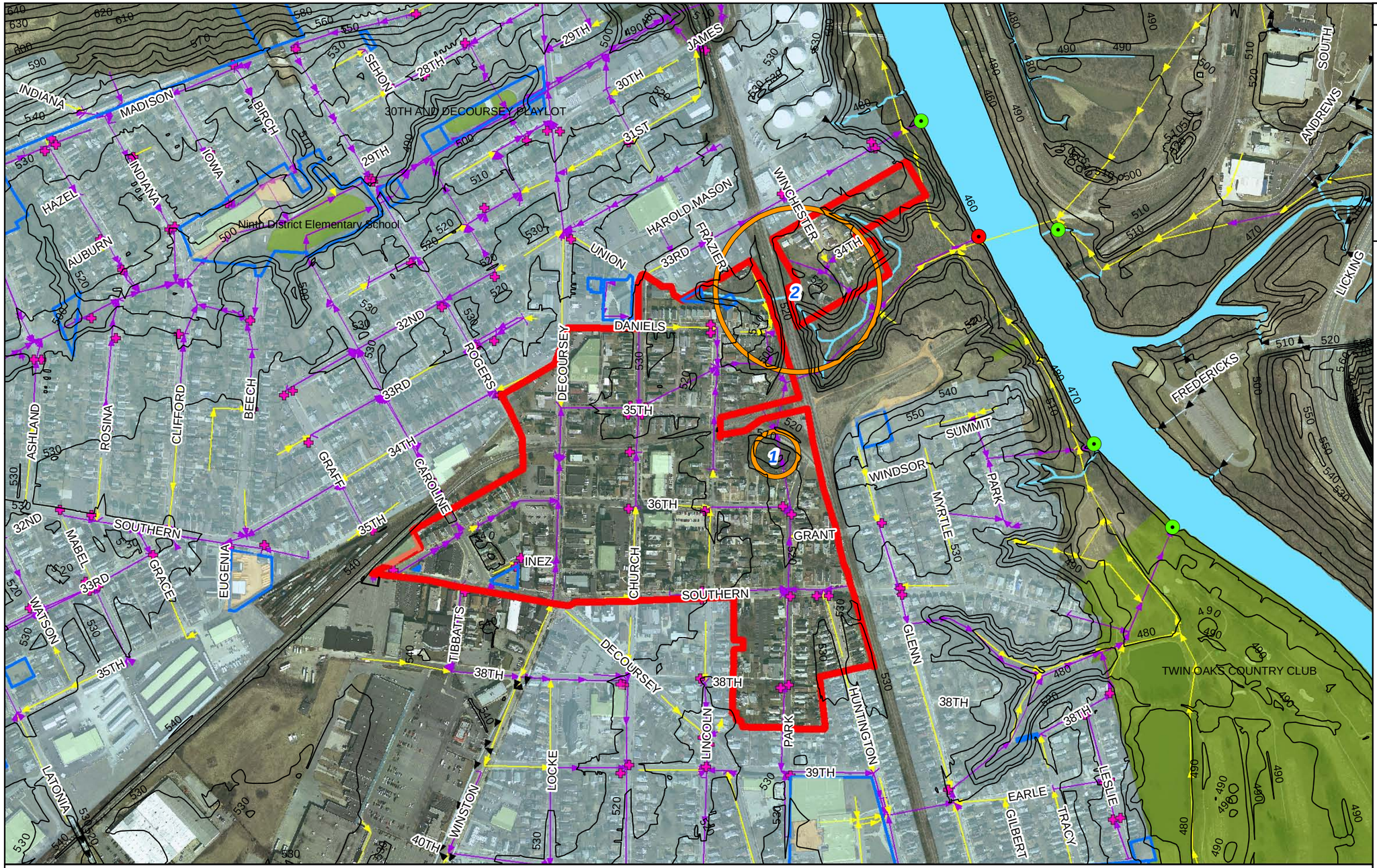

CSO ID - 880081 (66.07 acres)

CSO Statistics:

No. of overflows/yr: 65
Avg. annual overflow volume: 21,873,000 GAL

AAOV/acre of drainage area: 331,100 GAL

Imperviousness: 46% (2% tree cover)

Rooftops:	612,919 SF	47%
Roadways:	451,539 SF	34%
Parking/Sidewalks:	247,828 SF	19%

Land Use:

Residential:	1,352,613 SF	47%
Commercial:	526,089 SF	18%
Industrial:	225 SF	0%
Unknown:	998,903 SF	35%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 1,312,286 SF

Roadways:

Roadways:	451,539 SF	34%
Number of Catch Basins:	53	
Catch Basins on Repair List:	21	

Single Family Residential:

Rooftops:	346,740 SF	26%

Rooftops Over 10,000 SF: 64,700 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 11,600 SF

Potential Opportunities:

1. Low Lying Area
2. Small Sewer Separation

CSO 880081
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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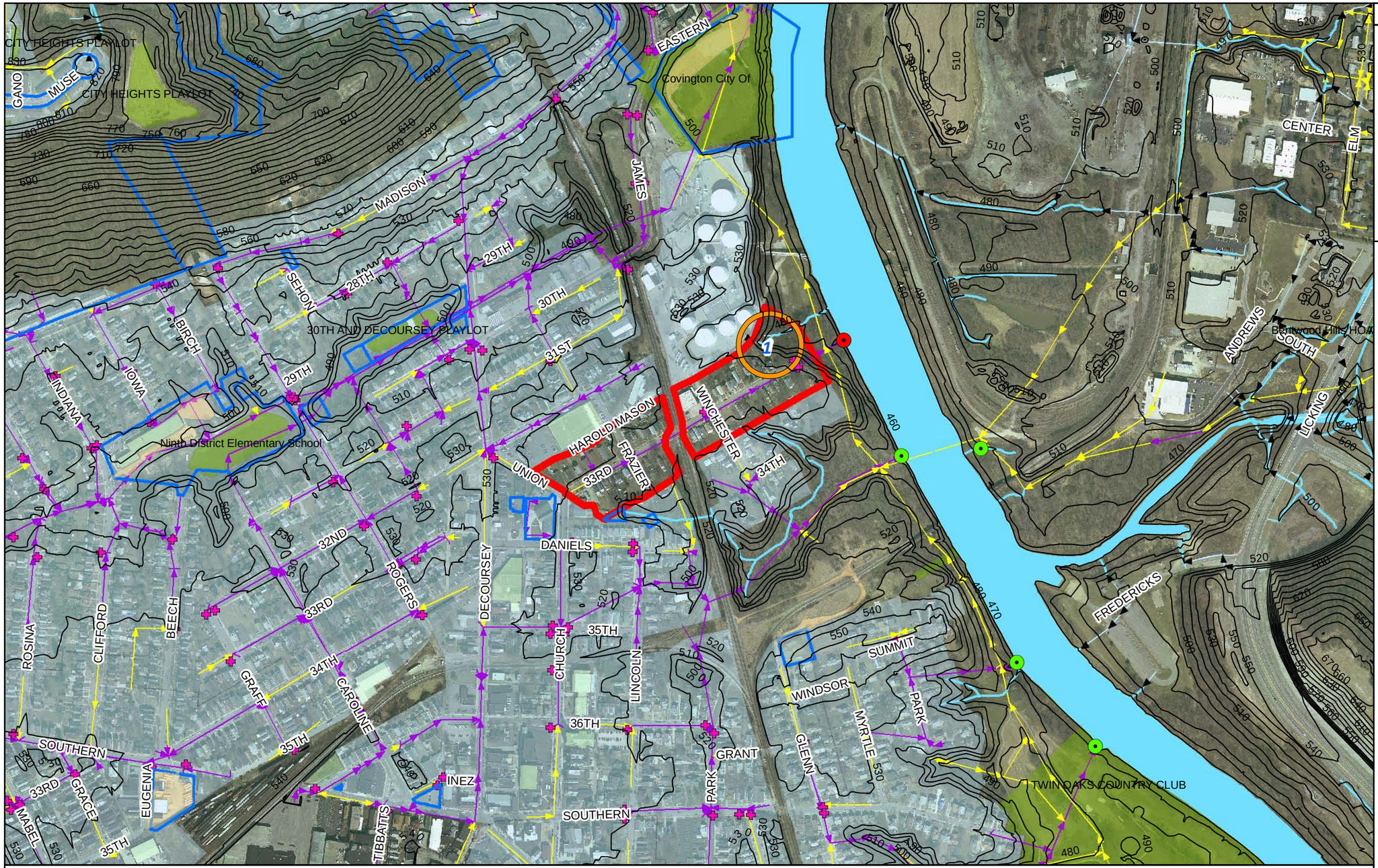

CSO 880082
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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CSO ID - 880082 (10.80 acres)

CSO Statistics:

No. of overflows/yr: 11
Avg. annual overflow volume: 784,000 GAL

AAOV/acre of drainage area: 72,600 GAL

Imperviousness: 33% (11% tree cover)

Rooftops:	68,963 SF	45%
Roadways:	57,138 SF	37%
Parking/Sidewalks:	28,125 SF	18%

Land Use:

Residential:	272,255 SF	58%
Commercial:	17,158 SF	4%
Industrial:	59,145 SF	13%
Unknown:	121,849 SF	26%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: **154,226 SF**

Roadways:

Roadways:	57,138 SF	37%
Number of Catch Basins:	10	
Catch Basins on Repair List:	4	

Single Family Residential:

Rooftops:	58,227 SF	38%

Rooftops Over 10,000 SF: **0 SF**

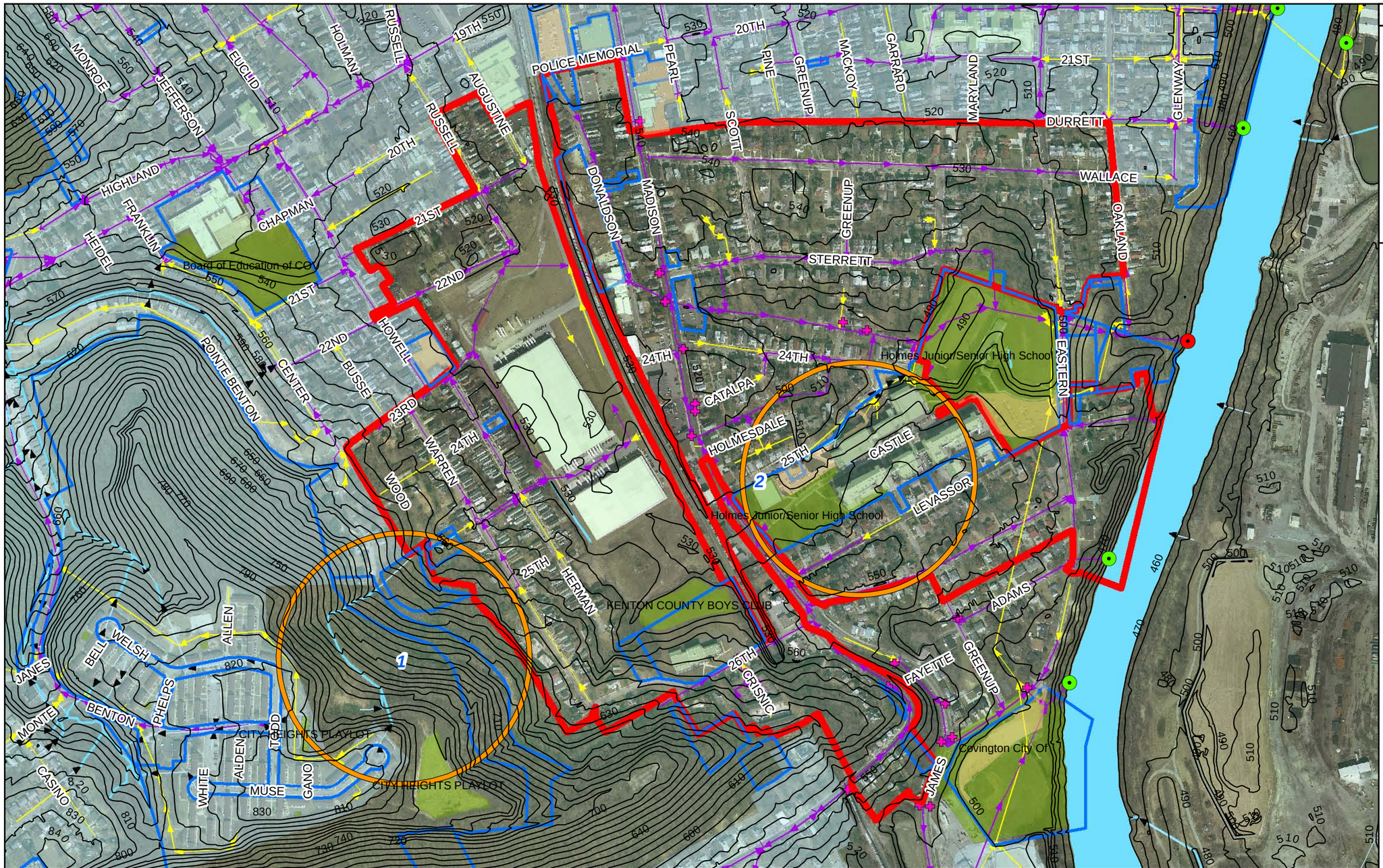
Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **3,800 SF**

Potential Opportunities:

1. Utilize Existing Natural Systems

1
2
3
4
5
CSO 910065
Covington Catholic High School
Notre Dame Academy
Highland and Beston Fields
Board of Education of Co
Holmes Junior/Senior High School
KENTON COUNTY BOYS' CLUB
Covington City Of
CITY HEIGHTS PLAYLOT
30TH AND DECOURSEY PLAYLOT
35TH STREET PLAYLOT
Nash District Elementary School
HIGHLAND AND GARRISON PLAYGROUND
Bluegrass Swim Club
South Hills Country Club
Fort Wright Golf Driving Range
Bill Cappel Sports Complex
Mother of God Cemetery
Linden Grove Cemetery
Devou Park
Ben Snyder Park
Bennett Flats Park
Kenton County Airport
Latonia Golf Course
Turkey Foot Golf Club
Twin Oaks Country Club
Vista Pointe
Creekwood
Aspendales
Three Mile
Jacqueline
Fredericks
Summit
Windsor
Park
Grant
Inez
Southern
Daniels
Union
Harold Mason
Winchester
Decoursey
Lincoln
Caroline
Grace
Eugenia
Mabel
Watson
Alabama
Alberta
Aberdeen
Rosina
Clifford
Beech
Ashland
Alexandria
Dakota
Newton
Ashland
Auburn
Iowa
Indiana
Seven
Bristol
Ohio
Church
Winston
Locke
Park
Gilbert
Earle
Jessie
Tracy
Vermont
Michigan
Elmwood
Mckee
Decoursey
Boston
Doris
Sail
Janet
Sunset
Valley View
Kyles
Montclair
Mt Vernon
Howard Tazewell
Cottage
Emerson
Castle Hill
Nuemeier
Cloverfield
Wrights Point
Mccrae
Kimberly
Castle
Bradfordridge
Sanatorium
Farrell
Kenbridge
Valley
Marrison
Nelson
Lorraine
Edwin
Kimes
Cecelia
Arlington
Cedar Ridge
Stroser
Far Hills
Elberta
Ramp
Emery
Upland
Henry Clay
Bluegrass
Fayette
Ridgemont
Hanser
BassWood
Cumberland
Diana
Monte
Francis
Tower
Roxie
Casino
Woman
Muse
Gano
White
Allen
Bell
Welch
Phelps
Dorian
James
Genevieve
Okan
Lorraine
Roman
Ramp
Maplecliff
St Anthony
Ramp
Fair Hills
Stroser
Arlington
Cecelia
Oakcrest
Jefferson
Erlich
18th
Highland
Framan
Herbel
Chapman
20th
21st
Russell
Augustine
22nd
Pointe Benton
Center
Benton
Woodview
Warren
Wood
24th
25th
Herman
Pine
Greenup
Scott
Fountaine
Sterrett
Durrett
Wallace
Glenway
Catalpa
Hollesdale
Castle
Levassor
Eastern
Adams
Fayette
Greenup
Steel Plant
Licking
Aspendales
Marie
North
Elm
Center
Vista Pointe
Andrews South
Creekwood
Mcdick



CSO ID - 910068 (193.67 acres)

CSO Statistics:

No. of overflows/yr:	47
Avg. annual overflow volume:	49,309,000 GAL
AAOV/acre of drainage area:	254,600 GAL

Imperviousness: 36% (3% tree cover)

Rooftops:	1,640,331 SF	55%
Roadways:	797,230 SF	27%
Parking/Sidewalks:	570,736 SF	19%

Land Use:

Residential:	4,013,820 SF	48%
Commercial:	1,988,624 SF	24%
Industrial:	964,459 SF	11%
Unknown:	1,466,573 SF	17%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: 3,008,297 SF

Roadways:

Roadways:	797,230 SF	27%
Number of Catch Basins:	144	
Catch Basins on Repair List:	11	

Single Family Residential:

Rooftops:	785,730 SF	26%

Rooftops Over 10,000 SF: 449,100 SF

Parking Lots Over 15,000 SF: 34,100 SF

Public Parcels: 961,300 SF

Potential Opportunities:

1. Area Flowing into the CSS
2. Green Retrofit Site - Covington Ind School

CSO 910068
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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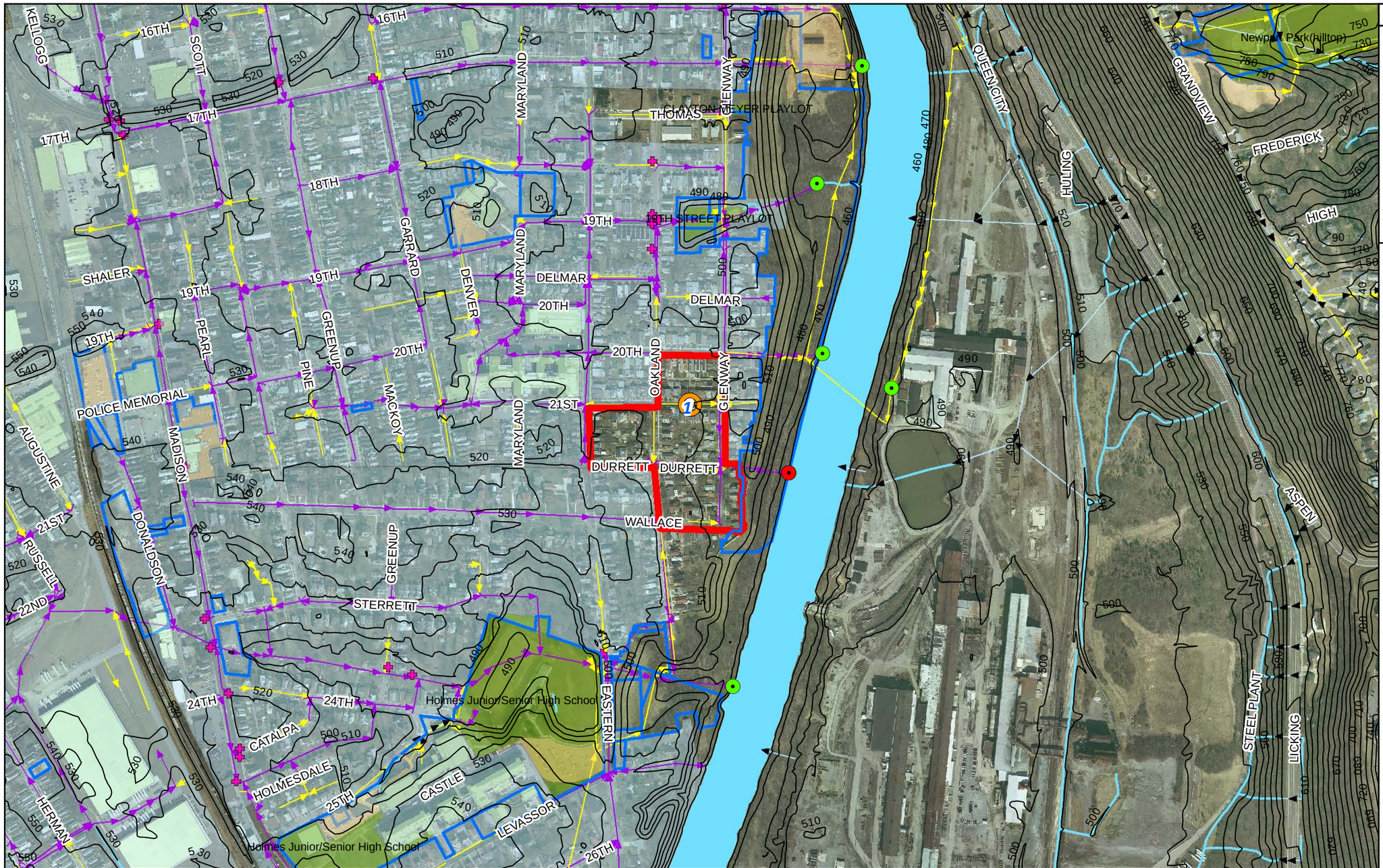

CSO 930102
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 930102 (9.31 acres)

CSO Statistics:

No. of overflows/yr: 0
Avg. annual overflow volume: 0 GAL

AAOV/acre of drainage area: 0 GAL

Imperviousness: 45% (0% tree cover)

Rooftops:	113,305 SF	63%
Roadways:	67,804 SF	37%
Parking/Sidewalks:	0 SF	0%

Land Use:

Residential:	265,876 SF	66%
Commercial:	14,577 SF	4%
Industrial:	0 SF	0%
Unknown:	125,077 SF	31%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **181,110 SF**

Roadways:

Roadways:	67,804 SF	37%
Number of Catch Basins:	9	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	101,272 SF	56%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **0 SF**

Potential Opportunities:

1. Green Street - 21st & 22nd Street

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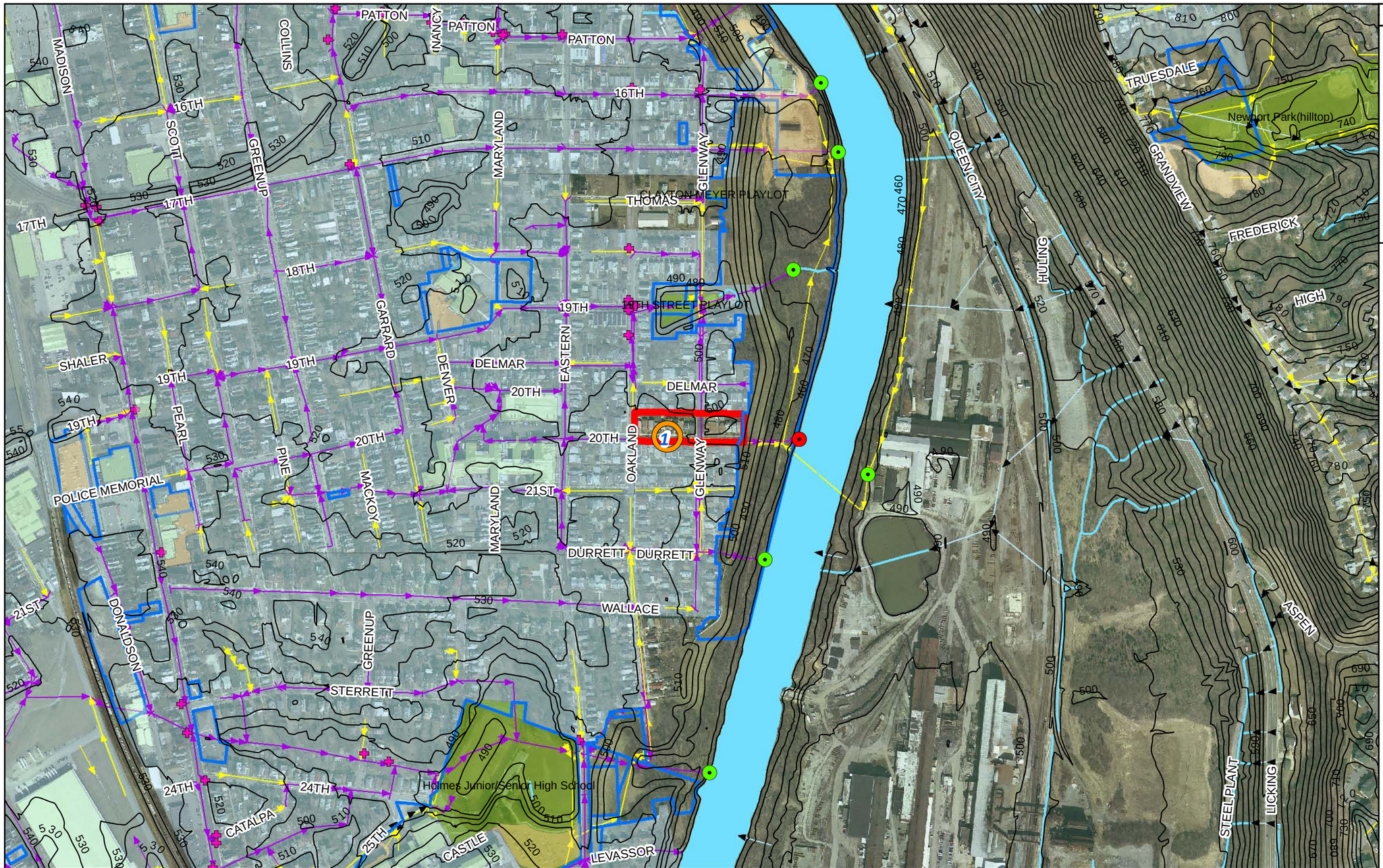


CSO ID - 930103 (1.72 acres)

CSO Statistics:

No. of overflows/yr:	3
Avg. annual overflow volume:	86,000 GAL
AAOV/acre of drainage area:	49,800 GAL

Imperviousness: 51% (0% tree cover)

Rooftops:	20,728 SF	54%
Roadways:	17,835 SF	46%
Parking/Sidewalks:	0 SF	0%

Land Use:

Residential:	46,893 SF	63%
Commercial:	0 SF	0%
Industrial:	0 SF	0%
Unknown:	28,079 SF	37%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **38,563 SF**

Roadways:

Roadways:	17,835 SF	46%
Number of Catch Basins:	2	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	20,574 SF	53%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **0 SF**

Potential Opportunities:

1. Green Street - 20th Street

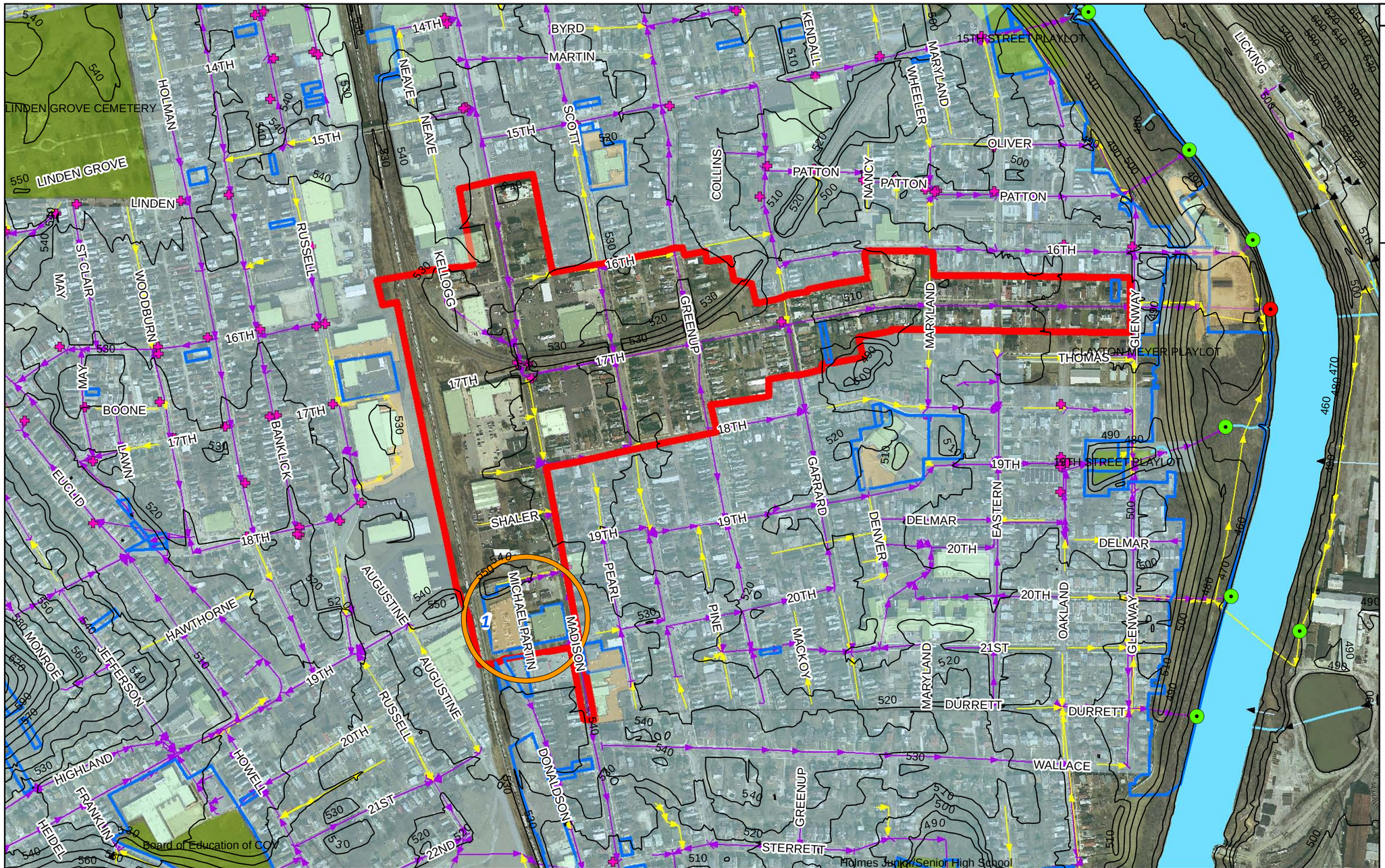
CSO 930103
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

STRAND ASSOCIATES, INC® ENGINEERS



CSO ID - 930104 (64.92 acres)

CSO Statistics:

No. of overflows/yr:	2
Avg. annual overflow volume:	100,000 GAL
AAOV/acre of drainage area:	1,500 GAL

Imperviousness: 51% (0% tree cover)

Rooftops:	576,904 SF	40%
Roadways:	452,537 SF	32%
Parking/Sidewalks:	407,031 SF	28%

Land Use:

Residential:	736,131 SF	26%
Commercial:	869,765 SF	31%
Industrial:	42,895 SF	2%
Unknown:	1,179,062 SF	42%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **1,436,472 SF**

Roadways:

Roadways:	452,537 SF	32%
Number of Catch Basins:	51	
Catch Basins on Repair List:	5	

Single Family Residential:

Rooftops:	202,109 SF	14%

Rooftops Over 10,000 SF: **168,300 SF**

Parking Lots Over 15,000 SF: **34,000 SF**

Public Parcels: **81,800 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Covington

- CSO 930104
- Surrounding CSOs
- Point of Entry
- Catch Basin Repair List
- Streams
- Combined Sewer
- Sanitary Sewer
- Storm Sewer
- CSO Drainage Area
- Surrounding CSO Areas
- Public Ownership
- Roof Over 10,000 SF
- Parking Lot Over 15,000 SF
- OKI Green Space
- Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

STRAND ASSOCIATES, INC® ENGINEERS

CSO ID - 930105 (99.30 acres)

CSO Statistics:

No. of overflows/yr:	66
Avg. annual overflow volume:	31,074,000 GAL
AAOV/acre of drainage area:	313,000 GAL

Imperviousness: 48% (0.03% tree cover)

Rooftops:	1,197,641 SF	58%
Roadways:	64,886 SF	31%
Parking/Sidewalks:	223,649 SF	11%

Land Use:

Residential:	2,377,422 SF	55%
Commercial:	774,085 SF	18%
Industrial:	0 SF	0%
Unknown:	1,173,775 SF	27%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **2,070,156 SF**

Roadways:

Roadways:	64,886 SF	31%
Number of Catch Basins:	117	
Catch Basins on Repair List:	7	

Single Family Residential:

Rooftops:	742,775 SF	36%

Rooftops Over 10,000 SF: **183,300 SF**

Parking Lots Over 15,000 SF: **44,100 SF**

Public Parcels: **284,800 SF**

Potential Opportunities:

1. Area Flowing into the CSS
2. Green Retrofit Site - KY School Building Authority

CSO 930105
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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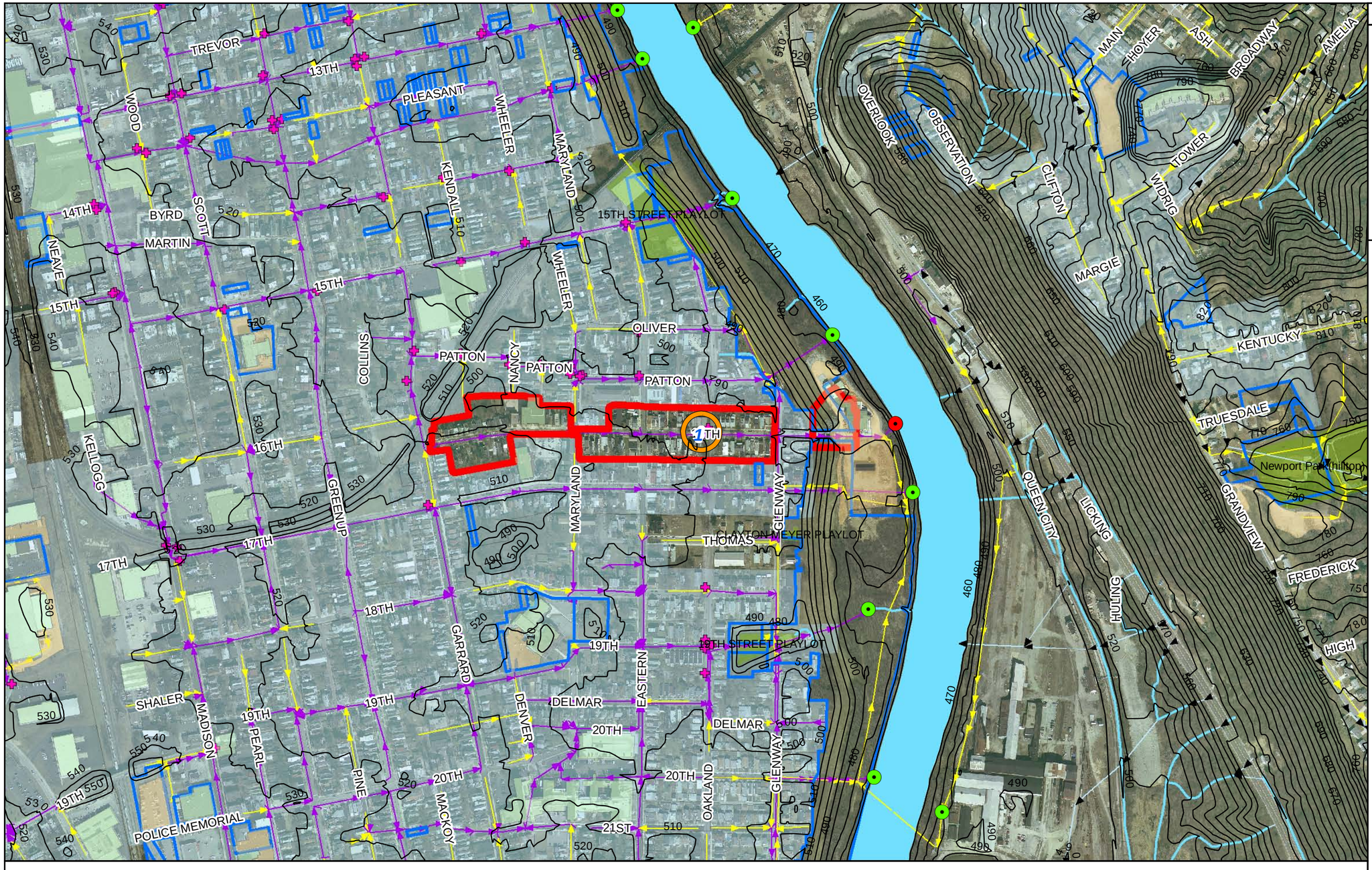

CSO 930106
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
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CSO ID - 930106 (10.21 acres)

CSO Statistics:

No. of overflows/yr:	4
Avg. annual overflow volume:	42,000 GAL
AAOV/acre of drainage area:	4,200 GAL

Imperviousness: 49% (0% tree cover)

Rooftops:	119,405 SF	55%
Roadways:	63,121 SF	29%
Parking/Sidewalks:	36,453 SF	17%

Land Use:

Residential:	231,701 SF	52%
Commercial:	88,473 SF	20%
Industrial:	0 SF	0%
Unknown:	124,713 SF	28%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **218,979 SF**

Roadways:

Roadways:	63,121 SF	29%
Number of Catch Basins:	6	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	68,259 SF	31%

Rooftops Over 10,000 SF: **23,400 SF**

Parking Lots Over 15,000 SF: **17,900 SF**

Public Parcels: **29,200 SF**

Potential Opportunities:

1. Green Street - 16th Street

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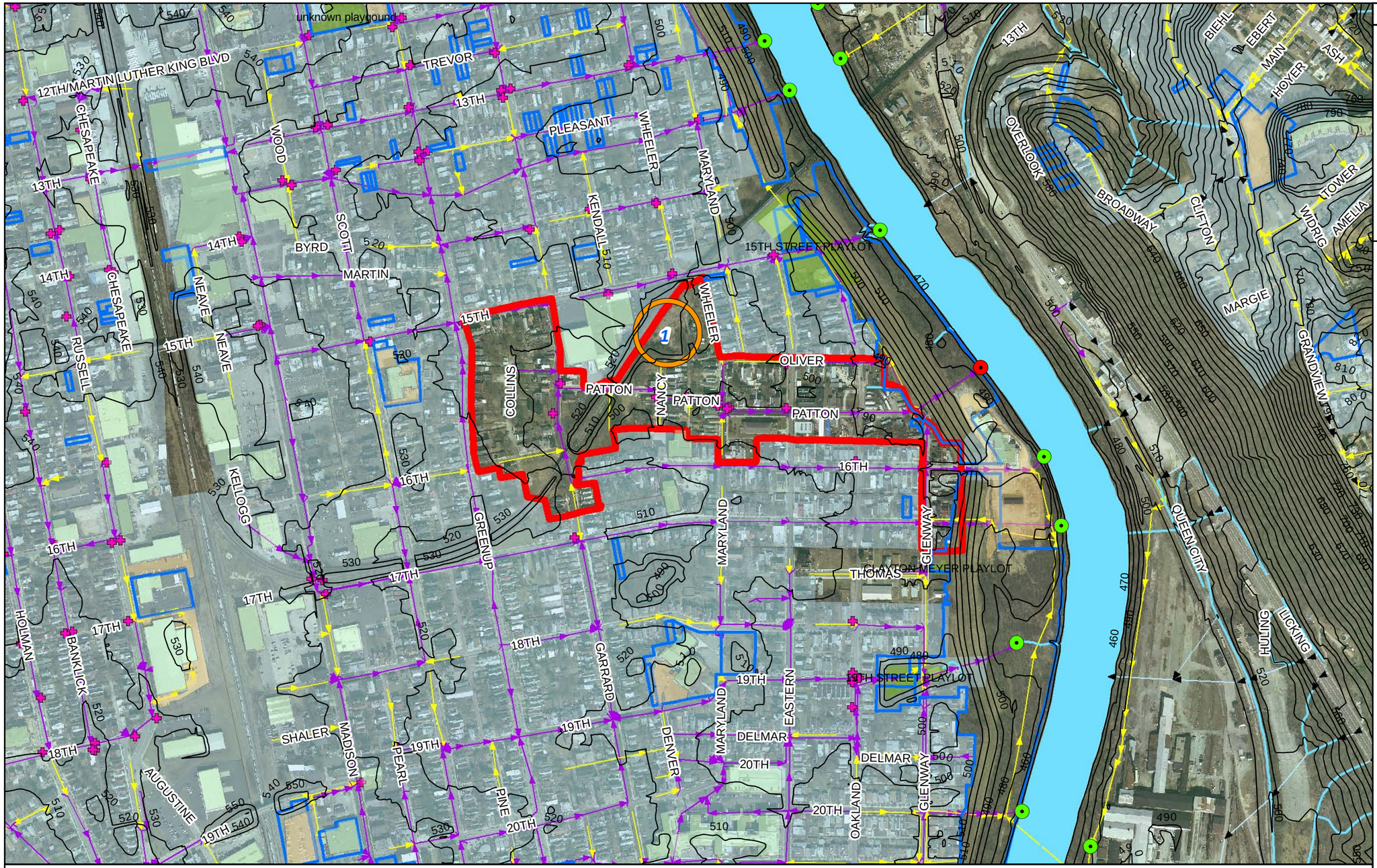

CSO ID - 960063 (29.86 acres)

CSO Statistics:

No. of overflows/yr:	23
Avg. annual overflow volume:	5,568,000 GAL
AAOV/acre of drainage area:	186,500 GAL

Imperviousness: 38% (0% tree cover)

Rooftops:	236,247 SF	48%
Roadways:	226,704 SF	46%
Parking/Sidewalks:	29,290 SF	6%

Land Use:

Residential:	547,326 SF	42%
Commercial:	186,322 SF	14%
Industrial:	0 SF	0%
Unknown:	566,879 SF	44%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **492,240 SF**

Roadways:

Roadways:	226,704 SF	46%
Number of Catch Basins:	37	
Catch Basins on Repair List:	12	

Single Family Residential:

Rooftops:	129,267 SF	26%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **19,700 SF**

Potential Opportunities:

1. Utilize Existing Green Space - ROW

CSO 960063
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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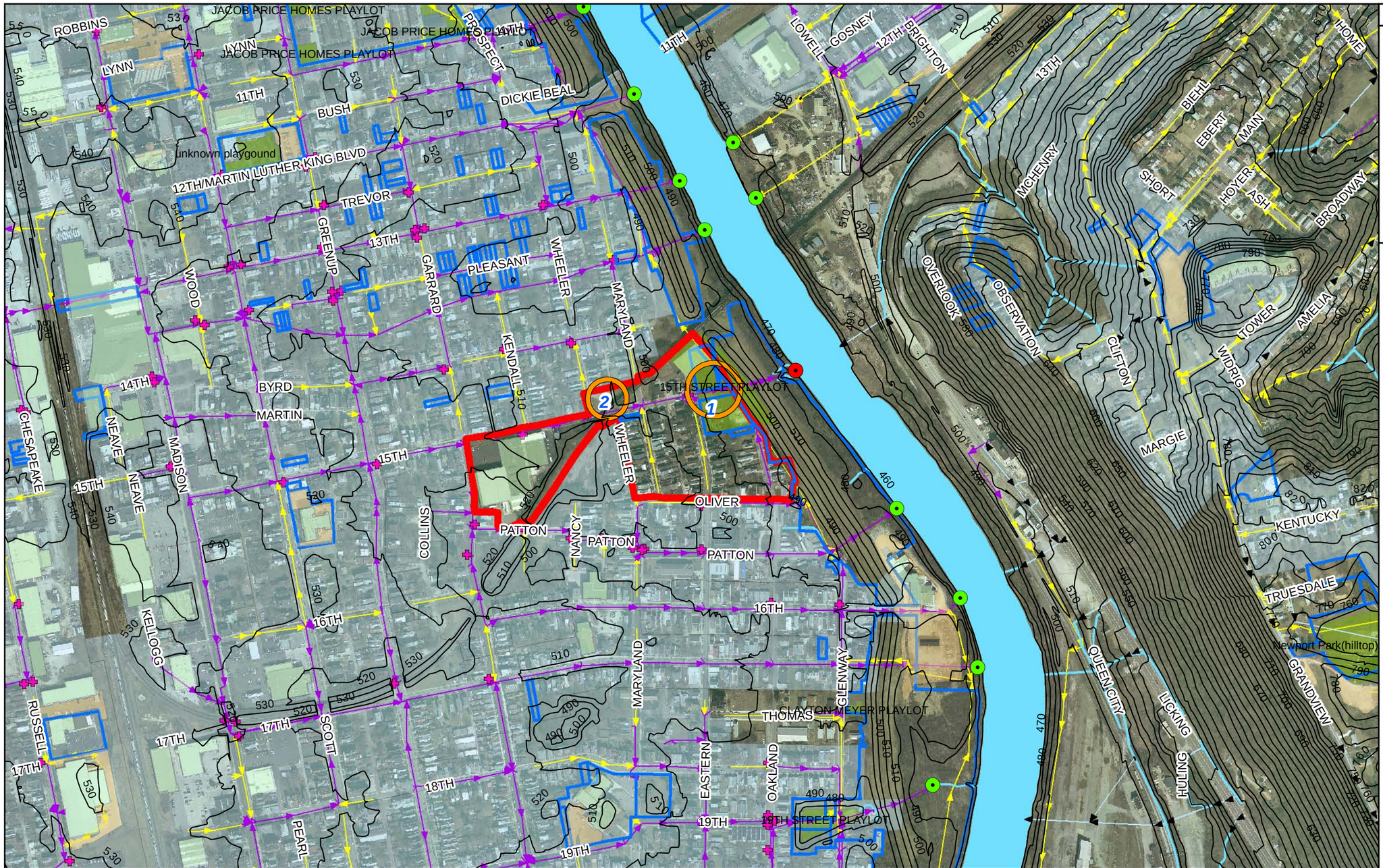

CSO 960064
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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STRAND ASSOCIATES, INC® ENGINEERS

CSO ID - 960064 (15.53 acres)

CSO Statistics:

No. of overflows/yr: 2
Avg. annual overflow volume: 20,000 GAL

AAOV/acre of drainage area: 1,300 GAL

Imperviousness: 49% (0% tree cover)

Rooftops:	186,651 SF	56%
Roadways:	86,670 SF	26%
Parking/Sidewalks:	57,723 SF	17%

Land Use:

Residential:	220,063 SF	33%
Commercial:	75,498 SF	11%
Industrial:	122,805 SF	18%
Unknown:	258,313 SF	38%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **331,044 SF**

Roadways:

Roadways: 86,670 SF 26%
Number of Catch Basins: 19
Catch Basins on Repair List: 2

Single Family Residential:

Rooftops: 62,830 SF 19%

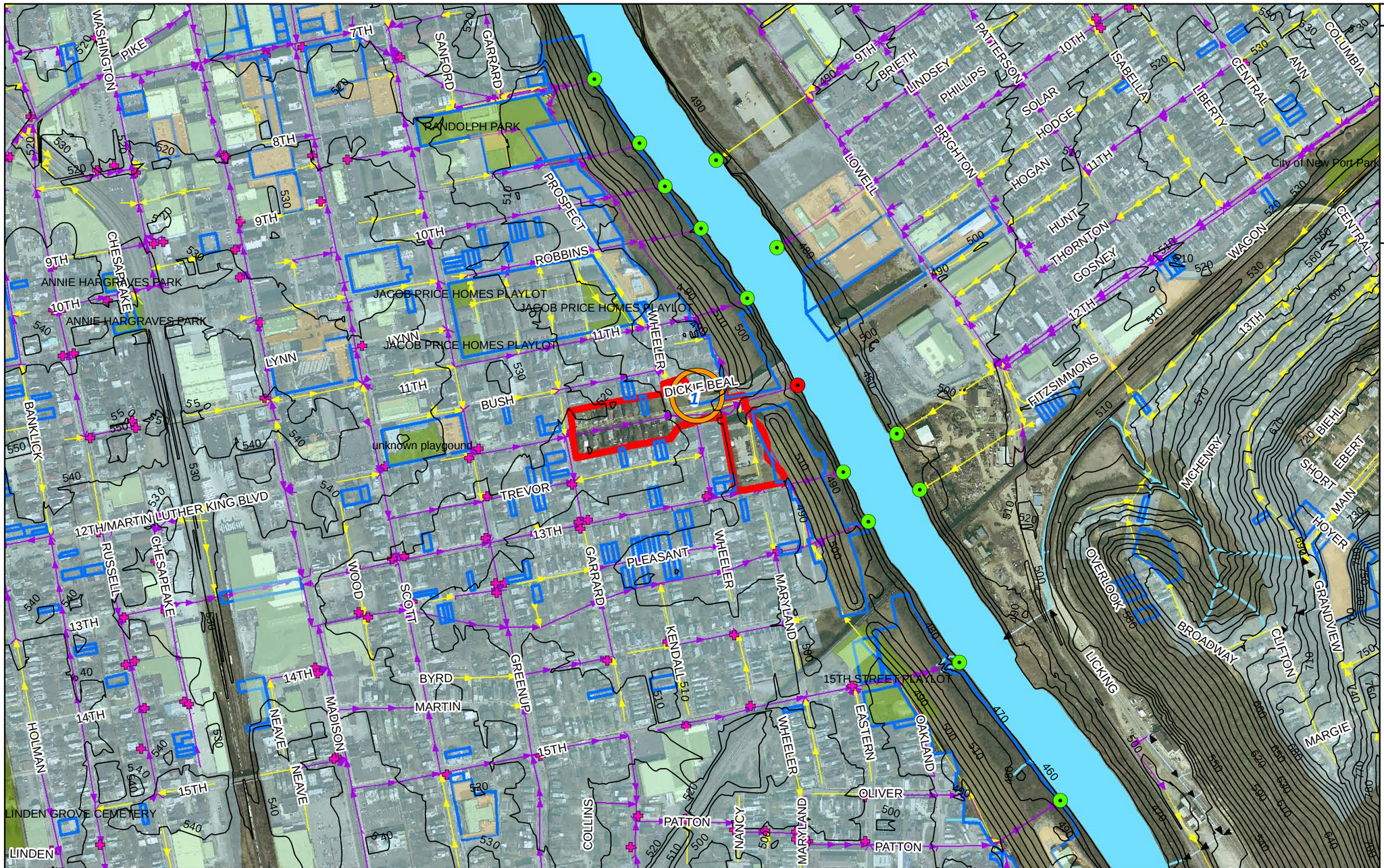
Rooftops Over 10,000 SF: **96,300 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **62,000 SF**

Potential Opportunities:

1. Utilize Existing Green Space - Covington Park Commissioners
2. Utilize Existing Green Space - ROW



CSO 980073
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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STRAND ASSOCIATES, INC. ENGINEERS

CSO ID - 980073 (5.52 acres)

CSO Statistics:

No. of overflows/yr: 12
Avg. annual overflow volume: 158,000 GAL

AAOV/acre of drainage area: 28,700 GAL

Imperviousness: 48% (0% tree cover)

Rooftops:	33,386 SF	29%
Roadways:	59,715 SF	51%
Parking/Sidewalks:	23,246 SF	20%

Land Use:

Residential:	95,216 SF	40%
Commercial:	51,821 SF	22%
Industrial:	0 SF	0%
Unknown:	93,322 SF	39%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **116,347 SF**

Roadways:

Roadways:	59,715 SF	51%
Number of Catch Basins:	3	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	20,755 SF	18%

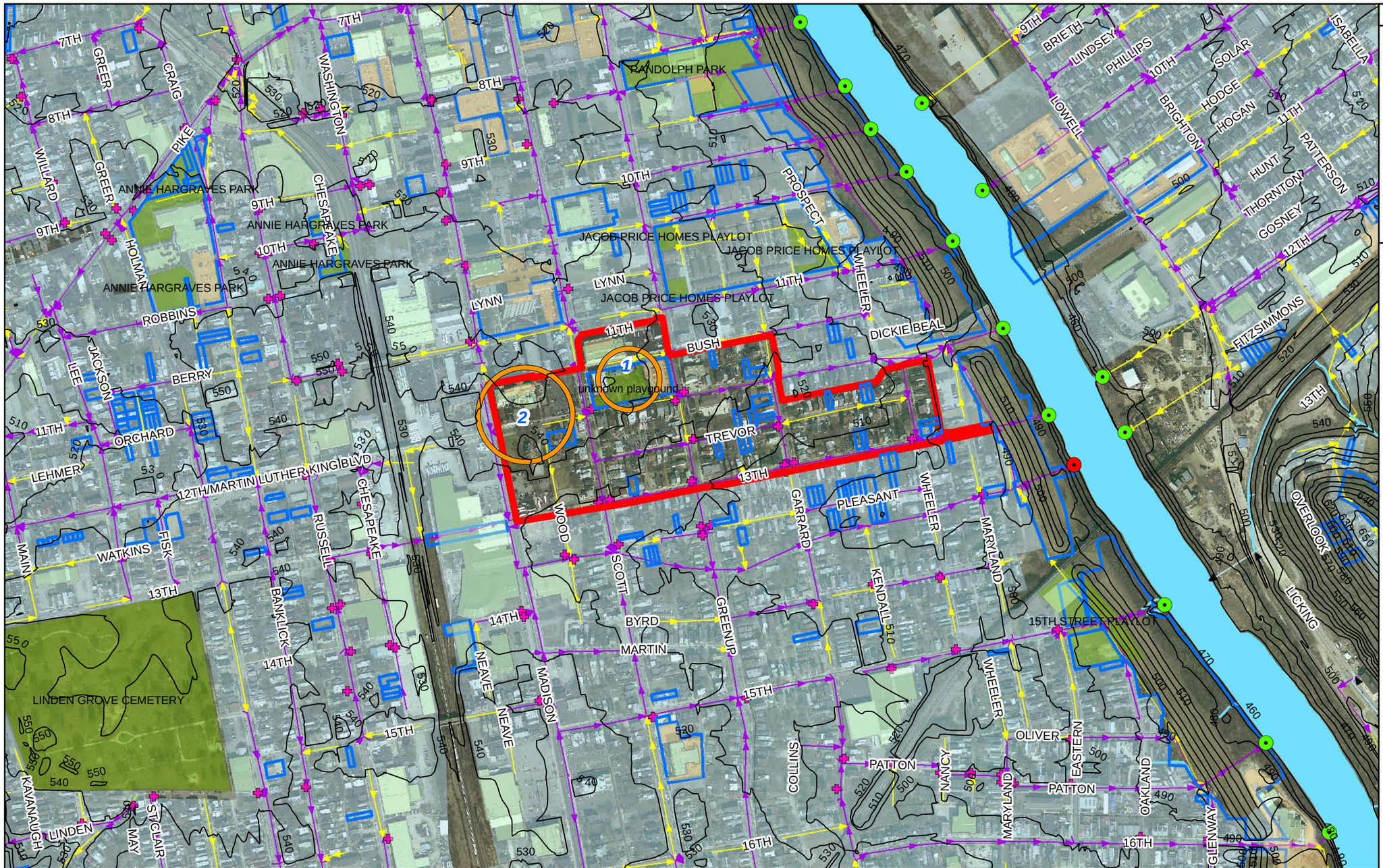
Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **19,200 SF**

Potential Opportunities:

1. Utilize Existing Green Space - ROW



CSO ID - 980080 (29.71 acres)

CSO Statistics:

No. of overflows/yr: 3
Avg. annual overflow volume: 39,000 GAL

AAOV/acre of drainage area: 1,300 GAL

Imperviousness: 52% (0% tree cover)

Rooftops:	289,156 SF	43%
Roadways:	245,721 SF	37%
Parking/Sidewalks:	134,188 SF	20%

Land Use:

Residential:	439,774 SF	34%
Commercial:	433,051 SF	33%
Industrial:	0 SF	0%
Unknown:	421,315 SF	33%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **669,065 SF**

Roadways:

Roadways:	245,721 SF	37%
Number of Catch Basins:	45	
Catch Basins on Repair List:	13	

Single Family Residential:

Rooftops:	124,904 SF	19%

Rooftops Over 10,000 SF: **34,200 SF**

Parking Lots Over 15,000 SF: **16,000 SF**

Public Parcels: **128,100 SF**

Potential Opportunities:

1. Green Retrofit Site - Covington Ind School
2. Green Retrofit Site - Diocese of Covington

CSO 980080
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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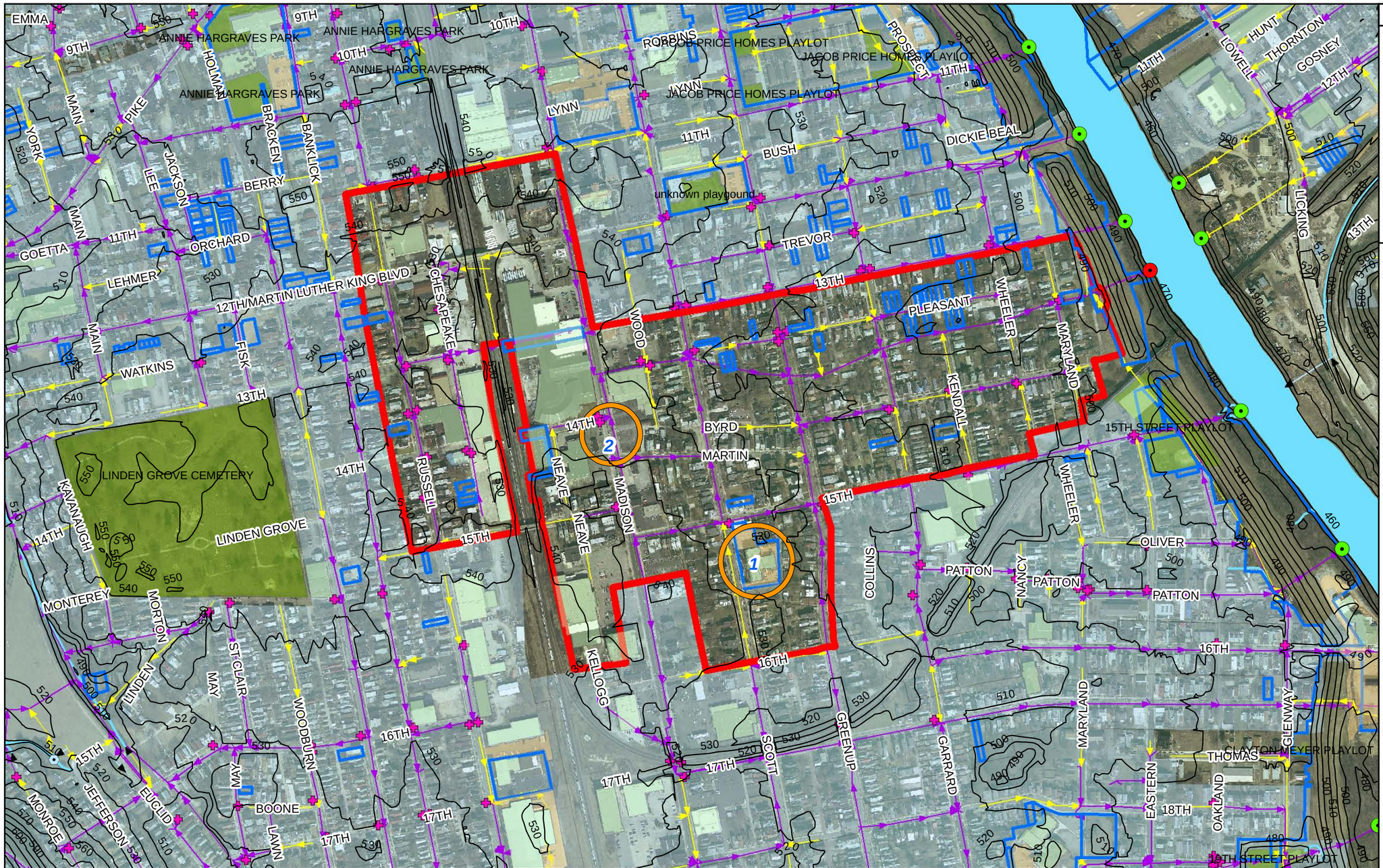

CSO ID - 980081 (114.95 acres)

CSO Statistics:

No. of overflows/yr:	75
Avg. annual overflow volume:	55,931,000 GAL
AAOV/acre of drainage area:	486,600 GAL

Imperviousness: 54% (0% tree cover)

Rooftops:	1,383,837 SF	52%
Roadways:	735,141 SF	27%
Parking/Sidewalks:	560,738 SF	21%

Land Use:

Residential:	1,906,801 SF	38%
Commercial:	1,359,060 SF	27%
Industrial:	354,282 SF	7%
Unknown:	1,387,258 SF	28%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low/Medium

Total Impervious Area: 2,679,716 SF

Roadways:

Roadways:	735,141 SF	27%
Number of Catch Basins:	103	
Catch Basins on Repair List:	27	

Single Family Residential:

Rooftops:	535,441 SF	20%

Rooftops Over 10,000 SF: 442,600 SF

Parking Lots Over 15,000 SF: 22,300 SF

Public Parcels: 189,100 SF

Potential Opportunities:

1. Green Retrofit Site - Covington Ind School
2. Green Street - Madison Avenue

CSO 980081
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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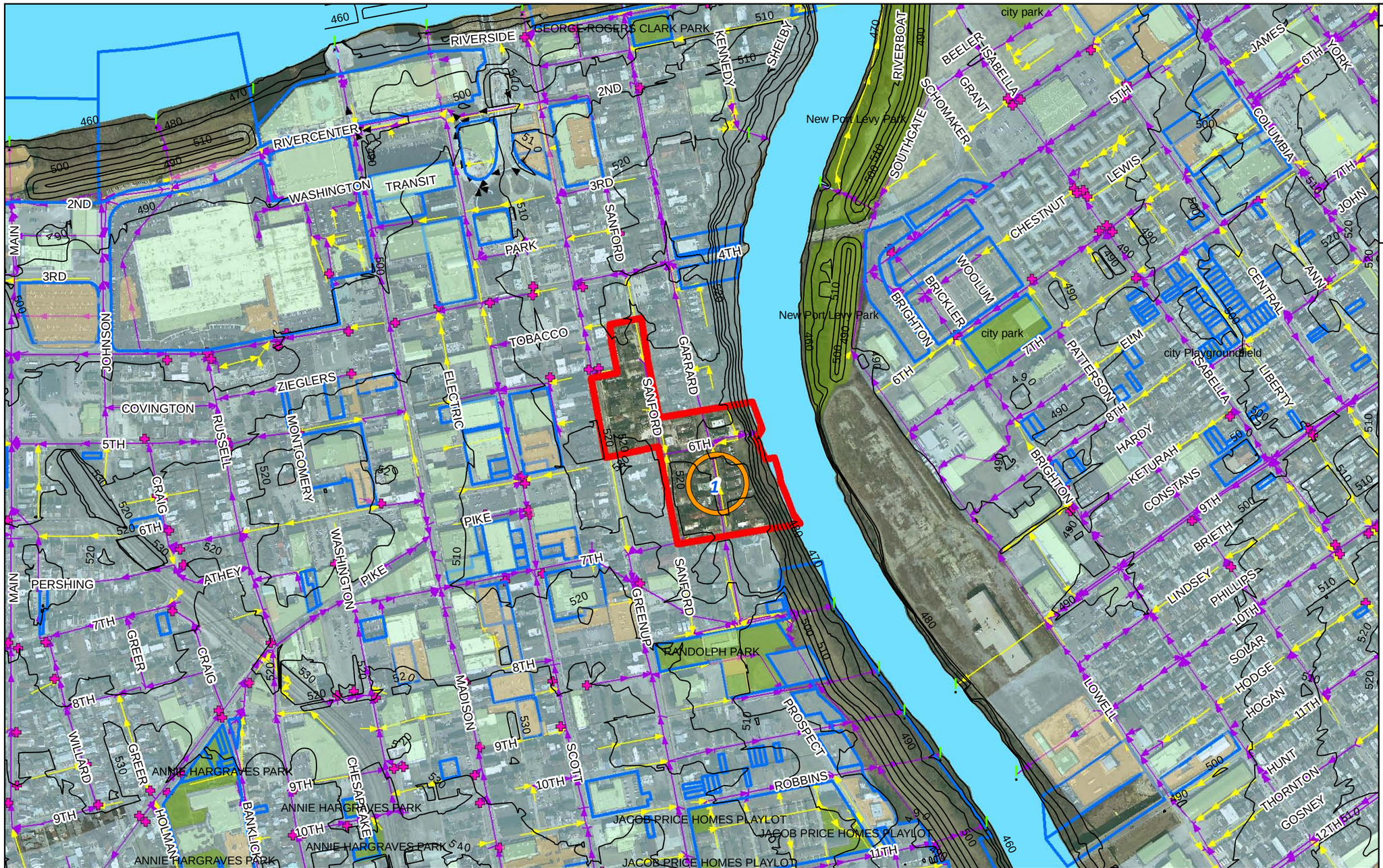

CSO ID - 1420141 (11.10 acres)

CSO Statistics:

No. of overflows/yr:	32
Avg. annual overflow volume:	746,000 GAL
AAOV/acre of drainage area:	67,200 GAL

Imperviousness: 46 % (10 % tree cover)

Rooftops:	94,749 SF	42%
Roadways:	83,671 SF	37%
Parking/Sidewalks:	46,064 SF	21%

Land Use:

Residential:	178,772 SF	37%
Commercial:	154,341 SF	32%
Industrial:	0 SF	0%
Unknown:	150,076 SF	31%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **224,484 SF**

Roadways:

Roadways:	83,671 SF	37%
Number of Catch Basins:	10	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	21,341 SF	10%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **0 SF**

Potential Opportunities:

1. Small Sewer Separation

CSO 1420141
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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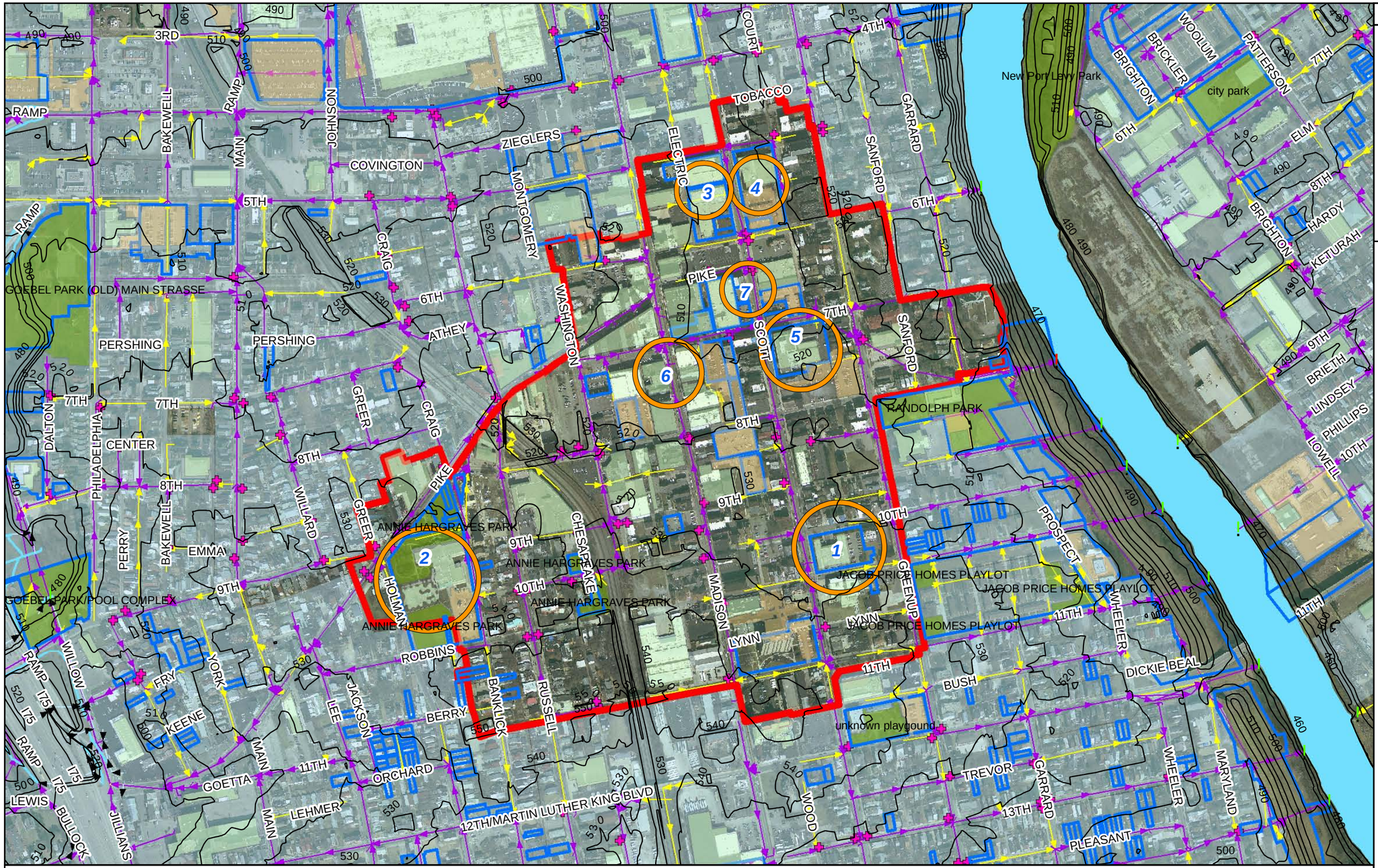

CSO ID - 1420142 (129.40 acres)

CSO Statistics:

No. of overflows/yr:	71
Avg. annual overflow volume:	104,100,000 GAL
AAOV/acre of drainage area:	804,500 GAL

Imperviousness: 66% (0% tree cover)

Rooftops:	1,616,686 SF	44%
Roadways:	1,055,335 SF	28%
Parking/Sidewalks:	1,031,880 SF	28%

Land Use:

Residential:	706,303 SF	13%
Commercial:	3,061,905 SF	54%
Industrial:	20,908 SF	0%
Unknown:	1,847,360 SF	33%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **3,703,901 SF**

Roadways:

Roadways:	1,055,335 SF	28%
Number of Catch Basins:	179	
Catch Basins on Repair List:	45	

Single Family Residential:

Rooftops:	167,120 SF	5%

Rooftops Over 10,000 SF: **810,200 SF**

Parking Lots Over 15,000 SF: **323,100 SF**

Public Parcels: **800,400 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Covington
2. Green Retrofit Site - Covington Ind School
3. Green Retrofit Site - Covington Ind School
4. Green Retrofit Site - Kenton County Library
5. Green Retrofit Site - United States of America
6. Green Street - Madison Street
7. Green Street - Scott Street

CSO 1420142
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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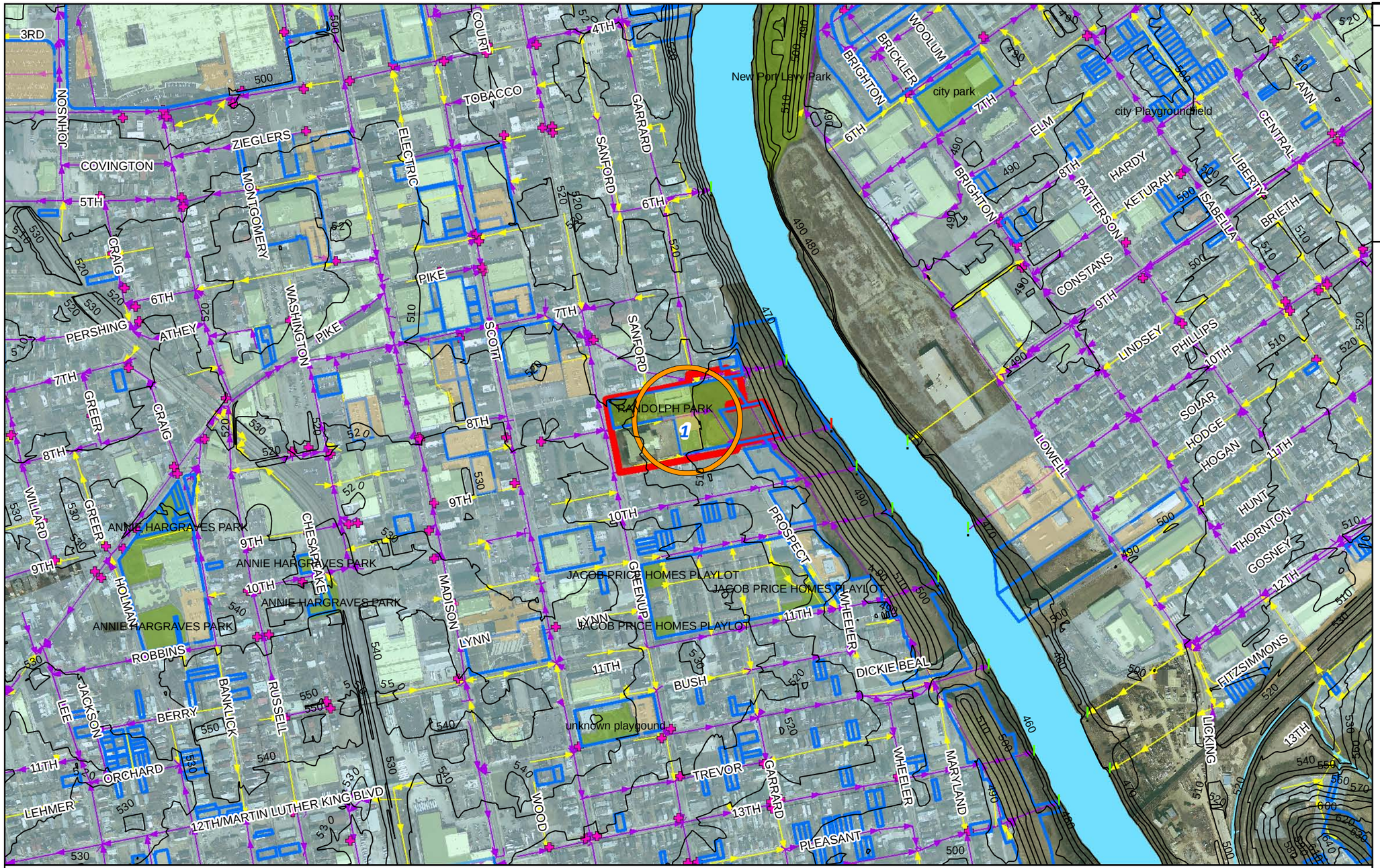

! CSO 1420144	Combined Sewer	Public Ownership	
! Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF	
2 Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF	
Catch Basin Repair List	CSO Drainage Area	OKI Green Space	
Streams	Surrounding CSO Areas	Best Opportunities	

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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CSO ID - 1420144 (6.16 acres)

CSO Statistics:

No. of overflows/yr: 1
Avg. annual overflow volume: 19,000 GAL

AAOV/acre of drainage area: 3,000 GAL

Imperviousness: 42% (0% tree cover)

Rooftops:	47,238 SF	42%
Roadways:	21,068 SF	19%
Parking/Sidewalks:	44,469 SF	39%

Land Use:

Residential:	36,026 SF	13%
Commercial:	191,677 SF	71%
Industrial:	0 SF	0%
Unknown:	40,466 SF	15%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Zero

Total Impervious Area: **112,774 SF**

Roadways:

Roadways:	21,068 SF	19%
Number of Catch Basins:	9	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	0 SF	0%

Rooftops Over 10,000 SF: **28,500 SF**

Parking Lots Over 15,000 SF: **15,200 SF**

Public Parcels: **171,600 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Covington

STRAND ASSOCIATES, INC® ENGINEERS

! CSO 1420145	Combined Sewer	Public Ownership	
! Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF	
2 Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF	
Б Catch Basin Repair List	CSO Drainage Area	OKI Green Space	
Streams	Surrounding CSO Areas	Best Opportunities	

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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CSO ID - 1420145 (5.58 acres)

CSO Statistics:

No. of overflows/yr: 2
Avg. annual overflow volume: 21,000 GAL

AAOV/acre of drainage area: 3,700 GAL

Imperviousness: 34% (0% tree cover)

Rooftops:	43,339 SF	53%
Roadways:	27,731 SF	34%
Parking/Sidewalks:	11,317 SF	14%

Land Use:

Residential:	127,475 SF	52%
Commercial:	59,109 SF	24%
Industrial:	0 SF	0%
Unknown:	56,535 SF	23%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: 82,388 SF

Roadways:

Roadways:	27,731 SF	34%
Number of Catch Basins:	7	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	15,094 SF	18%

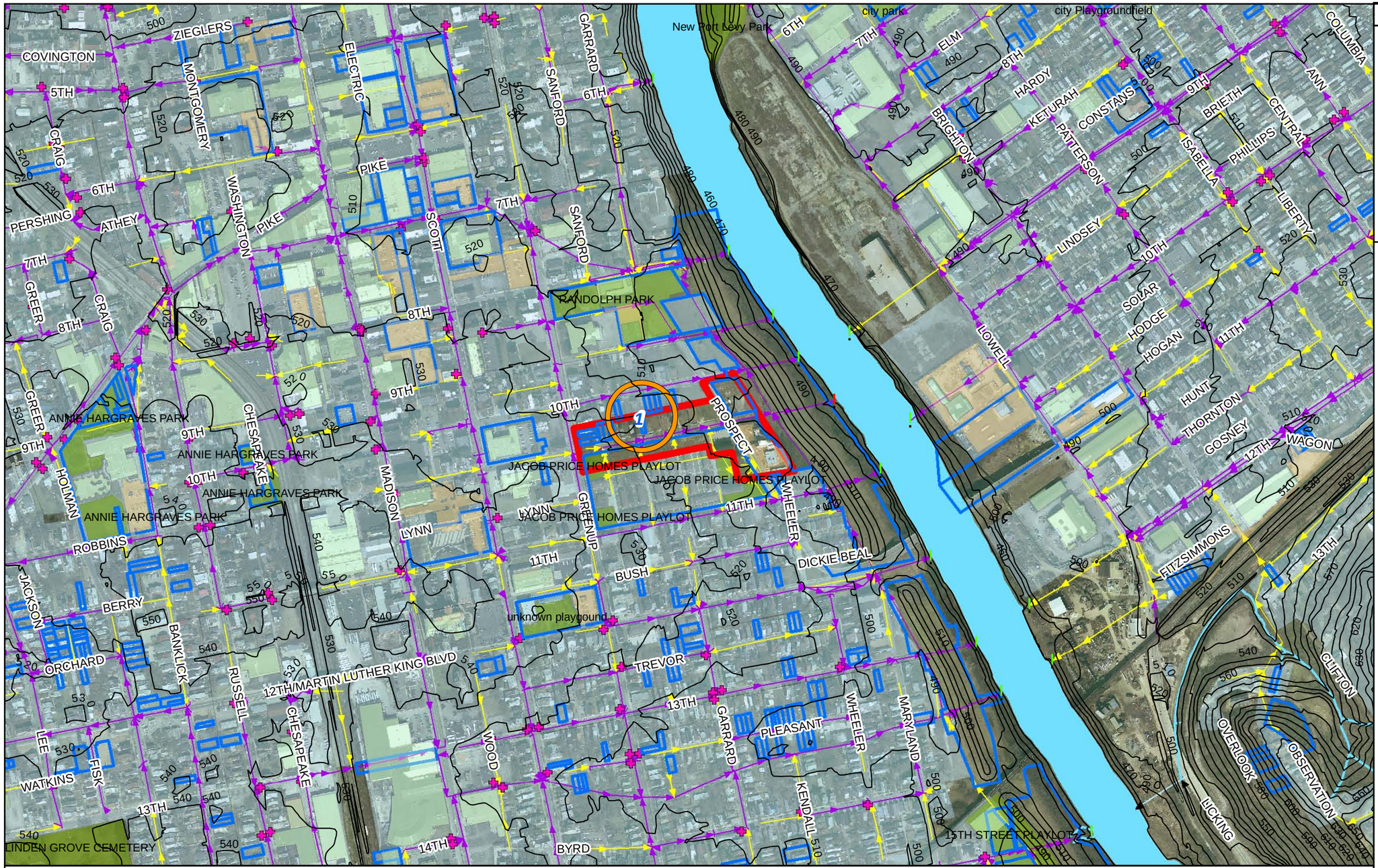
Rooftops Over 10,000 SF: 0 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 31,400 SF

Potential Opportunities:

1. Green Retrofit Site - City of Covington



! CSO 1420146
! Surrounding CSOs
2 Point of Entry
Б Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

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SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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CSO ID - 1420146 (6.10 acres)

CSO Statistics:

No. of overflows/yr: 1
Avg. annual overflow volume: 13,000 GAL

AAOV/acre of drainage area: 2,100 GAL

Imperviousness: 41% (0% tree cover)

Rooftops:	32,904 SF	30%
Roadways:	45,006 SF	41%
Parking/Sidewalks:	31,158 SF	29%

Land Use:

Residential:	51,400 SF	19%
Commercial:	141,250 SF	53%
Industrial:	0 SF	0%
Unknown:	73,099 SF	28%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low/Medium

Total Impervious Area: 109,069 SF

Roadways:

Roadways:	45,006 SF	41%
Number of Catch Basins:	8	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	1,617 SF	1%

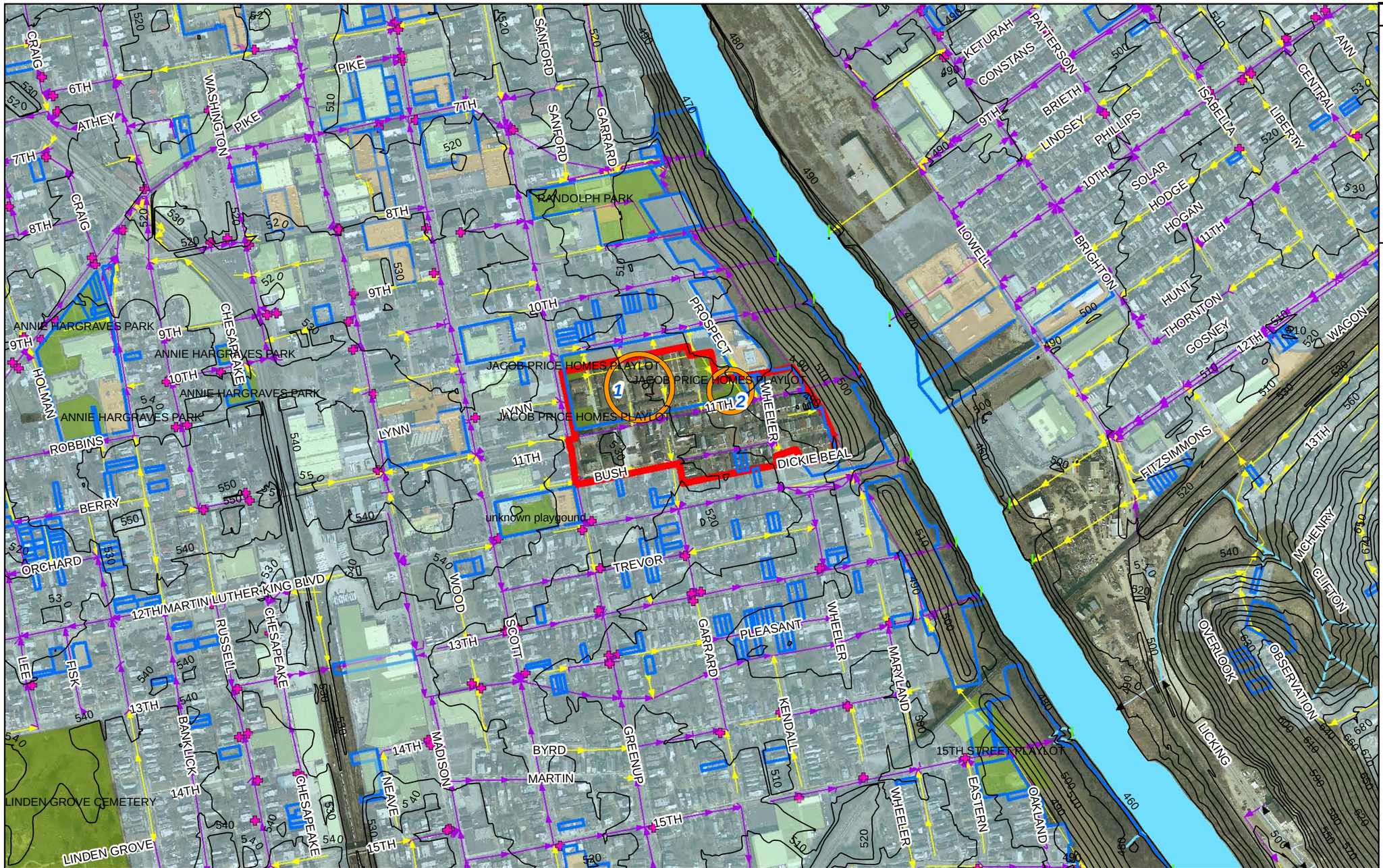
Rooftops Over 10,000 SF: 0 SF

Parking Lots Over 15,000 SF: 18,300 SF

Public Parcels: 107,500 SF

Potential Opportunities:

1. Green Retrofit Site - City of Covington



! CSO 1420147	Combined Sewer	Public Ownership
! Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF
2 Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF
Catch Basin Repair List	CSO Drainage Area	OKI Green Space
Streams	Surrounding CSO Areas	Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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CSO ID - 1420147 (14.71 acres)

CSO Statistics:

No. of overflows/yr:	3
Avg. annual overflow volume:	17,8000 GAL
AAOV/acre of drainage area:	12,100 GAL

Imperviousness: 41% (0% tree cover)

Rooftops:	132,296 SF	50%
Roadways:	113,258 SF	43%
Parking/Sidewalks:	18,501 SF	7%

Land Use:

Residential:	207,906 SF	32%
Commercial:	280,169 SF	44%
Industrial:	0 SF	0%
Unknown:	152,812 SF	24%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: 264,055 SF

Roadways:

Roadways:	113,258 SF	43%
Number of Catch Basins:	11	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	54,060 SF	20%

Rooftops Over 10,000 SF: 0 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 227,000 SF

Potential Opportunities:

1. Green Retrofti Site - City of Covington
2. Utilize Existing Green Space - Jacob Paice Homes

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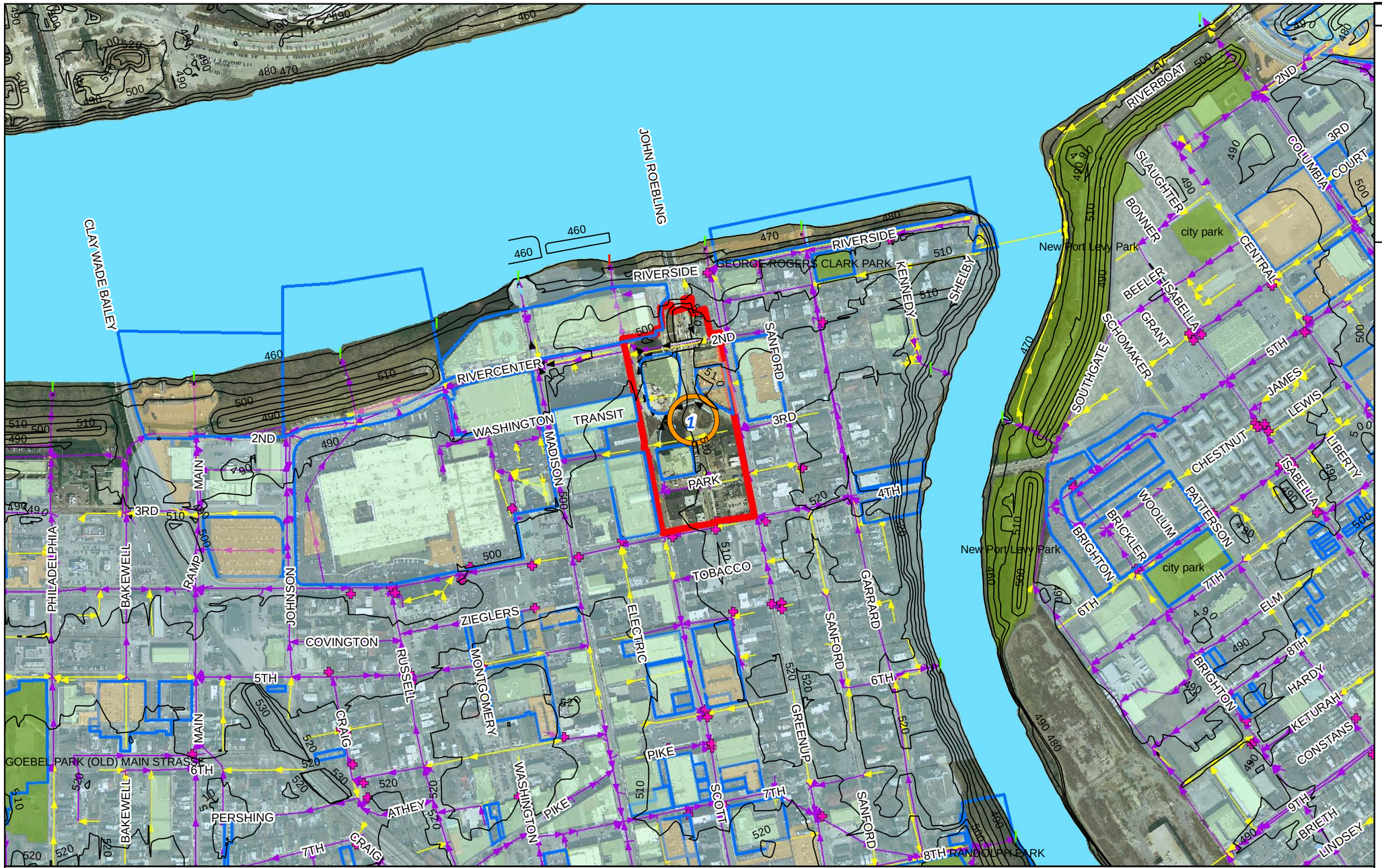


! CSO 1440204	Combined Sewer	Public Ownership
! Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF
2 Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF
Б Catch Basin Repair List	CSO Drainage Area	OKI Green Space
Streams	Surrounding CSO Areas	Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1440204 (10.64 acres)

CSO Statistics:

No. of overflows/yr: 1
Avg. annual overflow volume: 2,000 GAL

AAOV/acre of drainage area: 0 GAL

Imperviousness: 65% (0% tree cover)

Rooftops:	94,414 SF	31%
Roadways:	141,446 SF	47%
Parking/Sidewalks:	67,548 SF	22%

Land Use:

Residential:	0 SF	0%
Commercial:	191,474 SF	41%
Industrial:	0 SF	0%
Unknown:	271,865 SF	59%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Zero

Total Impervious Area: **303,409 SF**

Roadways:

Roadways:	141,446 SF	47%
Number of Catch Basins:	7	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	0 SF	0%

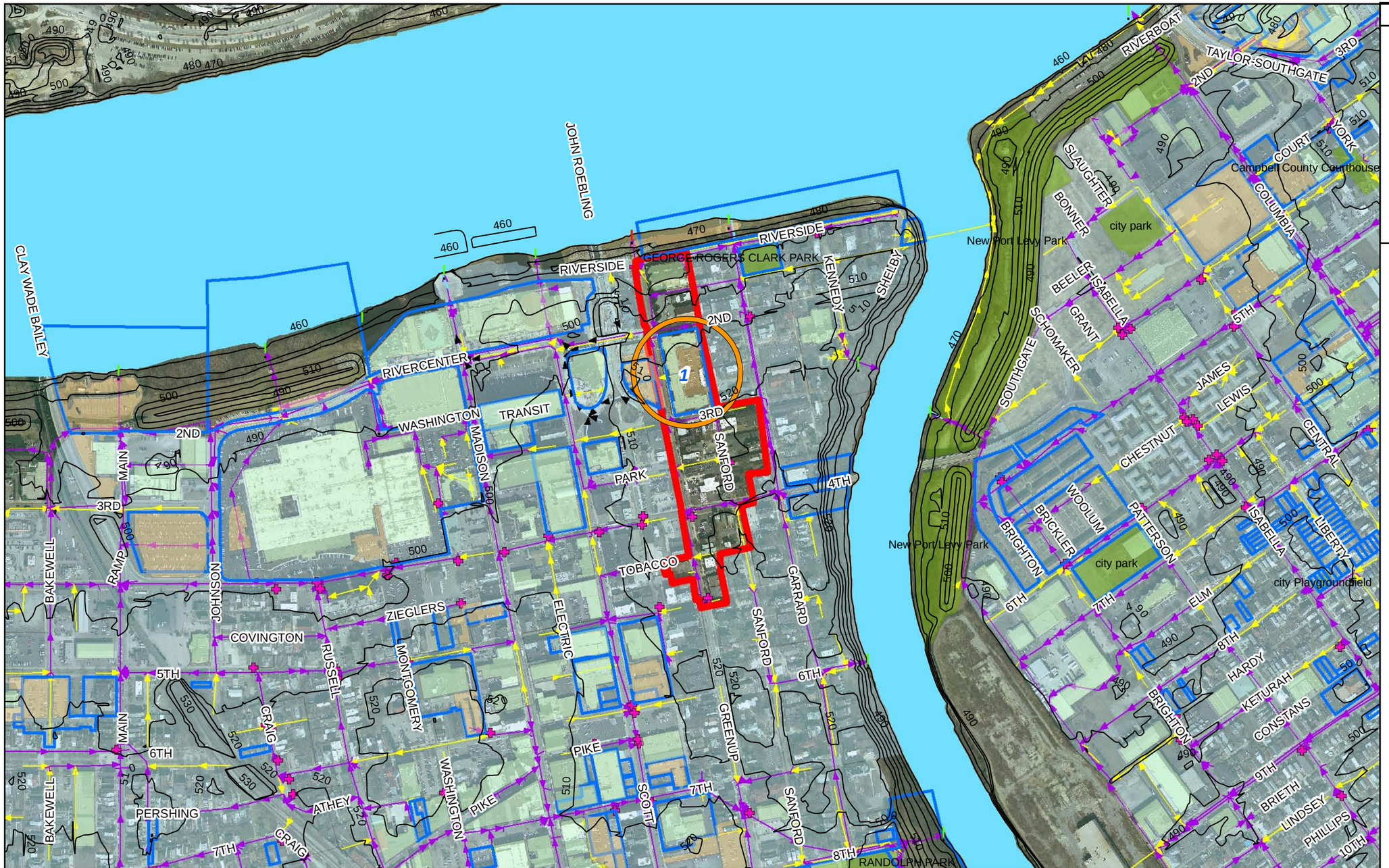
Rooftops Over 10,000 SF: **44,500 SF**

Parking Lots Over 15,000 SF: **33,900 SF**

Public Parcels: **97,900 SF**

Potential Opportunities:

1. Utilize Existing Green Space - ROW



CSO ID - 1440205 (12.26 acres)

CSO Statistics:

No. of overflows/yr:	19
Avg. annual overflow volume:	624,000 GAL
AAOV/acre of drainage area:	50,900 GAL

Imperviousness: 74% (0% tree cover)

Rooftops:	165,064 SF	42%
Roadways:	123,598 SF	31%
Parking/Sidewalks:	106,473 SF	27%

Land Use:

Residential:	74,140 SF	14%
Commercial:	259,141 SF	49%
Industrial:	0 SF	0%
Unknown:	200,575 SF	38%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **395,136 SF**

Roadways:

Roadways:	123,598 SF	31%
Number of Catch Basins:	21	
Catch Basins on Repair List:	5	

Single Family Residential:

Rooftops:	15,127 SF	4%

Rooftops Over 10,000 SF: **58,000 SF**

Parking Lots Over 15,000 SF: **24,600 SF**

Public Parcels: **75,900 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Covington

! CSO 1440205
! Surrounding CSOs
2 Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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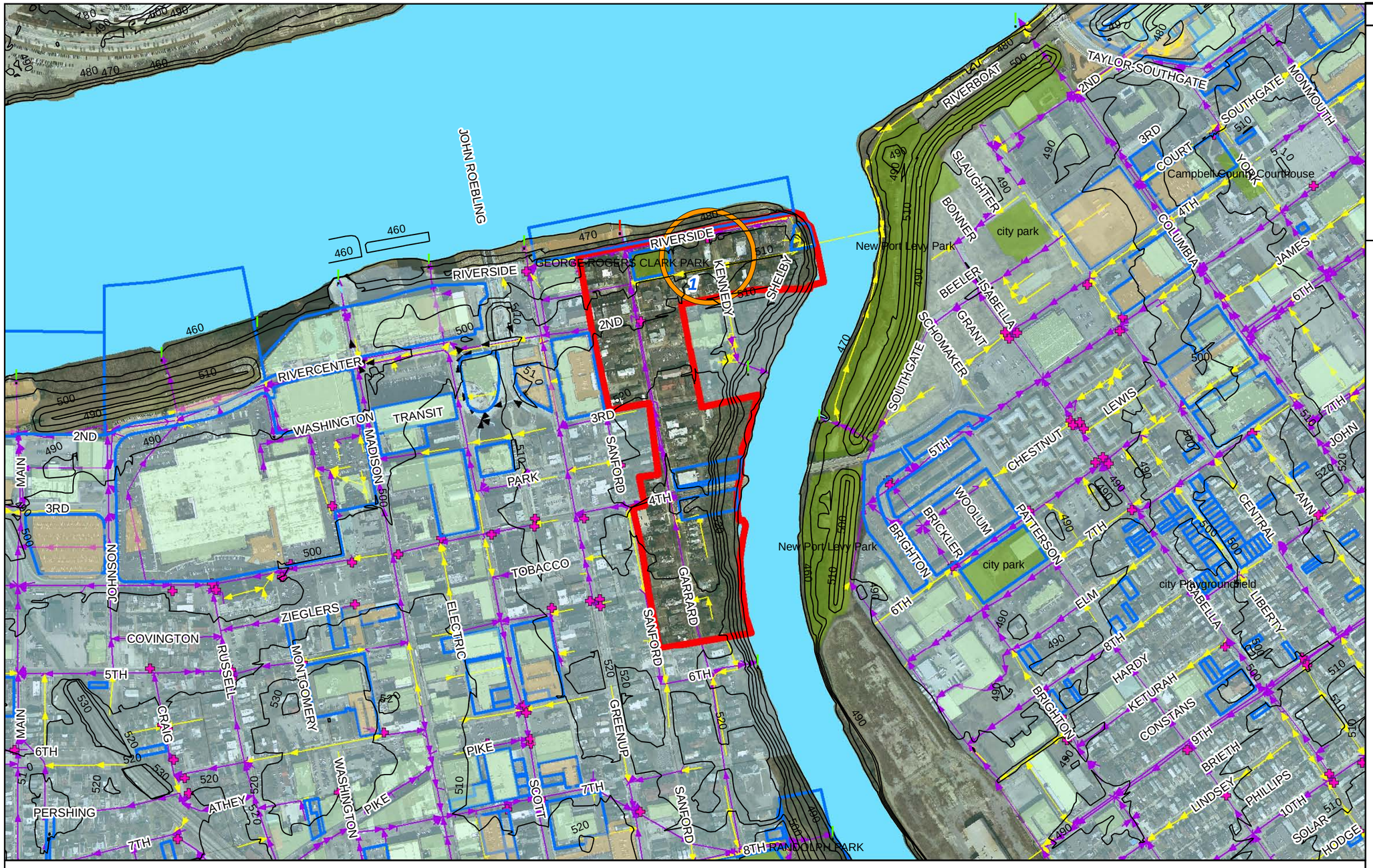

CSO ID - 1440206 (26.79 acres)

CSO Statistics:

No. of overflows/yr:	33
Avg. annual overflow volume:	3,378,000 GAL
AAOV/acre of drainage area:	126,100 GAL

Imperviousness: 43% (7% tree cover)

Rooftops:	214,475 SF	43%
Roadways:	195,410 SF	39%
Parking/Sidewalks:	94,350 SF	19%

Land Use:

Residential:	497,875 SF	43%
Commercial:	358,513 SF	31%
Industrial:	0 SF	0%
Unknown:	306,426 SF	26%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low/Medium

Total Impervious Area: **504,235 SF**

Roadways:

Roadways:	195,410 SF	39%
Number of Catch Basins:	21	
Catch Basins on Repair List:	2	

Single Family Residential:

Rooftops:	101,262 SF	20%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **99,500 SF**

Potential Opportunities:

1. Small Sewer Separation

! CSO 1440206
! Surrounding CSOs
2 Point of Entry
6 Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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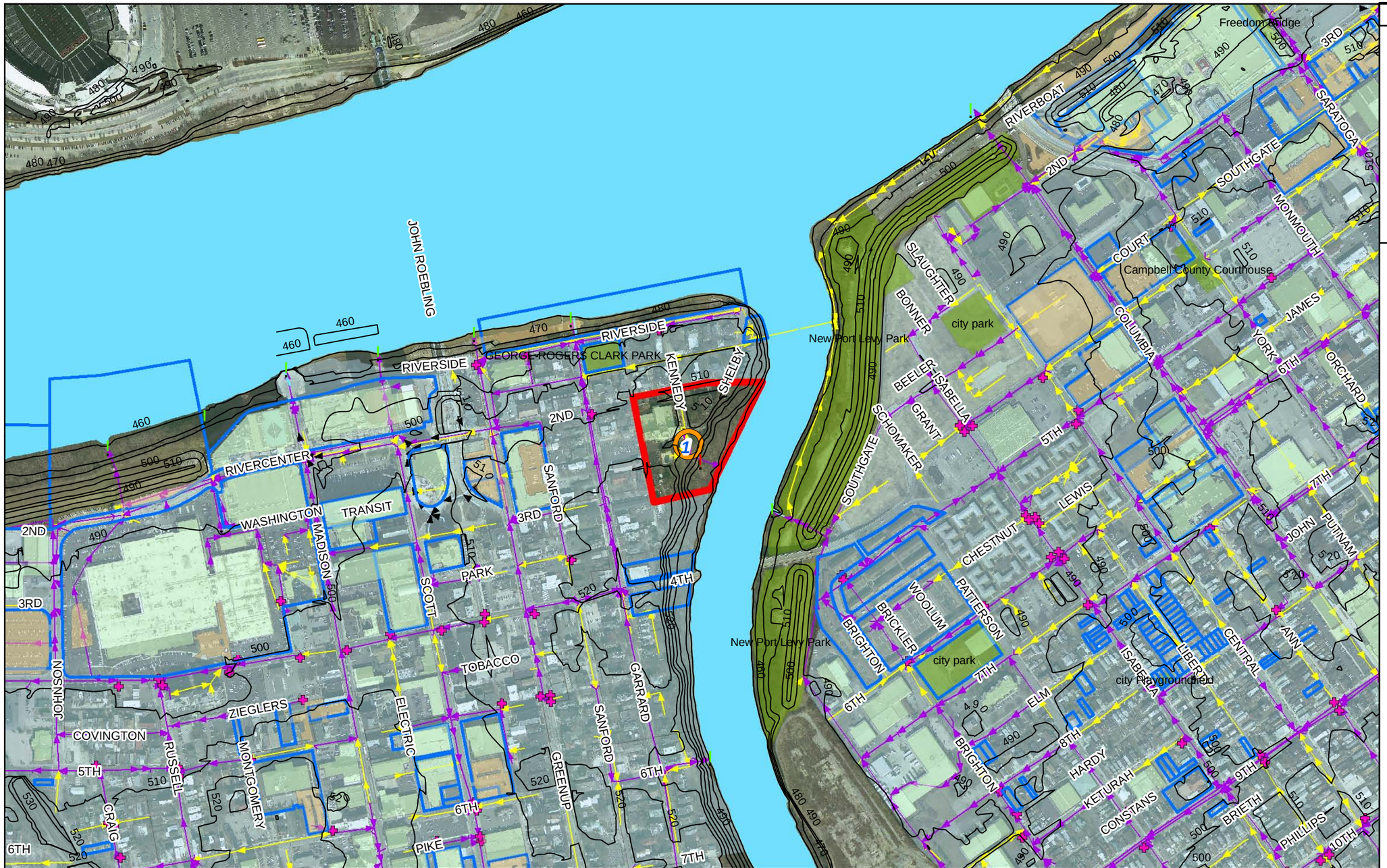

!	CSO 1440207	Combined Sewer	Public Ownership
!	Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF
2	Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF
6	Catch Basin Repair List	CSO Drainage Area	OKI Green Space
	Streams	Surrounding CSO Areas	Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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CSO ID - 1440207 (5.49 acres)

CSO Statistics:

No. of overflows/yr:	0
Avg. annual overflow volume:	0 GAL
AAOV/acre of drainage area:	0 GAL

Imperviousness: 29% (0% tree cover)

Rooftops:	38,269 SF	55%
Roadways:	28,782 SF	41%
Parking/Sidewalks:	2,886 SF	4%

Land Use:

Residential:	185,550 SF	82%
Commercial:	0 SF	0%
Industrial:	0 SF	0%
Unknown:	39,926 SF	18%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 69,937 SF

Roadways:

Roadways:	28,782 SF	41%
Number of Catch Basins:	2	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	9,077 SF	13%

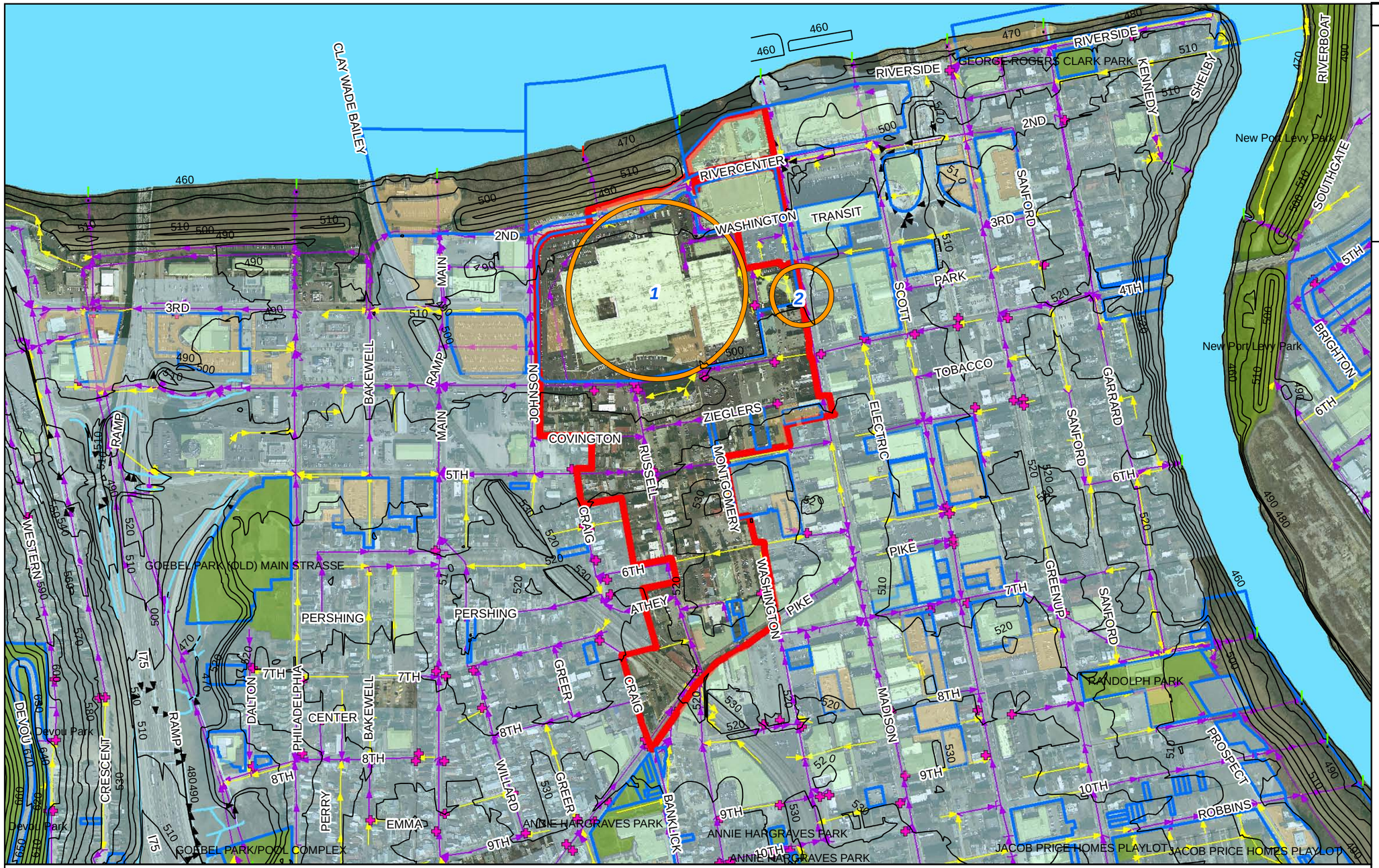
Rooftops Over 10,000 SF: 24,800 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 0 SF

Potential Opportunities:

1. Utilize Existing Green Space - Marc Hult



CSO ID - 1440209 (54.17 acres)

CSO Statistics:

No. of overflows/yr:	92
Avg. annual overflow volume:	56,391,000 GAL
AAOV/acre of drainage area:	1,041,100 GAL

Imperviousness: 76% (0% tree cover)

Rooftops:	869,808 SF	49%
Roadways:	438,620 SF	25%
Parking/Sidewalks:	479,903 SF	27%

Land Use:

Residential:	292,095 SF	12%
Commercial:	1,653,072 SF	70%
Industrial:	0 SF	0%
Unknown:	414,361 SF	18%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **1,788,332 SF**

Roadways:

Roadways:	438,620 SF	25%
Number of Catch Basins:	63	
Catch Basins on Repair List:	14	

Single Family Residential:

Rooftops:	66,365 SF	4%

Rooftops Over 10,000 SF: **603,400 SF**

Parking Lots Over 15,000 SF: **81,800 SF**

Public Parcels: **1,078,000 SF**

Potential Opportunities:

1. Green Retrofit Site - United States of America
2. Green Street - Madison Street

! CSO 1440209
! Surrounding CSOs
2 Point of Entry
Б Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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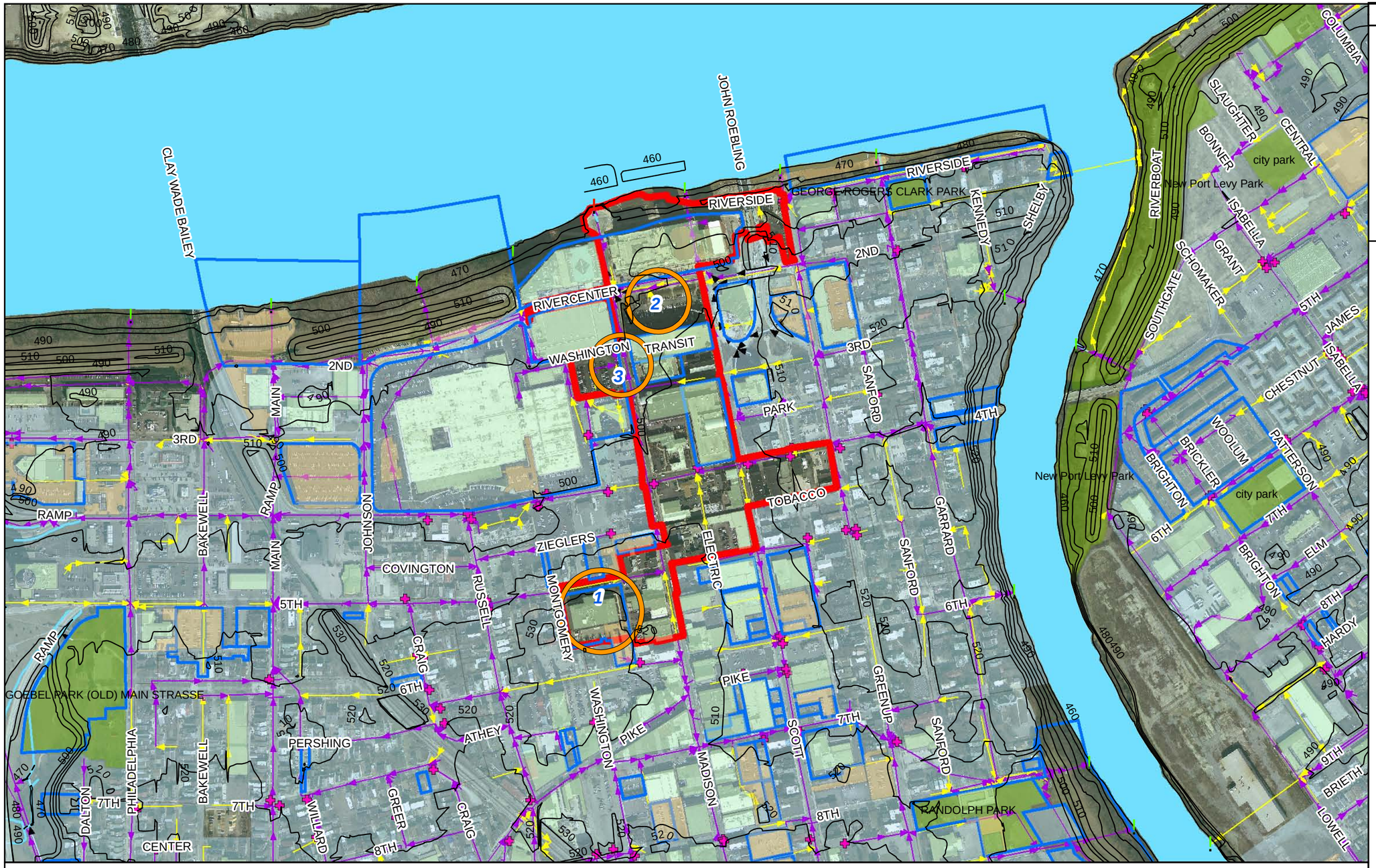

! CSO 1440212
! Surrounding CSOs
2 Point of Entry
6 Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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CSO ID - 1440212 (30.94 acres)

CSO Statistics:

No. of overflows/yr:	54
Avg. annual overflow volume:	5,983,000 GAL
AAOV/acre of drainage area:	193,400 GAL

Imperviousness: 77% (0% tree cover)

Rooftops:	480,595 SF	46%
Roadways:	302,800 SF	29%
Parking/Sidewalks:	253,610 SF	24%

Land Use:

Residential:	0 SF	0%
Commercial:	932,944 SF	69%
Industrial:	0 SF	0%
Unknown:	414,746 SF	31%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Zero

Total Impervious Area: **1,037,006 SF**

Roadways:

Roadways:	302,800 SF	29%
Number of Catch Basins:	27	
Catch Basins on Repair List:	5	

Single Family Residential:

Rooftops:	0 SF	0%

Rooftops Over 10,000 SF: **364,700 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **457,300 SF**

Potential Opportunities:

1. Green Retrofit Site - United States of America
2. Green Retrofit Site - William Butler
3. Green Street - Madison Street

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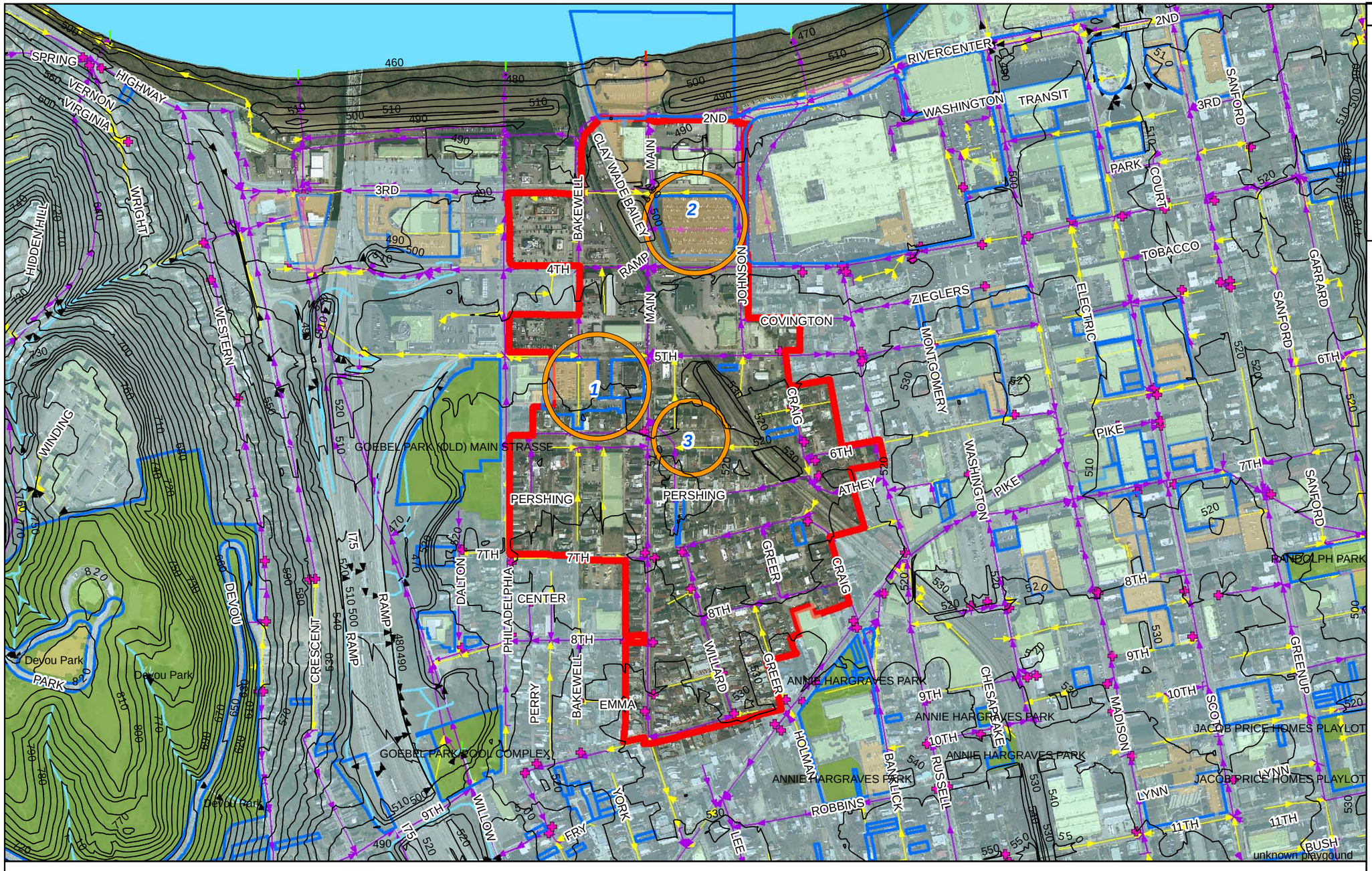

CSO ID - 1470093 (79.80 acres)

CSO Statistics:

No. of overflows/yr:	58
Avg. annual overflow volume:	43,684,000 GAL
AAOV/acre of drainage area:	547,400 GAL

Imperviousness: 63% (0% tree cover)

Rooftops:	771,948 SF	35%
Roadways:	799,956 SF	36%
Parking/Sidewalks:	625,567 SF	28%

Land Use:

Residential:	918,257 SF	26%
Commercial:	1,119,174 SF	32%
Industrial:	103,818 SF	3%
Unknown:	1,334,908 SF	38%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **2,197,471 SF**

Roadways:

Roadways:	799,956 SF	36%
Number of Catch Basins:	15	
Catch Basins on Repair List:	19	

Single Family Residential:

Rooftops:	307,999 SF	14%

Rooftops Over 10,000 SF: **148,700 SF**

Parking Lots Over 15,000 SF: **179,800 SF**

Public Parcels: **226,600 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Covington
2. Green Retrofit Site - United States of America
3. Green Street - ROW

! CSO 1470093
! Surrounding CSOs
2 Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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3-B.1 - Initial Combined Sewer Area

Green Infrastructure Opportunities

East Basin CSO Sewersheds
570089
570090
600094
600097
610071
620075
620077
640090
650090
660085
770096
790084
790086

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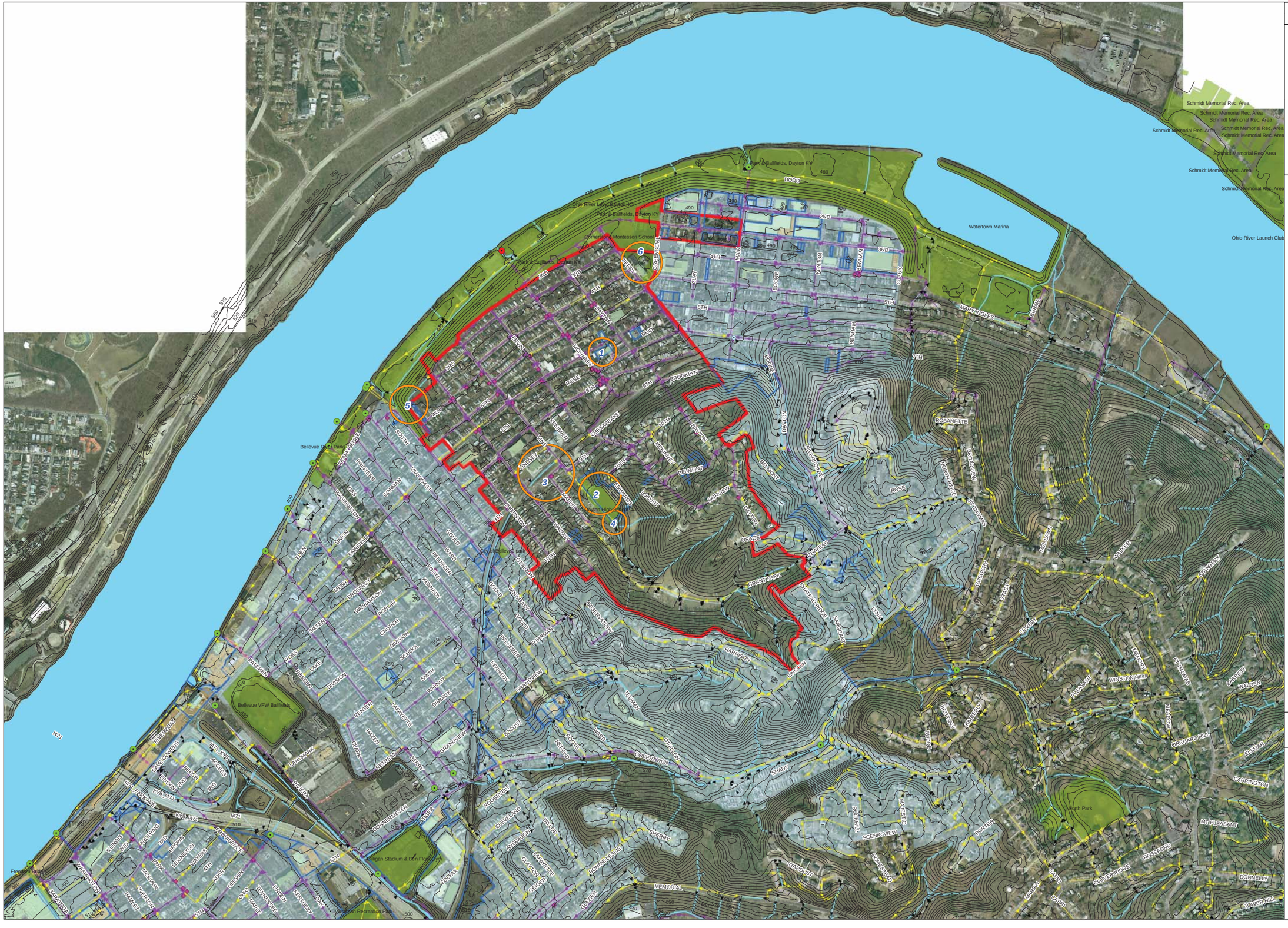

CSO ID - 570089 (267.55 acres)

CSO Statistics:

No. of overflows/yr:	62
Avg annual overflow volume:	49,986,000 GAL
Avg. duration:	0
AAOV/acre of drainage area:	186,800 GAL

Imperviousness: 30% (23% tree cover)

Rooftops:	1,776,989 SF	51%
Roadways:	1,387,276 SF	40%
Parking/Sidewalks:	314,963 SF	9%

Landuse:

Residential:	6,195,487 SF	53%
Commercial:	2,095,758 SF	18%
Industrial:	0 SF	0%
Unknown:	3,363,319 SF	29%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 3,479,228 SF

Roadways:

Roadways:	1,387,276 SF	40%
Number of Catch Basins::	211	
Catch Basins on Repair List:	41	

Single Family Residential:

Rooftops:	1,396,627 SF	40%

Rooftops Over 10,000 SF: 90,000 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 332,500 SF

Potential Opportunities:

1. Green Retrofit Site - City of Dayton
2. Green Retrofit Site - Dayton School District
3. Small Sewer Separation
4. Surface Entry Point
5. Surface Entry Point
6. Utilize Existing Green Space - Unknown Owner

GREEN INFRASTRUCTURE INIATIVE
SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

- CSO 570089
- Surrounding CSOs
- Point of Entry
- Catch Basin Repair List
- Streams
- Combined Sewer
- Sanitary Sewer
- Storm Sewer
- CSO Drainage Area
- Surrounding CSO Areas
- Public Ownership
- Roof Over 10,000 SF
- Parking Lot Over 15,000 SF
- OKI Green Space
- Best Opportunities

STRAND ASSOCIATES ENGINEERS

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CSO ID - 570090 (249.90 acres)

CSO Statistics:

No. of overflows/yr: 56
Avg annual overflow volume: 36,283,000 GAL

AAOV/acre of drainage area: 145,200 GAL

Imperviousness: 27% (29% tree cover)

Rooftops:	1,412,226 SF	49%
Roadways:	1,076,409 SF	37%
Parking/Sidewalks:	419,924 SF	14%

Landuse:

Residential:	5,798,683 SF	53%
Commercial:	2,650,124 SF	24%
Industrial:	0 SF	0%
Unknown:	2,436,924 SF	22%

Green Concepts

Suitability for Shallow Infiltration: Poor
Downspout Disconnect Effectiveness: Medium

Total Impervious Area: 2,908,559 SF

Roadways:

Roadways:	1,076,409 SF	37%
Number of Catch Basins::	154	
Catch Basins on Repair List:	5	

Single Family Residential:

Rooftops:	742,034 SF	26%

Rooftops Over 10,000 SF: 460,100 SF

Parking Lots Over 15,000 SF: 34,700 SF

Public Parcels: 844,100 SF

Potential Opportunities:

1. Green Retrofit Site - City of Dayton
2. Green Retrofit Site - City of Dayton
3. Green Retrofit Site - Dayton Housing Commission
4. Surface Entry Point

GREEN INFRASTRUCTURE INIATIVE
SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

- CSO 570090
- Surrounding CSOs
- Point of Entry
- Catch Basin Repair List
- Streams
- Combined Sewer
- Sanitary Sewer
- Storm Sewer
- CSO Drainage Area
- Surrounding CSO Areas
- Public Ownership
- Roof Over 10,000 SF
- Parking Lot Over 15,000 SF
- OKI Green Space
- Best Opportunities

0 250 500 1,000 1,500 2,000 Feet

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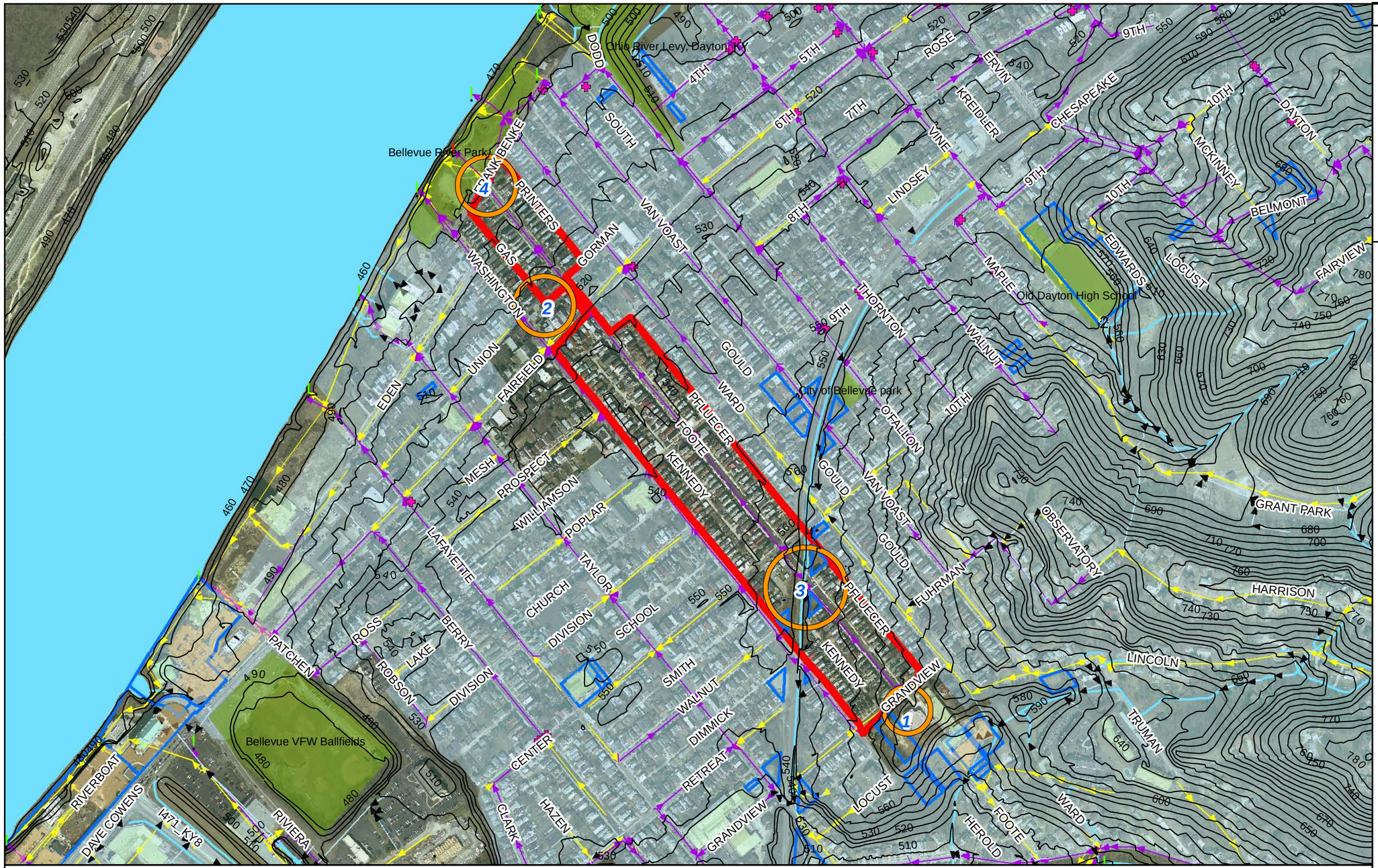

! CSO 600094	Combined Sewer	Public Ownership
! Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF
2 Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF
Б Catch Basin Repair List	CSO Drainage Area	OKI Green Space
Streams	Surrounding CSO Areas	Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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CSO ID - 600094 (25.64 acres)

CSO Statistics:

No. of overflows/yr: 26
Avg. annual overflow volume: 1,644,000 GAL

AAOV/acre of drainage area: 64,100 GAL

Imperviousness: 47% (0% tree cover)

Rooftops:	307,627 SF	58%
Roadways:	218,042 SF	41%
Parking/Sidewalks:	2,539 SF	0%

Land Use:

Residential:	671,594 SF	60%
Commercial:	59,460 SF	5%
Industrial:	0 SF	0%
Unknown:	385,650 SF	35%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **528,208 SF**

Roadways:

Roadways:	218,042 SF	41%
Number of Catch Basins:	15	
Catch Basins on Repair List:	2	

Single Family Residential:

Rooftops:	279,454 SF	53%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **12,500 SF**

Potential Opportunities:

1. Area Flowing into the CSS
2. Area Flowing into the CSS
3. Green Retrofit Site - City of Bellevue
4. Utilize Existing Green Space - Bellevue River Park

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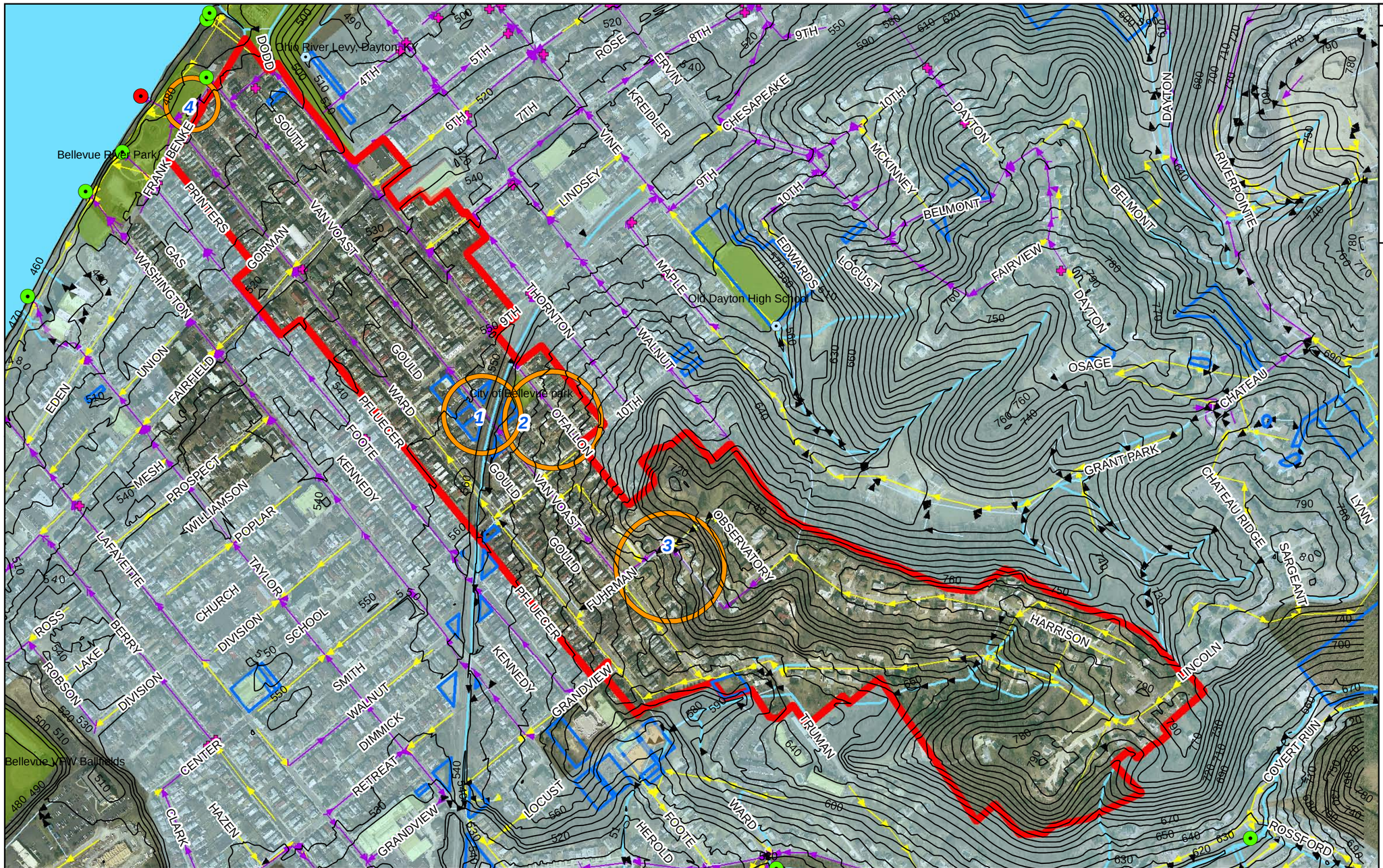

CSO ID - 600097 (117.29 acres)

CSO Statistics:

No. of overflows/yr:	36
Avg. annual overflow volume:	4,545,000 GAL
AAOV/acre of drainage area:	38,800 GAL

Imperviousness: 32% (17% tree cover)

Rooftops:	896,171 SF	54%
Roadways:	679,072 SF	41%
Parking/Sidewalks:	77,514 SF	5%

Land Use:

Residential:	3,446,291 SF	67%
Commercial:	263,895 SF	5%
Industrial:	0 SF	0%
Unknown:	1,398,792 SF	27%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **1,652,757 SF**

Roadways:

Roadways:	679,072 SF	41%
Number of Catch Basins:	41	
Catch Basins on Repair List:	4	

Single Family Residential:

Rooftops:	779,295 SF	47%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **59,600 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Bellevue
2. Small Sewer Separation
3. Small Sewer Separation
4. Utilize Exisitng Green Space - Bellevue River Park

CSO 600097
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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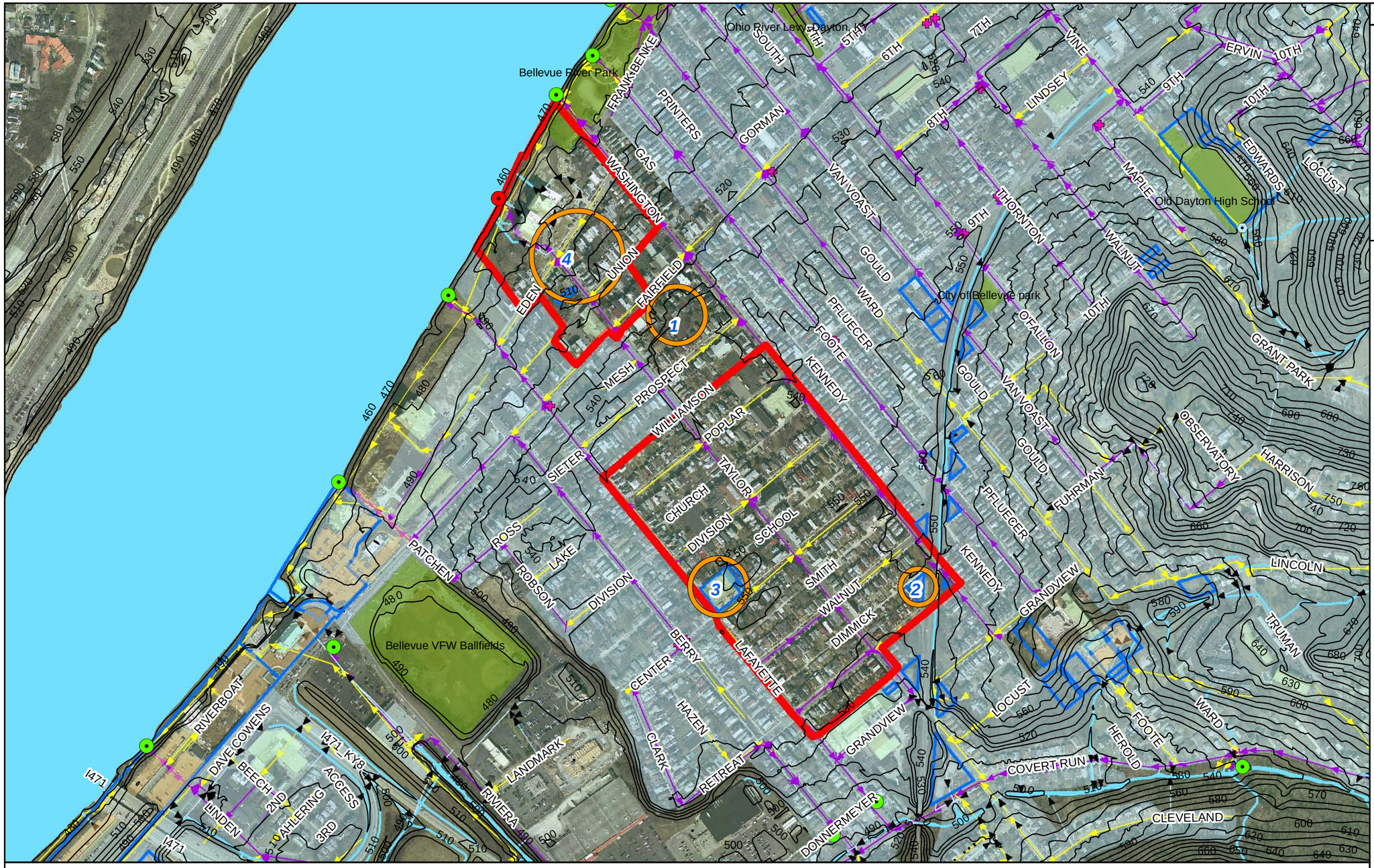
STRAND ASSOCIATES, INC® ENGINEERS



CSO ID - 610071 (52.28 acres)

CSO Statistics:

No. of overflows/yr:	68
Avg. annual overflow volume:	14,117,000 GAL
AAOV/acre of drainage area:	270,000 GAL

Imperviousness: 50% (0.9% tree cover)

Rooftops:	587,292 SF	52%
Roadways:	405,124 SF	36%
Parking/Sidewalks:	140,523 SF	12%

Land Use:

Residential:	1,160,552 SF	51%
Commercial:	434,092 SF	19%
Industrial:	0 SF	0%
Unknown:	682,456 SF	30%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **1,132,939 SF**

Roadways:

Roadways:	405,124 SF	36%
Number of Catch Basins:	23	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	391,472 SF	35%

Rooftops Over 10,000 SF: **62,100 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **38,000 SF**

Potential Opportunities:

1. Area Flowing into the CSS
2. Green Retrofit Site - City of Bellevue
3. Green Retrofit Site - City of Bellevue
4. Small Sewer Separation

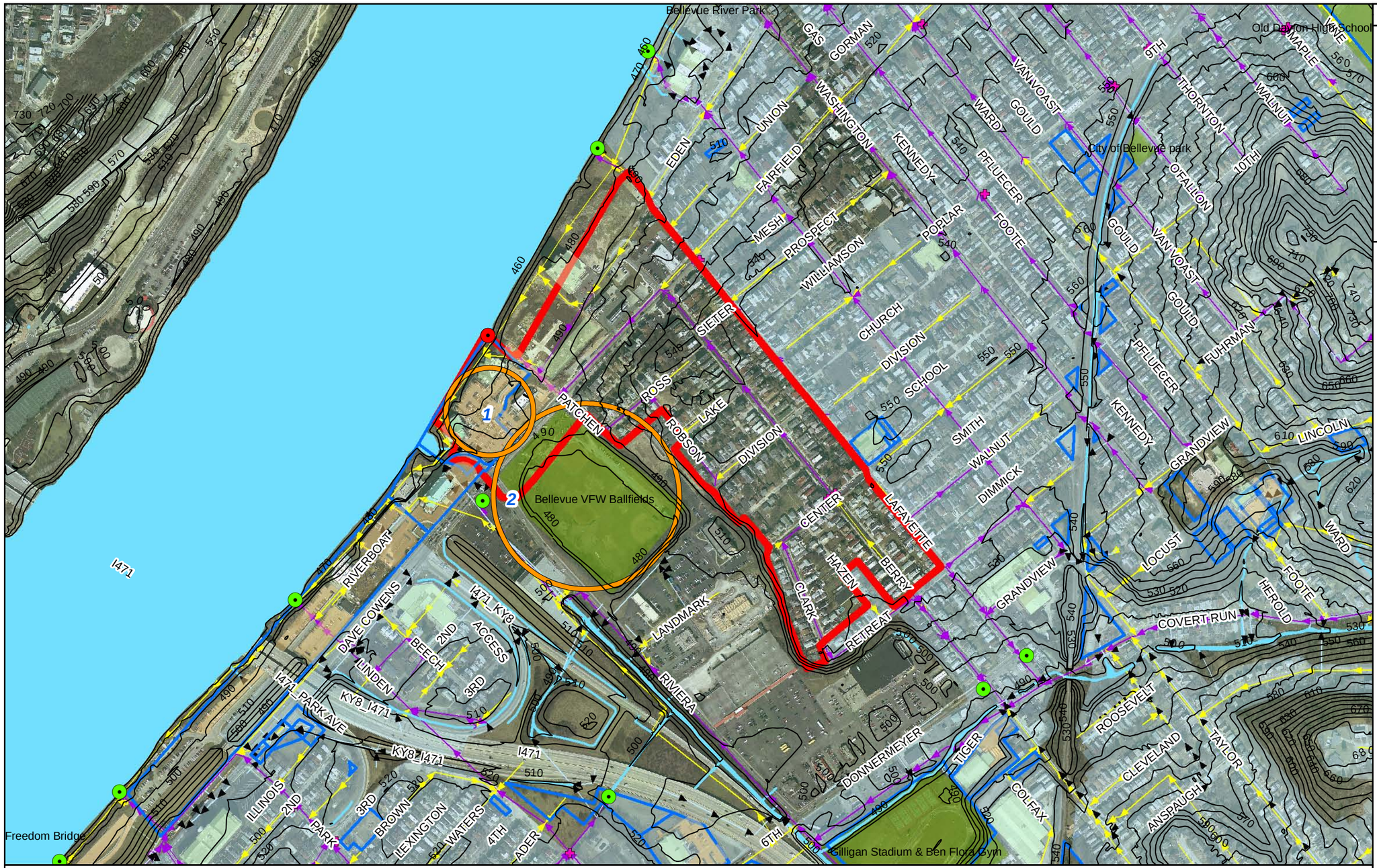
CSO 610071
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

STRAND ASSOCIATES, INC. ENGINEERS



CSO 620075
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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STRAND ASSOCIATES, INC. ENGINEERS

CSO ID - 620075 (46.67 acres)

CSO Statistics:

No. of overflows/yr: 59
Avg. annual overflow volume: 9,957,000 GAL

AAOV/acre of drainage area: 13,500 GAL

Imperviousness: 47% (0% tree cover)

Rooftops:	459,206 SF	48%
Roadways:	253,226 SF	27%
Parking/Sidewalks:	236,787 SF	25%

Land Use:

Residential:	893,645 SF	44%
Commercial:	653,459 SF	32%
Industrial:	0 SF	0%
Unknown:	485,929 SF	24%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **949,219 SF**

Roadways:

Roadways:	253,226 SF	27%
Number of Catch Basins:	27	
Catch Basins on Repair List:	2	

Single Family Residential:

Rooftops:	322,116 SF	34%

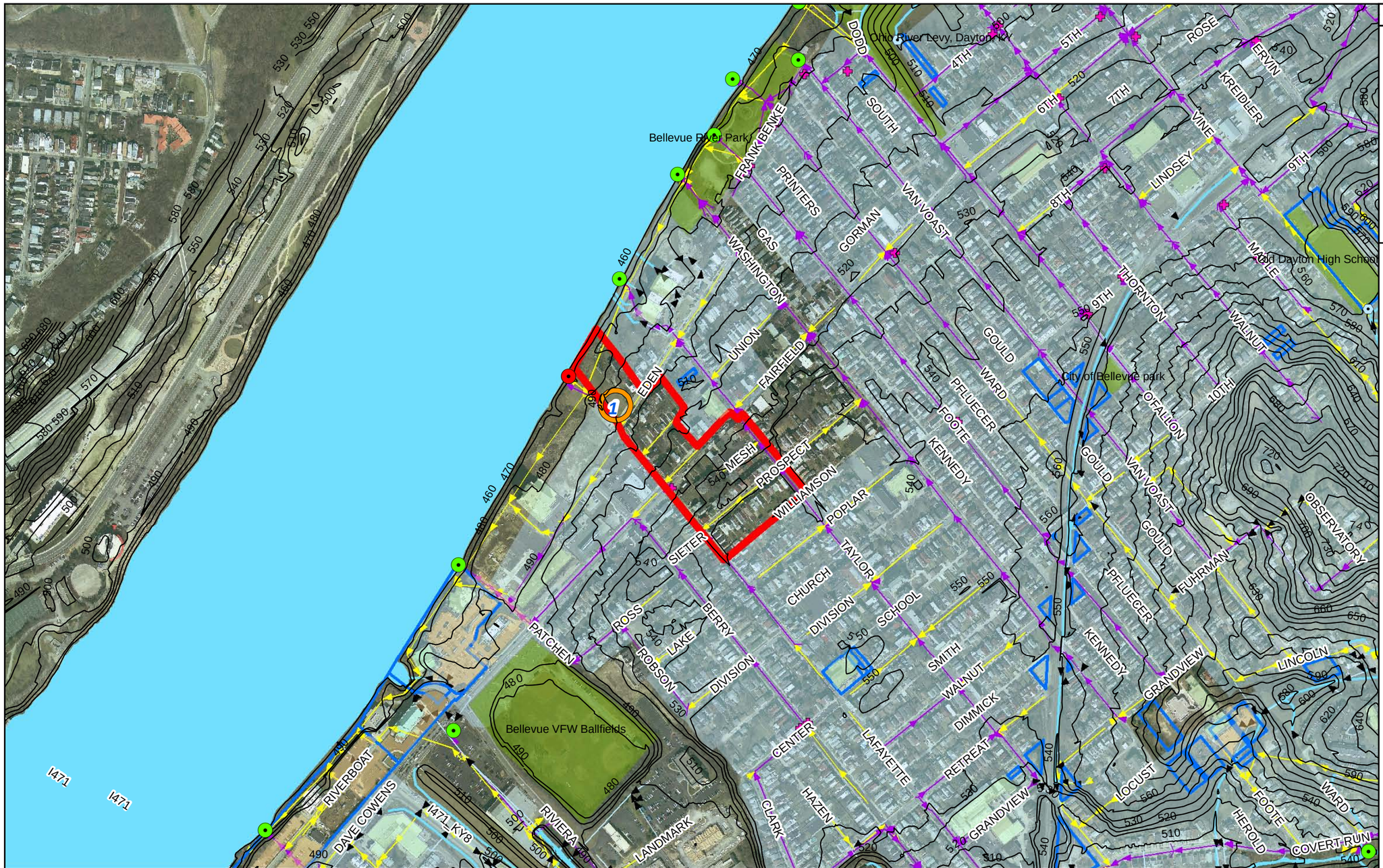
Rooftops Over 10,000 SF: **54,500 SF**

Parking Lots Over 15,000 SF: **94,500 SF**

Public Parcels: **156,700 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Bellevue
2. Utilize Existing Green Space - VFW Ballfields



CSO ID - 620077 (10.19 acres)

CSO Statistics:

No. of overflows/yr:	25
Avg. annual overflow volume:	319,000 GAL
AAOV/acre of drainage area:	977,400 GAL

Imperviousness: 46% (0% tree cover)

Rooftops:	102,613 SF	50%
Roadways:	79,538 SF	39%
Parking/Sidewalks:	22,091 SF	11%

Land Use:

Residential:	261,449 SF	59%
Commercial:	59,498 SF	13%
Industrial:	0 SF	0%
Unknown:	122,799 SF	28%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **204,243 SF**

Roadways:

Roadways:	79,538 SF	39%
Number of Catch Basins:	7	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	77,352 SF	38%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **0 SF**

Potential Opportunities:

1. Green Retrofit Site - Grunenwald Trust

CSO 620077
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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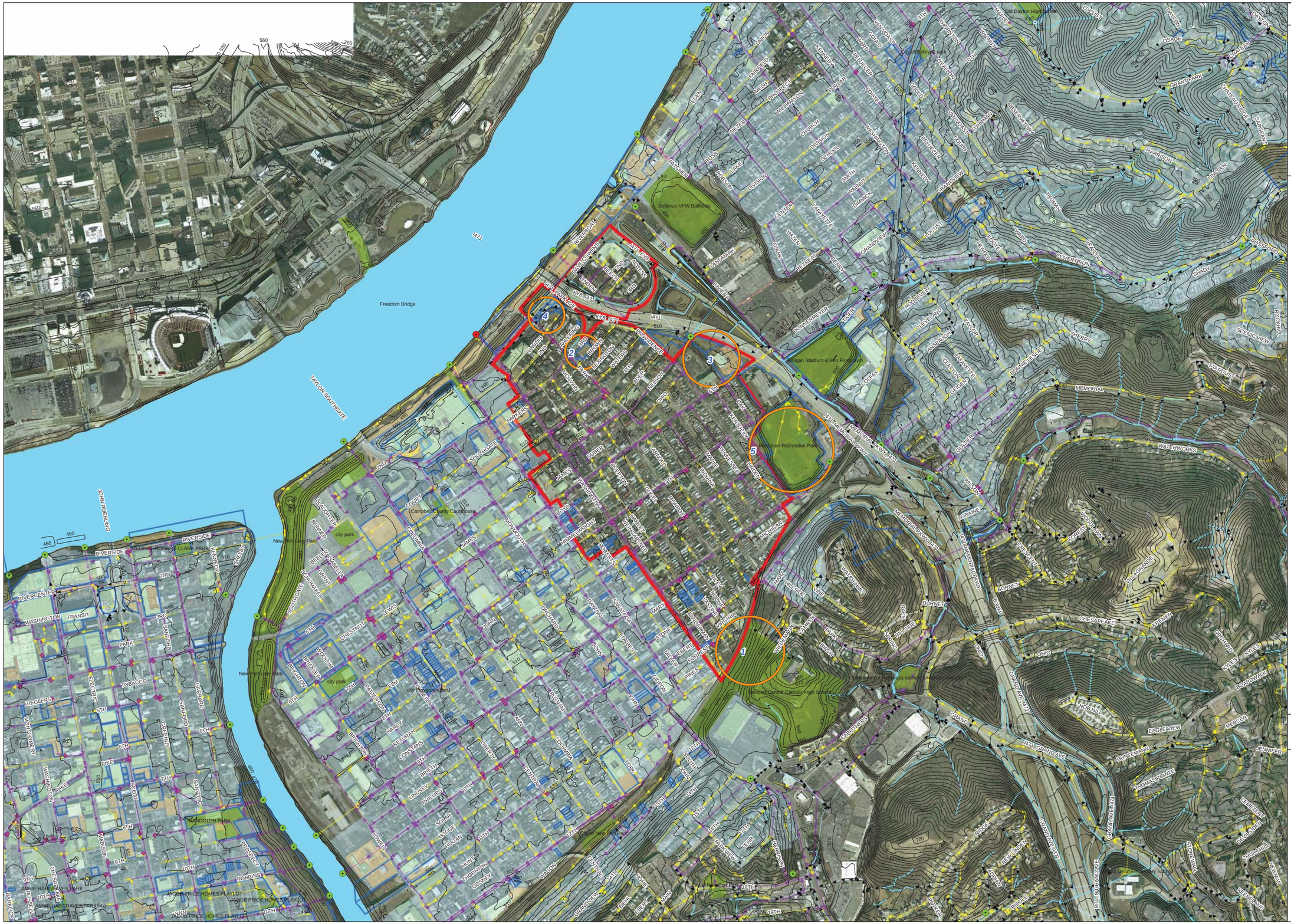
STRAND ASSOCIATES, INC® ENGINEERS



CSO ID - 640090 (192.80 acres)

CSO Statistics:

No. of overflows/yr:	25
Avg annual overflow volume:	319,000 GAL
AAOV/acre of drainage area:	1,700 GAL

Imperviousness: 53% (0.10% tree cover)

Rooftops:	2,048,330 SF	46%
Roadways:	1,852,054 SF	42%
Parking/Sidewalks:	510,865 SF	12%

Landuse:

Residential:	3,528,849 SF	42%
Commercial:	1,582,946 SF	19%
Industrial:	0 SF	0%
Unknown:	3,286,443 SF	39%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 4,411,249 SF

Roadways:

Roadways:	1,852,054 SF	42%
Number of Catch Basins::	190	
Catch Basins on Repair List:	33	

Single Family Residential:

Rooftops:	1,506,502 SF	34%

Rooftops Over 10,000 SF: 206,300 SF

Parking Lots Over 15,000 SF: 60,600 SF

Public Parcels: 331,400 SF

Potential Opportunities:

1. Area Flowing into the CSS
2. Green Retrofit Site - City of Newport
3. Green Retrofit Site - City of Newport/Campbell County
4. Green Retrofit Site - KTC
5. Utilize Existing Green Space - Mussman Recreation Park

GREEN INFRASTRUCTURE INIATIVE SANITATION DISTRICT NO.1 OF NORTHERN KY FORT WRIGHT, KY

- CSO 640090
- Surrounding CSOs
- Point of Entry
- Catch Basin Repair List
- Streams
- Combined Sewer
- Sanitary Sewer
- Storm Sewer
- CSO Drainage Area
- Surrounding CSO Areas
- Public Ownership
- Roof Over 10,000 SF
- Parking Lot Over 15,000 SF
- OKI Green Space
- Best Opportunities

0 250 500 1,000 1,500 2,000 Feet

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7
Bellevue VFW Ballfields
Paul Brown Stadium
Freedom Bridge
Ockerman Recreation Park
Campbell County Courthouse
Bishop Central Catholic High School
North Park
Highland Hills Road
Immaculate Elementary School
Highlands Middle School
Highlands High School
Bellevue Baptist Church
Cemetery
I471
KY8
MEMORIAL PKWY
GRANDVIEW
MONMOUTH
MONTROSE
MT PLEASANT
WINSTON HILL
COVERT RUN
ORCHARD HILL
CARRINGTON
DONNELLY
TOWER HILL
SOUTHGATE
FAIRFIELD
WILSON
RIDGEWAY
WATERWORKS
TAYLOR MILL
CHESAPEAKE
EAGLEVIEW
THOMAS POINTE
NOB HILL
HUNTSMAN
MAPLE GRANDVIEW
SUMMER HILL
NEWLINDEN
LAYCOCK
MEMORIAL
CHESTNUT
HOLLY
HIGHLAND
MILLER
LUMLEY
FOREST
ELMWOOD
BELLEFAIRE
PITTHOMAS
HARRIS
BIKE
WALDEN
ESMAR
CLEVELAND
ASHBURN
GRAYTON
GLOVER
SHERRY
DONNERSBERGER
TAYLOR
ROOSEVELT
HARRISON
LINCOLN
GRANT PARK
CHATEAU RIDGE
SARGENT
LYMAN
OBSERVATORY
MAPLE
GREGORY
STACY
COVERT
WHITCOMB
PLEASANT
BRITTANY
KIMBERLY
BUTLER
ROSEFORD
SCENIC VIEW
MAJESTIC
PORTER
STARDUST
HOMESTEAD
MARIAN
CAROL
CAROLYN
GLOVERBRIDGE
BARKSDALE
STARKMORE
ROSEMONT
HAWKWOOD
WILDWOOD
SPRUCE
RIVERSIDE
DRIVE
HARRIMER
STOVE
BURNET
ORCHARD
KYLES
BOARDWALK
PARK
MERCER
JENNIFER
INDIANA
OHIO
MAINE
GLEN ROYAL
MAYO
WATER
ROBROY
STERLING
MONTROSE
ELMWOOD
FOREST
BELLEFAIRE
LUMLEY
MILLER
HIGHLAND
MAYFIELD
LILAC
DIANA
HIGHVIEW
AZALEA
NEWMAN
KENSELAER
CHURCHILL
STONEVIEW
CEMETERY
BENSLEY
DAISY
GRANDVIEW
HAMPTON
PIERCE
ASPEN
DAVID
RIDGE
GRANDVIEW
MAPLEWOOD
ELMWOOD
PARKVIEW
ROSEMONT
STARKMORE
TOWER HILL
SOUTHGATE
HOLLY
PITTHOMAS
BELLEFAIRE
BIKE
WALDEN
ESMAR
CARRINGTON
DONNELLY
MT PLEASANT
ROSSFORD
MONTROSE
ELMWOOD
FOREST

CSO 660085	Combined Sewer	Public Ownership
Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF
Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF
Catch Basin Repair List	CSO Drainage Area	OKI Green Space
Streams	Surrounding CSO Areas	Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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CSO ID - 660085 (11.35 acres)

CSO Statistics:

No. of overflows/yr: 0
Avg. annual overflow volume: 0 GAL

AAOV/acre of drainage area: 0 GAL

Imperviousness: 33% (23% tree cover)

Rooftops:	79,156 SF	48%
Roadways:	84,323 SF	52%
Parking/Sidewalks:	0 SF	0%

Land Use:

Residential:	337,037 SF	68%
Commercial:	27,194 SF	6%
Industrial:	0 SF	0%
Unknown:	130,089 SF	26%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **163,479 SF**

Roadways:

Roadways:	84,323 SF	52%
Number of Catch Basins:	12	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	78,724 SF	48%

Rooftops Over 10,000 SF: **0 SF**

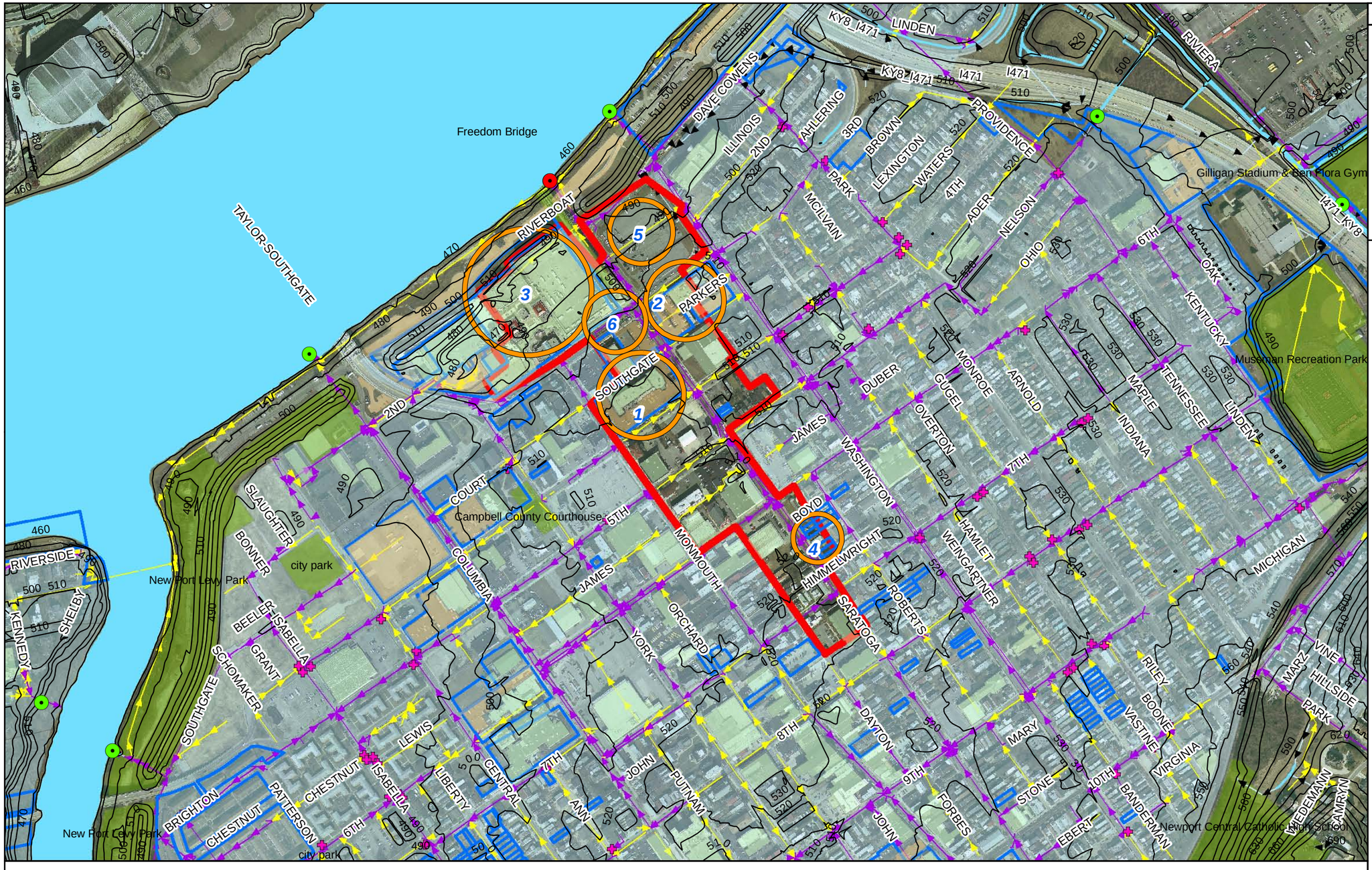
Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **17,800 SF**

Potential Opportunities:

1. Area Flowing into the CSS

STRAND ASSOCIATES, INC® ENGINEERS



CSO 770096
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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CSO ID - 770096 (33.87 acres)

CSO Statistics:

No. of overflows/yr: 65
Avg. annual overflow volume: 6,558,000 GAL

AAOV/acre of drainage area: 193,600 GAL

Imperviousness: 77% (0% tree cover)

Rooftops:	539,367 SF	47%
Roadways:	255,987 SF	23%
Parking/Sidewalks:	341,194 SF	30%

Land Use:

Residential:	109,744 SF	7%
Commercial:	932,325 SF	63%
Industrial:	0 SF	0%
Unknown:	433,308 SF	29%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **1,136,548 SF**

Roadways:

Roadways:	255,987 SF	23%
Number of Catch Basins:	39	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	34,119 SF	3%

Rooftops Over 10,000 SF: **390,600 SF**

Parking Lots Over 15,000 SF: **86,300 SF**

Public Parcels: **466,800 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Newport
2. Green Retrofit Site - City of Newport
3. Green Retrofit Site - City of Newport
4. Green Retrofit Site - Newport Housing Authority
5. Green Retrofit Site - Newport on the Levee
6. Green Street - 3rd Street

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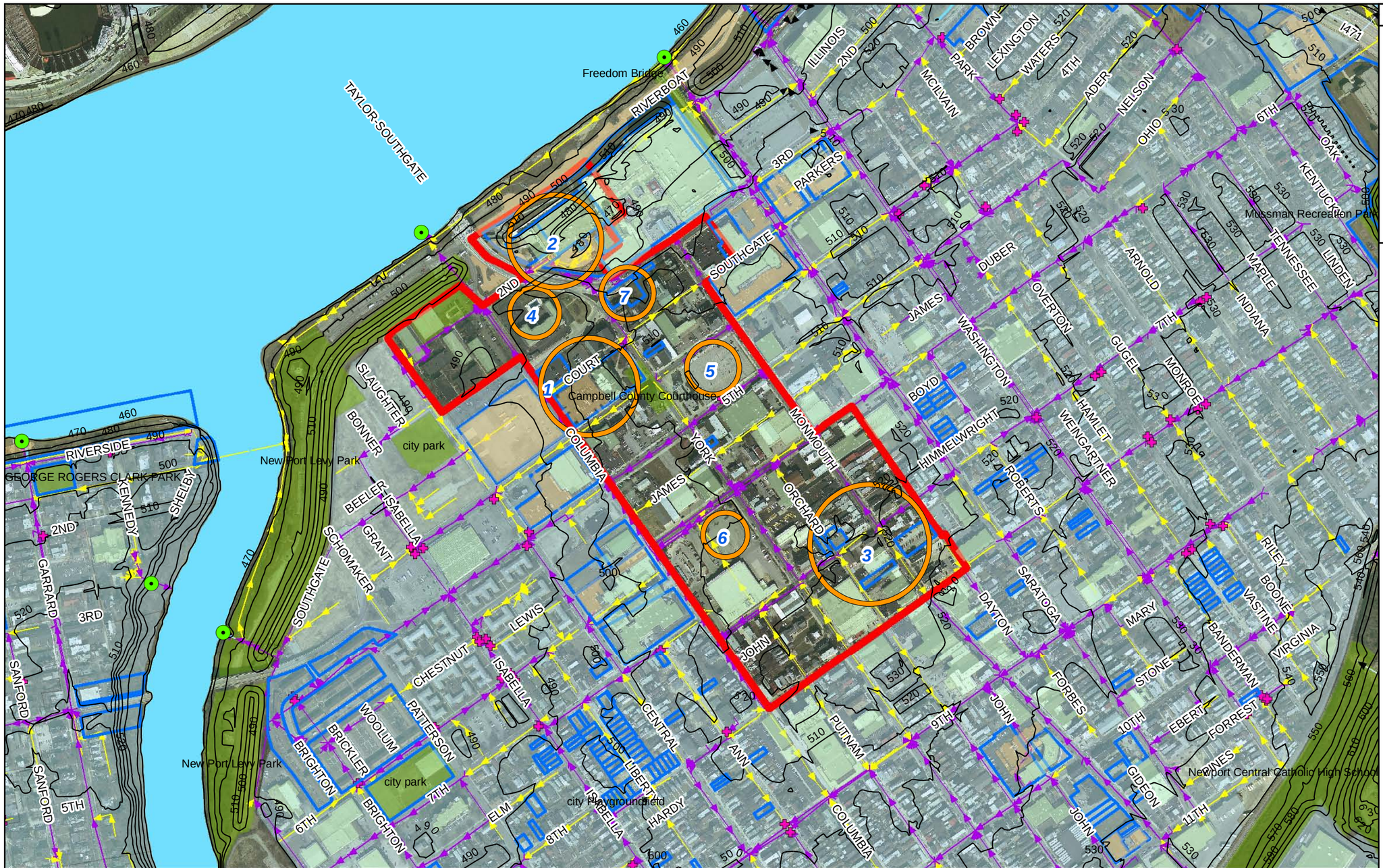

CSO ID - 790084 (66.39 acres)

CSO Statistics:

No. of overflows/yr:	74
Avg. annual overflow volume:	14,325,000 GAL
AAOV/acre of drainage area:	215,800 GAL

Imperviousness: 73% (0% tree cover)

Rooftops:	795,341 SF	38%
Roadways:	522,825 SF	25%
Parking/Sidewalks:	796,169 SF	38%

Land Use:

Residential:	118,298 SF	4%
Commercial:	1,922,050 SF	66%
Industrial:	0 SF	0%
Unknown:	851,731 SF	29%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **2,114,335 SF**

Roadways:

Roadways:	522,825 SF	25%
Number of Catch Basins:	70	
Catch Basins on Repair List:	2	

Single Family Residential:

Rooftops:	33,469 SF	2%

Rooftops Over 10,000 SF: **449,700 SF**

Parking Lots Over 15,000 SF: **67,400 SF**

Public Parcels: **363,700 SF**

Potential Opportunities:

1. Green Retrofit Site - Campbell County
2. Green Retrofit Site - CIty of Newport
3. Green Retrofit Site - City of Newport
4. Green Retrofit Site - CPPY
5. Green Retrofit Site - DW Productions
6. Green Retrofit Site - Wiedemann Square LTD
7. Utilize Existing Green Space - KY Transportation Cabinet

CSO 790084
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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STRAND ASSOCIATES, INC® ENGINEERS

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Campbell County Courthouse
Campbell County Detention Center
Newport Central Catholic High School
Newport Housing Authority
Newport Housing Authority
Newport Housing Authority

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3-B.1 - Initial Combined Sewer Area

Green Infrastructure Opportunities

North Basin CSO Sewersheds
1470089
1480185
1480187-1
1480187-2
1490132
1490172
1500131
1710114
1710116
1710119
1710121
1710124
1720109
1730259
1730263
1840130
1850158
1870193
1870194
1880090
1880091

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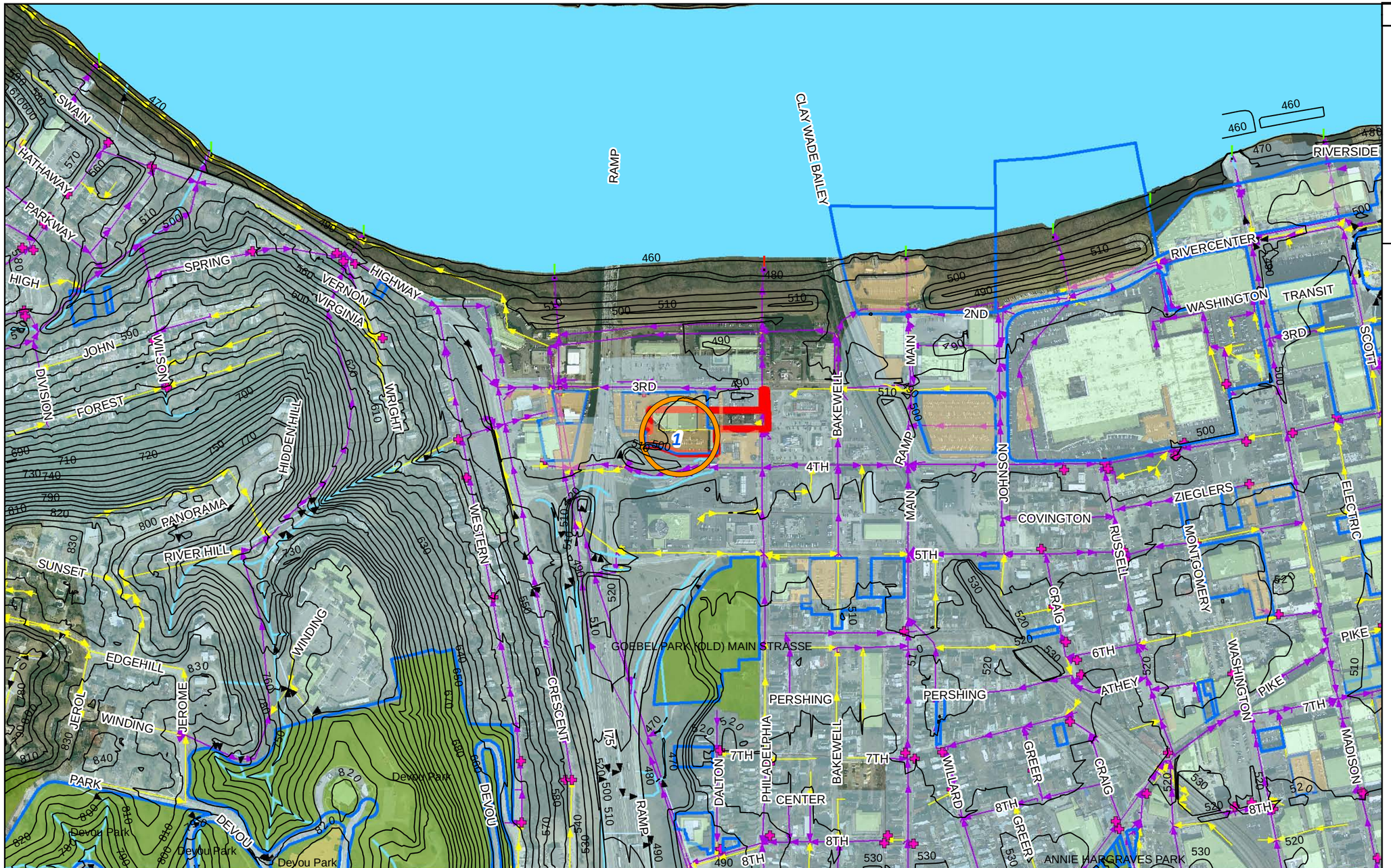

! CSO 1470089
! Surrounding CSOs
2 Point of Entry
Б Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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CSO ID - 1470089 (2.12 acres)

CSO Statistics:

No. of overflows/yr: 6
Avg. annual overflow volume: 435,000 GAL

AAOV/acre of drainage area: 205,000 GAL

Imperviousness: 89% (0% tree cover)

Rooftops:	31,193 SF	38%
Roadways:	11,741 SF	14%
Parking/Sidewalks:	39,208 SF	48%

Land Use:

Residential:	0 SF	0%
Commercial:	84,629 SF	92%
Industrial:	0 SF	0%
Unknown:	7,788 SF	8%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Zero

Total Impervious Area: 82,142 SF

Roadways:

Roadways:	11,741 SF	14%
Number of Catch Basins:	101	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	0 SF	0%

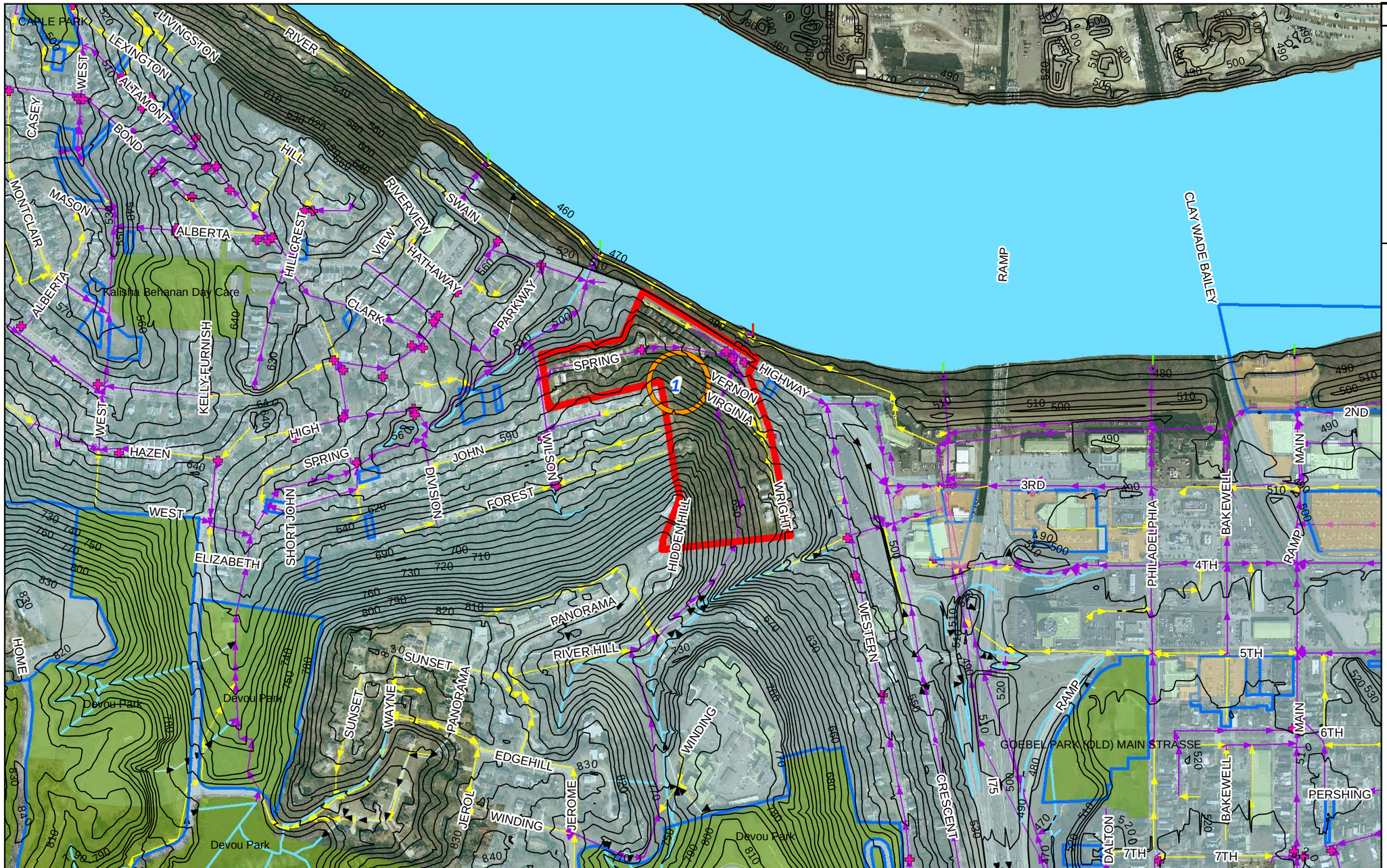
Rooftops Over 10,000 SF: 28,900 SF

Parking Lots Over 15,000 SF: 33,500 SF

Public Parcels: 63,000 SF

Potential Opportunities:

1. Green Retrofit Site - City of Covington



CSO ID - 1480185 (15.83 acres)

CSO Statistics:

No. of overflows/yr:	29
Avg. annual overflow volume:	1,853,000 GAL
AAOV/acre of drainage area:	117,000 GAL

Imperviousness: 22% (40% tree cover)

Rooftops:	75,084 SF	49%
Roadways:	77,123 SF	50%
Parking/Sidewalks:	2,433 SF	2%

Land Use:

Residential:	539,185 SF	78%
Commercial:	9,080 SF	1%
Industrial:	0 SF	0%
Unknown:	141,422 SF	21%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: High

Total Impervious Area: **154,641 SF**

Roadways:

Roadways:	77,123 SF	50%
Number of Catch Basins:	0	
Catch Basins on Repair List:	4	

Single Family Residential:

Rooftops:	48,320 SF	31%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **0 SF**

Potential Opportunities:

1. Utilize Existing Green Space - Tuscany LLC

! CSO 1480185
! Surrounding CSOs
2 Point of Entry
~~5~~ Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

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STRAND ASSOCIATES, INC.® ENGINEERS

CSO ID - 1480187-1 (1,768.92 acres)

CSO Statistics:

No. of overflows/yr:	72
Avg annual overflow volume:	684,779,000 GAL
AAOV/acre of drainage area:	387,100 GAL

Imperviousness: 27% (23% tree cover)

Rooftops:	8,313,375 SF	40%
Roadways:	8,920,039 SF	43%
Parking/Sidewalks:	3,677,448 SF	18%

Landuse:

Residential:	32,988,869 SF	43%
Commercial:	24,741,265 SF	32%
Industrial:	619,136 SF	1%
Unknown:	18,704,891 SF	24%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Medium

Total Impervious Area: 20,910,862 SF

Roadways:

Roadways:	8,920,039 SF	43%
Number of Catch Basins::	735	
Catch Basins on Repair List:	71	

Single Family Residential:

Rooftops:	4,691,097 SF	22%

Rooftops Over 10,000 SF:

Parking Lots Over 15,000 SF:

Public Parcels:

Potential Opportunities:

1. Area Flowing into the CSS
2. Area Flowing into the CSS
3. Green Retrofit Site - Bluffs Condominiums at Devou
4. Green Retrofit Site - City of Covington
5. Green Retrofit Site - City of Covington
6. Green Retrofit Site - City of Covington
7. Green Retrofit Site - City of Covington
8. Green Retrofit Site - City of Covington
9. Green Retrofit Site - City of Covington
10. Green Retrofit Site - City of Ft. Wright
11. Green Retrofit Site - City of Ft. Wright
12. Green Retrofit Site - City of Ft. Wright
13. Green Retrofit Site - Comm KY No KY State Voc School
14. Green Retrofit Site - Commonwealth of KY
15. Green Retrofit Site - Commonwealth of KY
16. Green Retrofit Site - Covington Board of Education
17. Green Retrofit Site - Covington Community Center
18. Green Street - Amsterdam Street
19. Small Sewer Separation
20. Surface Entry Point
21. Surface Entry Point
22. Surface Entry Point
23. Surface Entry Point
24. Surface Entry Point
25. Surface Entry Point
26. Surface Entry Point
27. Surface Entry Point
28. Utilize Existing Green Space - City of Covington
29. Utilize Existing Green Space - Devou Park
30. Utilize Existing Green Space - City of Park Hills
31. Utilize Existing Green Space - Goebels Park
32. Utilize Existing Green Space - Diocese of Covington & Sisters of Notre Dame of Covington

GREEN INFRASTRUCTURE INIATIVE
SANITATION DISTRICT NO.1 OF NORTHERN KY
FORT WRIGHT, KY

CSO ID - 1480187-2 (1,768.92 acres)

CSO Statistics:

No. of overflows/yr:	72
Avg annual overflow volume:	684,779,000 GAL
AAOV/acre of drainage area:	387,100 GAL

Imperviousness: 27% (23% tree cover)

Rooftops:	8,313,375 SF	40%
Roadways:	8,920,039 SF	43%
Parking/Sidewalks:	3,677,448 SF	18%

Landuse:

Residential:	32,988,869 SF	43%
Commercial:	24,741,265 SF	32%
Industrial:	619,136 SF	1%
Unknown:	18,704,891 SF	24%

Green Concepts

Suitability for Shallow Infiltration: Poor
Downspout Disconnect Effectiveness: Medium

Total Impervious Area: 20,910,862 SF

Roadways:

Roadways:	8,920,039 SF	43%
Number of Catch Basins::	735	
Catch Basins on Repair List:	71	

Single Family Residential:

Rooftops:	4,691,097 SF	22%

Rooftops Over 10,000 SF: 1,226,700 SF

Parking Lots Over 15,000 SF: 367,700 SF

Public Parcels: 10,495,800 SF

Potential Opportunities:

1. Area Flowing into the CSS
2. Area Flowing into the CSS
3. Green Retrofit Site - Bluffs Condominiums at Devou
4. Green Retrofit Site - City of Covington
5. Green Retrofit Site - City of Covington
6. Green Retrofit Site - City of Covington
7. Green Retrofit Site - City of Covington
8. Green Retrofit Site - City of Covington
9. Green Retrofit Site - City of Covington
10. Green Retrofit Site - City of Covington
11. Green Retrofit Site - City of Ft. Wright
12. Green Retrofit Site - City of Ft. Wright
13. Green Retrofit Site - Comm KY No KY State Voc School
14. Green Retrofit Site - Commonwealth of KY
15. Green Retrofit Site - Commonwealth of KY
16. Green Retrofit Site - Covington Board of Education
17. Green Retrofit Site - Covington Community Center
18. Green Street - Amsterdam Street
19. Small Sewer Separation
20. Surface Entry Point
21. Surface Entry Point
22. Surface Entry Point
23. Surface Entry Point
24. Surface Entry Point
25. Surface Entry Point
26. Surface Entry Point
27. Surface Entry Point
28. Utilize Existing Green Space - City of Covington
29. Utilize Existing Green Space - Devou Park
30. Utilize Existing Green Space - City of Park Hills
31. Utilize Existing Green Space - Goebels Park
32. Utilize Existing Green Space - Diocese of Covington & Sisters of Notre Dame of Covington

GREEN INFRASTRUCTURE INIATIVE SANITATION DISTRICT NO.1 OF NORTHERN KY FORT WRIGHT, KY

CSO ID - 1490132 (119.30 acres)

CSO Statistics:

No. of overflows/yr:	37
Avg. annual overflow volume:	17,920,000 GAL
AAOV/acre of drainage area:	150,200 GAL

Imperviousness: 20% (33% tree cover)

Rooftops:	479,173 SF	45%
Roadways:	462,214 SF	44%
Parking/Sidewalks:	112,618 SF	11%

Land Use:

Residential:	2,661,958 SF	51%
Commercial:	1,714,725 SF	33%
Industrial:	0 SF	0%
Unknown:	820,007 SF	16%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: 1,054,005 SF

Roadways:

Roadways:	462,214 SF	44%
Number of Catch Basins:	60	
Catch Basins on Repair List:	20	

Single Family Residential:

Rooftops:	373,491 SF	35%

Rooftops Over 10,000 SF: 11,900 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 1,318,700 SF

Potential Opportunities:

1. Green Street - Highway Avenue
2. Point of Entry
3. Point of Entry
4. Utilize Existing Green Space - Devou Park
5. Utilize Exisitng Natural Systems

CSO 1490132
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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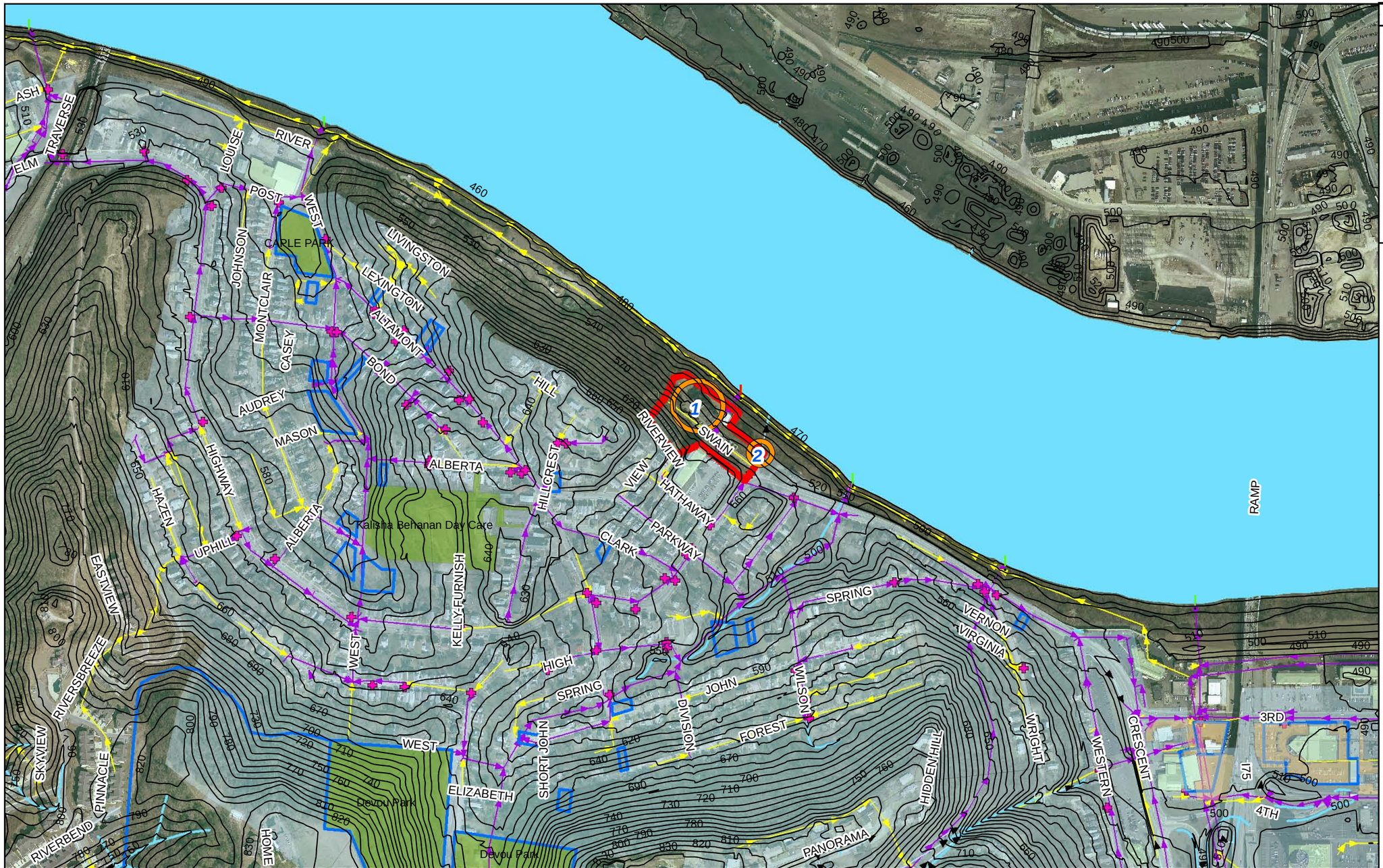


! CSO 1490172	Combined Sewer	Public Ownership	
! Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF	
2 Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF	
Catch Basin Repair List	CSO Drainage Area	OKI Green Space	
Streams	Surrounding CSO Areas	Best Opportunities	

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1490172 (3.14 acres)

CSO Statistics:

No. of overflows/yr: 0
Avg. annual overflow volume: 0 GAL

AAOV/acre of drainage area: 0 GAL

Imperviousness: 38% (3% tree cover)

Rooftops:	21,497 SF	41%
Roadways:	11,184 SF	22%
Parking/Sidewalks:	19,295 SF	37%

Land Use:

Residential:	45,760 SF	33%
Commercial:	66,042 SF	48%
Industrial:	0 SF	0%
Unknown:	25,106 SF	18%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Zero

Total Impervious Area: 51,976 SF

Roadways:

Roadways:	11,184 SF	22%
Number of Catch Basins:	2	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops: 0 SF 0%

Rooftops Over 10,000 SF: 0 SF

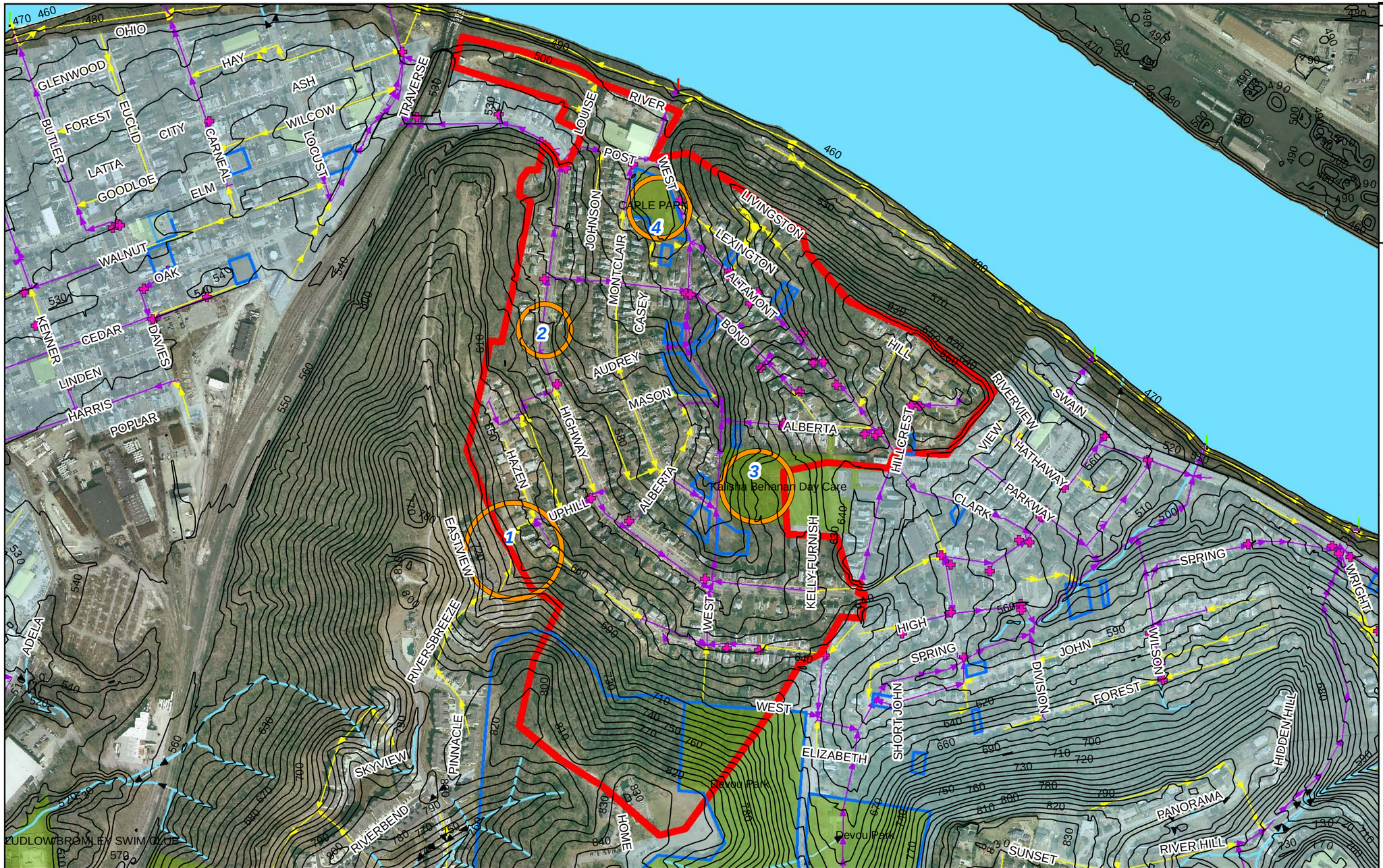
Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 0 SF

Potential Opportunities:

1. Green Retrofit Site - Lowes Norman M Trustee
2. Small Sewer Separation

STRAND ASSOCIATES, INC® ENGINEERS



CSO ID - 1500131 (117.46 acres)

CSO Statistics:

No. of overflows/yr:	53
Avg. annual overflow volume:	9,302,000 GAL
AAOV/acre of drainage area:	79,200 GAL

Imperviousness: 24% (23% tree cover)

Rooftops:	636,211 SF	52%
Roadways:	499,437 SF	41%
Parking/Sidewalks:	82,461 SF	7%

Land Use:

Residential:	3,098,112 SF	61%
Commercial:	888,145 SF	17%
Industrial:	100,324 SF	2%
Unknown:	1,029,996 SF	20%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: 1,218,109 SF

Roadways:

Roadways:	499,437 SF	41%
Number of Catch Basins:	92	
Catch Basins on Repair List:	33	

Single Family Residential:

Rooftops:	529,902 SF	44%

Rooftops Over 10,000 SF: 31,800 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 725,300 SF

Potential Opportunities:

1. Area Flowing into the CSS
2. Green Street - Highway Avenue
3. Utilize Existing Green Space - Kalisha Behanan Day Care
4. Utilize Existing Green Space - Caple Park

CSO 1500131
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

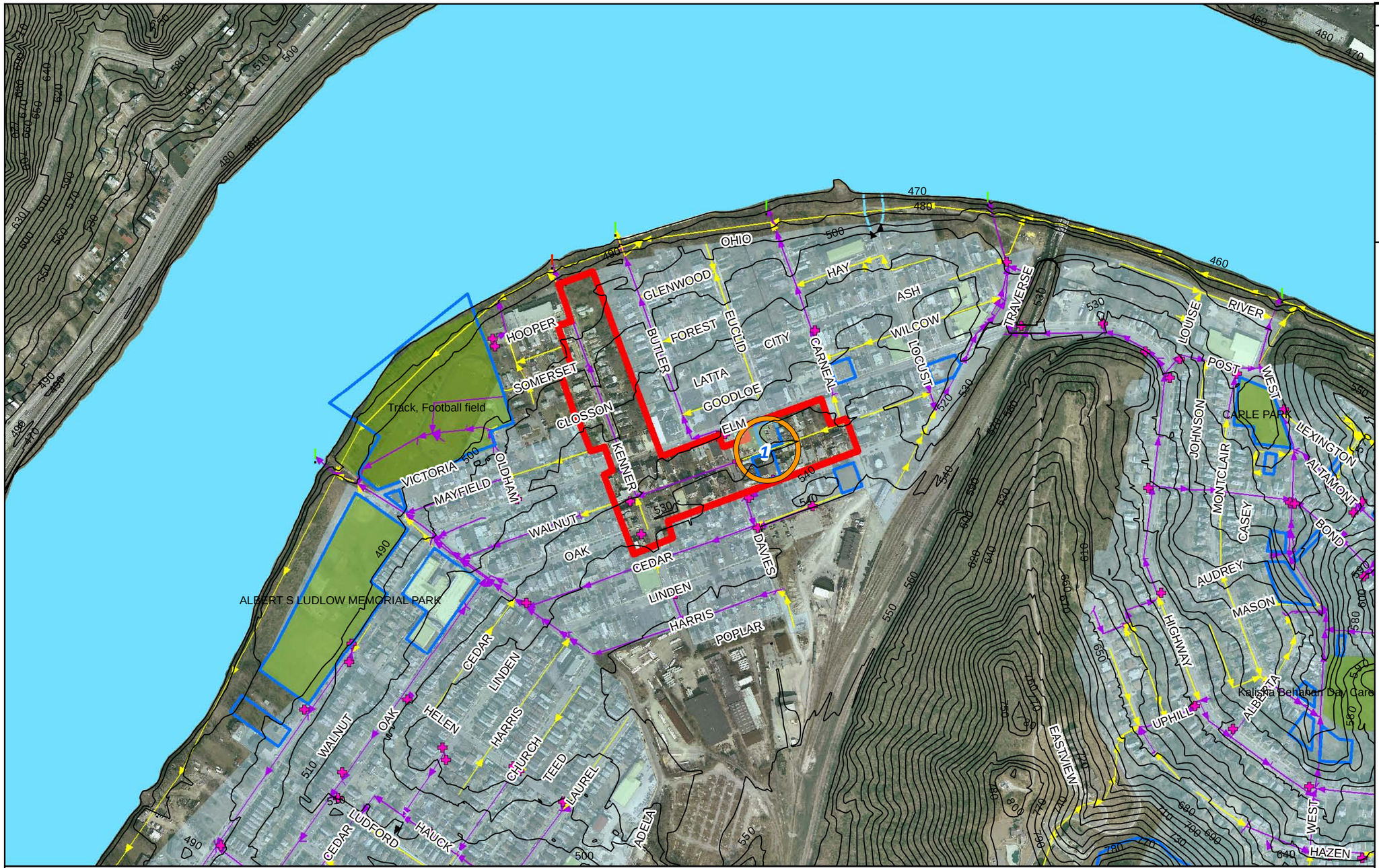
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

STRAND ASSOCIATES, INC® ENGINEERS



CSO 1710114	Combined Sewer	Public Ownership	
Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF	
Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF	
Catch Basin Repair List	CSO Drainage Area	OKI Green Space	
Streams	Surrounding CSO Areas	Best Opportunities	

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1710114 (14.48 acres)

CSO Statistics:

No. of overflows/yr: 12
Avg. annual overflow volume: 765,000 GAL

AAOV/acre of drainage area: 52,800 GAL

Imperviousness: 49% (0% tree cover)

Rooftops:	175,751 SF	57%
Roadways:	98,156 SF	32%
Parking/Sidewalks:	33,730 SF	11%

Land Use:

Residential:	293,198 SF	46%
Commercial:	174,012 SF	28%
Industrial:	803 SF	0%
Unknown:	162,589 SF	26%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 307,637 SF

Roadways:

Roadways:	98,156 SF	32%
Number of Catch Basins:	11	
Catch Basins on Repair List:	6	

Single Family Residential:

Rooftops:	77,272 SF	25%

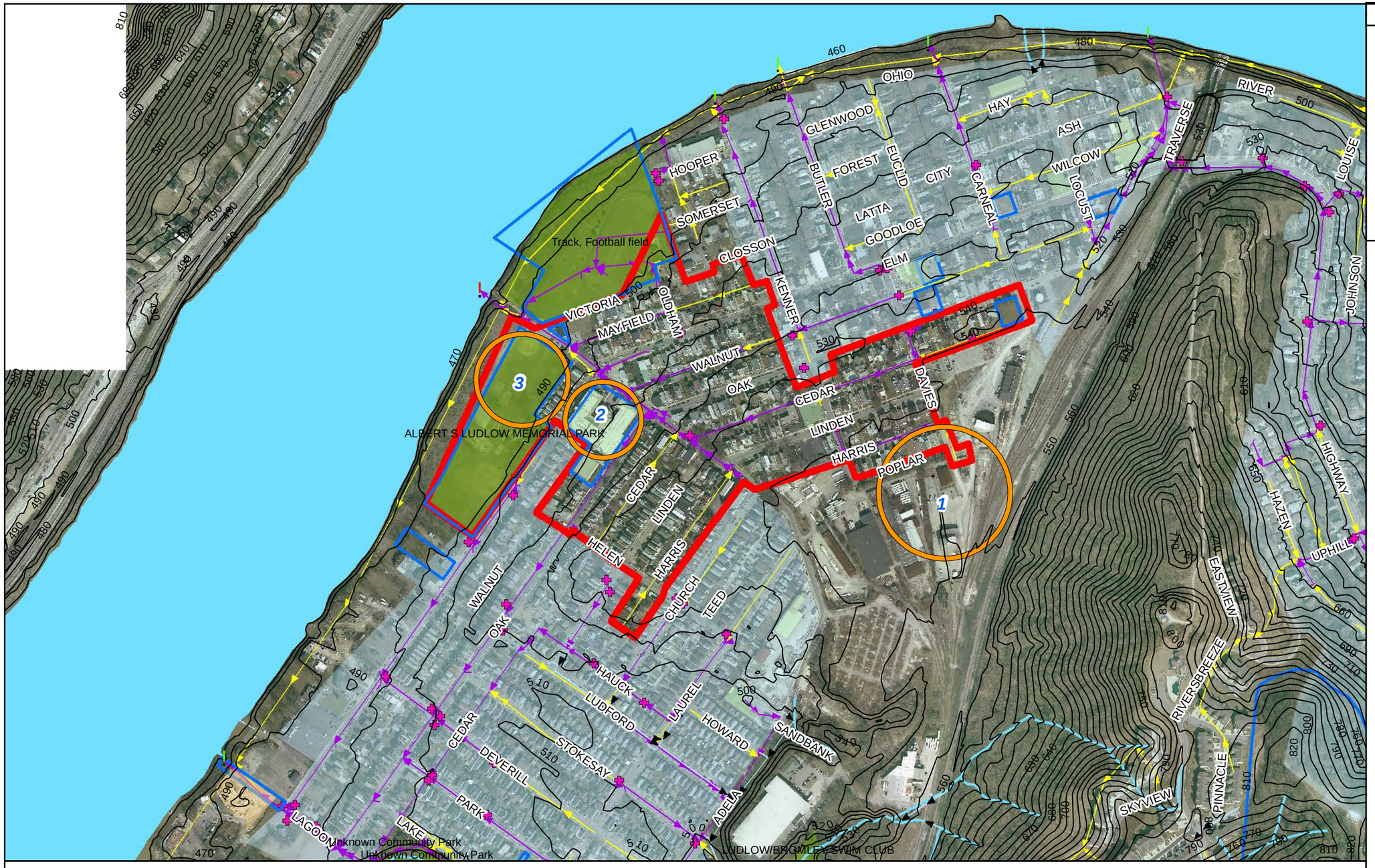
Rooftops Over 10,000 SF: 12,200 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 25,700 SF

Potential Opportunities:

1. Green Retrofit Site - City of Ludlow



CSO ID - 1710116 (53.65 acres)

CSO Statistics:

No. of overflows/yr:	56
Avg. annual overflow volume:	29,298,000 GAL
AAOV/acre of drainage area:	546,100 GAL

Imperviousness: 45% (0% tree cover)

Rooftops:	587,709 SF	55%
Roadways:	392,889 SF	37%
Parking/Sidewalks:	80,035 SF	8%

Land Use:

Residential:	1,050,538 SF	45%
Commercial:	672,925 SF	29%
Industrial:	10,858 SF	0%
Unknown:	602,636 SF	26%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **1,060,632 SF**

Roadways:

Roadways:	392,889 SF	37%
Number of Catch Basins:	36	
Catch Basins on Repair List:	6	

Single Family Residential:

Rooftops:	371,628 SF	35%

Rooftops Over 10,000 SF: **74,200 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **455,600 SF**

Potential Opportunities:

1. Area Flowing into the CSS
2. Green Retrofit Site - City of Ludlow
3. Utilize Existing Green Space - Ludlow Memorial Park

CSO 1710116
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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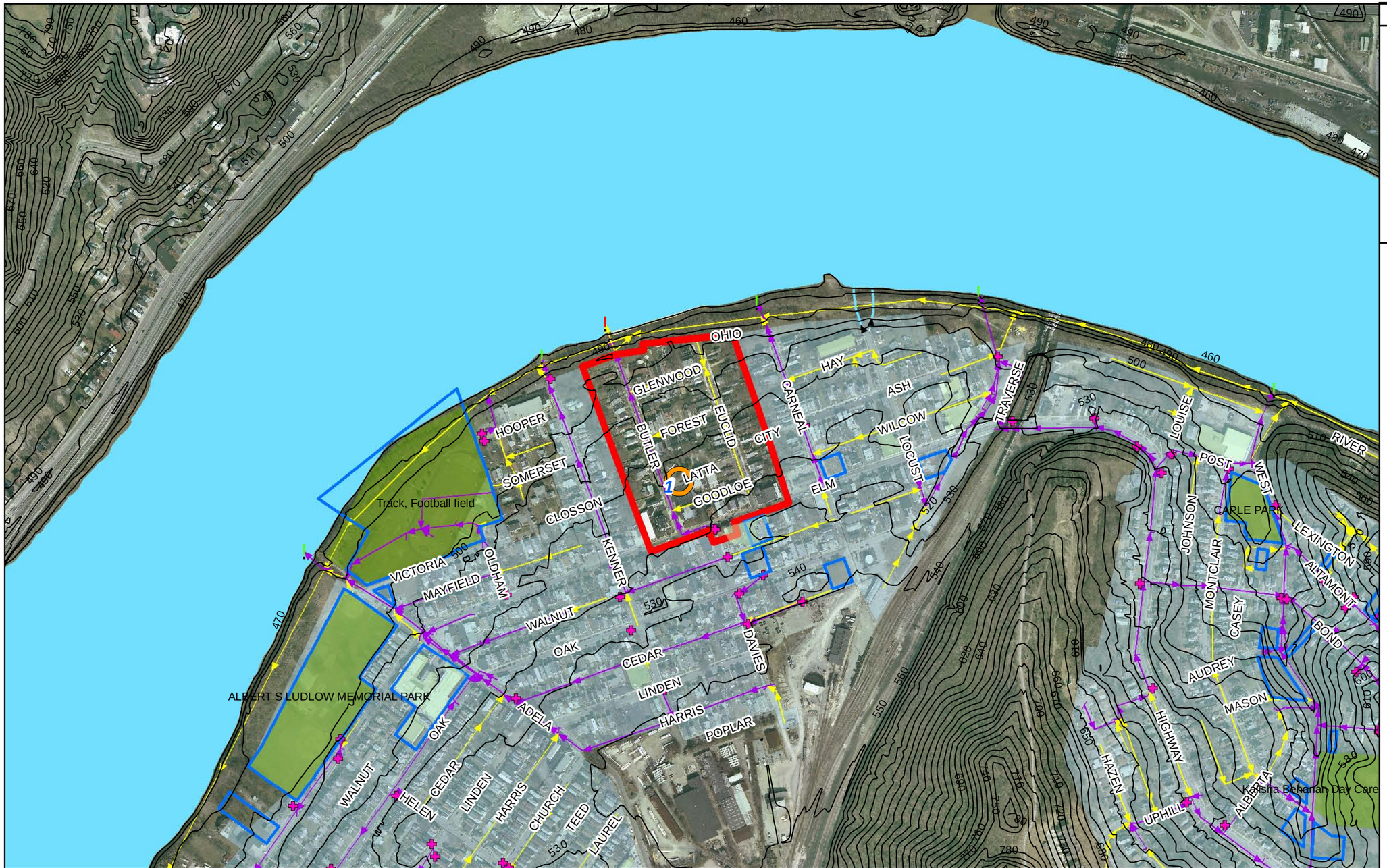


! CSO 1710119
! Surrounding CSOs
2 Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1710119 (15.91 acres)

CSO Statistics:

No. of overflows/yr: 35
Avg. annual overflow volume: 18,279,000 GAL

AAOV/acre of drainage area: 1,148,700 GAL

Imperviousness: 45% (0% tree cover)

Rooftops:	174,924 SF	56%
Roadways:	115,522 SF	37%
Parking/Sidewalks:	21,020 SF	7%

Land Use:

Residential:	377,715 SF	54%
Commercial:	136,588 SF	20%
Industrial:	7,683 SF	1%
Unknown:	171,191 SF	25%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low/Medium

Total Impervious Area: 311,466 SF

Roadways:

Roadways:	115,522 SF	37%
Number of Catch Basins:	4	
Catch Basins on Repair List:	2	

Single Family Residential:

Rooftops:	105,384 SF	34%

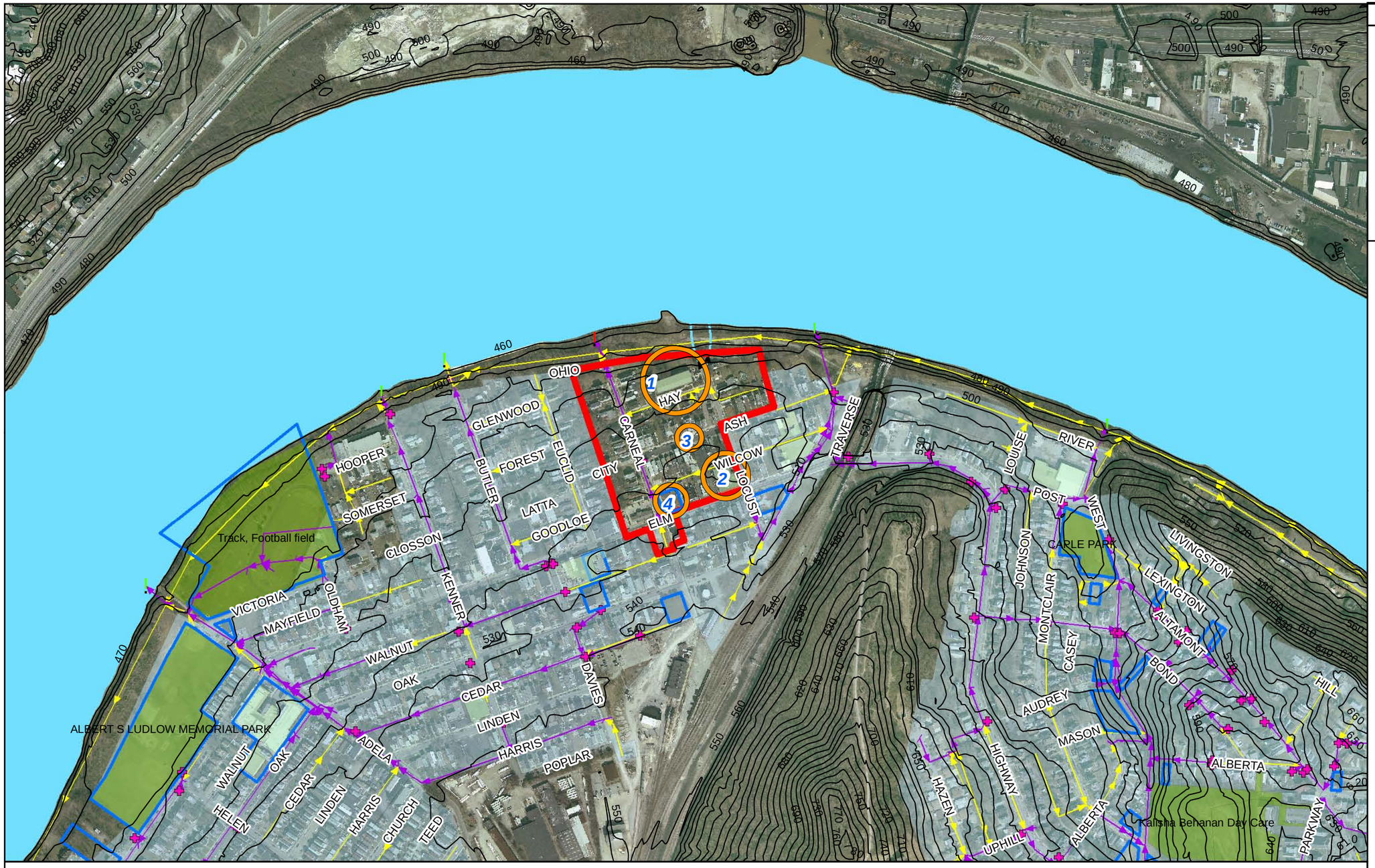
Rooftops Over 10,000 SF: 0 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 0 SF

Potential Opportunities:

1. Green Street - Latta Street



CSO ID - 1710121 (13.73 acres)

CSO Statistics:

No. of overflows/yr:	23
Avg. annual overflow volume:	11,553,000 GAL
AAOV/acre of drainage area:	841,400 GAL

Imperviousness: 44% (0% tree cover)

Rooftops:	133,154 SF	51%
Roadways:	80,454 SF	31%
Parking/Sidewalks:	46,749 SF	18%

Land Use:

Residential:	304,262 SF	51%
Commercial:	171,757 SF	29%
Industrial:	0 SF	0%
Unknown:	122,146 SF	20%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **260,357 SF**

Roadways:

Roadways:	80,454 SF	31%
Number of Catch Basins:	6	
Catch Basins on Repair List:	1	

Single Family Residential:

Rooftops:	77,647 SF	30%

Rooftops Over 10,000 SF: **22,600 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **10,200 SF**

Potential Opportunities:

1. Green Retrofit Site - High Point Ltd.
2. Green Retrofit Site - Rujoro Property LLC
3. Green Street - Ash Street
4. Utilize Existing Green Space - City of Ludlow

! CSO 1710121
! Surrounding CSOs
2 Point of Entry
6 Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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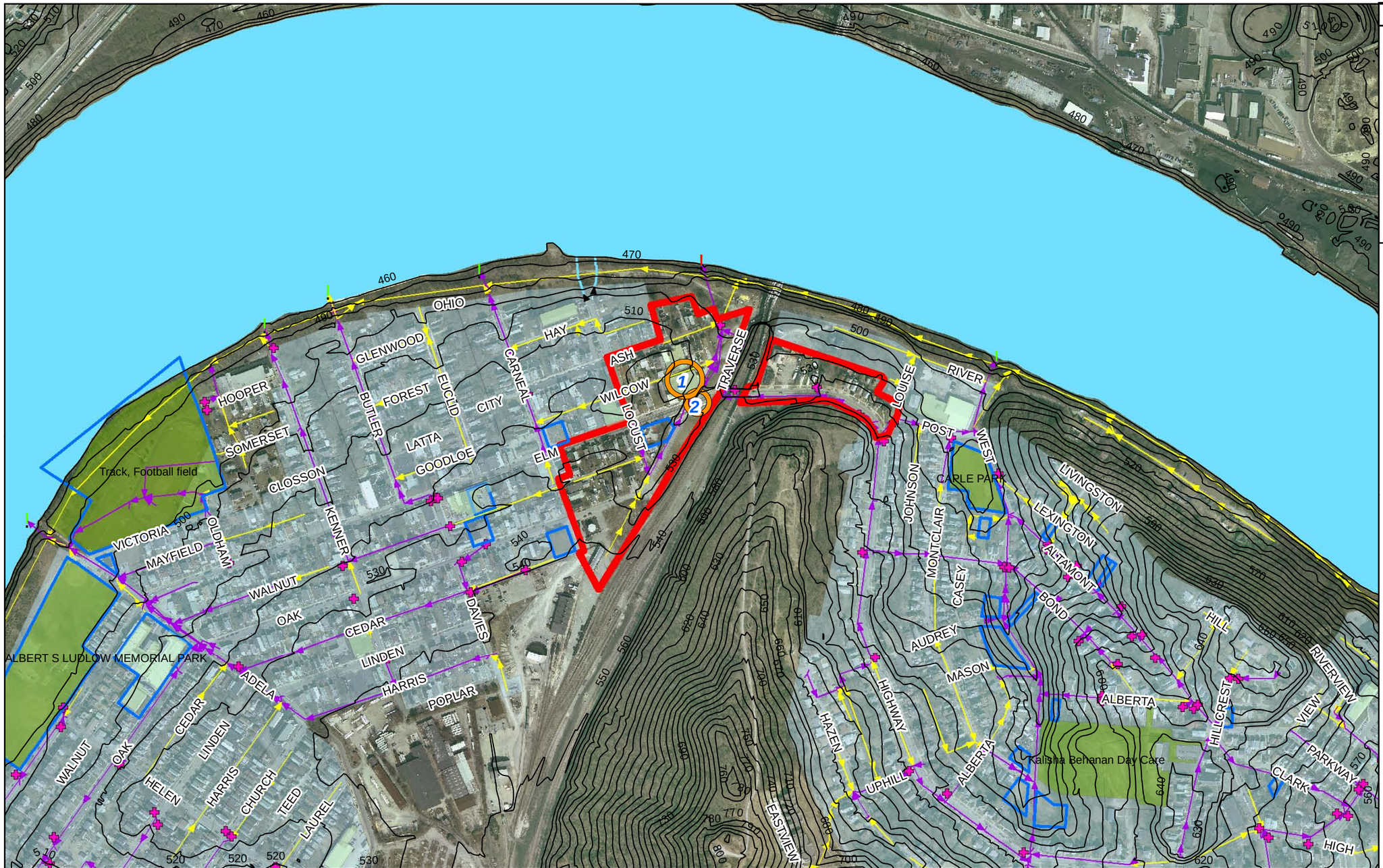

CSO ID - 1710124 (16.63 acres)

CSO Statistics:

No. of overflows/yr: 34
Avg. annual overflow volume: 5,997,000 GAL

AAOV/acre of drainage area: 360,600 GAL

Imperviousness: 48% (1% tree cover)

Rooftops:	138,416 SF	40%
Roadways:	132,514 SF	38%
Parking/Sidewalks:	746,76 SF	22%

Land Use:

Residential:	224,875 SF	31%
Commercial:	162,104 SF	22%
Industrial:	106,390 SF	15%
Unknown:	231,045 SF	32%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 345,606 SF

Roadways:

Roadways:	132,514 SF	38%
Number of Catch Basins:	14	
Catch Basins on Repair List:	3	

Single Family Residential:

Rooftops:	63,326 SF	18%

Rooftops Over 10,000 SF: 27,500 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 14,300 SF

Potential Opportunities:

1. Green Retrofit Site - Barker Alan
2. Green Street - Elm Street

! CSO 1710124
! Surrounding CSOs
2 Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

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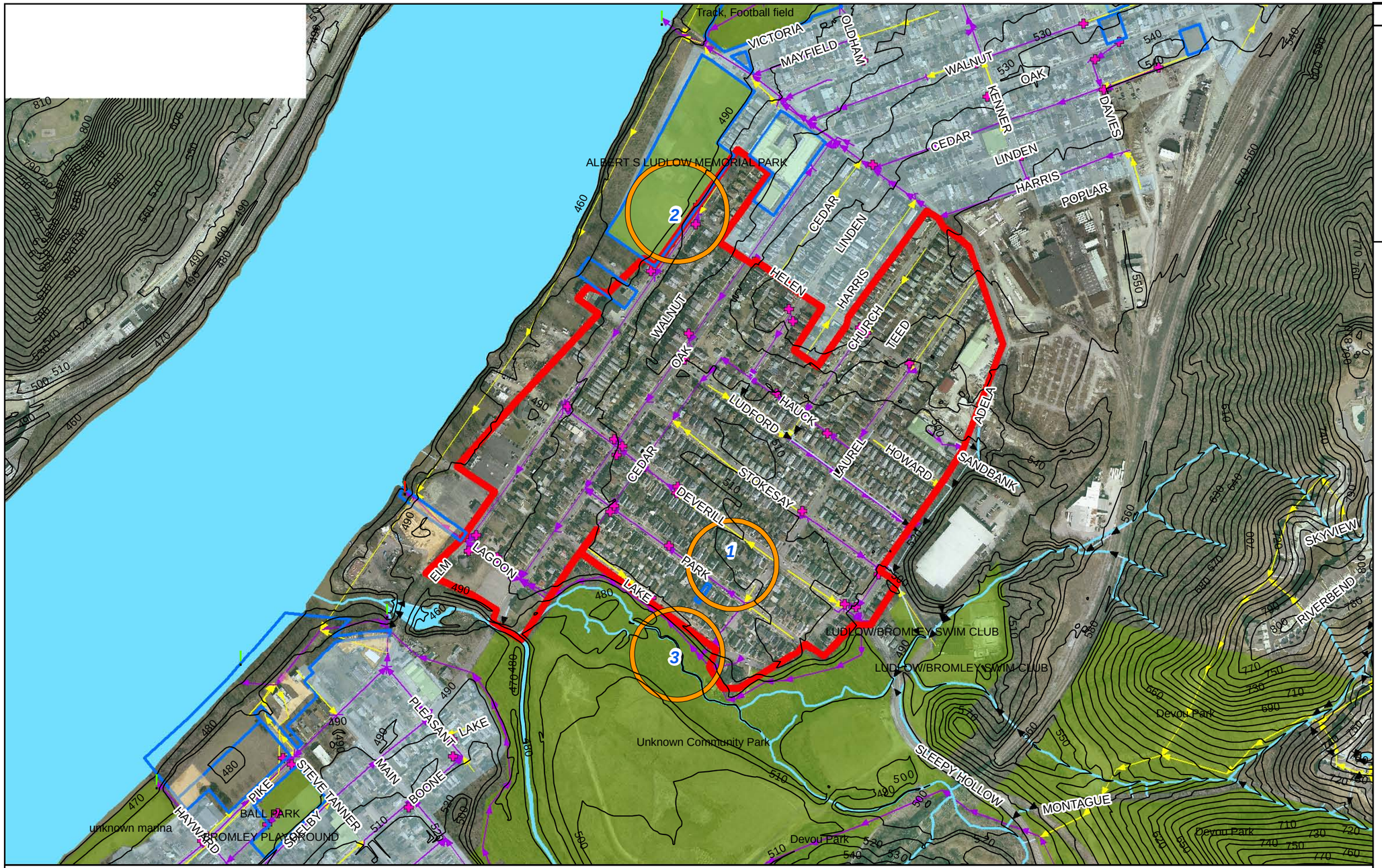
STRAND ASSOCIATES, INC® ENGINEERS



! CSO 1720109	Combined Sewer	Public Ownership
! Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF
2 Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF
Б Catch Basin Repair List	CSO Drainage Area	OKI Green Space
Streams	Surrounding CSO Areas	Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1720109 (89.01 acres)

CSO Statistics:

No. of overflows/yr:	40
Avg. annual overflow volume:	23,677,000 GAL
AAOV/acre of drainage area:	266,000 GAL

Imperviousness: 48% (0.29% tree cover)

Rooftops:	993,822 SF	54%
Roadways:	640,824 SF	35%
Parking/Sidewalks:	213,681 SF	12%

Land Use:

Residential:	2,369,519 SF	61%
Commercial:	478,118 SF	12%
Industrial:	0 SF	0%
Unknown:	1,029,606 SF	27%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: **1,848,327 SF**

Roadways:

Roadways:	640,824 SF	35%
Number of Catch Basins:	65	
Catch Basins on Repair List:	32	

Single Family Residential:

Rooftops:	849,576 SF	46%

Rooftops Over 10,000 SF: **26,000 SF**

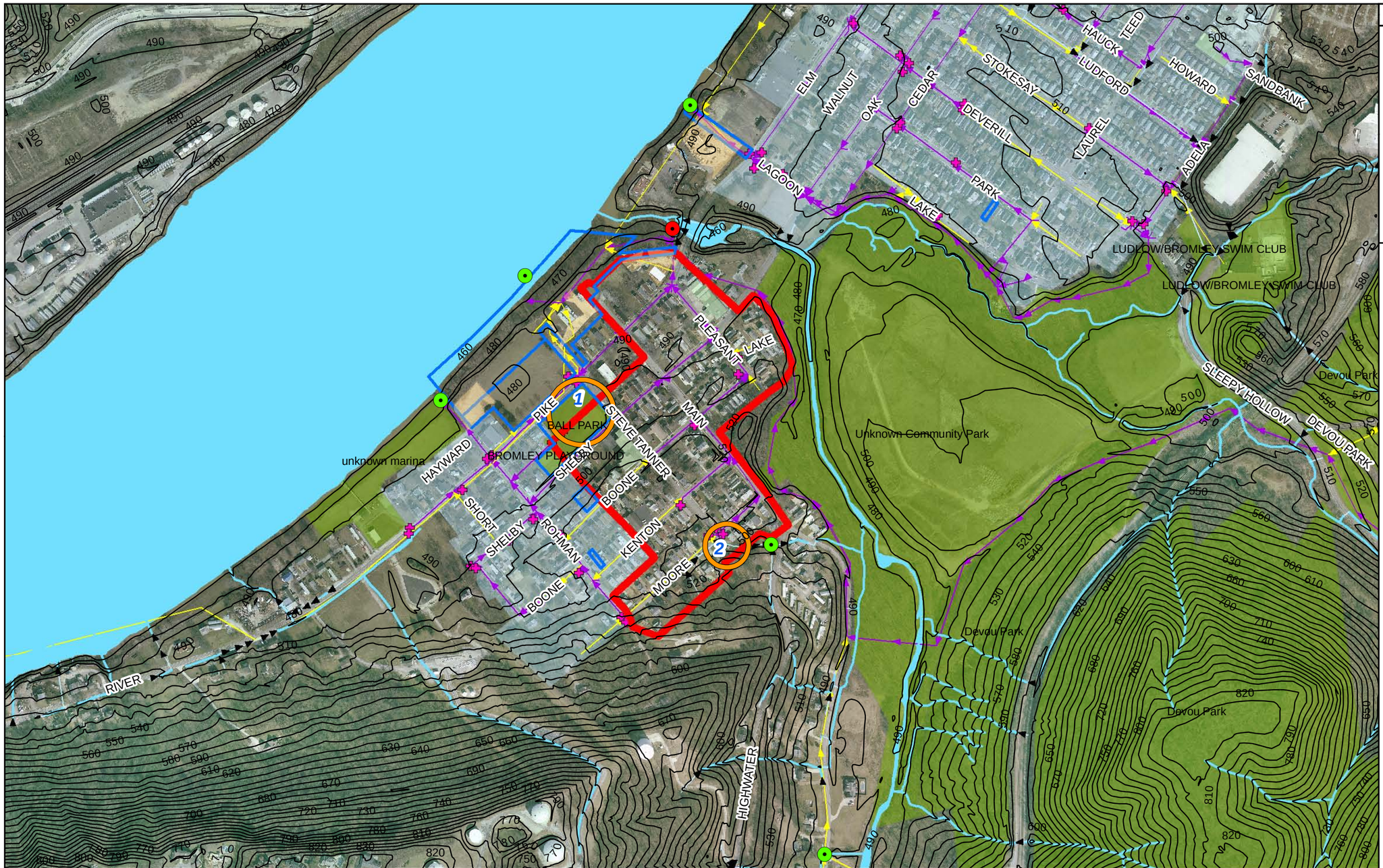
Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **13,000 SF**

Potential Opportunities:

1. Small Sewer Separation
2. Utilize Existing Green Space - Albert Ludlow Memorial Park
3. Utilize Existing Natural Systems

STRAND ASSOCIATES, INC® ENGINEERS



CSO 1730259
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1730259 (27.87 acres)

CSO Statistics:

No. of overflows/yr: 31
Avg. annual overflow volume: 2,994,000 GAL

AAOV/acre of drainage area: 107,400 GAL

Imperviousness: 44% (1% tree cover)

Rooftops:	264,718 SF	50%
Roadways:	220,818 SF	42%
Parking/Sidewalks:	43,454 SF	8%

Land Use:

Residential:	627,921 SF	52%
Commercial:	217,802 SF	18%
Industrial:	0 SF	0%
Unknown:	368,299 SF	30%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 528,990 SF

Roadways:

Roadways:	220,818 SF	42%
Number of Catch Basins:	25	
Catch Basins on Repair List:	9	

Single Family Residential:

Rooftops:	189,491 SF	36%

Rooftops Over 10,000 SF: 29,700 SF

Parking Lots Over 15,000 SF: 19,100 SF

Public Parcels: 41,900 SF

Potential Opportunities:

1. Utilize Existing Green Space - Bromley Park
2. Utilize Existing Natural Systems

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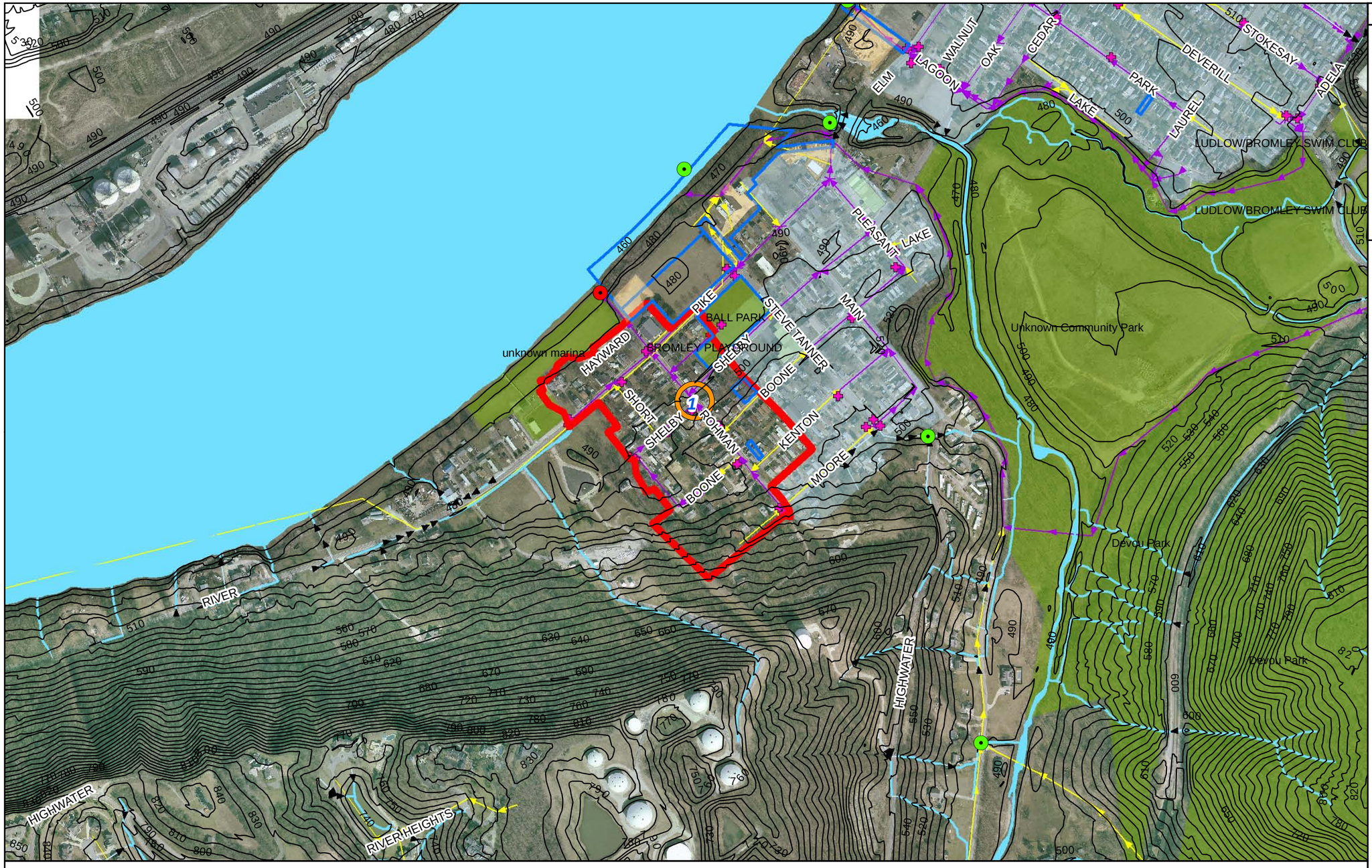

CSO ID - 1730263 (20.145 acres)

CSO Statistics:

No. of overflows/yr:	39
Avg. annual overflow volume:	2,400,000 GAL
AAOV/acre of drainage area:	119,100 GAL

Imperviousness: 39% (4% tree cover)

Rooftops:	181,459 SF	54%
Roadways:	126,195 SF	37%
Parking/Sidewalks:	30,758 SF	9%

Land Use:

Residential:	589,637 SF	67%
Commercial:	73,741 SF	8%
Industrial:	0 SF	0%
Unknown:	214,301 SF	24%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness Medium

Total Impervious Area: **338,412 SF**

Roadways:

Roadways:	126,195 SF	37%
Number of Catch Basins:	22	
Catch Basins on Repair List:	13	

Single Family Residential:

Rooftops:	156,967 SF	46%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **0 SF**

Public Parcels: **24,500 SF**

Potential Opportunities:

1. Green Street - Rohman Street

CSO 1730263
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

STRAND ASSOCIATES, INC.® ENGINEERS

! CSO 1840130
! Surrounding CSOs
2 Point of Entry
~~5~~ Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1840130 (83.17 acres)

CSO Statistics:

No. of overflows/yr:	25
Avg. annual overflow volume:	1,117,000 GAL
AAOV/acre of drainage area:	13,400 GAL

Imperviousness: 49% (0.18% tree cover)

Rooftops:	797,940 SF	45%
Roadways:	506,498 SF	29%
Parking/Sidewalks:	468,406 SF	26%

Land Use:

Residential:	1,504,656 SF	42%
Commercial:	729,246 SF	20%
Industrial:	522,850 SF	14%
Unknown:	866,183 SF	24%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low

Total Impervious Area: 1,772,844 SF

Roadways:

Roadways:	506,498 SF	29%
Number of Catch Basins:	56	
Catch Basins on Repair List:	11	

Single Family Residential:

Rooftops:	440,911 SF	25%

Rooftops Over 10,000 SF: 193,000 SF

Parking Lots Over 15,000 SF: 34,700 SF

Public Parcels: 78,500 SF

Potential Opportunities:

1. Green Retrofit Site - Covington Board of Education
2. Green Retrofit Site - Interplastic Corp
3. Small Sewer Separation

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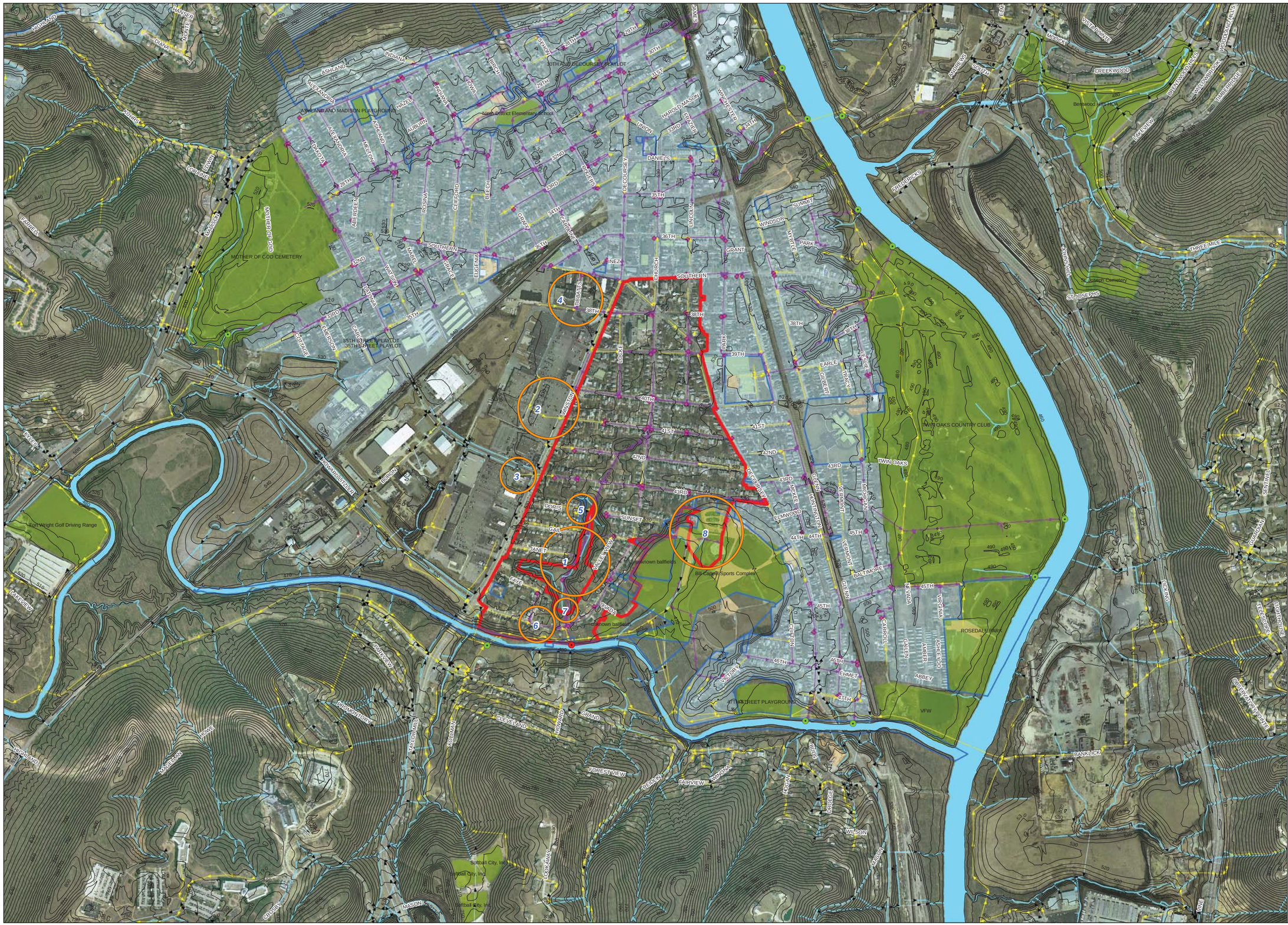
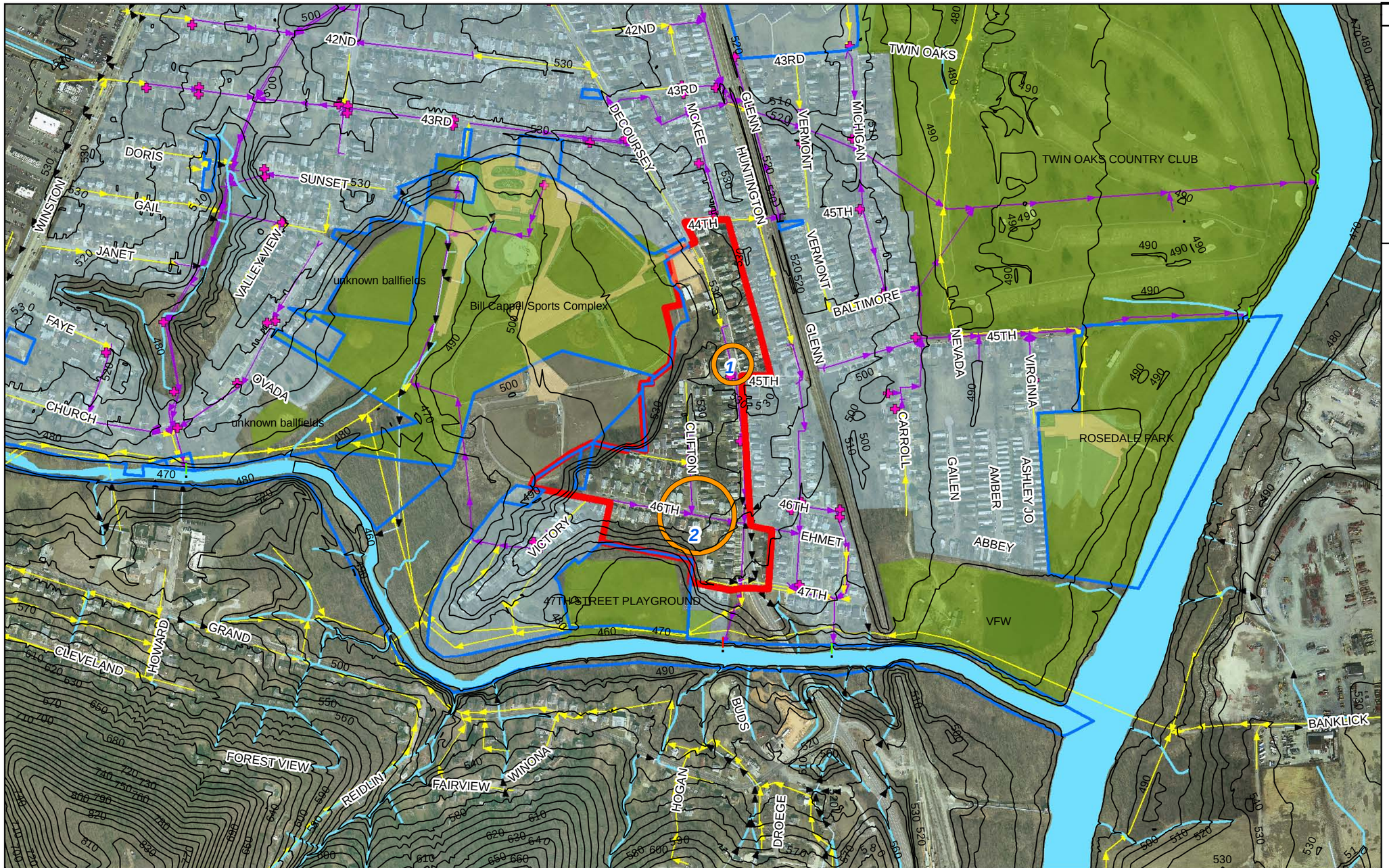

1
2
3
4
5
6
7
8
Fort Wright Golf Driving Range
Softball City, Ind
Softball City, Ind
Softball City, Ind
Softball City, Ind
MOTHER OF GOD CEMETERY
Nash District Elementary School
KENTON COUNTY PUBLIC LIBRARY
Bill Cagen Sports Complex
unknown ballfields
unknown ballfields
unknown ballfields



CSO ID - 1870193 (21.73 acres)

CSO Statistics:

No. of overflows/yr:	24
Avg. annual overflow volume:	1,288,000 GAL
AAOV/acre of drainage area:	59,300 GAL

Imperviousness: 36% (11% tree cover)

Rooftops:	182,091 SF	54%
Roadways:	125,738 SF	37%
Parking/Sidewalks:	29,231 SF	9%

Land Use:

Residential:	687,735 SF	73%
Commercial:	58,528 SF	6%
Industrial:	0 SF	0%
Unknown:	200,465 SF	21%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low/Medium

Total Impervious Area: **337,061 SF**

Roadways:

Roadways:	125,738 SF	37%
Number of Catch Basins:	9	
Catch Basins on Repair List:	2	

Single Family Residential:

Rooftops:	163,203 SF	48%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **22,300 SF**

Public Parcels: **23,000 SF**

Potential Opportunities:

1. Green Street - Decoursey Street
2. Small Sewer Separation

! CSO 1870193
! Surrounding CSOs
2 Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

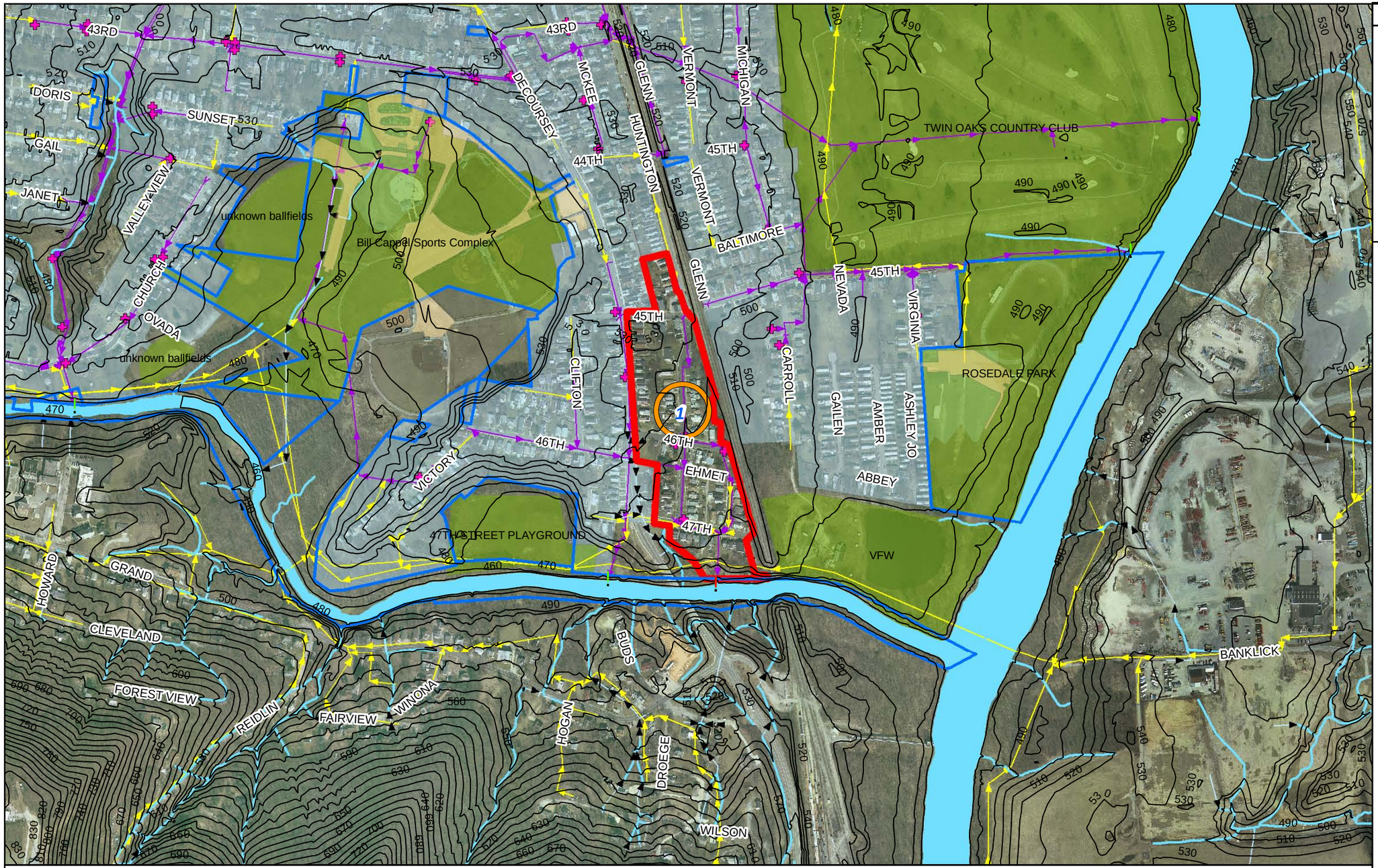
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

STRAND ASSOCIATES, INC.® ENGINEERS



CSO 1870194	Combined Sewer	Public Ownership	
Surrounding CSOs	Sanitary Sewer	Roof Over 10,000 SF	
Point of Entry	Storm Sewer	Parking Lot Over 15,000 SF	
Catch Basin Repair List	CSO Drainage Area	OKI Green Space	
Streams	Surrounding CSO Areas	Best Opportunities	

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

CSO ID - 1870194 (12.52 acres)

CSO Statistics:

No. of overflows/yr: 4
Avg. annual overflow volume: 126,000 GAL

AAOV/acre of drainage area: 10,000 GAL

Imperviousness: 39% (0% tree cover)

Rooftops:	122,751 SF	58%
Roadways:	80,578 SF	38%
Parking/Sidewalks:	7,736 SF	4%

Land Use:

Residential:	377,665 SF	69%
Commercial:	29,299 SF	5%
Industrial:	0 SF	0%
Unknown:	138,266 SF	25%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low/Medium

Total Impervious Area: 211,065 SF

Roadways:

Roadways:	80,578 SF	38%
Number of Catch Basins:	11	
Catch Basins on Repair List:	5	

Single Family Residential:

Rooftops:	114,139 SF	54%

Rooftops Over 10,000 SF: 0 SF

Parking Lots Over 15,000 SF: 0 SF

Public Parcels: 0 SF

Potential Opportunities:

1. Small Sewer Separation

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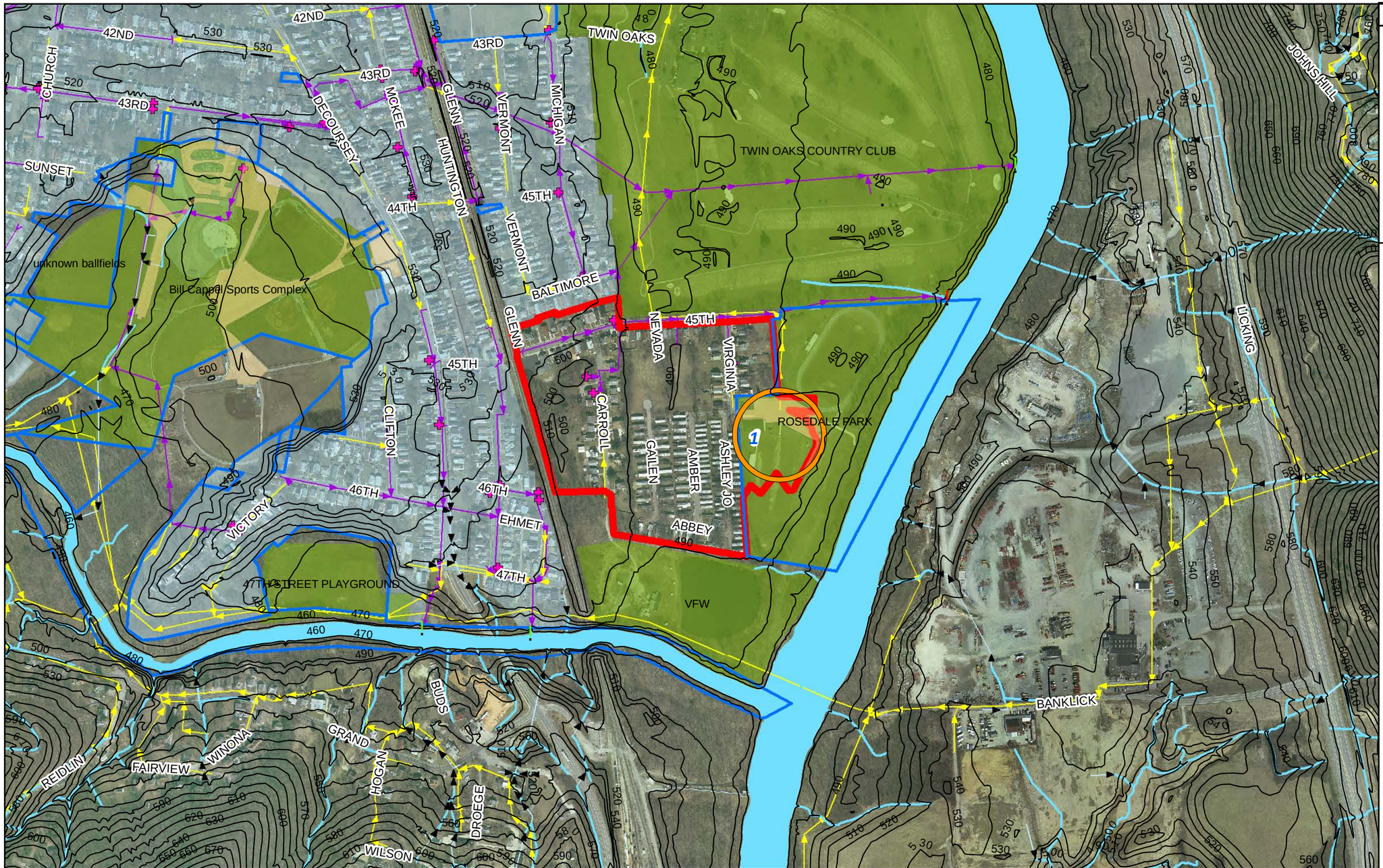


CSO ID - 1880090 (28.54 acres)

CSO Statistics:

No. of overflows/yr:	19
Avg. annual overflow volume:	2,106,000 GAL
AAOV/acre of drainage area:	73,800 GAL

Imperviousness: 30% (0% tree cover)

Rooftops:	193,511 SF	52%
Roadways:	89,076 SF	24%
Parking/Sidewalks:	91,768 SF	25%

Land Use:

Residential:	476,633 SF	38%
Commercial:	663,045 SF	53%
Industrial:	0 SF	0%
Unknown:	103,590 SF	8%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Very Low

Total Impervious Area: **374,355 SF**

Roadways:

Roadways:	89,076 SF	24%
Number of Catch Basins:	14	
Catch Basins on Repair List:	4	

Single Family Residential:

Rooftops:	86,045 SF	23%

Rooftops Over 10,000 SF: **0 SF**

Parking Lots Over 15,000 SF: **38,500 SF**

Public Parcels: **148,900 SF**

Potential Opportunities:

1. Green Retrofit Site - City of Covington

! CSO 1880090
! Surrounding CSOs
2 Point of Entry
Catch Basin Repair List
Streams

Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas

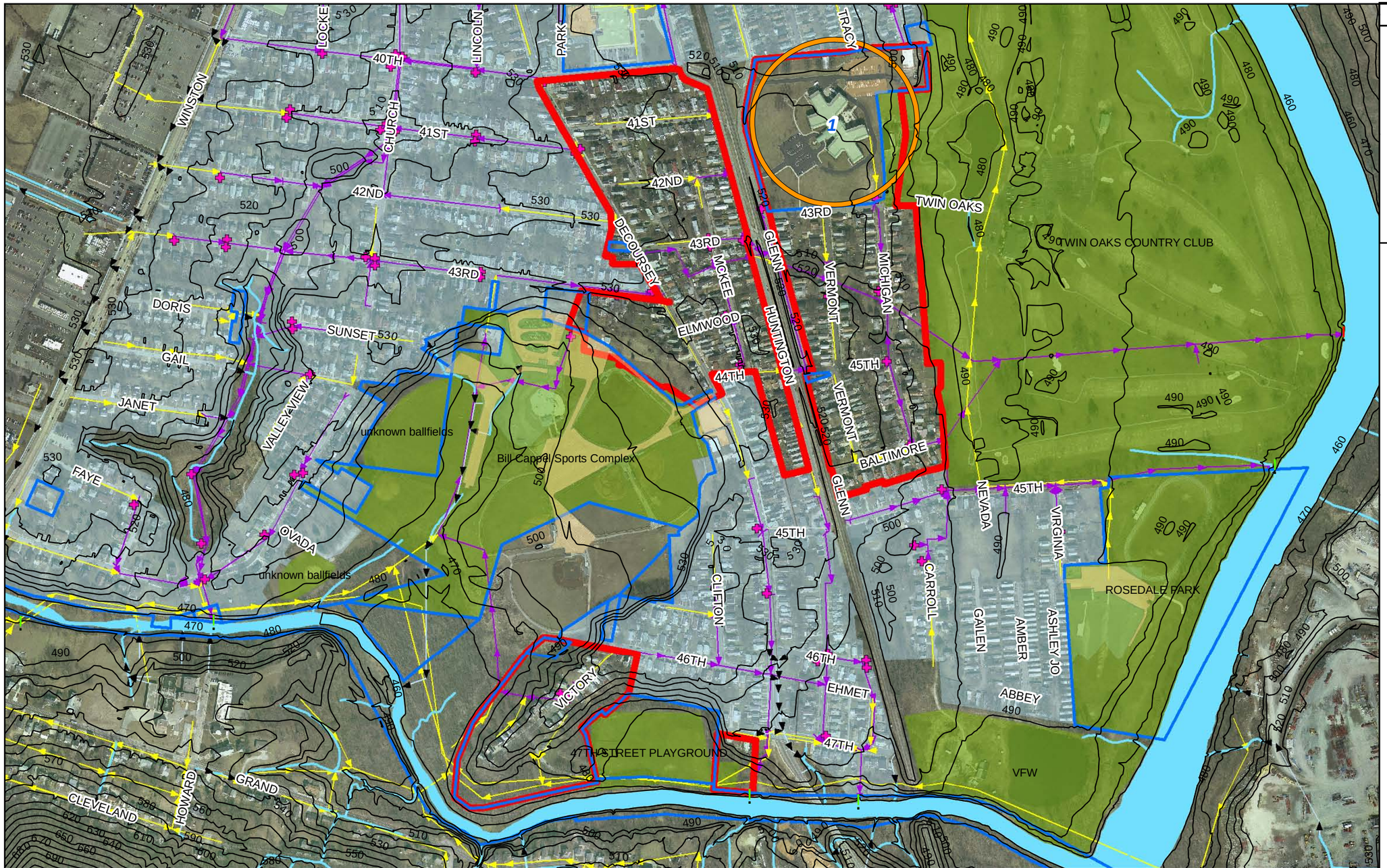
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

STRAND ASSOCIATES, INC® ENGINEERS



CSO ID - 1880091 (71.46 acres)

CSO Statistics:

No. of overflows/yr:	5
Avg. annual overflow volume:	2,191,000 GAL
AAOV/acre of drainage area:	30,700 GAL

Imperviousness: 32% (9% tree cover)

Rooftops:	571,510 SF	57%
Roadways:	344,144 SF	34%
Parking/Sidewalks:	93,387 SF	9%

Land Use:

Residential:	1,979,154 SF	64%
Commercial:	633,830 SF	20%
Industrial:	0 SF	0%
Unknown:	499,577 SF	16%

Green Concepts

Suitability for Shallow Infiltration: Poor

Downspout Disconnect Effectiveness: Low/Medium

Total Impervious Area: 1,009,041 SF

Roadways:

Roadways:	344,144 SF	34%
Number of Catch Basins:	38	
Catch Basins on Repair List:	15	

Single Family Residential:

Rooftops:	455,661 SF	45%

Rooftops Over 10,000 SF: 44,600 SF

Parking Lots Over 15,000 SF: 43,400 SF

Public Parcels: 563,000 SF

Potential Opportunities:

1. Green Retrofit Site - Kenton County Corp Prop

CSO 1880091
Surrounding CSOs
Point of Entry
Catch Basin Repair List
Streams
Combined Sewer
Sanitary Sewer
Storm Sewer
CSO Drainage Area
Surrounding CSO Areas
Public Ownership
Roof Over 10,000 SF
Parking Lot Over 15,000 SF
OKI Green Space
Best Opportunities

GREEN INFRASTRUCTURE INITIATIVE
SANITATION DISTRICT NO. 1 OF NORTHERN KENTUCKY
FORT WRIGHT, KY

0 250 500 1,000 1,500 2,000 Feet

1:6,000

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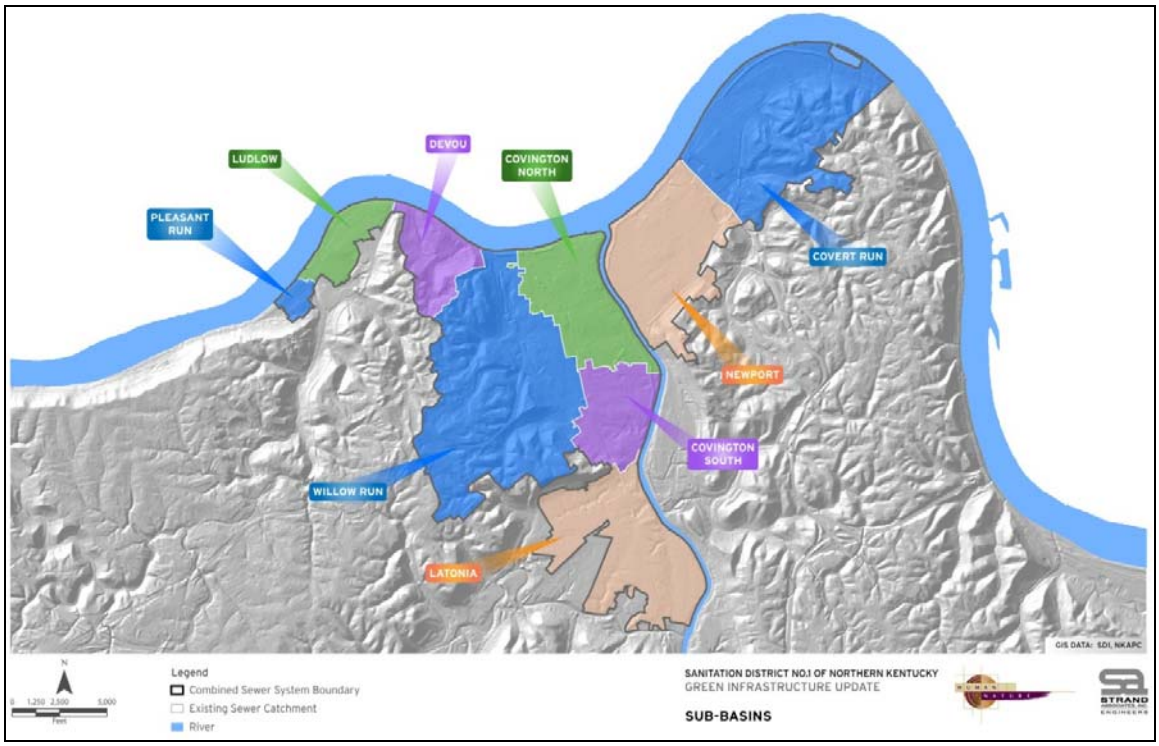
Appendix 3-B.2
Refined Combined Sewer System Green Infrastructure Analysis

Overview

After the completion of the original opportunities mapping and the identification of the initial green opportunities within the combined sewer system, a more detailed green infrastructure analysis was performed. The refined green analysis builds upon the information gathered and represented on the original opportunities maps to identify specific projects that reduce and remove storm water runoff from the combined system based on the different characteristics of the CSO sewersheds. The 62 CSO sewersheds delineated as part of the initial green infrastructure opportunities analysis were grouped into nine sub-basins based on merging sewershed boundaries into larger study areas. The sub-basins are Pleasant Run, Ludlow, Devou, Covington North, Covington South, Latonia, Newport, and Covert Run, as shown in Figure 4. Each of the nine sub-basins have been further evaluated to identify specific opportunity areas where green infrastructure projects will reduce or remove storm water runoff from the combined system.

Figure 4. Refined Green Infrastructure Analysis Sub-Basins



Analysis Sub-Basins

By building on the information or inventory of data collected for each CSO sewershed as part of the initial analysis, different projects and strategies have been proposed for different areas of the combined system. The green strategies considered in this evaluation include storm water separation, large scale retention/detention basins, and typical green infrastructure features such as bioinfiltration, green streets, site retrofits and downspout disconnections to reduce the amount of storm water runoff entering the combined sewer system and improve water quality. In addition to the identified projects, it is anticipated that additional projects will be identified through

partnerships with both public and private entities interested in incorporating green infrastructure into other planned activities.

Over 60 green infrastructure projects, with 98 water quality features have been proposed for the SD1 combined sewer system. These projects have been ranked and prioritized for the Integrated Solution for 2025. As SD1 continues to foster partnerships and evaluate the combined system for green infrastructure opportunities, the list of proposed projects will be evaluated and adjusted. As specific projects are selected for inclusion in future five year watershed plan submittals, the specific details of individual projects and project components will be refined and optimized to achieve a desired cost-benefit ratio.

Table 4 summarizes the types of strategies to remove storm water from the CSS; Table 4 also provides an estimate of the associated cost and CSO reduction benefit that may be achieved collectively with the proposed green infrastructure projects in the combined system.

Table 4. Summary of Green Infrastructure CSO Reduction Projects

Summary of Green Infrastructure CSO Reduction Projects	
Number of Projects	64
Proposed Storm Sewer (Feet)	109,460
Water Quality Features	98
Bioinfiltration/Infiltration	23
Detention/Retention	40
Site BMPs/Offloading	35
Area Removed from the CSS (Acres)	2,349
Area Transferred within the CSS (Acres)	47
Total Area Impacted (Acres)	2,396
Total Project Construction Cost	$87,149,200.00
Total Project Capital Cost	$135,952,752.00
Total Annual CSO Volume Removed (MG)	489

Refined Green Infrastructure Analysis Maps

The following series of maps details the refined analysis conducted for each of the Sub-basins within the combined sewer system. Two maps are provided for each of the sub-basins (Table 5). The first map presents an overview of existing conditions, and the second details opportunities, strategies, and goals specific to that sub-basin.

Table 5. List of Sub-Basin Analysis Maps

	Description
1	Covert Run Sub-Basin Existing Conditions Overview
2	Covert Run Sub-Basin Opportunities Overview
3	Covington North Sub-Basin Existing Conditions Overview
4	Covington North Sub-Basin Opportunities Overview
5	Covington South Sub-Basin Existing Conditions Overview
6	Covington South Sub-Basin Opportunities Overview
7	Devou Park Sub-Basin Existing Conditions Overview
8	Devou Park Sub-Basin Opportunities Overview
9	Latonia Sub-Basin Existing Conditions Overview
10	Latonia Sub-Basin Opportunities Overview
11	Ludlow Sub-Basin Existing Conditions Overview
12	Ludlow Sub-Basin Opportunities Overview
13	Newport Sub-Basin Existing Conditions Overview
14	Newport Sub-Basin Opportunities Overview
15	Pleasant Run Sub-Basin Existing Conditions Overview
16	Pleasant Run Sub-Basin Opportunities Overview
17	Willow Run Sub-Basin Existing Conditions Overview
18	Willow Run Sub-Basin Opportunities Overview

Green Infrastructure Concept Graphics

Based on the inventory and analysis performed, and the opportunities identified through the refined analysis of individual sub-basins, SD1 has begun developing concept plans for selected project areas. These concept plans not only highlight proposed green project locations, but also identify specific locations for strategic partnerships and opportunities to enhance community connectivity throughout the surrounding project area. Table 6 outlines three concept plans that have already been developed for projects proposed within the combined system. As SD1 continues with the implementation of the green infrastructure CSO reduction projects, additional concepts plans will be developed for individual project study areas.

Table 6. Green Infrastructure Concept Graphics

	Description
19	Willow Run Study Area
20	Goebel Park Study Area
21	Church Street Study Area

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COVERT RUN

Total Area: 1,381 acres

Combined Sewer Overflows (Permitted CSOs)
Number: 10

Contributing to Direct Entry Points
Drainage Area: 185 acres
Annual Runoff: 56 MG

CSO #0570089
CSO #0570090
CSO #0600097
CSO #0600094
CSO #0610072
CSO #0610071
CSO #0620077
CSO #0620075
CSO #0650090
CSO #0650100

MAIN ST
THIRD AVE
FIFTH AVE
SEVENTH AVE
BERRY ST
VAN VOAST AVE
WALNUT ST
DAYTON PIKE
FAIRFIELD AVE
CENTER ST
FOOTE AVE
COVERT RUN PIKE
ROSSFORD AVE
SCENIC VIEW DR
E 3RD ST
471
E 5TH ST
E 9TH ST

GIS DATA: SD1, NKAPC

N
0 600 1,200
Feet

Legend
- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

COVERT RUN SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

COVERT RUN

Total Area: 1,381 acres

Combined Sewer Overflows
(Permitted CSOs)
Number: 10

Contributing to Opportunities
Drainage Area: 420.6 acres
Annual Runoff (without roof):121.1 MG

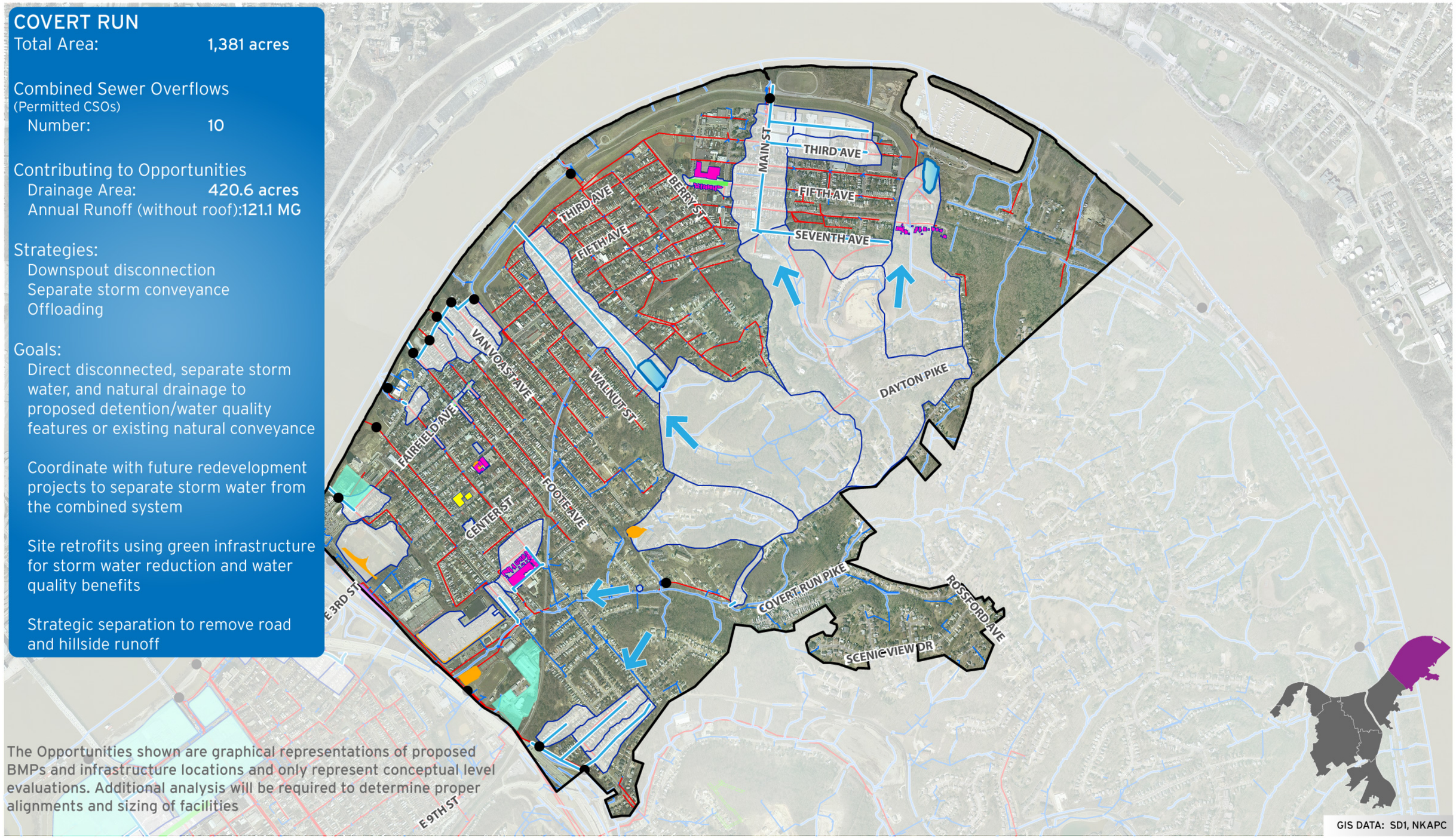
Strategies:
Downspout disconnection
Separate storm conveyance
Offloading

Goals:
Direct disconnected, separate storm water, and natural drainage to proposed detention/water quality features or existing natural conveyance

Coordinate with future redevelopment projects to separate storm water from the combined system

Site retrofits using green infrastructure for storm water reduction and water quality benefits

Strategic separation to remove road and hillside runoff



The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities

GIS DATA: SD1, NKAPC

N
0 600 1,200
Feet

Legend
Existing Combined Sewers
Existing Storm Sewers
Existing Drainage Channel
Diversion
Detention
Offloading
Bioinfiltration
Downspout Disconnection
Stream Restoration
Green Street
Proposed Storm Sewers
Green Parking
Drainage Area
Stormwater Flow

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

COVERT RUN SUB-BASIN
OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

COVINGTON NORTH

Total Area: 664 acres

Combined Sewer Overflows
Number: 20

Contributing to Direct Entry Points
Drainage Area: 5.7 acres
Annual Runoff: 3.5 MG

CSO #1440209
CSO #1440212
CSO #1440204
CSO #1440205
CSO #1440206
CSO #1470093
CSO #1470089
CSO #1420141
CSO #1420142
CSO #1420144
CSO #1420145
CSO #1420146
CSO #1420147
CSO #0980073
CSO #0960064
CSO #0930106
CSO #0930104
CSO #0960063
CSO #0980081
CSO #0980080

RIVER GTR
EAST 3RD ST
4TH ST
MAIN ST
WEST 5TH ST
MADISON AVE
GREENUP ST
GARRARD ST
PHILADELPHIA ST
PIKE ST
EAST 12TH ST
RESCENT AVE
W 3RD ST
W 5TH ST
MONMOUTH ST
E 5TH ST
E 6TH ST
E 8TH ST
E 9TH ST
E 10TH ST
YORK ST
CENTRAL AVE
E 11TH ST
12TH ST
16TH ST
MONTAGUE RD
AMSTERDAM RD E
BANKLICK ST
RUSSELL ST
NDVIEW AVE
75

GIS DATA: SD1, NKAPC

N
0 500 1,000
Feet

Legend
- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

COVINGTON NORTH SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE
STRAND ASSOCIATES, INC. ENGINEERS

COVINGTON NORTH

Total Area: 664 acres

Combined Sewer Overflows (Permitted CSOs)
- Number: 20

Contributing to Opportunities
- Drainage Area: 172 acres
- Annual Runoff (without roof): 76 MG

Strategies:
- Downspout disconnection
- Separate storm conveyance
- Offloading
- Infiltration

Goals:
- Direct disconnected and separate storm water to proposed detention/water quality features
- Coordinate with future redevelopment projects to separate storm water from the combined system
- Site retrofits using green infrastructure for storm water reduction and water quality benefits

The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities

GIS DATA: SD1, NKAPC

N

0 500 1,000
Feet

Legend
- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Diversion Structure
- Detention
- Infiltration
- Green Parking Lot
- Offloading
- Downspout Disconnection
- Drainage Area
- Proposed Separate Storm Sewers

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

COVINGTON NORTH SUB-BASIN
OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

COVINGTON SOUTH

Total Area: 445 acres

Combined Sewer Overflows (Permitted CSOs)
Number: 8

Contributing to Direct Entry Points
Drainage Area: 68 acres
Annual Runoff: 26 MG

CSO #0930106
CSO #0960063
CSO #0930104
CSO #0930105
CSO #0930103
CSO #0930102
CSO #0910068
CSO #0910065

EAST 15TH ST
BANKLICK ST
RUSSELL ST
MADISON AVE
GREENUP ST
GARRARD ST
EAST 18TH ST
GLENWAY AVE
WEST 18TH ST
WEST 19TH ST
HIGHLAND AVE
I-75
CENTER ST
EAST 24TH ST
JAMES AVE
EMERY DR
MONTE LN
MADISON PIKE

GIS DATA: SD1, NKAPC

N
0 400 800
Feet

Legend
- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

COVINGTON SOUTH SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE
STRAND ASSOCIATES, INC. ENGINEERS

COVINGTON SOUTH

Total Area: 445 acres

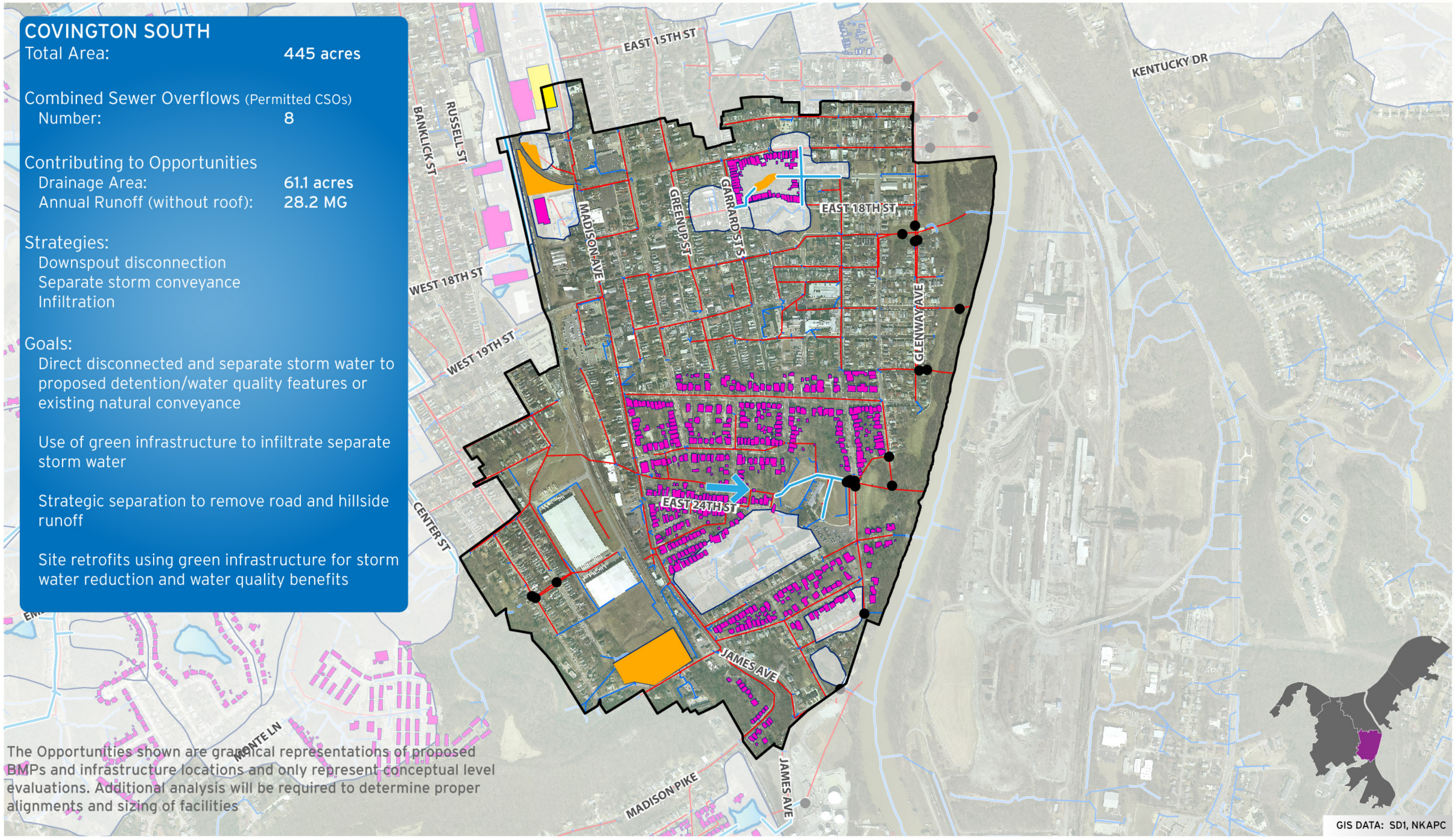
Combined Sewer Overflows (Permitted CSOs)
- Number: 8

Contributing to Opportunities
- Drainage Area: 61.1 acres
- Annual Runoff (without roof): 28.2 MG

Strategies:
- Downspout disconnection
- Separate storm conveyance
- Infiltration

Goals:
- Direct disconnected and separate storm water to proposed detention/water quality features or existing natural conveyance
- Use of green infrastructure to infiltrate separate storm water
- Strategic separation to remove road and hillside runoff
- Site retrofits using green infrastructure for storm water reduction and water quality benefits

The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities



N

0 400 800

Feet

Legend

- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Diversion Structure
- Detention
- Bioinfiltration
- Downspout Disconnection
- Green Parking
- Drainage Area
- Proposed Storm Sewers
- Stormwater Flow

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

COVINGTON SOUTH SUB-BASIN
OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

DEVOU PARK

Total Area: 356 acres

Combined Sewer Overflows (Permitted CSOs)
Number: 3

Contributing to Direct Entry Points
Drainage Area: 101 acres
Annual Runoff: 30 MG

CSO #1500131

CSO #1490172

CSO #1490132

ELM ST
HIGHWAY AVE
RIVER RD
ALTAMONT RD
HAZEN ST
HIGHWAY AVE
HIGHWAY AVE
JOHN ST
FOREST AVE
PANORAMA DR
PARK LN
PARK RD
MONTAGUE RD
ADELA AVE
ELM ST
HELEN ST
LUDFORD ST
DEVERILL ST
OAK ST
LAKE ST
75
RIVER CTR
WEST 3RD ST
WEST 4TH ST NC
WEST 5TH ST
WESTERN AVE
CRESCENT AVE
PHILADELPHIA ST
YORK ST
MAIN ST
BANKLICK ST
PIKE ST

GIS DATA: SD1, NKAPC

N

0 400 800
Feet

Legend

- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

DEVOU PARK SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

DEVOU PARK

Total Area: 356 acres

Combined Sewer Overflows (Permitted CSOs)
- Number: 3

Contributing to Opportunities
- Drainage Area: 235.4 acres
- Annual Runoff (without roof): 62.9 MG

Strategies:
- Downspout disconnection
- Separate storm conveyance
- Offloading

Goals:

Direct disconnected, separate storm water, and natural drainage to proposed detention/water quality features or existing natural conveyance

Strategic separation to remove road and hillside runoff

The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities

ELM ST
HIGHWAY AVE
RIVER RD
ALTAMONT RD
HAZEN ST
HIGHWAY AVE
HIGHWAY AVE
JOHN ST
FOREST AVE
PANORAMA DR
WESTERN AVE
PARK LN
PARK RD
MONTAGUE RD
LAKE ST
75
RIVER CTR
WEST 3RD ST
WEST 4TH ST NC
WEST 5TH ST
PHILADELPHIA ST
YORK ST
MAIN ST
CRESCENT AVE
BANKLICK ST
PIKE ST
GIS DATA: SD1, NKAPC

N

0 400 800

Feet

Legend

- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Detention
- Offloading
- Downspout Disconnection
- Drainage Area
- Proposed Storm Sewers
- Stormwater Flow
- Diversion Structure

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

DEVOU PARK SUB-BASIN
OPPORTUNITIES OVERVIEW

HUMAN NATURE

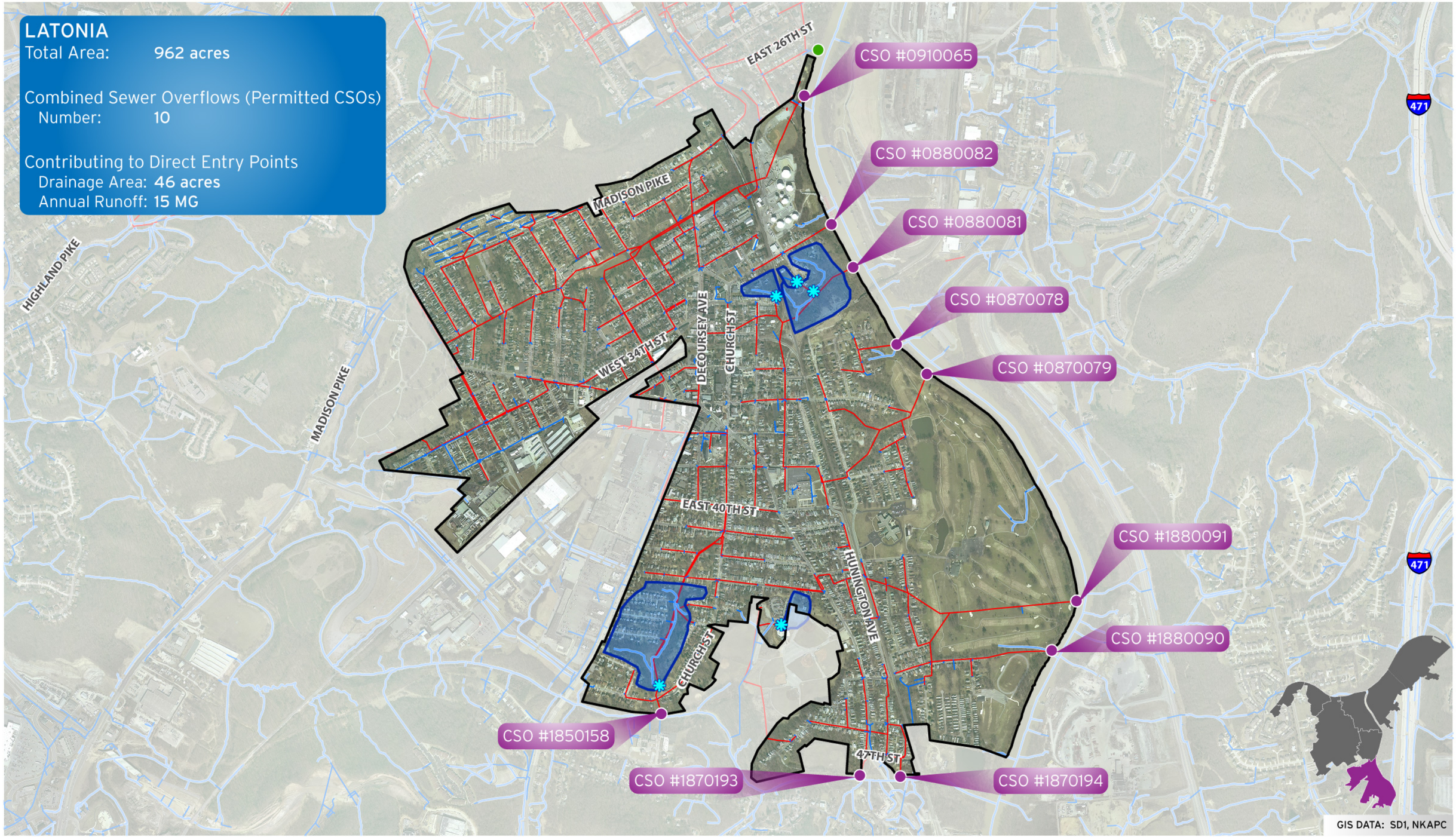
STRAND ASSOCIATES, INC. ENGINEERS

LATONIA

Total Area: 962 acres

Combined Sewer Overflows (Permitted CSOs)
Number: 10

Contributing to Direct Entry Points
Drainage Area: 46 acres
Annual Runoff: 15 MG



N

0 600 1,200

Feet

Legend

- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

LATONIA SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

LATONIA

Total Area: 962 acres

Combined Sewer Overflows (Permitted CSOs)
- Number: 10

Contributing to Opportunities
- Drainage Area: 294.2 acres
- Annual Runoff (without roof): 68.1 MG

Strategies:
- Downspout disconnection
- Separate storm conveyance

Goals:
- Direct disconnected and separate storm water to proposed detention/water quality features or existing natural conveyance
- Strategic separation to remove road and hillside runoff

EAST 26TH ST
MADISON PIKE
WEST 34TH ST
DECOURSEY AVE
CHURCH ST
EAST 40TH ST
HUNNINGTON AVE
CHURCH ST
47TH ST
471

The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities

GIS DATA: SD1, NKAPC

N

0 600 1,200
Feet

Legend
- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Detention
- Downspout Disconnection
- Proposed Storm Sewer
- Drainage Area
- Diversion Structure

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

LATONIA SUB-BASIN
OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

LUDLOW

Total Area: 245 acres

Combined Sewer Overflows (Permitted CSOs)
Number: 7

Contributing to Direct Entry Points
Drainage Area: 22 acres
Annual Runoff: 9 MG

CSO #1710119
CSO #1710121
CSO #1710124
CSO #1710114
CSO #1710116
CSO #1720109
CSO #1730259

GLENWOOD AVE
BUTLER ST
EUCLID AVE
CARNEAL ST
ASH ST
ELM ST
DAVIES ST
OAK ST
KENNER ST
PIKE ST
LAGOON ST
DEVERILL ST
RIVER RD
HIGHWAY AVE
WEST ST
ALTAMONT RD
UPHILL ST

GIS DATA: SD1, NKAPC

N
0 300 600
Feet

Legend
- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

LUDLOW SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

LUDLOW

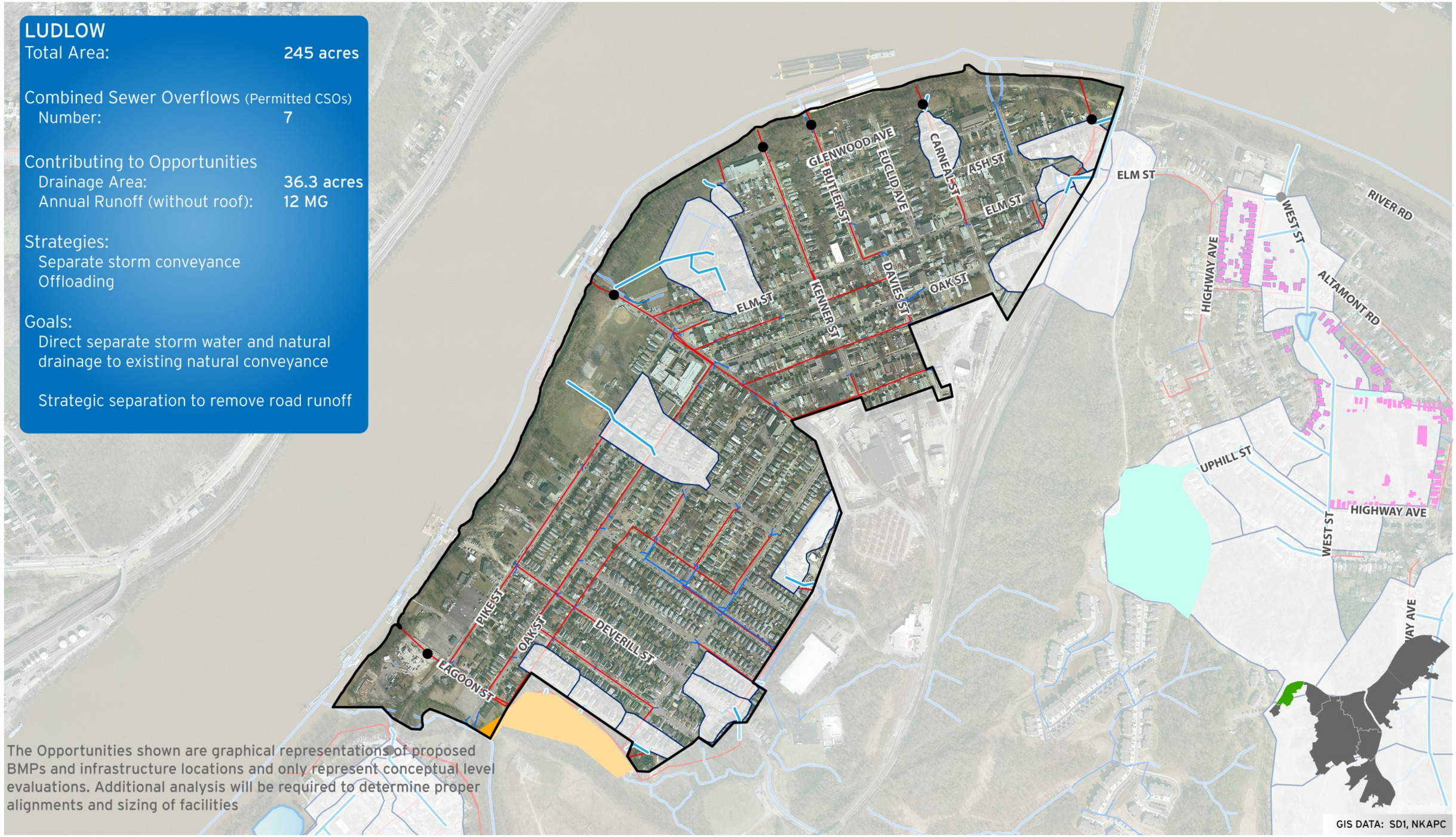
Total Area: 245 acres

Combined Sewer Overflows (Permitted CSOs)
- Number: 7

Contributing to Opportunities
- Drainage Area: 36.3 acres
- Annual Runoff (without roof): 12 MG

Strategies:
- Separate storm conveyance
- Offloading

Goals:
- Direct separate storm water and natural drainage to existing natural conveyance
- Strategic separation to remove road runoff



The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities

GIS DATA: SD1, NKAPC

N

0 300 600

Feet

Legend
- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Bioinfiltration
- Drainage Area
- Proposed Storm Sewers
- Diversion Structure

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

LUDLOW SUB-BASIN
OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

NEWPORT

Total Area: 939 acres

Combined Sewer Overflows (Permitted CSOs)
Number: 8

Contributing to Direct Entry Points
Drainage Area: 61 acres
Annual Runoff: 39 MG

CSO #0630061
CSO #0650090
CSO #0640090
CSO #0770096
CSO #0650100
CSO #0790084
CSO #0790086
CSO #0840116

LINCOLN AVE
TAYLOR AVE
COVERT RUN PIKE
ROSSFORD AVE
RIVER CTR
WEST 3RD ST
WESTERN AVE
WEST 5TH ST
PHILADELPHIA ST
MAIN ST
PIKE ST
EAST 7TH ST
WEST 12TH ST
RUSSELL ST
MADISON AVE
PIKE ST
MONMOUTH ST
W 4TH ST
W 5TH ST
E 6TH ST
E 7TH ST
PARK AVE
E 8TH ST
E 9TH ST
E 10TH ST
YORK ST
CENTRAL AVE
W 9TH ST
W 10TH ST
W 11TH ST
W 12TH ST
W 13TH ST
E 11TH ST
12TH ST
15TH ST
17TH ST
471
75

GIS DATA: SD1, NKAPC

N
0 650 1,300
Feet

Legend
- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

NEWPORT SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

NEWPORT

Total Area: 939 acres

Combined Sewer Overflows (Permitted CSOs)
- Number: 8

Contributing to Opportunities
- Drainage Area: 141.5 acres
- Annual Runoff (without roof): 57.2 MG

Strategies:
- Offloading
- Separate storm conveyance

Goals:
- Coordinate with future redevelopment projects to separate storm water from the combined system
- Direct separate storm water to existing natural conveyance
- Strategic separation to remove road runoff

The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities

GIS DATA: SD1, NKAPC

N

0 650 1,300

Feet

Legend

- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Green Street
- Detention
- Offloading
- Downspout Disconnection
- Stream Restoration
- Proposed Storm Sewers
- Drainage Area
- Diversion Structure

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY

GREEN INFRASTRUCTURE UPDATE

NEWPORT SUB-BASIN

OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

PLEASANT RUN

Total Area: 68 acres

Combined Sewer Overflows (Permitted CSOs)
Number: 2

Contributing to Direct Entry Points
Drainage Area: 4.2 acres
Annual Runoff: 1.3 MG

CSO #1730259

CSO #1730263

OAK ST
LAKE ST
PARK ST
LAUREL ST
PIKE ST
OAK ST
PLEASANT ST
MAIN ST
STEVE TANNER ST
PIKE ST
SHORT ST
ROHMAN AVE

GIS DATA: SD1, NKAPC

N

0 150 300
Feet

Legend

- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

PLEASANT RUN SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

PLEASANT RUN

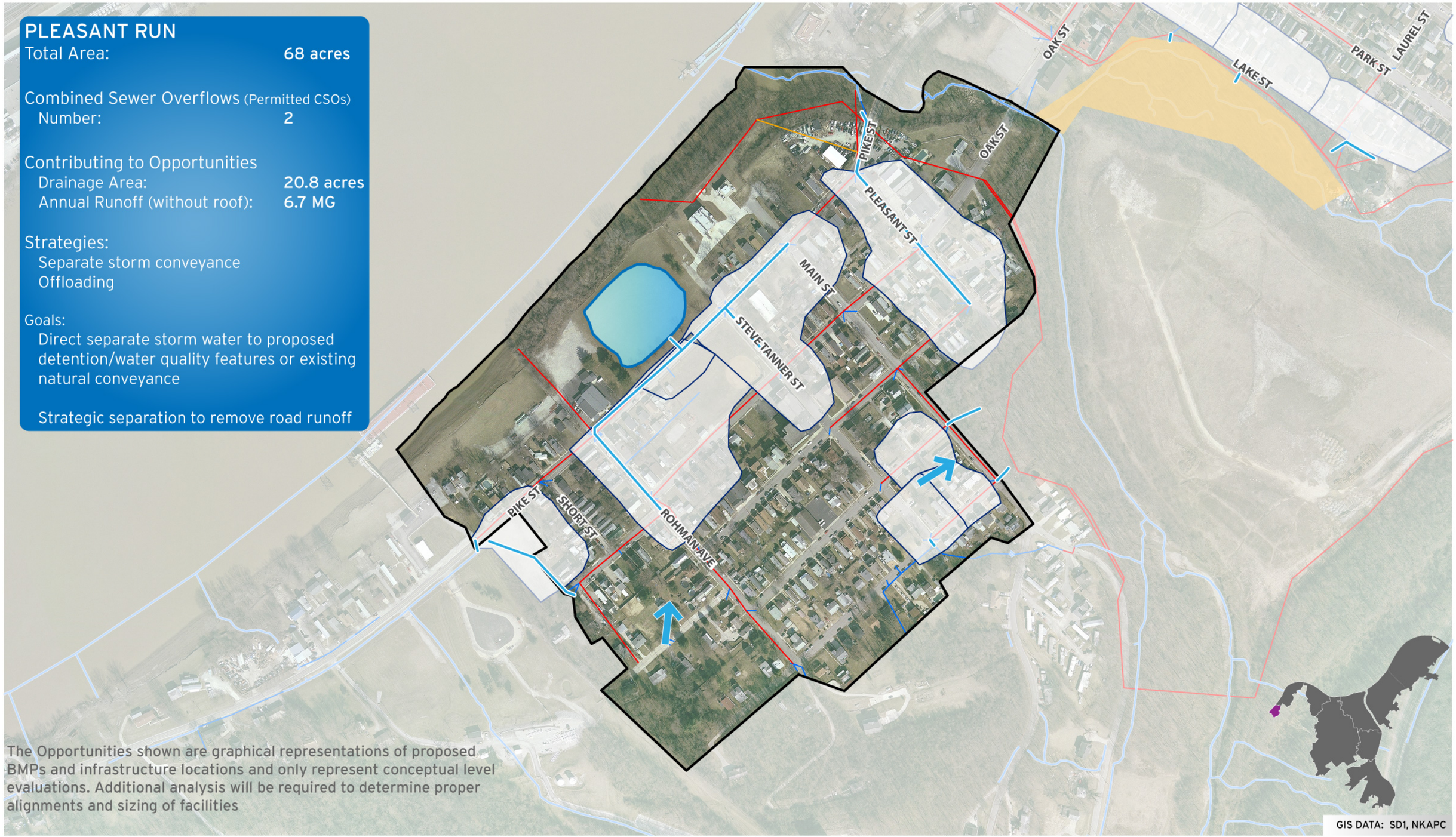
Total Area: 68 acres

Combined Sewer Overflows (Permitted CSOs)
- Number: 2

Contributing to Opportunities
- Drainage Area: 20.8 acres
- Annual Runoff (without roof): 6.7 MG

Strategies:
- Separate storm conveyance
- Offloading

Goals:
- Direct separate storm water to proposed detention/water quality features or existing natural conveyance
- Strategic separation to remove road runoff



The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities

GIS DATA: SD1, NKAPC

N

0 150 300

Feet

Legend

- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Detention
- Bioinfiltration
- Proposed Storm Sewers
- Drainage Area
- Stormwater Flow

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

PLEASANT RUN SUB-BASIN
OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

WILLOW RUN

Total Area: 1,871 acres

Combined Sewer Overflows)Permitted CSOs)
Number: 3

Contributing to Direct Entry Points
Drainage Area: 1,032 acres
Annual Runoff: 377 MG

CSO #1480187

CSO #1470089

CSO #1350155

RIVER
HIGHWATER
AMSTERDAM
ST JOHNS
DIXIE
HIGHLAND
PIKE
MAIN
5TH
SCOTT
GREENUP
MADISON
20TH
WALLACE
STERRETT
JAMES
30TH
DECOURSEY
75

GIS DATA: SD1, NKAPC

N

0 900 1,800
Feet

Legend

- CSO Existing
- CSO To be Permitted
- Direct Entry Point
- Combined Sewers
- Storm Sewers
- Drainage Channel
- Entry Point Drainage Basin

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY
GREEN INFRASTRUCTURE UPDATE

WILLOW RUN SUB-BASIN
EXISTING CONDITIONS OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

WILLOW RUN

Total Area: 1,871 acres

Combined Sewer Overflows (Permitted CSOs)
- Number: 3

Contributing to Opportunities
- Drainage Area: 1,358.6 acres
- Annual Runoff (without roof): 423.5 MG

Strategies:
- Downspout disconnection
- Separate storm conveyance
- Offloading

Goals:

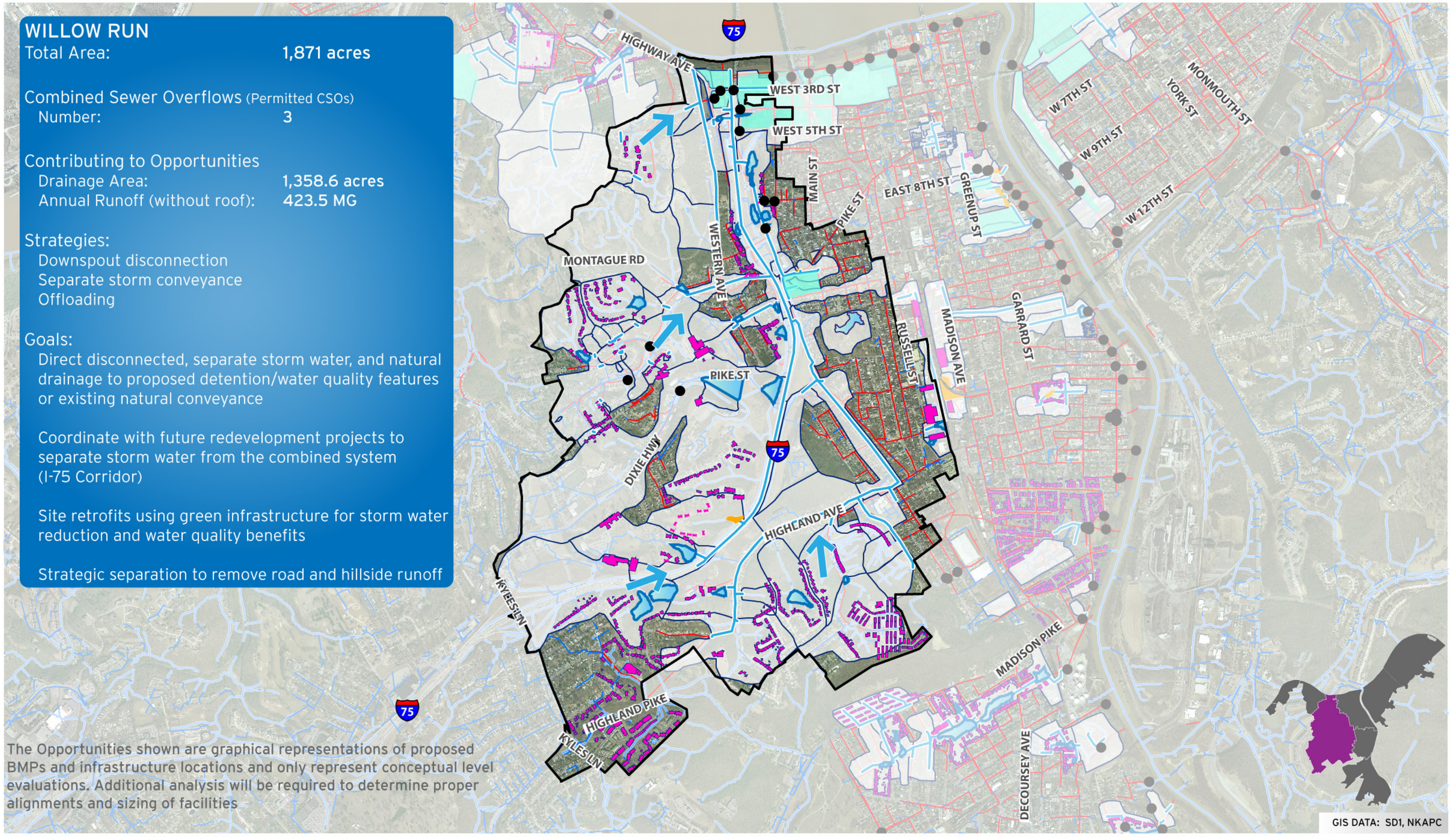
Direct disconnected, separate storm water, and natural drainage to proposed detention/water quality features or existing natural conveyance

Coordinate with future redevelopment projects to separate storm water from the combined system (I-75 Corridor)

Site retrofits using green infrastructure for storm water reduction and water quality benefits

Strategic separation to remove road and hillside runoff

The Opportunities shown are graphical representations of proposed BMPs and infrastructure locations and only represent conceptual level evaluations. Additional analysis will be required to determine proper alignments and sizing of facilities



N

0 900 1,800

Feet

Legend

- Existing Combined Sewers
- Existing Storm Sewers
- Existing Drainage Channel
- Detention/Retention
- Offloading
- Bioinfiltration
- Downspout Disconnection
- Drainage Area
- Proposed Storm Sewers
- Stormwater Flow
- Diversion Structure

SANITATION DISTRICT NO.1 OF NORTHERN KENTUCKY

GREEN INFRASTRUCTURE UPDATE

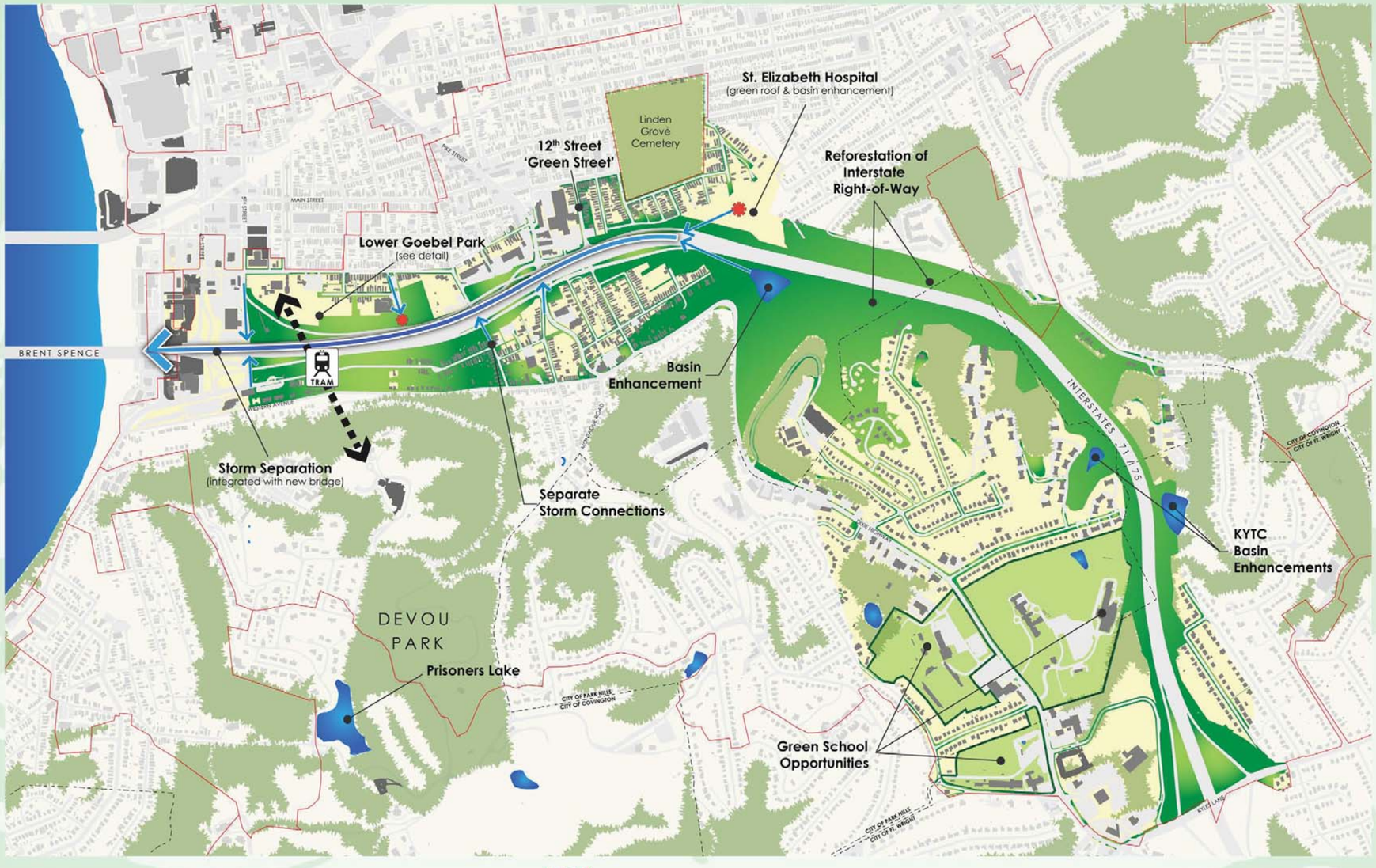
WILLOW RUN SUB-BASIN

OPPORTUNITIES OVERVIEW

HUMAN NATURE

STRAND ASSOCIATES, INC. ENGINEERS

COMBINED SEWER SYSTEM willow run study area



legend

- Stormwater directed to storm separation
- Jurisdictional boundary
- Sewershed boundary
- Basin/storage opportunities
- Green school opportunities

N

feet 0 500 1,000

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components

Green infrastructure is not only a cost-effective and sustainable approach to stormwater management, but also provides possibilities for improving the quality of life in Northern Kentucky. Along with reducing the frequency and volume of combined sewer overflows (CSOs), green infrastructure can help restore natural systems in highly-urbanized areas such as the Willow Run Study Area, site of an historic stream by the same name.

REFORESTATION

There are 227 acres of right-of-way in the Willow Run Study Area. Adaptive reforestation techniques along interstate right-of-way will help capture and infiltrate stormwater, while creating a unique and innovative green highway corridor through Northern Kentucky.

GOEBEL PARK STORMWATER WETLAND

Green infrastructure can transform Goebel Park into 'Kentucky's Green Gateway'. A proposed wetland park can help remove stormwater from the combined sewer system, improve water quality, and create a valuable recreational amenity for the entire region.

RETROFIT EXISTING STORMWATER BASINS

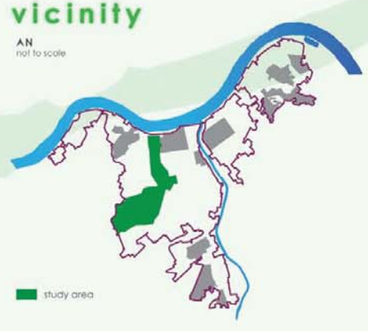
Detention basins located in the interstate corridor provide highly-visible opportunities for integrating green infrastructure. Retrofitting existing overflow structures can help capture and infiltrate stormwater, ultimately reducing the volume that reaches the combined sewer system. Integrating natural plant species and filtering sediment will help improve the quality of water that is discharged from these basins to the Ohio River.

STRATEGIC PARTNERSHIPS

Engaging public and institutional agencies helps create green infrastructure programs that have the momentum to survive future changes in government and program priorities. Collaboration with local stakeholders, such as students and teachers, should be an integral component of the green infrastructure strategy. There are 241 acres of public and semi-public properties located in the Willow Run Study Area.

vicinity

AN
not to scale



COMBINED SEWER SYSTEM kentucky's 'green gateway' at goebel park

legend

- Pedestrian-Neighborhood connections
- Wetland vegetation
- Reforestation areas
- Greenspace
- Elevated boardwalk
- Paved pedestrian trail

vicinity

AN
not to scale

N

feet
0 500 1,000

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COMBINED SEWER SYSTEM church street study area

components

Green infrastructure is not only a cost-effective and sustainable approach to stormwater management, but also provides possibilities for improving the quality of life in Northern Kentucky. Along with reducing the frequency and volume of combined sewer overflows (CSOs), green infrastructure can help restore natural systems and reconnect to the Banklick Creek.

STORMWATER SEPARATION & NEIGHBORHOOD INFILTRATION

Impervious surfaces cover 34 percent of the Church Street Study Area. Separating stormwater runoff from entering the combined system is possible through direct separation and a neighborhood infiltration network. The infiltration network involves disconnecting residential downspouts and directing stormwater through rain gardens, bioswales, and to a stormwater wetland park.

RECREATIONAL OPPORTUNITIES

The heart of the green infrastructure solution for the Study Area is a 3.5-acre stormwater wetland park. This area is surrounded by a 0.8-mile pedestrian trail loop through restored habitat. Native wetland plants and amended soils provide a valuable, natural filter for stormwater before it flows directly into the Banklick Creek.

IMPROVED NEIGHBORHOOD CONNECTIVITY

Two neighborhood connections are proposed in the Church Street Study Area. These connections will fully integrate the residential area with the Bill Cappel Sports Complex, as well as a 1.3 mile proposed pedestrian trail loop.

vicinity

legend

- Bioswale
- Pedestrian trail
- Jurisdictional boundary
- Separated stormwater pipes
- Proposed stormwater street inlets
- Potential green roof
- Roofs diconnected from sanitary system
- Study area (154 acres)

N

feet 0 250 500

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Appendix 3-C

Watershed Control Measures Opportunity Analysis

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TECHNICAL MEMO:
WATERSHED CONTROL MEASURES OPPORTUNITY ANALYSIS FOR PRIORITY NORTHERN KENTUCKY WATERSHEDS

March 25, 2011

Prepared for:

Sanitation District No. 1
1045 Eaton Drive
Ft. Wright, KY 41017

LimnoTech
Water | Environment | Scientists | Engineers

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SECTION 1. INTRODUCTION

The term "watershed control measure" is used to describe a project or program that is intended to reduce or prevent pollutant loading to waterways from storm water runoff or other non-overflow sources in the watershed. The emphasis on pollutant reduction differentiates these controls from green infrastructure which is primarily focused on mitigating hydrologic impacts. Watershed control projects could include retention basins, constructed wetlands, bioretention systems, biofiltration systems, or other controls designed for pollutant reduction. These measures are meant to complement wet weather point source control measures, such as combined sewer overflow (CSOs) and sanitary sewer overflow (SSOs) controls. The Consent Decree for Sanitation District No. 1 of Northern Kentucky (SD1) states that:

> "If Watershed Plans identify…nonpoint sources…that are contributing to water quality impairment…the Watershed Plans shall also identify planned control measures…to offset the level of CSO controls or to delay the elimination of an SSO…"

Monitoring data of the SD1 service area has demonstrated significant non-CSO/SSO bacteria loading. Based on this monitoring data and the provision in the Consent Decree, SD1 undertook an analysis to identify opportunities for watershed control measures and to evaluate the potential benefits and costs of these opportunities. Because the identification and assessment of watershed controls was driven by the Consent Decree, the following guiding principles were identified for watershed controls:

- Focus on bacteria control; and
- Consider wet weather control first, then evaluate dry weather flow controls.

The identification of watershed control opportunities is an outgrowth of the "watershed approach" supported by SD1 that emphasizes a holistic approach to water quality improvement in Northern Kentucky. This memo presents a detailed description of the methods and findings of SD1's watershed control opportunity analysis.

1.1 Objectives

SD1 supports a watershed approach to water resource management, which is endorsed in USEPA's Watershed Approach Framework, "…makes good sense for environmental, financial, social, and administrative reasons."[1] In the context of SD1's watershed planning process, the watershed approach includes identification and evaluation of measures to control sources of bacteria beyond CSOs and SSOs, since such measures can often be more cost effective and lead to greater water quality improvement. In addition, SD1's Consent Decree provides for the inclusion of control measures addressing nonpoint sources as potential offsets for CSO level of control. SD1's approach utilizes watershed control measures designed to reduce nonpoint sources that are also contributing to water quality impairment.

The objectives of the watershed control measure opportunity analysis were:

- To identify opportunities for a range of watershed control types;
- To assess the feasibility and water quality improvement potential of each type of watershed control measure; and

[1] http://www.epa.gov/owow/watershed/framework/ch5.html

- To identify which watershed control measure types should be included in SD1's watershed plans. based on the feasibility assessment of watershed control measure types; and
- To identify which watershed control measure types should be included in SD1's Watershed Plans, based on the feasibility assessment.

1.2 Types of Watershed Controls

The following major types of watershed controls were considered in SD1's overall watershed planning process:

- Regional Watershed Controls: These are relatively large opportunities for retention basins or constructed wetlands, typically with upstream drainage areas greater than one square mile. Two major forms of regional watershed controls were considered: instream and side-stream.
- Decentralized Watershed Controls: These control measures are somewhat smaller than regional controls and consist of storm water wetlands, bioretention/biofiltration basins (i.e. modified detention basins), enhanced retention basins, and similar controls treating smaller drainage areas, typically less than one square mile.
- Stream Restoration: Stream restoration, consisting of creating "naturalized" instream pools & meanders to increase residence time to promote bacteria die-off. Additionally, riparian buffers were also evaluated as part of the overall stream restoration evaluation.

Each of these watershed control measure types is discussed in detail in Sections 2 through 4.

1.3 Watershed Prioritization

The SD1 study area is comprised of sixteen watersheds, covering an area of 592 square miles (Figure 1.1). These watersheds range in size from 4.2 to 170 square miles and contain approximately 500 miles of named streams and several thousand miles of unnamed tributaries. Implementation of watershed controls throughout this vast area within the first Watershed Plans is impractical. Therefore, watersheds were prioritized based on the estimated annual CSO volumes within the watersheds. This focus on CSOs in prioritizing watersheds is a practical approach based on the "delay and offset" clause of SD1's Consent Decree. In this first round of watershed planning, only watersheds whose waterways receive CSOs were considered for siting of watershed controls, although some of the spatial opportunity analyses were conducted across the entire study area.

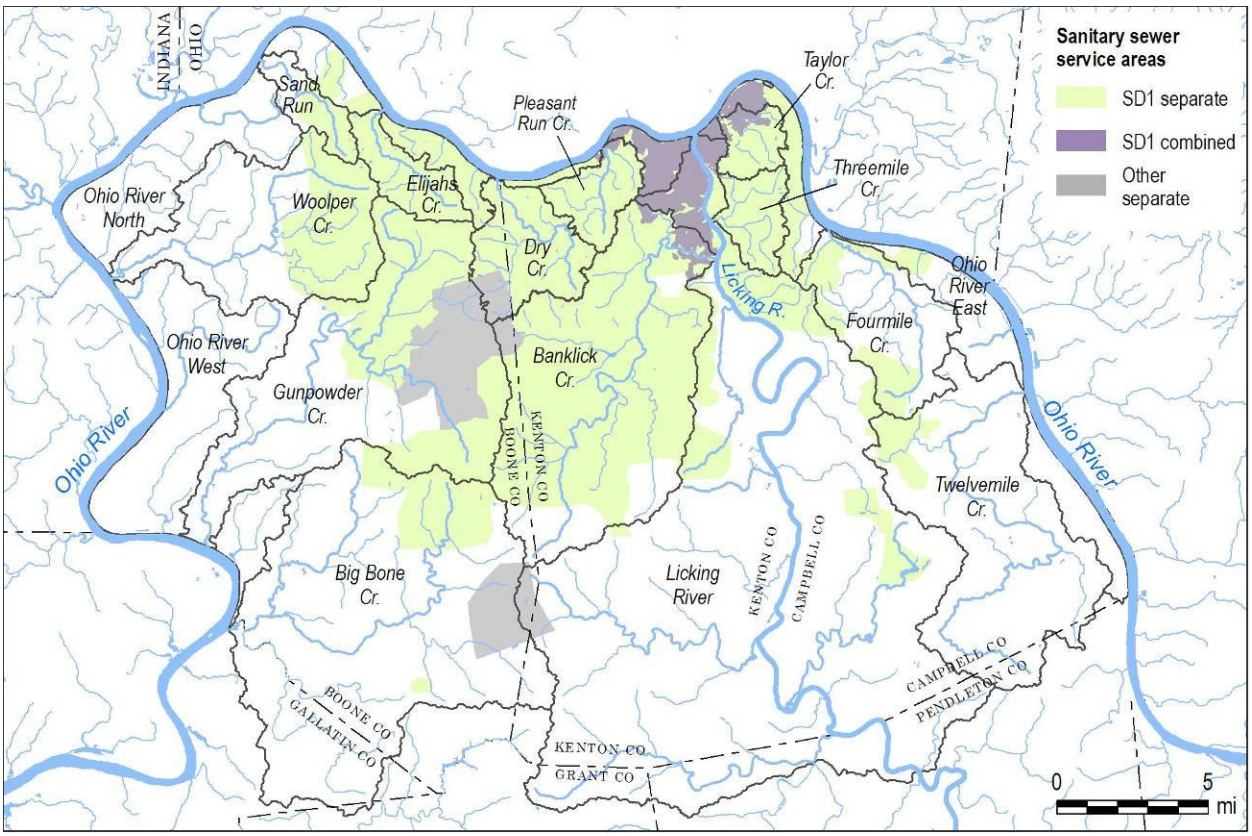

Figure 1.1 Watersheds in the Northern Kentucky Study Area (June 2009)

Table 1.1 summarizes information on CSOs in each watershed, including the modeled CSO volumes in the typical year and the rankings based on these values. SD1's Watershed Assessment Tool (WAT!) was also used to estimate total bacteria loads from each watershed as a secondary consideration.

Seven watersheds contain CSOs (Table 1.1) and were the focus of the watershed control opportunity analysis in this round of watershed planning. An eighth watershed, Threemile Creek, was also included because, although it does not contain any CSOs, it flows into the Licking River, which does receive CSOs. The following eight watersheds were targeted for identification of watershed controls in the first Watershed Plans:

- Banklick Creek
- Fourmile Creek
- Licking River
- Ohio River East
- Ohio River North
- Pleasant Run Creek
- Taylor Creek
- Threemile Creek

Table 1.1 Watershed Prioritization Factors

Watershed	CSO Typical Year Spill Vol. (MG)[2]	CSO Volume Rank	Elevated Bacteria During Dry Weather	Overall Bacteria Load Ranking from WAT!
Banklick Creek	58.8	4	X	7
Big Bone Creek	-	-		12
Dry Creek	-	-	X	5
Elijahs Creek	-	-		8
Fourmile Creek	2.4	7	X	10
Gunpowder Creek	-	-	X	13
Licking River[1]	731.4	2	X	9
Ohio East Tributaries[1]	275.6	3		3
Ohio North Tributaries	793.6	1		1
Ohio West Tributaries	-	-		16
Pleasant Run Creek	2.7	6	X	6
Sand Run	-	-	X	15
Taylor Creek	8.4	5	X	2
Threemile Creek	-	-	X	4
Twelvemile Creek	-	-	X	11
Woolper Creek	-	-		14
Total	**1,872.9**	**-**	**-**	**-**

[1] Includes drinking water intakes

[2] Model calculations are current as of June 2009.

Within the eight priority watersheds, the bacteria sources were modeled with the watershed assessment tool (WAT!) for Northern Kentucky. The results from WAT! indicate that the major sources of bacteria are CSOs, SSOs, and storm water runoff. As seen in Figure 1.2, runoff (nonpoint source loading) is a significant source of bacteria in all of the watersheds, underscoring the importance of controlling these sources with watershed control measures.

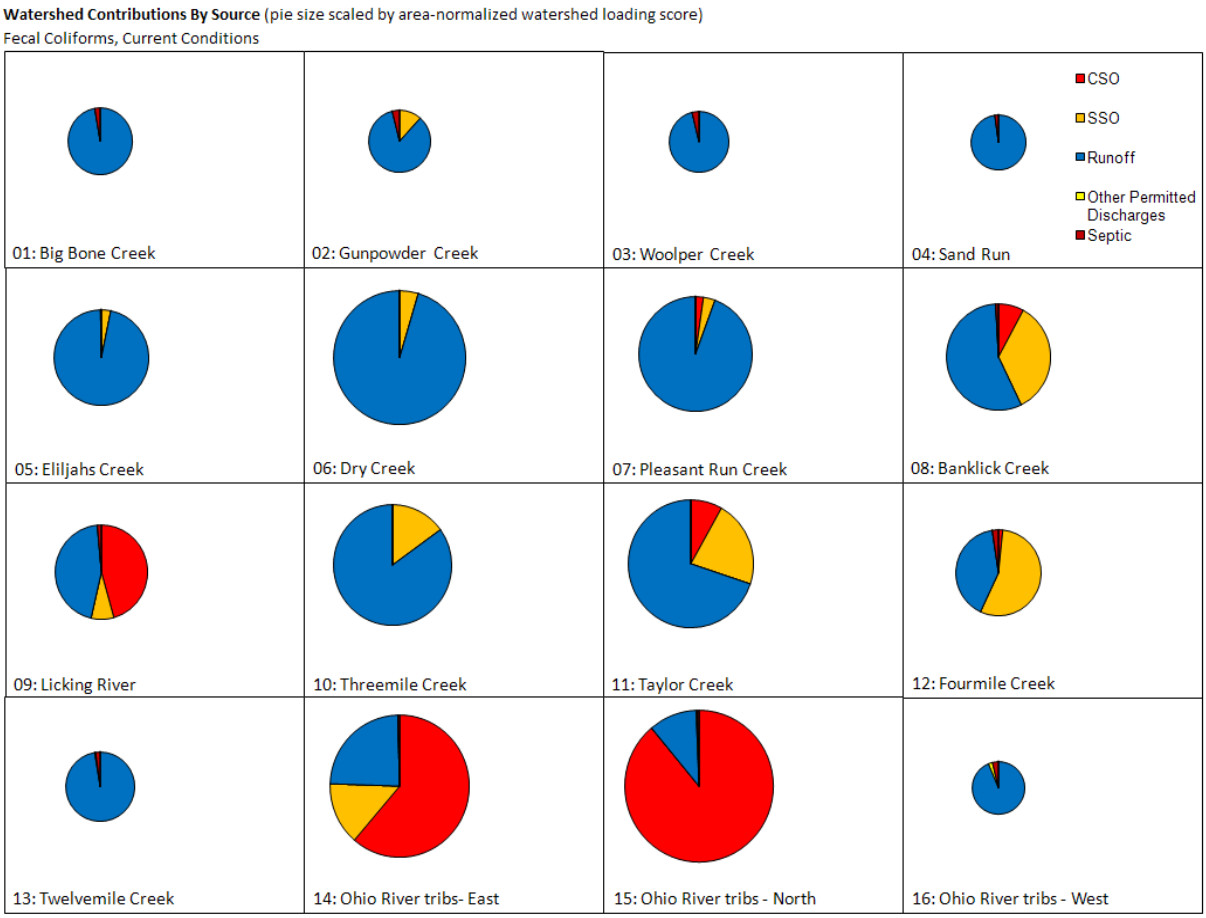

Figure 1.2 WAT! Area-Normalized Results Indicating Fecal Coliform Impact

1.4 Evaluation of Potential Benefits of Watershed Controls

SD1 has developed water quality models as part of its watershed planning process and three of those models were used to evaluate the potential water quality benefits of the regional and decentralized watershed controls. These models are described below.

1.4.1 Banklick Creek Watershed Model

The Banklick Creek watershed model was developed using Hydrologic Simulation Program - Fortran (HSPF), an USEPA-supported watershed model. The model was originally developed in 2004 as part of a federal grant to develop and apply a Watershed Assessment Protocol to understand water quality problems on a watershed basis (LimnoTech, 2004). The model was updated to incorporate a more detailed land cover analysis and to link dry weather and wet weather loads to instream densities of bacteria. Calibration and validation of the model is discussed in Appendix 2-B of the Watershed Plans.

1.4.2 Ohio River Tributary Model

Ohio River tributary watershed model was developed using HSPF, for a 355-square mile area encompassing Twelvemile Creek, Fourmile Creek, Threemile Creek, Pleasant Run Creek, Dry Creek, Elijahs Creek, Sand Run, Woolper Creek, Gunpowder Creek, Big Bone Creek and several areas with direct drainage to the Ohio River. The model was developed to simulate bacteria load in storm water runoff, flow and bacteria routing through streams, and instream losses of bacteria. Calibration and validation of the model is discussed in Appendix 2-B of the Watershed Plans.

1.4.3 Model Assumptions and Limitations

The Banklick Creek and Ohio River tributary watershed models were used to evaluate the potential benefit of watershed controls for water quality improvement. It is important to note that these model calculations are estimates; the results presented here are based on a number of modeling assumptions and are not certain enough to represent predictive performance calculations. Several general assumptions and limitations should be noted with respect to the two HSPF models used for this analysis:

- HSPF is a lumped parameter model (e.g. it doesn't account for the specific locations of various land uses within subwatersheds). Instead, it lumps similar land uses together in the hydrologic and water quality calculations.
- HSPF assumes that the stage/storage characteristics of the stream channels within each subwatershed are constant.
- HSPF calculates flow and concentration at only the outlet of each subwatershed, not at locations within the subwatersheds. Because of this, the model is most useful to evaluate benefits of controls measures when the control is placed at subwatershed outlets. To simulate controls at other locations, it is necessary to reconfigure the model and further subdivide subwatersheds.

In addition to the general HSPF model limitations, there are additional model limitations specific to the Banklick Creek and Ohio River tributary HSPF models:

- Site-specific information was not available for many of the hydrological and water quality parameters in the model, including infiltration rates for land cover classifications, bacteria densities in runoff from undeveloped lands, and instream bacterial decay rates. In these cases, the parameters were specified using literature values and adjusted through the calibration process.
- Although there are multiple sources/mechanisms that can contribute to bacteria loads (e.g. failing septics, direct deposition by livestock, straight pipes, illicit connections), sources were input as a single load in the model with an oscillating magnitude that repeated every 5 days. The amplitude and period of the oscillation were used as calibration parameters so that the distribution of measured bacteria densities and frequency of exceedance of water quality standards observed in the data were reasonably reproduced.

One additional model limitation should be noted for the Banklick Creek HSPF model:

- SD1's storm water outfall water quality data showed that bacteria densities were lower in runoff from areas developed more recently. The build-up and wash-off parameters for developed land uses were set so that the calculated site mean bacteria densities generally

matched the "old" vs. "new" storm water outfall sampling data. "New" and "old" development areas were identified from census-reported age of dwelling information. These assignments, while methodical, used professional judgment to set the criteria defining "old" vs. "new". The Ohio River tributary model calibration was approached somewhat differently than the Banklick model. As a result, it was calibrated with a single build up/wash off parameterization that fell somewhere between the "old" and "new" values used in the Banklick model.

1.4.4 Watershed Assessment Tool

The WAT!, which is described in detail in Appendix 2-B of the Watershed Plans, was used in this analysis to evaluate the potential benefits of riparian buffers. The WAT! has been developed for the entire study area and its estimates represent annual loads of fecal coliform bacteria and nutrients based on source characteristics, including loading potential, slope, and proximity to streams. This information enables SD1 to evaluate relative impacts of pollutants on water quality and to examine relative contributions of different sources at the subwatershed, watershed, and regional scales. The WAT! has been used to prioritize watersheds for development of detailed models, to evaluate watershed control opportunities, and to provide a relative assessment of the benefits of the Five-year Improvement Program and Full System Bounding Analysis across all watersheds. The WAT! will continue to be further refined and developed to reflect updated monitoring data.

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SECTION 2. REGIONAL WATERSHED CONTROL MEASURES

In the SD1 watershed planning process, regional watershed control measures are relatively large opportunities for retention basins or wetlands, typically with upstream drainage areas greater than one square mile. Because regional control measures target relatively large drainage areas, they typically involve centralized interception and treatment of water in streams, both perennial and intermittent. In addition to water quality treatment, these controls have other benefits. For example, they are generally more natural looking in appearance than other control measures and they can provide habitat, as well as recreational and education opportunities. Two major forms of regional watershed controls were considered: instream and side-stream.

2.1 Regional Control Measure Technologies

2.1.1 Regional Retention Basins

Retention basins (or wet ponds) are designed to contain a permanent level of water at all times. Retention basins are a fairly common control measure and can be designed to treat a variety of storm events. They are often used to capture runoff from single sites, such as a residential subdivision or a commercial shopping center. In this study, the term "regional retention" is used to refer to retention basins that are designed to capture runoff from larger areas, such as subwatersheds. Because the retention basins maintain a standing pool of water, they provide treatment under non-storm conditions by increasing hydraulic residence time. Under wet weather conditions, the retention basins are designed to store a water quality volume for at least 24 hours.

By capturing runoff from larger land areas, regional retention basins can treat larger volumes of storm water. The ability of retention to treat pollution has been well studied. A literature review conducted as part of the SD1 watershed planning process (LimnoTech, 2011) found that retention basins had a treatment efficiency that ranged from 57% to 79% for fecal coliform removal, with a median of 69%. When siting a retention area, minimum drainage area and poorly draining soil are necessary to keep consistent water levels at all times (USEPA 1999b; USEPA 2006c). Removal estimates for other pollutants are summarized in Table 2.1.

Table 2.1 Retention Basin Pollutant Removal

Reference	Brief Description	Published Pollutant Removal %			
		TSS	Total P	NH_4-N	NO_3-N
Mallin et al. 2002	Wilmington, NC	-	-	83	63
Borden et al. 1998	High Point, NC	20 to 56	40 to 41	-64 to 2	16 to 66
Hossain et al. 2005	Spokane, Washington	68.1 to 99.4	-	-	-
USEPA 2006	Austin, Texas	54	46	-	45
USEPA 2006	Unqua, NY	60	45	-	-
USEPA 2006	Austin, Texas	92	80	-	-17

2.1.2 Regional Constructed Wetlands

Constructed wetlands are control measures designed to replicate and enhance the treatment processes that natural wetlands provide. There are several design variations for constructed wetlands. Surface flow (SF) and subsurface flow (SSF) constructed wetlands can be designed to function with either horizontal flow (HF) or vertical flow (VF). Careful choice of the different designs or combinations of them can allow for the treatment of a variety of pollutants. A literature review conducted as part of the SD1 watershed planning process found that constructed wetlands had a treatment efficiency that ranged from 54% to 89% for fecal coliform removal, with a median of 66%.

A key component of constructed wetlands is the hydraulic retention time (HRT). HRT represents the average length of time water is held in the constructed wetland. The aforementioned literature review (LimnoTech, 2011) found that, for wetlands with HRT of 2 days or less, treatment efficiencies were as low as ~30%, whereas for HRT greater than 2 days, treatment efficiencies were typically greater than 80%.

2.2 Forms of Regional Control Measures Considered

Two forms of regional watershed controls were evaluated in this analysis: instream controls and side-stream controls. Each of these forms is discussed below.

2.2.1 Instream Controls

Instream controls are retention basins or wetlands that rely on modification of an existing stream channel to create a wetland or basin overlaying a reach of the stream, with an impounded volume of water to increase hydraulic residence time and promote treatment. In the case of wetlands, a relatively small grade modification can be used in conjunction with lowering of the floodplain to create what is essentially an in-line wetland.

In the case of instream retention, the required stream modification is more extensive, consisting of construction of an earth dam across the stream channel to create an in-line impoundment that is six to ten feet deep. A typical cross-section of an instream retention basin is depicted in Figure 2.1.

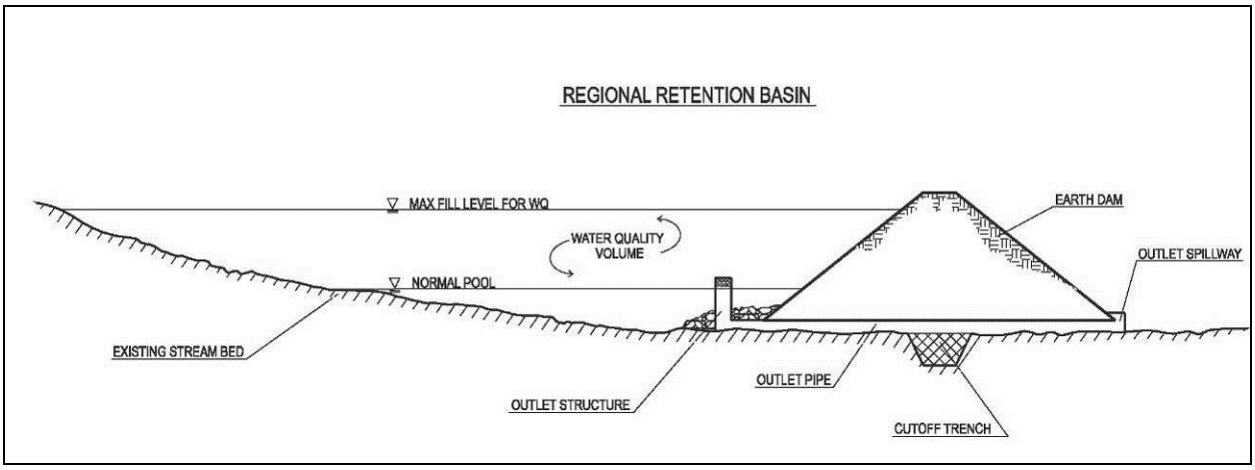

Figure 2.1 Typical Cross-Section of Instream Retention Basin

After discussing the concept of instream regional control measures with the Corps of Engineers and the Kentucky Division of Water, it became apparent that impacts of this form of regional control measure on the existing stream channel and the potential for negative impacts on stream biota would create significant permitting challenges. For this reason, SD1 decided not to pursue instream regional controls in this watershed planning cycle.

2.2.2 Side-Stream Controls

Side-stream control measures are an alternative to instream control measures, where water is diverted from an existing stream into a control measure that is built adjacent to the stream. The diversion of water can be accomplished by gravity or pumping and the side-stream control can be either a basin or a wetland. A conceptualized example of a side-stream constructed wetland is depicted in Figure 2.2.

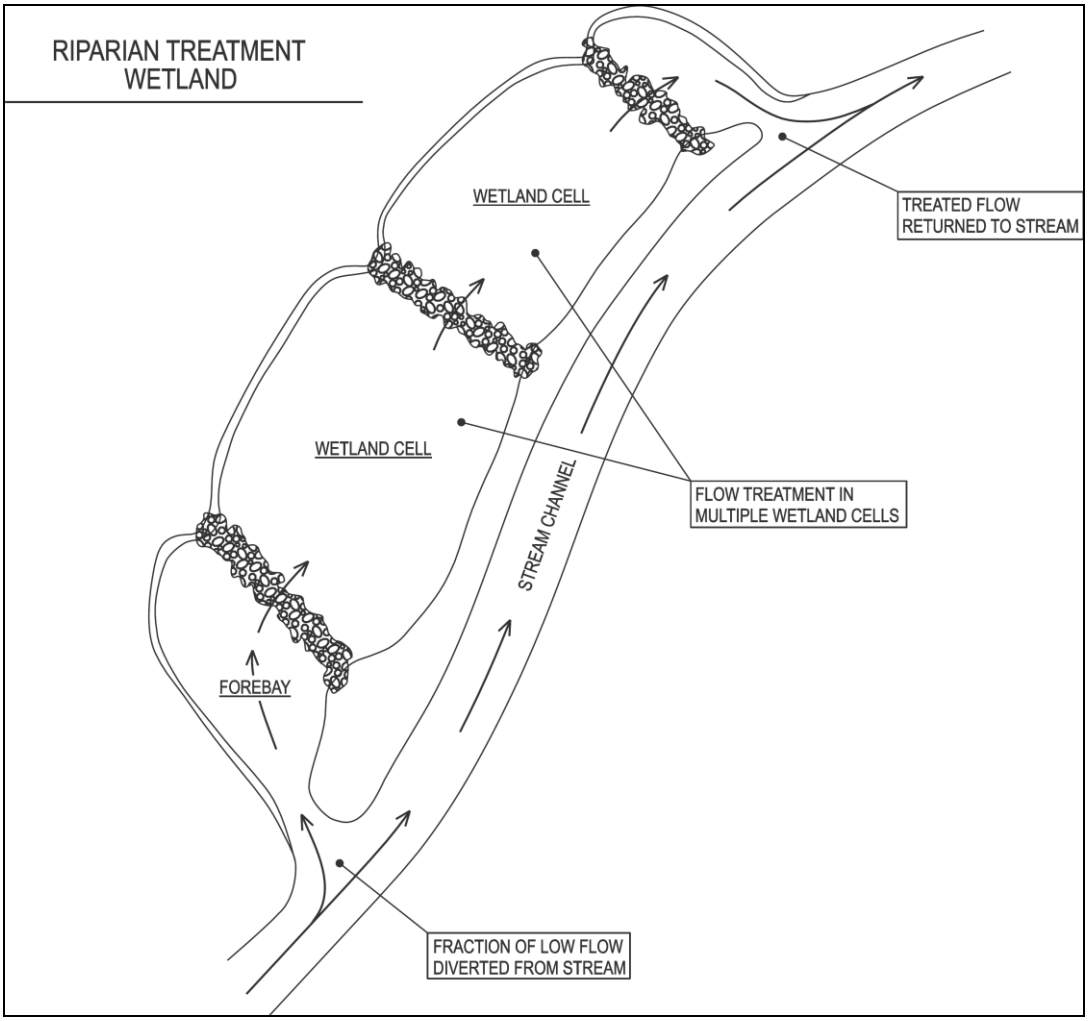

Figure 2.2 Conceptual Layout of a Side-stream Constructed Wetland

Because side-stream regional control measures have a relatively small impact on the stream channel, permitting challenges are relatively small. Therefore, the opportunity analysis proceeded with the side-stream concept for the source assessment and site identification portion of the analysis.

2.3 Regional Source Assessment

Although SD1 has not yet collected sufficient watershed monitoring data to clearly pinpoint specific sources, studies have shown that certain land uses generate higher bacteria loads in runoff than others. Based on this premise, three targeted land uses were identified: pasture agriculture, residential subdivisions, and public areas. Pasture agriculture is a significant nonpoint source of bacteria pollution due to livestock waste. Additionally, a large portion of the study area is known to contain agriculture. Residential subdivision aggregates were targeted due to the presence of domestic pets and suburban wildlife's potential to contribute to bacterial loading. Public areas were chosen due to the presence of domestic pets and suburban wildlife. The general approach developed to identify watershed control measure opportunities in the study area involved several steps:

- Reclassification of GIS data
- Screening of potential source areas
- Identification of opportunities to address potential source areas

The first two of these steps are discussed generally below, followed by a detailed discussion of the source area screening process for each watershed. The identification of specific opportunities in priority watersheds is discussed in detail in Section 2.5.

2.3.1 Reclassification of GIS Data

In order to effectively review and select control measures across the entire study area, a geographic information system (GIS) project was created with the parcel data from Boone, Kenton, and Campbell Counties. Due to inconsistencies with the parcel datasets, the data was modified and reclassified in a way that supported the identification of sources and opportunities within the watersheds.

Each of the parcel datasets contained ownership information and provided various land use classifications. However, the land use classification was often missing or inconsistent across the counties, and lacked the level of detail necessary to support specific source identification (e.g. it was unclear if an agricultural parcel was forested or pasture land, which can make a significant difference in the levels of bacteria present).

The three county parcel data reclassification combined traditional land use and land cover classifications into 31 categories that were selected with bacteria source and control opportunities in mind (Table 2.2).

Table 2.2 Reclassification of Parcels

Ag – AFO	County	Residential Multi Family
Ag - Forest and Shrub/Scrub	Federal	Residential Single Family Individual
Ag - Grassland/Herbaceous	Golf Course - Private	Residential Single Family Suburban Subdivision
Ag - Other Land Cover	Golf Course - Public	Residential Single Family Vacant
Ag - Pasture/Hay	Hunt Fish Lake Club	Residential Traditional Street Grid
Ag - Row Crops	Industrial	Sanitation District #1
Airport	N KY Water District	School Private
Cemetery	Park	School Public
Church	ROW	Stable
City	Residential Mobile Home	State
Commercial		

Reclassification of the parcel data began with a series of queries on the parcel owner name. Next, using a 2005 National Land Cover Data (NLCD) updated to 2007 conditions, agriculture land cover within the parcels was identified. Parcels with greater than 25% of their area composed of pasture/hay were classified “Ag-Pasture/Hay”. Additionally, if the largest single classification in

a parcel was pasture/hay the parcel was assigned the "Ag- Pasture/Hay" classification. Other agriculture classifications were assigned based on majority.

Finally, the residential parcels were classified using visual identification. Aerial imagery for each watershed was visually inspected to determine the residential classification of parcels. Parcels identified as residential single family suburban subdivision, residential single family vacant, and residential multi family were then aggregated. This process produced one parcel aggregate for an entire development/subdivision. It effectively reduced the number of source parcels to manageable units (Table 2.3) which were assumed to have centralized leadership in the form of homeowner associations. This grouping provided greater opportunity for control measure construction.

Table 2.3 Aggregation of Residential Parcels

Watershed	Residential Parcel Counts	
	Original Parcels	Aggregated Parcels
Banklick Creek	22,578	92
Fourmile Creek	1,897	40
Licking River	5,392	307
Ohio River East	2,550	34
Ohio River North	1,101	38
Pleasant Run Creek	2,816	65
Taylor Creek	4,763	38
Threemile Creek	3,318	36

2.3.2 Screening of Potential Source Areas

The goal of the screening process was to identify large contiguous areas of a key land uses for their potential as a bacteria source or for their potential as a site for a watershed control measure. The screening also determined areas, in each of the eight watersheds, where there was the maximum amount of land area with the minimal number of parcels, to help focus future analysis towards the most cost-effective locations.

The screening process first grouped the reclassified parcel data into three targeted categories: public, agricultural, and residential. Based on the assumption that property size was roughly analogous to runoff load, the parcels (and aggregated subdivisions) were then ranked by size.

A "knee-of-the-curve" analysis was used to further narrow the number of parcels that presented potential sources of bacteria pollution. This method involved the careful review of the size ranked parcel plots for each watershed by targeted source category. Based on the plots, cutoffs were identified at the point of diminishing returns. Cutoffs were chosen where the most source parcel area could be retained while keeping the least number of parcels. Often this occurred at natural breaks in the data. Parcels larger than this cutoff were considered to contain the most effective nonpoint sources and opportunities for control measure implementation[2].

[2] Regardless of parcel size, properties owned by SD1 were left in the analysis.

This approach effectively identified the largest land area coverage with the fewest properties (or property aggregates) for each of the land use types. A focus on these areas will likely yield a more effective benefit in controlling runoff loads.

2.3.3 Watershed-Specific Source Identification

Utilizing the approach defined in the above source area screening method, each watershed was analyzed for potential sources of wet weather bacteria pollution. This process resulted in the identification of 3,222 potential source areas representing 68,412 acres of land in the eight priority watersheds. Through the "knee-of-the-curve" methodology, the areas of focus were reduced to 356 potential sources (39,935 acres). 89% of the potential source areas were reduced and only 42% of the area was lost. A detailed discussion of the results for each priority watershed is found below.

Banklick Creek

The Banklick Creek watershed is located in center of the study area and crosses the boundary of Boone and Kenton counties. Within the watershed, 574 potential source parcels were identified in the GIS. Through the knee-of-the-curve method, this number was reduced to 86. As seen in Figure 2.3, the initial source areas were reduced in number by 85% while retaining 75% of the identified area.

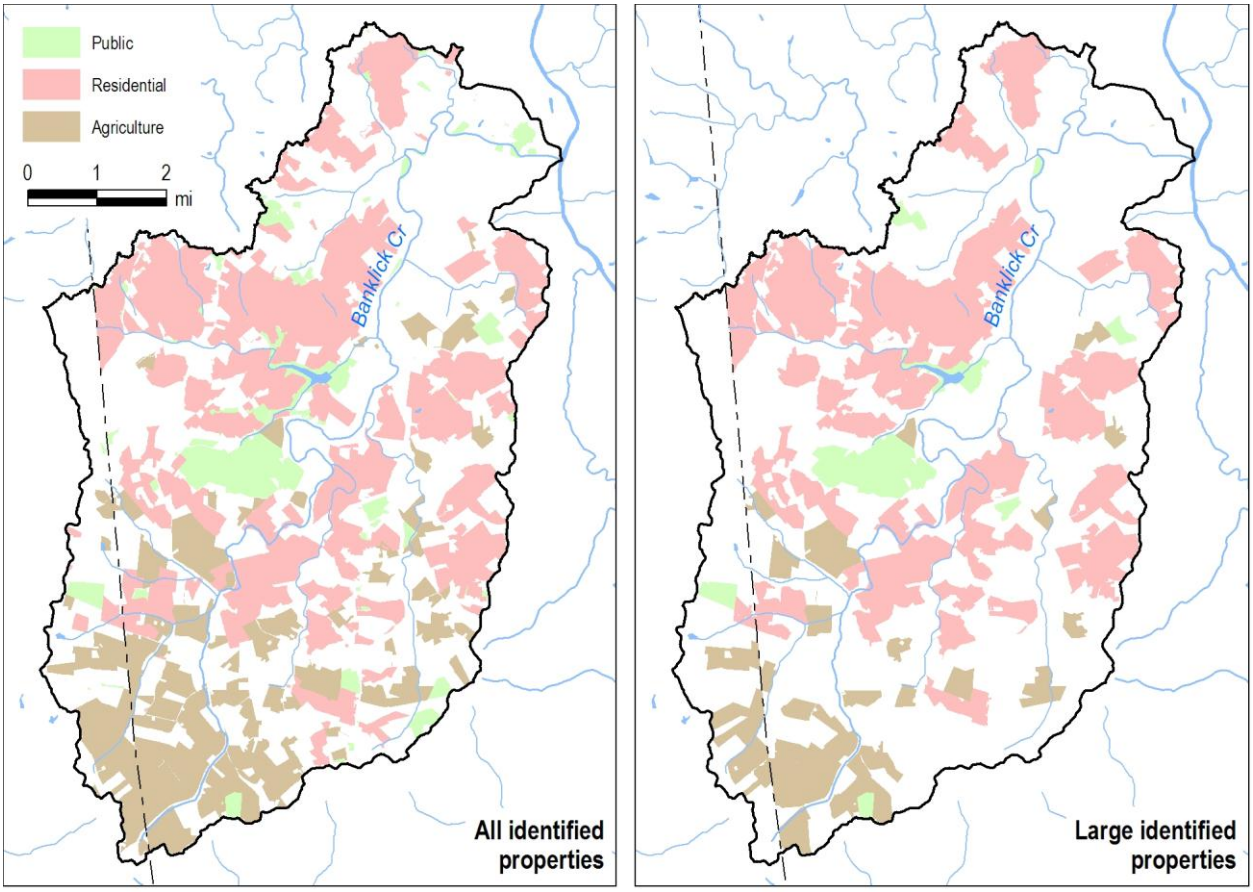

Figure 2.3 Banklick Creek Potential Source Parcel Identification

Agricultural Properties

Within the Banklick Creek watershed, 242 parcels representing 5,574 acres were identified as pasture/hay. The parcels were ranked by size and plotted in order to identify any natural cutoff values (Figure 2.4)[3]. Based on the knee-of-the-curve method, a 45 acre cutoff was chosen. This cutoff resulted in 41 potential source parcels (2,962 acres). 17% of the identified agriculture source parcels make up 53% of the agricultural source parcel area.

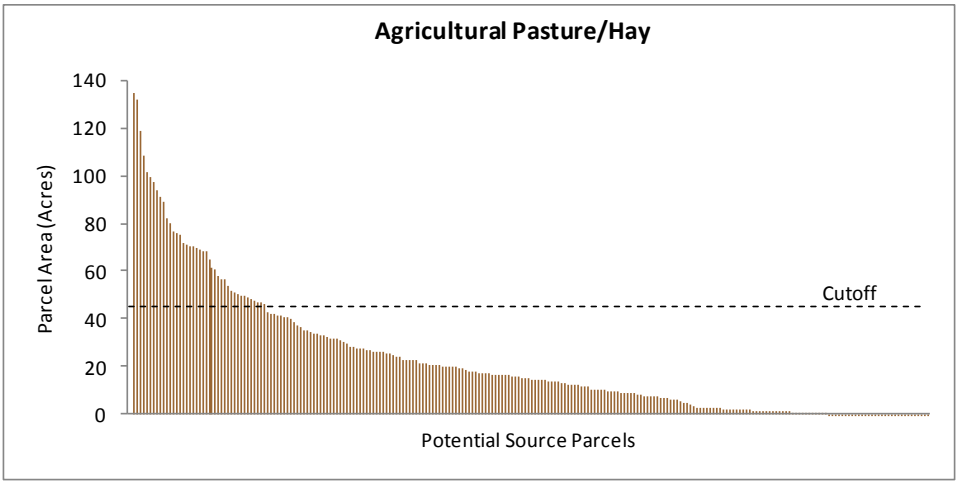

Figure 2.4 Banklick Creek Agricultural Source Parcels

Public Properties

240 public properties were identified in the Banklick Creek Watershed. These parcels combine to cover an area of 1,978 acres. The area ranked plot (Figure 2.5) indicated that the ideal size for a cutoff is 40 acres. This 40 acre cutoff resulted in 20 large parcels. These 20 parcels make up 8% of the identified public parcels in number and 62% of the area.

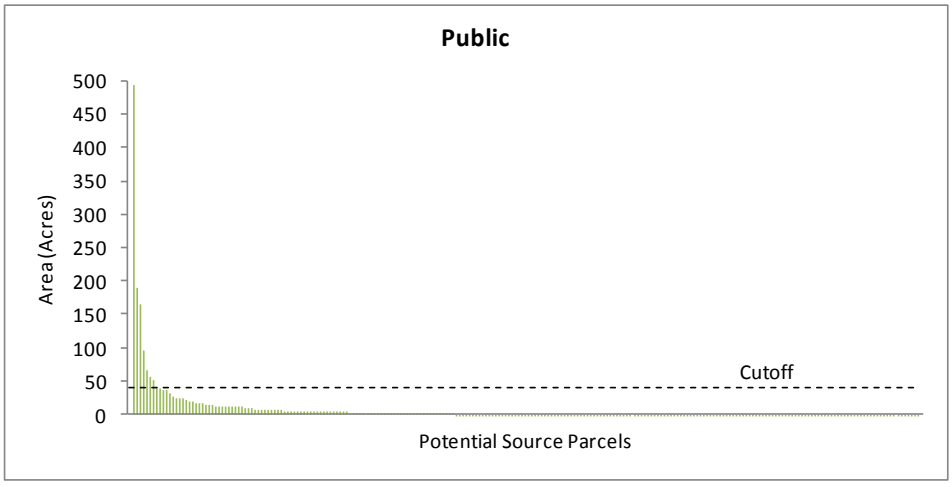

Figure 2.5 Banklick Creek Public Source Parcels

[3] For clarity of plots, unique parcel/aggregate identifiers are not shown. However each identified source parcel or parcel aggregate was assigned an ID for the analysis.

Residential Properties

The site identification process resulted in 92 residential parcel aggregates representing 10,588 acres of land. The ranked plot (Figure 2.6) indicated that that a cutoff of 100 acres would retain 88% of the residential area but reduce the number of parcel aggregates to 27%.

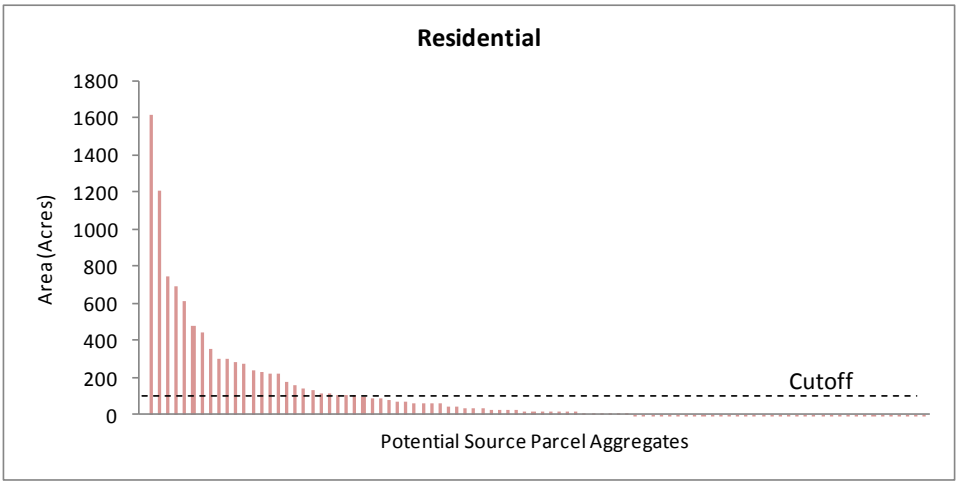

Figure 2.6 Banklick Creek Residential Source Parcel Aggregates

Fourmile Creek

Fourmile Creek is located in Campbell County and drains directly to the Ohio River. There were 150 potential source parcels identified covering an area of 2,942 acres. The knee-of-the-curve method reduced this number by 80% to 30 parcels or aggregated units (Figure 2.7). These 30 properties still represent 58% of the initially identified source area.

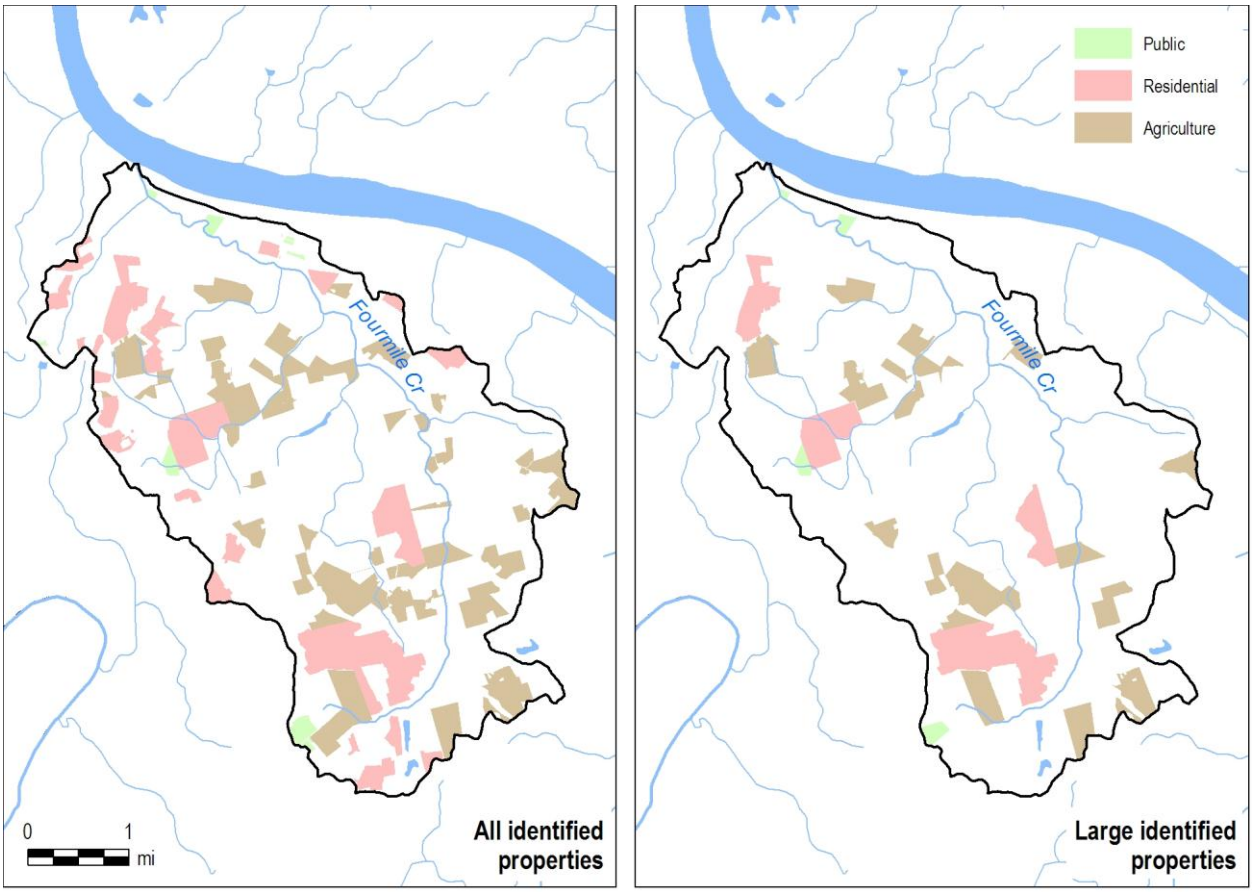

Figure 2.7 Fourmile Creek Potential Source Parcel Identification

Agricultural Properties

There were 84 agricultural parcels identified in the Fourmile Creek watershed. These parcels covered an area of 1,604 acres. A cutoff of 30 acres was chosen based on the ranked area plot (Figure 2.8). The 30 acre cutoff reduced the number of potential parcels to 20. These 20 parcels represented 24% of the identified agricultural parcels and 59% of the area.

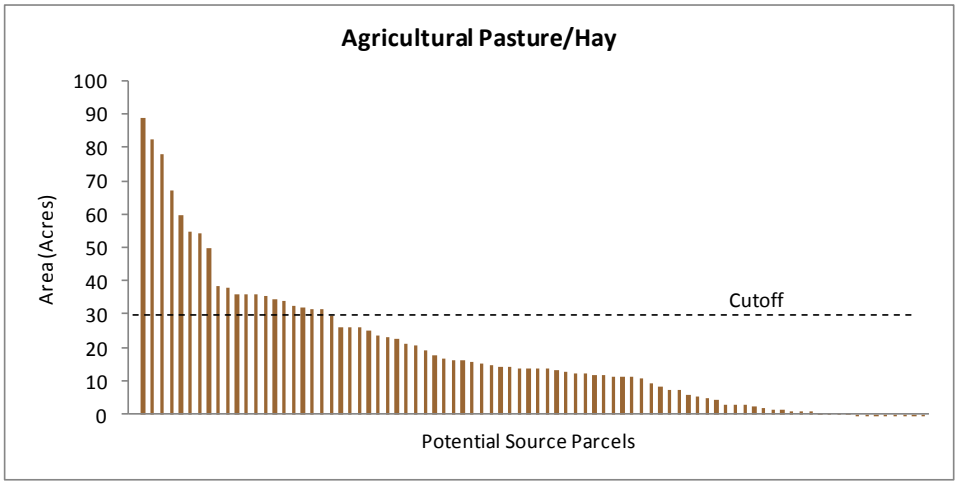

Figure 2.8 Fourmile Creek Agricultural Source Parcels

Public Properties

Within Fourmile Creek, there were 26 public parcels with a total land area of 91 acres. The size ranked plot (Figure 2.9) indicated that the best cutoff choice was 18 acres. The parcels above this cutoff value represent 19% of the public properties and 73% of the public property area.

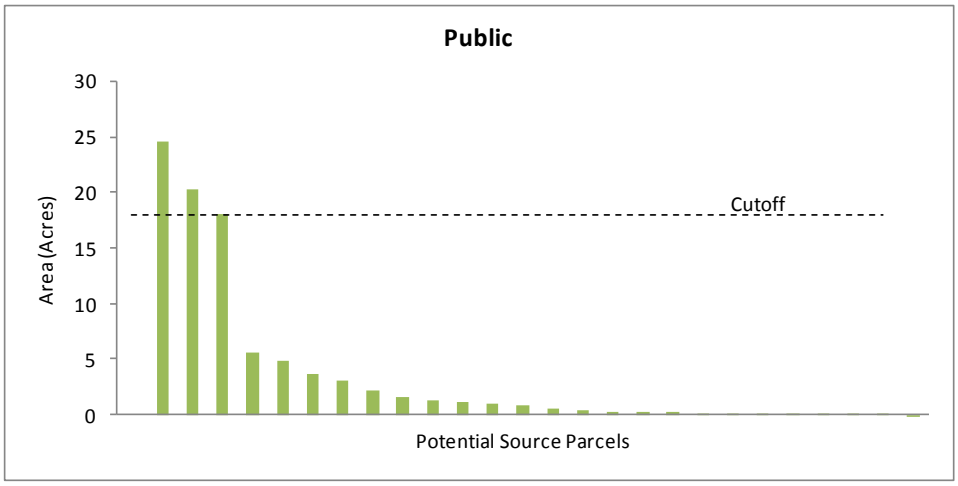

Figure 2.9 Fourmile Creek Public Source Parcels

Residential Properties

There were 40 residential property aggregates representing 1,247 acres in the Fourmile Creek watershed. The resulting area ranked plot (Figure 2.10) indicated that a 70 acre size cutoff resulted in 5 large parcel aggregates. These 5 parcel aggregates account for 13% of the residential properties and 63% of the residential property area.

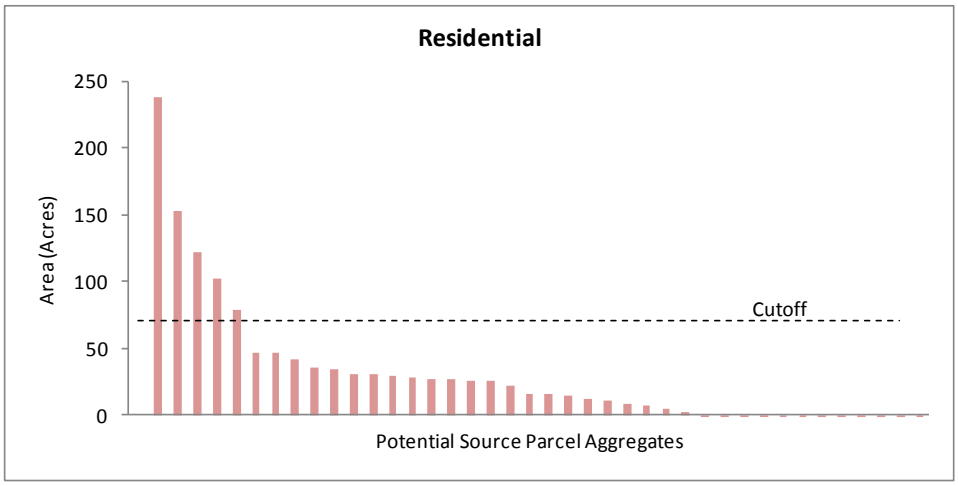

Figure 2.10 Fourmile Creek Residential Source Parcel Aggregates

Licking River

The Licking River watershed is the largest of the watersheds in the study area. 1,749 parcels and aggregated residential units were initially identified. Through the knee-of-the-curve process this number was reduced by 92% while still retaining 44% of the identified area. This reduction is seen in Figure 2.11.

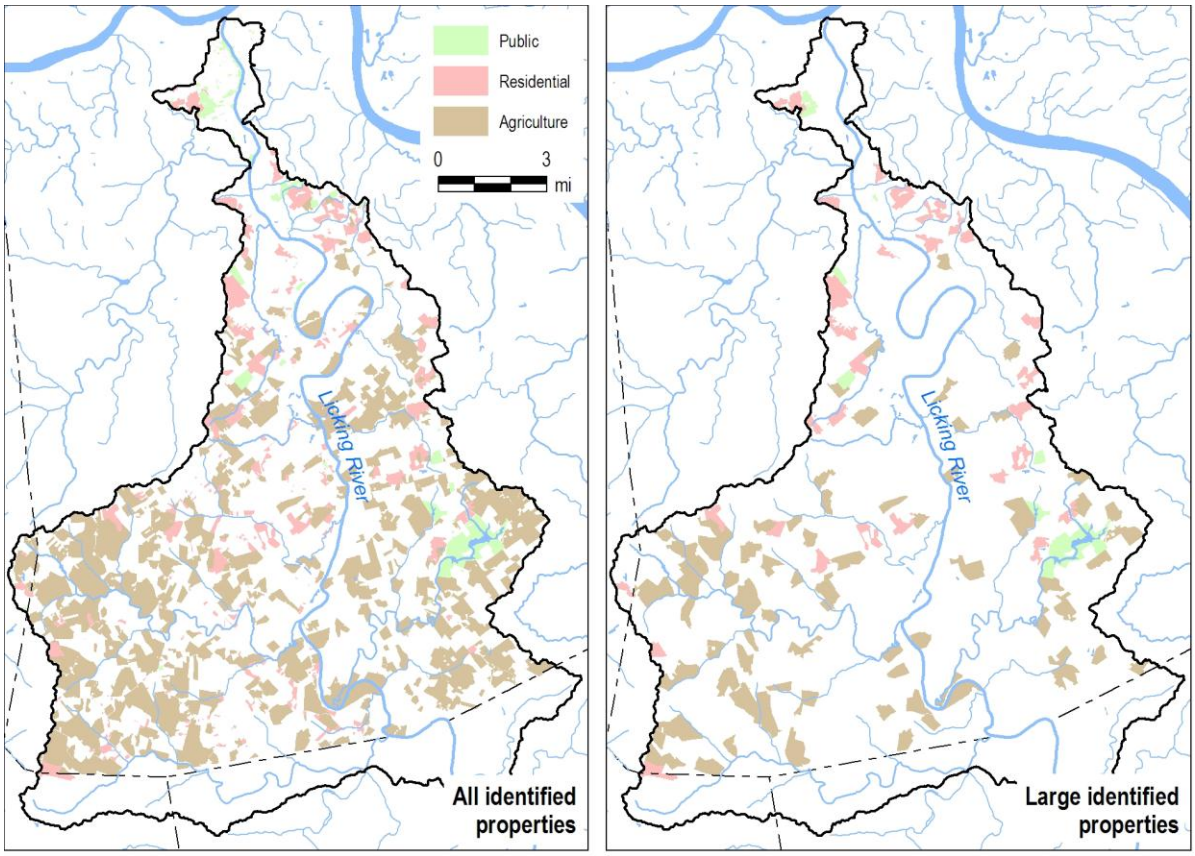

Figure 2.11 Licking River Potential Source Parcel Identification

Agricultural Properties

There were 1,008 parcels (26,946 acres) of pasture in the Licking River watershed. Once plotted by parcel size (Figure 2.12), it was possible to see that a 70 acre cutoff would significantly decrease the targeted parcels to 93. These 93 parcels represent 9% of the agricultural properties and 37% of the originally identified area.

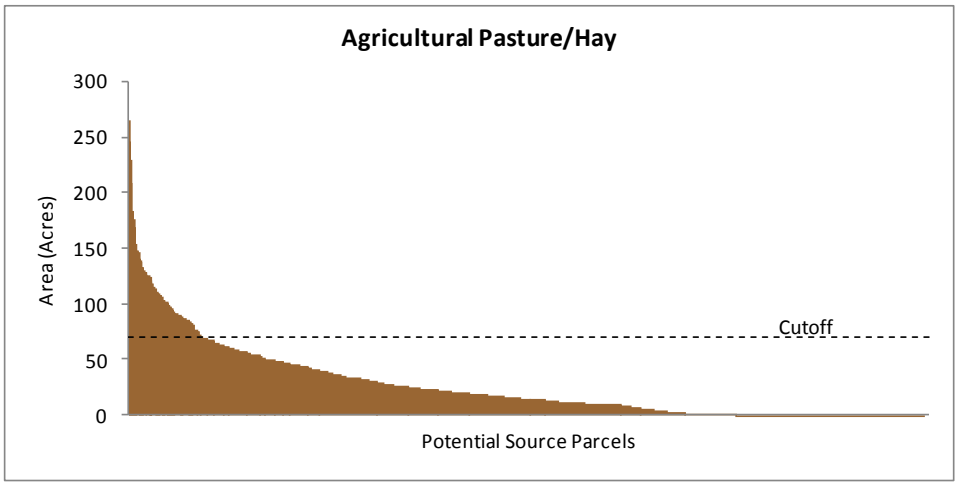

Figure 2.12 Licking River Agricultural Source Parcels

Public Properties

In the Licking River watershed, 434 public parcels were identified. The parcels (1,967 acres) were ranked by size and plotted (Figure 2.13). Based on the plot, a cutoff value of 60 acres was chosen. Seventeen parcels are larger than this cutoff. These selected parcels represent 4% of the public parcels and 65% of the area.

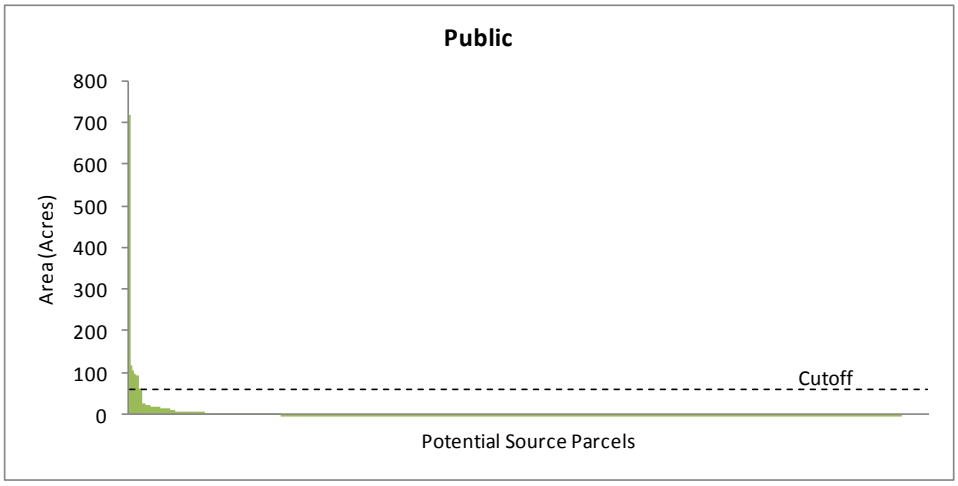

Figure 2.13 Licking River Public Source Parcels

Residential Properties

There were 307 residential aggregates identified in the Licking River watershed. These residential areas (3,344 acres) were ranked by size and plotted (Figure 2.14). A cutoff of 50 acres was chosen and reduces the focus property aggregates to 29. These 29 property aggregates correspond to 9% of the identified residential areas and 63% of the area.

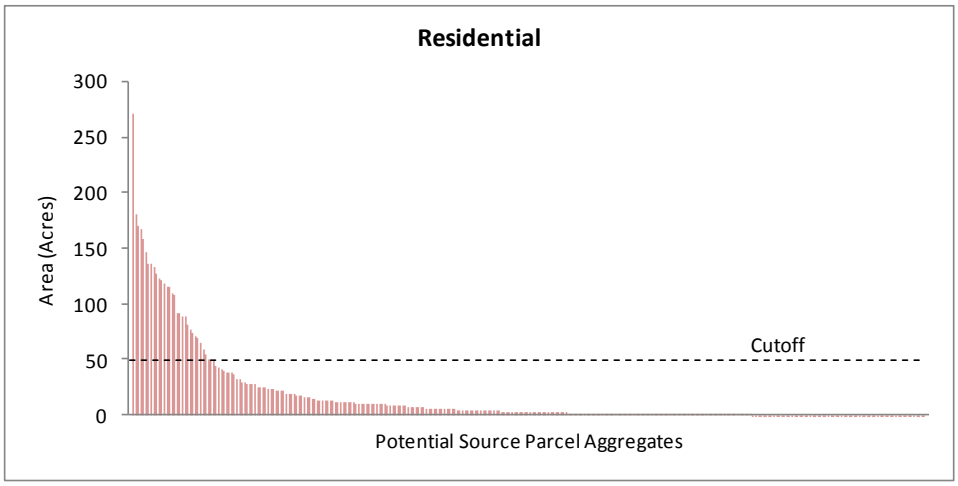

Figure 2.14 Licking River Residential Source Parcel Aggregates

Ohio River East

In the Ohio River East watershed a total of 179 potential source parcels were identified. These parcels covered an area of 3,447 acres and were located throughout the watershed (Figure 2.15). The knee-of-the-curve process reduced the parcel count by 80% while still retaining 65% of the original area.

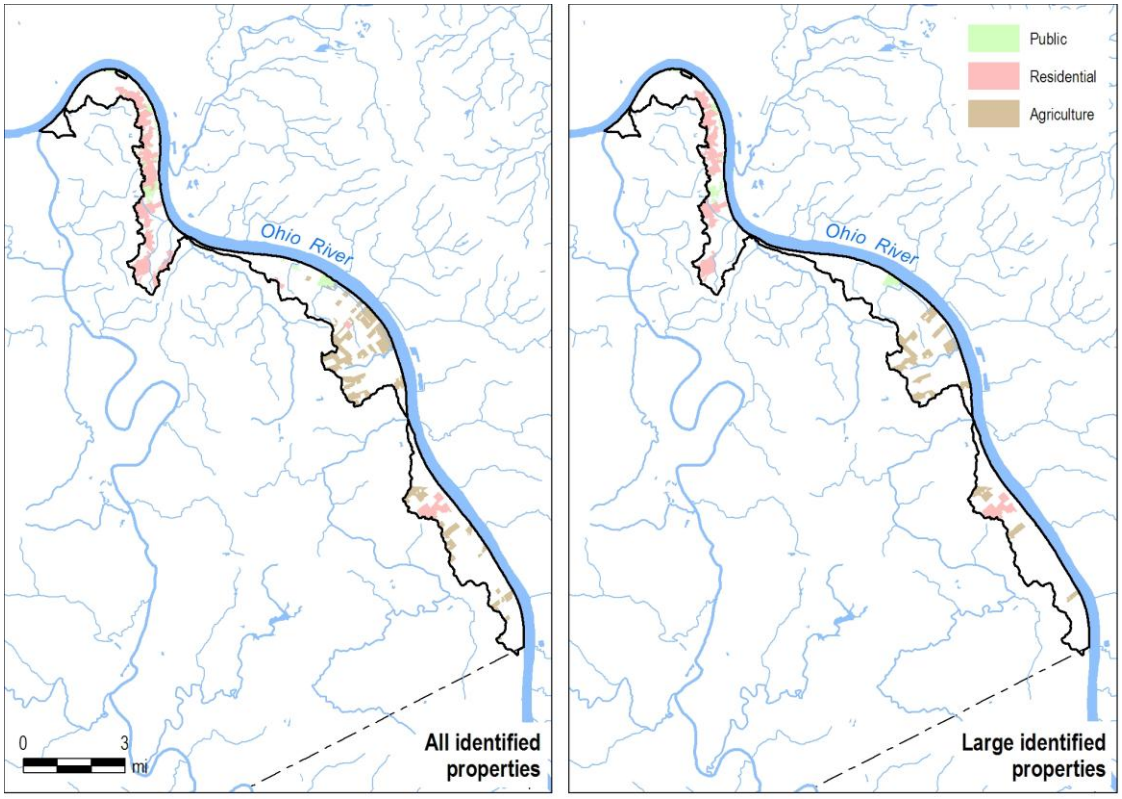

Figure 2.15 Ohio River East Potential Source Parcel Identification

Agricultural Properties

There were 78 agricultural pasture/hay parcels identified in the Ohio River East watershed. The ranked area plot (Figure 2.16) resulted in a cutoff selection of 30 acres. By choosing this cutoff, the number of agricultural pasture/hay parcels was cut to 18 while still retaining 55% of the originally identified area.

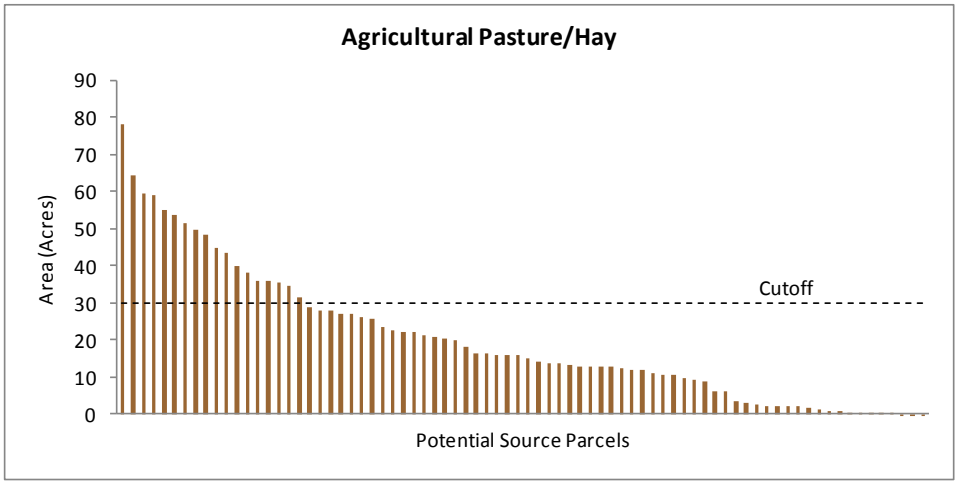

Figure 2.16 Ohio River East Agricultural Source Parcels

Public Properties

There were 67 public properties identified as potential source parcels. These properties represent 340 acres throughout the watershed. Based on a 10 acre cutoff (Figure 2.17), the number of public properties was reduced to 10 (274 acres). This smaller subset of source parcels still represents 81% of the originally identified area.

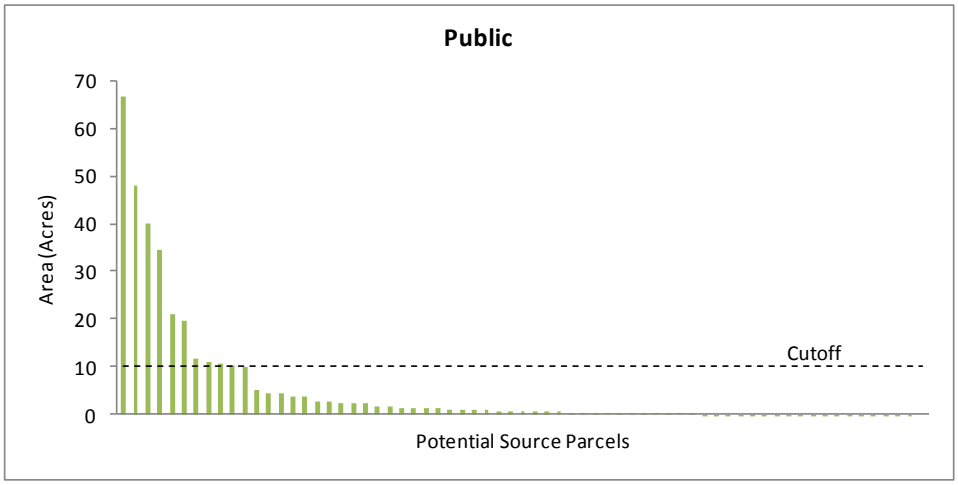

Figure 2.17 Ohio River East Public Source Parcels

Residential Properties

In the Ohio River East watershed, 34 aggregated parcels, covering an area of 1,532 acres were identified. After plotting the aggregated parcels by size (Figure 2.18), a 100 acre cutoff was chosen. This cutoff resulted in 7 large aggregated units. The knee-of-the-curve process showed that the selected 7 sources represent 21% of the parcels by count and 72% of the area.

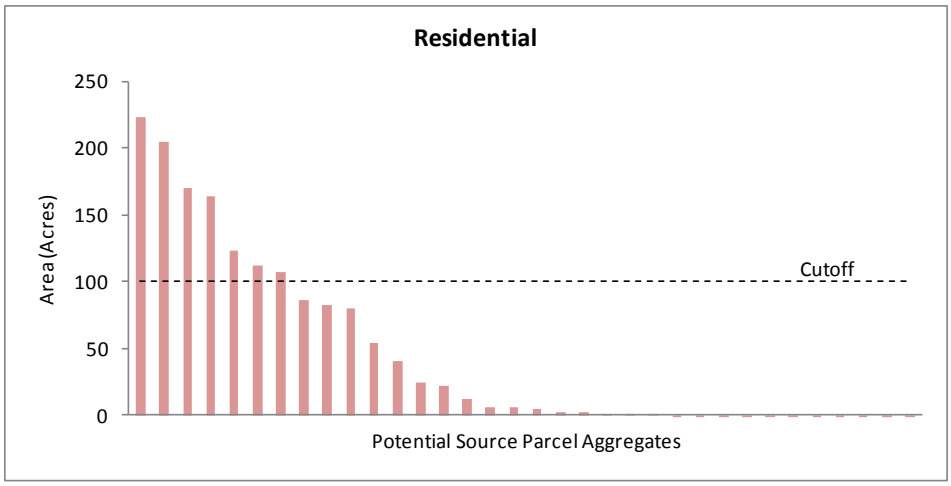

Figure 2.18 Ohio River East Residential Source Parcel Aggregates

Ohio River North

The Ohio River North watershed was found to contain 191 potential source parcels (4,187 acres). The parcels were reduced in number by 88%. Twenty-three parcels were identified as target sources making up 82% of the originally identified parcels (Figure 2.19).

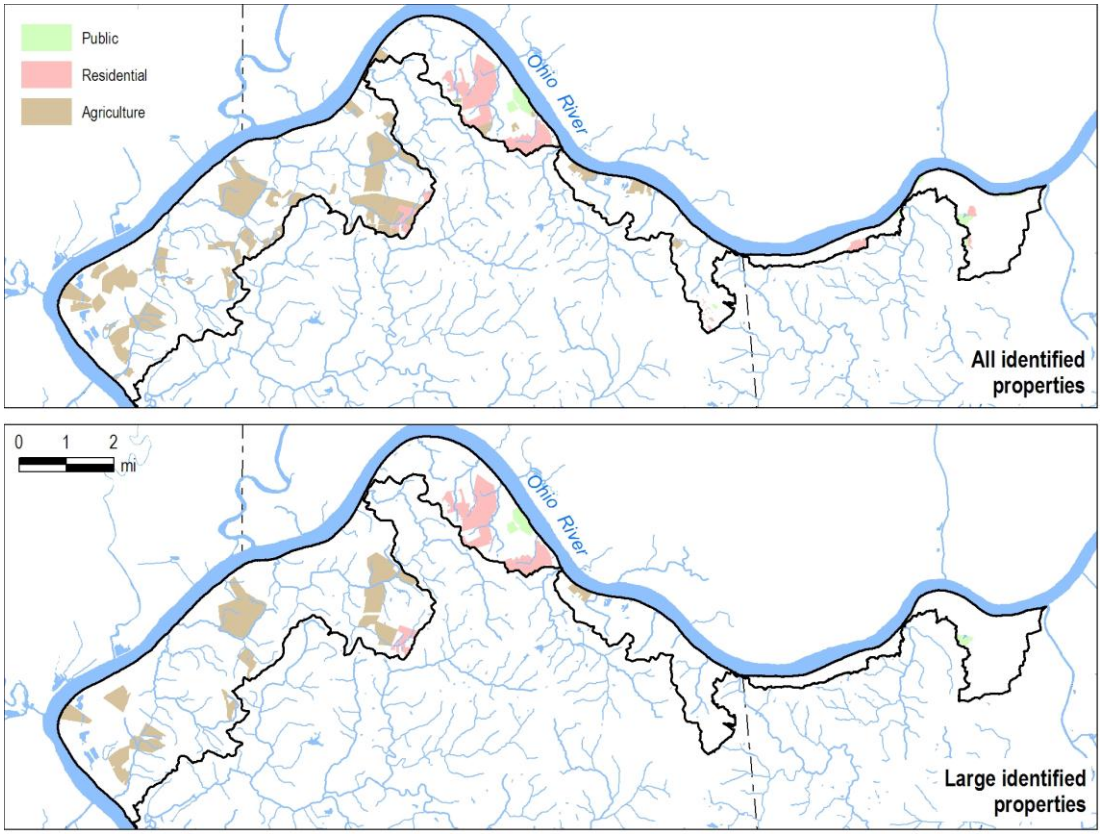

Figure 2.19 Ohio River North Potential Source Parcel Identification

Agricultural Properties

In the Ohio River North watershed, 105 parcels (2,968 acres) of pasture area were identified. The area ranked plot (Figure 2.20) pointed toward a 50 acre cutoff value. These reduced source parcels represent 15% of the parcel count will retaining 58% of the area.

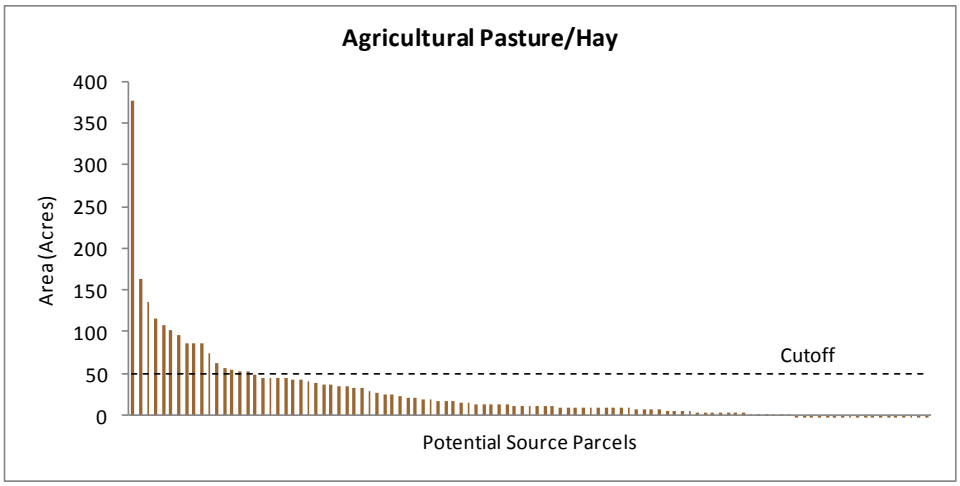

Figure 2.20 Ohio River North Agricultural Source Parcels

Public Properties

There were 48 parcels identified as public properties. The parcels covered an area of 224 acres and once ranked and plotted by area (Figure 2.21) suggested a cutoff selection of 10 acres. Parcels greater than 10 acres represented 8% of the count (4 parcels) but 67% of the identified area.

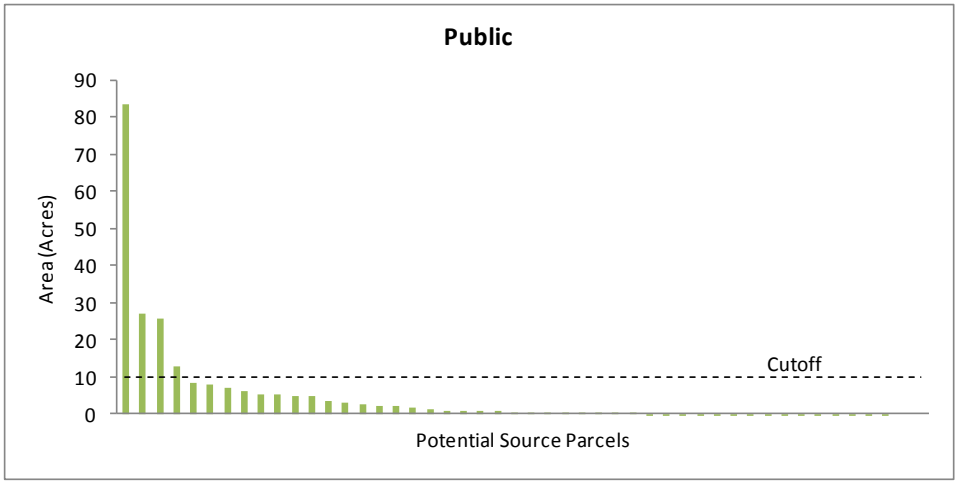

Figure 2.21 Ohio River North Public Source Parcels

Residential Properties

There were 38 parcels or parcel aggregates were identified as residential in the Ohio River North watershed. These aggregated parcels represent an area of 994 acres. After plotting the data (Figure 2.22), a cutoff value of 100 acres was chosen. This cutoff decreased the number of residential aggregates to 3 while retaining 87% of the originally identified area.

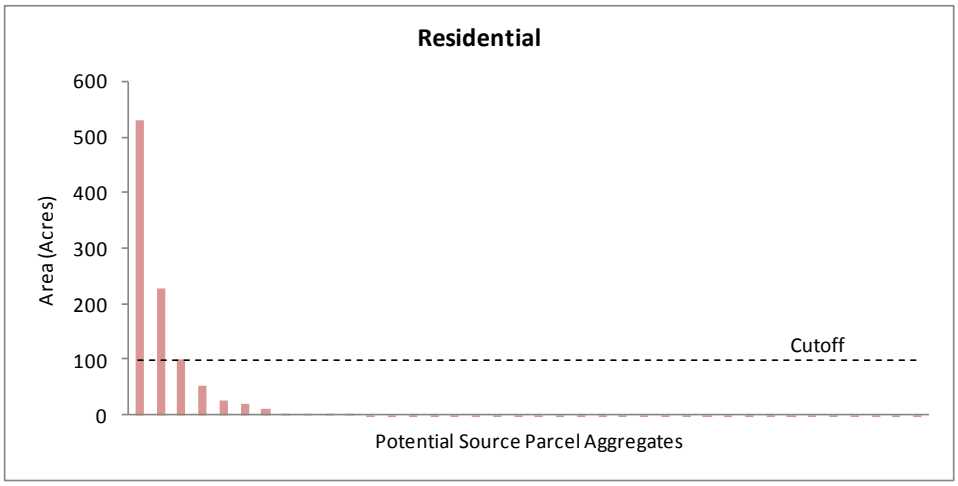

Figure 2.22 Ohio River North Residential Source Parcel Aggregates

Pleasant Run Creek

The Pleasant Run Creek watershed is a relatively small watershed located in the northern portion of the study area. A total of 121 source parcels were initially identified in the GIS, which were subsequently reduced by 93% using the knee-of-the-curve cutoff. This reduction lowered the number of parcels to 8 while retaining 89% (1,985 acres) of the originally identified area (Figure 2.23).

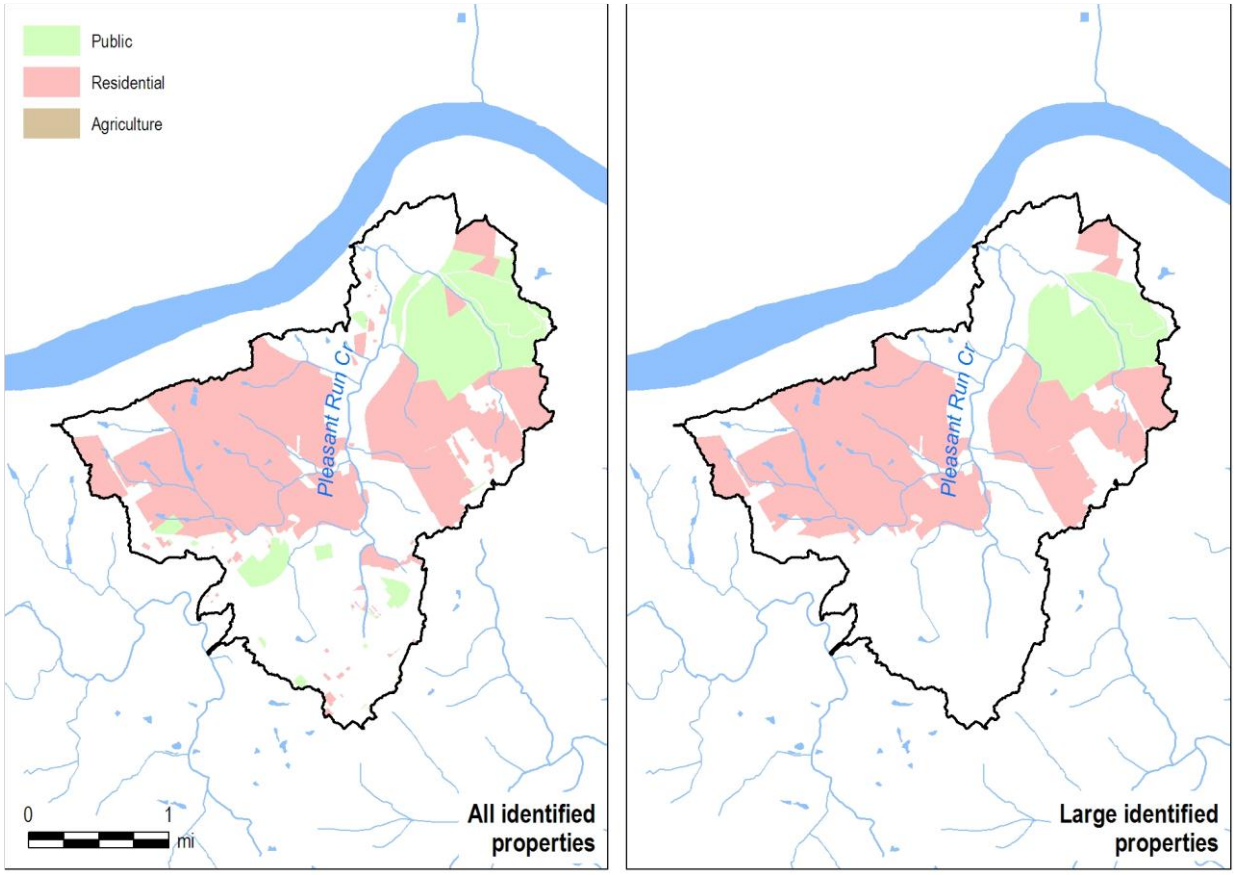

Figure 2.23 Pleasant Run Creek Potential Source Parcel Identification

Agricultural Properties

In the Pleasant Run Creek watershed, no pasture parcels were identified. This watershed is located in an urban portion of the study area and contained no pasture/hay land use classifications.

Public Properties

Fifty-six parcels (545 acres) were identified as public in the initial GIS analysis of the Pleasant Run Creek watershed. Based on the resulting plot (Figure 2.24), a cutoff of 40 acres was chosen. The 3 parcels larger than this cutoff account for only 5% of the originally identified parcel count. However, the three parcels account for 69% of the area.

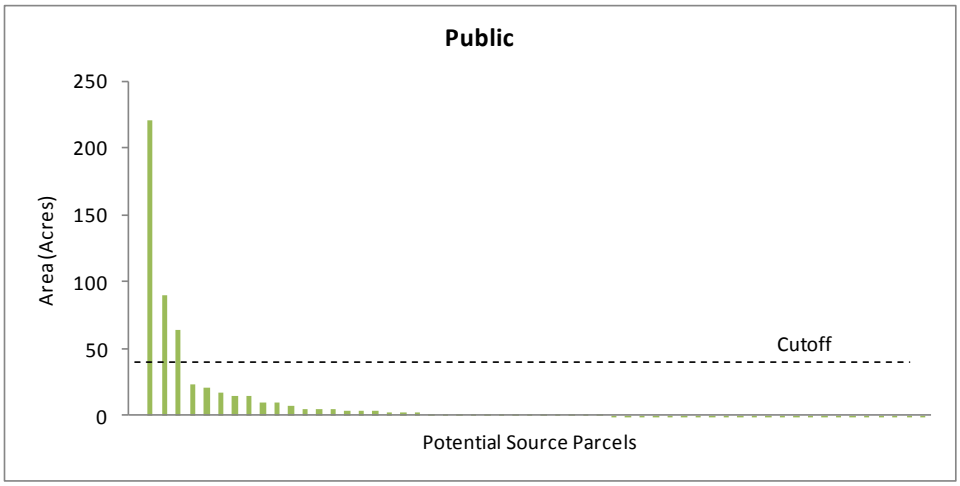

Figure 2.24 Pleasant Run Creek Public Source Parcels

Residential Properties

Sixty-five residential aggregates with a total area of 1,690 acres were identified in the Pleasant Run Creek watershed. A 40-acre cutoff was chosen for the watershed after careful review of the aggregates ranked by area (Figure 2.25). Five parcels were found to be larger than 40 acres. These parcel aggregates represented 95% of the original area with only 8% of the parcel aggregates.

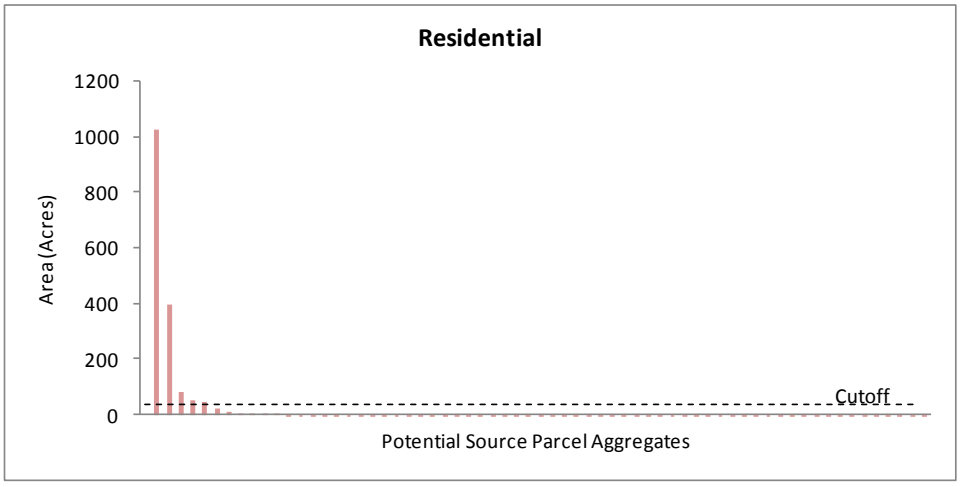

Figure 2.25 Pleasant Run Creek Residential Source Parcel Aggregates

Taylor Creek

Taylor Creek drains to the Ohio River and was found to contain 134 unfiltered source parcels. Through the knee-of-the-curve process, this number was reduced to 11 source parcels. These parcels represent an area of 1,417 acres or 82% of the originally identified source parcels (Figure 2.26).

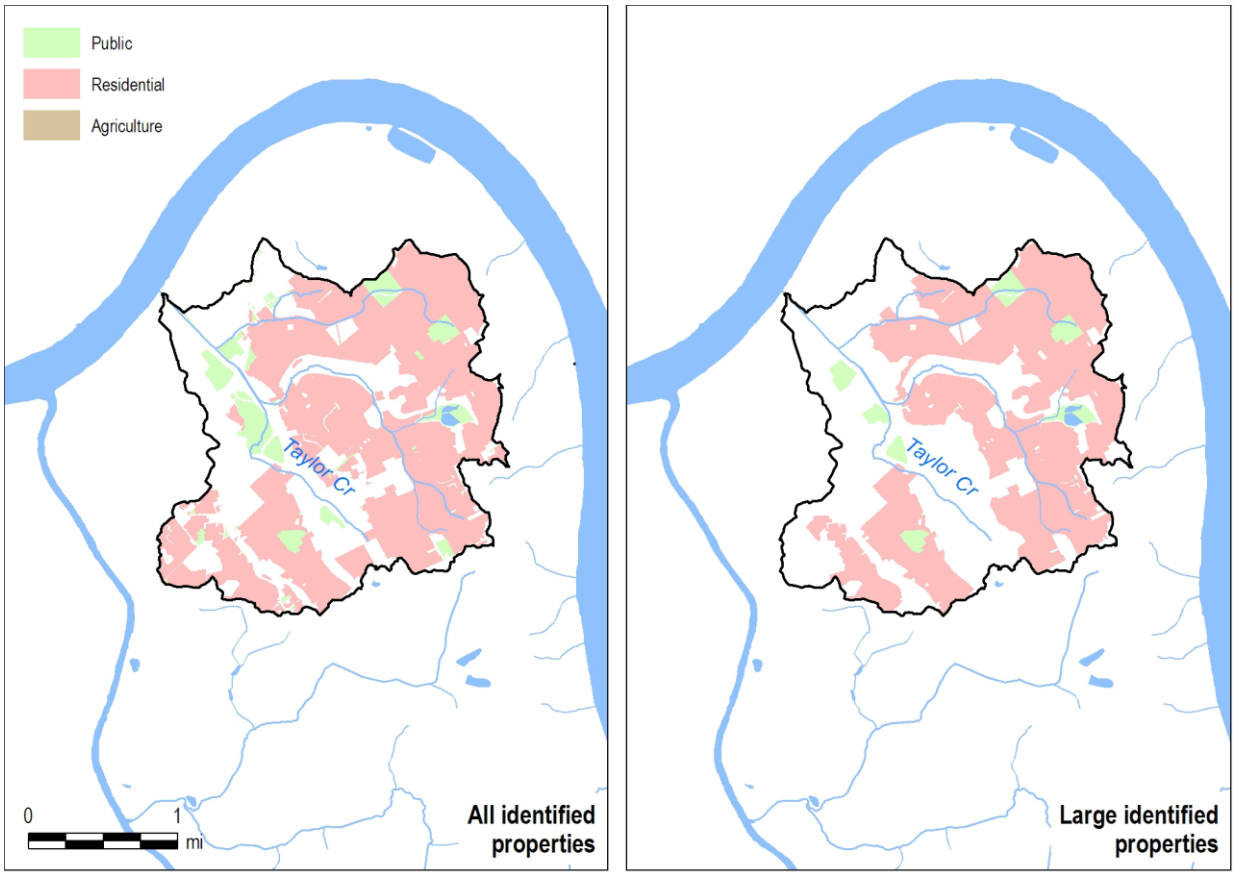

Figure 2.26 Taylor Creek Potential Source Parcel Identification

Agricultural Properties

In the Taylor Creek watershed, no pasture parcels were identified. This watershed is located in an urban portion of the study area and contained no pasture/hay land use classifications.

Public Properties

A total of 96 public properties were identified in the Taylor Creek watershed totaling an area of 185 acres. An area ranked plot (Figure 2.27) indicated that 10 acres was a reasonable cutoff value, retaining 7 parcels that account for 55% of the original area.

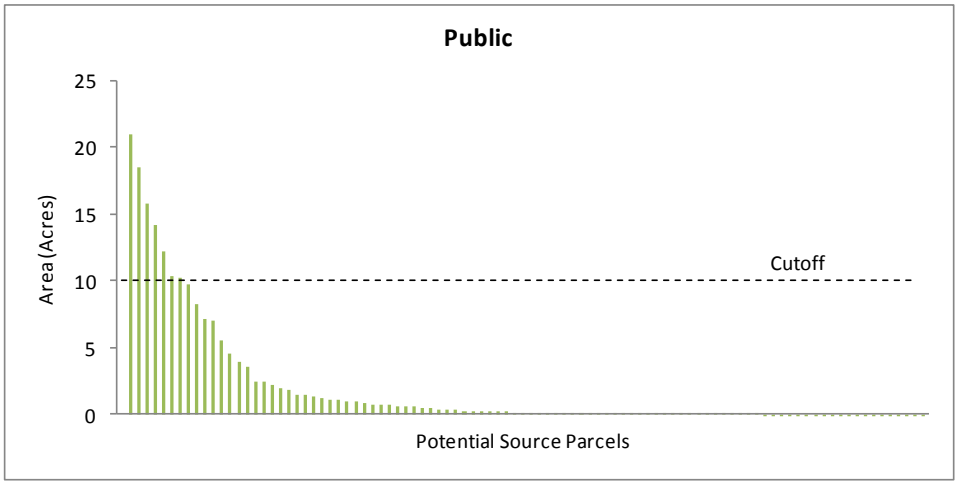

Figure 2.27 Taylor Creek Public Source Parcels

Residential Properties

In the Taylor Creek watershed, 38 residential parcels or parcel aggregates were initially identified. These parcel aggregates totaled an area of 1,552 acres. Based on the ranked plot of the parcel aggregates (Figure 2.28), a cutoff value of 80 acres was chosen. Thus, 11% or 4 parcel aggregates accounted for 85% of the residential source area.

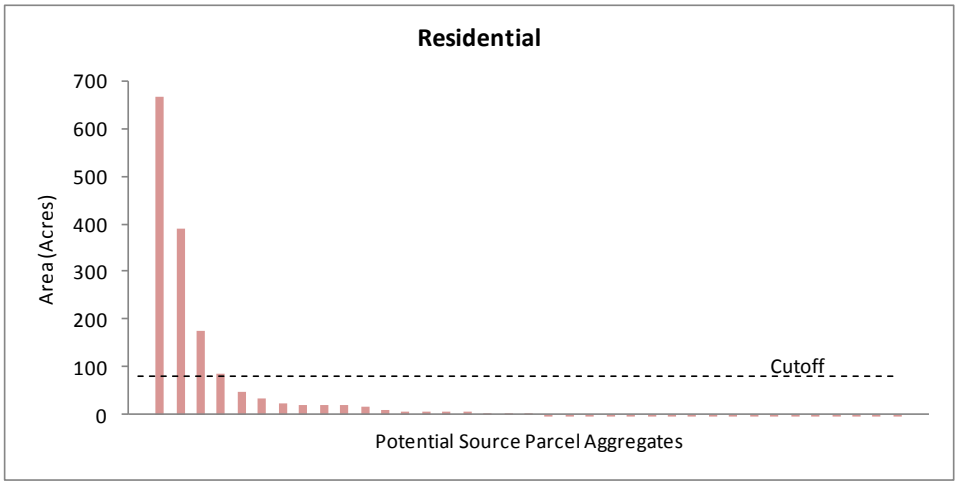

Figure 2.28 Taylor Creek Residential Source Parcel Aggregates

Threemile Creek

In the Threemile Creek watershed, 124 source parcels were originally identified representing an area of 1,523 acres. The parcel count was reduced by 81%, resulting in 24 parcels or parcel aggregates for further consideration of site location. This reduction was able to significantly reduce the number of potential sites while retaining 85% of the originally identified source parcel area (Figure 2.29).

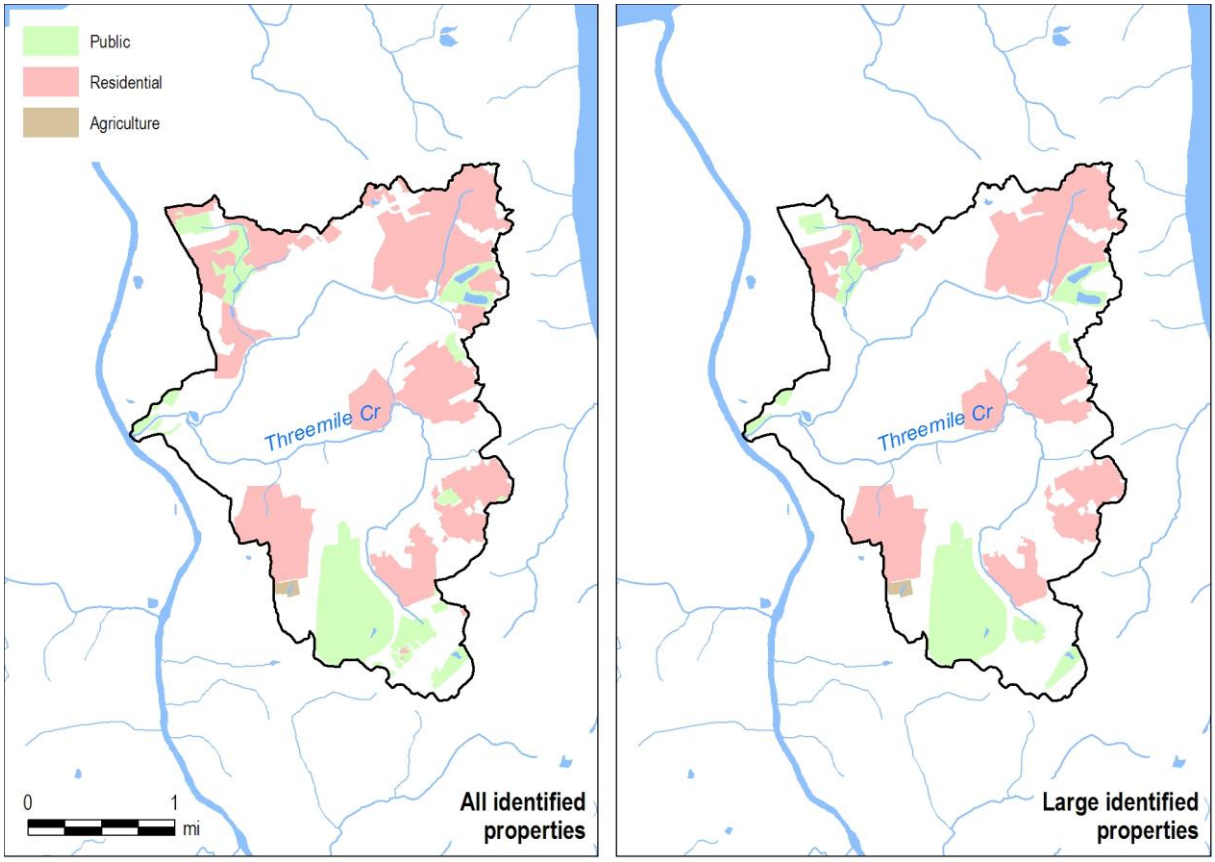

Figure 2.29 Threemile Creek Potential Source Parcel Identification

Agricultural Properties

In the Threemile Creek watershed, only one pasture parcel was identified. This 9.7 acre parcel was retained for further analysis.

Public Properties

Eighty-seven properties totaling 423 acres were identified as public property in the Threemile Creek watershed. After ranking the parcels by area (Figure 2.30) a cutoff of 5 acres was chosen. This cutoff reduced the number of parcels to 15, representing 85% of the initially identified public source area.

Figure 2.30 Threemile Creek Public Source Parcels

Residential Properties

In the Threemile Creek watershed, 36 residential aggregates were identified. These parcel aggregates totaled to an area of 1,090 acres. The area ranked plot of the data (Figure 2.31), informed the decision to choose a cutoff value of 50 acres. 22% of the parcel aggregates (8 parcel aggregates) were larger than this cutoff and accounted for 85% of the residential source area.

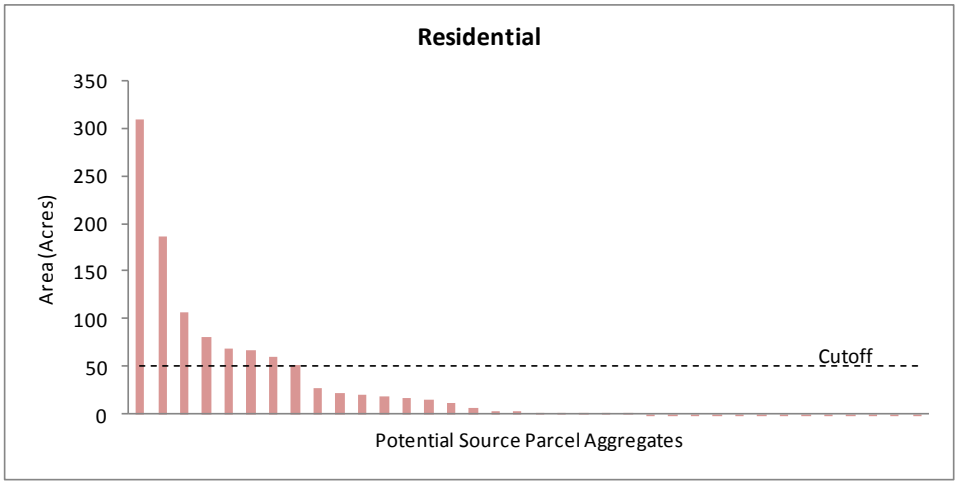

Figure 2.31 Threemile Creek Residential Source Parcel Aggregates

2.3.4 Screening Summary

The screening process described in this section resulted in a substantial reduction in the number of properties and area requiring evaluation and helped focus the effort to identify watershed control opportunities that would have significant pollution control benefit. The results of the screening are summarized in Table 2.4.

Table 2.4 Summary of Parcel Screening

Watershed	Land Use Type	Total Parcel Count	Total Area (acres)	Cutoff Value (acres)	Cutoff Area (acres)	% Of Area Represented in Cutoff	Count of Parcels Greater than Cutoff	% of Parcels Represented by Cutoff
Banklick Creek	Pasture	242	5574	45	2962	53	41	17
Banklick Creek	Public	240	1978	40	1220	62	20	8
Banklick Creek	Residential	92	10588	100	9362	88	25	27
Fourmile Creek	Pasture	84	1604	30	950	59	20	24
Fourmile Creek	Public	26	91	18	67	73	5	19
Fourmile Creek	Residential	40	1246	70	693	56	5	13
Licking River	Pasture	1008	26946	70	10399	39	93	9
Licking River	Public	434	1967	60	1274	65	17	4
Licking River	Residential	307	5289	50	3344	63	29	9
Ohio River East	Pasture	78	1575	30	858	54	18	23
Ohio River East	Public	67	340	10	274	81	10	15
Ohio River East	Residential	34	1532	100	1103	72	7	21
Ohio River North	Pasture	105	2968	50	1715	58	16	15
Ohio River North	Public	48	224	10	149	67	4	8
Ohio River North	Residential	38	994	100	860	87	3	8
Pleasant Run Creek	Pasture	-	-	-	-	-	-	-
Pleasant Run Creek	Public	56	545	40	373	69	3	5
Pleasant Run Creek	Residential	65	1690	40	1612	95	5	8
Taylor Creek	Pasture	-	-	-	-	-	-	-
Taylor Creek	Public	96	185	10	102	55	7	7
Taylor Creek	Residential	38	1552	80	1315	85	4	11
Threemile Creek	Pasture	1	10	0	10	100	1	100
Threemile Creek	Public	87	423	5	360	85	15	17
Threemile Creek	Residential	36	1090	50	930	85	8	22

The following results were obtained by applying the "knee-of-the-curve" process:

- The number of target properties classified as agricultural pasture/hay were reduced from 1,518 to 189 that represented 44% of all agricultural pasture/hay in the priority watersheds.
- The list of 1,054 public properties in the priority watersheds was reduced to 81 properties that represent 66% of the public property area.

- Residential properties and residential property aggregates were reduced from the original count of 650 to 86 properties or property aggregates that represent 80% of the total residential area in the priority watersheds.

Subsequent opportunity identification focused on these target areas. Sites downstream from very large or multiple potential bacteria source properties were given preference. Once areas of high loading potential were identified, spatial analyses were conducted to identify specific site opportunities where projects could be feasibly built. This site opportunity identification process is discussed in the following section.

2.4 Site Opportunity Identification Process

After completion of the regional source assessment, SD1 undertook an evaluation of site opportunities where large regional control measures could feasibly be built. The factors used to indicate site potential included the following:

- Large undeveloped or sparsely developed riparian areas; and
- Low, relatively level riparian topography.

To identify areas where these conditions exist, a thorough GIS evaluation was conducted. To begin the opportunity identification process, several datasets were created and compiled into ArcGIS.

The most critical dataset utilized in the evaluation process was percent slope. This dataset was created from a 10 meter digital elevation model (DEM) and added to the GIS project. The percent slope dataset covers the entire NKY area and allowed for a visual inspection to be conducted in each major watershed. Visual inspection of the data was conducted to identify areas greater than or equal to roughly ten acres along perennial (USGS solid "blueline") streams, with less than a ten percent slope. Figure 2.32 displays the percent slope and blueline stream datasets. Percent slope was symbolized to only show areas where slope was less than ten percent. Areas in red (less than four percent slope) were highly favored in the visual evaluation.

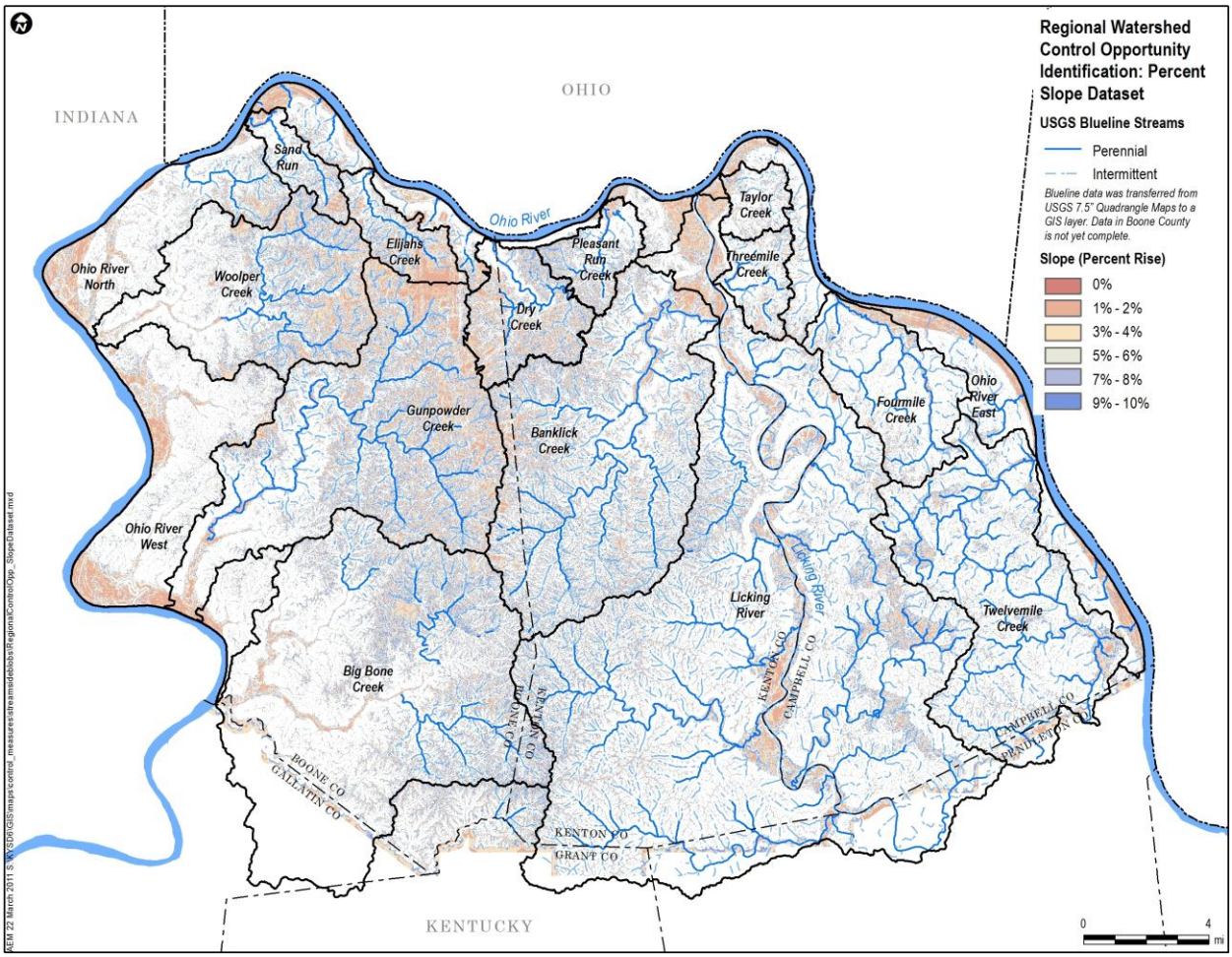

Figure 2.32 Percent Slope Overlaid with Perennial Stream Data

To begin the evaluation, the perennial, blueline streams of each major watershed were thoroughly scanned for adjacent areas of regular and low slope. Figure 2.33 shows an example of areas that might be considered based on these criteria alone in a downstream portion of the Banklick Creek Watershed.

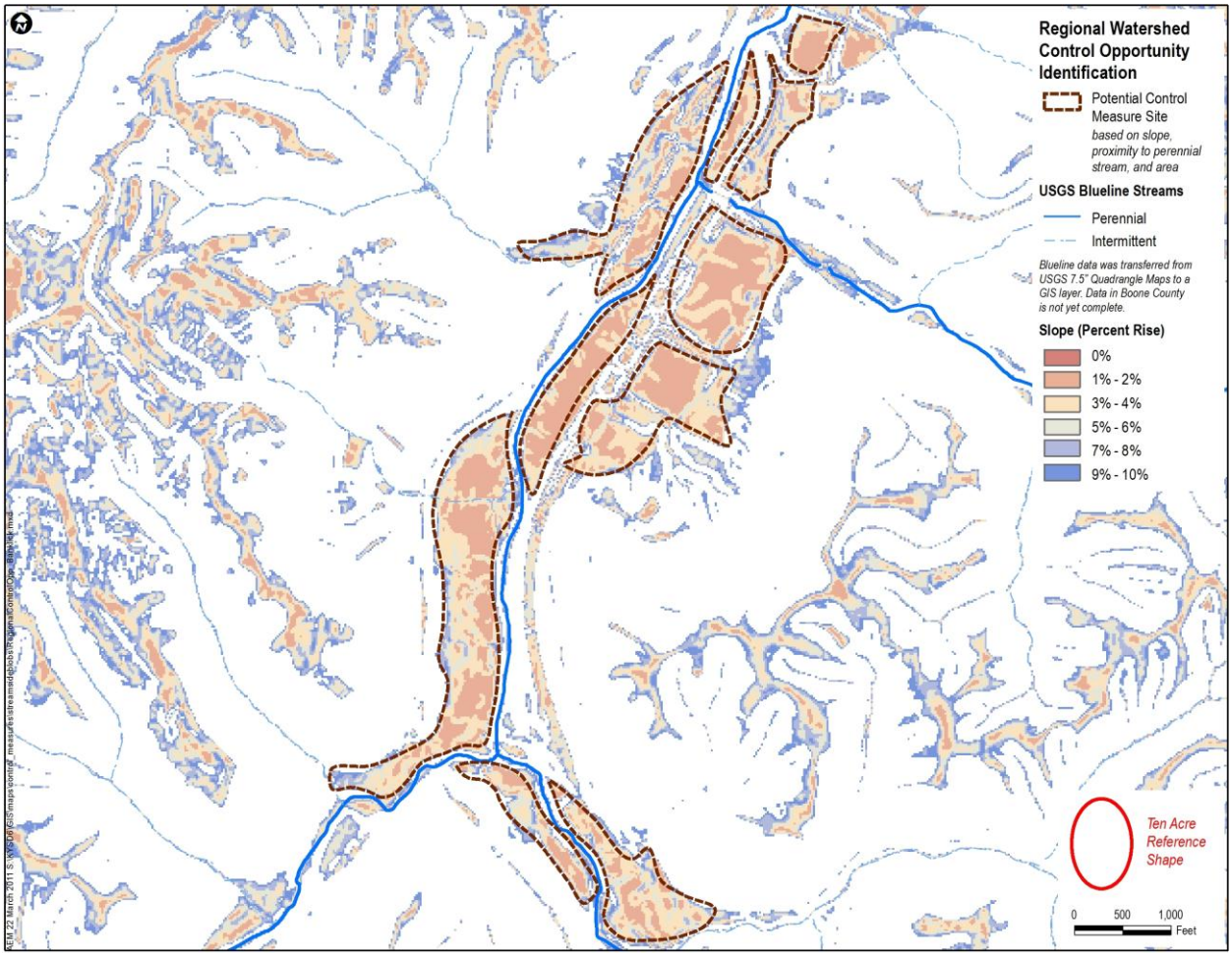

Figure 2.33 Banklick Watershed Example of Riparian Areas with Suitable Slope Conditions

Each area identified in this initial screening had a regular and minimal slope, was situated adjacent to a perennial stream, and had a relative area greater than or close to ten acres.

The second level of screening involved the addition of other ancillary datasets in order to isolate the best locations for a regional watershed control. An ideal location would be vacant, open land that is not obstructed by buildings or roads. The following datasets were added to the GIS project in order to further evaluate the landscape conditions:

- Pavement
- Building Footprints
- 2008 Aerial Imagery

Figures 2.34 and 2.35 show the potential control measure site locations from Figure 2.33 with the ancillary datasets; pavement, building footprints, and aerial imagery.

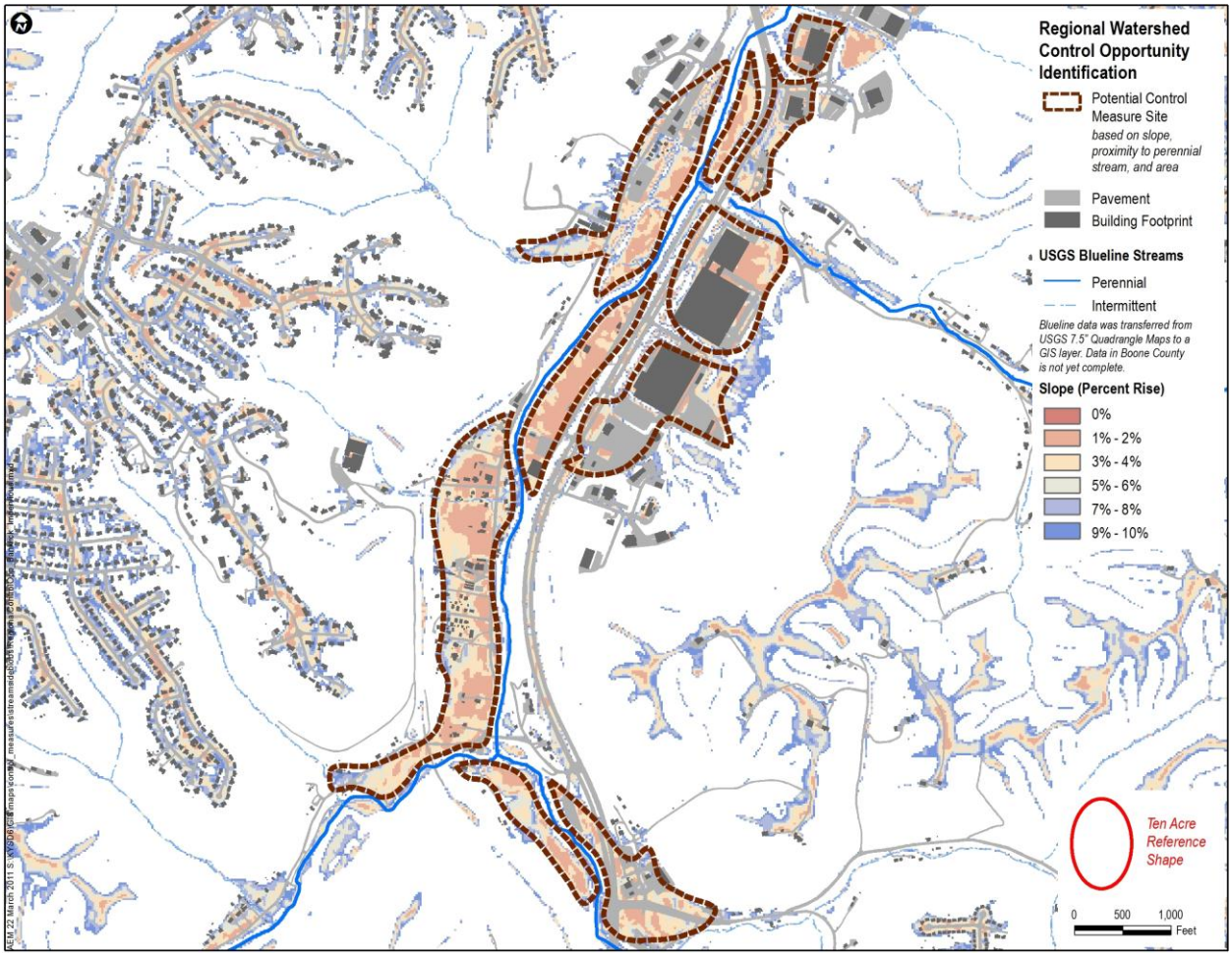

Figure 2.34 Banklick Watershed Example with Slope, Pavement, and Building Footprints

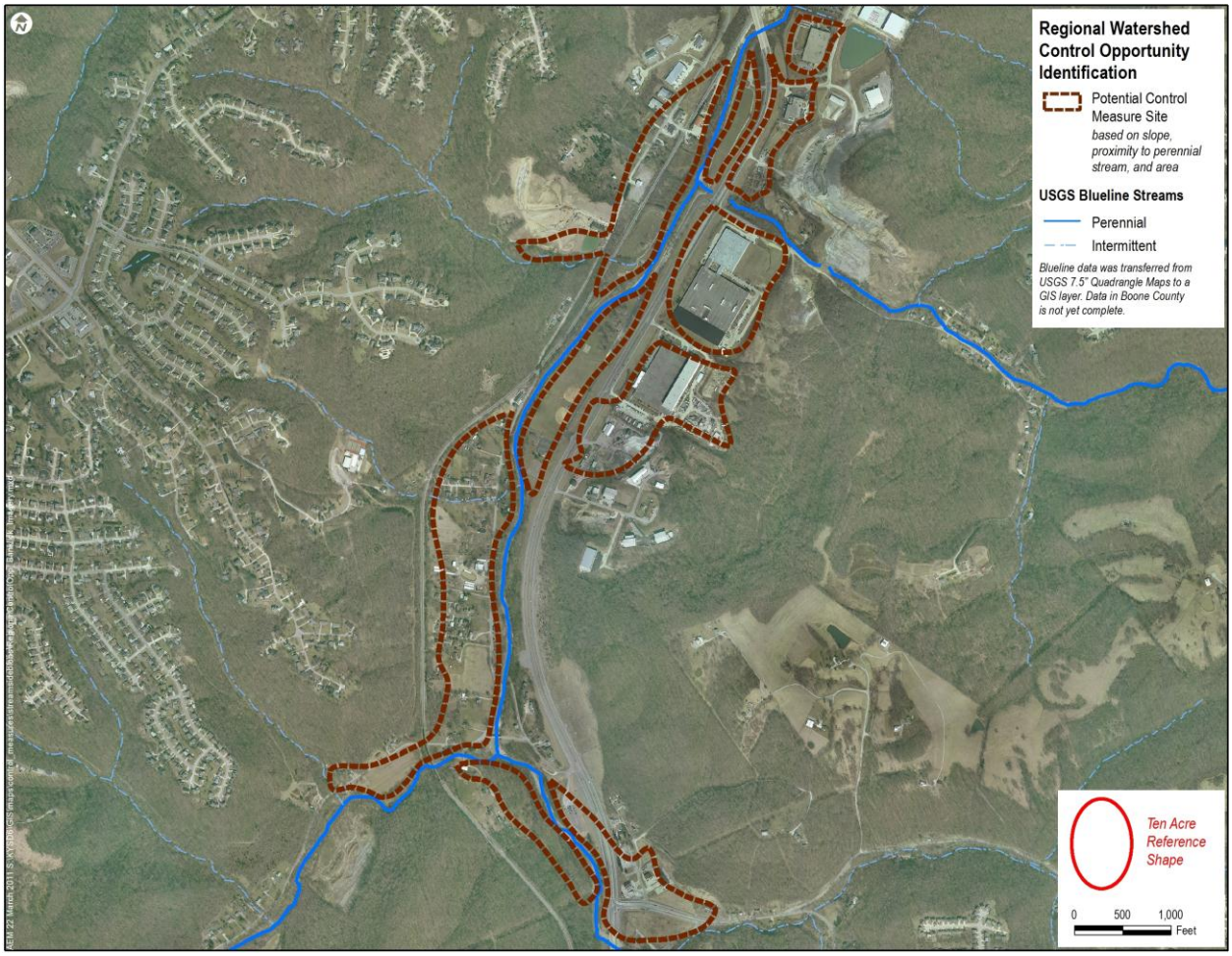

Figure 2.35 Banklick Watershed Example with 2008 Aerial Imagery

In the two figures above, it can be observed that many of the sites with preferred slope conditions will not be suitable as a regional control measure. Many of these sites contain roads, houses, development, and agriculture. In other locations within the SD1 service area, other features such as a waterway, wetland, golf course, etc. might have prevented it from becoming a final screening opportunity.

Figure 2.36 displays the portion of Banklick Creek mapped above with the refined, final screening opportunities.

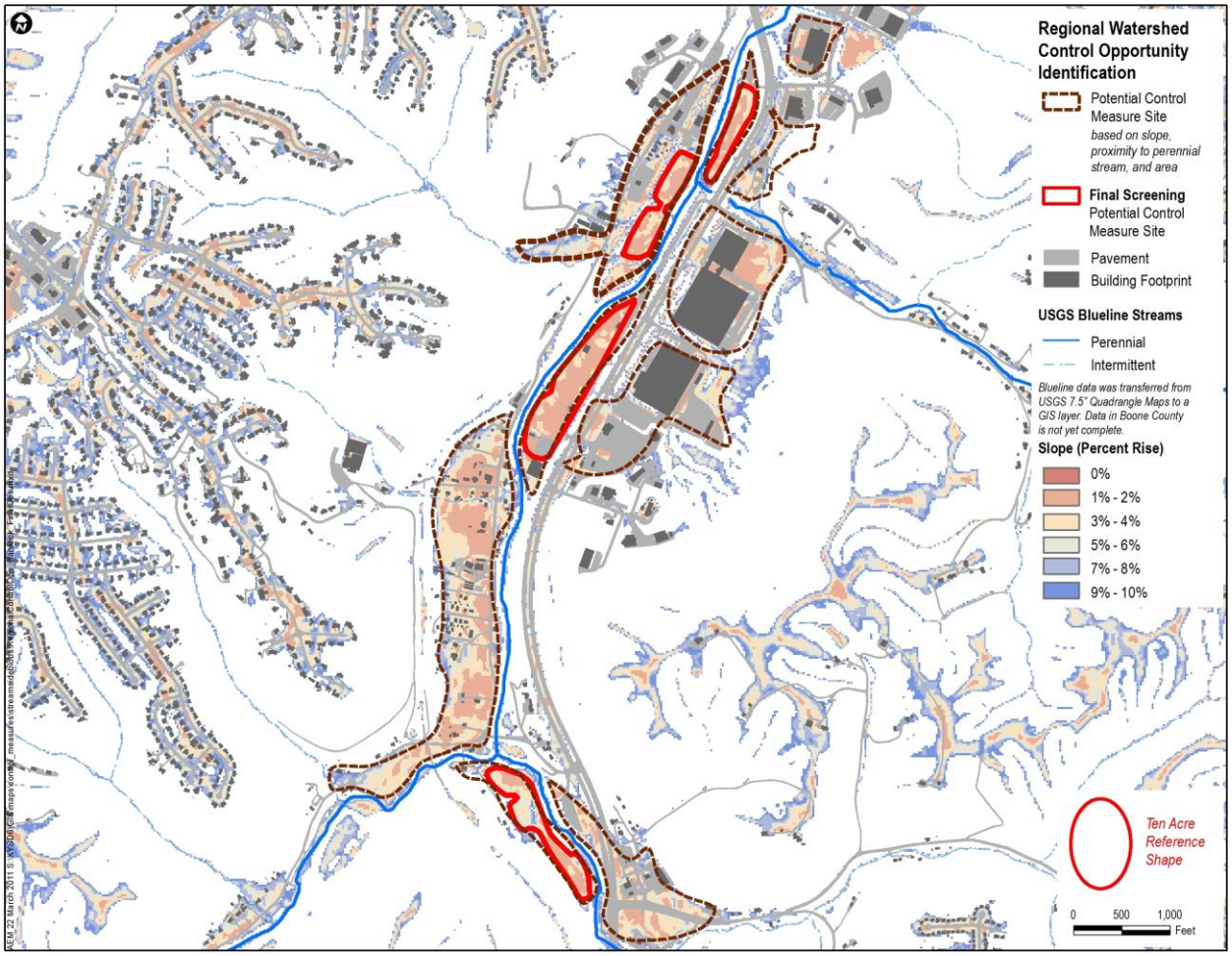

Figure 2.36 Banklick Watershed Example with Final Screening Result

The four sites mapped above with a bold, red outline were chosen as final regional watershed control opportunities based on their proximity to perennial streams, ideal slope conditions, and absence of obstructing features and undevelopable land cover types. The boundaries of these sites were refined to only include the flattest areas and to avoid roads, buildings, and other obstructions.

The process described above was repeated for each major watershed in the SD1 service area.

2.5 Regional Control Measure Opportunity Identification Findings

Once the GIS evaluation was completed for each watershed, 121 regional watershed control opportunities were identified within the SD1 service area. Figure 2.37 displays these opportunities.

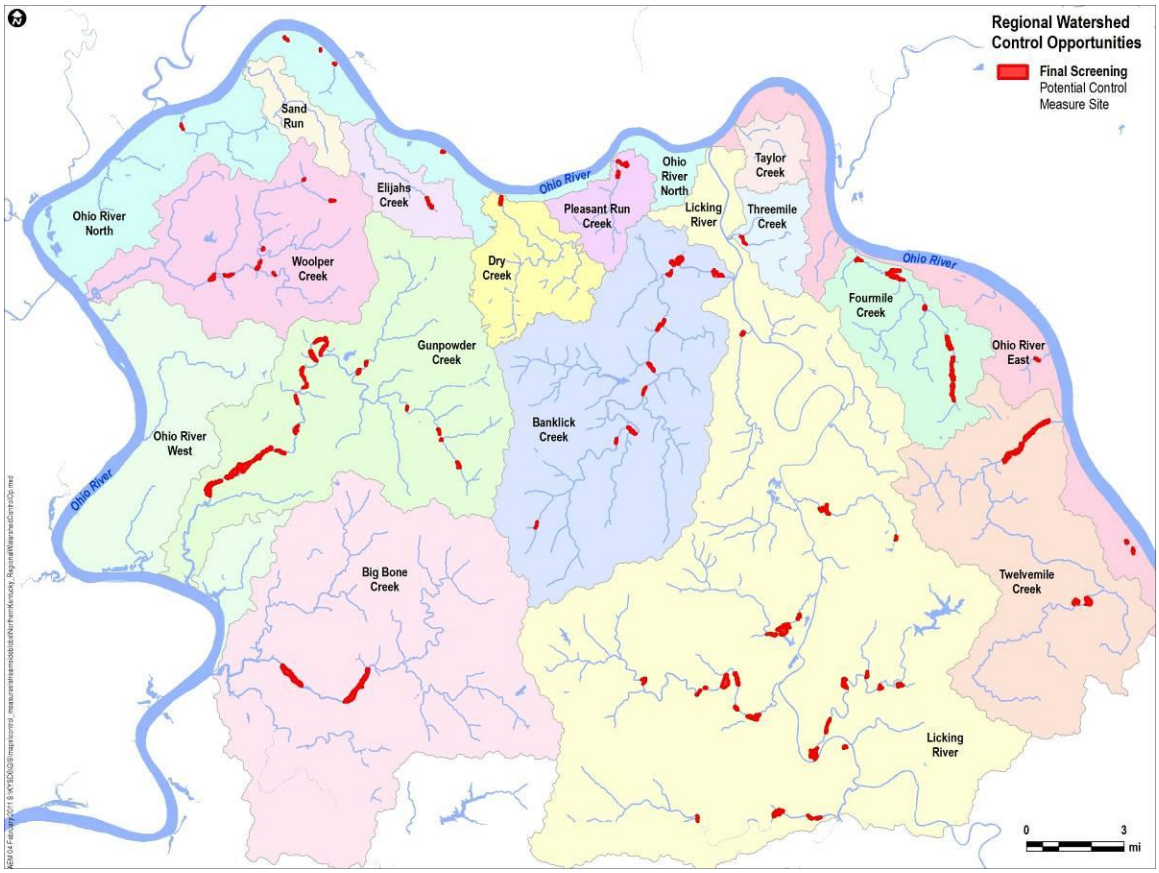

Figure 2.37 Potential Regional Control Measure Site Opportunities

The regional control measure siting opportunity analysis identified 121 potential sites throughout the study area. Of these, 74 were located in priority watersheds, as shown in Table 2.5

Table 2.5 Distribution of Regional Control Measure Siting Opportunities in Priority Watersheds

Watershed	No. of Regional Control Measure Opportunities
Banklick Creek	12
Fourmile Creek	14
Licking River	32
Ohio River East	4
Ohio River North	5
Pleasant Run	4
Taylor Creek	0
Threemile Creek	3

After reviewing the potential site opportunities in the priority watersheds, several watersheds were eliminated from further consideration for the first set of Watershed Plans:

- Ohio River East, Ohio River North, Pleasant Run watersheds were eliminated because few opportunities were identified and they drain directly to the Ohio River; flows from those watersheds are much smaller than the flow of the Ohio River, making it unlikely that watershed controls in those watersheds could make a measurable improvement in Ohio River water quality. Furthermore, the identified opportunities are located at the lower end of the watersheds so that very few stream miles of the watersheds could be improved.
- The Licking River was eliminated because the identified opportunities are on relatively small tributaries of the Licking outside of the SD1 service area and the flow in the Licking is very large compared to the flows of these tributaries. It is unlikely that watershed controls on those small streams would have a significant impact on water quality in the Licking River.
- Threemile Creek watershed was eliminated from consideration because only one opportunity was identified and the flow of Threemile creek is relatively small compared to the Licking River. Also, as with control opportunities in the Ohio River tributaries, the identified opportunities are located at the lower end of the watersheds so that very few stream miles of the watersheds could be improved.
- Taylor Creek watershed was eliminated because no siting opportunities were indentified.

After completing the opportunity analysis described above, Banklick Creek and Fourmile Creek were the two remaining watersheds with potential sites for further consideration of regional watershed controls for the first set of Watershed Plans. Each of these watersheds is discussed in more detail below.

2.5.1 Banklick Watershed Regional Control Measure Opportunities

As identified in the preceding section, 12 opportunities for regional watershed control measures were identified in Banklick Creek. Each of these locations was evaluated by calculating the water quality volume calculated to provide an estimate of the control measure volume needed for water quality improvement. Water quality volume is a commonly used screening-level calculation for sizing of constructed wetlands and storm water basins that estimates the storage needed to capture and treat the runoff from 90% of the average annual rainfall. The calculation yields a volume that is proportional to the area of the catchment, the imperviousness of the catchment, and the depth of rainfall that represents 90% of all annual rain events. The water quality volume (WQ_v) calculation is:

$$WQ_v = (P \times R_v \times A)/12$$

Where:

P = Target rainfall depth (inches)

R_v, Volumetric Runoff Coefficient, calculated as $R_v = 0.05 + 0.009(I)$

I = Catchment imperviousness (%)

A = Catchment area (acres)

For this analysis, a rainfall depth of 0.8 inches was selected, to be consistent with SD1's new storm water regulations for new development. This calculation yields a volume in acre-feet,

which can then be used to estimate the areal size of a wetland or retention basin, if the depth of the control measure is assumed. The area needed to accommodate the water quality volume was calculated for a range of depths between 3 and 10 feet, keeping in mind that constructed wetlands usually have shallower depths and retention basins tend to have greater depths. Available area at each opportunity location was compared to the water quality volume-based area and if the former was approximately equal to or greater than the latter, the opportunity was retained.

Of the 12 potential opportunities identified in Banklick watershed, one is the site of the Banklick regional constructed wetland pilot project discussed in Section 2.7. Only one of the remaining 11 sites had sufficient area available as indicated by the water quality volume-based comparison described above. That site is located on Brushy Fork, just upstream of the confluence with Banklick Creek, and was carried forward to the analysis of potential benefits.

2.5.2 Fourmile Watershed Regional Control Measure Opportunities

In Fourmile Creek watershed, 14 potential opportunities for regional watershed control measures were identified. As with the Banklick opportunities, the available space at these 14 locations was evaluated by calculating the water quality volume for each. Only six of the 14 sites had close to enough area for a regional control measure based on this calculation. Of those six, a few were located adjacent to each other, allowing them to be potentially combined for a single project. For purposes of this first five-year planning cycle, two adjacent opportunities were selected for inclusion in the analysis of potential water quality benefits, described in Section 2.6.

2.6 Potential Water Quality Benefits of Regional Watershed Controls

As discussed in Section 1.4, computer models developed for the watershed planning process were used to evaluate the potential water quality benefits of regional watershed controls. The results of these analyses are discussed below.

2.6.1 Potential Water Quality Benefits of the Banklick Constructed Wetland

The Banklick Creek watershed model was used to assess the potential water quality benefits of the Banklick Creek constructed wetland. Before discussing the results of that modeling analysis, it should be noted that two significant assumptions were made with respect to wetland operation and pollutant removal effectiveness:

- It was assumed that the removal effectiveness of the wetland is a function of the bacteria loading rate per unit area. This assumption is based on data from the NADB, as described in Section 2.6. Actual pollutant removal effectiveness will be a function of a number of factors including, but not necessarily limited to, loading rate, hydraulic residence time, and weather.
- The model estimates are based on simulations using the typical five-year hydrologic period of 1992 through 1996. Actual Banklick Creek flows and bacteria densities may vary significantly from those modeled for this period.

These assumptions, limitations, and simplifications are all reasonable in the context of available information and the objective of developing a conceptual design for the wetland.

Figure 2.38 shows the geometric mean fecal coliform density in Banklick Creek, as predicted by the water quality model, with and without the Banklick Creek constructed wetland, which is located downstream of River Mile 5.4. As seen in Figure 2.38, the geometric mean of fecal coliform decreases significantly downstream of the wetland when compared to pre-construction conditions.

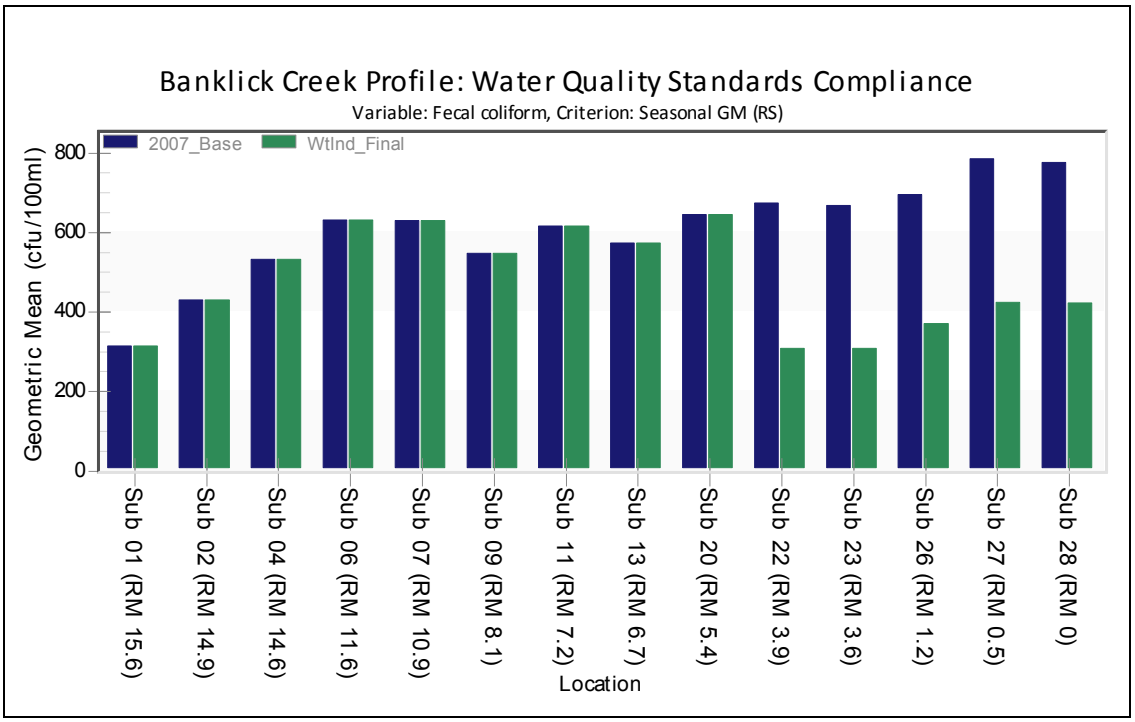

Figure 2.38 Geometric Mean of Fecal Coliform Upstream and Downstream of the Banklick Creek Regional Wetland

This decrease in fecal coliform bacteria also translates to an increase in the number of days of compliance. The portion of Banklick Creek downstream of the constructed wetland has more days in compliance than prior to wetland construction (Figure 2.39).

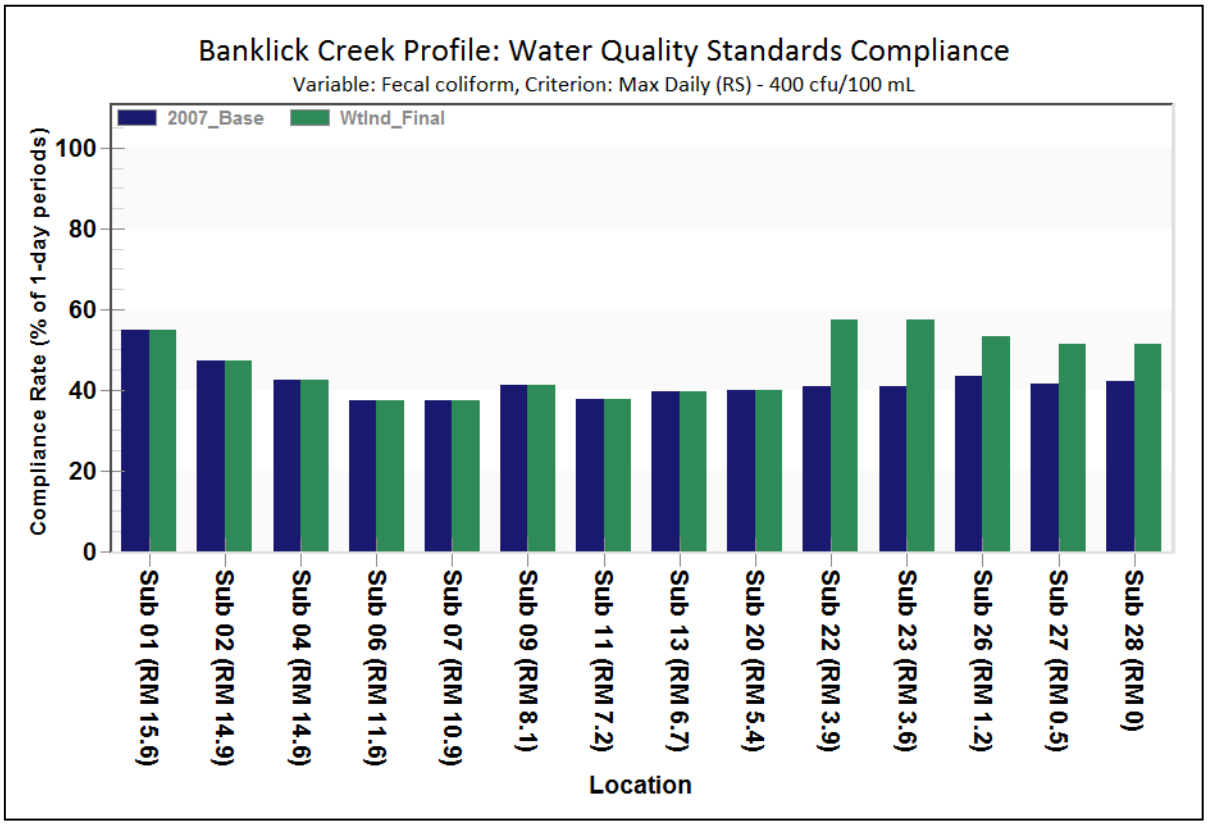

Figure 2.39 Modeled Water Quality Standards Compliance Rate Downstream and Upstream of the Banklick Creek Regional Wetland

These results show that the benefits to water quality and public health protection are projected to be significant. As shown in Figure 2.38:

- Immediately downstream of the wetland, the geometric mean is calculated to improve from approximately 672 cfu/100mL to approximately 306 cfu/100 ml, about a 54% reduction.
- At the downstream end of Banklick Creek, the recreational season geometric mean is calculated to decrease from 782 cfu/100mL to approximately 419 cfu/100 ml, an approximate reduction of 46%.

As shown in Figure 2.39, the model also calculates improvement in the geometric mean bacteria density during the recreational season:

- Immediately downstream of the wetland, the model calculates that the wetland will provide about 31 more days in a typical recreation season below the 400 cfu/100mL bacteria threshold. This represents an increase from 40% to 58% of the recreational season.
- In downstream reaches (near the mouth of Banklick) the model calculates that, with the wetland, about 95 days of the recreational season will be below 400 cfu/100 ml (a total of 51%), compared to about 76 days without it.

The potential water quality benefits for other pollutants have not yet been quantified.

2.6.2 Potential Water Quality Benefits of Regional Watershed Controls

Although the Banklick constructed wetland was specifically modeled to evaluate the potential benefits of the project, a more standardized modeling analysis was developed to assess the potential benefits of regional watershed controls in general. For this analysis, two potential sites were selected, one in Banklick on Brushy Fork and one in Fourmile on Fourmile Creek itself. The locations of these two sites are shown in Figure 2.40. At each location, the following variations of regional control measures were modeled:

- Side-stream constructed wetlands – Constructed wetlands located in the floodplain area, adjacent to the stream. Low-head boulder weirs (one foot or less in height) would allow flow to pass under normal dry weather conditions, but would create a backwater effect under wet weather conditions sufficient to divert wet weather flows out of the channel and into the wetland. Water flows through the wetland by gravity and re-enters the stream channel downstream.
- Side-stream wet weather basins – Off-channel ponds constructed in the floodplain, adjacent to stream. No instream structures would be used, but structures on the bank would allow water to flow from the stream into the basin when a design stage is reached during wet weather.

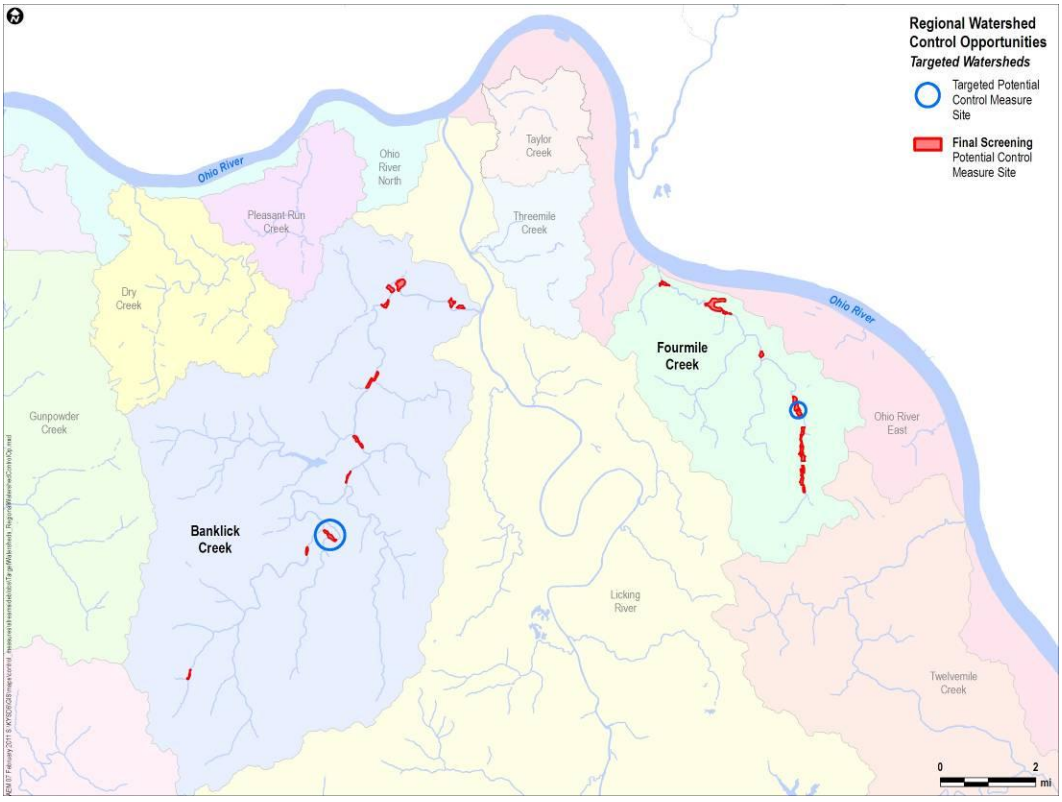

Figure 2.40 Location of Regional Control Measure Site Opportunities Selected for Modeling Analysis

The Banklick regional watershed control site selected for modeling is shown in Figure 2.414 and the Fourmile regional watershed control site selected for modeling is shown in Figure 2.42.

Figure 2.41 Conceptual Plan of Regional Control Measure on Banklick Creek

Figure 2.42 Conceptual Plan of Regional Control Measure on Fourmile Creek

Modeling results for the Banklick Creek regional control measure are depicted graphically in Figures 2.43 and 2.44, as follows:

- Figure 2.43 shows the geometric mean fecal coliform density in Banklick Creek, by model segment, with the regional control measure on Brushy Fork in place, both as a constructed wetland and as a retention basin.
- Figure 2.44 shows the compliance rate, by model segment, for the same two regional control measures.

These simulations represent 2030 watershed development conditions, to be consistent with modeling results for other control measures presented in this plan. All three scenarios shown in these results assume SSOs are eliminated and runoff from new development is managed to the first 0.8" of rainfall.

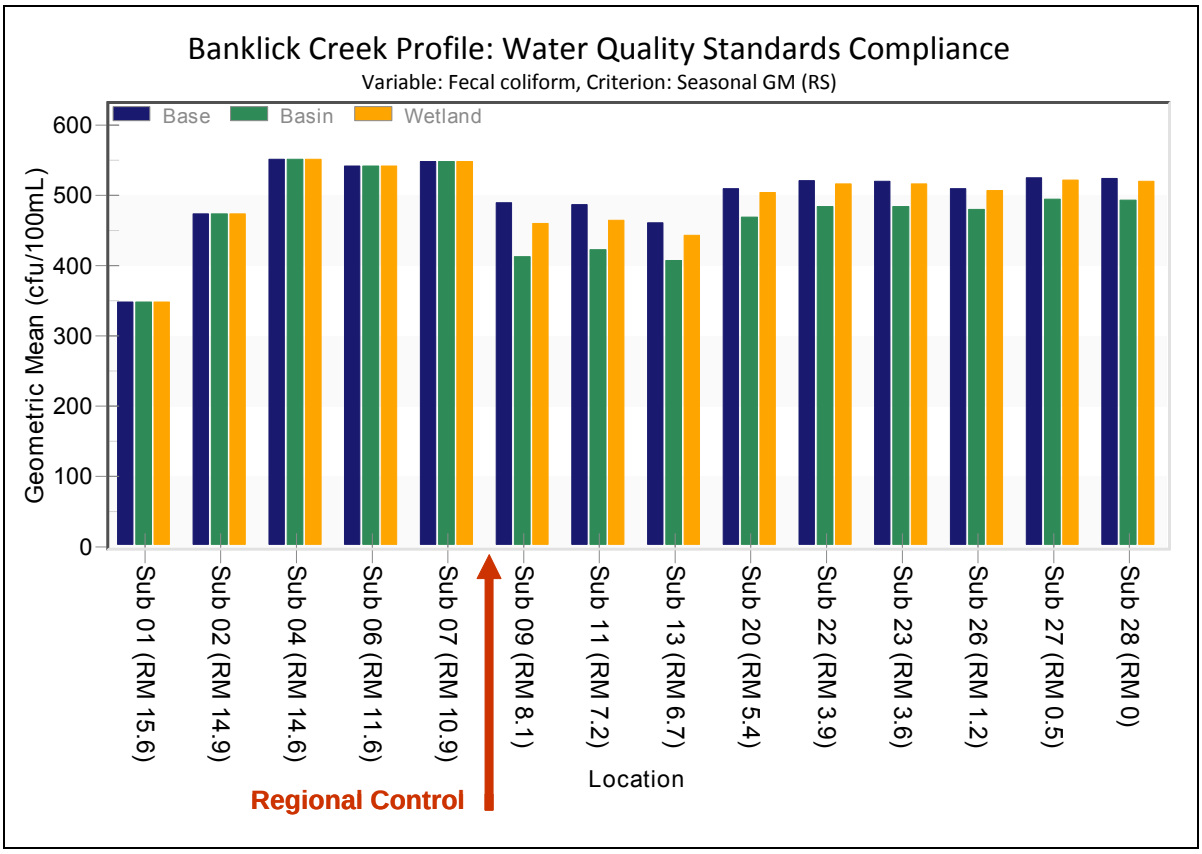

Figure 2.43 Geometric Mean of Fecal Coliform in Banklick Creek With and Without Regional Watershed Control Measure on Brushy Fork

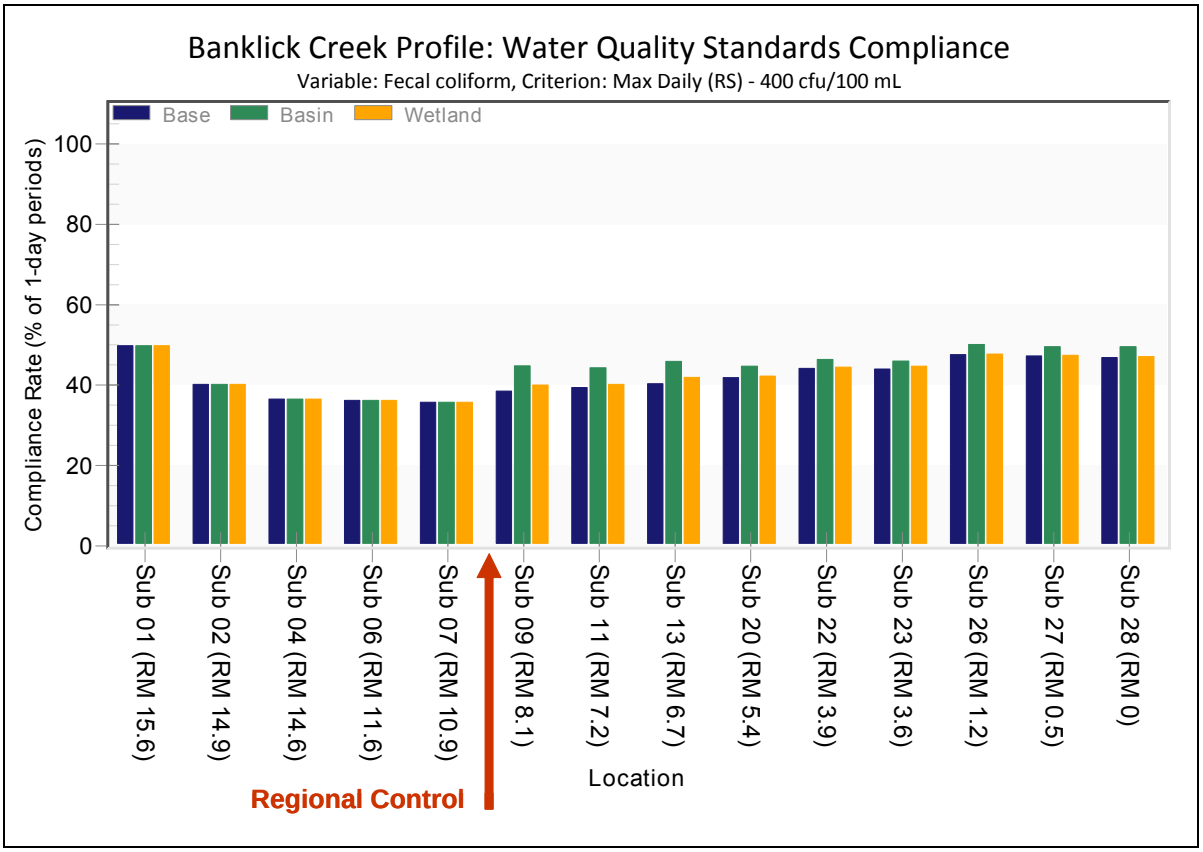

Figure 2.44 Modeled Water Quality Standards Compliance in Banklick Creek With and Without Regional Watershed Control Measure on Brushy Fork

Although these model results show that the regional watershed control measure on Brushy Fork has some water quality benefit in Banklick Creek, the benefit is relatively modest. For example, the largest improvement in the recreation season geometric mean bacteria density is at RM 8.1 (immediately downstream of the confluence of Brushy Fork with Banklick Creek) where the recreation season geometric mean was improved by 16% (from 489 cfu/100 ml to 413 cfu/100 ml) over baseline conditions with a side-stream retention basin. At that location, the compliance rate was increased by about 6% (from 39% to 45%).

The reason these benefits are not more significant is that the regional control measure is located on Brushy Fork and while there are significant improvements in Brushy Fork water quality immediately downstream from the regional control measure, the flow in Banklick Creek is significantly larger than that from Brushy Fork and the immediate benefits are diluted. The recreation season geometric mean at the downstream end of Brushy Fork (not shown on the graph) is improved by 81%, from 216 cfu/100 ml to 40 cfu/100 ml.

Modeling results for the Fourmile Creek regional control measure are depicted graphically in Figures 2.45 and 2.46, as follows:

- Figure 2.45 shows the geometric mean fecal coliform density in Fourmile Creek, by model segment, with the regional control measure in place, both as a constructed wetland and as a retention basin.
- Figure 2.46 shows the compliance rate, by model segment, for the same two regional control measures.

As with the Banklick results, these simulations represent 2030 watershed development conditions, to be consistent with modeling results for other control measures presented in this plan. All three scenarios shown in these results assume SSOs are eliminated and runoff from new development is managed to the first 0.8" of rainfall.

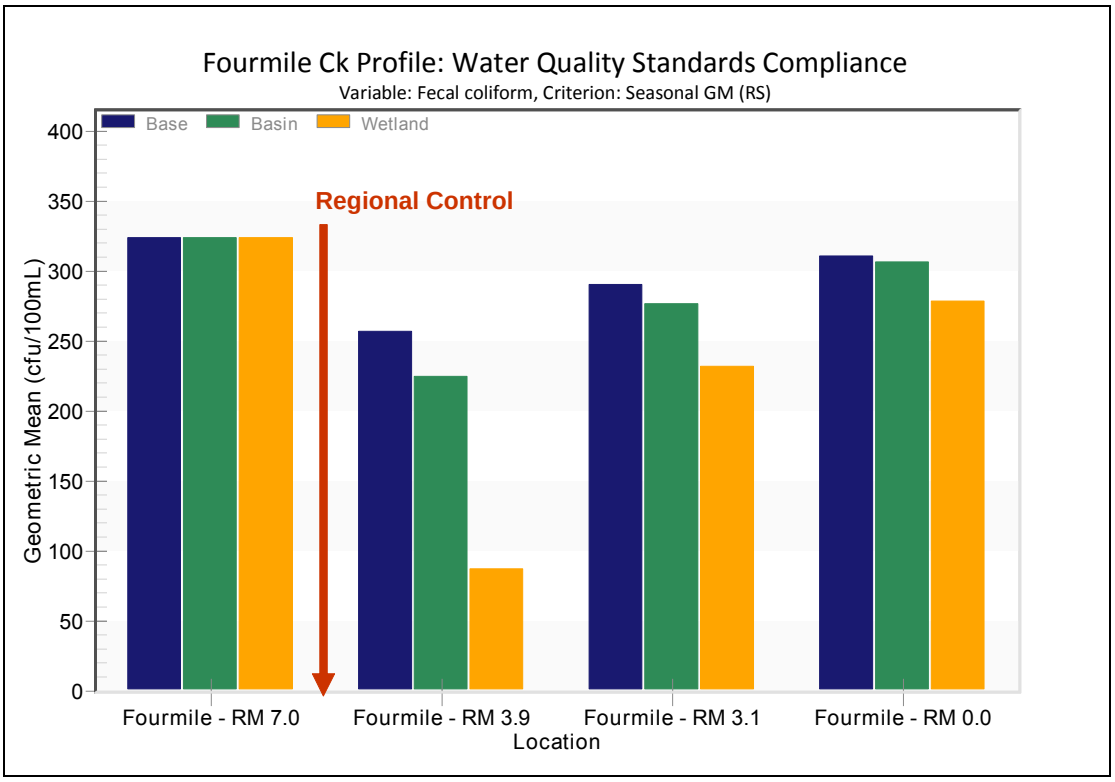

Figure 2.45 Geometric Mean of Fecal Coliform in Fourmile Creek With and Without Regional Watershed Control Measures

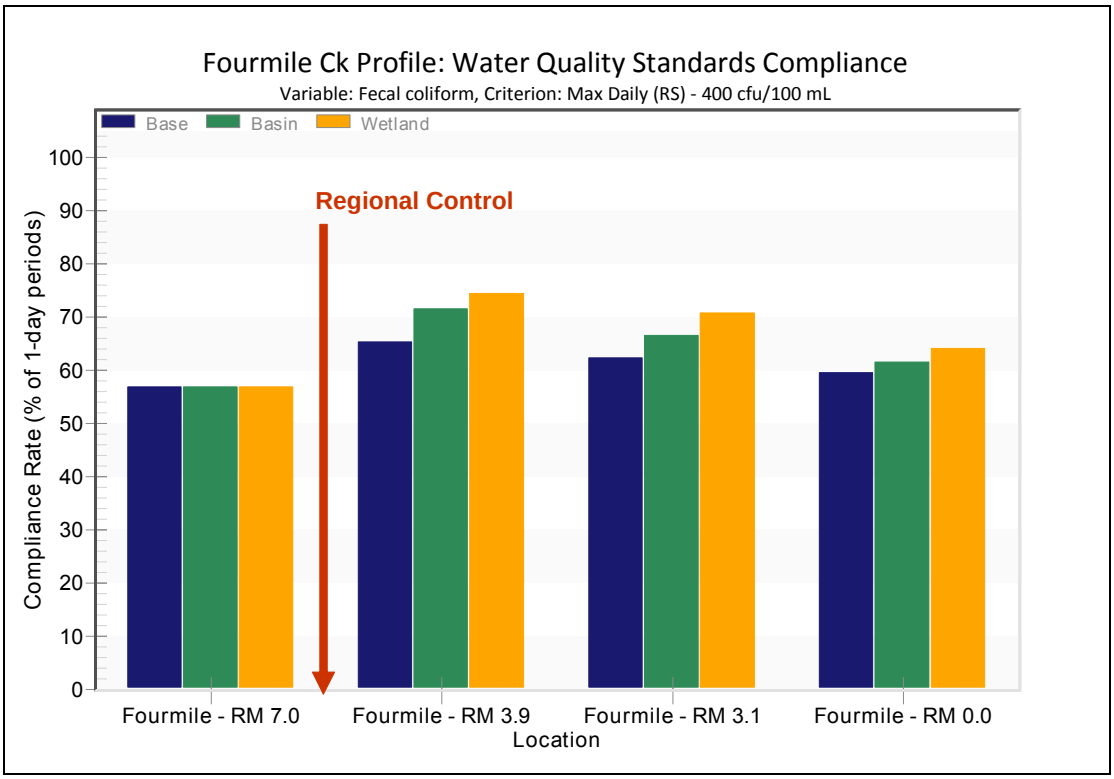

Figure 2.46 Modeled Water Quality Standards Compliance in Fourmile Creek With and Without Regional Watershed Control Measure

The results for Fourmile Creek are somewhat better than for Banklick Creek. Immediately downstream of the regional control measure, the recreation season geometric mean is improved by 66% (from 257 cfu/100 ml to 87 cfu/100 ml) over baseline conditions with a side-stream wetland. The compliance rate was improved by about 12% (from 66% to 74%).

2.7 Banklick Regional Wetland Pilot Project

Early in the watershed planning process, SD1 recognized the value of a pilot project to demonstrate the concept and performance of the regional watershed control measure. It would also allow SD1 to test design parameters and the expected efficiency of regional watershed controls. Because of the number of potential sites identified and the further analysis performed, a constructed wetland in the Banklick watershed was selected.

The most promising site opportunity in Banklick watershed was determined to be an undeveloped parcel adjacent to Banklick Creek, lying on a bend in the creek (Figure 2.47). The property (also known as the Taylor Property) is composed of relatively low-lying topography with direct access to the creek. Because the site was undeveloped, it provided enough space for approximately 6 acres of constructed wetland. Another key aspect of the Taylor property is that it is upstream of Public Service Park and the Bill Cappel Fields, which are public access points to Banklick Creek. Siting the constructed wetlands upstream of these locations addresses the need for human health protection. A combination of site location and potential upstream pollution

sources made this parcel an ideal opportunity for the creation of the Banklick Creek constructed wetland.

The Banklick Creek constructed wetland has been conceptually designed as a free water surface (FWS) constructed wetland. FWS wetlands "mimic natural wetlands and can be better habitat for certain wetland species because of standing water through most if not all of the year" (Mitsch and Gosselink, 2007). This fits with project objectives of reducing pollutants and providing ancillary habitat benefits at the same time. The primary operating period for the wetland is during the recreational season (May 1 through October 31) for bacteria reduction, however, year around performance of the wetland to reduce other pollutants of concern (e.g. solids, nutrients, etc.) will also be evaluated. The final design of the Banklick wetland is shown in Figure 2.48.

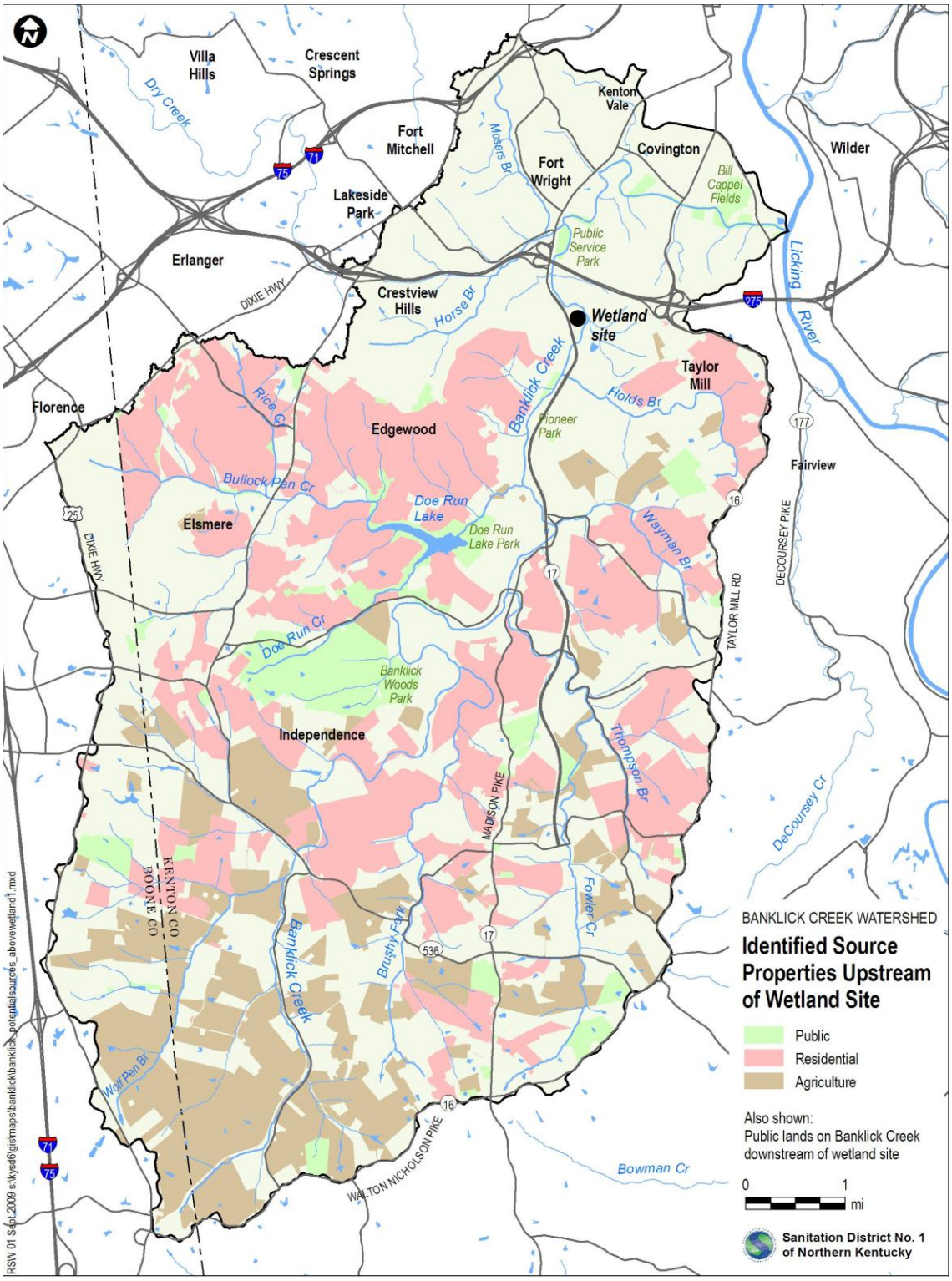

Figure 2.47 Location of the Banklick Creek Regional Constructed Wetland

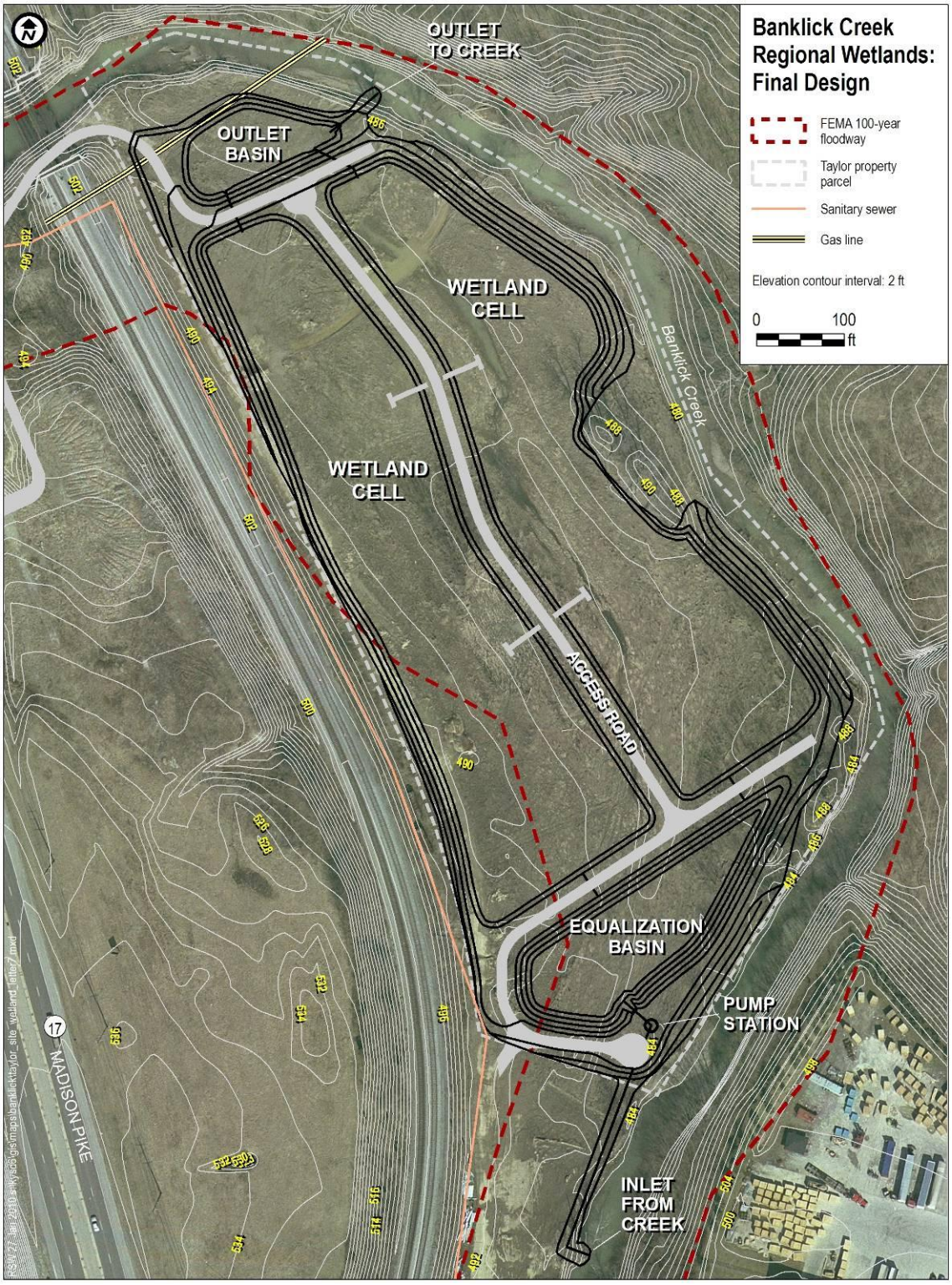

Figure 2.48 Final Design of the Banklick Creek Regional Constructed Wetland

Based on the final project design, water will be pumped from Banklick Creek by a pump station located near the south (upstream) end of the property. The pump station will direct flow into an equalization basin, also at the south end of the property, to allow settling of suspended solids and provide temporary storage of those settled solids. From the equalization basin, the water will flow by gravity into two parallel wetland cells. These cells are divided by a center berm; the combined area of the two cells is approximately six acres. Division of the wetland into two parallel cells facilitates maintenance and allows concurrent testing of performance under varying operational parameters. A discharge manifold at the upstream end of each cell distributes flow across the width of each cell.

Conceptual design of the constructed wetland was evaluated with information from the North American Treatment Wetland Database (NADB, USEPA 1999). The NADB is an USEPA sponsored database of constructed treatment wetland performance data. These data indicate that effluent quality can be described as a function of influent unit area loading, which takes into account influent pollutant load and wetland size (Figure 2.49).

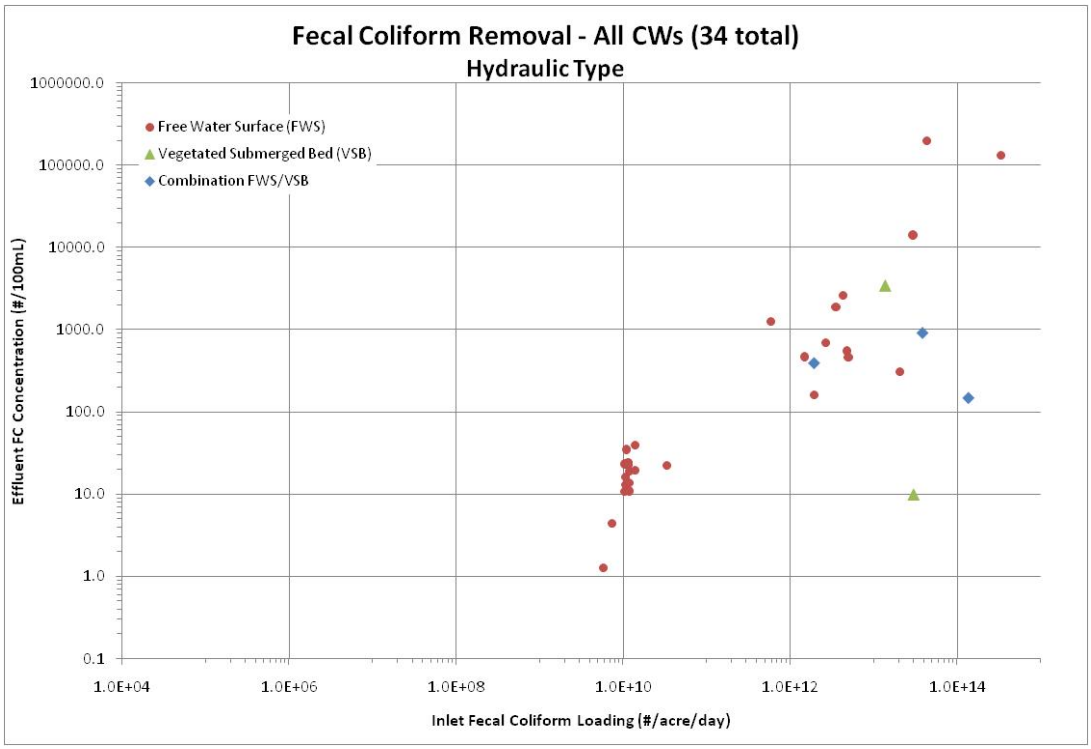

Figure 2.49 Fecal Coliform Removal by Constructed Wetland Type

Since initially identifying the Taylor property as the primary candidate location for a constructed wetland pilot project on Banklick Creek, SD1 has procured project funding under the American Recovery and Reinvestment Act (ARRA), purchased the property, completed design, and begun construction of the Banklick wetland. Construction is expected to be complete by the summer of 2011. Monitoring of the wetland will begin in 2011, although it will take at least a year for wetland plants to become established and it may be two years or more before the wetland is fully functional.

2.8 Summary of Findings for Regional Watershed Controls

The modeling results, combined with the outcome of the opportunity analysis, lead to the following conclusions regarding the opportunities and benefits of regional watershed control measures:

- Limited opportunities for regional watershed controls of suitable size were identified. In most cases, site opportunities larger than 10 acres in size will be required to accommodate sufficiently large watershed controls, along with site amenities (e.g., access roads).
- Because the size of the regional watershed control measure is proportional to the size of the contributing drainage area, very large drainage areas cannot be managed using regional watershed controls due to lack of sufficient space.
- Implementation of regional watershed controls on tributaries can have a substantial water quality improvement benefit on the tributary, but may not have significant water quality benefit on the downstream waterway.

Because of the limited opportunities and the modeled benefits, SD1 has decided not to pursue regional watershed control measures in the first Five-year Improvement Program, beyond the ongoing Banklick Creek constructed wetland. Work will continue on the Banklick regional wetland and the monitoring of that project will provide valuable data to inform future control measure design. It should also be noted that the opportunity analysis conducted here assumed that a minimum of excavation would be desirable in constructing regional watershed control measures, to keep costs down. However, as more monitoring data are obtained and sources are better understood, there may be situations where sites requiring more excavation to build a regional control measure become more attractive.

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SECTION 3. DECENTRALIZED (NON-REGIONAL) WATERSHED CONTROL MEASURES

Decentralized watershed control measures are storm water control measures with upstream drainage areas smaller than one square mile, but typically greater than 5 acres. Decentralized watershed control measures are designed to control storm water runoff closer to the source, as compared to regional control measures which are sited adjacent to streams to improve water quality some distance downstream from source areas. Decentralized watershed controls may be new projects built for water quality improvement or they may be retrofit projects involving redesign of existing storm water basins to enhance storm water quality.

3.1 Decentralized Control Measure Types

As described above, decentralized control measures in the SD1 watershed planning process are intended to control runoff from areas typically larger than 5 acres, which means that certain control measure types are appropriate whereas others are not. The types of control measures considered in this analysis include:

- Storm water wetlands,
- Bioretention/biofiltration basins (conventional detention basins modified to incorporate bioretention or biofiltration features into the basin to provide water quality improvement benefits),
- Enhanced retention basins (conventional retention basins modified to incorporate forebays or other improvement features to the basin to provide water quality improvement benefits).

Wetlands, detention basins, and retention basins are all commonly used storm water control measures for drainage areas over 5 acres. Detention basins have the potential to be adapted to include bioretention and/or biofiltration functions to provide additional water quality treatment and retention basins can be modified with additional water quality improvement features as noted above.

3.2 Opportunity Identification Process

Because the focus of decentralized watershed controls is on treating storm water, spatial data describing existing storm water infrastructure were used as a starting point in the opportunity identification process. Specifically, existing storm water outfalls in SD1's geodatabase were targeted for initial review. As with the regional control opportunity analysis, the watersheds containing CSOs or discharging into CSO impacted waters were targeted for this planning cycle. These watersheds were the Licking River, Banklick Creek, Threemile Creek, Fourmile Creek, Taylor Creek, and Pleasant Run Creek. The Ohio River East and Ohio River North watersheds were not included in this analysis because they contain relatively small tributaries to the Ohio River; flows from those storm water catchments are much smaller than the flow of the Ohio River, making it unlikely that watershed controls in those watersheds could make a measurable improvement in Ohio River water quality.

The opportunity analysis began by selecting outfalls identified in the SD1 geodatabase as "major" outfalls. These outfalls are owned by SD1, the Kentucky Transportation Cabinet, and

municipalities. Overall, 287 ”closed system” outfalls and 27 ”open system” outfalls were considered major (pipe diameter of greater than 36” for “closed systems” and drainage area greater than 50 acres for “open systems”). In addition to these 314 outfalls, 427 other outfalls, lacking outfall geometry information in GIS, were brought into the analysis. These outfalls were analyzed in order to retain a complete analysis of the outfalls in SD1’s storm water service area. Figure 3.1 depicts analyzed closed outfalls in teal and open outfalls in purple.

Next, the Network Analyst extension of ArcGIS was used to define the catchments for each outfall. A network of storm water conduits and enforced flow direction rules was created and the service area tool of Network Analyst was utilized to delineate draft catchments. The service area tool of Network Analyst is traditionally used to determine the area a facility, such as a fire station, can reach through a road network in a certain amount of time or distance traveled. These same principles were applied to the concept of a storm water outfall. Each storm water outfall was designated as a facility and the service area tool then calculated the area upstream of the outfall until it reached the end of the network. These catchments reflected the position of the storm water outfalls and flow direction of the storm water conduits. Topography was not taken into account in these coarse catchment delineations, but it proved to be a good indicator of the relative size of the outfall and its associated drainage area. This was seen when the coarse network analyst derived catchments were compared to field verified outfall dimensions and detailed delineations that included both topography and storm water conduits.

This coarse storm water-conduit based approach was used to provide an initial estimate of drainage area for 741 outfalls mentioned previously, 314 of which are considered major and 427 unknown. These unrefined catchment areas were used to determine cutoffs for the size of catchments investigated for siting decentralized watershed controls. Ranked plots of estimated drainage areas were developed, and an appropriate cutoff size was determined. Figure 3.2 is a ranked catchment area plot with 75 acres as the cutoff. This plot shows only a subset of the data, for illustration purposes. Initial conduit-based delineations were later refined using land topography for catchments estimated to be at least as large as the cutoff area. When refined, some of the catchment areas may have fallen below the cutoff size.

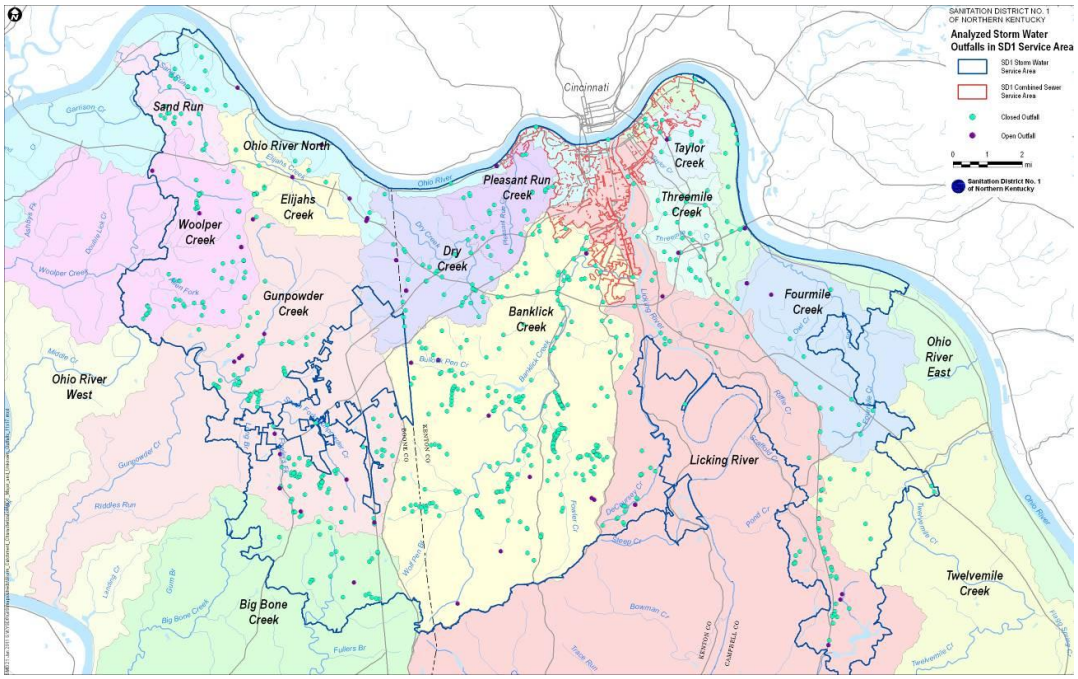

Figure 3.1 Analyzed Storm Water Outfalls in SD1 Service Area
(Note: City of Florence was not included in this analysis)

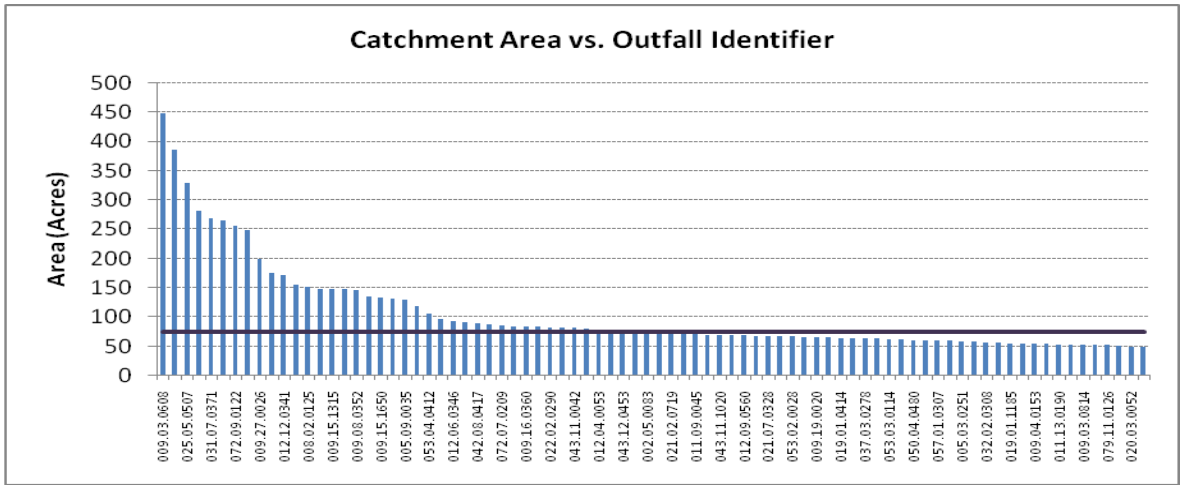

Figure 3.2 Ranked Estimated Catchment Areas

Of the 741 outfalls identified, whose catchment areas were preliminarily delineated using network analyst, 358 were in the six target watersheds, as summarized in Table 3.1.

Table 3.1 Summary of Delineated Catchment Areas in Target Watersheds

Watershed	Number of Outfalls Identified
Banklick Creek	273
Fourmile Creek	16
Licking River	2
Pleasant Run	24
Taylor Creek	15
Threemile Creek	28

The overall distribution of catchment size, as determined using Network Analyst, was used to determine a reasonable size cutoff, to identify target catchments for control measure opportunity analysis. Initially, a 75 acre-cutoff was used and catchment delineations were refined using topographic data in conjunction with the Network Analyst results. The area cutoff was subsequently decreased to 22 acres to identify the 100 largest catchments for storm water control opportunities in the six priority watersheds. These catchments subsequently underwent a more refined delineation, which resulted in some catchments being determined to be smaller than originally thought. Figure 3.3 depicts the delineated storm water catchments in green with corresponding major outfalls in blue. Table 3.2 summarizes these 100 storm water catchments by watershed.

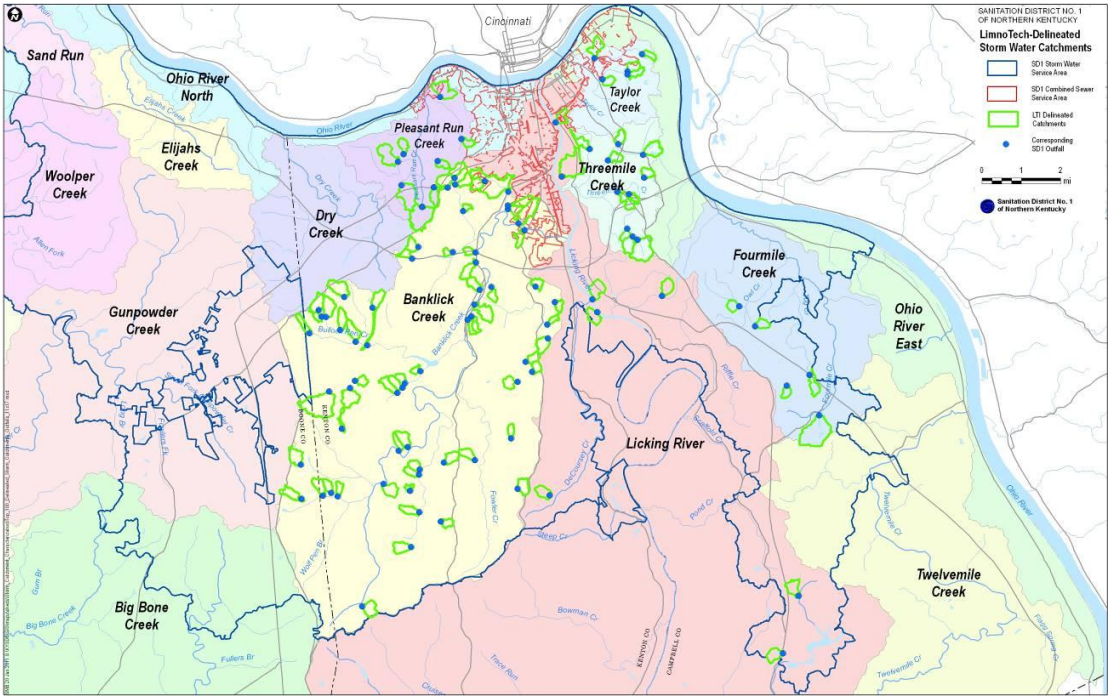

Figure 3.3 100 Delineated Storm Water Catchments in Northern Kentucky

Table 3.2 Summary of Delineated Catchment Areas by Watershed

Watershed	Number of Catchments	Total Area of Catchments in Watershed (acres)	Size Range of Catchments (acres)	Average Size of Catchments (acres)
Licking	8	624.0	45.9 – 182.6	78.0
Banklick	63	3469.0	12.5 – 291.1	55.1
Threemile	10	601.3	27.6 – 159.0	60.1
Fourmile	5	434.6	30.7 – 261.7	86.9
Taylor	5	213.2	28.8 – 67.3	42.7
Pleasant Run	9	878.4	31.4 – 178.9	97.6

Analysis of these catchments included computing properties such as the following:

- Catchment area
- Watershed
- Water quality volume
- Percent impervious
- Type of impervious land
- Land use
- City
- County
- Ownership
- Hydrologic soil group
- Presence of hydric soils
- R factor
- Sewer type
- Aerial imagery observations

For each catchment, the water quality volume was calculated to provide an estimate of the control measure volume needed for water quality improvement (See Section 2.5.1 for a description of this calculation).

Each of the catchments delineated in priority watersheds were mapped in GIS with an accompanying table of information to classify the watershed. Table 3.3 is an example of a table generated for a catchment delineated in the Pleasant Run Creek watershed. The accompanying map is in Figure 3.4.

Table 3.3 Example of Delineated Catchment Properties Summary Table

Structure ID	009.15.1315
Catchment Area (Acres)	140.0
Water Quality Volume (Acre-Feet)	4.9
Impervious Area (%)	33.2
Impervious Area (Acres)	
Road	18.8
Building	14.5
Parking Lot	10.1
Large Driveway	1.3
Land Use (Acres)	
Developed, low intensity	49.4
Developed, high intensity	47.0
Developed, open space	26.4
Developed, medium intensity	10.1
Deciduous forest	3.7
Evergreen forest	1.9
City, Co. (Acres)	
Fort Mitchell, Kenton Co.	140.0
Ownership (Acres)	
Single Family	68.1
Office Tower - 3 Story & Up	7.5
40 OR More Unit Apartments	6.6
Mobile Home Park	4.0
Community Shopping Center	3.7
Swim Club	3.1
Office Bldg 1 or 2 Story	3.0
Motel	1.8
3-19 Unit Apartments	1.7
Vacant Land	1.6
Day Care Center	1.1
Two Family	1.0
Hydrologic Soil Groups (Acres)	
C	140.0
Hydric Soils (Acres)	4.4
R Factor (Acres)	
5 < R <= 10	98.1
2 < R <= 5	28.6
Sewer Type (Acres)	
SD1 Separate Sewers	140.0
Notes	
• Discharges to tributary to Pleasant Run Creek	
• Ample space for storm water controls	
• Area needed for water quality volume = 0.5-1.6 ac.	
• Retrofit existing pond (Privately owned)	

* Areas < 1 acre not reported

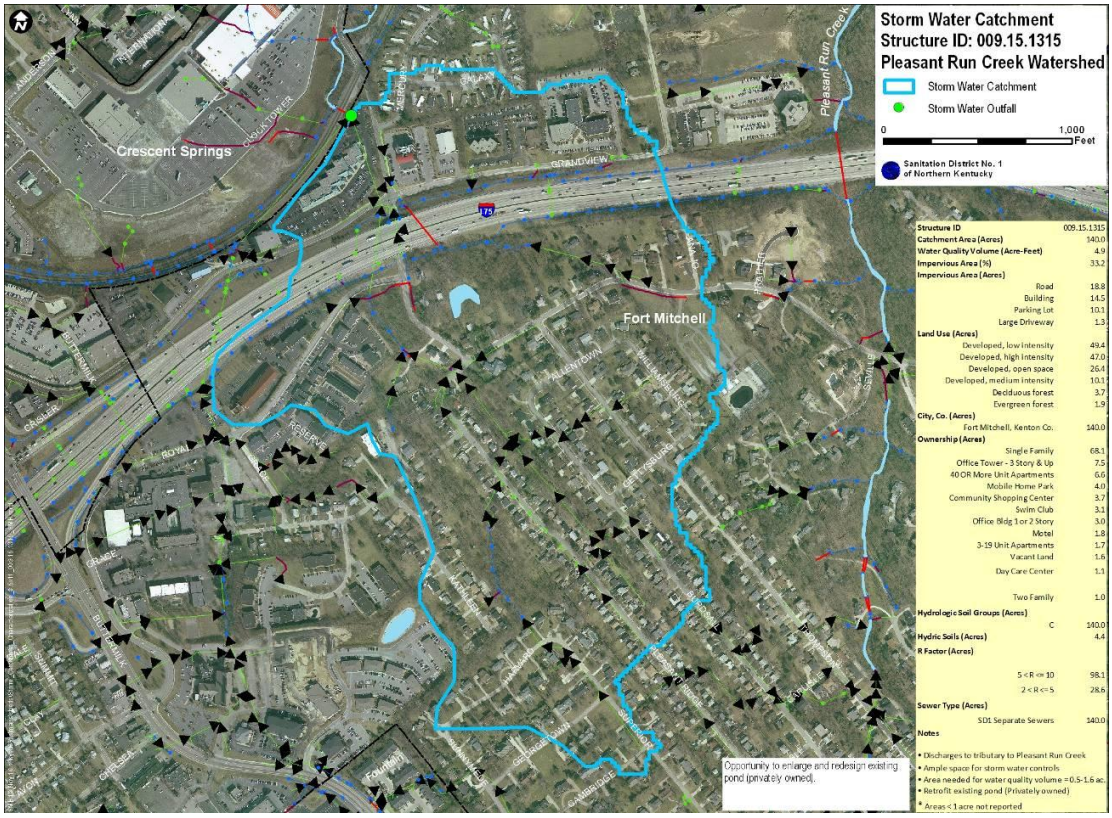

Figure 3.4 Example of Delineated Catchment Map

Aerial imagery was inspected for each of the delineated catchments in order to identify suitable locations for control measures based on the required water quality volume. Considerations for this include:

- Existing land use and state of development
- Presence of forested areas
- Proximity to streams
- Presence of storm water conduits upstream of the outfall
- Apparent sources of bacteria loading
- Ownership

The maximum area needed to accommodate the water quality volume was represented in GIS by green polygons and placed based on the criteria above. Figure 3.5 shows an example of retrofitting an existing pond by increasing its size.

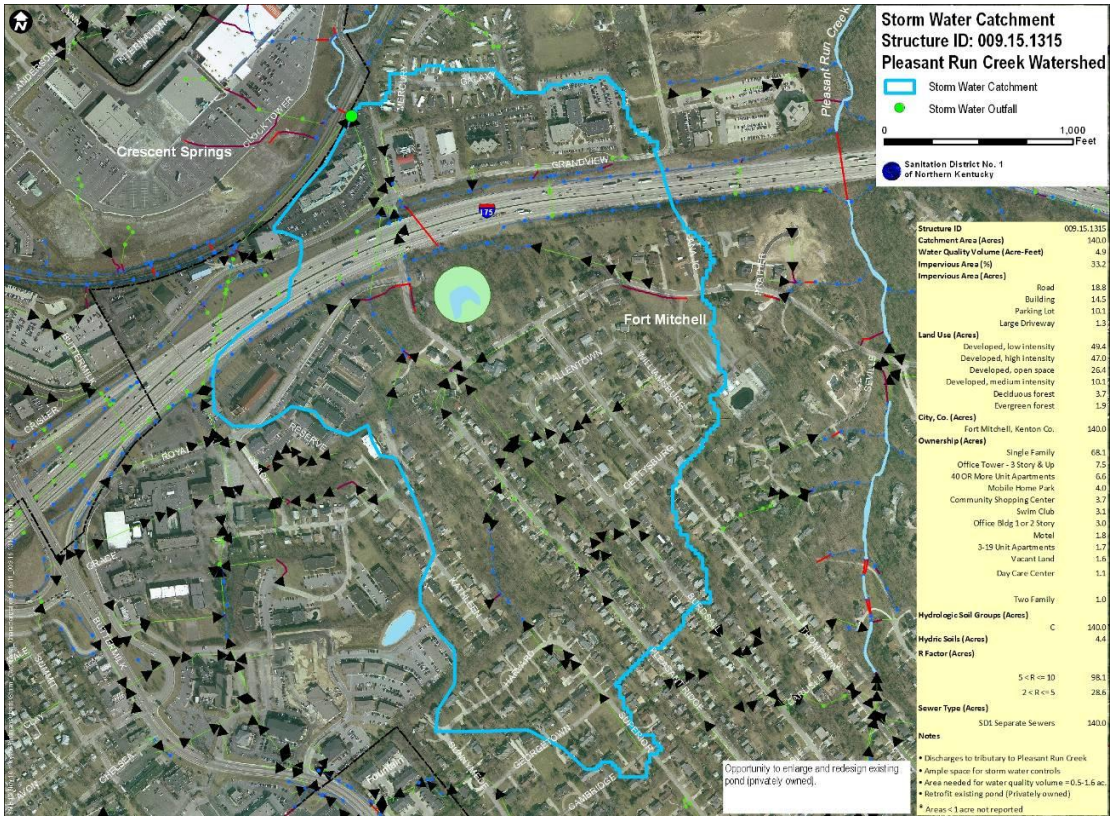

Figure 3.5 Example of Delineated Catchment Map with Water Quality Volume Depicted

Land ownership near the proposed control and near the outfall was investigated to determine whether the control measure could be placed on public land such as land owned by local municipalities or by the Kentucky Transportation Cabinet. Highway interchanges were identified specifically as suitable locations for controls. Maps were generated for areas near the proposed control with land ownership and elevation contours displayed, such as the example shown in Figure 3.6. In this particular example, the existing pond lies on private property. However, just downstream of the outfall, there are many publicly-owned parcels, depicted with orange dashed polygon boundaries.

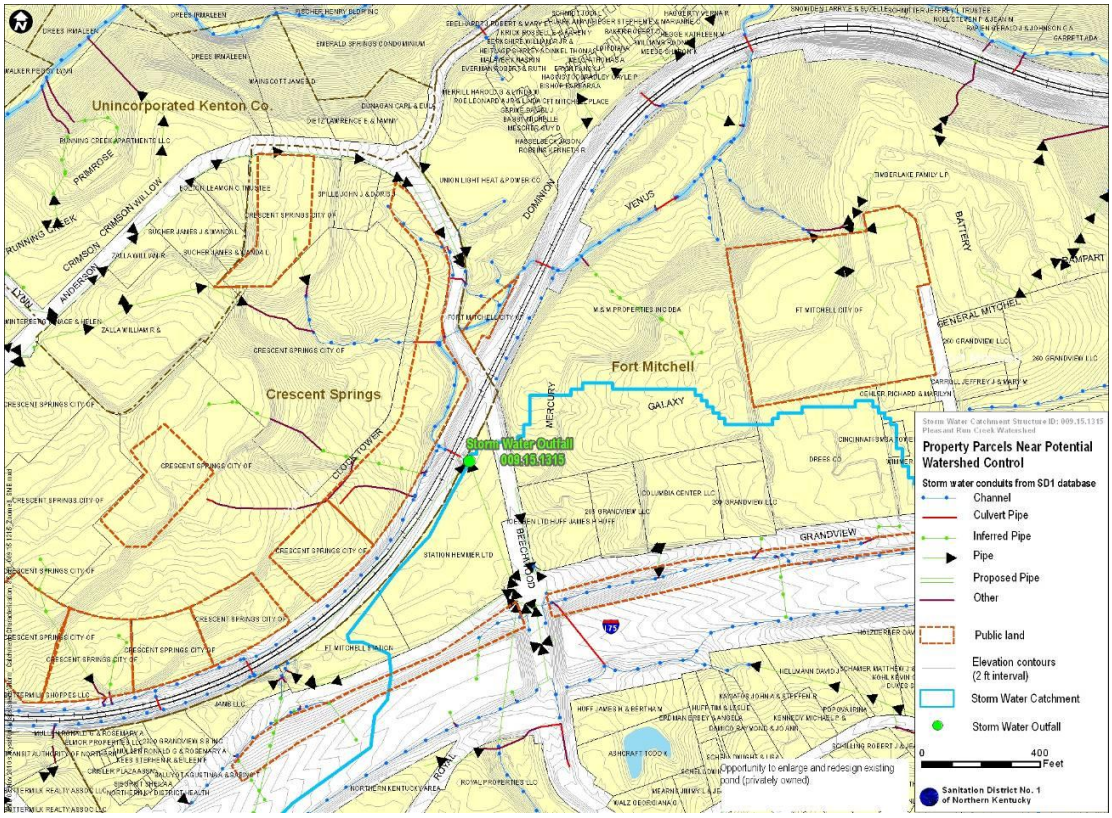

Figure 3.6 Example of Zoomed-In Delineated Catchment Map with Ownership Depicted

Once possible locations were identified, suitable types of control measure were considered. Options include:

- Newly constructed basins with bioretention or biofiltration features
- Storm water wetlands
- Retrofit of existing basins/ponds
- Daylighting storm water conduits

Using this desktop analysis, a number of potential locations were identified as preferred candidate sites and targeted for site inspection to provide an on-the-ground assessment of site conditions and to help evaluate control measure opportunity. To test the approach, site visits were conducted for 26 of the top 100 catchments. The site visits indicated that most of the locations are suitable candidates for either new projects or retrofits. Based on these findings, the decision was made to include decentralized watershed controls as a component of the overall water quality improvement program for SD1.

3.3 Implementation Program for Decentralized Watershed Controls

The opportunity analysis discussed in the preceding section demonstrated that opportunities exist for new or retrofit projects to enhance water quality in storm water runoff. However, almost no data are available to identify where storm water pollutant loading priority areas might exist. In 2009, SD1 updated plans to implement a Source Identification Program (SIP) that will generate

watershed data to identify and verify sources of bacteria loading to streams in the SD1 service area. Although originally conceived as a program to identify dry weather sources of bacteria loading, SD1 has modified the SIP to include wet weather bacteria sources as well. As such, the SIP will provide the means for prioritizing decentralized watershed control measures identified using the opportunity analysis approach described here.

3.4 Decentralized Watershed Control Modeling Analysis

Because of the focus of decentralized watershed controls on controlling pollutant loading from storm water, they have a great deal in common with two other water quality improvement programs dealing with storm water:

- Storm Water Control in RDII Priority Areas – SD1 has identified priority areas for elimination of rainfall-derived infiltration and inflow (RDII) from the separate sanitary system to address sanitary sewer overflows (SSOs). In conjunction with these RDII priority removal projects, SD1 plans to implement storm water control measures to manage storm water.
- Storm Water Management Program – New storm water regulations will require implementation of storm water control measures to manage the runoff produced from the first 0.8" of rainfall for new development projects.

To varying degrees, the timing and location of these two programs and the implementation of decentralized storm water control measures are somewhat uncertain. Because the specific nature of projects under each program and the exact timing and spatial distribution of the projects are not defined at this time, the three decentralized control measure programs are considered as related water quality improvement programs for watershed planning purposes and were modeled as a single program.

Figure 3.7 shows modeled recreation season geometric mean bacteria density in Banklick Creek, as a result of the three decentralized control measure programs. Figure 3.8 shows the model-predicted compliance rate (2030 conditions), represented as the percent of days during the recreation season with average bacteria density less than 400 cfu/100 ml.

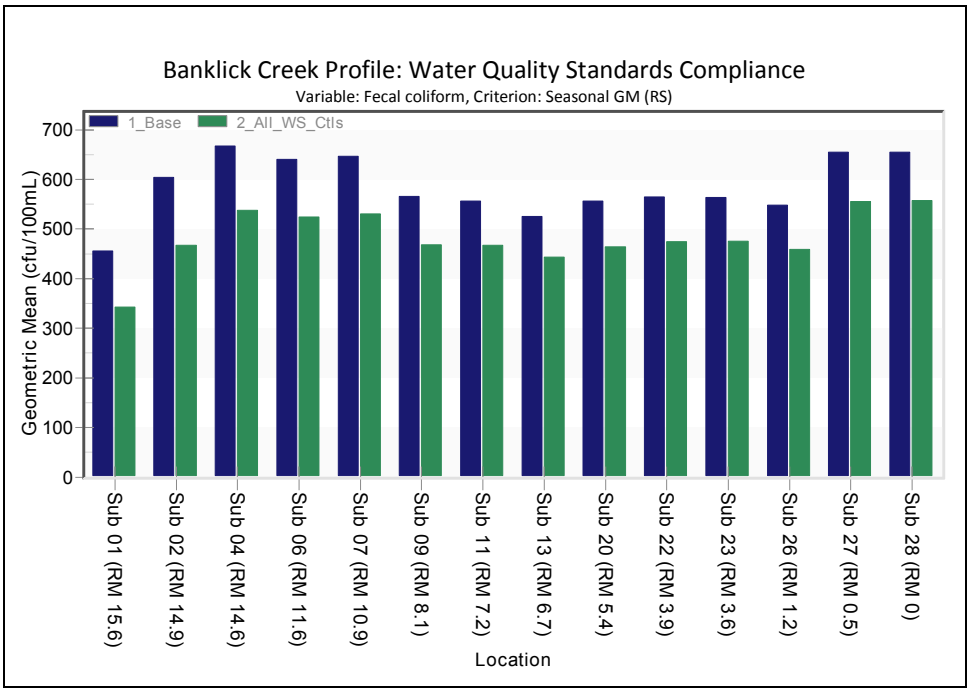

Figure 3.7 Modeling Results for Recreation Season Geomean in Banklick Creek as a Result of Decentralized Control Measure Programs

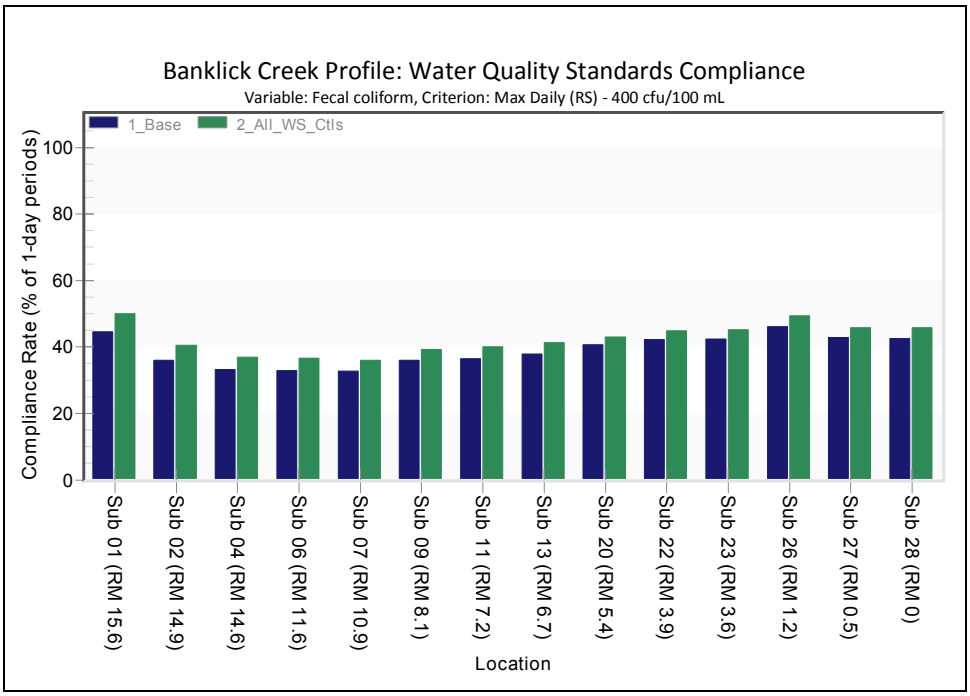

Figure 3.8 Modeled Water Quality Standards Compliance in Banklick Creek as a Result of Decentralized Control Measure Programs

These model results show that the three decentralized control measure programs can potentially result in a significant benefit to water quality in Banklick Creek. Specifically, the results show:

- The decentralized control measure programs result in an improvement in the recreation season geomean bacteria density of up to 25%, from 456 cfu/100 ml to 343 cfu/100 ml at river mile 15.6. At the mouth of Banklick Creek an improvement of 15% is estimated, from 655 cfu/100 mil to 557 cfu/100 ml.
- The compliance rate (number of recreation season days with an average bacteria density less than 400 cfu/100 ml) is estimated to improve by a little over 5% at river mile 15.6 to about 3% near the mouth.

3.5 Summary of Findings for Decentralized Watershed Controls

Based on the opportunity analysis and modeling results described in the preceding sections, it appears that a program of decentralized watershed controls can be a significant element of SD1's overall program of water quality improvement. Specifically, the following findings are supported:

- Multiple opportunities for decentralized watershed controls exist throughout the SD1 service area.
- Decentralized watershed control opportunities include both new control measures and retrofit opportunities at existing storm water basins.
- Decentralized watershed controls will complement other programs planned by SD1 such as storm water management at high priority RDII elimination projects and storm water controls for new construction.

Some aspects of implementing decentralized watershed controls remain to be clarified, including costs, treatment effectiveness, and how SD1 will work with existing landowners. This can be accomplished by implementing a series of pilot projects and monitoring the outcomes. In the first five-year planning cycle, SD1 plans to identify and implement up to three decentralized watershed control measures.

SECTION 4. STREAM RESTORATION

Stream restoration commonly refers to a range of activities intended to improve the function or aesthetics of a stream. In the context of SD1's watershed planning effort, stream restoration has a specific meaning, as described below. Riparian buffers and livestock exclusion were also considered as activities related to stream restoration.

4.1 Stream Restoration in the SD1 Watershed Planning Context

Stream restoration or enhancement techniques are frequently used to improve water quality in a variety of ways, including those listed in Table 4.1.

Table 4.1 Examples of Stream Restoration Activities that Reduce Problem Bacteria Levels (Modified from Burnett 2010)

Restoration Action	Bacteria Reducing Benefits
Livestock Exclusion	Decreases direct deposit of bacterial sources (Zeckoski et al., 2007; Benham et al., 2008)
Riparian Buffer	Reduces direct bacteria loading through interception (Larsen et al., 1994)
Channel Naturalization	Reduce bacteria loading by increasing transient storage time within active channel and substrate (Brukaveckas, 2007)
Floodplain Reconnection	Reduces bacteria loading by increasing frequency of flood waters entering natural retention zones in floodplain (Brukaveckas, 2007)

4.1.1 In-Channel Stream Restoration Practices

Within the stream channel, some of the key processes believed to be responsible for bacteria removal in aquatic systems include filtration, solar irradiation, sedimentation and others (Davies and Bavor, 2000). With a stream restoration focus, the effectiveness of bacterial treatments (controls) seem to be related to the rate to which particles suspended in water will bind to fine sediments and settle into the substrates (Davies and Bavor, 2000). Control features such as in-channel pool development, channel lengthening or threaded channel development, and riparian floodplain development can all be considered and implemented where appropriate to increase settling rates of suspended materials (Saldi-Caromile et al., 2004).

In the context of SD1's watershed planning effort, stream restoration refers to projects that integrate in-channel pools, channel lengthening, and riparian floodplain reconnection to increase hydraulic residence time, thereby increasing bacteria die-off. SD1 conducted a focused evaluation to identify potential stream restoration opportunities, as described in Section 4.2, below.

4.1.2 Riparian Buffers Restoration

Riparian buffers are vegetated areas of land adjacent to water bodies, composed of multiple levels vegetation and have varying widths (Figure 4.1). Riparian buffers are very similar to vegetated filter strips, but vegetated filter strips can be anywhere on the landscape.

Research has shown that riparian buffers can be effective at reducing a variety of pollutants including nitrogen, phosphorus, sediments, and bacteria. Riparian buffers function by physical filtration and plant uptake of pollutants from overland flow. The slowing of overland flow

promotes infiltration and roots of plants in the riparian buffer take up and transform pollutants and nutrients from shallow groundwater (Novotny 2003). In order to be effective in the removal of pollutants, riparian buffers must receive direct overland flow of polluted waters. If agricultural or storm water drainage ditches bypass the buffers and convey runoff directly to the stream, no treatment can occur. With proper siting, bacteria pollutant removal rates have been reported to range from 23% to 99% (Table 4.2).

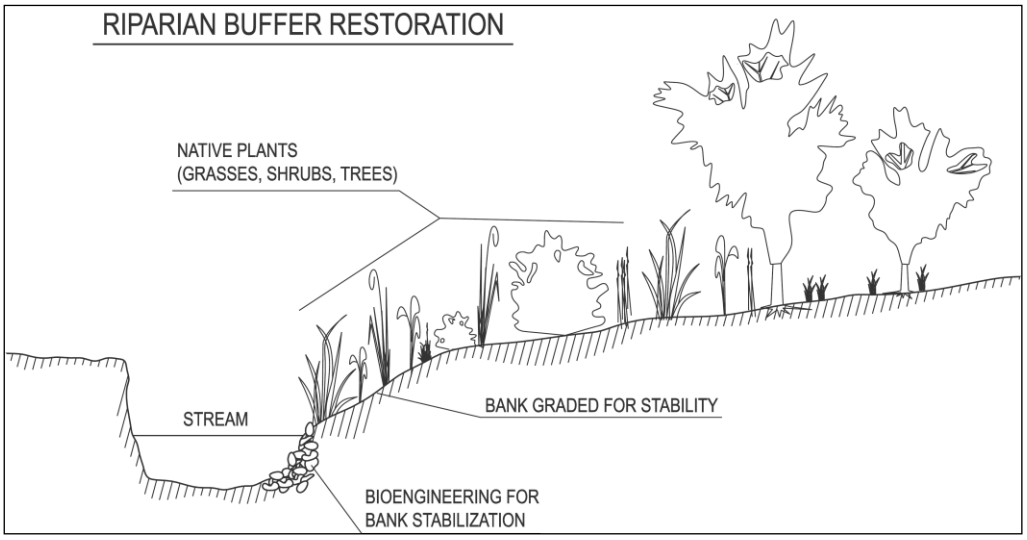

Figure 4.1 Conceptual Layout of Riparian Buffer

Table 4.2 Riparian Buffer and Vegetated Filter Strip Pollutant Removal

Reference	Study Scale	Published Pollutant Removal				
		Fecal coliform	Fecal streptococci	Solids	Total Phosphorus	Nitrogen
Coyne et al. 1998	Field	75% - 91%	68% - 74%	96% - 98%	-	-
Lowrance et al. 1997	Lit. Review	-	-	30% - 80%	50% -70%	40% - 60%
Mankin et al. 2007	Field	-	-	97.9%	42.9%	44.4%
Roodsari et al. 2005	Plot	23% - 67%	-	-	-	-
Sullivan et al. 2007	Field	99%	-	-	-	-

These results suggest that riparian buffers can be very effective at controlling pollutant loading to streams via direct runoff. Riparian buffers also provide other ancillary benefits. Biological benefits include increased riparian and aquatic habitat. Another benefit of riparian buffers is their ability to cool streams through shading, allowing less temperature tolerant aquatic species to survive. The buffer root structures can also help stabilize stream banks.

4.1.3 Livestock Exclusion

Direct access of livestock to streams can be a major source of bacterial loading in rural areas Figure 4.2). Measures used to prevent this direct access to streams are referred to as livestock exclusion.

Figure 4.2 Cows Freely Entering Stream (Photo: KY Division of Water 2008)

Livestock exclusion requires the cooperation of the animal husbandry operators and involves restricting access to streams so agricultural animals cannot directly deposit waste into surface waters. Provisions for alternate water sources for livestock, is also often required. Quantifying the results of this control measure can be difficult, but research has shown reductions of fecal coliform post implementation of exclusionary fencing (Line 2003; Meals 2001).

It is not currently known whether the presence of livestock in streams is a problem in the study area and, if it is, what the magnitude of the problem may be. Some information on this may be revealed from results of the Source Identification Program that is currently being pilot tested.

4.2 Stream Restoration Opportunity Identification

The stream restoration opportunity identification process focused on six priority watershed shown in Figure 4.3. These are: Banklick Creek, Fourmile Creek, Pleasant Run Creek, Taylor Creek, Threemile Creek and the Licking River. The Ohio River East and Ohio River North watersheds were not included in this analysis because they contain relatively small tributaries to the Ohio River; flows from those storm water catchments are much smaller than the flow of the Ohio River, making it unlikely that watershed controls in those watersheds could make a measurable improvement in Ohio River water quality.

The objective of this effort was to identify locations within priority watersheds where restoration actions might result in a reduction in problem bacteria levels.

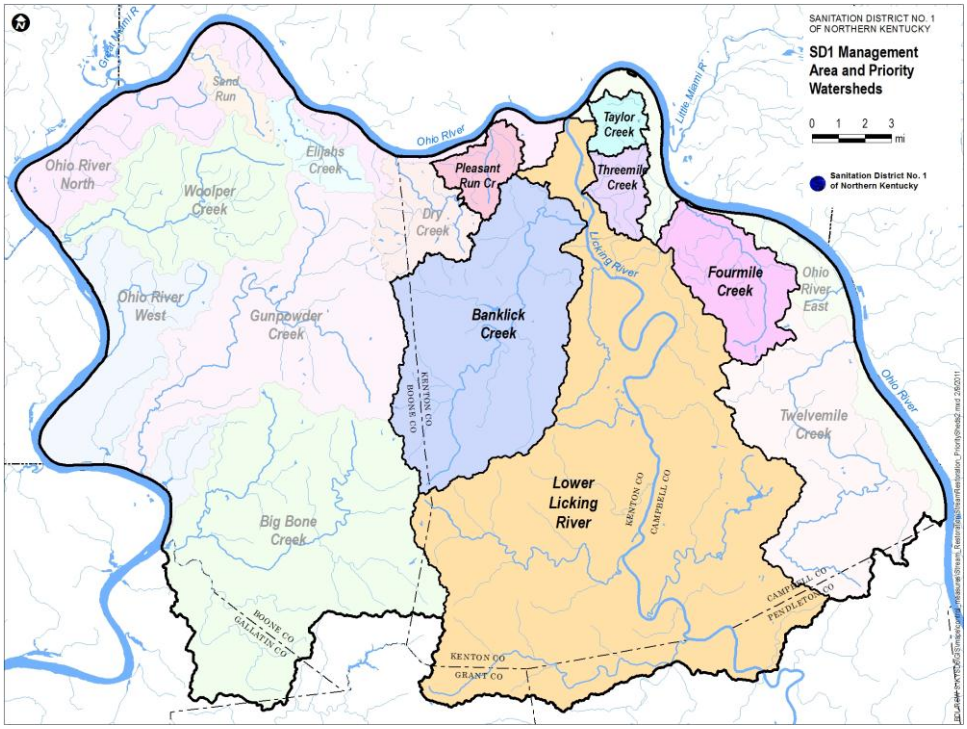

Figure 4.3 Priority Watersheds Considered in the Bacteria Control Evaluation of Restoration Options

A detailed GIS evaluation was conducted across portions of the District's service area to identify segments within priority watersheds that may offer stream enhancement or restoration options for reducing or controlling problem bacteria inputs. Updated spatial data layers were compiled from the SD1 Infrastructure Geodatabase for a visual evaluation and identification of potential restoration stream segments. GIS data used to support the restoration evaluation included:

- SD1's storm conduit (which includes USGS solid "blueline streams, perennial);
- Floodplains;
- Elevation contours (2 ft.);
- Side-stream control sites (low gradient riparian areas lacking developed forestlands);
- Aerial imagery (2007); and
- Ponds, lakes and wetlands.

A GIS project was then created to allow a visual assessment of locations within the priority watersheds that might provide restoration opportunities. Only perennial streams within the priority watersheds were included in the GIS examination. High resolution, aerial imagery was combined with the perennial stream layer to allow fine-scale examination and identification of modified streams and reaches that met the following minimum criteria:

- Designated perennial stream segment (see Table 4.3);
- Possible anthropogenic alterations to the stream plan pattern and/or channel cross-section;
- 100 feet or more in length;

- 20 feet or more of riparian width; and
- Restoration options appear reasonable (implementable) and appropriate (dimension, pattern and profile) for system.

Techniques were specifically considered for altered stream reaches that appeared to offer bacteria control opportunities such as in-channel pool development, channel lengthening or threaded channel development, and riparian floodplain development or reconnection.

Table 4.3 Target Watersheds Included in the Stream Restoration Opportunity Analysis

Priority Watershed	Watershed Area (mi^2)	Perennial Stream Lengths (Miles)
Banklick Creek	58.2	45
Fourmile Creek	17.8	20
Pleasant Run	6.5	5
Taylor Creek	4.2	8
Threemile Creek	5.9	5
Licking River	170	128

The six priority watersheds included 211 miles of evaluated perennial streams as detailed in Table 4.3. The potential restoration segments were identified for each watershed. The results of this evaluation are summarized by watershed below and include the number of identified segments, the total length of potential restoration segments, stream segment within the watershed and length within the steam segments. Maps are also included depicting the locations of the restoration segments for further consideration. As SD1 considers specific locations for implementing bacteria reductions, these areas could aid in site selection across the study area.

4.2.1 Stream Restoration Opportunities in Banklick Creek Watershed

In total, 42 potential stream restoration segments were identified in Banklick Creek watershed, totaling 37,085 feet, as summarized in Table 4.4 and shown in Figure 4.4.

Table 4.4 Stream Restoration Opportunity Summary in Banklick Creek Watershed

Stream Reach	Total Reach Length (ft)
Banklick Creek	22,910
Brushy Fork	5,490
Bullock Pen Creek	130
Fowler Creek	4,840
Holds Branch	110
Unnamed Tributary	1,505
Wolf Pen Branch	2,100

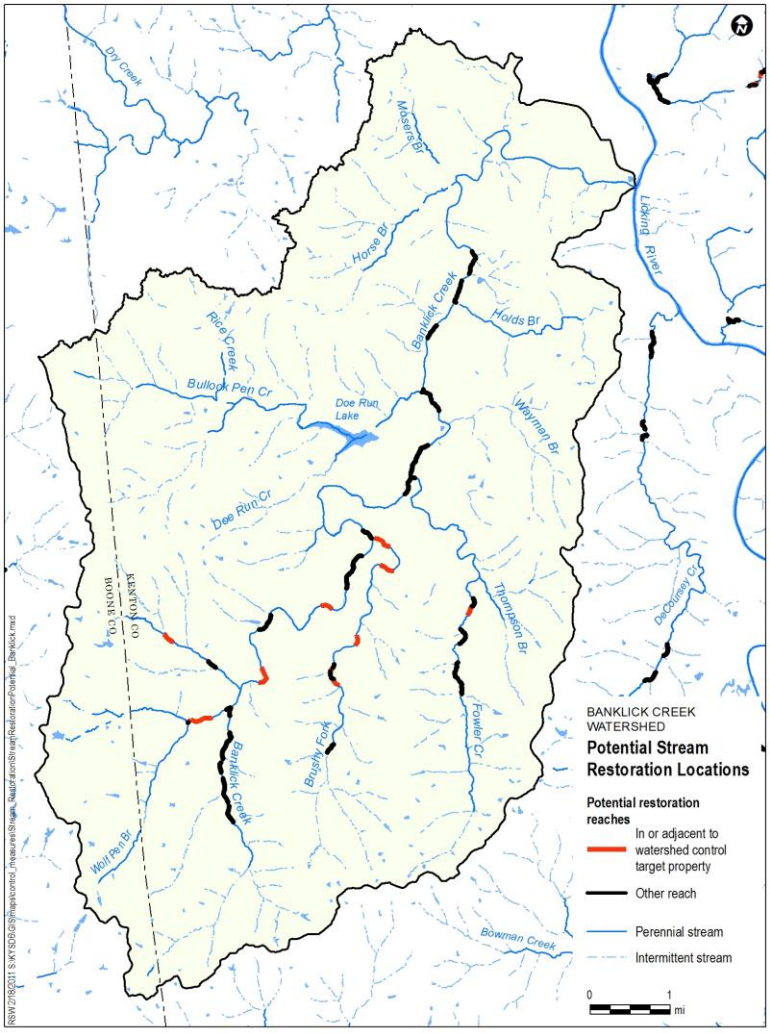

Figure 4.4 Banklick Creek Stream Restoration Opportunity Locations

4.2.2 Stream Restoration Opportunities in Fourmile Creek Watershed

In total, 19 potential stream restoration segments were identified in Fourmile Creek watershed, totaling 23,995 feet, as summarized in Table 4.5 and shown in Figure 4.5.

Table 4.5 Stream Restoration Opportunity Summary in Fourmile Creek Watershed

Stream Reach	Total Reach Length (ft)
Duck Creek	1,165
Fourmile Creek	12,545
Owl Creek	7,150
Tug Creek	2,350
Unnamed Tributary to Duck Creek	785

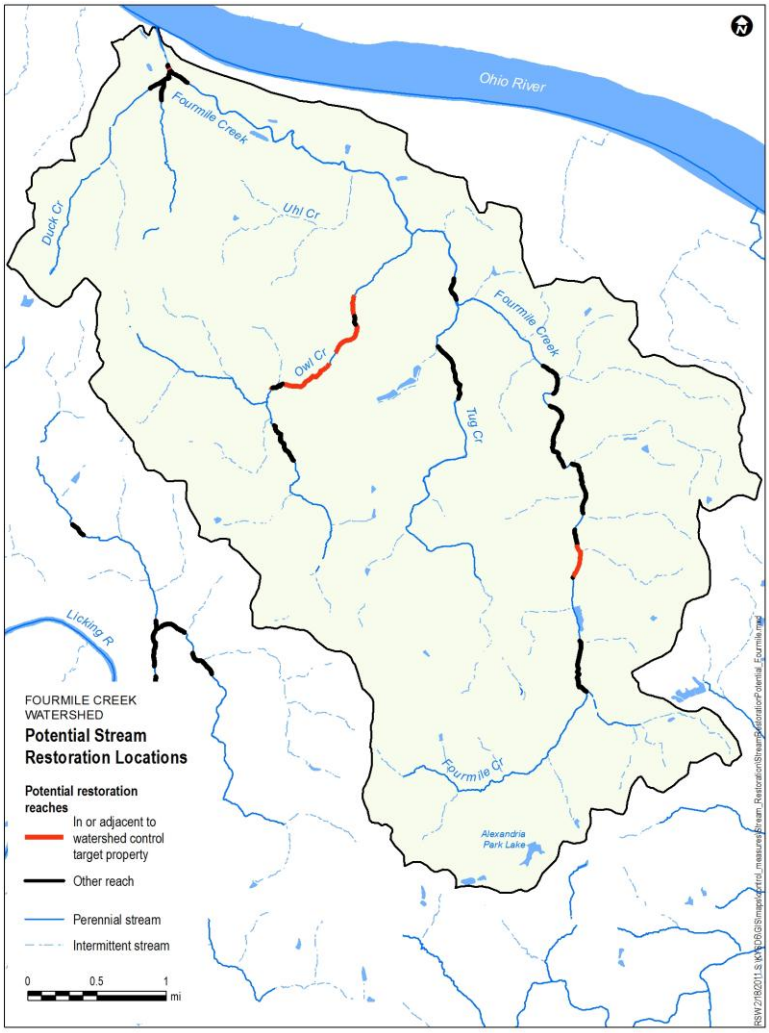

Figure 4.5 Fourmile Creek Stream Restoration Opportunity Locations

4.2.3 Stream Restoration Opportunities in Licking River Watershed

In total, 53 potential stream restoration segments were identified in the Licking River watershed, totaling 103,910 feet, as summarized in Table 4.6 and Figure 4.6.

Table 4.6 Stream Restoration Opportunity Summary in Licking River Watershed

Stream Reach	Total Reach Length (ft)
Bowman Creek	8,935
Cruises Creek	16,335
DeCoursey Creek	4,980
Little Cruises Creek	365
North Fork Grassy Creek	22,775
Phillips Creek	9,200
Plum Creek	3,830
Pond Creek	8,245
Pooles Creek	255
Riffle Creek	5,300
Rodmard Branch	490
Scaffold Creek	1,780
Steep Creek	5,455
Trace Run	695
Unnamed Tributary to Cruises Creek	1,355
Unnamed Tributary to Philips Creek	6,470
Unnamed Tributary to Pooles Creek	885
Unnamed Tributary to Riffle Creek	920
Unnamed Tributary to Willow Creek	3,355
Willow Creek	2,285

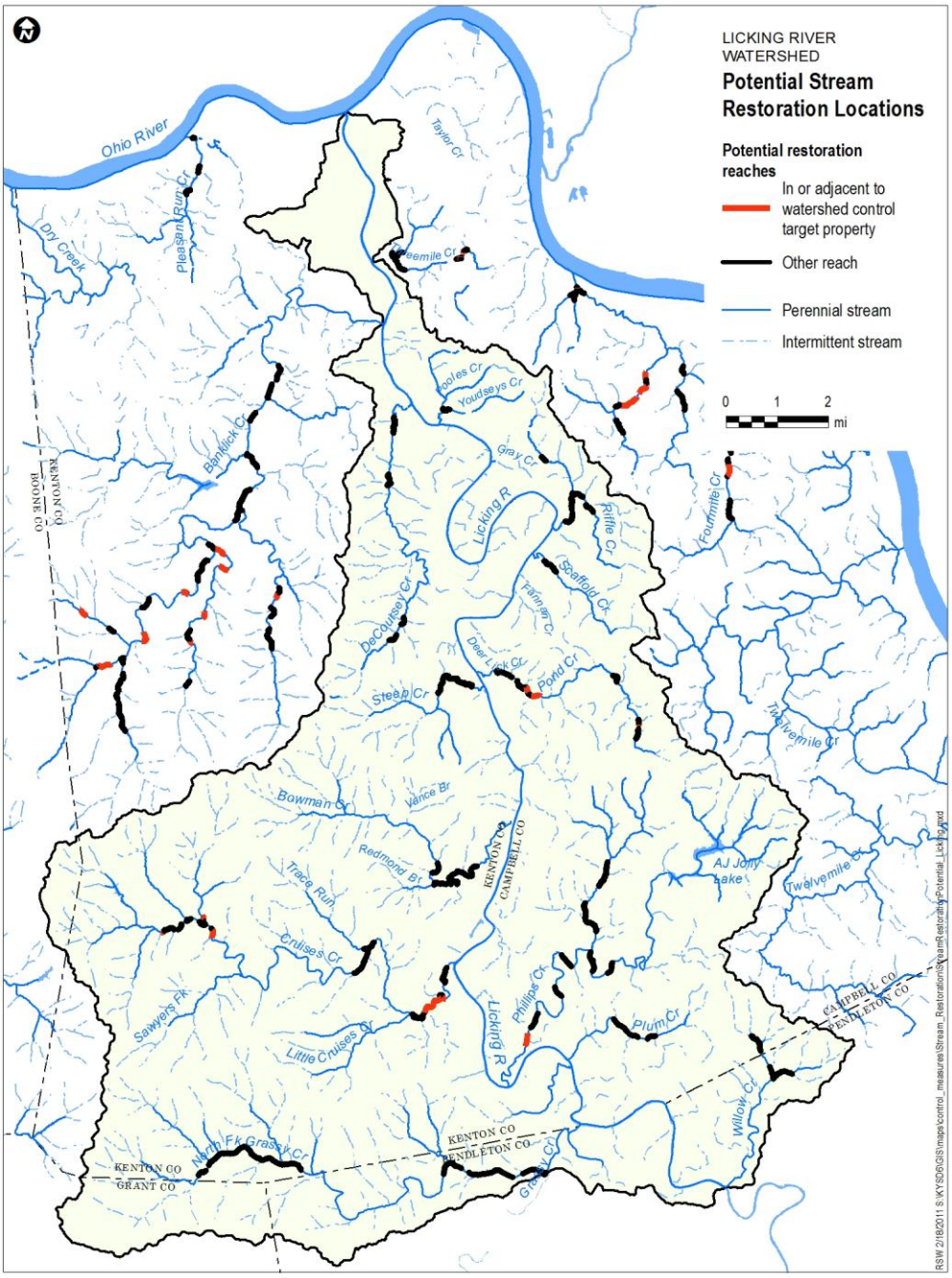

Figure 4.6 Licking River Watershed Stream Restoration Opportunity Locations

4.2.4 Stream Restoration Opportunities in Pleasant Run Creek Watershed

In total, three potential stream restoration segments were identified in Pleasant Run Creek watershed, totaling 1,790 feet, shown in Figure 4.7.

Figure 4.7 Pleasant Run Creek Stream Restoration Opportunity Locations

4.2.5 Stream Restoration Opportunities in the Taylor and Threemile Creek Watersheds

In total, 7 potential stream restoration segments were identified in the Threemile Creek watershed, totaling 5,600 feet, as summarized in Table 4.7 and Figure 4.8. None were identified in the Taylor Creek watershed.

Table 4.7 Stream Restoration Opportunity Summary in the Threemile Creek Watershed

Stream Reach	Total Reach Length (ft)
North Branch Threemile Creek	1,690
Threemile Creek (mainstem)	3,910

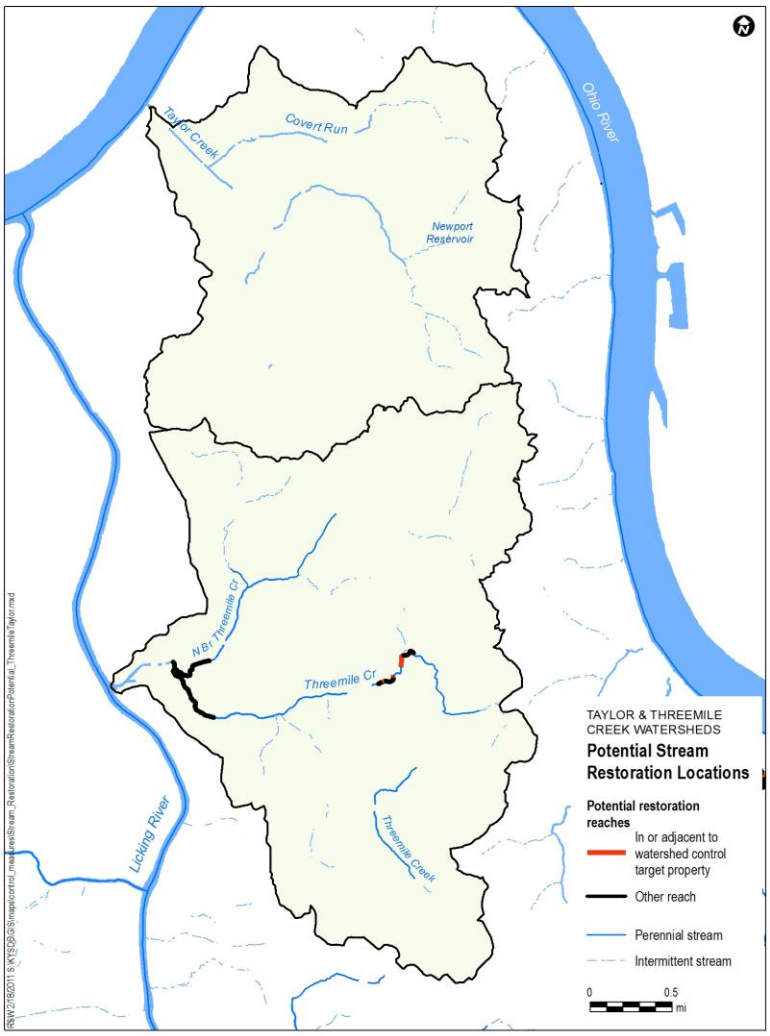

Figure 4.8 Taylor and Threemile Creek Stream Restoration Opportunity Locations

4.3 Riparian Buffers Opportunity Identification

Buffer site selections focused on public and agricultural parcels. Public parcels represented the best opportunity from a construction and access standpoint. Pasture lands represented the most opportunity for bacteria to enter the waterways as a non-point source. This prioritization was used to focus on these two parcel types for the buffer analysis.

All of the agriculture and public properties were first overlaid on the National Hydrography Dataset (NHD) high resolution dataset. Parcels adjacent to or containing rivers were selected as potential buffer sites. These potential sites could represent the need for either riparian buffer upgrade or the construction of new buffers. The length of potential buffers within each parcel was calculated. Finally, the drainage area of each buffer within the targeted source parcels was delineated. The delineated drainage area was then clipped to the source parcel (Figure 4.9). This allowed for an understanding of the area of targeted bacteria source which would be treated with the buffer upgrade or installation.

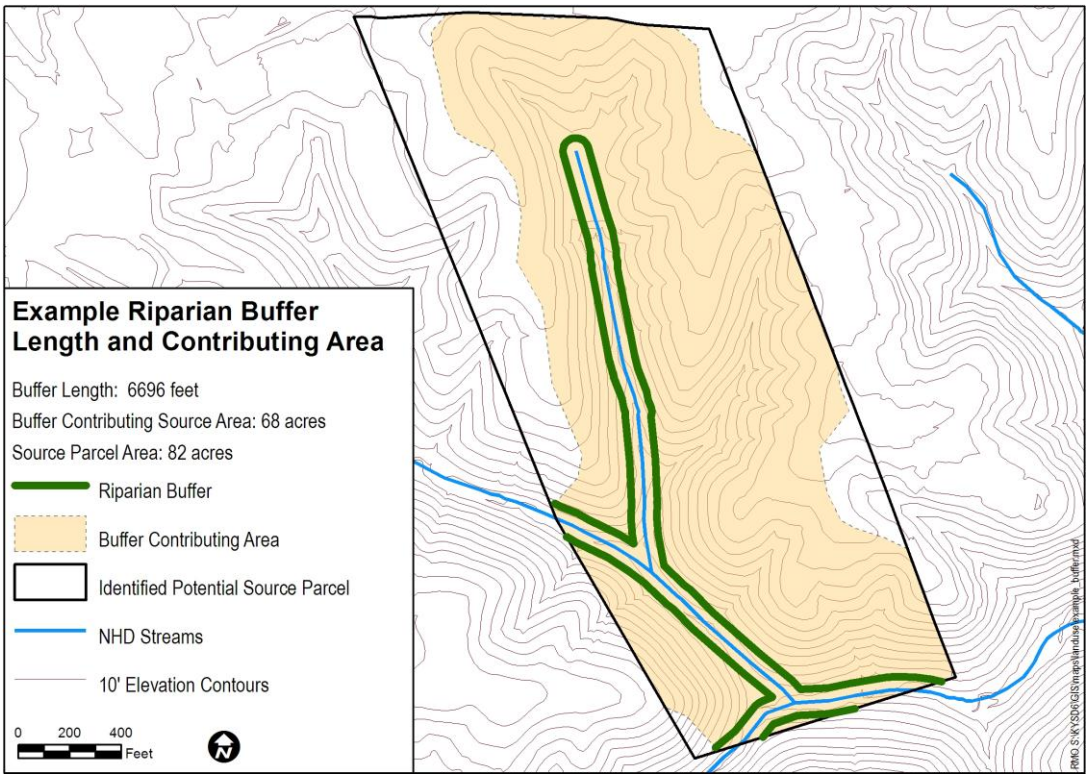

Figure 4.9 Riparian Buffer Measure Example

Many opportunities were identified across the eight priority watersheds for restoration or preservation of riparian buffers. These opportunities were evaluated further by reviewing aerial photography to evaluate existing riparian land use and condition. Because of their potential benefit for improvement of water quality, habitat, and overall stream health, SD1 intends to support riparian buffer initiatives during the first five-year improvement program.

4.3.1 Riparian Buffer Opportunities in Banklick Creek Watershed

A total of 67 potential buffer locations were identified in Banklick Creek (Figure 4.10). These buffers would treat 2,922 acres of pasture and public land. This represents 70% of the Banklick Creek public and pasture parcel area identified earlier in the analysis. The total length of potential buffers in the watershed is 32.1 miles[4].

[4] Buffer length refers to the total bank length found within source parcels where buffers can be constructed, upgraded, or preserved.

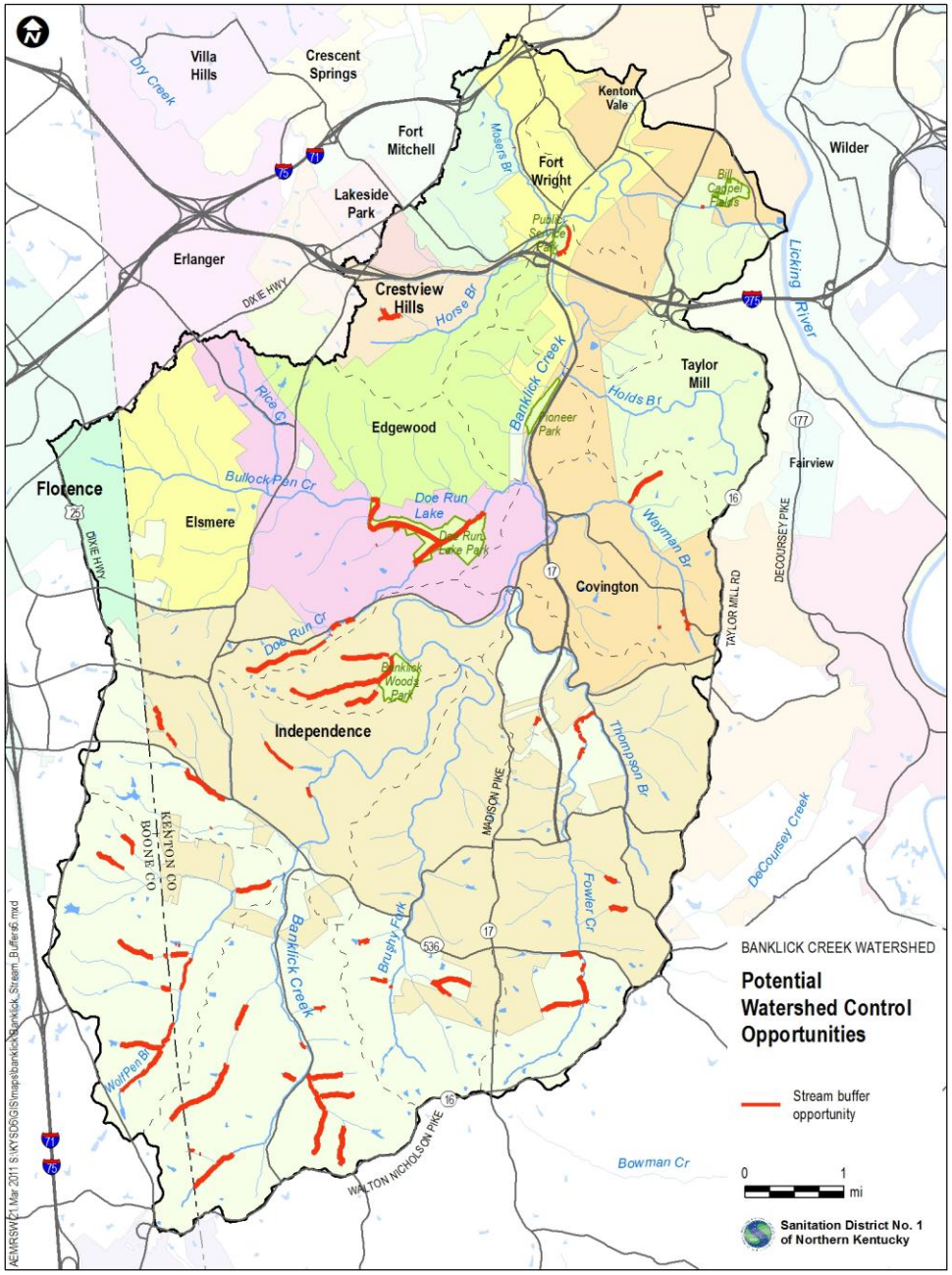

Figure 4.10 Banklick Creek Riparian Buffer Restoration Opportunity Locations

4.3.2 Riparian Buffer Opportunities in Fourmile Creek Watershed

In the Fourmile Creek watershed, 30 potential riparian buffers were identified (Figure 4.11). These buffers totaled 10.4 in length. The buffers were found to drain an area of 748 acres of pasture and public source parcels. This area represented 74% of the area associated with these two identified sources.

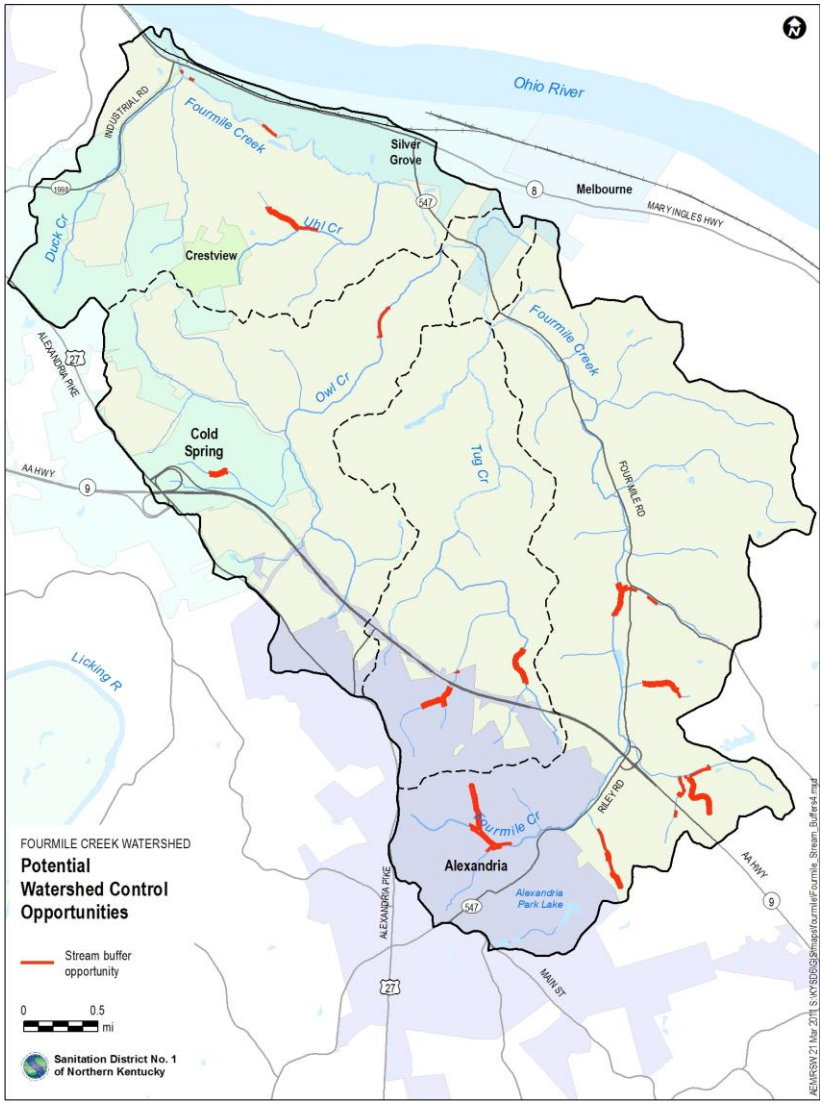

Figure 4.11 Fourmile Creek Riparian Buffer Restoration Opportunity Locations

4.3.3 Riparian Buffer Opportunities in Licking River Watershed

Potential buffers in the Licking River watershed totaled to 106.1 miles in length (Figure 4.12). The buffers contributing area made up 81% (9,421 acres) of identified pasture and public parcels.

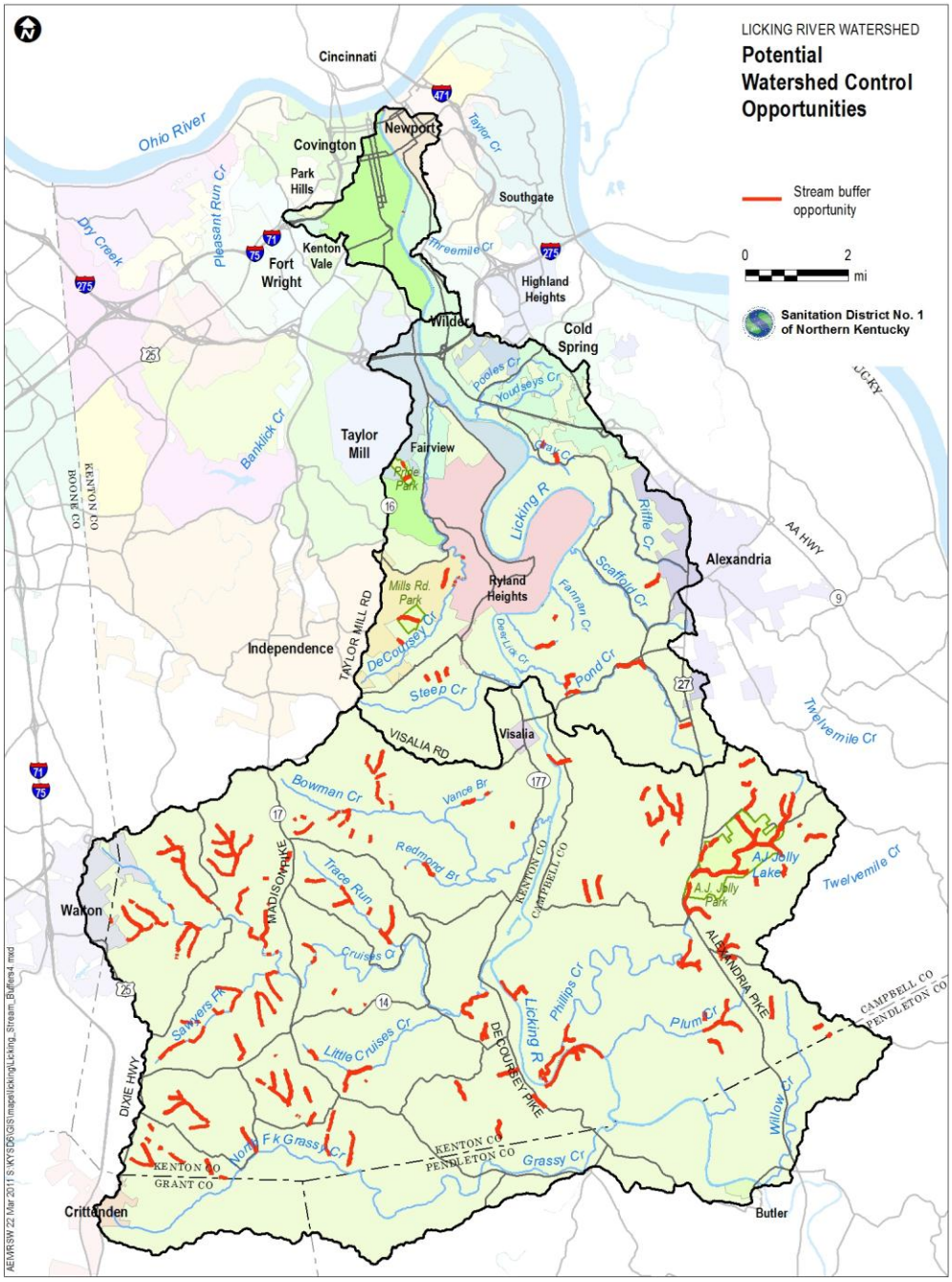

Figure 4.12 Licking River Watershed Riparian Buffer Restoration Opportunity Locations

4.3.4 Riparian Buffer Opportunities in Pleasant Run Creek Watershed

One reach was identified as a potential location for riparian buffers, but it was located in Devou Park and this tributary reach is already wooded (Figure 4.13).

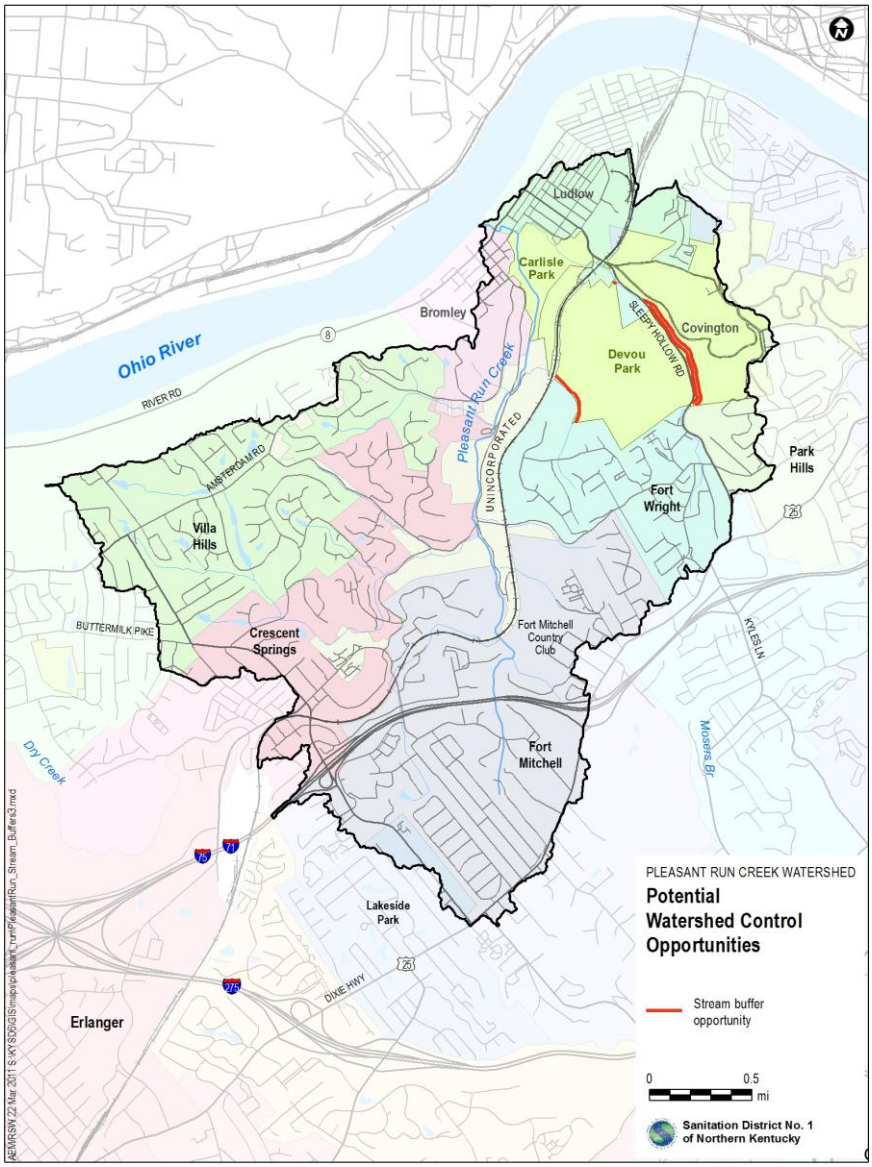

Figure 4.13 Pleasant Run Creek Riparian Buffer Restoration Opportunity Locations

4.3.5 Riparian Buffer Opportunities in the Taylor Creek Watershed

Within the 7 identified public parcels in the Taylor Creek watershed 1 mile of potential stream buffer was identified (Figure 4.14). The contributing drainage area to these buffers was found to include 47 acres (46%) of the public source parcels.

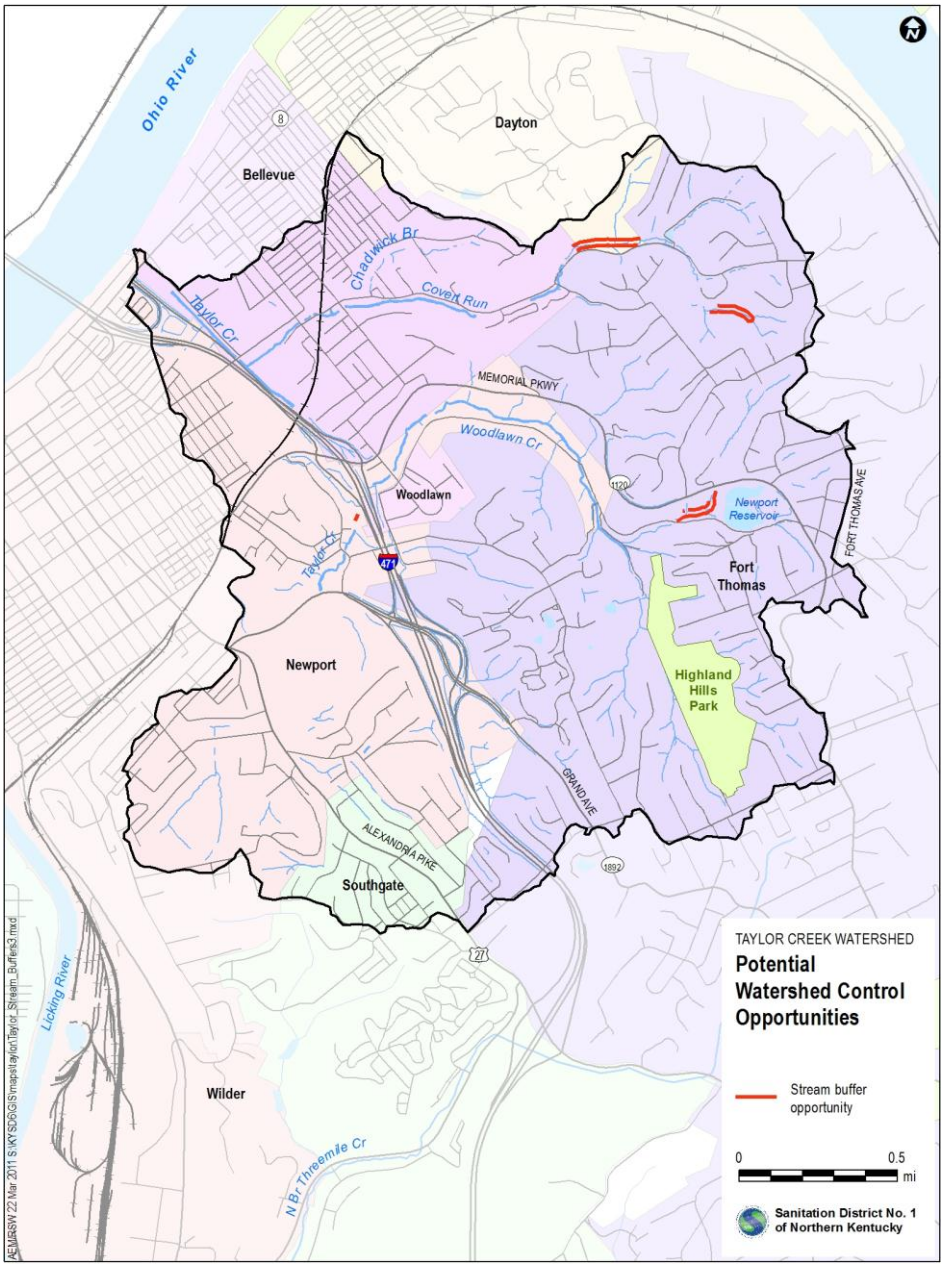

Figure 4.14 Taylor Creek Riparian Buffer Restoration Opportunity Locations

4.3.6 Riparian Buffer Opportunities in the Threemile Creek Watershed

In Threemile Creek, 1.8 miles of riparian buffer were identified (Figure 4.15). The contributing area of these buffers contains 79 acres (21%) of identified public and pasture property in the watershed.

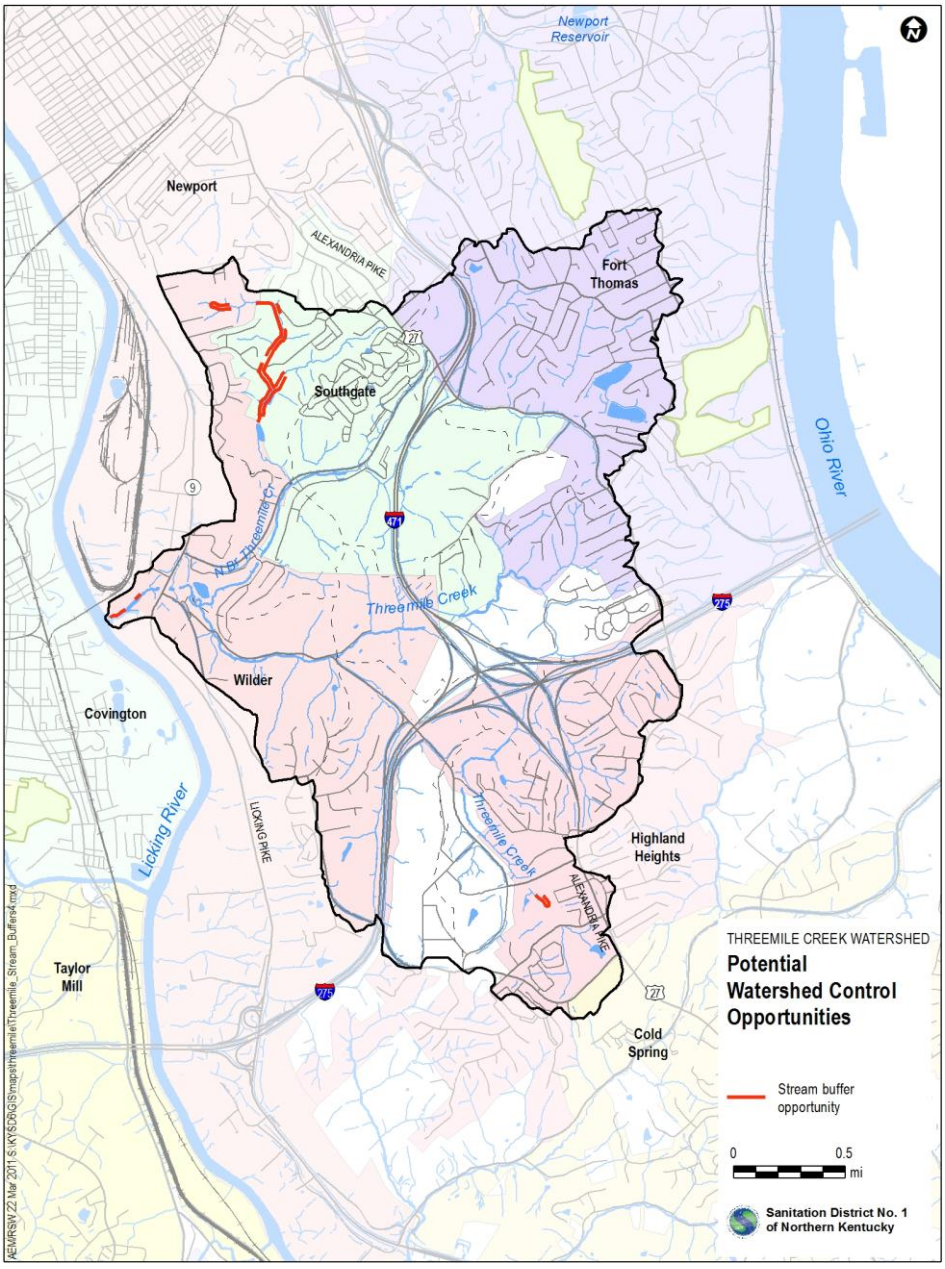

Figure 4.15 Threemile Creek Riparian Buffer Restoration Opportunity Locations

4.3.7 Riparian Buffer Opportunities in the Ohio River East Watershed

Some opportunities for riparian buffers were identified (Figure 4.16) in the Ohio River East watershed. 10.8 miles of potential riparian buffers were selected in the Ohio River East watershed. The contributing area of these potential buffer sites included 63% (715 acres) of pasture or public source parcels in the watershed.

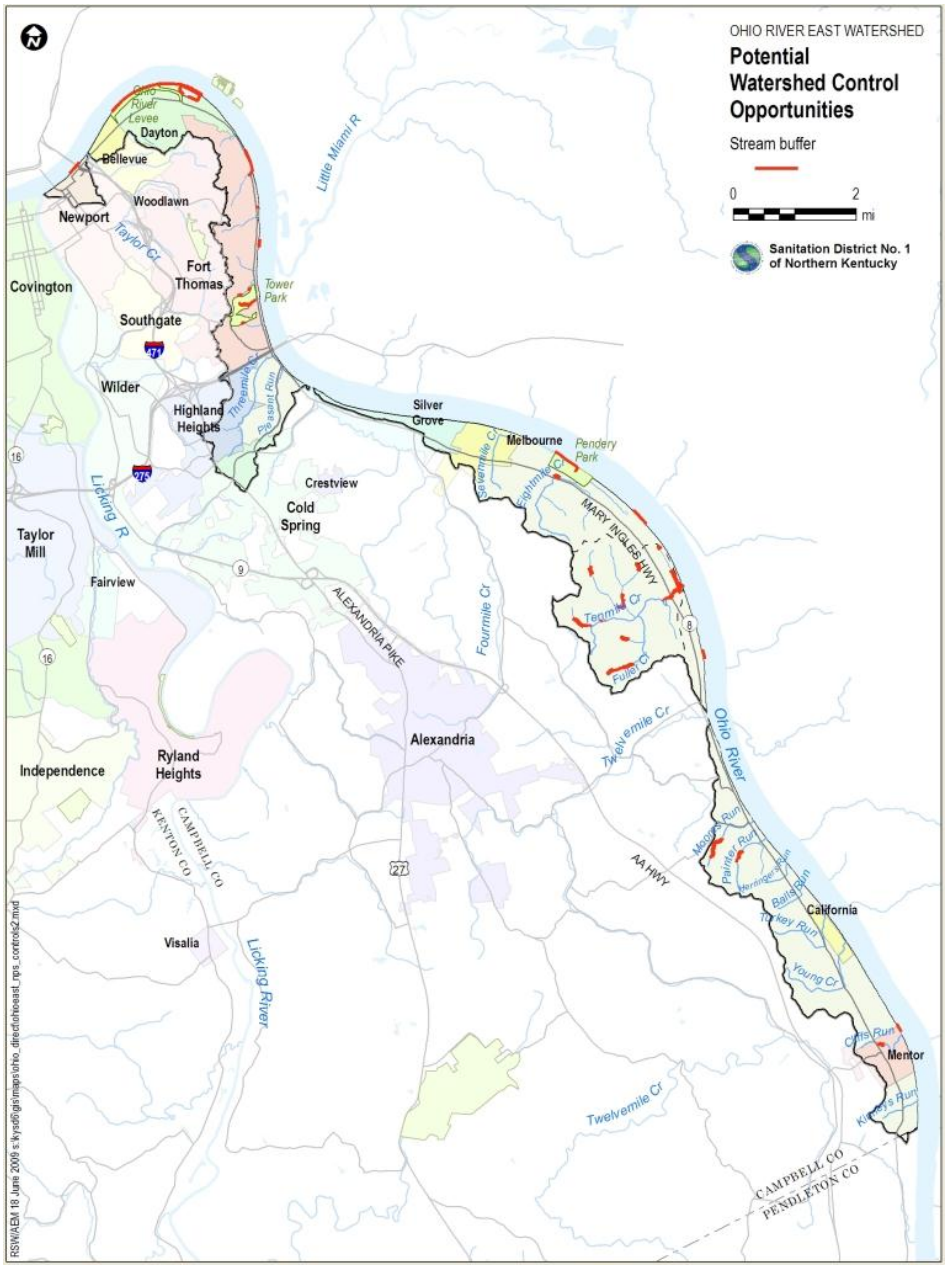

Figure 4.16 Ohio River East Riparian Buffer Restoration Opportunity Locations

4.3.8 Riparian Buffer Opportunities in the Ohio River North Watershed

In the Ohio River North watershed, 13.7 miles of potential riparian buffer were identified (4.17). The contributing area of these buffers (1,156 acres) includes 62% of the identified pasture and public parcel area.

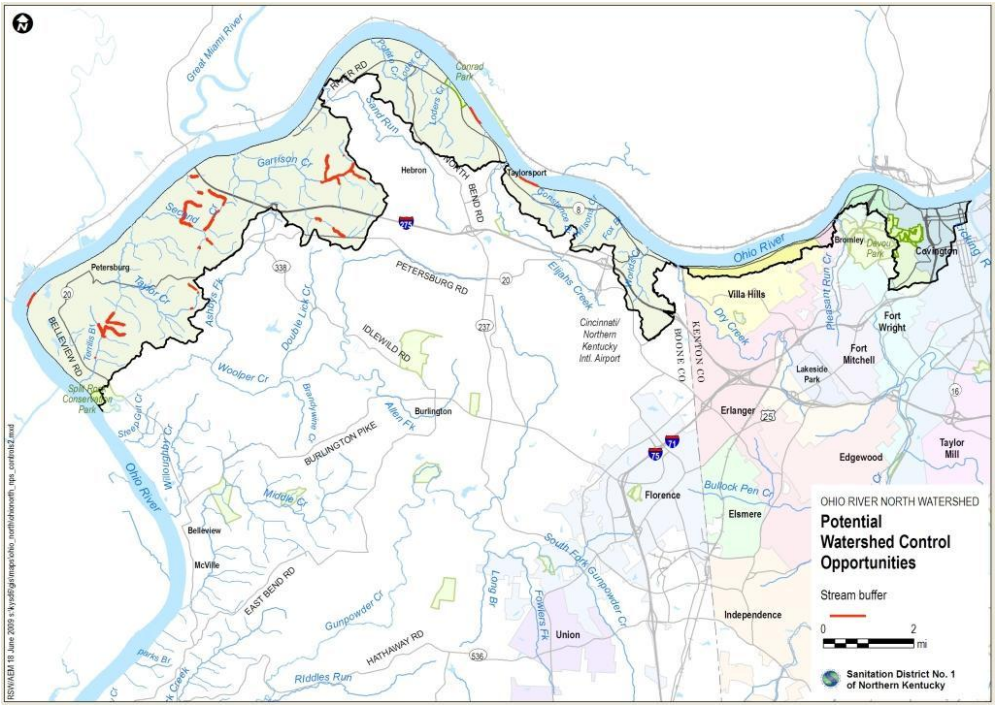

Figure 4.17 Ohio River North Riparian Buffer Restoration Opportunity Locations

The opportunities for riparian buffers identified in this analysis are spatially dispersed and each buffer opportunity by itself is likely to have local benefits. However, in order to maximize the benefit of riparian buffers, large-scale implementation is necessary, which will require the cooperation of many property owners. SD1 will provide technical support for third parties (such as local watershed councils) to implement riparian buffers and provide ordinance support for planning and zoning agencies that encourage open space preservation. The potential water quality benefits of large-scale riparian buffer implementation were analyzed as a way to determine which watersheds might see the greatest benefits from buffers. The results of this analysis are presented in the next section.

4.4 Stream Restoration Water Quality Improvement Potential

Potential water quality improvements from in-channel stream restoration and riparian buffers were evaluated and are discussed below.

4.4.1 Water Quality Improvement Potential for In-Stream Restoration Practices

After completing the stream restoration opportunity analysis, it was observed that most of the reaches identified in target watersheds were relatively short. As such, an evaluation was required to determine what length would constitute a sufficiently long reach to achieve significant water

quality improvement. To answer this question, the end goal of increasing hydraulic residence time to facilitate bacteria die-off was identified, and the increase in stream length required to achieve significant die-off under typical conditions was back-calculated.

This calculation was performed using a simple first-order decay rate equation:

$$D/D_o = e^{-kt}$$

Where:

D = the bacteria density after time "t"

D_o = the original bacteria density

k = the bacteria die-off rate constant

t = time

In this equation, the ratio of D/D_o represents the fraction of the original bacteria density remaining after time "t", so the quantity $1- D/D_o$ represents the fraction of the original bacteria density that has been treated. So:

$$1- D/D_o = 1- e^{-kt}$$

If "k" is a constant, then the quantity $1- D/D_o$ is a function of time, "t". In this calculation "t" represents the residence time in a restored reach of stream and can be calculated by assuming an average flow velocity and a distance:

$$t = d/V$$

Where:

d = the length of the restored stream reach

V = the average flow velocity

A spreadsheet was prepared to make this calculation for a range of flow velocities and distances (Table 4.8).

Table 4.8 Bacteria Die-Off in Stream Reaches as a Function of Added Stream Length and Flow Velocity (Decay Rate = 2/day)

Added Stream Length		Flow Velocity					
Feet	Miles	Ft/Sec					
		1	2	5	10	15	20
500	0.09	1.2%	0.6%	0.2%	0.1%	0.1%	0.1%
1000	0.19	2.3%	1.2%	0.5%	0.2%	0.2%	0.1%
2000	0.38	4.5%	2.3%	0.9%	0.5%	0.3%	0.2%
3000	0.57	6.7%	3.4%	1.4%	0.7%	0.5%	0.3%
4000	0.76	8.8%	4.5%	1.8%	0.9%	0.6%	0.5%
5000	0.95	10.9%	5.6%	2.3%	1.2%	0.8%	0.6%
6000	1.14	13.0%	6.7%	2.7%	1.4%	0.9%	0.7%
7000	1.33	15.0%	7.8%	3.2%	1.6%	1.1%	0.8%
8000	1.52	16.9%	8.8%	3.6%	1.8%	1.2%	0.9%
9000	1.70	18.8%	9.9%	4.1%	2.1%	1.4%	1.0%
10000	1.89	20.7%	10.9%	4.5%	2.3%	1.5%	1.2%
11000	2.08	22.5%	12.0%	5.0%	2.5%	1.7%	1.3%
12000	2.27	24.3%	13.0%	5.4%	2.7%	1.8%	1.4%

The calculations in Table 4.8 show that, assuming a bacteria die-off rate of 2/day, under normal flow conditions, significant increases in reach length would be required to achieve relatively modest decreases in bacteria density in the streams. For example, adding 1.5 miles of stream channel through constructed meanders and pools would result in only about 17% decrease in bacteria density under very low flow conditions (velocity = 1 ft/sec). Given a minimum estimated cost of $600 per linear foot of stream restoration (really stream channel creation), addition of 1.5 miles of stream length would cost $4,752,000 before land acquisition, easements, and costs associated with access challenges, utility interferences, environmental, or other factors that could increase project costs.

While there are many good reasons to perform stream restoration and increasing stream channel length as discussed here would likely provide significant ancillary benefits, the cost of this type of project cannot be justified solely on the bacteria reduction benefit. Therefore, SD1 will not be including stream restoration as a central component of its water quality strategy in this watershed planning program.

4.4.2 Water Quality Improvement Potential for Riparian Buffers

The Watershed Analysis Tool (WAT!) was used to evaluate the potential benefits of riparian buffers in each priority watershed, which are designed to reduce pollutant loading from non-point sources. In this analysis, the measure of effectiveness was the percentage of total load that the buffers were able to capture. The results are presented in Table 4.9.

Table 4.9 WAT! Results for Simulation of Riparian Buffers in Priority Watersheds

Watershed	Total Baseline[5] Bacteria Load[6] Predicted by WAT!	Bacteria Load Reduced by Buffers	Percent Load Reduction from Baseline[7]
Banklick Creek	2.12E+16	5.19E+14	2.5%
Fourmile Creek	4.24E+15	1.34E+14	3.2%
Licking River	4.84E+16	1.74E+15	3.6%
Ohio River East	1.29E+16	1.33E+14	1.0%
Ohio River North	2.34E+16	1.57E+14	0.7%
Taylor Creek	2.81E+15	8.48E+12	0.3%
Pleasant Run	3.08E+15	8.23E+12	0.3%
Threemile Creek	3.37E+15	2.48E+13	0.7%

These results suggest that the benefits of riparian buffers are relatively small compared to overall loads entering waterways. They are also relatively small compared to the potential load reductions by constructed wetlands and regional retention. This is due, primarily, to the fact that riparian buffers only address runoff from a very small local drainage area, but constructed wetlands and regional retention address flows from the entire upstream drainage area. Based on this observation, construction of new riparian buffers is not planned by SD1 in the first five years. Instead, SD1 will provide technical support for third parties (such as local watershed councils) to implement riparian buffers and provide ordinance support for planning and zoning agencies that encourage open space preservation. SD1 will also provide technical support to these parties in demonstrating their potential effectiveness through modeling.

4.5 Summary of Findings for Stream Restoration

The major findings related to the evaluation of stream restoration as watershed control measures are as follows:

- The cost of in-channel stream restoration cannot be justified solely on the bacteria reduction benefit, although there are many good reasons to perform stream restoration and increasing stream channel length as discussed in this analysis would likely provide significant ancillary benefits.

[5] Baseline load includes point sources and non-point sources, prior to implementation of any control measures.
[6] Loads are represented in cfu/100 ml.
[7] Percent load reduction is for the entire watershed.

- Numerous opportunities exist for riparian buffer restoration, but large-scale implementation would be required to achieve significant water quality benefits related to bacteria reduction.

Because of the implementation challenges noted in the preceding analysis and the limitations on achieving significant improvements in instream bacteria densities through stream and riparian buffer restoration, SD1 is not planning any specific stream and riparian buffer restoration projects in the first five-year planning cycle. SD1 will, however, provide technical support to third parties interested in such projects.

SECTION 5. SUMMARY OF FINDINGS

Several types of watershed control measures were evaluated in support of SD1's watershed planning effort. For each type of control measure, a rigorous opportunity analysis was conducted to identify where projects of each type could feasibly be sited in target watersheds where waterways are potentially affected by CSOs. Modeling and other technical evaluations were performed to estimate the potential benefits of each control measure type, leading to the following conclusions:

- Regional Watershed Control Measures: New regional watershed control measures, consisting mainly of large side-stream constructed wetlands or retention basins with upstream drainage areas greater than one square mile, will not be a focus in SD1's watershed strategy for the first Five-year Improvement Program because limited opportunities were identified in watersheds where the benefits of such projects could be demonstrated. SD1 will complete construction of the Banklick regional constructed wetland and conduct monitoring as planned, to gain knowledge about the design and performance of such control measures.
- Decentralized Watershed Control Measures: SD1 intends to develop some new decentralized watershed control measures in target watersheds in the first Five-year Improvement Program. These projects will consist of control measures located to capture and treat storm water from drainage areas of less than one square mile. Several potential projects have been identified and are being investigated, but none have been committed to at this time. These projects may be newly constructed projects or retrofits of existing storm water controls. SD1 expects to complete up to three such projects as part of the first Five-year Improvement Program. These projects will be a component of an overall program of nonpoint source control implemented by SD1.
- Stream Restoration: In the context of SD1's watershed planning effort, stream restoration refers to projects that integrate in-channel pools, channel lengthening, and riparian floodplain reconnection to increase hydraulic residence time, thereby increasing bacteria die-off. An evaluation of potential opportunities was conducted, along with a parallel evaluation of the potential benefits and costs. On this basis, it was concluded that very large projects involving creation of miles of new stream channel would be required to achieve desired benefits and that the cost associated with these projects would not justify the limited benefits. Additionally, riparian buffers were also evaluated as potential water quality improvement measures; however large-scale implementation would be required to achieve significant water quality benefits related to bacteria reduction. Although SD1 recognizes that there are several ancillary benefits that can potentially be realized from stream restoration and riparian buffer projects, these projects will not be included as a central component of the water quality strategy in this planning cycle. However, SD1 will continue to pursue partnerships with entities such as watershed groups to provide technical support for these initiatives.

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Appendix 3-D

Source Identification Program Protocol

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SOURCE IDENTIFICATION PROGRAM PROTOCOL

Prepared for: **Sanitation District No. 1 of Northern Kentucky**

February 2011

LimnoTech
Water | Environment | Scientists | Engineers

Ann Arbor, Michigan
www.limno.com

DOCUMENT HISTORY

ORIGINAL: November 2008

REVISION No.1: June 2009

REVISION No.2: February 2011

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INTRODUCTION

Sanitation District No. 1 (SD1) is gathering information on water quality, pollutant sources and source control options in sixteen watersheds spanning the Northern Kentucky area. This information will be used to develop SD1's first set of Watershed Plans. The watershed characterization information, water quality data and modeling results indicate that most of the watersheds are impacted by both wet and dry weather sources of bacteria. The purpose of this paper is to document the need for a Source Identification Program (SIP) and describe SD1's approach for implementing the program. The information from this program will inform the watershed/water quality models and can be used to identify subwatersheds where dry weather sources should be further investigated for corrective action. It can also be used to evaluate the feasibility of implementing wet weather controls.

As the results of this program will be used to inform SD1's watershed planning activities, the geographical extent and scope of the effort of this program distinguish it from similar programs, such as SD1's Illicit Discharge Detection and Elimination Program (IDDEP), which is being conducted as part of the Phase II storm water permit requirements. This protocol was developed to serve as a starting point for developing the methods and elements of the program. It has been and will continue to be refined as the program evolves over the next five-year planning cycle.

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BACKGROUND

On April 18, 2007, Sanitation District No. 1 (SD1) entered into a Consent Decree (2:2005CV00199) with the U.S. Environmental Protection Agency (EPA), the U.S. Department of Justice (DOJ), and the Kentucky Environmental and Public Protection Cabinet (Cabinet). The purpose of the Consent Decree is to address CSOs and SSOs and to improve water quality throughout SD1's service area. SD1 must develop, submit, and implement Watershed Plans for sixteen watersheds that accomplish specific goals by no later than December 31, 2025.

To identify the most cost-effective solutions for the sewer overflows, a massive amount of information must be assembled. Although SD1 has made substantial progress in characterizing the sewer infrastructure and reducing overflows, additional work is being conducted to identify the cause of the overflows, understand their impacts, and develop proposed solutions. In addition, new technologies, such as green infrastructure, provide an environmentally-preferred way to reduce sewer overflows and provide greater watershed benefits (EPA et al., 2007).

Other pollutant sources such as urban and agricultural storm water runoff, failing septic tanks, straight pipe discharges, and livestock feeding operations, as well as stream bank erosion are also contributing to water quality problems. SD1 is gathering information and developing tools to understand where these pollutant sources may be located and how they are collectively impacting water quality during dry and wet weather conditions. Specifically, SD1 has been characterizing the 16 watersheds by collecting additional instream dry and wet weather water quality data during rainfall events and base flow conditions, conducting CSO, SSO and storm water outfall water quality sampling, and developing detailed water quality models in priority watersheds.

Information from the watershed characterization suggests that impairments of recreational uses (as measured by instream densities of indicator bacteria) are a prevalent water quality problem. Indicator bacteria are used as a surrogate for microbial pathogens in wastewater and water quality assessments. Sewer overflows and other wet weather sources such as storm water runoff are known to contribute to high levels of bacteria (EPA, 2004). SD1 has therefore focused on identifying wet weather sources of bacteria within the sanitary and storm water system service areas, and evaluating the potential water quality benefit that can be gained through controls of these sources.

The watershed characterization information, water quality data and modeling results indicate that both wet weather runoff and dry weather source loads may have significant impacts on bacteria levels in some watersheds. For the purposes of characterizing instream data, samples that are collected during and immediately following rainfall events that produce runoff are defined as "wet weather." Samples that are collected when the stream is at base flow and at least 72 hours after the last rainfall event are defined as "dry weather."

Neither dry weather sources nor runoff sources are typically addressed within the scope of a traditional LTCP. An important benefit of SD1's watershed-based approach is that it allows for the identification and control of such sources, recognizing that important water quality benefits can result and that these controls may be more cost effective than a traditional approach.

In general, people are more likely to recreate near or in the stream during dry weather conditions. Therefore, implementing watershed controls on dry weather bacteria sources may have greater benefit in terms of human exposure than focusing on wet weather sources for some locations. The average dry weather density in many watersheds tend to consume the stream's assimilative capacity with respect to applicable fecal coliform water quality standard thresholds (400 cfu/100 ml as single sample maximum and 200 cfu/100 ml as 30-day geometric mean density). Maximum dry weather densities in nearly all watersheds have been in excess of 1,000 cfu/100 ml.

Sewer overflows are a known wet weather source of bacteria, and are generally located in the older urbanized areas, near the mouth of Northern Kentucky waterways. SD1 has invested significant resources to determine the cause of sewer overflows and to implement controls to reduce or eliminate overflows. Water quality monitoring, modeling and characterization have shown that the elimination of SD1's overflows will not eliminate wet weather exceedances of the bacteria criteria. This is due in part to contributions from runoff.

SD1 has made some progress in identifying dry weather sources and runoff sources by reviewing instream bacteria data. Specific watershed projects that address these sources will be developed in the five-year planning cycles of the Watershed Plan updates using data and information from this program. Watershed model results for Banklick Creek and Taylor Creek suggest that investigation into dry weather sources is needed to better reflect and distinguish between dry and wet weather source loads in the models. Instream data suggest that investigation of dry weather sources and runoff in other watersheds may also be beneficial for watershed planning.

Identifying and verifying bacteria sources can be extremely challenging. Bacteria sources may be diffuse, isolated (e.g. one failing septic system in a neighborhood), difficult to trace to their origin (e.g. a storm water outfall with dry weather flow may be servicing 30+ homes or businesses), and their magnitudes can vary over time so that their impacts are not always captured in monitoring data. SD1 has invested extensive resources into mapping the infrastructure associated with the region's municipal separate storm sewer system (MS4). This SIP will not only allow SD1 to confirm existing data on the MS4 structures but also to catalog other potential wet weather sources and, if monitoring data warrant, to develop recommendations for addressing sources with potentially high levels of bacteria.

The remainder of this paper presents SD1's strategy and program components for characterizing and identifying dry weather and wet weather runoff source loads and then developing an action plan to identify and ultimately address the sources. An

approximate timetable for the Watershed Plans based on the strategy described in this paper is as follows:

- Year 1 (2009): Develop a Source Identification Program (Steps 1 through 3) and pilot the program in one watershed

- Year 2 and Year 3 (2010-2011): Continue the pilot application and adjust the SIP before applying to other watersheds.

- Year 4 through 19 (2012-2027): Implement the program in one watershed per year starting with the priority watersheds that have consistently shown high instream dry and wet weather bacteria densities.

- Year 5 through 20: Develop the Action Plan for the watershed surveyed the previous year and incorporate solutions into the appropriate Watershed Plans.

SD1 has piloted the program in the Banklick Creek watershed for dry weather sources and is currently making adjustments before applying it to other watersheds. The level of effort required for each watershed will vary and will depend in part on the extent of the bacteria impact on instream water quality, the number of potential sources, the area of investigation needed and the investment needed to support the recommendations in the Action Plan.

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SOURCE IDENTIFICATION PROGRAM OVERVIEW

SD1's strategy for the SIP contains four steps:

1. Study Area Assessment and Prioritization (completed)
2. Initial Watershed Assessment
3. Field Reconnaissance
4. Action Plan

Each step is described in the following sections and shown in Figure 1. The process was piloted beginning in January 2009 in the Banklick Creek watershed for dry weather sources and a summary of results to date is attached. The assessment with respect to the four steps described in this program is on-going.

The purpose of Step 1, Study Area Assessment and Prioritization, was to analyze existing information across the study area to identify watersheds that appear to have dry and/or wet weather impacts and to prioritize these watersheds for investigation. The results of this step for bacteria impacts are presented at the end of this document.

Within each watershed, existing data and information are used to conduct Step 2, Initial Watershed Assessment. The purpose of this step is to identify potential "hot spots" of elevated bacteria loading so that the field reconnaissance (Step 3) can be conducted more efficiently. For wet weather sources, this step may also include an assessment of the potential benefit of runoff control using GIS and detailed water quality models. An assessment of the appropriateness and benefit of bacteria source tracking sampling will be evaluated during this step. A final determination on proceeding with bacteria source tracking sampling and analysis may be determined as part of the field reconnaissance (Step 3) activities. For dry weather-focused investigations, the outcome of this step will be a map or list of major (e.g. blue-line) stream segments within the watershed that will be surveyed during the field reconnaissance. An example analysis for the Banklick Creek watershed has been developed as part of the pilot of this program and is attached. For wet weather focused investigations, the outcome of this step will be a map or list of storm water catchment areas within the watershed that will be surveyed during the field reconnaissance.

The Field Reconnaissance step is intended to gather the necessary information to identify specific source loading inputs. For dry weather-focused investigations, the activities in this step include field surveys where crews physically walk the stream during dry weather conditions to identify locations of pipes, structures and unusual instream conditions (e.g. sewage odors). Flowing pipes and pipes that appear to have dry-weather activities (e.g. straight-pipe) will be characterized as likely dry weather sources. Pipes that appear to serve a wet-weather function (e.g. roof downspouts) will be noted as potential wet weather sources. For wet weather-focused

investigations, the activities in this step include field surveys where the feasibility of siting a BMP to control runoff will be evaluated.

Locations for additional monitoring will also be identified and subsequently sampled during dry or wet weather conditions, depending on the source identified. Since the initial field survey is focused on the major (blue-line) stream segments, any smaller tributary reaches that warrant field surveying will also be identified. Additional field reconnaissance activities will be conducted outside the normal field survey season (Nov-Mar), weather permitting, while additional monitoring can be conducted at any time, provided the dry and/or wet weather monitoring criteria are met.

The results from this step will be used to update the information from Step 2 (Initial Watershed Assessment), refine the models, and develop the Action Plan. This step is labor-intensive and requires the most time and resources to conduct. Therefore, using existing information to identify "hot spots" (to the extent possible) can make this step more efficient.

The components of the Action Plan include developing recommendations to further identify specific sources and identify the types of potential control projects that could be considered for future Watershed Plans. Factors that will be included in evaluating specific control projects include responsible party, funding mechanism, water quality benefit, and feasibility of implementation. Coordination with local entities will be initiated to the extent that proposed source controls require. Revisions to SD1's monitoring program based on the source control projects will also be considered during this step.

Additional detail on each step of the program is provided in the following sections. Figure 1 presents an outline of the program and the tasks associated with each step.

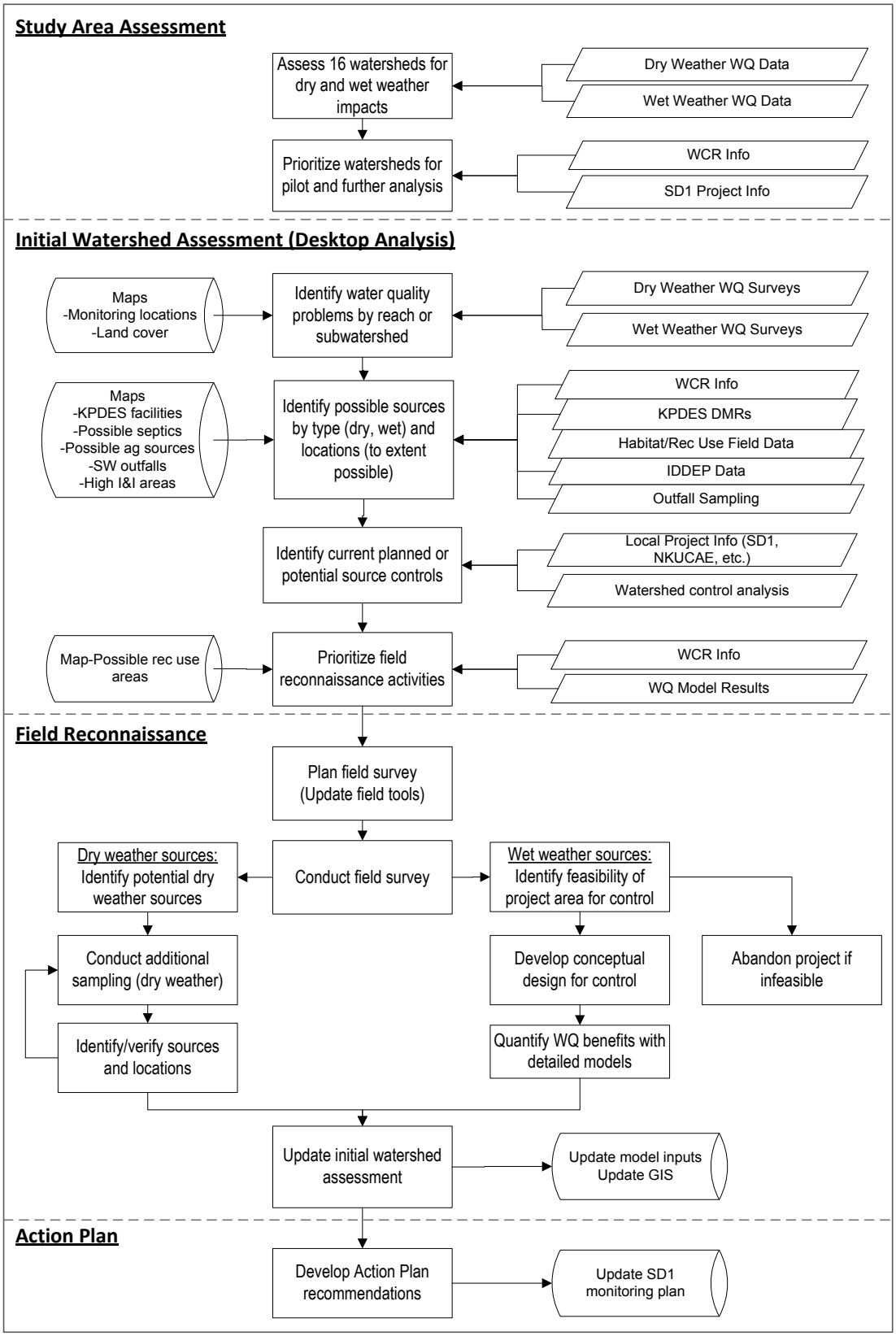

Figure 1. Source Identification Program Components

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STEP 1: STUDY AREA ASSESSMENT AND PRIORITIZATION

This task was completed as part of the pilot of the program (November 2008, updated December 2010) using data from 2002-2008 (update used data from 2002-2009). The initial focus of the pilot was to identify watersheds impacted by dry weather sources, as data and watershed characterization suggest these sources are important in several watersheds. Results are described in the "Pilot Application of Protocol" section of this memorandum. This section describes the protocol with respect to dry weather sources although as shown in Figure 1, it can also be similarly applied for wet weather sources.

The purpose of this step was to identify watersheds that appear to have bacteria impacts using existing information and then to prioritize these watersheds for investigation. Subtask 1.1 includes several strategic considerations that were addressed in the pilot application.

SUBTASK 1.1: IDENTIFY PROBLEM BY REACH OR SUBWATERSHED

In this task, the existing data will be evaluated by watershed to identify which watersheds are impacted by bacteria. The first activity under this task will be ensuring that SD1 has a clear and consistent approach for several key considerations regarding "dry weather" and "wet weather," including:

1. What is the definition of "dry weather" and "wet weather"?
   For the purposes of testing the protocol, "dry weather" is defined as periods preceded by at least 72 hours of no rainfall (<0.10 inches) and the stream is at base flow conditions (based on an analysis of the flow hydrograph during the time of evaluation or data collection). "Wet weather" is defined as occurring during and immediately following rainfall events that produce runoff. These definitions may be refined after the program is pilot-tested and more receiving water data are obtained.

2. If stream flow or precipitation data are used to determine "wet weather" or "dry weather", (e.g. flow is at base portion of hydrograph and is flowing rather than at stagnant conditions) how close to the watershed are the flow and precipitation monitoring locations required to be for use with watershed data?
   The current strategy is to be more inclusive with respect to data sources (e.g. using rainfall data collected at the airport for all watersheds) initially, then add more refinement if the program findings suggest additional spatial resolution is needed.

3. What criteria should be used to determine bacteria "impact" (e.g. fecal coliform geometric mean density, number of observations exceeding a specified fecal coliform threshold, such as 400 cfu/100 ml, etc.)?
   For the purposes of testing the protocol, a bacteria impact will be based on the magnitude of the geometric mean density and maximum density during "dry

weather" or during "wet weather" compared to the recreation season maximum fecal coliform criterion of 400 cfu/100 ml as well as the percent of dry weather sampling days where at least one observation exceeds the fecal coliform standard. The criteria used to determine bacteria impact may be refined after the program is pilot-tested and more receiving water data are obtained.

4. What period should be used to evaluate bacteria data? (e.g. 2006-present? 2002-2007?)
   For the purposes of testing the protocol, the data available from 2006-2009 were used to evaluate bacteria impacts in the watersheds, because data from these periods can be assigned to "dry" and "wet" categories using the criteria above. Subsequent evaluations will use data available from 2002 – present for datasets that can be assigned to a "dry" or "wet" category using the criteria above.

5. What standard should be used for comparison to data? (e.g. for dry weather data, should a 30-day geometric mean, maximum over 30-day period, or maximum applied as a single sample maximum criterion be used?)
   For the purposes of testing this protocol, given the data collection frequency (typically less than five samples/month), the dry weather fecal coliform data will be compared to the recreation season maximum criterion of 400 cfu/100 ml. The wet weather fecal coliform data will be compared to the same criterion. Histograms of bacteria densities may also be used to compare wet weather data within and between watersheds. The criteria used to determine bacteria impact may be refined after the program is pilot-tested and more receiving water data are obtained.

As the program progresses, consensus regarding these issues will ensure consistency with data handling and interpretation of results within SD1. This discussion should be completed prior to conducting any additional analyses with the data.

The data analysis will be conducted such that the presented results allow users to readily discern which watersheds have dry and wet weather source impacts (see Pilot Application of Protocol section of this memorandum).

SUBTASK 1.2: PRIORITIZE WATERSHEDS FOR FURTHER EVALUATION

Based on the results of Subtask 1.1, the watersheds will be prioritized for further evaluation with the SIP steps described below. In addition to determining the extent and magnitude of bacteria impact from Subtask 1.1, additional factors that will be considered in prioritization may include:

1. If the watershed warrants detailed analysis (based on watershed or infrastructure characterization programs);

2. Exceptional streams; and,

3. Watersheds where SD1 is already doing improvement projects.

Other factors to consider in prioritizing watersheds may be added as well as the program proceeds. The Watershed Characterization Reports (WCRs) are valuable resources to inform this prioritization. The current strategy is to identify one watershed to pilot the program, then refine the program and apply it to the remaining watersheds. As detailed later, Banklick Creek has been identified as a pilot watershed for testing the remaining steps of the protocol for dry weather sources.

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STEP 2: INITIAL WATERSHED ASSESSMENT

The purpose of this step is to understand what can be determined about dry and wet weather source loads using existing information and to prioritize, if necessary, additional data collection (Step 3) that is needed.

In this task, a detailed analysis of existing data and information will be conducted to identify locations within the watershed of elevated bacteria under dry and wet weather conditions, and the possible source types (e.g. failing septics, wildlife) contributing to the observed densities. This analysis differs from Step 1 in that the analysis is more spatially defined, with specific locations and potential source types identified. The outcome of this step is to have sufficient additional knowledge of the watershed so that the field reconnaissance (Step 3) can be conducted more efficiently. This step consists of four tasks, as described below.

An analysis has been conducted for Banklick Creek for dry weather sources for this paper as a pilot test example of the analysis envisioned for this program. The results from the pilot application to the Banklick watershed can be used to estimate the level of effort needed to assess other watersheds.

SUBTASK 2.1: IDENTIFY WATER QUALITY PROBLEMS BY REACH

The data evaluation conducted in Task 1 is intended to prioritize the watersheds. In this subtask, the data within an individual watershed are evaluated spatially and temporally to identify potential waterway reaches, subwatersheds or storm water catchment areas that may be contributing significant amounts of bacteria to the waterway and whether there are certain conditions (e.g. dry vs. wet) when the impacts tend to occur.

Data from individual sampling locations are compared from upstream to downstream to identify spatial gradients in bacteria densities during dry and wet weather conditions. Data are also evaluated over time to determine whether a temporal trend in either dry or wet weather conditions also exists. The outcome of this step is to prioritize specific reaches or subwatersheds for further investigation with the remaining subtasks in Task 2.

SUBTASK 2.2: IDENTIFY POSSIBLE SOURCES BY TYPE AND LOCATIONS

The goal of this task is to gain as much understanding regarding dry and wet weather sources as possible using existing data and information. Potential data sources that can be used in this task include:

- Watershed Characterization Reports (WCR)
- Illicit discharge detection and elimination program
- Storm water outfall sampling

- KPDES DMR data with violations or lack of routine monitoring data
- Qualitative data from the habitat and macroinvertebrate/fish sampling program
- High levels of instream fecal coliform data (dry weather and wet weather conditions)
- Suspected septic tank and straight pipe discharge locations
- Maps of suspected agricultural sources
- Maps of storm water catchment areas, outfall locations, and ditches
- Land cover and land use GIS data
- Aerial photography
- Locations where sewers cross streams

Maps with locations of possible sources will be produced to assist the evaluation in this task. It is likely, however, that the exact location of individual dry and wet weather sources cannot be determined in this analysis. Rather, the intent is to narrow down the areas with potential dry and wet weather sources to make the field reconnaissance more efficient.

SUBTASK 2.3: IDENTIFY CURRENT, PLANNED OR POTENTIAL SOURCE CONTROLS

The goal of this task is to verify whether any of the potential sources identified in Subtask 2.2 have been addressed or are planned for elimination. This will involve communication with SD1, KDOW, Northern Kentucky Health Department (NKHD), and Northern Kentucky University Center for Applied Ecology (NKUCAE), which implements mitigation projects funded by the Stream Corridor and Wetland Restoration Fund. Other resources identified through the WCR development will also be contacted to obtain the most recent information on current or planned source-related activities.

If instream data indicate wet weather source impacts, a desktop analysis of decentralized watershed control opportunities[1] may also be conducted to support identification of potential storm water source controls and locations. This analysis is conducted as follows:

Step 1. Delineate the storm water catchment for each storm water outfall within the watershed of interest. This is initially conducted using an automated GIS analysis based on existing storm water outfall and storm water conduit locations. Catchments selected for further analysis can be refined based on topography.

[1] Decentralized watershed control measures are new or retrofit storm water control measures with upstream drainage areas smaller than one square mile, but typically greater than 5 acres. These measures are typically designed to control storm water runoff close to the source.

Step 2. Characterize selected catchments to describe: catchment area, watershed, water quality volume, percent imperviousness, type of impervious land, land use, city, county, ownership, hydrologic soil group, presence of hydric soils, R factor, sewer type and aerial imagery observations.

Step 3. Calculate the water quality volume to estimate the control measure volume needed for water quality improvement. For this application, this is the volume needed to manage the first 0.8 inches of rainfall.

Step 4. Calculate the area needed to accommodate the water quality volume in Step 3. This area is calculated for a range of depths between 3 and 10 feet, to cover a range of potential controls that have different depths such as wetlands and retention basins.

Step 5. Identify potential locations for siting controls. This analysis is conducted using GIS, and considers characteristics of the catchment such as: existing land use and state of development; presence of forested areas; proximity to streams; presence of storm water conduits upstream of the outfall; apparent sources of bacteria loading; and ownership.

Step 6. Identify suitable types of control measures for the locations identified in Step 5, including: storm water wetlands, bioretention/biofiltration basins, enhanced retention basins, retrofits for existing ponds, and daylighting storm water conduits.

Step 7. Apply detailed models to estimate the water quality benefit of the potential controls.

SUBTASK 2.4: PRIORITIZE FIELD RECONNAISSANCE ACTIVITIES

If instream data indicate that a watershed has extensive dry weather source impacts, but source information is limited, it may be necessary to prioritize the field reconnaissance activities to focus on the portions of the stream where contact recreation is more likely to occur. To complete this task, recreational use data and maps of parks, aerial photos, etc. will be reviewed to determine reaches with observed contact recreation or potential for contact recreation. Additional information that may be considered in identifying priorities includes input from the Watershed Community Council or other stakeholder groups, NKHD, county Conservation Districts and local Natural Resources Conservation Service (NRCS) offices. Other options for prioritizing field reconnaissance include working from upstream to downstream or by the magnitude of the impact (e.g. start with reach showing highest bacteria density). The method used to prioritize field reconnaissance activities may vary by individual watershed.

If the desktop analysis of decentralized watershed control opportunities indicates a potential for wet weather BMP siting, then Step 3, Field reconnaissance, will be conducted to assess the feasibility of implementing the control.

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STEP 3: FIELD RECONNAISSANCE

The purpose of this task is to obtain evidence that provides specific information on the potential origin of dry and/or wet weather source loads that can then be used to identify additional data collection efforts and to support development of an Action Plan for correction or elimination of the source(s). During this task, the field reconnaissance may also be used to evaluate the feasibility of siting a BMP to control storm water. This information is obtained by conducting field surveys where crews walk the stream during dry weather and observe flowing pipes, note locations for additional monitoring and identify subreaches that appear to be impacted by sources based on visual inspection. It should be noted that the geographic extent of this field reconnaissance may extend beyond SD1's service area. In these instances, SD1 will communicate and coordinate with local entities regarding the planned field activities described in this task. If the source identification is largely wet weather-related, the field reconnaissance may be more focused on assessing storm water catchment areas for potential BMP siting. This step includes five subtasks.

SUBTASK 3.1: PLAN FIELD SURVEY

This subtask will prepare the tools needed for the field reconnaissance so that the extent of field activities is focused on critical areas and the data collected are processed as efficiently as possible. Conditions for sampling will be established during this task and may include criteria such as "no rainfall for previous 72 hours," for dry weather sampling. Note that for the dry weather pilot application in Banklick Creek, the conditions for surveying included "no rainfall during previous 72 hours" and focused on surveying the "blue line" streams in the subwatersheds, which are mostly perennial streams that are included in the medium resolution version of the National Hydrography Dataset.

As part of this task, the existing tools used for habitat characterization have been modified to allow for efficient, quality data collection. Data forms that allow the field crew to detail locations of pipes, animals (livestock with access to stream, wildlife), septics, KPDES discharges and locations where instream samples should be collected have been developed. These forms are downloaded to a handheld computer with built-in GPS (Trimble GeoXT or equivalent). The handheld GPS unit is pre-loaded with spatial data and, if possible, aerial photos (note that most field equipment lack sufficient memory to store aerial photo imagery). A database structure for storing and reporting on information (data and photos) is currently under development as part of this task.

SUBTASK 3.2: CONDUCT FIELD SURVEYS

The purpose of this task is to gather sufficient information to develop an inventory of likely dry and wet weather source loading locations and impaired subreaches. Two-person crews will be deployed to conduct field surveys in reaches mapped as highly likely to be impaired during dry and/or wet weather conditions. The crews will focus

on surveying the primary stream network in the impaired subreaches, though they may extend the surveying into ditches and swales if instream or watershed conditions warrant further exploration.

Prior to deploying to the field, the crew will review aerial photography information to plan where to survey and to identify where key city and/or SD1 service area boundaries are relative to the reach of interest. Depending on the watershed, it may be useful for the crew to conduct a watershed tour prior to beginning the field survey activities. The driving survey may provide a cursory check of potential sources that may not be evident from the stream bank (such as cows with access to a stream).

Once in the field, the crew will gather data on flowing pipes, sewage, and other source-related observations during a dry weather period. Although field surveys during wet weather are unlikely to be conducted (due to crew safety considerations), if surveys are conducted during wet conditions, similar data will be collected during wet weather periods. Data will be recorded on the field forms developed in Subtask 3.1. Ideally, these surveys will be conducted between late fall and late winter (November through March) when canopy interference with GPS and vegetation that limit sight reconnaissance are at a minimum. Decisions on surveying will also be based on whether the streams have ice cover, which can obscure information needed for the data forms. A crew can cover approximately 2-3 miles of stream (both banks) per day depending on the number of potential sources that are located.

The field crew will also identify locations where additional sampling is merited due to the condition of the stream or the presence of a possible bacteria source nearby.

The approach for source identification diverges beyond this step (Figure 2). If the focus is on dry weather sources, then field reconnaissance is focused on identifying the origin of the source loads. If the focus is on wet weather sources, then field reconnaissance is focused on evaluating the suitability of sites for storm water BMPs (e.g. decentralized watershed controls). The remainder of the subtasks are focused on dry weather source identification.

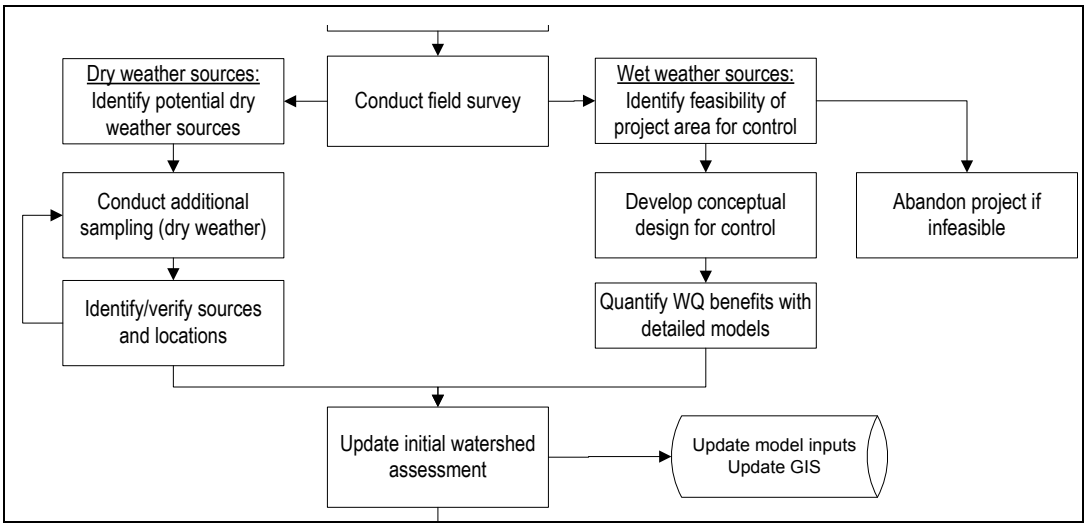

Figure 2. Field Reconnaissance for Dry and Wet Weather Sources

SUBTASK 3.3: CONDUCT ADDITIONAL SAMPLING

Additional monitoring can be conducted as part of the field surveying activities (Subtask 3.2) or as a follow-up activity. The decision to do field testing for tracer constituents (such as ammonia and detergents) will be identified up front as part of the Task 2 and will depend on the watershed and suspected sources. Field testing may be useful in not only identifying the source but also the magnitude of the impact. For example, elevated ammonia levels may indicate failing septics in an area where both septic and livestock sources are suspected (Pitt et al, 2000).

Additional monitoring may be recommended in locations that are identified during the field surveys as potential dry weather loading sources (e.g. flowing pipes) or appear to be potentially impacted by nearby dry weather sources. Monitoring will include bacteria parameters at a minimum. Sampling for bacteria source tracking analyses may also be conducted, depending on the watershed. Bacteria source tracking may be appropriate for reaches with high instream densities during dry weather but for which no possible dry weather sources were identified during the field survey.

However, depending on the suspected source, it may be beneficial to monitor other parameters that can serve as tracers for certain types of sources. For example, detergents and/or optical brighteners, ammonia and potassium can be used as supporting evidence of human sources. Analysis of these parameters can be conducted using analytical methods or field methods, depending on the level of quantitation desired (field tests are generally less reliable as a quantitative tool than laboratory methods).

Additional monitoring should be conducted as soon as reasonably possible after the field surveys to ensure that the conditions observed during the field surveys are still present when the monitoring is initiated. A general goal is to complete the additional

monitoring activities in a watershed before undertaking field surveys in a new watershed.

SUBTASK 3.4: IDENTIFY/VERIFY DRY WEATHER LOADING SOURCES AND LOCATIONS

The data collected during the stream surveys will be input into GIS and cross-referenced to existing source information to identify and verify dry weather source loading locations and possible source types. To the extent possible, individual dry weather sources will be determined whenever possible. Some activities, such as dye or smoke testing for illicit connections, may require coordination with the IDDEP.

SUBTASK 3.5: UPDATE INITIAL WATERSHED ASSESSMENT

The references used for the initial watershed assessment will be updated with the results of the field surveys, additional monitoring and modeling. The maps created for the initial watershed assessment will be updated to reflect the information collected in this step. The information will also be incorporated into the water quality models. For example, instream densities that reflect failing septic can be used as runoff target event mean densities for failing septic land cover areas in the watershed models.

SUBTASK 3.6: REFINE PROGRAM COMPONENTS (PILOT ONLY)

After the program is piloted in a watershed, the process described in this paper can be modified, if needed, before application to the remaining watersheds. The outcome of this task will be a revised protocol for the SIP.

STEP 4: ACTION PLAN

The components of the Action Plan include developing recommendations to further identify specific dry and wet weather sources and identify the type of potential control projects that should be included in revisions to the Watershed Plans. Factors that will be included in evaluating control projects include responsible party, funding mechanism, water quality benefit, coordination with local government entities and local landowners, and feasibility of implementation. Revisions to SD1's monitoring program (frequency and/or parameter lists) based on the source control projects will also be considered during this step.

Once the updated watershed assessment is completed, SD1 will have sufficient information to initiate a plan to identify potential bacteria sources and to develop a list of possible control project options.

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USE OF RESULTS FOR WATERSHED PLANNING

INFORMATION FOR 1ST SET OF WATERSHED PLANS

The concept of a SIP proposed herein can be further refined after the pilot application and inclusion in the first set of Watershed Plans. Agency review and feedback on the protocol and pilot results that are included in the first set of Watershed Plans may be used to refine the program and activities planned for subsequent Watershed Plans.

UPDATE MODELS

Information obtained during implementation of the SIP will be used to inform refinement of the watershed/water quality models, including:

- WAT!
- Banklick Creek Watershed Model
- Taylor Creek Model
- Ohio River Tributary Watershed Model
- Lower Licking River Watershed Model
- Lower Banklick and Licking River portions of the Ohio/Licking/Banklick model.

For example, the additional instream water quality data and more specific source information will provide additional data for refining the calibration of the models. It is also likely that implementation of the program will result in identification of additional data gaps (such as a better understanding of the potential magnitude of impact from various dry and wet weather source types).

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PILOT APPLICATION OF THE PROTOCOL

The first three steps of the protocol described in the previous sections were pilot-tested between November 2008 and April 2010 for dry weather sources. Results from the Pilot are described in this section. The graphs presented in this section have been updated to include the most recent data, and will support ongoing testing of the protocol through step 4 (Action Plan). Recommendations for additional refinements to the protocol are also included in this section.

STEP 1 RESULTS: IDENTIFYING WATERSHEDS IMPAIRED BY DRY WEATHER SOURCES

The purpose of this step is to identify watersheds that appear to have dry weather impacts using existing information and then to prioritize these watersheds for investigation. The following conditions were used to identify watersheds impaired by dry weather sources:

1. In this application, "dry weather" is defined as periods preceded by at least 72 hours of no rainfall (<0.10 inches) and the stream is at base flow conditions (based on an analysis of the flow hydrograph during the time of evaluation or data collection).

2. The current strategy relied on the USGS/SD1 continuous monitoring network precipitation data to characterize rainfall conditions. When USGS data were not available, the precipitation data from the Greater Cincinnati Airport was used.

3. In this application, a "dry weather" impact was based on the magnitude of the geometric mean density and maximum density during dry weather conditions relative to the recreation season maximum fecal coliform criterion of 400 cfu/100 ml as well as the percent of dry weather sampling days where at least one observation exceeds the fecal coliform standard.

4. SD1 Data available from 2006-2009 were used to evaluate dry weather impacts in the SD1 watersheds.

A simple bar graph showing the geometric mean and maximum densities during dry and wet weather are shown in Figure 3 for each watershed (grouped by SD1 Consent Decree basin). Table 1 shows a count of the number of dry weather sampling days where at least one observation exceeded the 400 cfu/100 ml threshold water quality standard criterion. The results shown in this table and Figure 3 indicate that the following watersheds are most impacted by dry weather sources:

- Dry Creek
- Fourmile Creek

- Pleasant Run
- Sand Run
- Taylor Creek
- Threemile Creek
- Woolper Creek
- Banklick Creek
- Ohio River West

In all of these watersheds, the maximum observed dry weather density was greater than the single sample maximum water quality standard criterion (400 cfu/100 ml) AND the average dry weather density (calculated as a geometric mean) is near or greater than the 30-day geometric mean water quality standard criterion (200 cfu/100 ml).

Table 2 shows a count of the number of wet weather sampling days where at least one observation exceeded the 400 cfu/100 ml threshold water quality standard criterion. These results indicate all sampled watersheds are impacted by wet weather sources. A cumulative frequency distribution (CFD) of the dry and wet weather densities were compiled for these watersheds using the data from 2006-2009 (Figures 4-12).

These CFDs were used to prioritize watersheds for further analysis. The prioritization was based on the distribution of dry weather densities above 400 cfu/100 ml and a comparison of the wet weather and dry weather curves. In general, the watersheds with higher frequencies of dry weather data above 400 cfu/100 ml and watersheds where the wet and dry weather CFDs were similar were given higher priority. However, the choice to continue the pilot using the Banklick Creek watershed was based on the assessment of the CFDs, professional judgment, and available information about the creek relative to other impacted watersheds.

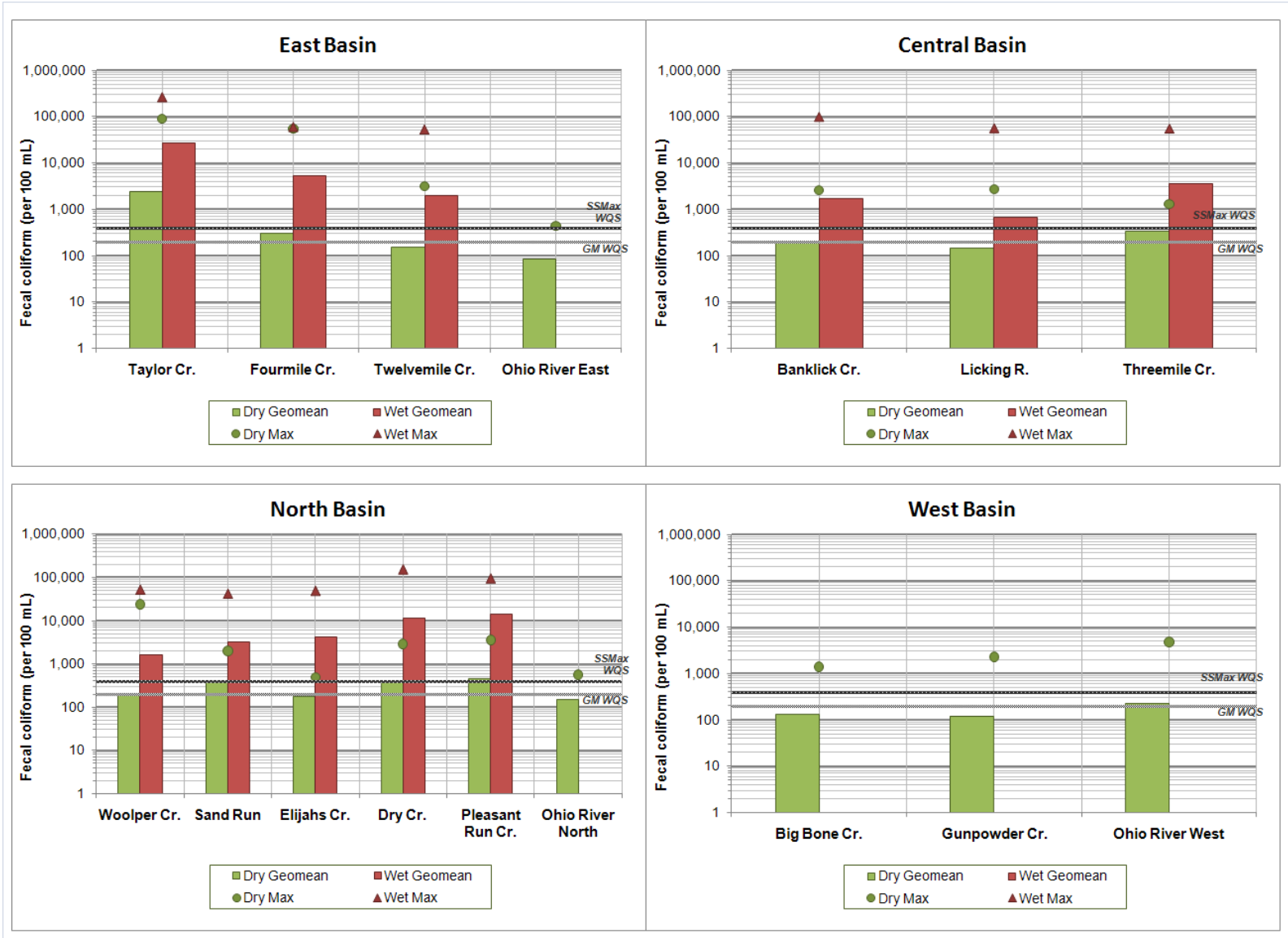

Figure 3. Watershed Monitoring Data, September 2006 to October 2009

Table 1. Summary of Dry Weather Data (2006-2009)

Basin	Watershed ID	Sampling Date Range	No. Sample Days	No. Days > 400 cfu/100 ml	No. Obser-vations	Average Dry Density (cfu/100 ml)	Max Dry Density (cfu/100 ml)
East	Taylor Creek	10/9/06-5/12/09	8	8	41	2,442	90,000
East	Fourmile Creek	10/9/06-5/20/09	7	6	39	301	54,000
East	Twelvemile Creek	10/25/06-5/19/09	5	3	37	153	3,100
East	Ohio River-East	10/9/06-5/20/09	6	1	8	86	440
Central	Banklick Creek	6/26/07-7/24/09	6	4	50	194	2,600
Central	Licking River	10/10/06-7/24/09	10	6	94	143	2,700
Central	Threemile Creek	10/10/06-7/24/09	8	5	22	342	1,280
North	Woolper Creek	10/3/06-10/25/09	9	5	53	200	24,000
North	Sand Run	10/3/06-6/23/09	6	4	10	381	2,000
North	Elijahs Creek	10/3/06-6/23/09	6	2	13	178	500
North	Dry Creek	10/3/06-6/24/09	8	7	28	365	2,900
North	Pleasant Run Creek	10/3/06-6/24/09	7	5	20	457	3,600
North	Ohio River-North	10/3/06-6/23/09	5	2	16	149	560
West	Big Bone Creek	9/27/06-6/30/09	5	4	26	131	1,400
West	Gunpowder Creek	9/27/06-6/30/09	7	3	29	117	2,300
West	Ohio River-West	9/27/06-6/30/09	5	3	20	225	4,800

Table 2. Summary of Wet Weather Data (2006-2009)

Basin	Watershed ID	Sampling Date Range	No. Sample Days	No. Days > 400 cfu/100 ml	No. Obser-vations	Average Wet Density (cfu/100 ml)	Max Wet Density (cfu/100 ml)
East	Taylor Creek	6/22/07-10/24/07	6	6	81	27,264	260,000
East	Fourmile Creek	7/19/07-10/9/08	8	8	128	5,348	60,000
East	Twelvemile Creek	9/27/06-10/28/06	6	5	136	1,992	52,700
East	Ohio River-East						
Central	Banklick Creek	5/7/08-10/10/09	11	11	147	1,696	99,000
Central	Licking River	7/22/09-10/10/09	9	9	139	678	55,300
Central	Threemile Creek	5/8/08-10/10/09	10	10	81	3,644	54,000
North	Woolper Creek	9/20/09-10/24/09	4	4	53	1,602	53,000
North	Sand Run	6/10/09-7/23/09	6	6	38	3,269	43,000
North	Elijahs Creek	6/10/09-7/23/09	6	6	41	4,112	50,000
North	Dry Creek	5/7/08-6/14/08	7	7	87	11,593	152,000
North	Pleasant Run Creek	5/7/08-6/15/08	7	7	66	14,415	95,000
North	Ohio River-North						
West	Big Bone Creek						
West	Gunpowder Creek						
West	Ohio River-West						

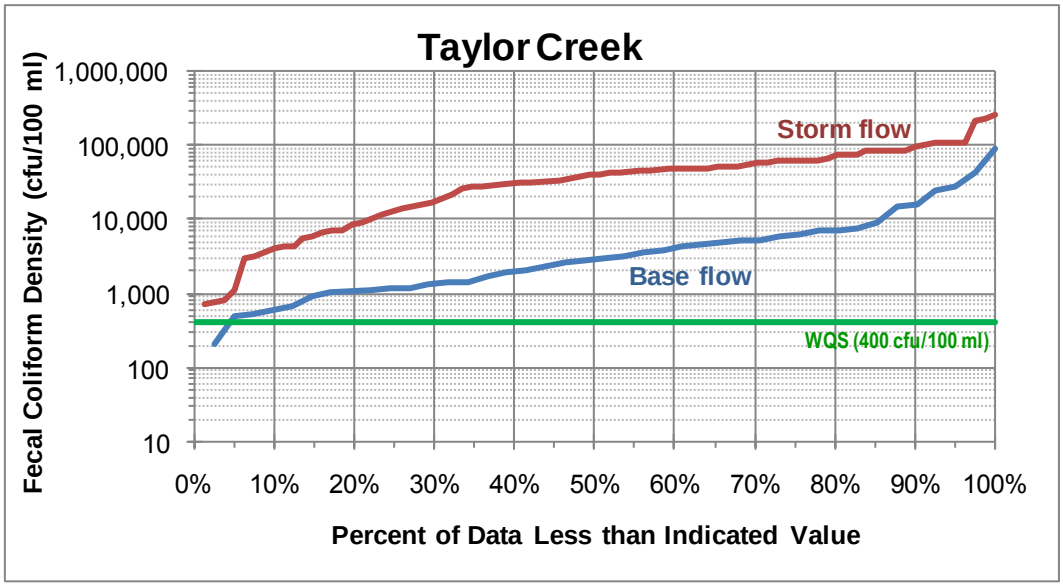

Figure 4. Cumulative Frequency Distribution of Taylor Creek Fecal Coliform Data (October 2006-May 2009).

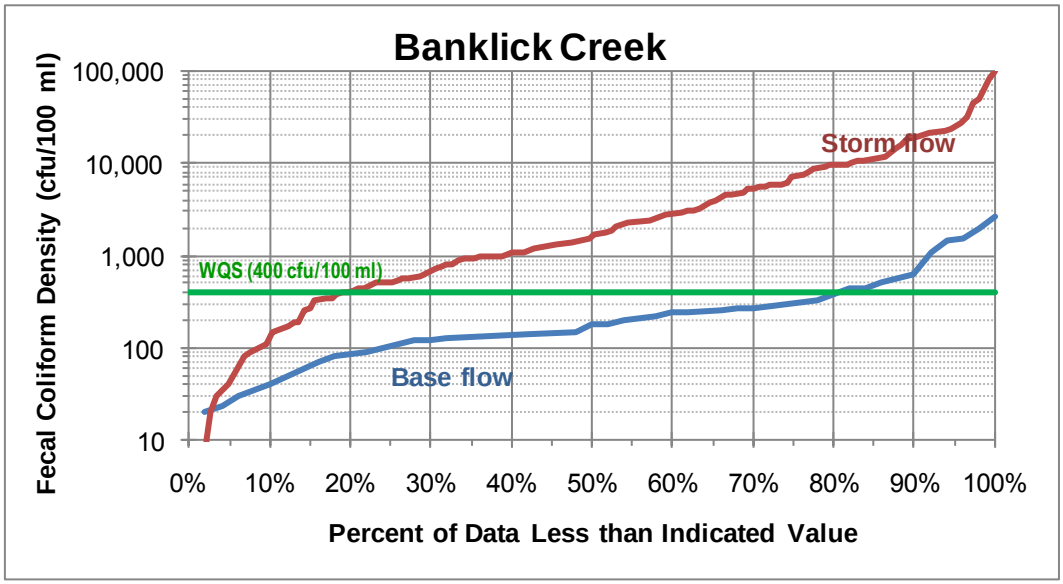

Figure 5. Cumulative Frequency Distribution of Banklick Creek Fecal Coliform Data (April 2002-July 2009).

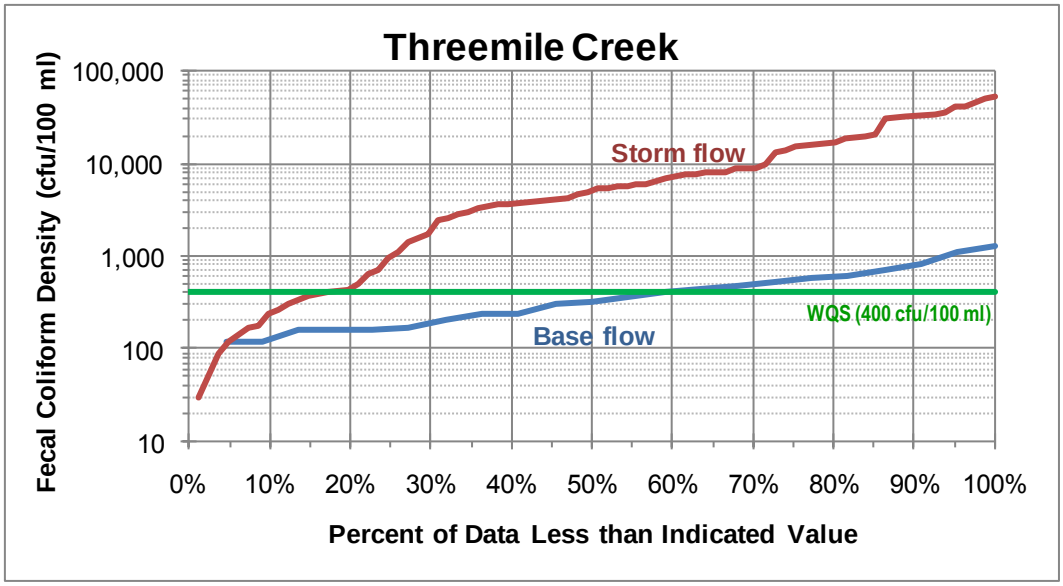

Figure 6. Cumulative Frequency Distribution of Threemile Creek Fecal Coliform Data (June 2007 – October 2009).

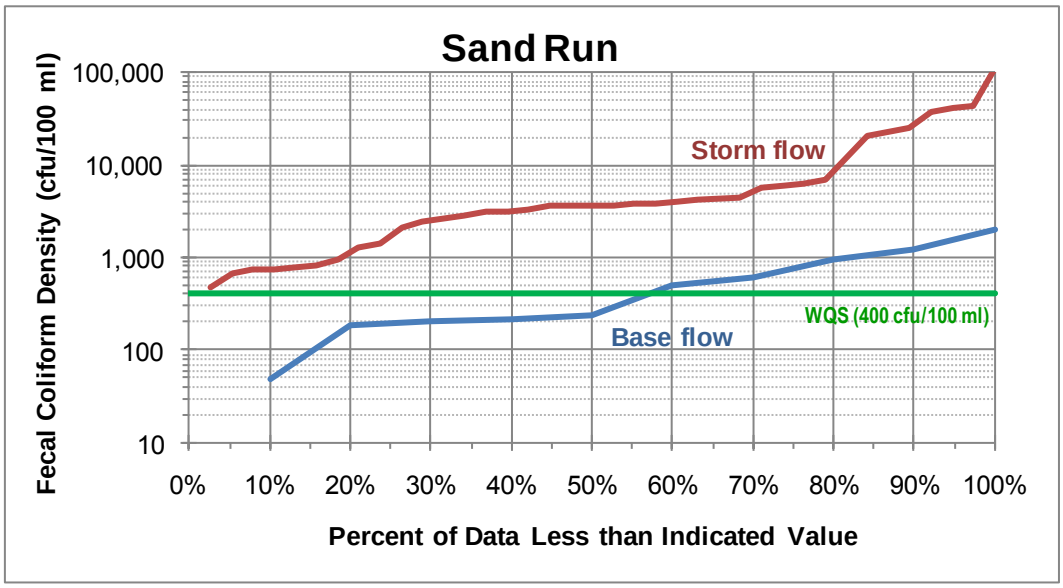

Figure 7. Cumulative Frequency Distribution of Sand Run Fecal Coliform Data (October 2006 – July 2009).

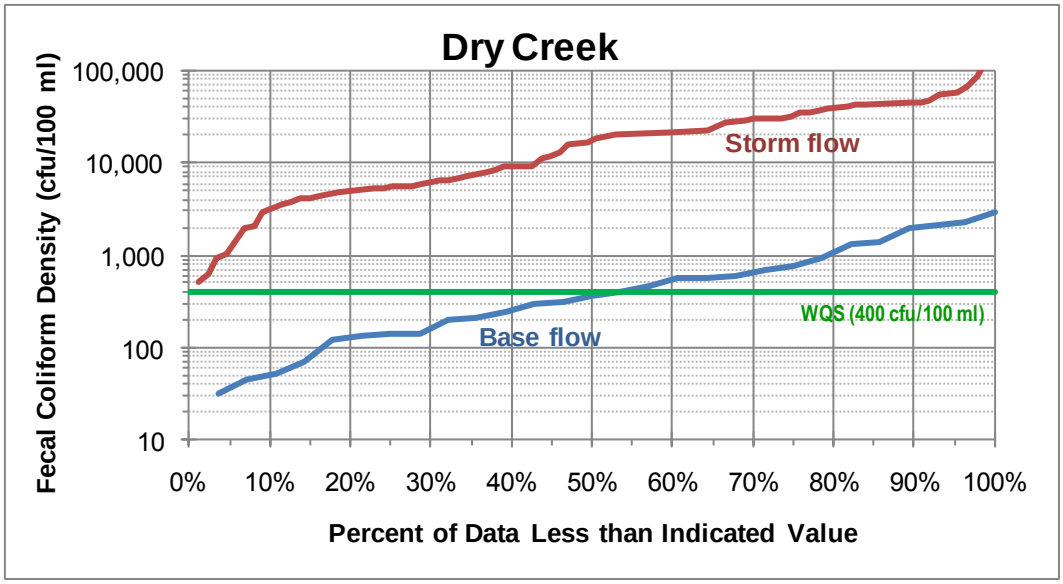

Figure 8. Cumulative Frequency Distribution of Dry Creek Fecal Coliform Data (October 2006 –June 2009).

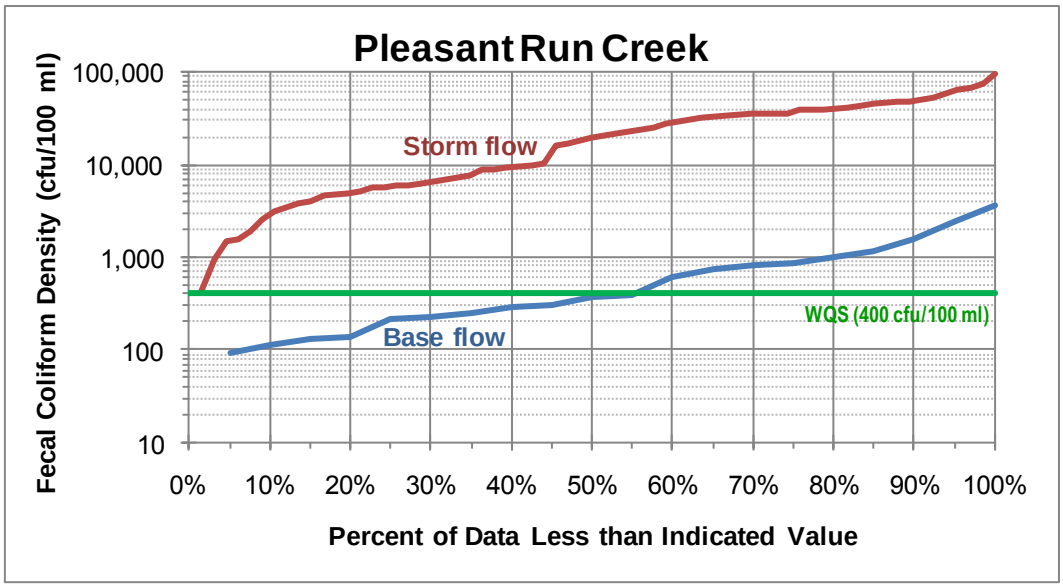

Figure 9. Cumulative Frequency Distribution of Pleasant Creek Fecal Coliform Data (October 2006 – June 2009).

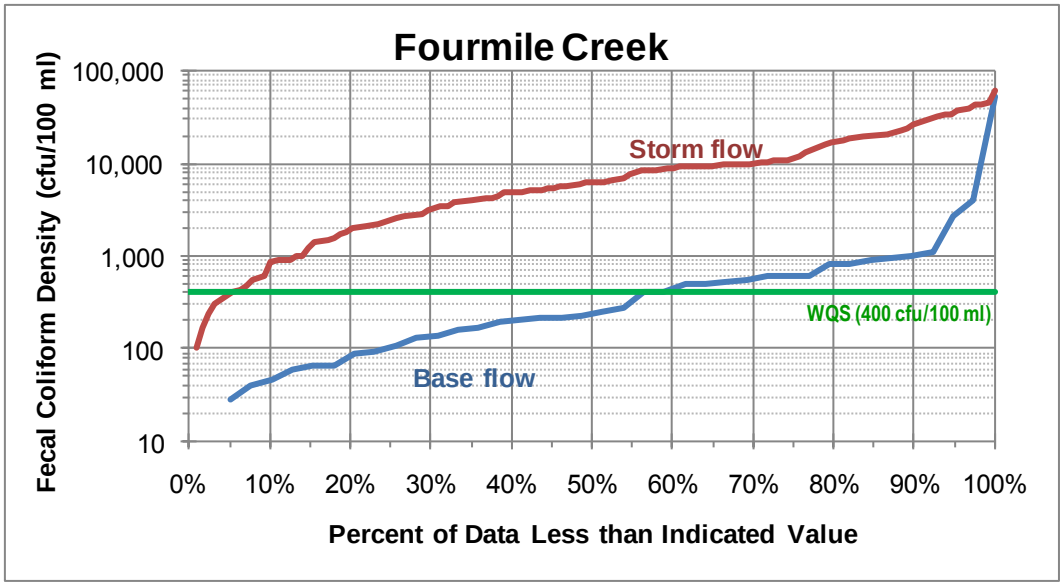

Figure 10. Cumulative Frequency Distribution of Fourmile Creek Fecal Coliform Data (October 2006 – May 2009).

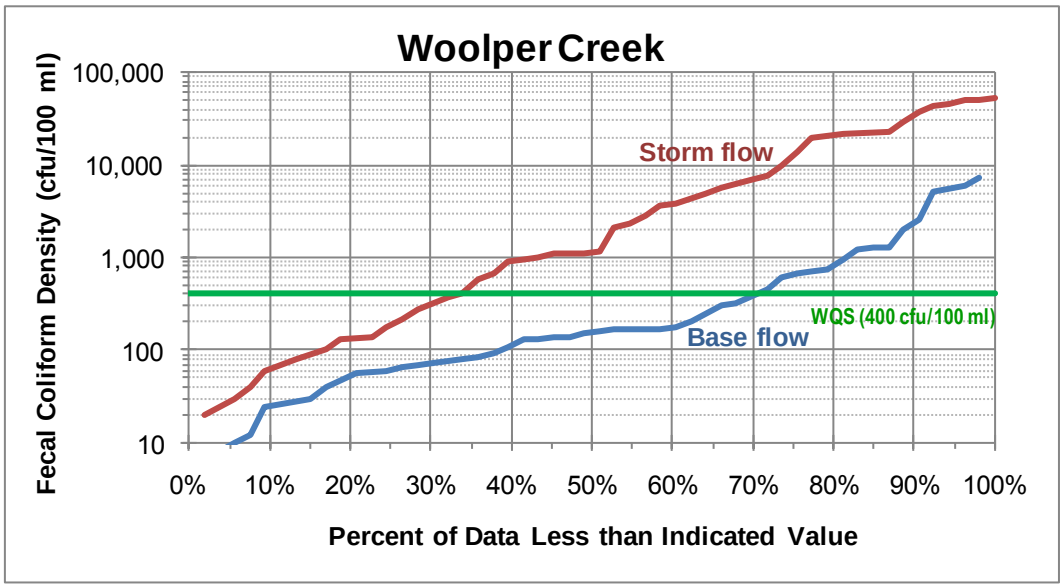

Figure 11. Cumulative Frequency Distribution of Woolper Creek Fecal Coliform Data (October 2006 – October 2009).

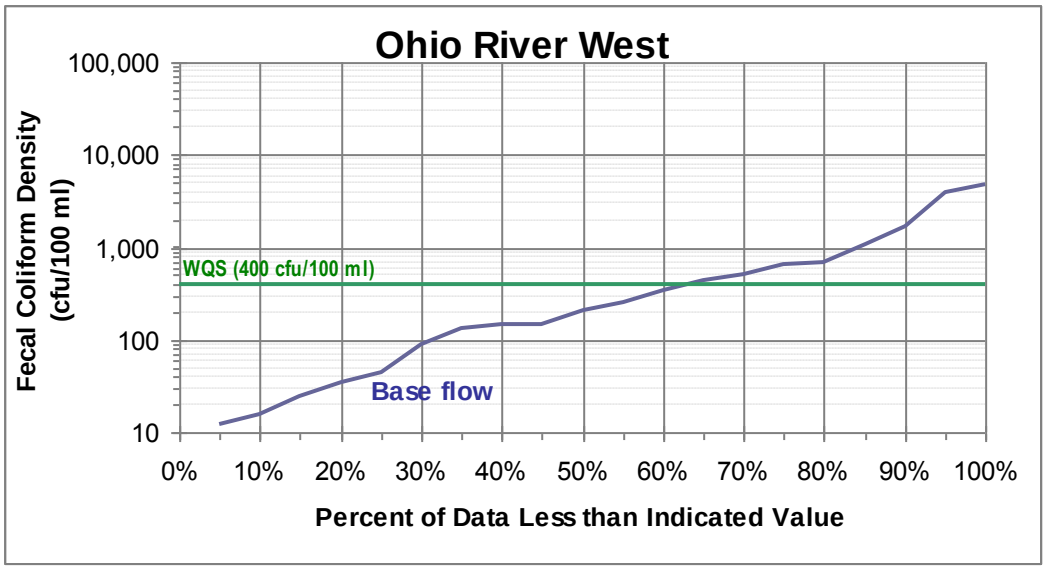

Figure 12. Cumulative Frequency Distribution of Ohio West Fecal Coliform Data (September 2006 – June 2009).

STEP 2 RESULTS: DETAILED ASSESSMENT OF THE BANKLICK CREEK WATERSHED

After identifying Banklick Creek as a priority watershed for dry weather source investigation, a detailed evaluation was conducted in accordance with the process described in Step 2. This evaluation was prepared as a separate, stand-alone document (LimnoTech, June 2009) and is included as an attachment to this protocol.

STEP 3 RESULTS: FIELD RECONNAISSANCE ACTIVITIES

Field surveys were conducted in the Banklick Creek watershed between January and March 2009 during dry weather conditions. The field forms were revised after these surveys and a field Standard Operating Procedure (SOP) describing the field procedures was developed based on the findings from these surveys. Preliminary findings include adding the provision that field surveys need to be conducted when streams are not ice covered.

As described in the Banklick Creek report, the field survey data, which included inventories of specific pipes and locations of livestock access to streams, were reviewed to identify locations for additional surveying and monitoring. Additional monitoring was conducted in April 2010 and tended to confirm the findings of the field reconnaissance. SD1 is currently developing recommendations for next steps, including an Action Plan.

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Banklick Creek Watershed
Dry Weather Source Identification

Prepared for: **Sanitation District No. 1 of Northern Kentucky**

LimnoTech
Water | Environment | Scientists | Engineers

Ann Arbor, Michigan
www.limno.com

DOCUMENT HISTORY

ORIGINAL: November 2008

REVISION No.1: June 2009

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1. SUMMARY

The Banklick Creek watershed has known elevated bacteria levels during dry weather conditions and appears on the 2008 303(d) list as impaired due to fecal coliform. Potential dry weather bacteria sources in this watershed have been identified through a review of recent water quality data, modeling results and source identification.

This report presents an analysis of available data and information, locations for investigation in the field, the results of the field investigation, and recommendations for further study of the targeted areas of the watershed. Potential bacteria sources and specific stream reaches are mapped.

2. WATERSHED OVERVIEW

Banklick Creek is a 19.2 mile long tributary to the Licking River. Portions of the headwaters for this creek are located in Boone County, but the majority of the 58-square mile watershed is located in Kenton County. The headwaters are primarily rural, but become highly developed in the downstream portions. Rural lands support agriculture (including cattle and horses) and forest, and are rapidly transitioning to more suburban uses. Based on predicted development, the amount of impervious surface in this watershed is expected to increase from 11% to 17% in the future.

The Kentucky Division of Water (KDOW) has identified the entire length of this creek as impaired due to bacteria, nutrients and organic enrichment (KDOW, 2008). The lower 8.2 miles are also impaired due to sedimentation. Doe Run Lake, an impoundment on Bullock Pen Creek (a major tributary of Banklick), has been identified as impaired due to low dissolved oxygen, nutrients and dissolved gas supersaturation (KDOW, 2008). Recent (2007-2008) water quality data reveal bacteria exceedances in two tributaries (Bullock Pen Creek, Fowler Creek) and along the length of the mainstem, during both dry and wet weather-related conditions.

The less developed portions of this watershed are the focus of this dry weather source identification effort. The focus area for this study includes the portion of Banklick Creek from the headwaters downstream to the Bullock Pen Creek confluence (headwaters downstream to approximately river mile 6.6), and encompasses a 44.7-square mile area. This focus area includes the following tributaries: Wolf Pen Branch, Brushy Fork, Fowler Creek, Wayman Branch, and Bullock Pen Creek. The entire Banklick Creek watershed is shown in Figure 1, along with the locations where water quality data have recently been collected. Note that individual municipalities are shown in different colors, with green used to indicate parks, schoolyards or other potential recreation areas. Subwatershed identification numbers are also shown in Figure 1 and are referred to in later sections of this report. The subwatershed numbers used in this report are consistent with the WAT! and notation used in the Watershed Characterization Reports. The focus area includes subwatersheds 6 through 13.

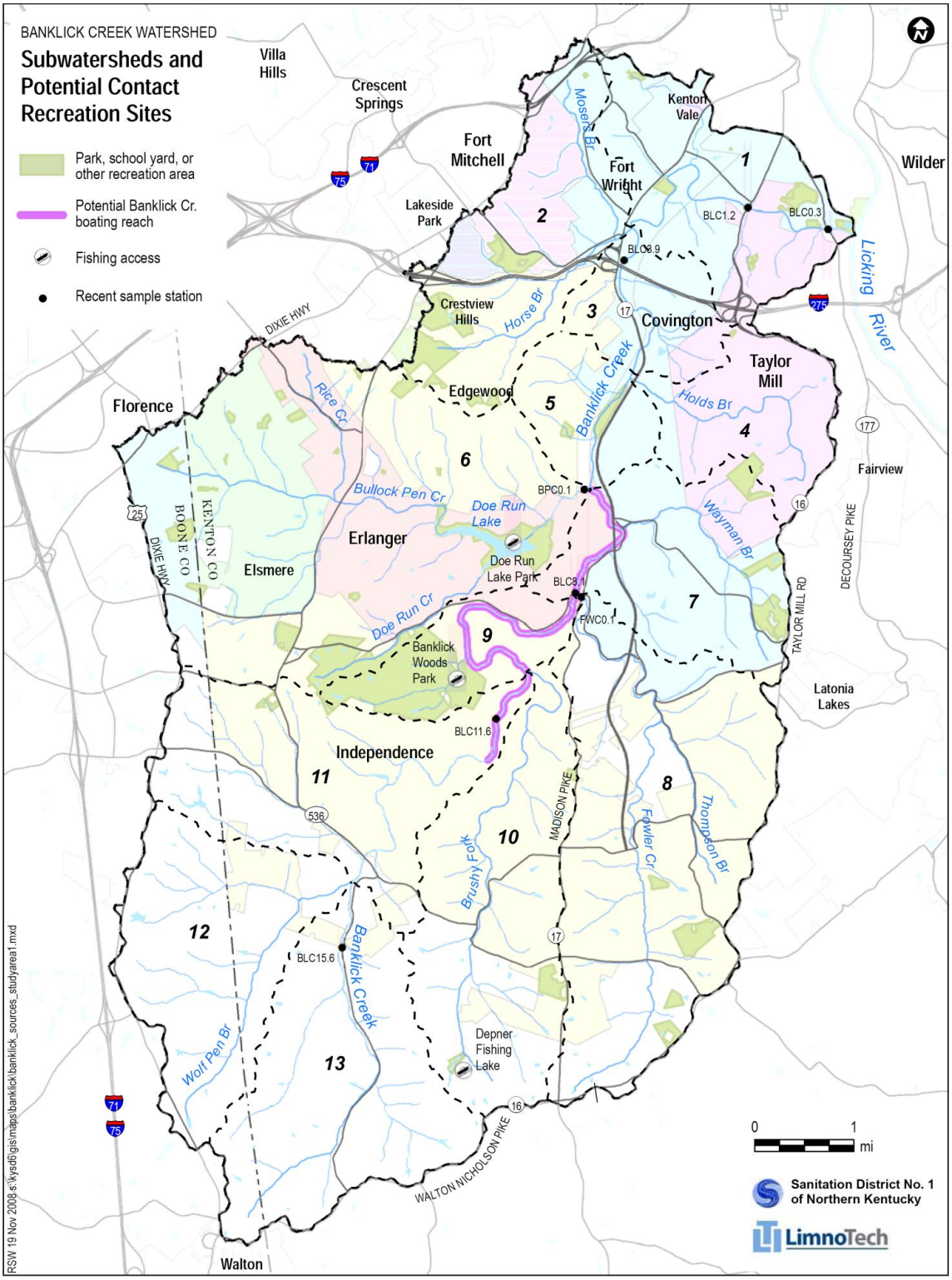

Figure 1. Banklick Creek Watershed

3. DATA ANALYSIS

The draft Banklick Creek Watershed Characterization Report (October, 2008) presents a comprehensive assessment of watershed characteristics, water quality problems, and potential pollutant sources. This report was heavily relied on for this assessment of dry weather sources. Additional information used to supplement this investigation includes base flow bacteria results, recreational use survey data that became available in November 2008, and both HSPF and WAT! base flow model runs conducted specifically for this effort to assess the magnitude of dry weather sources. Some potential sources, such as suspected illicit activity points, were not previously identified in the Watershed Characterization Report because of the high uncertainty surrounding their existence. However, for this work, they were mapped, so that they could be considered for investigation as part of the field effort. Locations where sewer lines cross streams were also identified. Finally, telephone interviews were conducted with Mark Hult (formerly with Banklick Creek watershed council) and Mark Jacobs (Kenton County Conservation District) to determine whether additional information on dry weather sources is available. No additional information was identified beyond that presented in the Watershed Characterization Report.

3.1 DATA SOURCES

Sources of the information used to characterize current conditions and identify dry weather bacteria sources in the Banklick Creek watershed are presented in Table 1. Although seemingly counterintuitive, information on wet weather sources, such as CSOs, SSOs, model-predicted overflow locations and storm water, was also considered primarily to inform the field effort. Some of these sources may be active during dry weather (e.g. a sanitary pump station that overflows (technically an SSO) due to a blockage in the system). Wet weather sources are shown in Figure 2. The assessment of SD1's storm water outfall sampling data indicated that the bacterial quality varies based on the age of the developed area. Portions of SD1's storm water service area were characterized as either "old" or "new" based on the age of development. Figure 2 also shows how the Banklick watershed was characterized.

The subsequent sections describe the water quality data analysis, source assessment, and information obtained to identify areas where people are more likely to come in contact with the creek.

Table 1. Data Sources

Information	Date	Notes
Assess water quality		
Three base flow bacteria surveys	2007-2008	Both fecal coliform and *E. coli* data were used
WAT! base flow bacteria scores by subwatershed	2008	Calculates relative bacteria contribution by subwatershed for known or likely dry weather sources
HSPF model results by subwatershed	2008	Predicts instream densities, simulating the same sources as WAT! HSPF is more spatially and temporally refined than WAT!
Identify potential bacteria sources		
Current land cover	2007	Used to differentiate between agricultural, forest and residential areas
KPDES permitted discharger locations	March 2008	Dischargers permitted as of March 2008
KPDES discharge monitoring reports	Jan. 07-June 08	Recent effluent monitoring data
Storm water pipe outlet locations	2008	Surrogate for potential illicit discharges
Old vs. new storm water classification by subwatershed	2008	Surrogate for potential illicit discharges; Older areas assumed more likely to have illicit discharges or cross connections
Model-predicted overflow locations (MPOL)	2008	Potential wet weather source that is not verified, but which is also modeled as having an overflow. Could be investigated to determine if it is a potential illicit discharge
Suspected illicit activity (SIA) points	2001-02	Not verified, but is addressed under the SD1 IDDEP program. Could be investigated under this program to determine if it is a potential illicit discharge
Parcels potentially served by septic	2006	Likely, but not verified
Identified septic problem area (hot spot)	2008	Known problem area
Locations where sewer lines cross streams or open storm water channels	2008	Potential sewage source
SSOs (includes SSOs at pump stations)	2008	Not observed to discharge during dry weather, but included as a potential dry weather sources, due to blockages etc.
Livestock – Permitted Animal Feeding Operations	2008	
Livestock – Observed	2008	Livestock locations observed through field visit
Livestock – Conservation District	2006-07	General livestock locations obtained from Conservation District
Identify locations where public may access or use the creek		
Possible public access points	2007	Open space GIS coverage from OKI Council of Governments
Fishing locations	2008	Fishing access locations
Boating (kayaking/canoeing)	2004 (date of last update for website)	American Whitewater website describes Banklick Creek from Independence Station Road to Doe Run (Bullock Pen Creek) confluence as a Class II to III waterway.

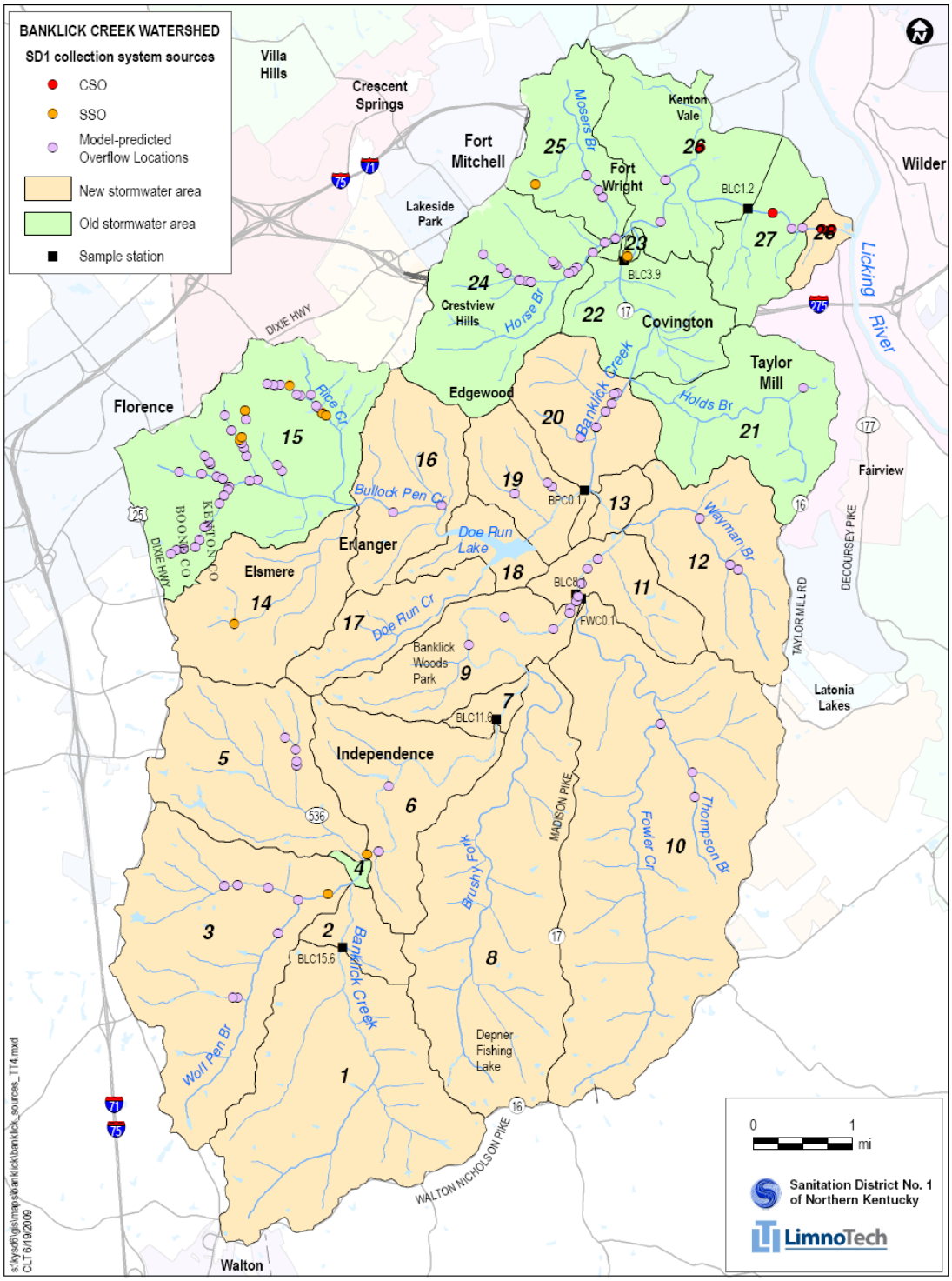

Figure 2. Wet Weather Bacteria Sources in the Banklick Creek Watershed[1]

[1] The subwatersheds shown in Figure 2 are model subwatershed identifiers and differ from those presented in Figure 1, which are WAT! subwatershed identifiers.

3.2 ASSESS INSTREAM CONDITIONS

Instream bacteria densities were assessed using recent monitoring data, and HSPF model results. Watershed Assessment Tool (WAT!) results were also assessed as they provide a surrogate load calculation, which can be used as an indicator of expected instream conditions. The results of this analysis are presented below.

3.2.1 Water Quality Data Analysis

SD1 completed three base flow water quality surveys between June 2007 and June 2008. Base flow fecal coliform and/or *E. coli* exceedances were observed at all five upstream locations sampled, during at least one survey. The highest densities were observed at Banklick Creek RM 11.6 and Bullock Pen Creek near the mouth (RM 0.1). Average densities by location and survey are shown in Figures 3 and 4. Densities are observed to vary significantly between surveys and between locations.

Base flow bacteria densities generally increase between Banklick Creek RM 15.6 and 11.6. Over this two mile reach, Banklick Creek receives inputs from subwatershed 12 (Wolf Pen Branch) and subwatershed 11 (drainage between Wolf Pen Branch and Brushy Fork).

Bacteria densities are also observed to increase over this same reach during wet weather conditions (Figure 5). Furthermore, during wet weather, the densities at Banklick Creek RM 15.6 are significantly higher than those measured during dry weather. There are few "wet weather only" sources in the three subwatersheds that drain to the sampling locations at RM 11.6 and 15.6 (See Table 2). As such, the identification and elimination of dry weather bacteria sources in this part of the watershed may also work to reduce wet weather loads.

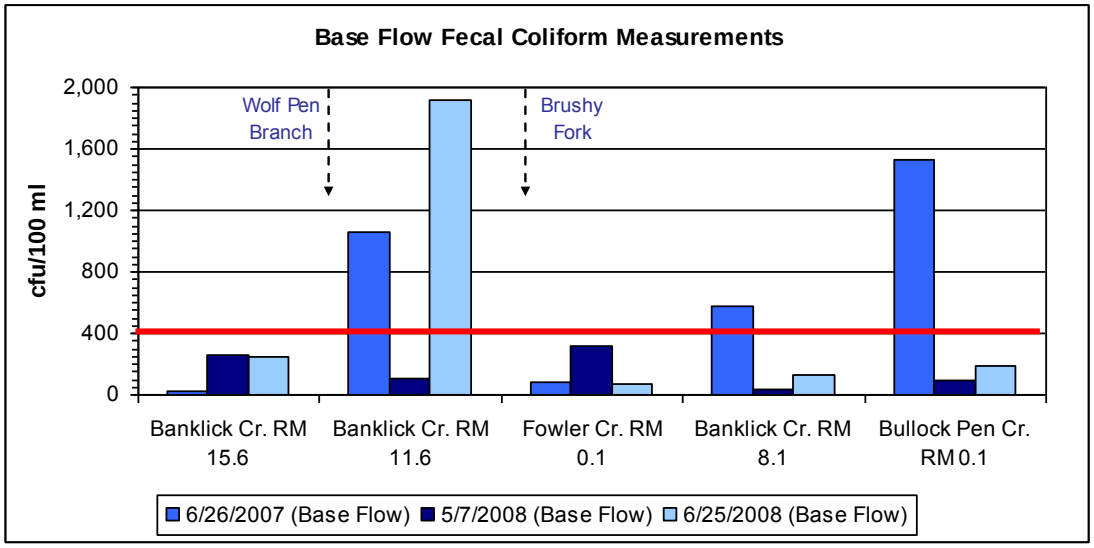

Figure 3. Average Base Flow Fecal Coliform Measurements Compared to 400 cfu/100 ml Criteria

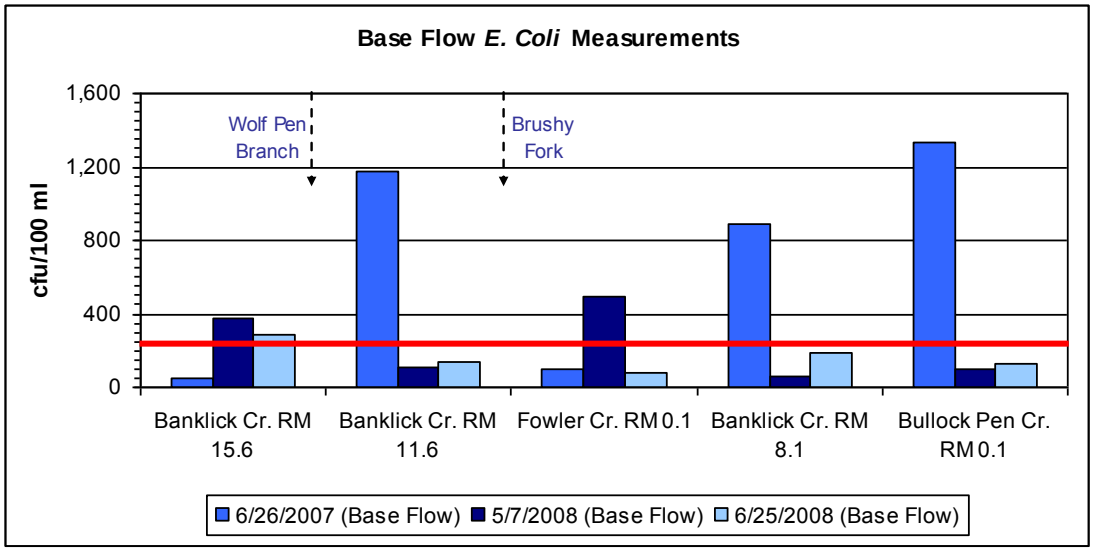

Figure 4. Average Base Flow *E. coli* Measurements Compared to 240 cfu/100 ml Criteria

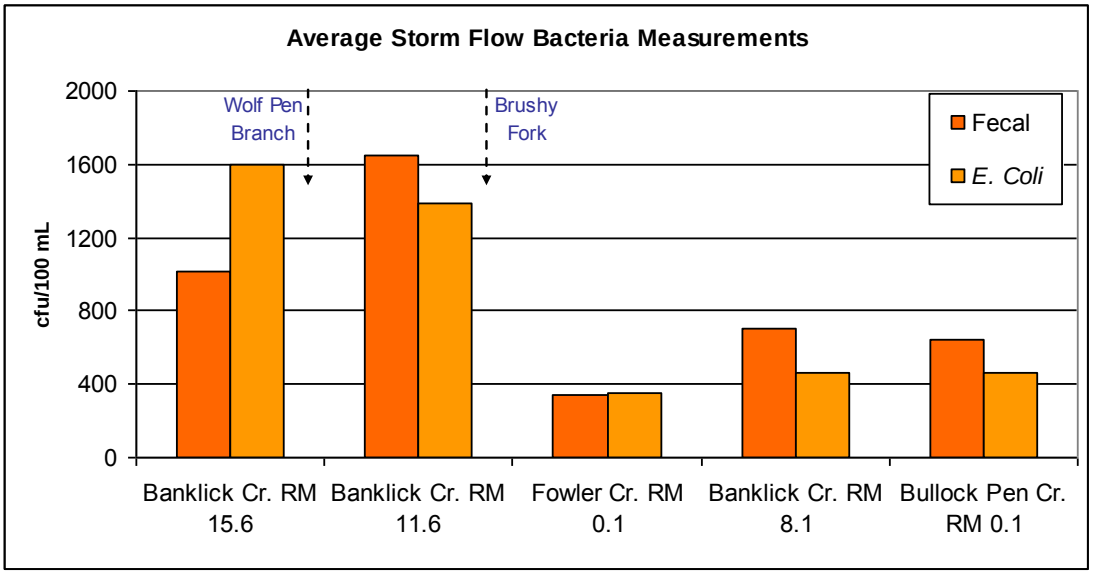

Figure 5. Average Storm Flow Bacteria Densities from May 2008 Survey

3.2.2 WAT! Results

WAT! was applied to simulate base flow bacteria loads in the Banklick Creek watershed. The predicted bacteria loads are generated by two categories of sources, septic systems and KPDES-permitted dischargers, and the resulting WAT! results directly reflect the presence of these sources and their estimated bacteria load.

WAT! results for the eight upstream subwatersheds are presented in Figure 6. Sampling locations have been included in this figure to facilitate comparison between WAT! results and the bacteria data presented in section 3.2.1. As shown, the WAT! results do not parallel the bacteria data. Because WAT! does not simulate livestock contributions during dry weather (e.g., livestock in streams), cross and illicit connections to the municipal separate storm sewer system (MS4) or straight pipe discharges, these results may indicate the importance of further investigating these sources. Another confounding factor may be that WAT! does not account for bacteria lost during instream transport from settling and die-off. A system-wide analysis did not indicate that the losses were significant, though individual subwatersheds, such as Fowler Creek where dry weather sources are concentrated in the headwaters, or certain conditions (e.g. dry weather only) may be more sensitive to these processes than the system as a whole.

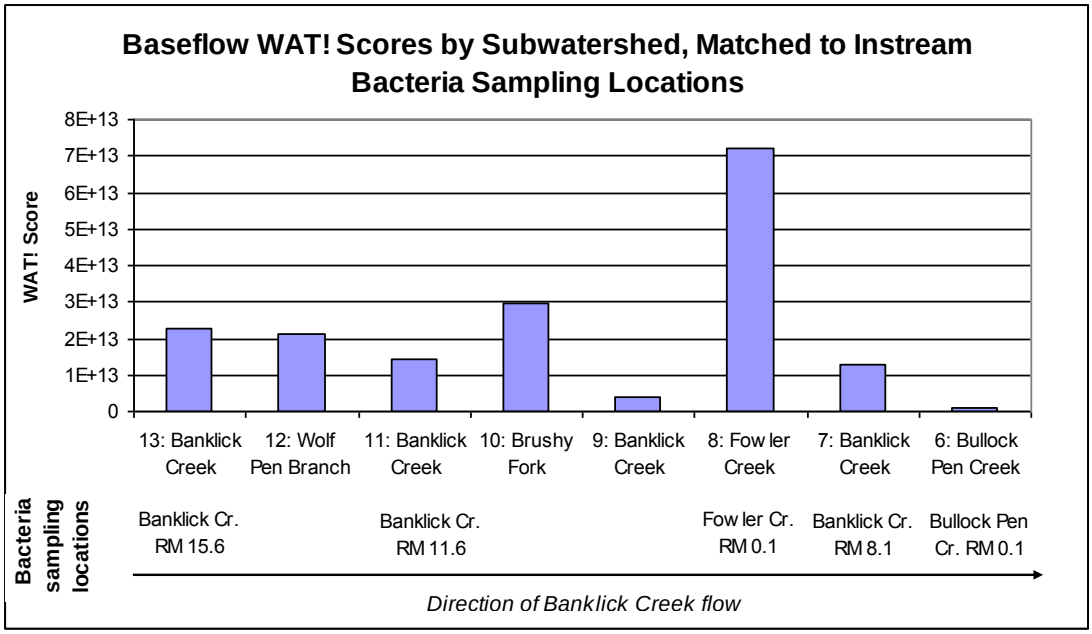

Figure 6. Base Flow WAT! Results by Subwatershed

3.2.3 HSPF

HSPF is another tool that was applied to examine dry weather sources in the watershed. HSPF simulates the focus area over nineteen subwatersheds, compared to the eight subwatersheds simulated in WAT! HSPF also simulates continuous stream flow and instream processes such as bacteria decay. A dry weather loading time series was developed from dry weather data collected between 2002 and 2007. The dry weather load in HSPF is not based on quantifying individual source contributions (e.g. septic vs. livestock, etc.) as with the WAT, rather, it is the total load due to all dry weather sources. The base flow HSPF results are presented in Figure 7. Approximate instream sampling locations are included on this figure.

HSPF results indicate the following subwatersheds[1] may be generating higher bacteria loads during base flow conditions: Fowler Creek (subwatershed 10), and tributaries draining to Banklick Creek between RM 15.6 and 11.6 (subwatersheds 4, 5 and 6). These results are generally consistent with the monitoring data, with the exception of Fowler Creek, which is predicted to have the highest dry weather bacteria geometric mean.

The model can also output flow and depth information at each subwatershed outlet. These results are presented in Section 5 to assist in determining which reaches warrant field investigation and how many field crew are needed for each reach.

[1] The subwatersheds shown in Figure 7 differ from those presented in Figure 1 and are not mapped in this report.

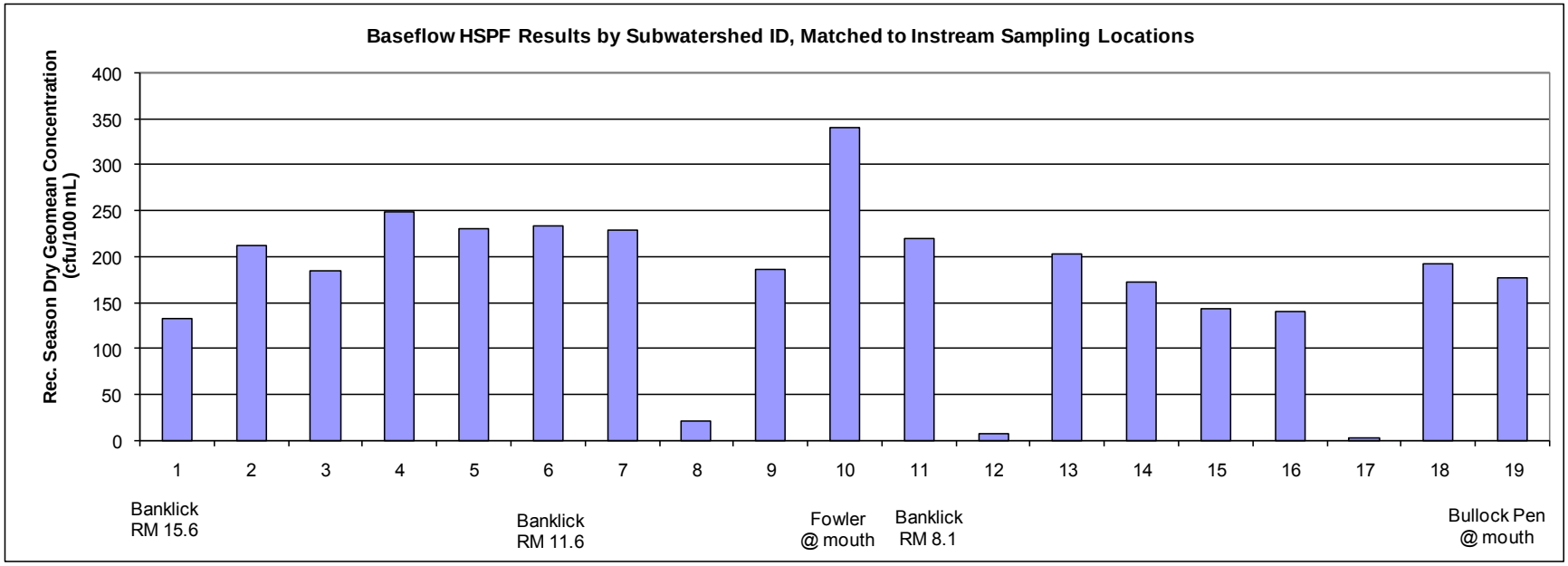

Figure 7. Base Flow HSPF Bacteria Results by HSPF Subwatershed

3.3 SOURCE IDENTIFICATION

Potential dry weather sources were identified by subwatershed, and are presented in Table 2. There are no recurring dry weather overflows from the sanitary sewer system (personal communication, 2008). Recurring dry weather overflows may not occur at SIAs and are not expected to occur at storm water outfalls either, however, all of these locations are included in this summary so that they could be considered for investigation during the field survey. Potential bacteria sources are shown in Figure 8. Current land cover is shown in Figure 9.

Table 2. Potential Bacteria Sources by Subwatershed

Subwatershed	Banklick Headwaters	Wolf Pen Branch	Banklick btwn Wolf Pen Branch & Brushy Fork	Brushy Fork	Banklick mainstem	Fowler Creek	Banklick Creek/ Wayman Branch	Bullock Pen
Subwatershed ID =>	13	12	11	10	09	08	07	06
Sanitary sewerline crossings of streams or open storm water channels	0	88	147	145	46	264	146	468
Storm water system	New	Old	New	New	New	New	New	Old
Storm water outfalls[1]	24	107	218	184	45	255	165	625
KPDES – sanitary	1	2				12		2
KPDES – violations (Jan 07-June 08 data)	Total ammonia	No data				3 fecal; 6 ammonia; 3 no data		1 fecal
Septic	Many	Many	Many	Many	Few	Many	Fewer	None
Septic hot spot						1		
Livestock	Yes, observed just upstream of RM 15.6	Yes, appear to have stream access	Yes					2 AFO; possible horse boarding near mouth
SIA (count)	3	18	6	8	6	9	15	36
Model-predicted overflow locations		1						5
Sanitary Sewer Overflows		2	1				1	15

[1]Storm water locations were based on October 30, 2008 version of SD1's geodatabase.

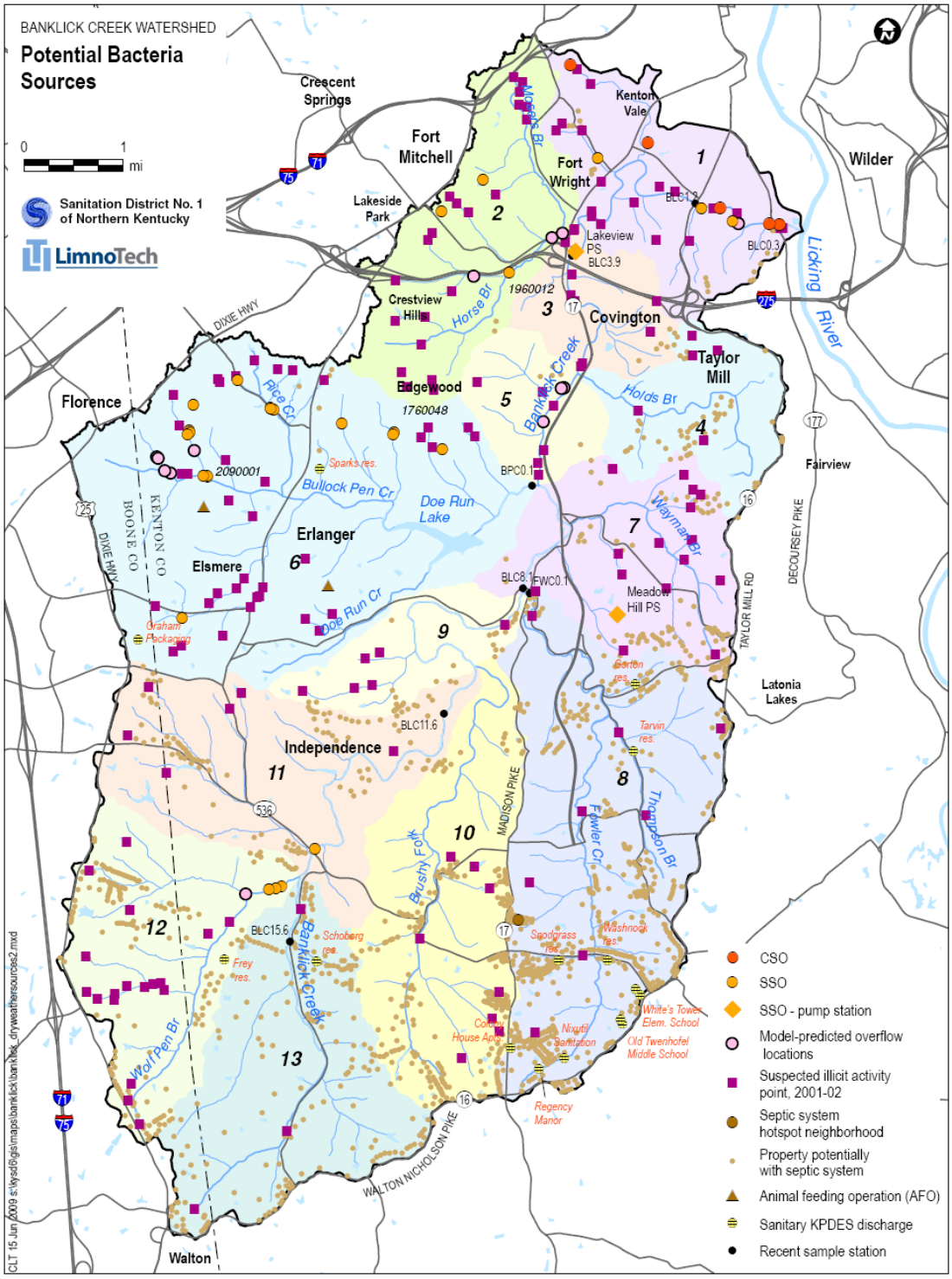

Figure 8. Potential Bacteria Sources

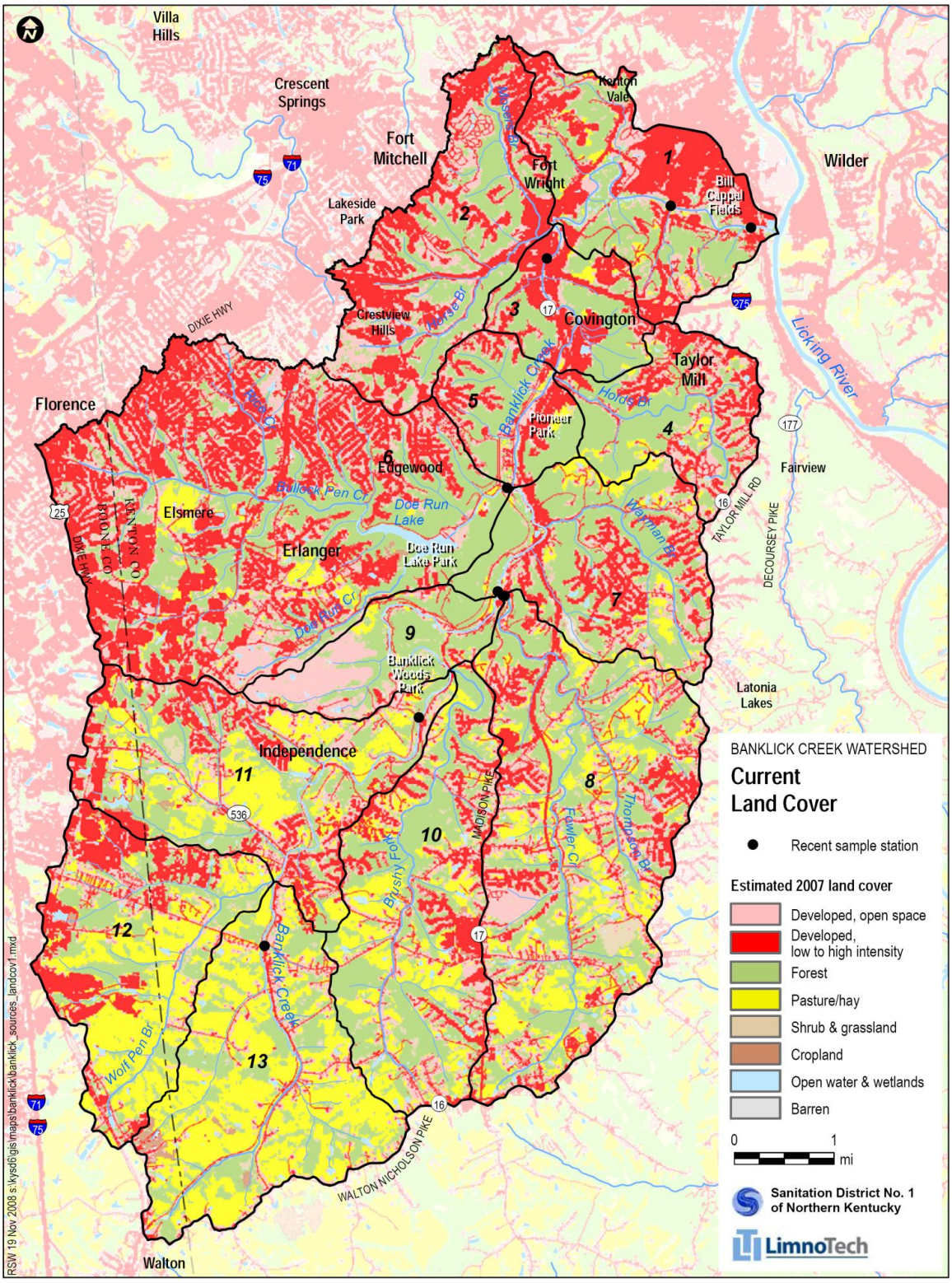

Figure 9. Current Land Cover

3.4 PUBLIC ACCESS

Locations where people are more likely to access Banklick Creek for recreation were identified by reviewing current (2007) land cover (Figure 9) and identifying the location of parks, schools and other public open spaces, and known fishing locations. Recreational use surveys were completed by SD1 during the 2008 base flow survey at each of the sampling locations shown in Figure 8. A reach of the mainstem is identified as a Class II to III waterway on a slightly outdated whitewater website. This reach is also mapped as a potential area for recreational boating, but its use has not been confirmed. No known swimming locations were identified in this watershed. No recreational uses, such as swimming, boating, or wading were observed during the 2008 base flow survey. Potential recreational locations are shown in Figure 1.

3.5 PLANNED IMPROVEMENTS

Planned improvement projects were identified as part of this work, through a review of the draft Banklick Creek Watershed Characterization Report, to ensure that effort is not expended identifying sources that are currently planned for elimination.

The following planned improvement projects were identified for this watershed:

- Stream and wetland restoration along Banklick Creek in Wolsing Preserve (which is near river mile 11.6)
- 3 projects on mainstem of Banklick Creek near RM 10.5 to address streambank erosion
- Doe Run Lake Master Plan developed to protect and enhance the lake and link the lake to adjacent areas using greenways, trails or stream corridors.

None of the projects currently planned are targeted at eliminating dry weather bacteria sources.

4. FIELD STUDY PLAN

4.1 FIELD SURVEY LOCATIONS

Subwatersheds identified for the source investigation are presented in Table 3. The column titled, "sources to consider" includes sources that may be more likely to contribute bacteria, based on a review of available data and modeling results; however all potential sources should be investigated during the field visit. The potential for contact recreation to occur within a subwatershed was rated based on the number of potential recreation areas identified.

Stream reaches to be investigated are presented in Figure 10.

Table 3. Subwatersheds Identified for Dry Weather Source Investigation

Subwatershed (as shown in Figure 1)	Priority[b]	WQ analysis	Sources to consider	Potential for contact recreation	Range of Dry Weather Flows (cfs)[c]	Range of Dry Weather Stream Depths (ft)[c]
Subwatershed 12 (Wolf Pen Branch)[a]	1	Bacteria densities increase downstream of these subwatersheds	Livestock Older storm water lines 1 KPDES discharger	Very low: No recreational areas identified	0 – 2.2 (0.6)	0.002 – 0.17 (0.05)
Subwatershed 11 (Banklick tributaries between Wolf Pen Branch & Brushy Fork)[a]	1		Illicit connections within older storm water system;	Low: Very few potential recreational areas	0.1 – 7.9 (2.2)	0.06 – 0.45 (0.21)
Subwatershed 13 (Banklick headwaters)[a]	1	Some dry weather exceedances. Wet weather sources may be same as dry weather.	Livestock 1 KPDES discharger	Very low: No recreational areas identified	0 – 2.6 (0.7)	0.02 – 0.17 (0.09)
Subwatershed 6 (Bullock Pen Creek)	1	Elevated bacteria densities in June 2007	Horses near mouth	High: Streams traverse several potential recreational areas	0 – 4.5 (1.1)	0 – 0.12 (0.03)
Subwatershed 8 (Fowler Creek)	2	Low bacteria densities near mouth but WAT!, WCR and HSPF model results suggest elevated densities in headwaters	Septic hot spot 9 KPDES dischargers Livestock	Low: Very few potential recreational areas	0-4.4 (1.2)	0 – 0.19 (0.05)

[a]It is suspected that the three headwater subwatersheds dry up on occasion during the summer. This should be considered when prioritizing stream reaches for source elimination.
[b]Subwatersheds with a priority value = 1 will be candidates for SD1 to survey. Subwatersheds with priority value = 2 will be evaluated by other groups (e.g Banklick Creek Watershed Council).
[c]Range is based on HSPF model results during dry weather (average dry weather value is provided in parentheses)

Fowler Creek is identified in Table 3 as a secondary priority because bacteria densities are not significantly elevated at the sampling location on this creek (located near the mouth). It is suspected, however, that bacteria densities closer to the Fowler Creek headwaters may be much higher. This conclusion is based on WAT! and HSPF model results, and maps showing the following potential bacteria sources: septic systems, one septic hotspot neighborhood, several KPDES-permitted

dischargers which have reported elevated fecal coliform densities in their discharge monitoring reports, and an estimated 146 locations where sewer lines cross either streams or open storm water channels. The Fowler Creek headwater may be of interest because there are several schools and other potential recreational areas located near the Fowler Creek headwaters.

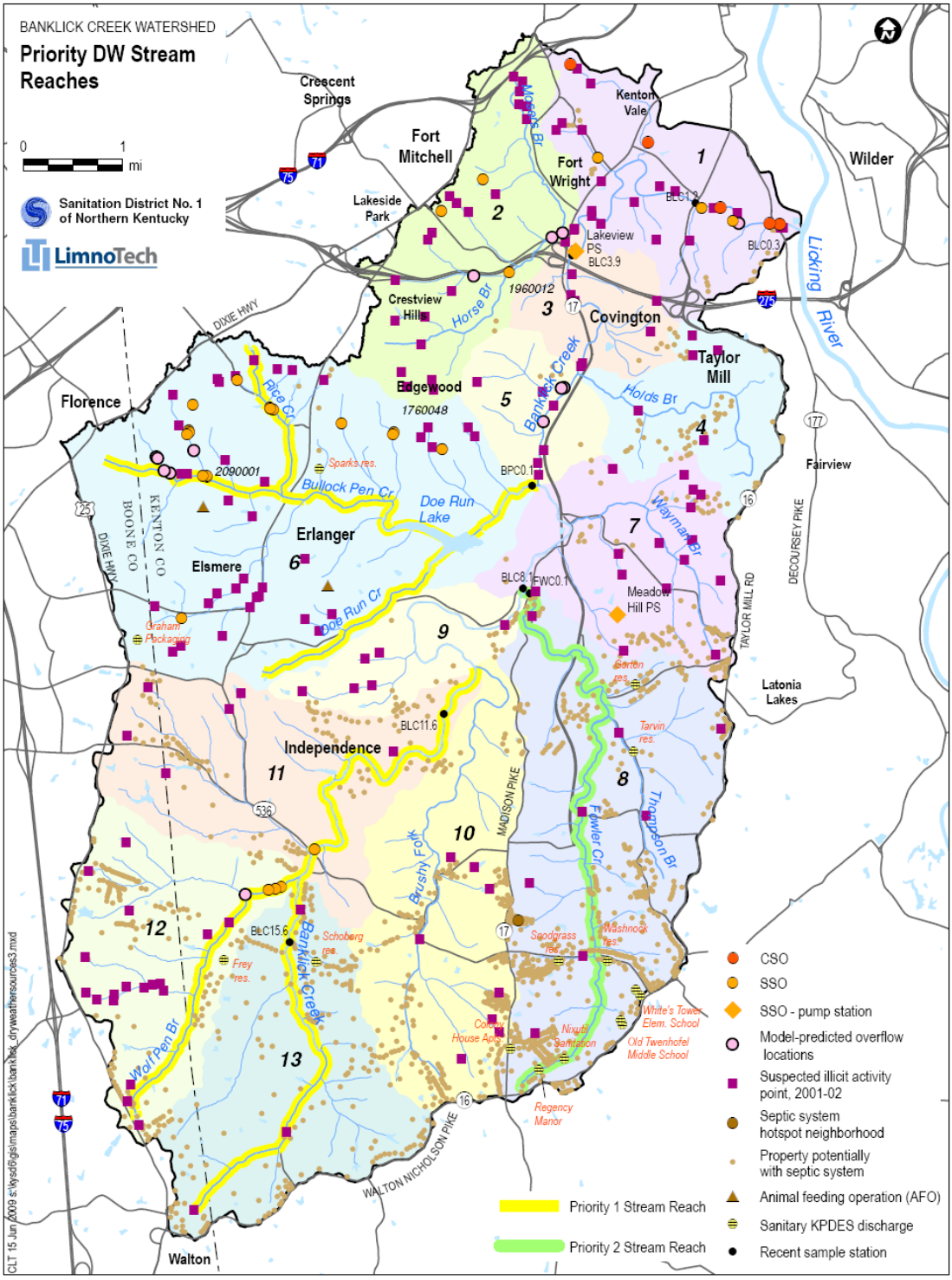

Figure 10. Major Stream Segments with High Potential for Dry Weather Bacteria Impacts

4.2 FIELD SURVEY

The purpose of the field survey was to gather sufficient information to develop an inventory of likely source loading locations and impaired subreaches. Two-person crews were deployed to conduct field surveys in reaches mapped as highly likely to be impaired during dry weather conditions. The crews focused on surveying the primary stream network in the headwater subreaches.

Prior to deploying to the field, the crew reviewed aerial photography information to plan where to survey and to identify where key city and/or SD1 service area boundaries were relative to the reach of interest. Field forms were set up on Trimble Geo XT handheld GPS units to record data on flowing pipes, sewage, and other source-related observations during a dry weather period. The information recorded on the field forms is shown in Table 4.

Table 4. Field Survey Information

Stream Features		*Point Source Features*		*Non-Point Source Features*	
Stream Flow	Low/Trickle	Structure ID		Bank	Right descending
	Medium/Normal	Pipe Diameter (inches)			Left descending
	High/Strong	Distance from Stream (feet)			In line
Bank Erosion	None	Bank	Right descending	Source Type	None
	Minor		Left descending		Septic (apparent)
	Moderate		In line		Livestock-fenced
	Major	Outfall Material	PVC (polyvinyl chloride)		Livestock w/ access to stream
Dominant Bed Material	Clay/Silt (<0.08mm)		RCP (reinforced concrete pipe)		Other
	Fine Sand (<0.08-1mm)		CMP (corrugated metal pipe)	Livestock Type	Cows
	Coarse Sand (1-2 mm)		HDPE (high density polyethylene)		Horses
	Gravel (2-64 mm)		Iron		Turkeys
	Cobble (64-256mm)		Clay		Pigs
	Boulder (>256mm)		Tributary		Chicken
	Bedrock		Other		Goats
Sediment Odor	NA	Discharge Odor	None		Sheep
	Sewage		Sewage		Other
	Rotten Eggs		Sulfurous	Distance from Channel	
	Rancid/Sour		Organic	Evidence	yes
	Petroleum		NA		no
	Fragrant		Other	Discharge Odor	None
	Other	Discharge Clarity	Clear		Sewage
Sediment Odor Severity	Faint/Barely Detectable		Opaque		Sulfurous
	Moderate/Easily Detectable		Cloudy		Organic
	Strong/Notice from Afar		NA		NA
Water Odor	NA		Other		Other
	Sewage	Discharge Type	None	Discharge Clarity	Clear
	Rotten Eggs		Groundwater Seep/Spring		Opaque
	Rancid/Sour		Roof drain (dry)		Cloudy
	Petroleum		Sanitary		NA
	Fragrant		Septic (apparent)		Other
	Other		Stormwater - closed		
Water Odor Severity	Faint/Barely Detectable		Stormwater - open		
	Moderate/Easily Detectable		Tributary		
	Strong/Notice from Afar		Other		
Water Color	NA	Deposit/Stain	NA		
	Black		Algae		
	Blue		Grease		
	Brown		Mineral		
	Gray		Oil		
	Green		Sediment		
	Orange	Deposit Severity	Slight		
	Red		Some		
	White		Severe		
	Yellow	Floating Solids	NA		
Color Severity	Slightly Tinted		Sewage		
	Moderately Tinted		Petroleum		
	Intense		Surface Scum		
Turbidity	Transparent		Foam		
	Translucent		Suds		
	Opaque		Natural Sheen		
			Other		
		Floating Solids Severity	Slight		
			Some		
			Severe		
		Source Flow	Trickle		
			Low Flow		
			1/4 Pipe/Channel		
			1/2 Pipe/Channel		
			3/4 Pipe/Channel		
			Full Pipe/Channel		
		Source Type	Wet only		
			Dry and Wet		

Field surveys were conducted in January, February and March 2009 by SD1 personnel with assistance from LimnoTech. Because these surveys were targeting dry weather sources, at least 72 hours without precipitation or snow melt conditions was required prior to conducting the surveys. Twenty miles of stream were walked in Subwatersheds 3, 6, 9, 11, 12 and 13 (Figure 10). Dry weather and wet weather sources were identified and the coordinates were recorded on the Trimble GeoXT. The identified source locations are shown on Figure 11.

Over the course of the survey, 158 potential dry and wet weather point sources were identified – see Figure 11. These sources are summarized in Attachment A, which shows that 73% were tributaries or drains entering the primary stream network. Pipe discharges to the streams were 22% of the total identified sources and groundwater discharges made up 5%. The majority of the tributaries were determined to be open storm water channels. Five of the pipe discharge locations were identified as sanitary or septic tank discharges and sewage odor was present at these locations. The dry weather flow at all locations ranged from a trickle to low flow.

Ten non-point source locations, such as areas where cattle have access to the stream, were also identified. These stream reaches were marked on the Trimble GeoXT as polylines. These sources are summarized in Attachment B and shown in Figure 11. Their location and adjacent land cover are shown in Figure 12.

Photographs of outfalls and non-point source locations are included in Attachment C.

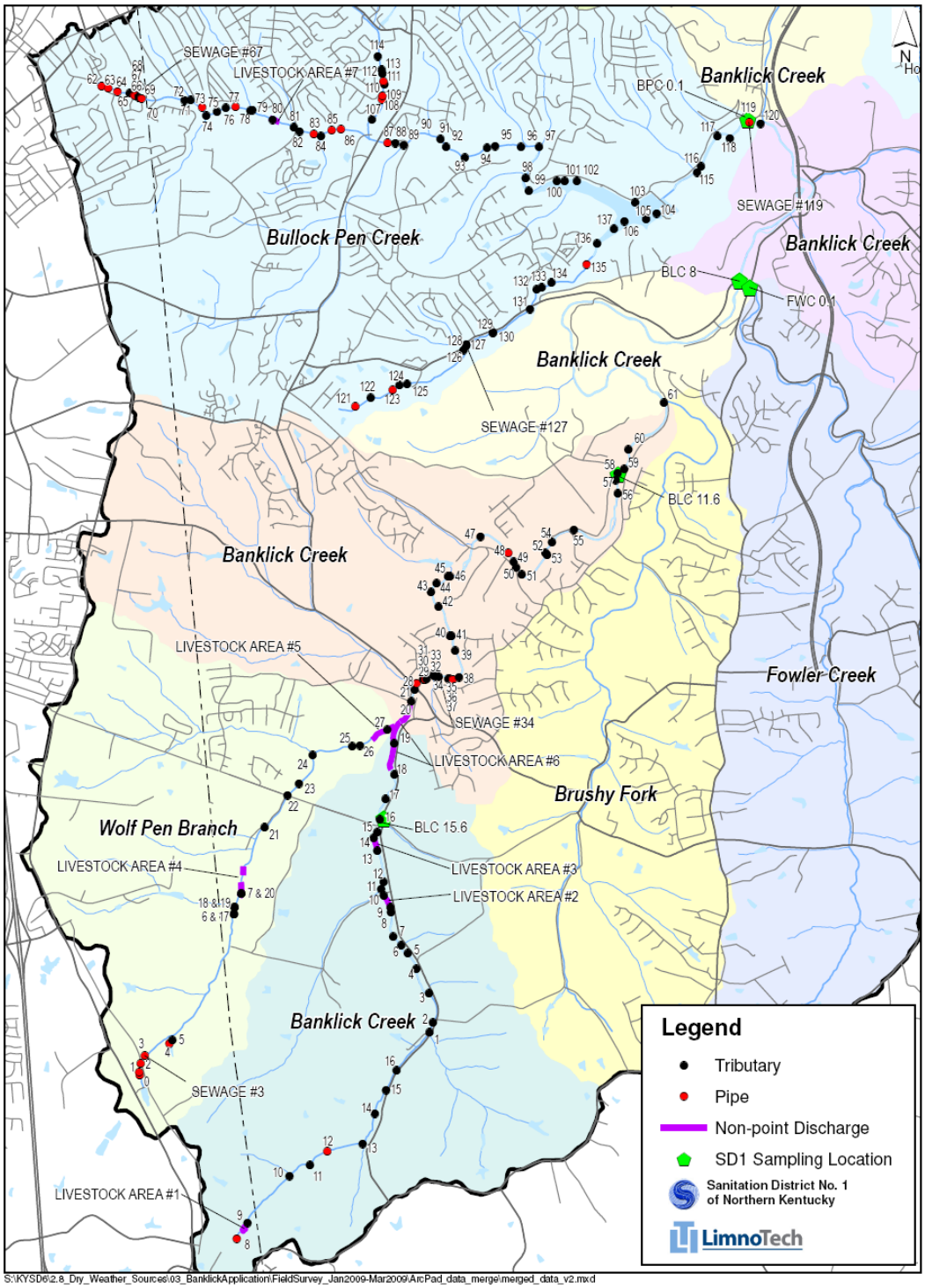

Figure 11. Source Locations Identified During Dry Weather Field Surveys

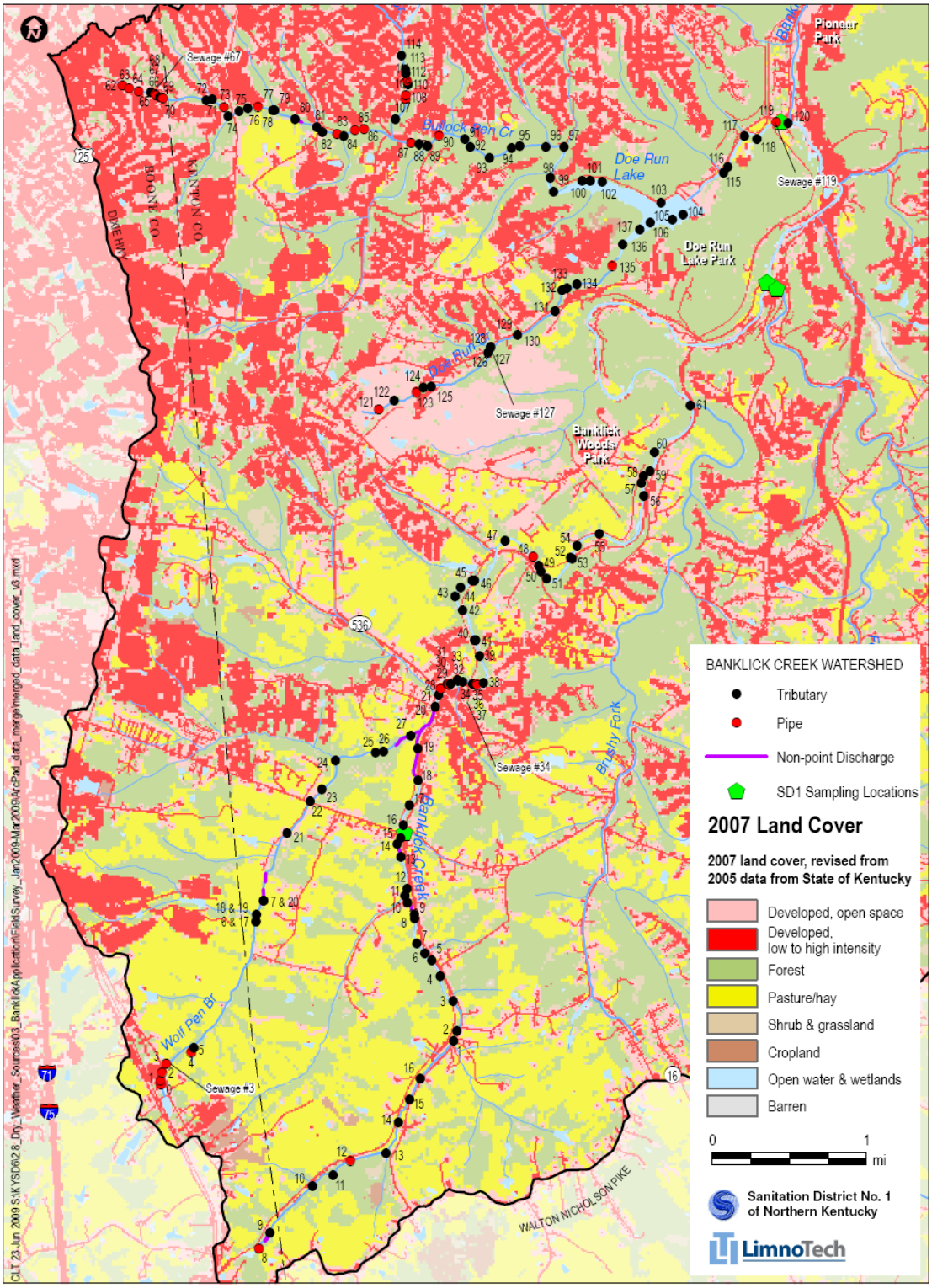

Figure 12. Land Cover and Source Locations

4.3 ADDITIONAL INVESTIGATIONS

The data collected during the stream surveys was input into GIS to cross-reference with existing source information and instream sampling data so that potential source loading locations and possible source types could be identified.

Several potential dry weather sources (point and nonpoint) were identified and inventoried. Targeted bacteria sampling to confirm the sources identified will be a beneficial next step. Bacterial source tracking may also be warranted. In addition, the winter field surveys focused on investigating the main stem waterway in each subwatershed. There were many smaller streams and ditches with intermittent flow that were not investigated. In situations where no potential sources were identified on the subwatershed main stem, it may be prudent to investigate these smaller streams.

For the Banklick Creek watershed, additional source investigation activities are summarized in Table 5. The general approach is to first conduct conventional bacteria analysis upstream and downstream of each potential dry weather source area and at existing SD1 monitoring locations. The objective of these analyses are to quantify the magnitude of the dry weather load from the potential sources and to estimate the load or load gain in bacteria observed at the monitoring locations. Pending the outcome of these analyses, additional field surveys into smaller stream reaches may be useful if the analytical results do not indicate a source. Finally, SD1 may conduct bacteria source tracking analysis at select monitoring locations to identify the predominant source type (animal vs. human, or possibly species-specific results), as appropriate.

The field surveyed watersheds have been divided into three discrete supplemental bacteria surveys for conventional bacteria analysis. Sampling upstream and downstream of each potential dry weather source will allow SD1 to quantify the load gain from the potential source. Sampling at the existing monitoring locations will permit SD1 to estimate the portion of the load from the identified sources. Samples collected in these surveys will be analyzed for fecal coliform and *E. coli* using standard quantitative methods. Survey 1 (Figure 13) is focused on identifying the sources of the historically high dry weather densities observed at RM 15.6 (Maher Road). Survey 2 (Figure 14) is focused on identifying the sources of the increased load historically observed between RM 15.6 and RM 11.6 (Independence). Survey 3 (Figure 15) is focused on identifying the sources of increased load observed at the mouth of Bullock Pen Creek. Because most of the potential sources identified in the subwatershed are upstream of Doe Run Lake, several sampling locations were added so that the settling/treatment efficiency of the lake at removing bacteria can be evaluated.

Field crews will complete the field forms used in the initial field survey during the supplemental surveys. Pending the results of these surveys, additional field work and/or bacteria source tracking will be considered.

Table 5. Additional Source Investigations

Survey	Locations	Sample No.	Coordinates		Task	Rationale	Priority
Survey #1 - Subwatershed #13	Livestock Area 1	22 (US)	-84.602441	38.88988876	Sample upstream and downstream of these source areas during dry weather for fecal coliform and *E. coli*	Confirm/quantify elevated bacteria from identified potential sources	High
		23 (DS)	-84.601118	38.89140924			
	Livestock Area 2	12 (US)	-84.584079	38.92093204			
		13 (DS)	-84.584987	38.92256055			
	Livestock Area 3	14 (US)	-84.585536	38.92617298			
		15 (DS)	-84.585872	38.92796302			
	SD1 Sample Location BLC 15.6	26	-84.584869	38.929416	Sample during dry weather for fecal coliform and *E. coli*	Characterize the elevated dry weather load at this station and estimate portion of load due to identified potential sources.	High
	Unnamed Tributary to Banklick Creek				Inspect the tributary for dry weather sources	These tributaries are located in agricultural areas with the potential for livestock access	To be done after receiving results from Survey #1 sampling effort

Table 5. Additional Source Investigations Continued

Survey	Locations	Sample No.	Coordinates		Task	Rationale	Priority
Survey #2 - Subwatershed # 11/12 and lower portion of #13	Sewage #3	8	-84.613886	38.90663458	Sample upstream and downstream of these source areas during dry weather for fecal coliform and *E. coli*	Confirm/quantify elevated bacteria from identified potential sources	High
		9	-84.61341	38.90702438			
	Livestock Area 4	10	-84.602594	38.92161125			
		11	-84.601499	38.92503794			
	Livestock Area 5	17	-84.586732	38.93675564			
		21	-84.583707	38.93815972			
	Livestock Area 6	16	-84.583811	38.93385358			
		18	-84.58159	38.94054409			
	Sewage #34	6	-84.578452	38.94294206			
		7	-84.577946	38.94293571			
	SD1 Sample Location BLC 15.6	26	-84.584869	38.929416	Sample during dry weather for fecal coliform and *E. coli*	Characterize the load gain between sampling stations and estimate portion of load due to identified potential sources.	High
	SD1 Sample Location BLC 11.6	27	-84.556552	38.96207687			
	Unnamed Tributaries to Banklick Creek				Inspect the tributary for dry weather sources	These tributaries are located in agricultural areas with the potential for livestock access	To be done after receiving results of Survey #2 sampling effort

Table 5. Additional Source Investigations Continued

Survey	Locations	Sample No.	Coordinates		Task	Rationale	Priority
Survey #3 - Subwatershed # 6	Sewage #127	4	-84.574839	38.97427706	Sample upstream and downstream of these source areas during dry weather for fecal coliform and *E. coli*	Confirm/quantify elevated bacteria from identified potential sources	High
		5	-84.575095	38.97400348			
	Sewage #67	0	-84.615179	38.99771851			
		1	-84.615742	38.99792855			
	Sewage #119	2	-84.541024	38.99533038			
		3	-84.540543	38.99557285			
	Livestock Area 7	19	-84.599282	38.99580809			
		20	-84.597703	38.99526883			
	Bullock Pen Creek Upstream of Doe Run Lake	25	-84.568077	38.990098	Sample during dry weather for fecal coliform and *E. coli*	Characterize the load entering Doe Run Lake	High
	Doe Run Creek Upstream of Doe Run Lake	24	-84.558633	38.984325			
	Upstream of SD1 Sample Location BPC 0.1	28	-84.551209	38.988222		Characterize the load gain between sampling stations and the "treatment" efficiency of Doe Run Lake	High

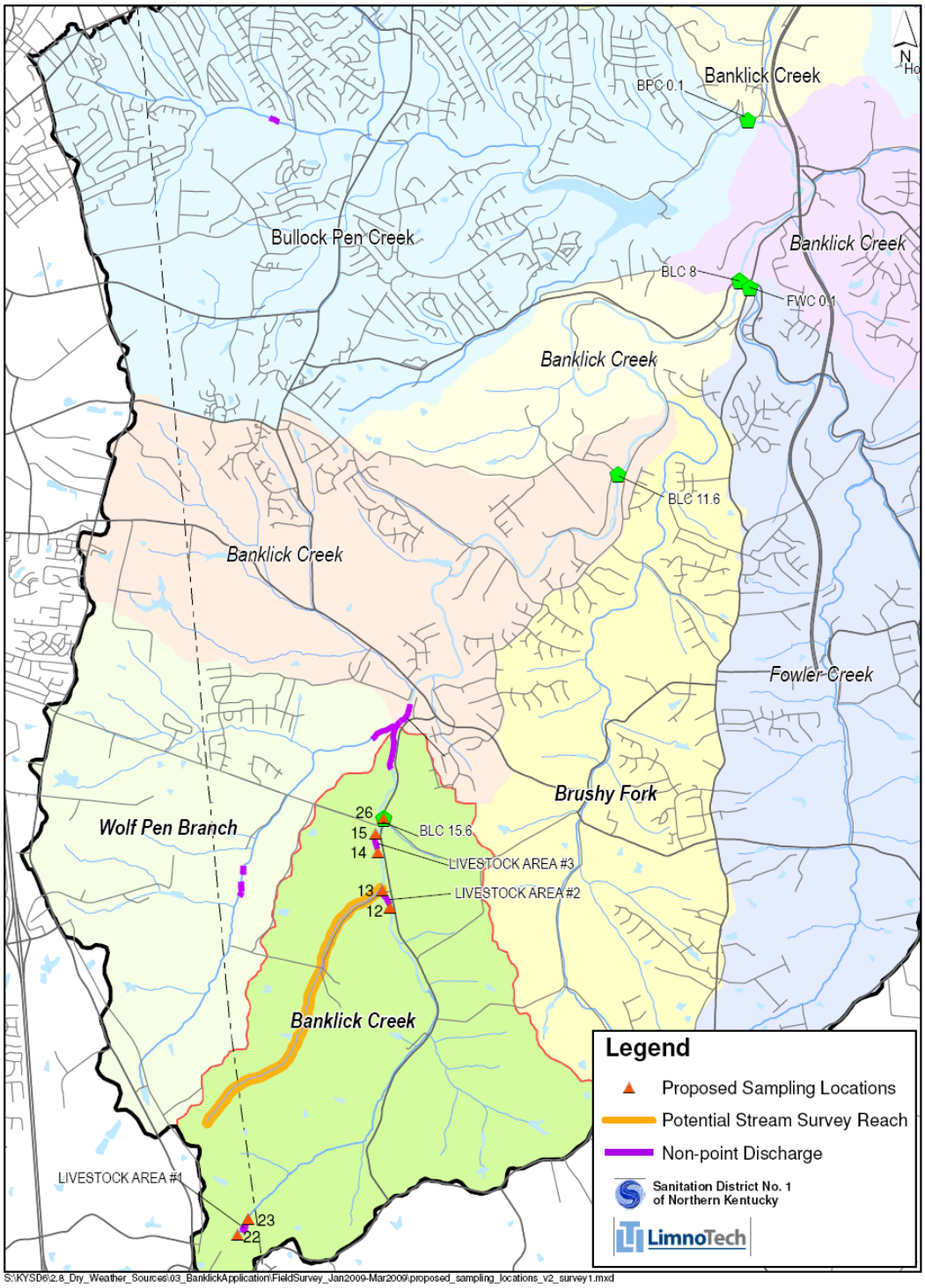

Figure 13. Survey 1 - Additional Investigation

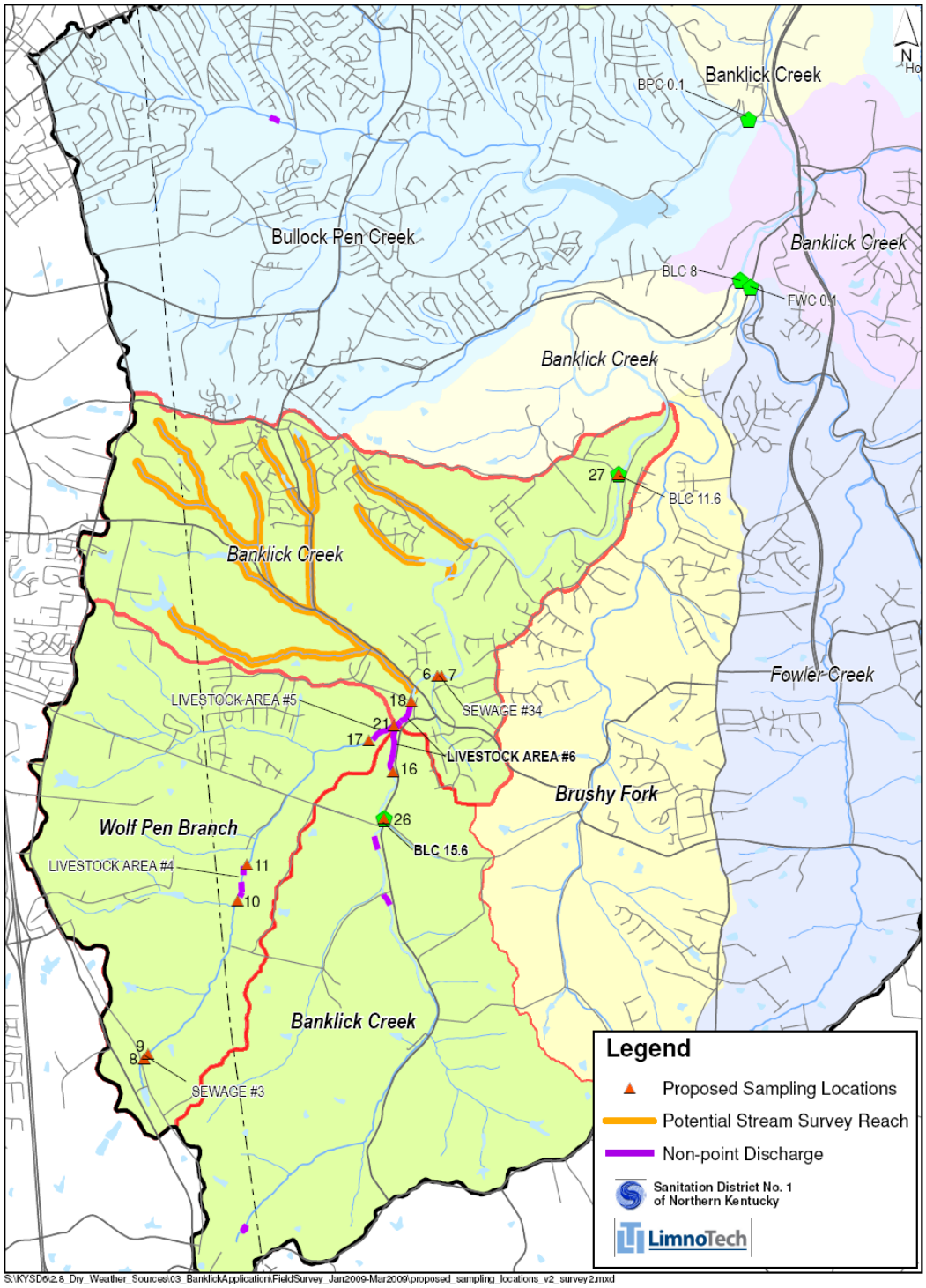

Figure 14. Survey 2 - Additional Investigation

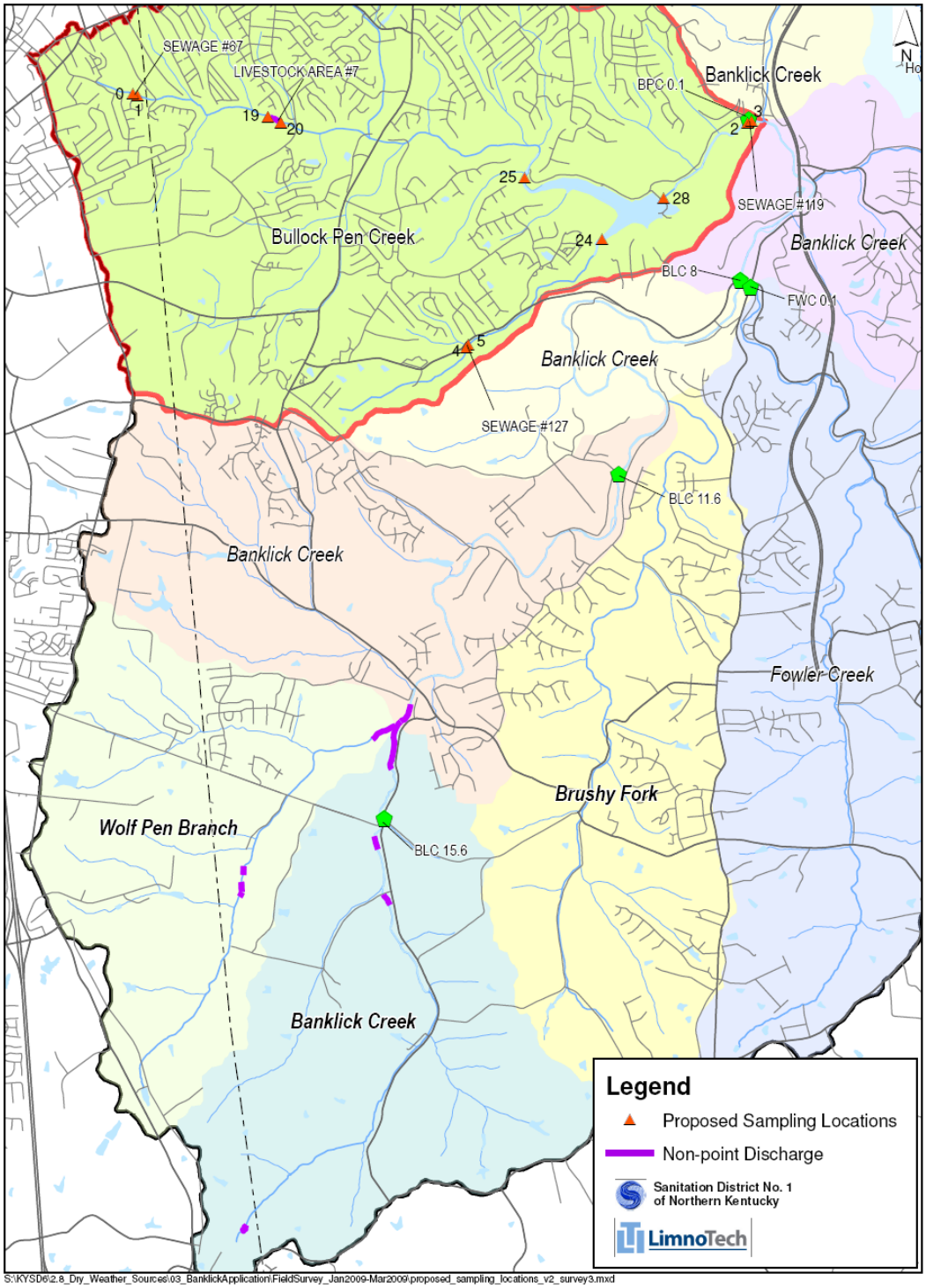

Figure 15. Survey 3 - Additional Investigation

5. REFERENCES

Kentucky Division of Water (KDOW), Kentucky Environmental and Public Protection Cabinet, 2008. 2008 Integrated Report to Congress on the Condition of Water Resources in Kentucky. Volume II. 303(d) List of Surface Waters. Final. May, 2008.

LimnoTech, Inc., 2008. 2008 Banklick Creek Watershed Characterization Report. October 2008. Draft.

Personal communication, 2008. e-mail from Eric Onderak to Penelope Moskus, November 18, 2008.

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ATTACHMENT A

Identified Point Source Summary

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Appendix A: Identified Point Source Summary

FID	DATE	BANK	PIPE DIA. (inches)	DISTANCE** (feet)	OUTFALL MATERIAL	DISCHARGE ODOR	DISCHARGE CLARITY	BANK EROSION	COMMENTS	STAIN	STAIN SEVERITY	FLOATING SOLIDS	SOLIDS SEVERITY	TIME	PHOTO1	STREAM FLOW	SOURCE FLOW	SOURCE TYPE	SEDIMENT ODOR	SEDIMENT ODOR SEVERITY	WATER ODOR	WATER ODOR SEVERITY	DOMINANT BED MATERIAL	STRUCTURE ID	DISCHARGE TYPE	WATER COLOR	WATER COLOR SEVERITY	TUBIDITY
0	1/20/09	In line	16	0	CMP	NA	Clear	Minor		No		NA		1:47:59 PM	130-3563	Low/Trickle	3/4 pipe/channel	dry and wet	NA		NA		F.Sand (0.08-1mm)		pond outfall*			
1	1/20/09	Right	4	2	HDPE	NA	NA	Minor		No		NA		2:10:47 PM	130-3565	Low/Trickle	None	wet only	NA		NA		F.Sand (0.08-1mm)		Roof drain (dry)			
2	1/20/09	Left	20	40	CMP	NA	NA	None	outfall from stormwater retention	N/A		NA		2:20:50 PM	130-3567	None	None	wet only	NA		NA		F.Sand (0.08-1mm)		Stormwater			
3	1/20/09	Left	4	75	HDPE	NA	NA	Minor		greywater*		NA		2:39:11 PM	130-3568	Low/Trickle	Other	dry and wet	NA		NA		F.Sand (0.08-1mm)		Septic (apparent)			
4	1/20/09	Right	12	100	Iron	NA	NA	Minor	pipe not flowing, flow from general direction	No		NA		3:06:35 PM	130-3569	Low/Trickle	None	dry and wet	NA		NA		F.Sand (0.08-1mm)		farm field retention*			
5	1/20/09	Right		50	GW coming from hillside*	NA	Clear	Minor		No		NA		3:14:18 PM	130-3571	Low/Trickle	Trickle	dry and wet	NA		NA		F.Sand (0.08-1mm)		groundwater drainage			
6	1/21/09	Right		0	trib	NA	Clear	None	trib from farm pond	N/A		NA		11:43:48 AM	1158	Low/Trickle	Trickle	dry and wet	NA		NA		Gravel (2-64mm)	064.05.0058	trib			
8	1/22/09	Left	6	100	PVC	NA	Clear	Minor		N/A		NA		9:47:46 AM	950	Low/Trickle	Trickle	dry and wet	NA		NA		Cobble (64-256)		pond overflow*			
9	1/22/09	Left		0	trib	NA	Clear	None		N/A		NA		10:16:07 AM	1019	Low/Trickle	Trickle	dry and wet	NA		NA		Cobble (64-256)	071.05.0127	trib			
10	1/22/09	Left		0	trib	NA	Clear	Moderate		N/A		NA		10:38:42 AM	1040	Low/Trickle	Trickle	dry and wet	NA		NA		Cobble (64-256)	071.05.0067	trib			
11	1/22/09	Left		0	trib	NA	Clear	Minor		N/A		NA		10:52:57 AM	1059	Low/Trickle	Trickle	dry and wet	NA		NA		Cobble (64-256)		trib			
12	1/22/09	Left		0	trib	NA	Clear	Minor		N/A		NA		11:08:05 AM	1110	Low/Trickle	Trickle	dry and wet	NA		NA		Cobble (64-256)	071.05.0025	trib			
13	1/22/09	Right		0	trib	NA	Clear	Moderate		N/A		NA		11:21:09 AM	1123/014	Low/Trickle	Trickle	dry and wet	NA		NA		Gravel (2-64mm)	071.05.017	trib			
14	1/22/09	Left		0	trib	NA	Clear	Minor		N/A		NA		11:34:11 AM	1130	Low/Trickle	Trickle	dry and wet	NA		NA		Gravel (2-64mm)	071.04.0118	trib			
15	1/22/09	Left		0	trib	NA	Clear	Moderate		N/A		NA		11:48:49 AM	1150	Low/Trickle	Trickle	dry and wet	NA		NA		Gravel (2-64mm)	071.04.0076	trib			
16	1/22/09	Left		0	trib	NA	Clear	Minor		N/A		NA		11:58:01 AM	1200	Low/Trickle	Trickle	dry and wet	NA		AN		Gravel (2-64mm)	071.04.0071	trib			
18	1/21/09	Left		0	trib	NA	Clear	Moderate		N/A		NA		12:05:48 PM	1213	Low/Trickle	Trickle	dry and wet	NA		NA		Cobble (64-256)	064.004.0127	trib			
20	1/21/09	Right		0	trib	NA	Clear	Minor		N/A		NA		12:37:12 PM	1241	Low/Trickle	Trickle	dry and wet	NA		AN		Cobble (64-256)	064.04..0115	trib			
21	1/21/09	Left		0	trib	NA	Clear	None	trib from field	N/A		NA		1:33:48 PM	130-3579	Low/Trickle	Trickle	dry and wet	NA		AN		Cobble (64-256)	064..01.0239	trib			
1	2/17/09	right			trib	NA	clear	none						10:45:49 AM	021709_001	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.04.0116	stormwater - open	NA		transparent
2	2/17/09	left			trib	NA	clear	minor						11:04:45 AM	021709_007	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	071.04.0050	stormwater - open	NA		transparent
3	2/17/09	right			trib	NA	clear	minor						11:28:18 AM	021709_011	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.03.0154	stormwater - open	NA		transparent
4	2/17/09	left			trib	NA	clear	minor						11:51:00 AM	021709_012	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	071.03.0133	stormwater - open	NA		transparent
5	2/17/09	right			trib	NA	clear	minor						12:00:06 PM	021709_013	medium/normal	trickle	dry and wet	NA		NA		bedrock	071.03.0119	stormwater - open	NA		transparent
6	2/17/09	right			trib	NA	clear	major						12:06:15 PM	021709_014	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.03.0098	stormwater - open	NA		transparent
7	2/17/09	left			trib	NA	clear	minor						12:17:09 PM	021709_016	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.03.0078	stormwater - open	NA		transparent
8	2/17/09	right			trib	NA	clear	minor						12:53:35 PM	021709_028	medium/normal	trickle	dry and wet	NA		NA		gravel (2-64mm)	071.03.0043	stormwater - open	NA		transparent
9	2/17/09	left			trib	NA	clear	minor	flows through cow field/evidence of cow manure					12:57:28 PM	021709_032	medium/normal	trickle	dry and wet	NA		NA		gravel (2-64mm)	071.03.0053	stormwater - open	NA	tinted	
10	2/17/09	right			trib	NA	clear	minor						1:13:09 PM	021709_037	medium/normal	low flow	dry and wet	NA		NA		clay/silt (<0.08mm)	071.03.0032	stormwater - open	NA		transparent
11	2/17/09	left			trib	NA	clear	minor						1:22:09 PM	021709_038	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.01.0124	stormwater - open	NA		transparent
12	2/17/09	right			trib	NA	cloudy	minor		sediment	slight			1:28:43 PM	021709_039	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.02.0355	stormwater - open	NA		transparent
13	2/17/09	left			clay	NA	clear	minor						1:56:13 PM	021709_055	medium/normal	trickle	dry and wet	NA		NA		bedrock		groundwater seep/spring	NA		transparent
14	2/17/09	left			trib	NA	clear	minor	flows through horse pasture	NA		NA		2:08:31 PM	021709_060	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.02.0230	stormwater - open	NA		transparent
15	2/17/09	left			trib	NA	clear	minor						2:16:38 PM	021709_061	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	071.02.0201	stormwater - open	NA		transparent
16	2/25/09	right			trib	NA	clear	moderate						10:12:37 AM	022509_001	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	071.02.0156	stormwater - open	NA		transparent
17	2/25/09	left			trib	NA	clear	moderate						10:28:19 AM	022509_002	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.02.0097	stormwater - open	NA		transparent
18	2/25/09	right			trib	NA	clear	moderate						10:43:43 AM	022509_004	medium/normal	low flow	dry and wet	NA		NA		bedrock	071.02.0054	tributary	NA		transparent
19	2/25/09	right			trib	NA	clear	moderate	flows through open pasture					11:20:19 AM	022509_012	medium/normal	trickle	dry and wet	NA		NA		bedrock		stormwater - open	NA		transparent
20	2/25/09	left						minor						11:41:12 AM	022509_015	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	064.01.0055	tributary	NA		transparent
21	2/25/09	left			trib	NA	clear	moderate	aerial crossing upstream					11:50:13 AM	022509_016	medium/normal	low flow	dry and wet	NA		NA		bedrock	058.02.0286	stormwater - open	NA		transparent
22	2/25/09	left			CMP	NA	clear	none						1:14:39 PM	022509_017	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	064.01.0162	stormwater - open	NA		transparent
23	2/25/09	left			trib	NA	clear	moderate						1:24:31 PM	022509_018	medium/normal	trickle	dry and wet	NA		NA		bedrock	064.01.0144	stormwater - open	NA		transparent
24	2/25/09	left			trib	NA	clear	moderate						1:39:49 PM	022509_019	medium/normal	low flow	dry and wet	NA		NA		bedrock	064.01.0098	stormwater - open	NA		transparent
25	2/25/09	left			trib	NA	clear	none						2:02:27 PM	022509_024	medium/normal	trickle	dry and wet	NA		NA		bedrock	064.01.0093	stormwater - open	NA		transparent
26	2/25/09	left			trib	NA	clear	major						2:08:24 PM	022509_025	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	064.01.0092	stormwater - open	NA		transparent
27	2/25/09	left			trib	NA	clear	moderate	trib flows through a cow field					2:36:28 PM	022509_032	medium/normal	trickle	dry and wet	NA		NA		bedrock	064.01.0088	stormwater - open	NA		transparent
28	3/4/09		18	10	PVC	NA	clear	none		algae	slight	NA		10:09:32 AM	030409_001	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0253	stormwater - closed	NA		transparent
29	3/4/09							minor						10:39:58 AM	030409_007	medium/normal			NA		NA		bedrock	058.02.0240	stormwater - open	NA		transparent
30	3/4/09	right	8	15	iron	NA	clear	minor	unknown 8" metal pipe with flap gate					10:46:07 AM	030409_008	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)		8" metal pipe*	NA		translucent
31	3/4/09	right			trib	NA	clear		looks like a new structure					10:58:03 AM	030409_010	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)		tributary	NA		translucent
32	3/4/09	right			trib	NA	clear	major						11:07:52 AM	030409_011	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0230	stormwater - open	NA		transparent
33	3/4/09	left			trib	NA	clear	major						11:10:27 AM	030409_012	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	058.02.0226	stormwater - open	NA		transparent
34	3/4/09	right		100	SSO*	sewage	NA	moderate		sewage	severe	NA		11:25:47 AM	030409_013	medium/normal		wet only	NA		NA		gravel (2-64mm)		sanitary	NA		transparent
35	3/4/09	right			spring*	NA	clear	moderate						11:40:49 AM	030409_015	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)		groundwater seep/spring	NA		translucent
36	3/4/09	right			trib	NA	clear	moderate						11:46:22 AM	030409_014	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0239	stormwater - open	NA		translucent
37	3/4/09	right	2	50	PVC	NA	NA	major	flow from pipe might not enter stream					12:00:48 PM	030409_016	medium/normal		dry and wet	NA		NA		cobble (64-256)		roof drain (dry)	NA		translucent
38	3/4/09	right			trib	NA	clear	major	the trib has shifted to this location					12:14:56 PM	030409_018	medium/normal	low flow	dry and wet	NA		NA		clay/silt (<0.08mm)	058.02.0228	stormwater - open	NA		translucent
39	3/4/09	right			trib	NA	clear	major						12:30:32 PM	030409_019	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	058.02.0179	stormwater - open	NA		translucent
40	3/4/09	right			trib	NA	clear	major						12:38:40 PM	030409_020	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0156	stormwater - open	NA		transparent
41	3/4/09	left			trib	NA	clear	major						12:41:04 PM	030409_021	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0150	stormwater - open	NA		transparent
42	3/4/09	left			trib	NA	clear							12:54:39 PM	030409_022	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0117	stormwater - open	NA		translucent
43	3/4/09	left			trib	NA	clear	major						1:01:15 PM	030409_023	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	058.02.0111	stormwater - open	NA		translucent
44	3/4/09	left			trib	NA	clear	major						1:09:12 PM	030409_024	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)		tributary	NA		translucent
45	3/4/09	left			trib	NA	clear	moderate						1:23:42 PM	030409_031	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0105	stormwater - open	NA		translucent
46	3/4/09	left			trib	NA	clear	major						1:29:34 PM	030409_032	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.02.0107	stormwater - open	NA		translucent
47	3/5/09	left			trib	AN	clear	major						12:32:08 PM	030509_036	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0236	stormwater - open	NA		transparent
48	3/5/09	left	40	10	CMP	NA	clear	major		algae	some	NA		12:49:30 PM	030509_039	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	058.01.0678	stormwater - closed	NA		translucent
49	3/5/09	right			trib	NA	clear	minor						12:59:41 PM	030509_044	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0375	stormwater - open	NA		translucent
50	3/5/09	right			trib	NA	clear	minor						1:05:01 PM	030509_045	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0376	tributary	NA		translucent
51	3/5/09	right			trib	NA	clear	major						1:13:58 PM	030509_046	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0379	stormwater - open	NA		translucent
52	3/5/09	right			trib	NA	clear	moderate						1:29:17 PM	030509_049	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0421	stormwater - open	NA		transparent
53	3/5/09	left			trib	NA	clear	moderate						1:34:59 PM	030509_050	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0249	stormwater - open	NA		translucent
54	3/5/09	left			trib	NA	clear	major						1:50:33 PM	030509_051	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0312	stormwater - open	NA		translucent
55	3/5/09	left			trib	NA	clear	minor						2:04:53 PM	030509_052	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0226	stormwater - open	NA		transparent
56	3/5/09	right			trib	NA	clear	minor						2:45:27 PM	030509_053	medium/normal	trickle	dry and wet	NA		NA		bedrock	058.01.0481	stormwater - open	NA		translucent
57	3/5/09	left			trib	NA	clear	moderate						2:52:54 PM	030509_056	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0196	stormwater - open	NA		transparent
58	3/5/09				trib	NA	clear	minor						2:56:59 PM	030509_059	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	058.01.0191	stormwater - open	NA		translucent
59	3/5/09	right			trib	NA	clear	minor						3:02:54 PM	030509_060	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	058.01.0188	stormwater - open	NA		transparent
60	3/5/09	left			trib	NA	clear	moderate						3:12:25 PM		medium/normal	trickle	dry and wet	NA		NA		boulder (>256mm)	058.01.0308	stormwater - open	NA		transparent
61	3/5/09	right			trib	NA	clear	major						4:11:16 PM	030509_085	medium/normal	1/4 pipe/channel	dry and wet	NA		NA		clay/silt (<0.08mm)	024.02.0153	stormwater - open	NA		translucent
62	3/9/09	right	15	7	RCP	NA	clear	minor	City of Florence structure	algae	some	NA		12:05:57 PM	030909_001	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)		stormwater - closed	NA		transparent
63	3/9/09	right	4	30	PVC	NA	NA	minor						12:16:20 PM	030909_002	medium/normal		wet only	NA		NA		gravel (2-64mm)		roof drain (dry)	NA		transparent
64	3/9/09	right	30	25	RCP	NA	clear	moderate		algae	some			12:29:52 PM	030909_004	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)		stormwater - closed	NA		transparent
65	3/9/09	left			trib	NA	clear	moderate						12:41:50 PM	030909_005	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	021.03.0122	stormwater - open	NA		transparent
66	3/9/09	left	1	4	PVC	NA	clear	minor	sump pump line	algae	some	NA		12:47:21 PM	030909_007	medium/normal	trickle	dry and wet	NA		NA		gravel (2-64mm)		sump pump line*	NA		transparent
67	3/9/09	left	1	10	PVC	NA	NA	minor	looks like a gray water liine					12:51:41 PM	030909_009	medium/normal	low flow	dry and wet	fragrant	moderate/easily detecte	NA		gravel (2-64mm)		sanitary	NA		transparent
68	3/9/09	right	15	20	RCP	NA	clear	minor		algae	slight			12:56:19 PM	030909_010	medium/normal	trickle	dry and wet	NA		NA		gravel (2-64mm)	021.03.0129	stormwater - closed	NA		transparent
69	3/9/09	right			trib	NA	clear	minor		NA		NA		1:02:24 PM	030909_012	medium/normal	trickle	dry and wet	NA		NA		gravel (2-64mm)		tributary	NA		transparent
70	3/9/09	right	15	10	RCP	NA	clear	minor		algae	severe	NA		1:11:57 PM	030909_013	medium/normal	low flow	dry and wet	NA		NA		bedrock		stormwater - closed	NA		transparent
71	3/9/09	left			trib	NA	clear	minor						1:37:58 PM	030909_014	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	021.03.0147	stormwater - open	NA		transparent
72	3/9/09	right			trib	NA	clear	minor						1:45:50 PM		medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	021.03.0148	stormwater - open	NA		transparent
73	3/10/09	right	12	30	RCP	NA	clear	minor		sediment	severe			8:50:00 AM	031009_001	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	021.03.0174	stormwater - closed	NA		transparent
74	3/10/09	right			trib	NA	clear	minor		NA		NA		8:58:06 AM	031009_002	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	021.05.0047	stormwater - open	NA		transparent
75	3/10/09	left			trib	NA	clear	minor		NA		NA		9:06:43 AM	031009_005	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.05.0044	stormwater - open	NA		transparent
76	3/10/09	left			trib	NA	clear	minor		algae	some	NA		9:13:09 AM	031009_006	medium/normal	low flow	dry and wet	NA		NA		bedrock	021.05.0040	stormwater - open	NA		transparent
77	3/10/09	left	15	50	RCP	NA	clear	minor	lots of trash	oil	some	NA		9:19:37 AM	031009_007	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	021.05.0038	stormwater - closed	NA		transparent
78	3/10/09	right			trib	NA	clear	minor		algae	some	NA		9:39:41 AM	031009_014	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	021..05.0041	stormwater - open	NA		transparent
79	3/10/09	left			trib	NA	clear	minor		NA		NA		9:43:16 AM	031009_015	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.02.0603	stormwater - open	NA		transparent
80	3/10/09	right			trib	NA	clear	major	flows through livestock field	algae	severe	NA		9:54:16 AM	031009_016	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.05..0657	stormwater - open	NA		transparent
81	3/10/09	left			trib	NA	clear	minor						10:08:25 AM	031009_018	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)	021.02.0632	stormwater - open	NA		transparent
82	3/10/09	right			trib	NA	clear	moderate						10:12:09 AM	031009_019	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)	021.05.0658	stormwater - open	NA		transparent
83	3/10/09	left	15		RCP	NA	clear	major	pipe outlet	NA		NA		10:20:16 AM	031009_020	medium/normal	trickle	dry and wet	NA		NA		boulder (>256mm)		pipe outlet*	NA		transparent
84	3/10/09	right			trib	NA	clear	major						10:24:07 AM	031009_021	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)	021.02.0641	stormwater - open	NA		translucent
85	3/10/09	left	42	20	RCP	NA	clear	minor		sediment	some			10:29:26 AM	031009_022	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)	021.02.0635	stormwater - closed	NA		transparent
86	3/10/09	left	42	10	RCP	NA	clear	moderate		sediment	some			10:35:44 AM	031009_023	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)	021.02.0634	stormwater - closed	NA		transparent
87	3/10/09	left	34	20	RCP	NA	clear	moderate	pipe outlet	algae	some	NA		12:57:15 PM	031009_024	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)		pipe outlet*	NA		transparent
88	3/10/09	left			trib	NA	clear	moderate						1:03:28 PM	031009_025	medium/normal	trickle	dry and wet	NA		NA		boulder (>256mm)	021.07.0293	stormwater - open	NA		transparent
89	3/10/09	right			trib	NA	clear	moderate						1:09:24 PM	031009_026	medium/normal	1/4 pipe/channel	dry and wet	NA		NA		cobble (64-256)	021.07.0295	stormwater - open	NA		transparent

Appendix A: Identified Point Source Summary

FID	DATE	BANK	PIPE DIA. (inches)	DISTANCE** (feet)	OUTFALL MATERIAL	DISCHARGE ODOR	DISCHARGE CLARITY	BANK EROSION	COMMENTS	STAIN	STAIN SEVERITY	FLOATING SOLIDS	SOLIDS SEVERITY	TIME	PHOTO1	STREAM FLOW	SOURCE FLOW	SOURCE TYPE	SEDIMENT ODOR	SEDIMENT ODOR SEVERITY	WATER ODOR	WATER ODOR SEVERITY	DOMINANT BED MATERIAL	STRUCTURE ID	DISCHARGE TYPE	WATER COLOR	WATER COLOR SEVERITY	TUBIDITY
90	3/10/09	left	20	2	RCP	NA	clear	moderate		algae	slight	NA		1:25:38 PM	031009_027	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	021.07.0284	stormwater - closed	NA		transparent
91	3/10/09	left			trib	NA	clear	moderate						1:35:53 PM	031009_028	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.07.0298	stormwater - open	NA		transparent
92	3/10/09	right			trib	NA	clear	major						1:41:07 PM	031009_029	medium/normal	1/4 pipe/channel	dry and wet	NA		NA		cobble (64-256)	021.07.0194	stormwater - open	NA		transparent
93	3/10/09	right			trib	NA	clear	major		sediment	some	NA		1:53:31 PM	031009_030	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)	021.07.0207	stormwater - open	NA		transparent
94	3/10/09	left			trib	NA	clear	minor		sediment	slight	NA		2:03:13 PM	031009_031	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.07.0197	stormwater - open	NA		transparent
95	3/10/09	left			trib	NA	clear	major		NA		NA		2:12:34 PM	031009_032	medium/normal	trickle	dry and wet	NA		NA		boulder (>256mm)	021.07.0193	stormwater - open	NA		transparent
96	3/10/09	left			trib	NA	clear	major		NA		NA		2:24:05 PM	031009_033	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.11.0466	stormwater - open	NA		transparent
97	3/13/09	left			trib	NA	clear	major		NA		NA		1:03:58 PM	031309_002	medium/normal	low flow	dry and wet	NA		NA		bedrock	021.11.0468	stormwater - open	NA		transparent
98	3/13/09	right			trib	NA	clear	major		sediment	some	NA		1:18:17 PM	031309_003	medium/normal	low flow	dry and wet	NA		NA		bedrock	021.09.0229	stormwater - open	NA		transparent
99	3/13/09	right			trib	NA	clear	moderate		sediment	slight	NA		1:27:07 PM	031309_004	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.09.0190	stormwater - open	NA		transparent
100	3/13/09	left			trib	NA	clear	major	lake is lower than normal					1:41:08 PM	031309_005	low/trickle	trickle	dry and wet	NA		NA		fine sand (0.08-1mm)	021.09.0305	stormwater - open	NA		transparent
101	3/13/09	left			trib	NA	clear	major	lake is lowe than normal	sediment	severe	NA		1:47:13 PM	031309_008	low/trickle	low flow	dry and wet	NA		NA		fine sand (0.08-1mm)	021.09.0234	stormwater - open	NA		transparent
102	3/13/09	left			trib	NA	clear	major	lake is lower than normal					1:55:35 PM	031309_010	low/trickle	low flow	dry and wet	NA		NA		fine sand (0.08-1mm)	021.09.0304	stormwater - open	NA		transparent
103	3/13/09	left			trib	NA	clear	major	lake is lower than normal					2:11:11 PM	031309_020	low/trickle	trickle	dry and wet	NA		NA		fine sand (0.08-1mm)	021.10.0360	stormwater - open	NA		transparent
104	3/13/09	right			trib	NA	clear	major	lake is loweer thann normal					2:22:49 PM	031309_021	low/trickle	trickle	dry and wet	NA		NA		fine sand (0.08-1mm)	021.10.0439	stormwater - open	NA		transparent
105	3/13/09	right			trib	NA	clear	major	lake is lower than normal	sediment	severe	NA		2:27:12 PM	031309_022	low/trickle	trickle	dry and wet	NA		NA		fine sand (0.08-1mm)	021.10.0440	stormwater - open	NA		translucent
106	3/13/09	right			trib	NA	clear	major	this actual point is in the middle of the lake	sediment	severe	NA		2:34:12 PM	031309_023	low/trickle	low flow	dry and wet	NA		NA		fine sand (0.08-1mm)	021.08.0542	stormwater - open	NA		translucent
107	3/17/09	right			trib	NA	clear	minor		algae	severe	foam	slight	12:13:32 PM	031709_001	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	021.01.0742	stormwater - open	NA		transparent
108	3/17/09	right	15	20	trib	NA	clear	minor		algae	severe	NA		12:23:09 PM	031709_002	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	021.01.0727	stormwater - closed	NA		transparent
109	3/17/09	right	15		PVC	NA	clear	minor		mineral	severe	NA		12:29:38 PM	031709_003	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	021.01.0311	stormwater - closed	NA		transparent
110	3/17/09	right			trib	NA	clear	none		algae	slight	NA		12:36:39 PM	031709_005	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)	021.01.0725	stormwater - open	NA		transparent
111	3/17/09	left	4		PVC	NA	clear	moderate	pvc pipe	algae	slight	NA		12:45:05 PM		medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)		pvc pipe*	NA		transparent
112	3/17/09	right			trib	NA	clear	moderate		algae	slight	surface scum	slight	12:54:01 PM	031709_006	medium/normal	trickle	dry and wet	NA		NA		gravel (2-64mm)	021.01.0649	stormwater - open	NA		transparent
113	3/17/09	left			trib	NA	clear	moderate		NA		NA		12:57:41 PM	031709_007	medium/normal	trickle	dry and wet	NA		NA		gravel (2-64mm)	021.01.0510	stormwater - open	NA		transparent
114	3/17/09	right			trib	NA	clear	moderate		algae	slight	NA		1:02:44 PM	031709_008	medium/normal	trickle	dry and wet	NA		NA		boulder (>256mm)	021.01.0645	stormwater - open	NA		transparent
115	3/17/09	left			trib	sewage	clear	minor		algae	some	NA		1:55:58 PM	031709_009	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.10.0340	stormwater - open	NA		translucent
116	3/17/09	left			trib	NA	clear	minor		algae	some	surface scum	some	2:03:39 PM	031709_010	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.10.337	stormwater - open	NA		transparent
117	3/17/09	left			trib	sewage	clear	minor		algae	slight	NA		2:20:13 PM	031709_012	medium/normal	low flow	dry and wet	NA		NA		gravel (2-64mm)	021.10.0464	stormwater - open	NA		transparent
118	3/17/09	right			trib	NA	clear	minor		sediment	slight	NA		2:27:44 PM	031709_013	medium/normal	low flow	dry and wet	NA		NA		fine sand (0.08-1mm)		groundwater seep/spring	NA		transparent
119	3/17/09	left	4	10	PVC	sewage	NA	minor	sanitary pipe					2:42:01 PM	031709_014	medium/normal	trickle	dry and wet	NA		NA		cobble (64-256)		sanitary	NA		transparent
120	3/17/09	right			trib	NA	clear	minor		NA		NA		2:47:49 PM	031709_016	medium/normal	low flow	dry and wet	NA		NA		fine sand (0.08-1mm)	023.01.0084	stormwater - open	NA		transparent
121	3/18/09	right	15		CMP	NA	clear	none	strong oil odor in the area	NA		NA		9:02:19 AM	031809_001	medium/normal	low flow	dry and wet	petroleum	strong/notice from away	petroleum	strong/notice from away	clay/silt (<0.08mm)	021.08.0372	stormwater - closed	NA		transparent
122	3/18/09	left			trib	NA	clear	minor						9:15:40 AM	031809_004	medium/normal	low flow	dry and wet	petroleum	moderate/easily detecte	petroleum	moderate/easily detecte	clay/silt (<0.08mm)	021.08.0315	stormwater - open	NA		transparent
123	3/18/09	right	15		CMP	AN	clear	minor		NA		foam	some	9:30:58 AM	031809_005	medium/normal	trickle	dry and wet	NA		NA		clay/silt (<0.08mm)	021.08.0197	stormwater - closed	NA		transparent
124	3/18/09	left			trib	NA		moderate	Kenton County golf course is washing their lawn mowers off upstream and causing grass clippings to fill the creek	sediment	some	grass clippings*		9:41:12 AM	031809_008	medium/normal	1/4/pipe/channel	dry and wet	NA		NA		clay/silt (<0.08mm)	021.08.0312	stormwater - open	NA		opaque
125	3/18/09	left			trib	NA	clear	minor		NA		NA		9:51:36 AM	031809_012	medium/normal	trickle	dry and wet	NA		NA		clay/silt (<0.08mm)	021.08.0311	stormwater - open	NA		transparent
126	3/18/09	left			trib	NA	clear	none		NA		NA		10:27:26 AM	031809_013	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.02.0289	stormwater - open	NA		transparent
127	3/18/09	right			TP overflow*	NA	NA	none	looks like private treatment plant overflows occasionally	toilet paper*	slight	sewage		10:31:20 AM	031809_014	medium/normal		dry and wet	NA		NA		cobble (64-256)		septic (apparent)	NA		transparent
128	3/18/09	left			trib	NA	clear	minor		algae	slight	NA		10:36:59 AM	031809_015	medium/normal	low flow	dry and wet	NA		NA		bedrock	021.08.0286	stormwater - open	NA		transparent
129	3/18/09	left			trib	NA	clear	minor		algae	slight	NA		10:58:51 AM	031809_018	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.08.0354	stormwater - open	NA		transparent
130	3/18/09	left			groundwater spring*	NA	clear	minor		algae	slight	NA		11:02:45 AM	031809_019	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)		groundwater seep/spring	NA		transparent
131	3/18/09	left			trib	NA	cloudy	major		sediment	slight	NA		11:13:45 AM	031809_020	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.08.0350	stormwater - open	NA		transparent
132	3/18/09	left			trib	NA	clear	moderate		algae	some	surface scum	severe	1:15:18 PM	031809_021	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.08.0348	stormwater - open	NA	slight	transparent
133	3/18/09	right			natural spring*	NA	clear	moderate		NA		NA		1:20:36 PM	031809_022	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)		groundwater seep/spring	NA		transparent
134	3/18/09	left			natural spring*	NA	clear	moderate		NA		NA		1:26:24 PM	031809_023	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)		groundwater seep/spring	NA		transparent
135	3/18/09	left	4		PVC	NA	clear	moderate	drainage pipe	algae	some	NA		1:47:54 PM	031809_024	medium/normal	low flow	dry and wet	NA		NA		boulder (>256mm)		drainage pipe*	NA		transparent
136	3/18/09	left			trib	NA	clear	moderate		algae	slight	NA		2:00:41 PM	031809_025	medium/normal	low flow	dry and wet	NA		NA		cobble (64-256)	021.08.0335	stormwater - open	NA		transparent
137	3/18/09	right			trib	NA	clear	minor		mineral	slight	surface scum	some	2:08:56 PM	031809_026	medium/normal	low flow	dry and wet	NA		NA		fine sand (0.08-1mm)	021.08.0541	stormwater - open	NA		transparent

= pipe discharge
= tributary entering stream
= groundwater entering stream

* Entered onto field form under "other"
** Distance from outfall to edge of stream

ATTACHMENT B

Identified Non-Point Source Summary

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Appendix B: Identified Non-Point Source Summary

LOCATION	DATE	BANK	DISTANCE (feet)	DISCHARGE ODOR	DISCHARGE CLARITY	EROSION	COMMENTS	TIME	PHOTO1	PHOTO2	STREAM FLOW	SOURCE TYPE	EVIDENCE	TYPE OF LIVESTOCK	SEDIMENT ODOR	TURBIDITY	WATER ODOR	DOMINANT BED MATERIAL
1	2/17/09	In line	0	None	Clear	None		1:09:24 PM	021709_034	1311	Medium/Normal	Livestock with access to stream	manure	Cows	NA	Transparent	NA	Bedrock
2	2/17/09	Left Descending	10	Organic	NA	Minor		2:04:19 PM	021709_056	1409	Medium/Normal	Livestock fenced	animals	Horses	NA	Transparent	NA	Bedrock
3	2/25/09	In line	0	None	NA	Major	one long pasture	11:12:17 AM	022509_005		Medium/Normal	Livestock with access to stream	manure	Cows	NA	Transparent	NA	Bedrock
4	2/25/09	Left Descending	15	None	NA	Minor		11:38:22 AM			Medium/Normal	Livestock-fenced	manure	Cows	NA	Transparent	NA	Bedrock
5	2/25/09	In line	0	None	NA	Major		2:32:06 PM	022509_027	022509_0031	Medium/Normal	Livestock with access to stream	manure	Cows	NA	Transparent	NA	Bedrock
6	3/10/09	Right Descending	20	None	NA	Minor		10:02:47 AM	031009_017		Medium/Normal	Livestock-fenced	manure	Cows	NA	Transparent	NA	Cobble (64-256)
7	1/21/09	Right Descending	0	None	NA	Minor		12:31:51 PM	1230		None	Livestock	---	---	NA	Transparent	NA	Cobble (64-256)
8	1/21/09	Right Descending	15	poop	NA	None		12:50:29 PM	1252	3573/3574/3575	Low/Trickle	Livestock	---	---	NA	Transparent	NA	Cobble (64-256)
12	1/21/09	Left Descending	10	None	Clear	Minor	cow field	1:05:02 PM	130-3575		Low/Trickle	Livestock	---	---	NA	Transparent	NA	Cobble (64-256)
13	1/22/09	In line	0	None	NA	Minor		10:08:05 AM	1006	1007	Low/Trickle	Livestock	---	---	NA	Transparent	NA	Cobble (64-256)

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ATTACHMENT C

Point and Non-Point Source Location Photographs

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Sewage Location #67

Sewage Location #34

Sewage Location #3

Livestock Area #1

Livestock Area #2

Livestock Area #3

Livestock Area #4

Livestock Area #4

Livestock Area #4

Livestock Area #5

Livestock Area #6

Livestock Area #7

SOURCE IDENTIFICATION PROGRAM FIELD SURVEY STANDARD OPERATING PROCEDURE

Prepared for: **Sanitation District No. 1 of Northern Kentucky**

March 9, 2009

LimnoTech
Water | Environment | Scientists | Engineers

Ann Arbor, Michigan
www.limno.com

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LIST OF FIGURES

Figure 1. Overview of Field Collection Procedures. 1

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1. INTRODUCTION

This Standard Operating Procedure (SOP) is intended for use during field data collection activities conducted for the Source Identification Program (SIP). The procedure outlined herein is for use with a Trimble GeoXT handheld running ArcPad version 7 or higher. Please refer to the ESRI ArcPad User Guide, 2007 for more detailed instruction. The user's guide can be found at: http://support.esri.com/index.cfm?fa=knowledgebase.documentation.viewDoc&PID=26&MetaID=1360

Figure 1 illustrates an overview of the field data collection procedure in a flow chart. Each of these steps is described in more detail in subsequent sections of this SOP.

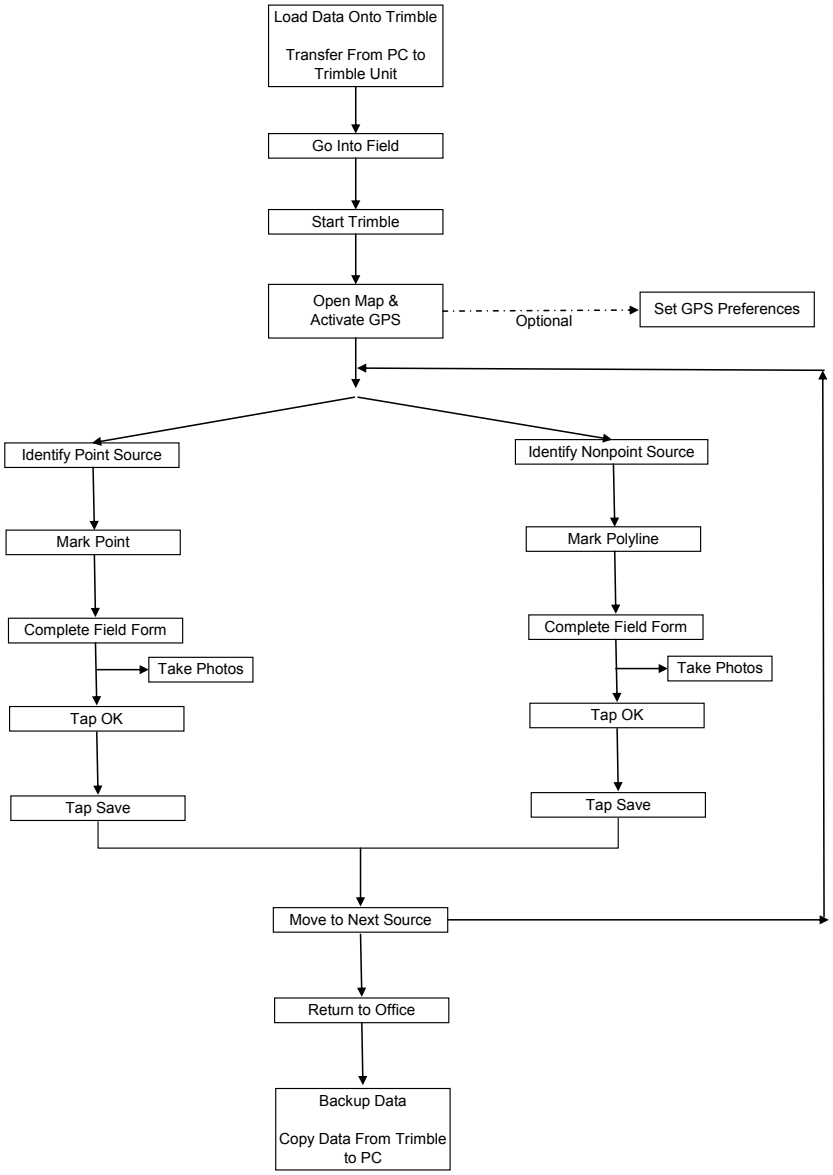

Figure 1. Overview of Field Collection Procedures.

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2. SETTING UP AND USING THE TRIMBLE

2.1 LOADING DATA

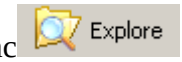
Data layers for use on the Trimble can be transferred from a PC.

1 To establish a connection between the Trimble and your PC, download and install Microsoft ActiveSync on the PC
http://www.microsoft.com/windowsmobile/en-us/help/synchronize/activesync45.mspx

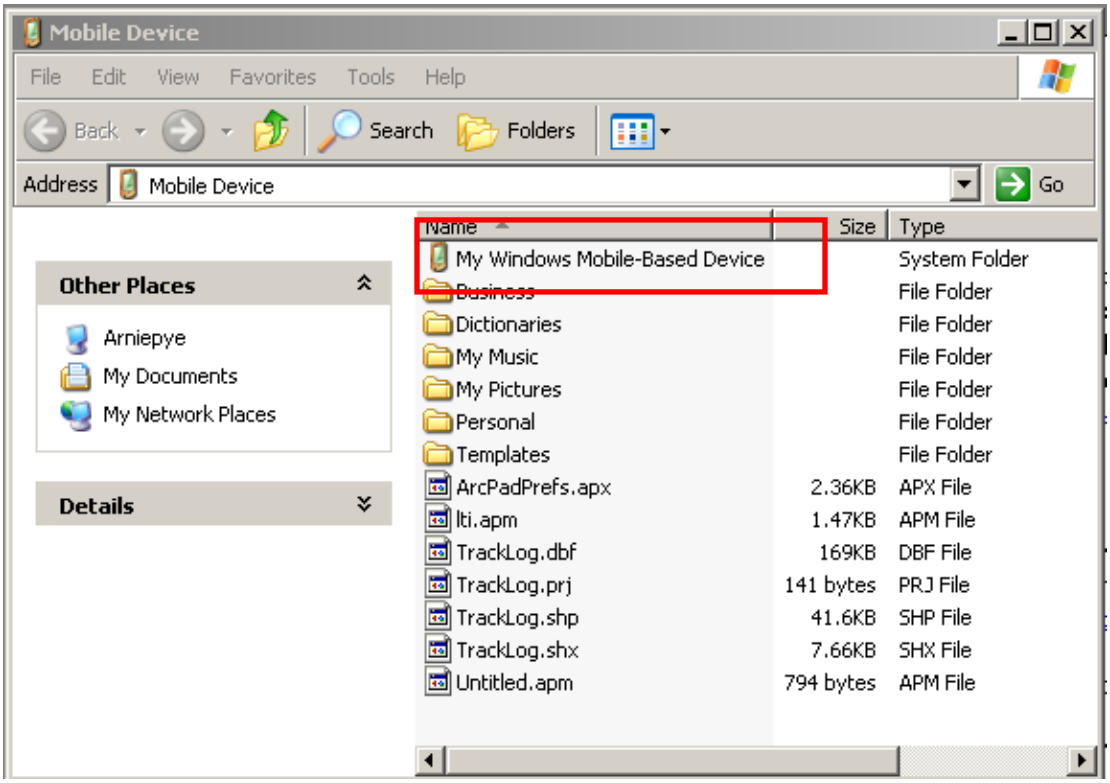
2 Start ActiveSync

3 Place Trimble in charging cradle and connect cradle to PC via a USB cable. If ActiveSync opens a connection wizard hit cancel.

4 If asked, establish a "guest partnership" not a "synchronization partnership"

5 Once connected click the explore button in ActiveSync 

6 This will open the Mobile Device window:



7 Open My Windows Mobile-Based Device → then open My Documents

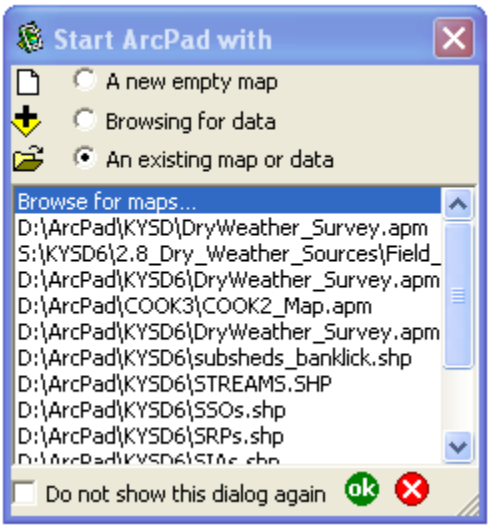
Note: Older model Trimbles or those running an older operating system may display folder information differently. Once you click the 'Explore' button you may be taken directly into the Mobile Device window. Open the Disk → then My Documents folder.

8 Transfer the project folder 'KYSD'(containing all the project files) from your PC onto the Trimble and into the My Documents (or Disk) folder. You can do this with a copy & paste or just drag the folder from one location to another. Press OK when prompted about file conversion. When file transfer has completed simply unplug the USB to disconnect. You only need to transfer the files onto the Trimble once, during initial setup preceding field activities.

2.2 ARCPAD START-UP

Press the power button on the Trimble. Start ArcPad. Arcpad is usually found as an icon on the screen or under the start menu, depending on setup. These are activated similarly to a Windows based PC.

1 ArcPad will prompt for a map location. (If the map has been previously opened you can select it from the top of the list).



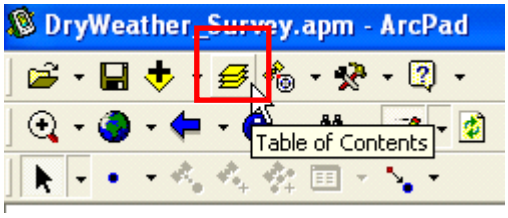
2 Choose 'An existing map or data', select 'Browse for maps…' and hit OK

3 Navigate to the KYSD folder and open the DryWeather_Survey.apm. (Once you have opened this map for the first time, ArcPad will display it at the top of list as shown above.)

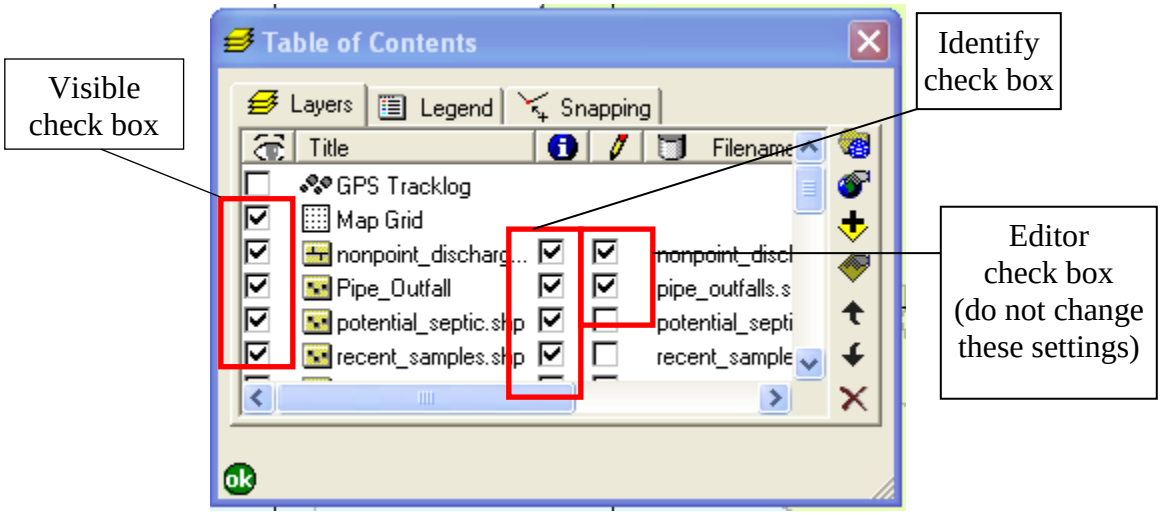
2.3 MANAGING LAYERS IN ARCPAD

The data displayed in ArcPad is kept in Layers. Layers are typically organized by data type. You may find it necessary to turn on or off layers. Layers that are turned off are not displayed on the map but are still contained within the map file. Since some layers contain large amounts of data, unchecking the viewable box can free up system resources.

1. Tap the layers button, called 'Table of Contents'

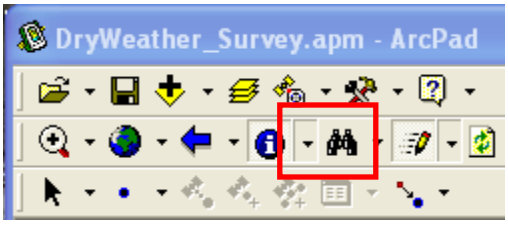


2. The Table of Contents will be displayed. Each title listed is a layer available in your map. The layer is turned on if the visible check box is checked.

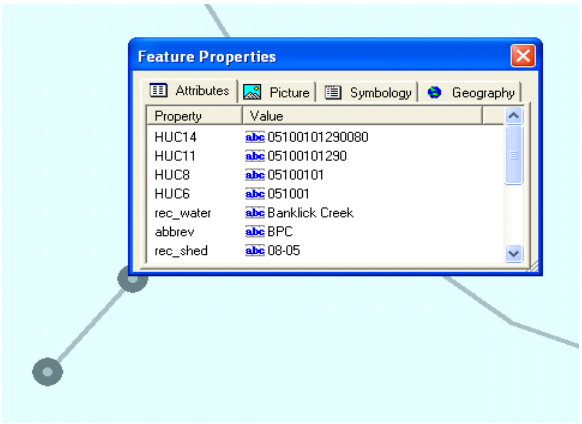


3. Other important features on the Table of Contents are the identify check box and the editor check box. The identify check box allows you to view the information contained in a layer, all layers should be checked. The editor check box settings should not be changed. The editable layers should be 'nonpoint_discharge' and 'Pipe_Outfall'.

4. The identify tool is used when information contained in a layer needs to be viewed. Tap the Identify tool (shown below).



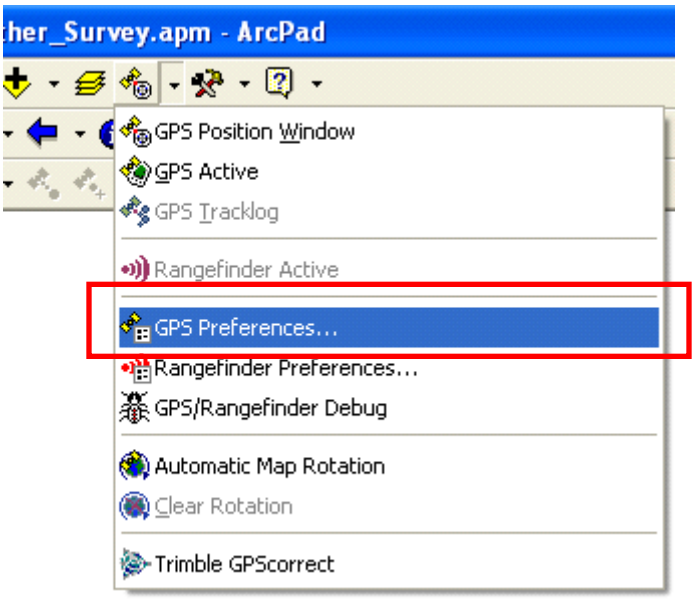
5 Tap the feature that you would like to retrieve information for. The feature properties will be displayed on the screen



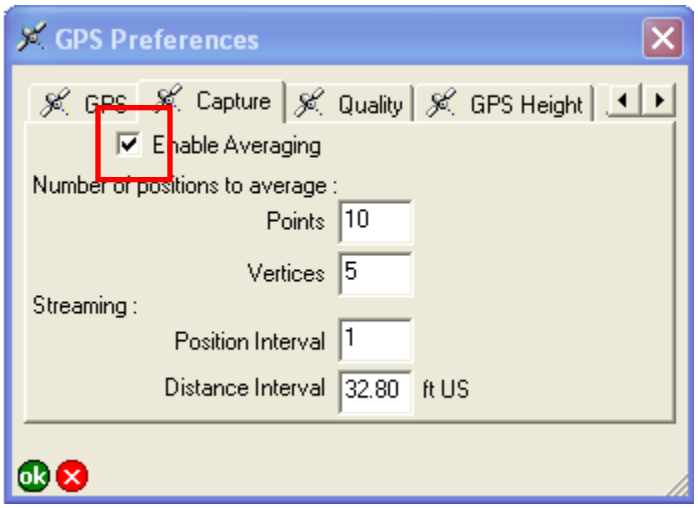
2.4 GPS PREFERENCES

To achieve better accuracy when marking locations the following changes can be made.

1 Open 'GPS Preferences'

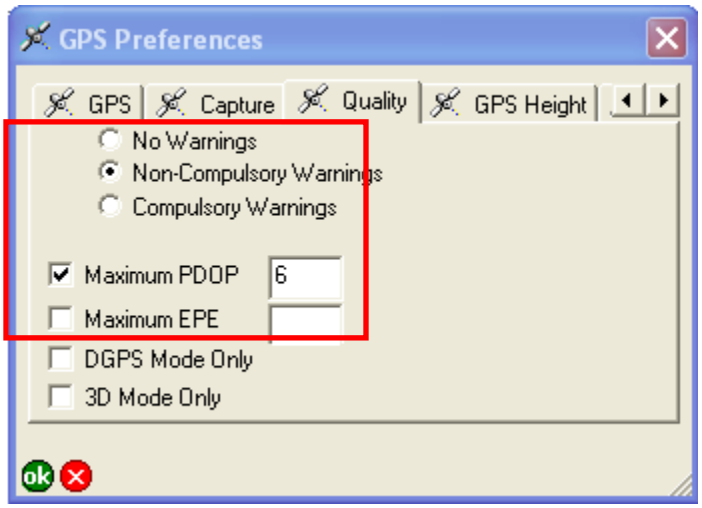


2 Click on the 'Capture' tab



3 Check the 'Enable Averaging' box. The default numbers should be shown above.

4 Click on the 'Quality' tab



5 Select 'Non-Compulsory Warnings', and check the Maximum PDOP box. Enter 6 in the box.

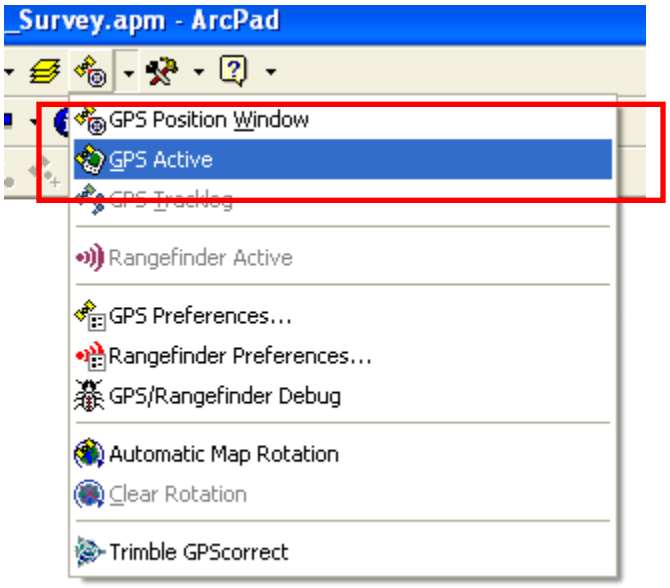
6 Hit OK to save the settings.

2.5 ACTIVATE GPS

The GPS can be turned on by selecting the GPS Position Button. When first activating the GPS place the Trimble unit in an area without overhead obstructions. Allow the unit some time to lock-on to satellites (~10-15min). Occasionally you will

find that satellite geometry is poor and acquiring a position fix can be time consuming (usually geometry will improve after about a half hour, grab some coffee). See the "GPScorrect" description in the next section for options to facilitate satellite locking.

GPS on/off can also be selected with the pull-down menu:

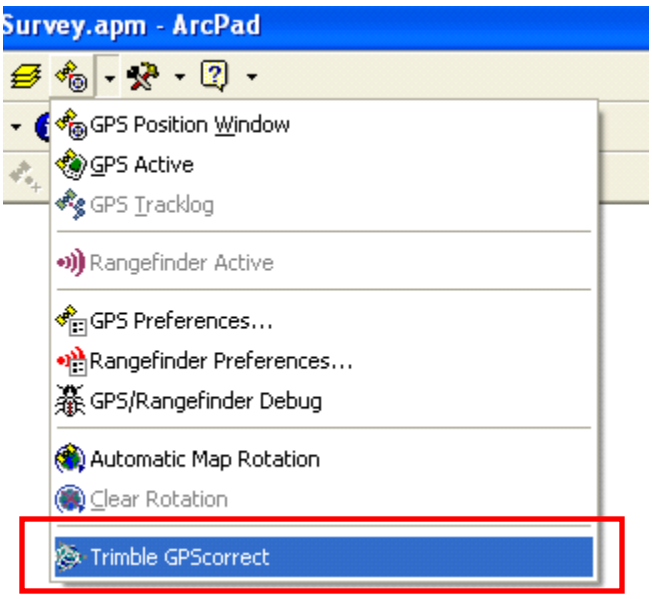


A GPS position window will open and display general information once a satellite connection has been made. The window can be closed and opened by tapping the GPS position button.

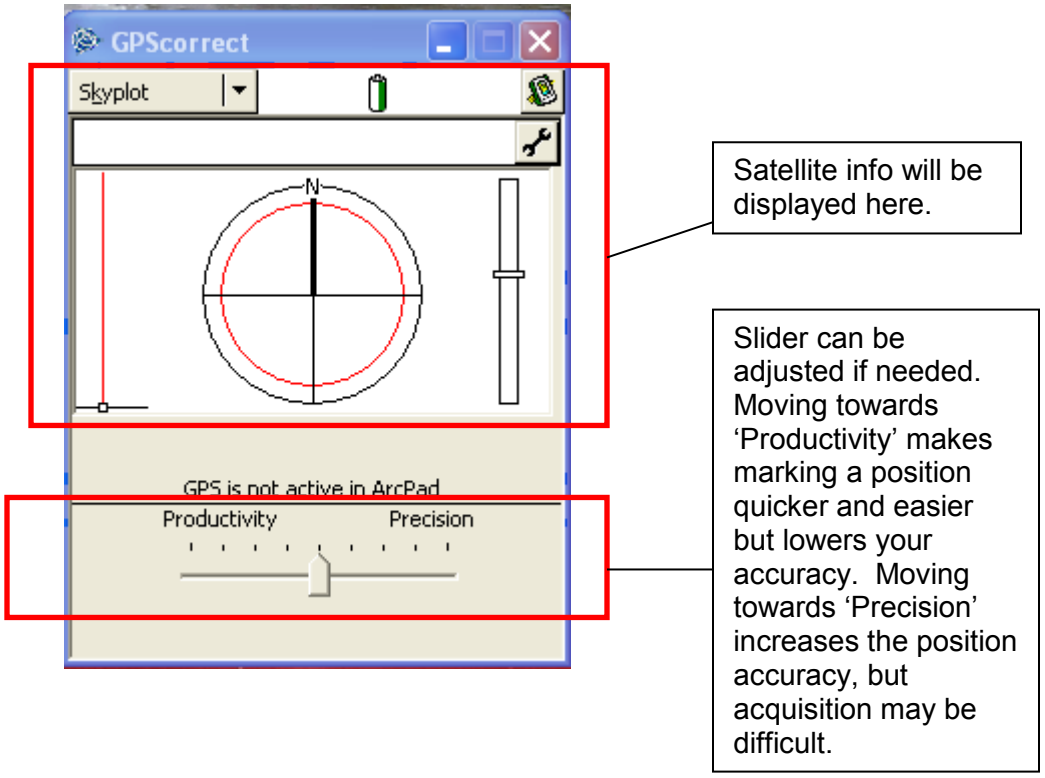
Remember - the GPS can be turned off (disabled) when not in use for long periods of time to conserve battery power.

2.6 GPSCORRECT

Shows important satellite geometry information. If you are having difficulty obtaining a position fix, open 'GPScorrect'.

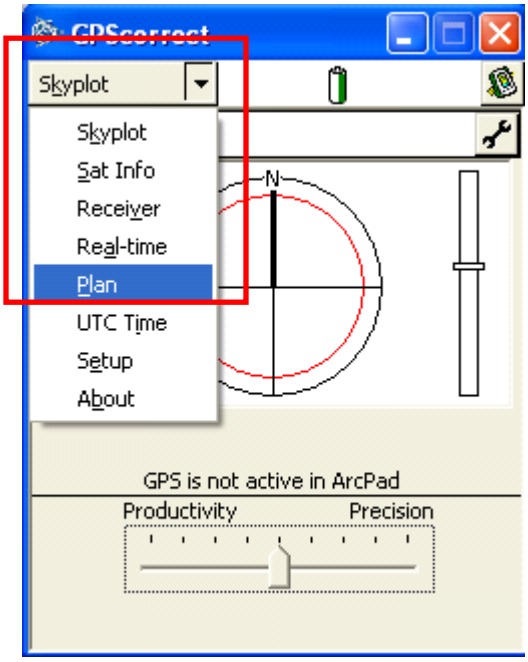


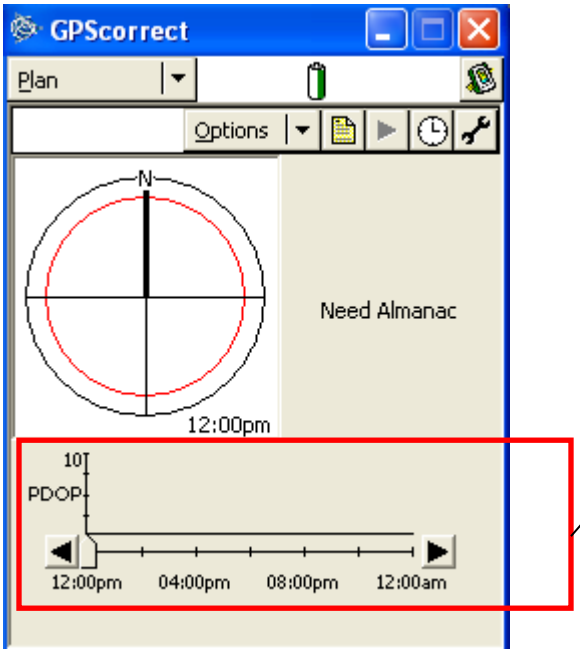
'Skyplot' will open and show satellite connections, geometry, and signal strength.



You may find it necessary to move the slider closer to 'Productivity' when a position is hard to mark. Positions can become hard to mark if there are overhead obstructions, terrain feature interference, or poor satellite geometry. You may also try moving the Trimble antenna around to face different portions of the sky.

Use the drop down menu to switch to 'Plan' view. This displays a plot of satellite geometry throughout the day by time. This will determine when satellite geometry is poor which means that position averaging will be difficult. Yellow and Red bars indicate poor geometry.



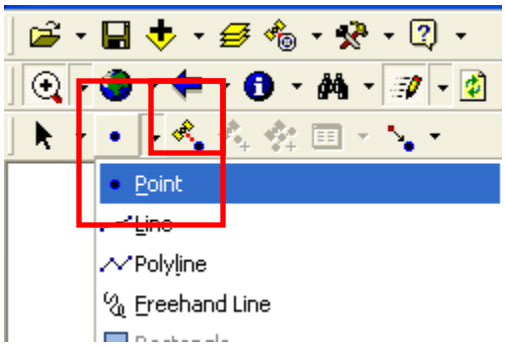


Yellow & red bars indicate poor satellite geometry. Avoid marking points during these time slots. Use the arrows to scroll through the day.

2.7 MARKING A POINT USING GPS

When the GPS is activated the point layer will become editable.

1) Select Point



2) Tap the GPS Point button to mark the location. Wait for the GPS to capture and average the GPS position.

3) Complete the Field form (see Field Form Section).

Note: You have the option to not store information on the discharge/outfall. If you do not want to save this point tap the cancel button

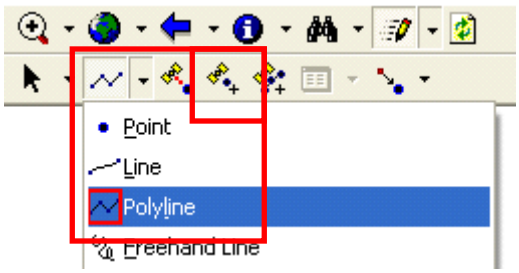
4) Tap OK

5) Tap Save . The point should now be located on the map. If the point is selected (indicated by a dashed outline), the attributes can be viewed and edited by tapping the properties tab

2.8 MARKING A POLYLINE USING GPS

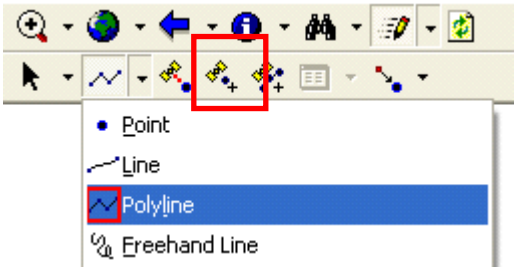
When the GPS is activated the polyline layer will become editable.

1) Select Polyline



2) You will create a polyline based on a series of individually captured averaged vertices.

3) At the start of the line, tap the GPS vertex button to mark the first location. Wait for the GPS to capture and average the vertex position.



4) Move to the next vertex location, again tap the vertex button .

5) Continue marking vertices until the polyline is completed. Tap the proceed button (Located at bottom of screen)

6) Complete the Field form (see Field Form Section).

7) If you do not want to save this line tap the cancel button

8) Tap OK

9) Tap Save . The polyline should now be located on the map. If the point is selected (indicated by a dashed outline), the attributes can be viewed and edited by tapping the properties tab

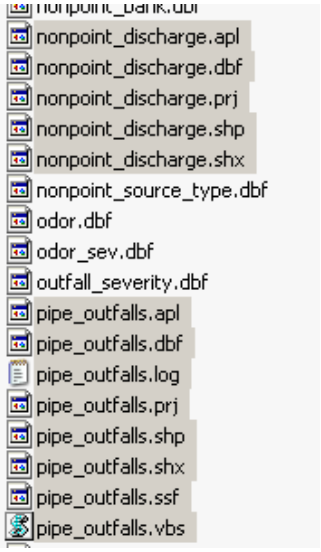
2.9 DATA BACKUP

At the end of every day, backup your data to a PC.

1. See 2.1 and follow the instructions for connecting the Trimble to a PC.

2. Using ActiveSync, connect to the Trimble and navigate to the location where the KYSD data folder is stored.

3. Organize the KYSD folder by name, and copy all of the files named ‘nonpoint_discharge’ (there are 5 files) and ‘pipe_outfalls’ (there are 8 files)from the Trimble onto your PC (see below). Alternatively, complete backup of the KYSD folder is fine.



4. Organize your backup data by date.

2.10 TRIMBLE STORAGE

When storing the Trimble deactivate the GPS and close ArcPad. Place the Trimble into suspend mode by pressing the power button once. Always store the Trimble in its charging cradle at night to charge the battery completely. Be cautious when pressing the power button. Holding down the power button for more than 3 seconds will reset the unit and any unsaved data will be lost.

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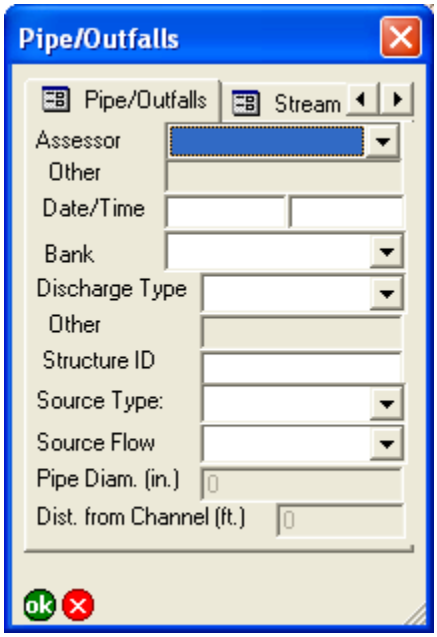
3. FIELD FORMS

3.1 COMPLETING PIPE/OUTFALL FIELD FORM

After marking a new point (see Section II.6), the pipe/outfall field form will be launched to document information about the source. The form has multiple tabs that need to be completed. To save time and promote consistency between surveys and crews, many of the boxes have pick lists to select values. This section steps through the content on each tab.

3.1.1 Pipe/Outfalls Tab



Assessor – Choose name from pick list or select "Other" and enter the new name in the *Other* box below the *Assessor* box.

Date/Time – Tap boxes to enter. The current date/time will automatically enter when each box is tapped.

Bank – Define outfall location facing downstream (or "descending") from pick list. The pick list includes the following choices:

- Left descending bank
- Right descending bank
- In line

Note that 'in line' means the source is crossing the waterbody completely.

Discharge Type – Choose type from pick list, which includes the following choices:

- None
- GW Seep/Spring
- Roof Drain (dry)
- Sanitary
- Septic (apparent)
- Storm water closed
- Storm water open
- Tributary
- Other (specify)

Note that both "Storm water open" and "Tributary" both refer to open channel sources, such as ditches or intermittent streams. Use "Storm water open" if the open channel has an SD1 structure ID assigned to it. Otherwise, assign the open channel to "Tributary".

Structure ID – Enter the Structure ID if an ID can be associated with this location. Note that information on the structure ID should be stored on the Trimble in the 'storm_conduits' and/or 'storm_structures' layers.

Source Type – Select a value from the pick list (choices are 'Wet only' and 'Dry and Wet') that reflect assessment of whether the source is active only during wet conditions or during both dry and wet periods.

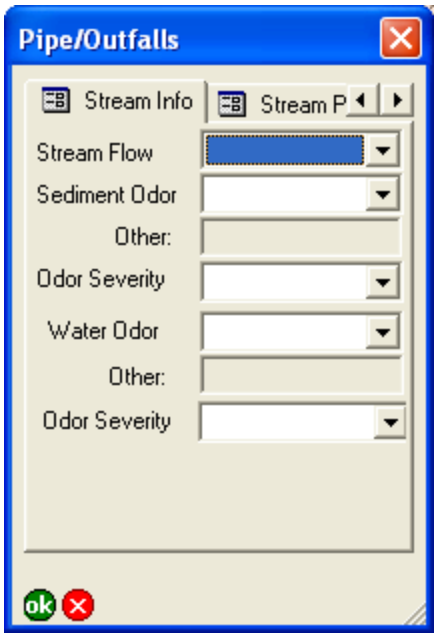
Source Flow – Choose a qualitative description of the flow level from pick list, which includes the following choices:

- Trickle
- Low Flow
- 1/4 Pipe/Channel
- 1/2 Pipe/Channel
- 3/4 Pipe/Channel
- Full Pipe/Channel

Enter Pipe Diameter (inches) and the Distance from the edge of the Channel (feet) if applicable.

3.1.2 Stream Info Tab

This is the first of two tabs to tally observations made about the receiving stream channel in the vicinity of the pipe/outfall discharge.



Stream Flow – Choose a qualitative description of the flow level from pick list, which includes the following choices:

- Low/Trickle
- Medium/Normal
- High/Strong

Sediment Odor – Choose a description of the odor from any exposed sediment in the channel, if detectible, from the pick list, which includes the following choices:

- N/A
- Sewage
- Rotten Eggs
- Rancid/Sour
- Petroleum

- Fragrant
- Other (specify)

Note that this field should still be filled out even if no odor is detected by choosing "N/A" from the pick list.

Odor Severity – Choose a description of the odor intensity from the pick list, which includes the following choices:

- Faint/Barely Detectible
- Moderate/Easily Detectible
- Strong/Notice From Afar

Water Odor – Choose a description of the odor of the water, if detected, from the pick list, which includes the following choices:

- N/A
- Sewage
- Rotten Eggs
- Rancid/Sour
- Petroleum
- Fragrant
- Other (specify)

Note that this field should still be filled out even if no odor is detected by choosing "N/A" from the pick list.

Odor Severity – Choose a description of the odor intensity from the pick list, which includes the following choices:

- Faint/Barely Detectible
- Moderate/Easily Detectible
- Strong/Notice From Afar

3.1.3 Stream Pg2 Tab

This tab is the second page that applies to observations made about the receiving stream channel in the vicinity of the pipe/outfall discharge.

Water Color – Select a color that describes the receiving stream channel color. The following options are available:

- N/A
- Black
- Blue
- Brown
- Gray
- Green
- Orange
- Red
- White
- Yellow
- Other (specify)

Color Severity – Choose a descriptor for the color intensity, the following choices are available:

- Slightly Tinted
- Moderately Tinted
- Intense

Turbidity – Choose a description for the degree of turbidity. The following choices are available:

- Transparent
- Translucent
- Opaque

Erosion – The purpose of this field is to register amount of erosion immediately downstream of the source. See examples below. The following choices are available:

- None
- Minor
- Moderate
- Major

In general, the level of erosion can be estimated by evaluating a few parameters:

- Bank Steepness & Height: the steeper & higher the bank, the higher the erosion levels could be
- Percent Surface Area Protected: The more bank area that is covered by plants and natural armoring (e.g. debris) the less likely it is to be eroded
- Rooting Depth: Trees and thick plant growth (deep & dense roots) will impart greater stability and less erosion

Erosion Examples

Major: Steep banks (usually >45 degrees), no plant growth and low root density

Moderate: Less steep (~30 degrees), some stabilizing vegetation

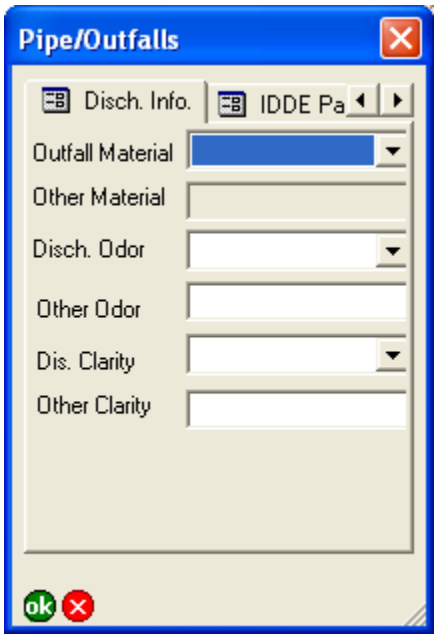
Minor: Low banks (less than 30 degrees), lots of vegetation

Dom. Bed Mat. – Select a description of the dominant bed material found in the stream channel. The following options are available:

- Clay/Silt (<0.08mm)
- F.Sand (0.08-1mm)
- C.Sand (1-2mm)
- Gravel (2-64mm)
- Cobble (64-256mm)
- Boulder (>256mm)
- Bedrock

3.1.4 Discharge Info Tab

This tab is for observations of the discharge conveyance and water.



Outfall Material – Enter the type of material the discharge pipe is constructed from. Options are:

- PVC (polyvinyl chloride)
- RCP (reinforced concrete pipe)
- CMP (corrugated metal pipe)
- HDPE (high density polyethylene)
- Iron
- Clay
- Tributary
- Other (specify)

Discharge Odor – If an odor from the discharge water is detected choose a description from the pick list, which includes the following choices:

- None
- Sewage

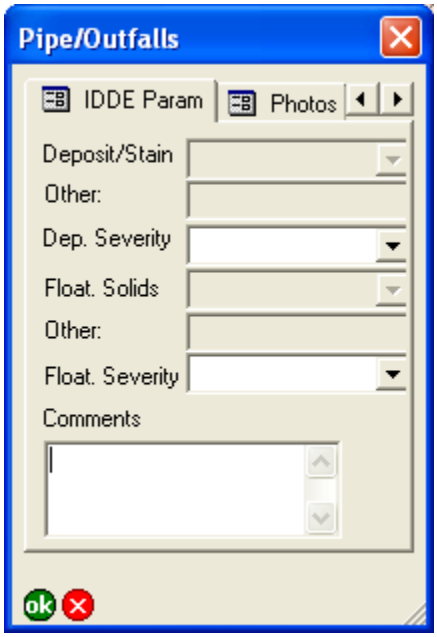
- Sulfurous
- Organic
- NA
- Other (specify)

Discharge Clarity – Choose a description of discharge clarity, the following choices are available:

- Clear
- Opaque
- Cloudy
- NA
- Other (specify)

3.1.5 IDDE Param Tab

This tab corresponds to IDDE pipe and water discharge descriptions.



Deposit/Stain – If a deposit or stain is noted choose a description from the following choices:

- N/A

- Algae
- Grease
- Mineral
- Oil
- Sediment
- Other (specify)

Deposit Severity – Choose a description that describes the severity of the deposit /stain, the following choices are available:

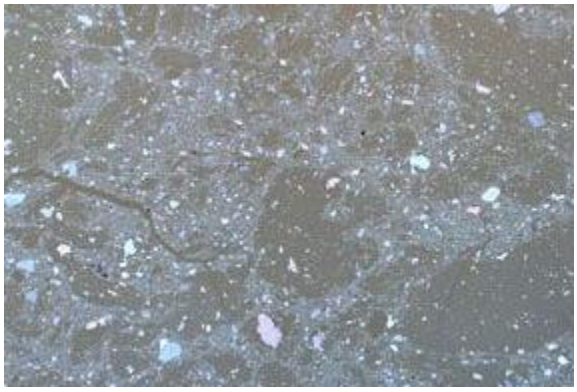
- Slight
- Some
- Severe

Floating Solids – If floating solids can be observed choose a description of any floating solids/materials. Some examples of a bacterial sheen are shown below. The following choices are available:

- N/A
- Sewage
- Petroleum
- Surface Scum
- Foam
- Suds
- Natural Sheen
- Other (specify)

A natural sheen usually consists of algae or bacteria.

- Surface sheen of bacteria. Bacteria colonies have angular edges and usually have a rainbow appearance but do not coalesce like oil when broken apart.



- Bacterial film. This type of bacteria colonies occur near ground water/surface water interfaces. Orange stain is a dead giveaway.

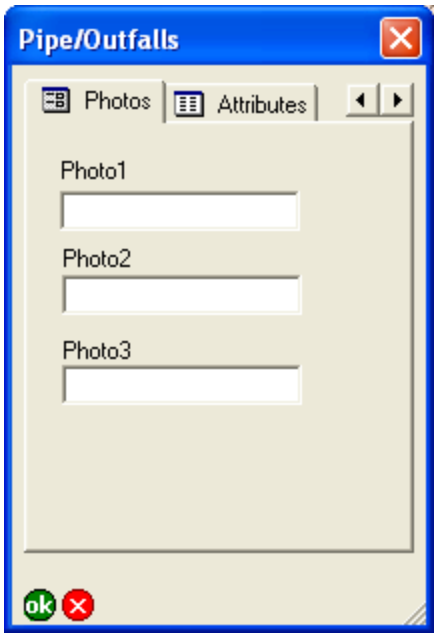
Float. Severity – Choose a description of the amount of floating materials present, the following options are available:

- Slight
- Some
- Severe

Comments – Add any additional observations in the box provided.

3.1.6 Photos Tab

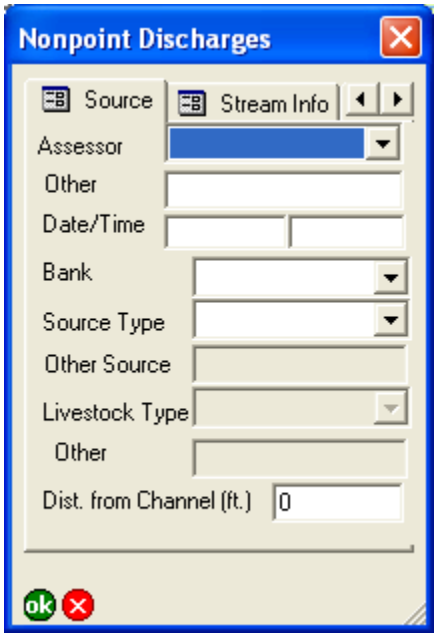
It is recommended that crews document sources with photos in addition to collecting the data logged on the field form. In general, no more than three photos are needed to visually document the source itself as well as other notable observations, such as unusual stream conditions. If available enter photo numbers here. If a unique photo number is not available be sure that the date/time has been entered on the camera.



3.2 COMPLETING NONPOINT DISCHARGES FIELD FORM

After marking a new polyline (see Section 2.7), the nonpoint discharges field form will be launched to document information about the source. The form has multiple tabs that need to be completed. To save time and promote consistency between surveys and crews, many of the boxes have pick lists to select values. This section steps through the content on each tab.

3.2.1 Source Tab



Assessor – Choose name from pick list or select "Other" and enter the new name in the *Other* box below the *Assessor* box.

Date/Time – Tap boxes to enter. The current date/time will automatically enter when each box is tapped.

Bank – Define outfall location facing downstream (or "descending") from pick list. The pick list includes the following choices:

- Left descending bank
- Right descending bank
- In line

Note that 'in line' means the source is crossing the waterbody completely.

Source Type – Choose a description of the nonpoint source, the following options are available:

- None
- Septic (apparent)
- Livestock-Fenced
- Livestock w/ access to creek
- Other (specify)

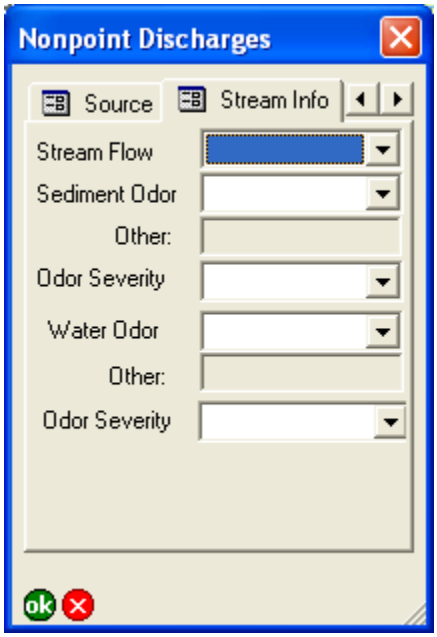
Livestock Type – If applicable, choose a livestock type, the options are available:

- Cows
- Horses
- Turkeys
- Pigs
- Chicken
- Goats
- Other (specify)

Dist. From Channel – Enter the distance from the edge of channel (feet) if applicable.

3.2.2 Stream Info Tab

This is the first of two tabs to tally observations made about the receiving stream channel in the vicinity of the nonpoint discharge.



Stream Flow – Choose a qualitative description of the flow level from pick list, which includes the following choices:

- Low/Trickle
- Medium/Normal
- High/Strong

Sediment Odor – Choose a description of the odor from any exposed sediment in the channel, if detectible, from the pick list, which includes the following choices:

- N/A
- Sewage
- Rotten Eggs
- Rancid/Sour
- Petroleum
- Fragrant
- Other (specify)

Note that this field should still be filled out even if no odor is detected by choosing "N/A" from the pick list.

Odor Severity – Choose a description of the odor intensity from the pick list, which includes the following choices:

- Faint/Barely Detectible
- Moderate/Easily Detectible
- Strong/Notice From Afar

Water Odor – Choose a description of the odor of the water, if detected, from the pick list, which includes the following choices:

- N/A
- Sewage
- Rotten Eggs
- Rancid/Sour
- Petroleum
- Fragrant
- Other (specify)

Note that this field should still be filled out even if no odor is detected by choosing "N/A" from the pick list.

Odor Severity – Choose a description of the odor intensity from the pick list, which includes the following choices:

- Faint/Barely Detectible
- Moderate/Easily Detectible
- Strong/Notice From Afar

3.2.3 StreamPg2 Tab

This tab is the second page that applies to observations made about the receiving stream channel in the vicinity of the nonpoint discharge.

Water Color – Select a color that describes the receiving stream channel color. The following options are available:

- N/A
- Black
- Blue
- Brown
- Gray
- Green
- Orange
- Red
- White
- Yellow
- Other (specify)

Color Severity – Choose a descriptor for the color intensity, the following choices are available:

- Slightly Tinted
- Moderately Tinted
- Intense

Turbidity – Choose a description for the degree of turbidity. The following choices are available:

- Transparent
- Translucent
- Opaque

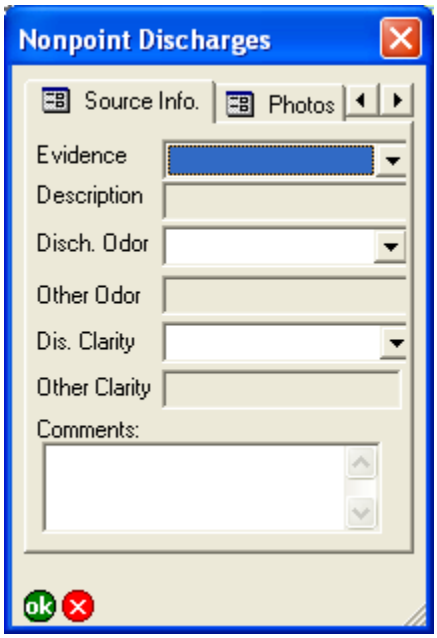
Erosion – The purpose of this field is to register the amount of erosion immediately downstream of the source. See examples in Section 3.1. The following choices are available:

- None
- Minor
- Moderate
- Major

Dom. Bed Mat. – Select a description of the dominant bed material found in the stream channel. The following options are available:

- Clay/Silt (<0.08mm)
- F.Sand (0.08-1mm)
- C.Sand (1-2mm)
- Gravel (2-64mm)
- Cobble (64-256mm)
- Boulder (>256mm)
- Bedrock

3.2.4 Source Info Tab



Evidence – Is there evidence of a discharge reaching the stream? Choose yes or no. If yes enter a description into the description box.

Disch. Odor – If an odor is detectable near the discharge, choose from one of the following:

- None
- Sewage
- Sulfurous
- Organic
- NA
- Other (specify)

Dis. Clarity – If applicable select a description for the discharge clarity, from one of the following:

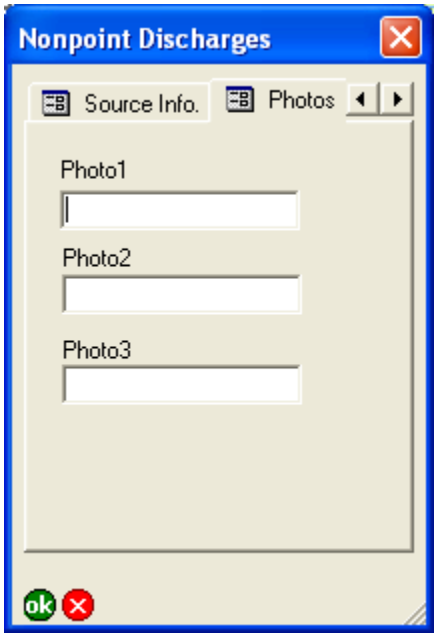
- Clear
- Opaque
- Cloudy
- NA

- Other (specify)

Comments – Add any additional observations in the box provided.

3.2.5 Photos Tab

It is recommended that crews document sources with photos in addition to collecting the data logged on the field form. In general, no more than three photos are needed to visually document the source itself as well as other notable observations, such as unusual stream conditions. If available enter photo numbers here. If a unique photo number is not available be sure that the date/time has been entered on the camera.



Appendix 4-A

Rate & Fee Schedule for Fiscal Years 2010 and 2011

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Sanitation District No. 1

FY 2009 Rates & Fees / Pending Rates and Fees for FY 2010 & 2011

Sanitary Sewer Rates -RESIDENTIAL

Quarterly Water Usage (Cubic Feet)

WATER USAGE	* * * * * Current Rates * * * * * APPROVED RATES / HCF	EFFECTIVE DATE
0 - 800	**$3.82**	* 4/1/2008
801 - 5000	**$3.60**	* 4/1/2008
5001 - 25,000	**$3.23**	* 4/1/2008
25,001 - 100,000	**$2.76**	* 4/1/2008
All Over 100,000	**$2.51**	* 4/1/2008
Minimum Bill (6 HCF) Per Quarter	**$22.92**	* 4/1/2008

Quarterly Rates for Unmetered Service

NUMBER OF ROOMS	APPROVED RATES	EFFECTIVE DATE
1 or 2 Room House	**$34.31**	* 4/1/2008
3, 4, 5 and 6 Room Houses	**$56.33**	* 4/1/2008
More than 6 Rooms	**$74.51**	* 4/1/2008

Sanitary Sewer Rates -RESIDENTIAL

Quarterly Water Usage (Cubic Feet)

WATER USAGE	* * FY 2010 Pending Rates * * PENDING RATES / HCF	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES / HCF	EFFECTIVE DATE
Flat Rate Per HCF of Usage	**$4.40**	* 4/1/2009	**$5.06**	* 4/1/2010
Minimum Bill (2 HCF) Per Month	**$8.80**	* 4/1/2009	**$10.12**	* 4/1/2010

Quarterly Rates for Unmetered Service

NUMBER OF ROOMS	* * FY 2010 Pending Rates * * PENDING RATES	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES	EFFECTIVE DATE
1 or 2 Room House	**$39.46**	* 4/1/2009	**$45.37**	* 4/1/2010
3, 4, 5 and 6 Room Houses	**$64.78**	* 4/1/2009	**$74.50**	* 4/1/2010
More than 6 Rooms	**$85.69**	* 4/1/2009	**$98.54**	* 4/1/2010

Sanitary Sewer Rates -NON-RESIDENTIAL

Quarterly Water Usage (Cubic Feet)

WATER USAGE	* * * * * Current Rates * * * * * APPROVED RATES / HCF	EFFECTIVE DATE
0 - 800	**$3.82**	* 4/1/2008
801 - 5000	**$3.60**	* 4/1/2008
5001 - 25,000	**$3.23**	* 4/1/2008
25,001 - 100,000	**$2.76**	* 4/1/2008
All Over 100,000	**$2.51**	* 4/1/2008
Minimum Bill (6 HCF) Per Quarter	**$22.92**	* 4/1/2008

Sanitary Sewer Rates -NON-RESIDENTIAL

Quarterly Water Usage (Cubic Feet)

WATER USAGE	* * FY 2010 Pending Rates * * PENDING RATES / HCF	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES / HCF	EFFECTIVE DATE
0 - 5000	**$4.40**	* 4/1/2009	**$5.06**	* 4/1/2010
5001 - 25,000	**$3.95**	* 4/1/2009	**$4.54**	* 4/1/2010
All Over 25,000	**$3.05**	* 4/1/2009	**$3.51**	* 4/1/2010
Minimum Bill (2 HCF) Per Month	**$8.80**	* 4/1/2009	**$10.12**	* 4/1/2010

Kelly School - Sanitary Sewer Rates - (Per Boone Co. Contract)

Flat Quarterly Rate for Sanitary Service

	* * * * * Current Rates * * * * * APPROVED RATES	EFFECTIVE DATE
Flat Quarterly Rate	**$3,726.00**	* 4/1/2008

Kelly School - Sanitary Sewer Rates - (Per Boone Co. Contract)

Flat Quarterly Rate for Sanitary Service

	* * FY 2010 Pending Rates * * PENDING RATES	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES	EFFECTIVE DATE
Flat Quarterly Rate	**$4,285**	* 4/1/2009	**$4,928**	* 4/1/2010

Sanitation District No. 1

FY 2009 Rates & Fees / Pending Rates and Fees for FY 2010 & 2011

Verona Commons - Sanitary Sewer Rates - (Per Boone Co. Contract)

Flat Quarterly Rate for Sanitary Service

WATER USAGE	* * * * * Current Rates * * * * * APPROVED RATES	EFFECTIVE DATE
Flat Quarterly Rate (Homeowners)	**$86.95**	* 4/1/2008

Verona Commons - Sanitary Sewer Rates - (Per Boone Co. Contract)

FY'09 Rate & Fee Adjustments

Flat Quarterly Rate for Sanitary Service

WATER USAGE	* * FY 2010 Pending Rates * * PENDING RATES	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES	EFFECTIVE DATE
Flat Quarterly Rate (Homeowners)	**$100**	* 4/1/2009	**$115**	* 4/1/2010

Misc - Sanitary Sewer Rates

Flat Quarterly Rate for Sanitary Service

DESCRIPTION	* * * * * Current Rates * * * * * APPROVED RATES	EFFECTIVE DATE
H7 - Covington Landing	**$1,375.00**	* 4/1/2008
H8 - Val Ct.	**$256.80**	* 4/1/2008
H9 - NKWD - Aqua Dr. Location	**$114.00**	* 4/1/2008

Misc - Sanitary Sewer Rates

FY'09 Rate & Fee Adjustments

Flat Quarterly Rate for Sanitary Service

DESCRIPTION	* * FY 2010 Pending Rates * * PENDING RATES	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES	EFFECTIVE DATE
H7 - Covington Landing	**$1,581**	* 4/1/2009	**$1,818**	* 4/1/2010
H8 - Val Ct.	**$295**	* 4/1/2009	**$340**	* 4/1/2010
H9 - NKWD - Aqua Dr. Location	**$131**	* 4/1/2009	**$151**	* 4/1/2010

Surcharge Rates

	* * * * * Current Rates * * * * * APPROVED RATES / LB.	EFFECTIVE DATE
Suspended Solids (over 300 parts per million)	**$0.138**	* 4/1/2008
B.O.D. (over 240 parts per million)	**$0.329**	* 4/1/2008
Total Kjeldahl Nitrogen (over 30 parts per million)	**$0.925**	* 4/1/2008
C.O.D. (over ??? parts per million)	**n/a**	n/a

Surcharge Rates

	* * FY 2010 Pending Rates * * PENDING RATES / LB.	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES / LB.	EFFECTIVE DATE
Suspended Solids (over 300 parts per million)	**$0.159**	* 4/1/2009	**$0.183**	* 4/1/2010
B.O.D. (over 240 parts per million)	**$0.378**	* 4/1/2009	**$0.435**	* 4/1/2010
Total Kjeldahl Nitrogen (over 30 parts per million)	**$1.064**	* 4/1/2009	**$1.223**	* 4/1/2010
C.O.D. (over ??? parts per million)	**n/a**	n/a	**n/a**	n/a

Sanitation District No. 1

FY 2009 Rates & Fees / Pending Rates and Fees for FY 2010 & 2011

Storm Water Rates

	* * * * * Current Rates * * * * *	
	APPROVED RATES	EFFECTIVE DATE
Quarterly Rate Per ERU	**$12.90**	* 4/1/2008

Storm Water Rates

	* * FY 2010 Pending Rates * *		* * FY 2011 Pending Rates * *	
	PENDING RATES	EFFECTIVE DATE	PENDING RATES	EFFECTIVE DATE
Quarterly Rate Per ERU	**TBD**	* 4/1/2009	**TBD**	* 4/1/2010

Sludge Hauling

	* * * * * Current Rates * * * * *	
	APPROVED RATES	EFFECTIVE DATE
Sludge Hauling Permit	**$100.00**	7/1/2007
	APPROVED RATES	EFFECTIVE DATE
Sludge Dumping	**$48.30**	7/1/2007

Sludge Hauling

	* * FY 2010 Pending Rates * *		* * FY 2011 Pending Rates * *	
	PENDING RATES	EFFECTIVE DATE	PENDING RATES	EFFECTIVE DATE
Sludge Hauling Permit	**$100.00**	7/1/2007	**$100.00**	7/1/2007
	PENDING RATES	EFFECTIVE DATE	PENDING RATES	EFFECTIVE DATE
Sludge Dumping	**$60.00**	7/1/2009	**$80.00**	7/1/2010

Capacity Connection Fees

	* * * * * Current Rates * * * * *	
Water Meter Size	APPROVED RATES	EFFECTIVE DATE
3/4"	**$3,000**	7/1/2008
1"	**$5,300**	7/1/2008
1 1/2"	**$11,950**	7/1/2008
2"	**$21,200**	7/1/2008
3"	**$47,700**	7/1/2008
4"	**$84,800**	7/1/2008
6"	**$190,450**	7/1/2008
8"	**$337,825**	7/1/2008
Multi-family Dwelling Units	APPROVED RATES	EFFECTIVE DATE
3 units	**$3,000**	7/1/2008
4 - 5 Units	**$5,300**	7/1/2008
6 - 12 Units	**$11,950**	7/1/2008
13 - 20 Units	**$21,200**	7/1/2008
21 - 50 Units	**$47,700**	7/1/2008
51 - 115 Units	**$84,800**	7/1/2008
116 - 250 Units	**$190,450**	7/1/2008
251 - 500 Units	**$337,825**	7/1/2008
over 500 Units	Must Discuss w./ SD1	

Capacity Connection Fees

	* * FY 2010 Pending Rates * *		* * FY 2011 Pending Rates * *	
Water Meter Size	PENDING RATES	EFFECTIVE DATE	PENDING RATES	EFFECTIVE DATE
3/4"	**$3,000**	7/1/2008	**$3,000**	7/1/2008
1"	**$5,300**	7/1/2008	**$5,300**	7/1/2008
1 1/2"	**$11,950**	7/1/2008	**$11,950**	7/1/2008
2"	**$21,200**	7/1/2008	**$21,200**	7/1/2008
3"	**$47,700**	7/1/2008	**$47,700**	7/1/2008
4"	**$84,800**	7/1/2008	**$84,800**	7/1/2008
6"	**$190,450**	7/1/2008	**$190,450**	7/1/2008
8"	**$337,825**	7/1/2008	**$337,825**	7/1/2008
Multi-family Dwelling Units	PENDING RATES	EFFECTIVE DATE	PENDING RATES	EFFECTIVE DATE
3 units	**$3,000**	7/1/2008	**$3,000**	7/1/2008
4 - 5 Units	**$5,300**	7/1/2008	**$5,300**	7/1/2008
6 - 12 Units	**$11,950**	7/1/2008	**$11,950**	7/1/2008
13 - 20 Units	**$21,200**	7/1/2008	**$21,200**	7/1/2008
21 - 50 Units	**$47,700**	7/1/2008	**$47,700**	7/1/2008
51 - 115 Units	**$84,800**	7/1/2008	**$84,800**	7/1/2008
116 - 250 Units	**$190,450**	7/1/2008	**$190,450**	7/1/2008
251 - 500 Units	**$337,825**	7/1/2008	**$337,825**	7/1/2008
over 500 Units	Must Discuss w./ SD1		Must Discuss w./ SD1	

Sanitation District No. 1

FY 2009 Rates & Fees / Pending Rates and Fees for FY 2010 & 2011

Additional Fees

SANITARY SERVICES	* * * * * Current Rates * * * * * APPROVED RATES	EFFECTIVE DATE
Plan Review	$325	7/1/2008
Sewer Construction Inspection (per foot)	$1.20	7/1/2008
Unusual Discharge	$50 / 1,000 Gal.	7/1/2008
Long-Term	$2.88 / HCF	7/1/2008
pH re-sampling cost, per week	$500	8/1/1998
Surcharge re-sampling cost	$700	8/1/1998
Pump Station Telemetry	$9,250	7/1/2008
Storm Sewer Connection Application	$85	7/1/2008
Sewer Manhole Tap Application	$400	7/1/2008
Sewer Lateral Abandonment Permit	$85	7/1/2008
Re-Inspection Fee	$85	7/1/2008
Bond Cost (Tapper)	$5,750	7/1/2006
Tapping Inspection	$85	7/1/2008
Tapper Program Certification	$150	7/1/2008
Annual Renewal of Tapper Cert.	$36	7/1/2008
Photocopies of Plans (per page)	$3	7/1/2008
Pretreatment Permit Tier 1 (per year)	$2,500	7/1/2008
Pretreatment Permit Tier 2 (per year)	$450	7/1/2008
Fat, Oil & Grease (FOG) Permit (per year)	n/a	n/a
General Labor (per hour)	$50-$65	7/1/2008

Additional Fees

SANITARY SERVICES	* * FY 2010 Pending Rates * * PENDING RATES	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES	EFFECTIVE DATE
Plan Review	$375	7/1/2009	$430	7/1/2010
Sewer Construction Inspection (per foot)	$1.40	7/1/2009	$1.60	7/1/2010
Unusual Discharge	$50 / 1,000 Gal.	7/1/2008	$50 / 1,000 Gal.	7/1/2008
Long-Term	$2.88 / HCF	7/1/2008	$2.88 / HCF	7/1/2008
pH re-sampling cost, per week	$500	7/1/1998	$500	7/1/1998
Surcharge re-sampling cost	$700	7/1/1998	$700	7/1/1998
Pump Station Telemetry	$9,250	7/1/2008	$9,250	7/1/2008
Storm Sewer Connection Application	$85	7/1/2008	$85	7/1/2008
Sewer Manhole Tap Application	$400	7/1/2008	$400	7/1/2008
Sewer Lateral Abandonment Permit	$85	7/1/2008	$85	7/1/2008
Re-Inspection Fee	$85	7/1/2008	$85	7/1/2008
Bond Cost (Tapper)	$5,750	7/1/2006	$5,750	7/1/2006
Tapping Inspection	$85	7/1/2008	$85	7/1/2008
Tapper Program Certification	$150	7/1/2008	$150	7/1/2008
Annual Renewal of Tapper Cert.	$36	7/1/2008	$36	7/1/2008
Photocopies of Plans (per page)	$3	7/1/2008	$3	7/1/2008
Pretreatment Permit Tier 1 (per year)	$3,000	7/1/2009	$3,600	7/1/2010
Pretreatment Permit Tier 2 (per year)	$540	7/1/2009	$650	7/1/2010
Fat, Oil & Grease (FOG) Permit (per year)	$250	7/1/2009	$250	7/1/2009
General Labor (per hour)	$55-$70	7/1/2009	$55-$75	7/1/2010

STORM WATER SERVICES	* * * * * Current Rates * * * * * APPROVED RATES	EFFECTIVE DATE
Plan Review	$500	8/1/2003
Inspection (per acre) (Not to exceed $1,000)	$60	8/1/2008
Administrative Fines (per violation)	$100 - $1,000	8/1/2003

Note: Each day of noncompliance is deemed a separate and distinct violation.

STORM WATER SERVICES	* * FY 2010 Pending Rates * * PENDING RATES	EFFECTIVE DATE	* * FY 2011 Pending Rates * * PENDING RATES	EFFECTIVE DATE
Plan Review	$575	7/1/2009	$675	7/1/2010
Inspection (per acre) (Not to exceed $1,000)	$60	7/1/2008	$70	7/1/2010
Administrative Fines (per violation)	$100 - $1,000	8/1/2003	$100 - $1,000	8/1/2003

Note: Each day of noncompliance is deemed a separate and distinct violation.

FINES	* * * * * Current Rates * * * * *	
Industrial Fines (per event, per day)		
First Offense	$500	7/1/2008
Second Offense	$750	7/1/2008
Third Offense	$1,000	7/1/2008
Tapper Fines (per event, per day)		
First Offense	$500	7/1/2008
Second Offense	$750	7/1/2008
Third Offense	$1,000	7/1/2008

FINES	* * FY 2010 Pending Rates * *		* * FY 2011 Pending Rates * *	
Industrial Fines (per event, per day)				
First Offense	$500	7/1/2008	$500	7/1/2008
Second Offense	$750	7/1/2008	$750	7/1/2008
Third Offense	$1,000	7/1/2008	$1,000	7/1/2008
Tapper Fines (per event, per day)				
First Offense	$500	7/1/2008	$500	7/1/2008
Second Offense	$750	7/1/2008	$750	7/1/2008
Third Offense	$1,000	7/1/2008	$1,000	7/1/2008

Appendix 4-B

Financial Capability Assessment of the Integrated Plan for 2025

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1.0 Introduction

SD1's Consent Decree calls for a financial capability assessment to be completed to determine the financial impact of the needs outlined in the Consent Decree in accordance with the February 1997 EPA document - *"CSO Guidance for Financial Capability Assessment and Schedule Development"* (EPA, 1997). The EPA recognizes that the implementation and scheduling of a wet-weather Consent Decree directly impacts a community's ability to afford the proposed remediation activities. The financial capability assessment measures the impact that the wet-weather improvements will have on both the current and future financial health of the community.

Affordability has many dimensions and requires multiple perspectives to adequately arrive at a reasonably acceptable definition from the community's perspective. Therefore, this analysis explores affordability of the wet-weather projects and implementation schedule based on two perspectives:

1. The method outlined in the 1997 EPA guidelines (See Sections 2.0 to 4.0).
2. The potential annual impacts of a full system solution (See Section 5.0) that assesses the amount of sanitary sewer rates that will be needed to support the wet-weather projects, the cost to typical residential customers within SD1's service area, and a comparison of these costs to the median household income (MHI).

2.0 Calculation of the Residential Indicator

The Residential Indicator is calculated by first determining the total cost of wastewater treatment and wet-weather control. A portion of the total cost is then allocated to residential customers based on the percentage of total flow generated from these customers. Finally, the total residential cost is allocated amongst the total number of households in the community to determine the wastewater treatment and wet-weather controls implementation cost per household. Once the wet-weather controls implementation cost per household is determined, the Residential Indicator is calculated by dividing the wastewater treatment and wet-weather controls implementation cost per household by the MHI of the community, and is compared to the EPA criteria for classifying the financial impact as "low," "mid-range," or "high." Table 2-1 shows the EPA's criteria for classifying the financial impact based on the calculated Residential Indicator.

Table 2-1
EPA Residential Indicator Financial Impacts

Financial Impact	Residential Indicator (Cost as a % of MHI)
Low	Less than 1% of MHI
Mid-Range	1% – 2% of MHI
High	Greater than 2% of MHI

2.1 Identification of Wastewater Treatment and Wet-Weather Control Costs

The existing costs for wastewater treatment operations and the projected costs for the proposed wastewater treatment and wet-weather controls were used to determine the Residential Indicator, and were estimated as described below. Attachment 1 to this appendix presents the EPA guidance worksheets and documentation of the financial capability assessment.

2.1.1 Current Wastewater Treatment Costs

The EPA defines current wastewater treatment costs as the current annual operation and maintenance (O&M) expenditures (excluding depreciation) plus current annual debt service payments (principal and interest). These costs are intended to represent the cash expenditures of current wastewater treatment operations. For the purpose of the FCA, current costs represent conditions in 2009, consistent with the submittal year for the first set of watershed plans.

Operation & Maintenance Costs

SD1's total actual O&M expenditures for fiscal year 2009 are $24.9 Million, based on information provided by SD1. This amount was lower than the actual O&M expenditures for fiscal year 2008 ($30.5 Million) but higher than the O&M expenses in fiscal year 2007 ($20.4 Million). The increase in the actual O&M expenses for fiscal year 2008 as compared to fiscal year 2007 is due to SD1 adding staff from 227 to 251 in fiscal year 2008, the majority of which occurred for the operation of the new Eastern Regional WRF. The actual O&M expenditures for fiscal year 2009 are higher than the actual O&M expenditures for fiscal years 2005, 2006 and 2007, as shown in Table 2-2, and lower than the actual O&M expenditure for fiscal year 2010.

Table 2-2
Historic O&M Expenditures ($000s)[1]

	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010
Personnel Expenditures	$11,703	$ 12,479	$ 14,329	$16,315	$17,222	18,076
Contract Services	(646)	(3,059)	(3,324)	(2,953)	(2,967)	(2,653)
Administrative & Office Operations	773	903	960	1,301	1,347	1,743
Utilities, Fuel Oil & Chemicals	4,414	5,564	5,929	6,596	6,551	7,198
Vehicle Operations	627	843	932	1,217	1,037	1,097
Miscellaneous	1,488	2,314	1,638	8,009	1,756	2,656
Total	$18,359	$19,044	$20,464	$30,485	$24,946	$28,117

[1]All figures are actual expenditures.

Source: SD1 Pro Forma 3.4 – 2-10-11Financial Model

In accordance with the 1997 EPA guidance document, reserves for depreciation, capital replacement, and other types of reserves are not included in the current O&M costs shown above.

Current Debt Service

Debt service is taken into account in the assessment since it represents a cash cost associated with wastewater treatment. SD1's current debt service as of 2009 includes payments for outstanding revenue bonds and Eastern Regional Plant Construction loans. The total amount of debt service in 2009 was $18.8 Million. A summary of SD1's outstanding debt is provided below.

- In 1998, SD1 issued Series 1998 A Revenue Bonds. These bonds were issued to make improvements to the sewage conveyance and wastewater treatment system. The debt service matured in 2008. The last payment was made in fiscal year 2009.
- In 2001, SD1 issued Series 2001 A Revenue Bonds. The debt service matures in 2031.
- The 1st Series 1998 Revenue Bonds were refinanced in 2005 into Series 2005 A Revenue Bonds. The debt service matures in 2018.

- In 2006, SD1 issued Series 2006 A Revenue Bonds. The debt service matures in 2036.
- In 2007, SD1 issued Series 2007 A Revenue Bonds. The debt service matures in 2038.
- In addition to the revenue bonds issued by SD1, The Kentucky Infrastructure Authority (KIA) issued a bond for Melbourne with a debt service that matures in 2013. In March 2007, this bond was paid in full.
- In 2005 SD1 received SRF loans under KIA for the Eastern Regional WRF design and construction. The debt service on the principal and interest payments began in 2008 and has been scheduled out to 2026.

Table 2-3 shows the line-item amounts for the above debt service payments (existing in 2009), along with the remaining and projected debt service payment schedules for all the bonds associated with existing and planned future wastewater projects. Debt service payments initiating after 2009 are associated with the following bond issues and loans:

- In 2009 SD1 procured SRF Loans for the Western Regional WRF design and construction. The debt service of the interest payments began in 2010. The debt service on the principal and interest payments is anticipated to begin in 2013 and has been scheduled out to 2026.
- In 2009 SD1 has debt service that started in 2010 with the issue of Series 2009 revenue bonds in the total amount of $54,880,000.
- In 2010 SD1 has proposed debt service that starts in 2011 with the issue of a Series 2010 revenue bonds in the total amount of $75,000,000 with various maturity dates.
- In 2010, SD1 secured loan funding from KIA for a new clarifier at the Dry Creek WWTP and several smaller infrastructure improvement projects for the total amount of $479,392.
- In 2011, SD1 has proposed debt service that starts in 2011 with various SRF loans for specific projects (as outlined in Table 2-3).
- SD1 has plans to issue a revenue bond in each subsequent year until 2024.

Table 2-3
Sanitation District Existing and Proposed Debt Service ($s)

Description	Actual 2009	Actual 2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
	Fiscal Year Ending June 30,																	
EXISTING DEBT SERVICE - BONDS																		
Series 1998 A Revenue Bonds	$ 2,651,513	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Series 2001 A Revenue Bonds	3,398,988	3,393,700	2,335,025	1,271,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Series 2005 A Refunding Bonds (1998A Refunded)	1,647,900	4,205,300	4,198,100	4,196,300	4,194,600	4,187,900	4,186,000	4,183,600	4,175,600	4,171,800	4,166,700	-	-	-	-	-	-	-
Series 2006 A Revenue Bonds	3,025,034	3,021,441	3,021,236	3,019,311	3,015,666	3,010,301	3,008,109	3,008,874	3,007,489	3,008,846	3,007,839	3,009,359	3,013,191	3,019,121	3,022,041	3,021,951	3,028,636	3,036,774
Series 2007 A Revenue Bonds	5,843,050	5,946,850	5,956,850	5,969,750	5,980,450	6,003,650	6,019,150	6,025,375	6,041,500	6,048,500	6,056,375	7,327,500	7,325,250	7,315,500	7,317,750	7,316,375	7,311,125	7,301,750
Series 2009 A Revenue Bonds (Gross Taxable BAB)	-	1,649,911	4,375,599	4,368,726	4,359,976	4,348,839	4,329,816	4,314,924	4,295,341	4,274,666	4,248,676	4,224,538	4,201,538	4,171,568	4,140,749	4,109,649	4,075,843	4,040,843
Series 2010 A Revenue Bonds (Gross Taxable BAB)	-	-	2,821,606	5,459,545	5,452,139	5,439,214	5,428,479	5,409,567	5,388,239	5,366,686	5,339,304	5,310,008	5,280,010	5,246,480	5,210,130	5,175,843	5,143,383	5,102,750
Series 2010 B Refunding Bonds (2001A Refunded)	-	-	522,196	1,770,625	3,031,725	3,019,825	3,012,475	3,005,425	2,998,488	2,995,613	2,991,738	2,992,175	2,987,100	2,990,100	2,985,000	2,986,700	2,985,000	2,989,700
Series 2010 C Revenue Bonds (Gross Taxable BAB)	-	-	56,819	1,984,364	1,976,149	1,973,859	1,965,253	1,953,390	1,940,278	1,921,009	1,905,615	1,888,190	1,863,005	1,836,624	1,809,409	1,782,195	-	-
Series 2010 D Revenue Bonds (Gross Taxable RZEBB)	-	-	226,225	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	2,467,913	4,217,140	4,187,078
Subtotal Bonds Debt Service:	**$ 16,566,484**	**$ 18,217,202**	**$ 23,513,656**	**$ 30,507,534**	**$ 30,478,618**	**$ 30,451,501**	**$ 30,417,195**	**$ 30,369,068**	**$ 30,314,848**	**$ 30,255,033**	**$ 30,184,160**	**$ 27,219,683**	**$ 27,138,007**	**$ 27,047,306**	**$ 26,952,992**	**$ 26,860,626**	**$ 26,761,127**	**$ 26,658,895**
EXISTING DEBT SERVICE - KIA																		
KY Infrastructure Auth.- Cold Spring	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KY Infrastructure Auth.- Melbourne	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KIA - Eastern Regional WRF	2,226,866	2,229,761	2,227,222	2,224,607	2,221,913	2,219,138	2,216,278	2,213,332	2,210,297	2,207,170	2,203,949	2,200,631	2,197,212	2,193,690	2,190,061	2,186,322	2,182,471	2,178,503
KIA - Western Regional WRF	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Subtotal KIA Debt Service:	**$ 2,226,866**	**$ 2,229,761**	**$ 2,227,222**	**$ 2,224,607**	**$ 2,221,913**	**$ 2,219,138**	**$ 2,216,278**	**$ 2,213,332**	**$ 2,210,297**	**$ 2,207,170**	**$ 2,203,949**	**$ 2,200,631**	**$ 2,197,212**	**$ 2,193,690**	**$ 2,190,061**	**$ 2,186,322**	**$ 2,182,471**	**$ 2,178,503**
Total Existing Debt Service	**$ 18,793,350**	**$ 20,446,963**	**$ 25,740,878**	**$ 32,732,141**	**$ 32,700,531**	**$ 32,670,639**	**$ 32,633,473**	**$ 32,582,400**	**$ 32,525,145**	**$ 32,462,203**	**$ 32,388,109**	**$ 29,420,314**	**$ 29,335,219**	**$ 29,240,996**	**$ 29,143,053**	**$ 29,046,948**	**$ 28,943,598**	**$ 28,837,398**
EXISTING & PROPOSED SRF																		
Sunnybrook Sewer Construction Loan	-	-	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899	316,899
DCWWTP Clarifier Construction Loan	-	-	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862	278,862
Frogtown Interceptor Construction Loan	-	-	59,400	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597	359,597
Southfork/Gunpowder Int Construction Loan	-	-	138,600	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506	843,506
Narrows Rd. PS Construction Loan	-	-	79,200	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216	511,216
Turkeyfoot/Industrial FM Construction Loan	-	-	38,500	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859	155,859
Western Regional Plant Construction Loan	-	122,229	725,483	863,483	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439	4,203,439
Dry Creek WWTP Headworks Prioject	-	-	28,600	303,600	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963	1,009,963
Stimulus Project Draw - Wetlands	-	-	11,924	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606	47,606
Stimulus Project Draw - Reforestation	-	-	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129	27,129
Stimulus Project Draw - Bioretention Basin	-	-	17,330	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668	50,668
Stimulus Project Draw - Banklick Creek Mitagation	-	-	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313	12,313
Lakeside Park Sewer Project	-	-	5,905	30,388	56,093	73,915	232,728	232,728	232,728	232,728	232,728	232,728	232,728	232,728	232,728	232,728	232,728	232,728
Vernon Lane I/I Removal	-	-	16,932	34,636	53,110	172,691	172,691	172,691	172,691	172,691	172,691	172,691	172,691	172,691	172,691	172,691	172,691	172,691
Church Street CSO Reduction Project	-	-	246	24,424	45,277	67,173	225,304	225,304	225,304	225,304	225,304	225,304	225,304	225,304	225,304	225,304	225,304	225,304
Ash St. FM, Silver Grove FM, Etc. Project	-	-	14,658	49,838	123,128	562,961	562,961	562,961	562,961	562,961	562,961	562,961	562,961	562,961	562,961	562,961	562,961	562,961
Kentucky Aire Pump Station Elimination	-	-	589	16,707	42,748	134,134	134,134	134,134	134,134	134,134	134,134	134,134	134,134	134,134	134,134	134,134	134,134	134,134
Ash Street Pump Station	-	-	9,836	18,675	61,442	215,085	215,085	215,085	215,085	215,085	215,085	215,085	215,085	215,085	215,085	215,085	215,085	215,085
Lakeview Pump Station Pump Replacemtn	-	-	16,912	77,227	288,401	288,401	288,401	288,401	288,401	288,401	288,401	288,401	288,401	288,401	288,401	288,401	288,401	288,401
Total SRF Debt Service	**$ -**	**$ 122,229**	**$ 1,799,317**	**$ 4,022,631**	**$ 8,487,256**	**$ 9,331,416**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**	**$ 9,648,361**
PROPOSED DEBT SERVICE																		
FY 2012 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FY 2013 Series - Bonds	-	-	-	-	989,847	989,847	989,847	989,847	989,847	989,847	989,847	989,847	989,847	989,847	989,847	989,847	989,847	989,847
FY 2014 Series - Bonds	-	-	-	-	-	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286	1,545,286
FY 2015 Series - Bonds	-	-	-	-	-	-	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466	7,092,466
FY 2016 Series - Bonds	-	-	-	-	-	-	-	7,567,939	7,567,939	7,567,939	7,567,939	7,567,939	7,567,939	7,567,939	7,567,939	7,567,939	7,567,939	7,567,939
FY 2017 Series - Bonds	-	-	-	-	-	-	-	-	15,452,859	15,452,859	15,452,859	15,452,859	15,452,859	15,452,859	15,452,859	15,452,859	15,452,859	15,452,859
FY 2018 Series - Bonds	-	-	-	-	-	-	-	-	-	14,026,442	14,026,442	14,026,442	14,026,442	14,026,442	14,026,442	14,026,442	14,026,442	14,026,442
FY 2019 Series - Bonds	-	-	-	-	-	-	-	-	-	-	16,403,805	16,403,805	16,403,805	16,403,805	16,403,805	16,403,805	16,403,805	16,403,805
FY 2020 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	13,709,460	13,709,460	13,709,460	13,709,460	13,709,460	13,709,460	13,709,460
FY 2021 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	20,603,812	20,603,812	20,603,812	20,603,812	20,603,812	20,603,812
FY 2022 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	12,758,515	12,758,515	12,758,515	12,758,515	12,758,515
FY 2023 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8,886,669	8,886,669	8,886,669	8,886,669
FY 2024 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	20,881,172	20,881,172	20,881,172
FY 2025 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15,036,821	15,036,821
FY 2026 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4,041,517
FY 2027 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FY 2028 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FY 2029 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FY 2030 Series - Bonds	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Proposed Debt Service	**$ -**	**$ -**	**$ -**	**$ -**	**$ 989,847**	**$ 2,535,133**	**$ 9,627,599**	**$ 17,195,538**	**$ 32,648,398**	**$ 46,674,839**	**$ 63,078,644**	**$ 76,788,104**	**$ 97,391,916**	**$110,150,431**	**$119,037,100**	**$139,918,271**	**$154,955,092**	**$158,996,609**
Total Existing, Proposed and SRF Debt Service	**$ 18,793,350**	**$ 20,569,192**	**$ 27,540,196**	**$ 36,754,772**	**$ 42,177,635**	**$ 44,537,188**	**$ 51,909,433**	**$ 59,426,299**	**$ 74,821,903**	**$ 88,785,403**	**$105,115,114**	**$115,856,778**	**$136,375,496**	**$149,039,787**	**$157,828,513**	**$178,613,581**	**$193,547,051**	**$197,482,368**

2.1.2 Projected Wastewater Treatment and Wet-Weather Control Costs

As required in the 1997 guidance document, estimates of projected wastewater treatment costs are made up of annual debt service payments (principal and interest) associated with future wastewater treatment and wet-weather control projects and incremental O&M expenditures associated with implementing the projected wastewater treatment and wet-weather control projects.

Projected Wastewater Treatment and Wet-Weather Projects – Capital Costs

Per SD1's Consent Decree, the requirement for the watershed program is "control of discharges from CSO outfalls consistent with the CSO Control Policy, the elimination of SSOs and Unpermitted Discharges in the Sewer System, and the improvement of water quality in the receiving waters." The CSO Control Policy states that "a primary objective of the long-term CSO control plan is to meet water quality standards, including the designated uses through reducing risks to human health and the environment by eliminating, relocating or controlling CSOs to the affected waters."

Therefore, the Consent Decree directly, and the CSO Control Policy by reference, require SD1 to assess a control program that eliminates SSOs and controls CSOs to a high enough level to allow current water quality standards to be met in local waterbodies (using either the Presumption Approach or Demonstration Approach as outlined in the Policy). This is the purpose of the Integrated Plan for 2025 presented in detail in Section 3B – i.e., to develop, size, and cost an integrated solution that eliminates SSOs and controls CSOs to meet water-quality based requirements.

As a reasonable reference point for Full Program Costs to use in the formal EPA Financial Capability Assessment analysis, SD1 used the Integrated Plan for 2025 cost for a program that achieves a Presumptive level of CSO control and an SSO level of service of one overflow, on average, every 2 years. Note that this is not a commitment by SD1 to this specific level of control, but rather is being used to assess the cost and affordability implications of a plan that will achieve compliance with the obligations of the Consent Decree. The cost for SD1 to implement this program is $2.4 Billion, in 2009 dollars. This amount includes capital costs for the following items:

- Asset management of wastewater and storm water systems including structural rehabilitation
- Initial Watershed Projects

  - Western Regional water reclamation facilities
  - Eastern Regional water reclamation facilities
- CSO controls
  - Green infrastructure projects
  - Green programs in combined areas
  - Gray control projects
- SSO controls
  - Rainfall-derived infiltration and inflow (RDII) removal Rehabilitation
  - Gray control projects
- Watershed controls
  - Source identification program decentralized projects
  - Stormwater best management practices in RDII removal areas
  - Green program in separate areas
- Anticipated facility planning projects
- Anticipated wastewater effluent limits for nitrogen and phosphorus

SD1 conducted a study of anticipated costs to meet potential future wastewater effluent limits changes for nitrogen and phosphorus. Due to the time span of the Consent Decree, the costs of these potential upgrades are included as capital improvements in the Full Program Costs for the Integrated Plan for 2025

Projected Incremental O&M Costs

In conjunction with the capital cost to maintain and construct the full system solution, by 2025, the additional annual projected O&M cost of these new or updated facilities and the inclusion of green programs in the combined and sanitary areas are estimated to be $26.6 Million, which is in addition to the existing $24.9 Million annual O&M cost SD1 incurred in fiscal year 2009.

2.2 Cost Per Household

The costs of current and projected wastewater treatment and wet-weather controls, identified above, were added together, and allocated to SD1's customers. The cost per household was determined by dividing SD1 residential cost by the number of SD1 residential customers. This analysis is described in detail below, and the calculations are provided in Attachment 1.

The total annual current and projected wastewater treatment and wet-weather costs (in 2009 dollars) was estimated to be $245.9 Million. The total cost allocated to SD1 customers was then further allocated between residential and non-residential SD1 customers, based on estimates of their respective contributions of wastewater flow. Average water consumption data for the period of 2006 through 2007 was used to estimate residential wastewater flow. During this period, approximately 61.6 percent of SD1 water consumption was associated with residential customers. The resulting cost allocation results are shown below:

Total cost allocated to SD1 customers	$245,900,000
Portion allocated to SD1 residential customers	$151,500,000
Portion allocated to SD1 non-residential customers	$94,400,000

Finally, the total cost allocated to SD1 residential customers was divided by the total number of SD1 residential customers to determine the cost per household, which was calculated to be $1,680 per household. These results are shown below:

Total cost allocated to SD1 residential customers	$151,500,000
Estimated number of residential customers	89,971
Cost per household	$1,680

2.3 Median Household Income

Multiple statistical sources were evaluated for MHI data within the Northern Kentucky region. Data was reviewed from the U.S. Census Bureau 2000 census, the U.S. Census Bureau's "CenStats" database, U.S. Census Bureau American Community Survey, and the Tri-Economic Development Corporation[1]. Based on the Federal nature of the Consent Decree and the amount of available information, the MHI information obtained from the U.S. Census Bureau's "CenStats" data was utilized for all years except 2009, where American Community Survey 1-Year Estimates were used since "CenStats" data was not available. The 2009 weighted MHI average of the three counties (Boone, Campbell and Kenton) by household, which SD1 serves, was calculated as $55,840. Table 2-4 shows MHI data for the three counties.

Table 2-4
U.S. Census Bureau MHI Data[1]

	MHI		
Year	**Boone**	**Campbell**	**Kenton**
1997	$ 48,999	$ 39,201	$ 41,581
1998	$ 51,323	$ 40,912	$ 42,676
1999	$ 53,092	$ 40,993	$ 42,814
2000	$ 55,418	$ 43,042	$ 44,657
2001	$ 54,557	$ 42,602	$ 44,361
2002	$ 55,617	$ 43,087	$ 45,147
2003	$ 57,609	$ 43,688	$ 46,635
2004	$ 58,749	$ 44,639	$ 47,729
2005	$ 56,262	$ 46,573	$ 48,673
2006	$ 57,964	$ 47,071	$ 52,654
2007	$ 66,690	$ 51,383	$ 50,734
2008	$ 66,178	$ 50,566	$ 52,633
2009 [2]	$ 68,369	$ 50,282	$ 50,660

[1] http://censtats.census.gov/usa/usa.shtml
[2] http://www.factfinder.census.gov/home/saff/main.html?_lang=en

Table 2-5 shows the number of households per county.

[1] http://www.census.gov/main/www/cen2000.html, http://censtats.census.gov/usa/usa.shtml and www.northernkentuckyusa.com

Table 2-5
U.S. Census Bureau American Community Survey Household Data[1]

	Households		
Year	**Boone**	**Campbell**	**Kenton**
2005	39,191	35,096	60,835
2006	40,063	35,038	61,572
2007	39,683	35,139	62,232
2008	42,196	35,427	64,878
2009	41,683	34,544	63,770

[1] U.S. Census Bureau American Community Survey (http://www.census.gov/acs/www/Products/)

Additionally, the 2000 Census data was reviewed to assess the variability in the range of income levels throughout the three counties, as shown in Figure 2-1. Note that the 2010 Census data was not available for this income level distribution assessment in time for the 2011 update; however, it is expected that while the regional MHIs have changed over time, the distribution of MHI levels across the region has remained fairly constant.

Figure 2-1
2000 Census Block MHI Map

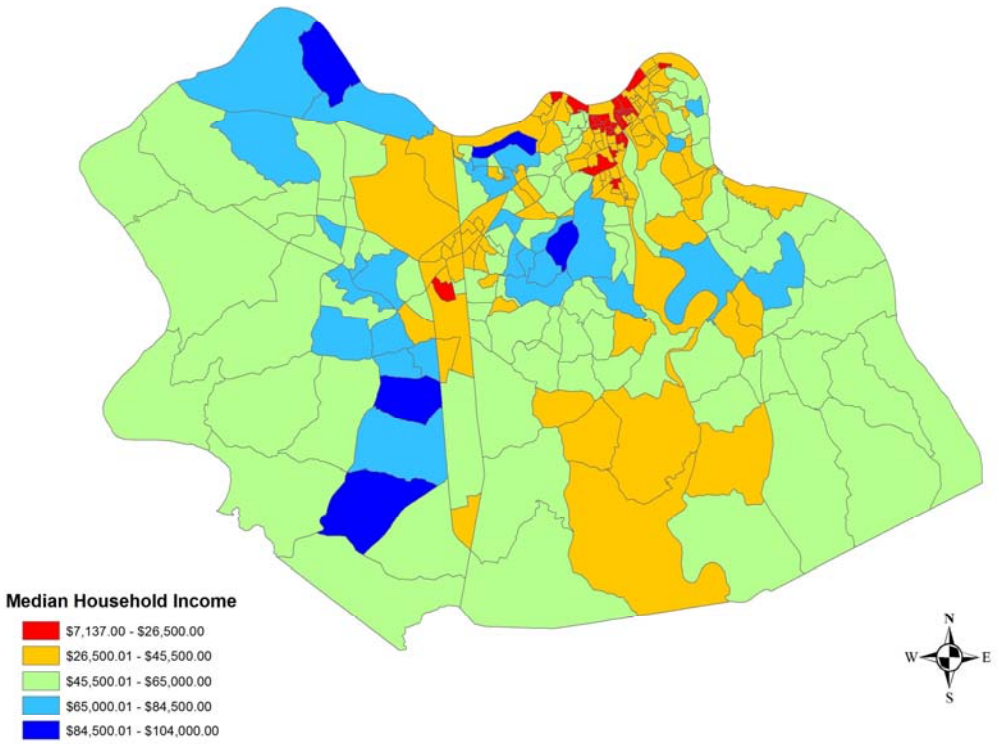


Table 2-6 summarizes several MHI statistics determined from the 2000 Census Block Group data, including the low and high, median, simple average, weighted average, and standard deviation.

Table 2-6
2000 Census Block Group MHI Statistics

Statistic	Value
Low	$7,137
High	$103,589
Simple Average	$45,816
Weighted Average	$48,817
Standard Deviation	$16,735

The Census Block Group data was also segregated into quartiles to determine the MHI of the lowest quartile. The data used for this portion of the analysis is from 2000. Table 2-7 shows the 2000 adjusted Census Block MHI quartile statistics.

Table 2-7
2000 Adjusted MHI Quartiles

Quartile	MHI
0-25%	≤$38,321
25-50%	$38,321-42,835
50-75%	$42,835-51,682
75-100%	≥$51,692

As reflected in the Census Block MHI statistics, approximately a quarter of regional households had income less than $38,321 in 2000, which corresponds to an income level of approximately $47,000 in 2009 dollars. Further, the statistics indicate highly variable income levels across SD1's service area. An income spread of approximately $96,000 between the lowest and highest MHI existed in 2000.

For the purposes of this evaluation, the 2009 weighted MHI for SD1 ($55,840), as presented above, was used for the financial capability assessment. The 2000 Census Block Group data discussed above is relevant to show the variability in MHI within SD1's service area, but it is not used in the FCA calculations.

The MHI data did not have to be adjusted to represent 2009 conditions (the year of interest), since 2009 data was available and used directly for this 2011 update. However, MHI adjustments through time were performed to support selected additional considerations (presented below), using an annual inflation factor. The average Consumer Price Index (CPI) during the past ten years (2001 through 2010) for the region that includes Ohio, Kentucky and Indiana was used as the annual inflation factor.[2] The "ten-year average CPI" for this region was calculated by removing the highest and lowest annual CPI from the 10-year period and averaging the remaining eight values. Utilizing this calculation method the average CPI was found to be 2.31 percent. .

2.4 Residential Indicator

The Residential Indicator was calculated by dividing the cost per household by the MHI. As shown below and detailed in Attachment 1, the Residential Indicator was calculated to be 3.02 percent.

The Residential Indicator was compared to EPA financial impact ranges presented in the EPA guidance document to assess the financial impact that wastewater treatment and wet-weather controls may have on SD1's residential customers. The assessment indicates that the financial impact on SD1 residential customers is in the "High" range, as shown below:

Financial Impact	Residential Indicator (Cost per household as % of MHI)
Low	Less than 1.0 Percent of MHI
Mid-Range	1.0 – 2.0 Percent of MHI
High	Greater than 2.0 Percent of MHI

2.4.1 Impacts to Specific Communities

While the median residential financial impact is in the high range, specific communities within SD1's service area will be impacted differently by the increased sewer costs. As introduced above, household income data was collected and examined from the U.S. Census Bureau 2000 American Community Survey. The impacts were estimated on the subset of the population with the lowest range of household income in the service area in order to gain perspective on the potential impacts to this vulnerable segment of the population. The seven lowest income communities (approximately 39 percent of the households of the three counties) were defined to gain an understanding of the effects of

[2] US Department of Labor, Bureau of Labor Statistics (ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt)

the residential cost to this group. The number of households and the calculated 2000 MHIs for these seven communities are shown below in Table 2-8.

Table 2-8
Seven Low Income Communities[1]

City	# of Households (2000)	Total Income All Households (2000)	2000 MHI
Bellevue	2,758	$100,804,900	36,550
California	26	975,000	37,500
Dayton	2,200	70,417,600	32,008
Newport	6,975	191,470,725	27,451
Silver Grove	474	15,380,352	32,448
Bromley	342	10,794,546	31,563
Covington	18,257	561,128,895	30,735
Ludlow	1,739	61,750,151	35,509
Total	32,771	$1,012,722,169	$30,903

[1] U.S. Census Bureau 2000 American Community Survey (http://www.census.gov/acs/www/Products/)

Using the CPI escalation method described above, the 2009 income level for the low income communities was calculated to be approximately $38,000.

$$\text{Low Income MHI}_{2009} = \text{Low Income MHI}_{2000} * (1 + \text{CPI})^{(2009-2000)}$$

SD1 customers at this income level have limited disposable income and every additional cost increment for sewer service directly competes for other necessities, such as food and shelter. For residents with income that falls within this group, the calculated wastewater treatment and wet-weather controls cost per household of $1,680, represents approximately 4.4 percent of household income, which would put the burden well above the “High” boundary range of 2 percent for the lower income population of the service area.

3.0 Financial Capability Indicators

The second phase of the assessment involves calculating financial capability indicators. These indicators characterize the community's ability to secure the funding necessary to implement the wastewater treatment and wet-weather controls.

The overall Financial Capability Index is based on six individual indicators that assess debt, socioeconomic, and financial management conditions in the community. These six indicators include:

- Debt Indicators
  - Bond rating
  - Overall net debt as a percent of full market property value
- Socioeconomic Indicators
  - Unemployment rate
  - Median household income
- Financial Management Indicators
  - Property tax revenues as a percent of full market property value
  - Property tax revenue collection rate

The EPA has established guidelines for interpreting these indicators and their associated impact on the overall financial capability of SD1. Table 3-1 identifies EPA guidance for ranking the various indicators. A detailed evaluation of each of these indicators is provided below.

Table 3-1
EPA Rating Criteria for Financial Capability Indicators

Indicator	Strong (3 pts)	Mid-Range (2 pts)	Weak (1 pt)
Bond Rating	AAA-A (S&P) or Aaa-A (Moody's)	BBB (S&P) or Baa (Moody's)	BB-D (S&P) or Ba-C (Moody's)
Overall Net Debt as a % of Full Market Property Value	Below 2%	2% to 5%	Above 5%
Unemployment Rate	More Than 1 Percentage Point Below National Average	Plus/Minus 1 Percentage Point of National Average	More Than 1 Percentage Point Above National Average
Median Household Income	More Than 25% Above Adjusted National Average	Plus/Minus 25% of Adjusted National Average	More Than 25% Below Adjusted National Average
Property Tax Revenues as a % of Full Market Property Value	Below 2%	2% to 4%	Above 4%
Property Tax Revenue Collection Rate	Above 98%	94% to 98%	Below 94%

3.1 Debt Indicators

The USEPA debt indicators were used to assess the current debt burden of SD1 and its ability to issue additional debt to finance the proposed wastewater treatment and wet-weather projects. The indicators include SD1's bond rating and the overall net debt as a percent of full market property value.

3.1.1 Bond Rating

SD1's Revenue Bond debt has been rated AA by Standard & Poors Corporation and Aa2 by Moody's. These ratings were received in 2010.

A credit rating of AAA, AA or Aaa places SD1 in "Strong" on this measure, based on the EPA indicator ranges shown below, and detailed in Attachment 1.

Bond Rating Indicator	Bond Rating
Strong	AAA, Aaa, AA, A
Mid-Range	BBB, Baa
Weak	BB, Ba, B, CCC, Caa, CC, Ca, C, D

3.1.2 Overall Net Debt as a Percent of Full Market Property Value

The EPA defines overall net debt as debt repaid by property taxes. It excludes debt that is repaid by special user fees (e.g., revenue debt). This indicator provides a measure of the debt burden on residents within the service area, measures the ability of the municipalities within the service area to issue additional debt, and includes the debt issued directly by the municipalities within the service area as well as debt of overlapping entities, such as school districts. This indicator compares the level of debt owed by the municipalities with the full market value of the real property used to support that debt and serves as a measure of the financial wealth of SD1's service region.

A summary of the net debt and full market property values for municipalities within the service area from 2005 to 2007 is shown in Table 3-2 and detailed in Attachment 1.

Table 3-2
Overall Net Debt as a Percentage of Full Market Property Value ($s)

Direct Net Debt	$ 267,330,968
Debt of Overlapping Entities	0
Overall Net Debt	267,330,968
Market Value of Property	16,185,436,998
Overall Net Debt as a % of Full Market Property Value	1.7%

Source: Direct Net Debt information from 2005-2007 CAFRs of communities with available information and Market Value of Property information from PVA offices of Kenton and Campbell County.

The overall net debt as a percentage of full market property value was calculated to be 1.7 percent, and places SD1 in the "Strong" range on this measure, based on the EPA indicator ranges shown below.

Net Debt Indicator	Net Debt as % of Full Market Property Value
Strong	Less than 2% Net Debt
Mid-Range	Between 2% and 5% Net Debt
Weak	Greater than 5% Net Debt

3.2 Socioeconomic Indicators

Socioeconomic indicators were calculated as an indicator of the economic well being of SD1 residential customers. The two socioeconomic indicators considered, per the EPA guidance document, were the unemployment rate and median household income.

3.2.1 Unemployment Rate

The average annual unemployment rate for the service area and the nation was reviewed for the period of 2004 through 2010. A comparison of these statistics is presented in Table 3-3.

Table 3-3
Unemployment Rate Comparison

Year	National (%)	Northern Kentucky (%)	Difference From National Average (%)
2004	5.5%	5.3%	0.2
2005	5.1%	5.3%	0.2
2006	4.6%	5.2%	0.6
2007	4.6%	5.0%	0.4
2008	5.8%	5.8%	0.0
2009	9.3%	9.3%	0.0
2010	9.6%	9.4%	(0.2)
Average	5.12%	5.32%	0.2

Source: U.S. Bureau of Labor Statistics

For the purposes of the assessment, the 2009 unemployment rate status for the Northern Kentucky region was used as a proxy for SD1's service area. The statistics show that the region's unemployment rate is consistently within one percentage point of the national average. In 2009, the average regional unemployment rate differed from the national average by 0.0 percent. The 2009 average annual unemployment rate statistics were used in this assessment to be consistent with the submittal year of for the first set of watershed plans, although the 2010 information would result in the same rating. Additional detail pertaining to this assessment is provided in Attachment 1.

Using the 2009 average annual unemployment rate of 9.3 percent places the region in the "Mid-Range" on this measure, based on the EPA indicator ranges shown below.

Unemployment Rate Indicator	Unemployment Rate Deviation From National Average
Strong	More Than 1% Below the National Average
Mid-Range	Within 1% of the National Average
Weak	More Than 1% Above the National Average

3.2.2 Median Household Income

The MHI is defined as the median amount of total income received per household during a calendar year in a given area. It serves as an overall indicator of the community's earning capacity. Table 3-4 compares the MHI of SD1 with the national MHI. Additional detail pertaining to this assessment is provided in Attachment 1.

Table 3-4
Sanitation District and National 2009 MHI

District MHI	$55,839
National MHI	$50,221
District MHI as % of National MHI	111%

SD1's adjusted MHI is approximately 111 percent of the adjusted national MHI, placing SD1 in the "Mid-Range" on this measure, based on the EPA indicator ranges shown below.

Median Household Income Indicator	MHI Rate as % of National Average
Strong	More Than 25% Above the Adjusted National MHI
Mid-Range	Within 25% of the Adjusted National MHI
Weak	More Than 25% Below the Adjusted National MHI

3.3 Financial Management Indictors

The USEPA-defined financial management indicators were used to evaluate SD1's overall ability to manage financial operations. These indicators are property tax revenues as a percent of full market property value, and the property tax revenue collection rate. For the purposes of this assessment, the tax revenue statistics for the municipalities within the service area were used to evaluate the financial management indicators.

3.3.1 Property Tax Revenues as a Percent of Full Market Property Value

This indicator is referred to as the "property tax burden" since it indicates the funding capacity available to support debt based on the wealth of the service area. It also indicates the effectiveness of managing community services.

For the 2006 fiscal year, the selected communities within the three counties serviced by SD1 levied real estate taxes ranging from 8 to 47 cents per hundred dollars of assessed valuation. District school property tax and county tax range from 51 to 92 cents and 21 to

28 cents per hundred dollars of assessed property value, respectively. Table 3-5 shows the assessed valuation of real property of the communities within SD1 used in this analysis and the total property tax revenues (includes real estate tax, district school tax, and county tax revenues). Additional detail pertaining to this assessment is provided in Attachment 1.

Table 3-5
Property Tax Revenues as a Percent of Full Market Property Value

Full Market Value of Real Property	$16,185,436,998
District Real Estate Property Tax Revenues[1]	38,263,038
District School Property Tax Revenues[1]	104,949,683
County Tax	41,293,139
Total Property Tax	$184,505,860
Property Tax Revenues as a Percentage of Full Market Property Value	1.14%

[1]SD1's service area

The District's Property Tax Revenues as a Percentage of Full Market Property Value is 1.14 percent, placing SD1 in the "Strong" range on this measure, based on the EPA indicator ranges shown below.

Property Tax Indicator	Property Tax as % of Real Property Value
Strong	Below 2% of the Market Value of Real Property
Mid-Range	Between 2% and 4% of the Market Value of Real Property
Weak	Above 4% of the Market Value of Real Property

3.3.2 Property Tax Revenue Collection Rate

The property tax revenue collection rate is an indicator of the efficiency of the tax collection system and the acceptability of tax levels to residents. Based on available information, a subset of the communities was used to determine this measure. Table 3-6 summarizes the property tax collected and levied within the SD1 service area in fiscal year 2006. Additional detail pertaining to this assessment is provided in Attachment 1.

Table 3-6
Property Tax Revenue Collection Rate

Total Subset District Property Tax Revenue Collected	$22,326,379
Total Subset District Property Tax Levied	$23,391,299
Property Tax Revenue Collection Rate	95.4%

The property tax collection rate in SD1's service area is approximately 95 percent, placing SD1 in the "Mid-Range" on this measure, based on the EPA indicator ranges shown below.

Property Tax Indicator	Property Tax Collection Rate
Strong	Greater Than 98%
Mid-Range	Between 94% and 98%
Weak	Below 94%

3.4 Summary of Financial Capability Indicators

The Financial Capability indicators were compared to the indicator benchmarks provided in the EPA Financial Capability Guidance document, and scored according to these benchmarks. A "Strong" rating was assigned 3 points, a "Mid-Range" rating was assigned 2 points, and a "Weak" rating was assigned 1 point. An overall score was then calculated as the simple average of the six indicator scores. Based on this analysis, SD1 has an overall Financial Capability Indicator score of 2.5, which corresponds to a "Mid-Range" financial capability indicator rating. Table 3-7 provides a summary of the financial indicators, scores associated with each indicator, and the average score for all indicators.

Table 3-7
Summary of Financial Capability Indicators

Indicator	Actual Value	Indicator Range	Score
Bond Rating	AA	Strong	3
Overall Net Debt as a Percent of Full Market Property Value	1.7%	Strong	3
Unemployment Rate	9.30%	Mid-Range	2
Median Household Income	$55,839	Mid-Range	2
Property Tax Revenues as a % of Full Market Property Value	1.14%	Strong	3
Property Tax Revenue Collection Rate	95.4%	Mid-range	2
Overall Financial Capability Indicator Score		**Mid-Range**	**2.5**

4.0 Financial Capability Matrix

The results of the Residential Indicator and the Financial Capability indicators assessment were combined into a Financial Capability Matrix to evaluate the level of financial burden that wastewater treatment and wet-weather control costs may impose on SD1. The matrix is intended to be used by SD1, EPA and KDOW to establish a wet-weather control implementation schedule. However, since wet-weather schedule has already been established by the Consent Decree, the financial capability assessment results provide an indication of the financial burden that will be placed on the service areas as a result of compliance with the Consent Decree. The Financial Capability Matrix is shown in Table 4-1.

Based on a Residential Indicator of 3.02 percent and a Financial Capability Indicator Score of 2.5, the Financial Capability Matrix indicates that implementation of the CD-required controls is a “High Range” burden for SD1, as shown in Table 4-1.

Table 4-1
Financial Capability Matrix

Financial Capability Indicator Score	Residential Indicator (Cost Per Household as a % of MHI)		
(Socioeconomic, Debt and Financial Indicators)	Low (Below 1%)	Mid-Range (Between 1.0 and 2.0%)	High (Above 2.0%)
Weak (Below 1.5)	Medium Burden	High Burden	High Burden
Mid-Range (Between 1.5 and 2.5)	Low Burden	Medium Burden	High Burden
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

5.0 Potential Annual Impacts of a Full System Solution

This section provides an alternative assessment of whether SD1's proposed wastewater treatment and wet-weather programs are "affordable" to SD1 and its customers using additional information relevant to assessing financial capability in addition to the two-phased EPA Financial Capability Assessment method. The method used in this section examines the *annual* cost of wastewater services as a percentage of MHI. In this analysis, the annual rate increases needed based on SD1's estimated annual revenue requirement was determined. The total annual wastewater costs per customer was then divided by the MHI of the North Kentucky region (as a proxy for the service area); the MHI of Boone, Campbell, and Kenton County; the MHI of the City of Newport (which is considered a low income community within the service area) and the low income communities previously defined.

An affordability threshold of wastewater utility costs (or rates) equal to 2.0 percent of the median household income of the service area was employed (based on the 2.0 percent standard typically used by the EPA) for the purpose of assessing the affordability of SD1's proposed wastewater treatment and wet-weather programs. However, it is important to note that using a community-wide affordability threshold does not imply that all customers served by SD1 will be able to "afford" wastewater utility service if the costs (or rates) are below the 2.0 percent threshold. Rather, the threshold is used as means to assess the community's ability to afford the programs as a whole.

5.1 Rate Impacts and Affordability

Historical sewer fund revenues and expenditures were reviewed along with the projected Integrated Plan for 2025 wastewater treatment and wet-weather capital improvement program information to develop a long-term cash flow and rate revenue requirements forecast. SD1's existing long-term financial model and projected required schedule to complete all projected wastewater treatment and wet-weather projects by 2025 was used to estimate the future revenue requirements. These revenue requirements were then used to estimate future sewer rates for residential customers. SD1's financial model is based on the following assumptions:

- Based on SD1's projections, operating expenses were projected to increase by 5.0 percent per year.
- Based on SD1's projections, CIP budgets were projected to increase by 3.0% per year to account for inflation.
- Based on SD1's projections, the rate of future customer growth was estimated to average approximately 720 customers per year from 2008 through 2026.
- The majority of the capital projects, including CSO and SSO projects, were assumed to be funded by revenue bonds, primarily, and the remaining portion with cash reserves and loans.
- An interest rate of 6.0 percent per annum and an amortization term of 30 years were used for Revenue Bond financing.
- An interest rate of 4.0 percent per annum and an amortization term of 20 years were used for State Revolving Loans.
- A debt service coverage target of 150 percent was assumed for all outstanding senior-lien revenue bond debt.

The projected capital program cost and schedule is summarized in Table 5-1 below.

Table 5-1
Projected Capital Program Costs
(Full Program Costs for the Integrated Plan for 2025)

Project Description	Current Project Cost
Total Capital Program	$2.4 Billion
Capital Program Implementation Period	2009 through 2026

5.1.1 Financial Impact on the Median Residential Household

The estimated future revenue requirements associated with the projected capital and O&M program, assuming that the programs are fully implemented over the next 16 years, is shown in Table 5-2 below. The results indicate that significant increases in future revenue requirements (and sewer rates) will be necessary to fund the program. Under the projected capital program, and the assumptions identified above, it is anticipated that the typical customer will pay more than seven times the cost for wastewater utility services than they paid in 2008 once the program is fully implemented in 2026.

Table 5-2
Projected Financial Impact on
Households & Communities within the Service Area

	Fiscal Year	Est. Rate Increase Required [1]	Annual Residential Stormwater Cost[2]	Est. Annual Residential Sewer Cost[3]	Est. Median Household Income (MHI)[4]	MHI Boone County[4]	MHI Campbell County[4]	MHI Kenton County[4]	MHI Newport, KY[5]	MHI Low Income Communities[6]	Residential Cost as a % of MHI	Residential Cost as a % of Boone County MHI	Residential Cost as a % of Campbell County MHI	Residential Cost as a % of Kenton County MHI	Residential Cost as a % of Newport, KY MHI	Residential Cost as a % Low Income Communities MHI
0	FY-2007	15.0%	$48	$275	$55,500	$66,700	$51,400	$50,700	$33,100	$36,300	0.6%	0.5%	0.6%	0.6%	1.0%	0.9%
1	FY-2008	20.0%	$50	$330	$56,100	$66,200	$50,600	$52,600	$33,900	$37,100	0.7%	0.6%	0.8%	0.7%	1.1%	1.0%
2	FY-2009	20.0%	$52	$367	$55,800	$68,400	$50,300	$50,700	$34,700	$38,000	0.8%	0.6%	0.8%	0.8%	1.2%	1.1%
3	FY-2010	15.0%	$53	$370	$57,100	$70,000	$51,500	$51,900	$35,500	$38,900	0.7%	0.6%	0.8%	0.8%	1.2%	1.1%
4	FY-2011	15.0%	$53	$425	$58,400	$71,600	$52,700	$53,100	$36,300	$39,800	0.8%	0.7%	0.9%	0.9%	1.3%	1.2%
5	FY-2012	15.0%	$54	$489	$59,800	$73,300	$53,900	$54,300	$37,100	$40,700	0.9%	0.7%	1.0%	1.0%	1.5%	1.3%
6	FY-2013	15.0%	$55	$562	$61,200	$75,000	$55,100	$55,600	$38,000	$41,600	1.0%	0.8%	1.1%	1.1%	1.6%	1.5%
7	FY-2014	15.0%	$57	$646	$62,600	$76,700	$56,400	$56,900	$38,900	$42,600	1.1%	0.9%	1.2%	1.2%	1.8%	1.7%
8	FY-2015	15.0%	$58	$743	$64,000	$78,500	$57,700	$58,200	$39,800	$43,600	1.3%	1.0%	1.4%	1.4%	2.0%	1.8%
9	FY-2016	15.0%	$59	$855	$65,500	$80,300	$59,000	$59,500	$40,700	$44,600	1.4%	1.1%	1.5%	1.5%	2.2%	2.0%
10	FY-2017	15.0%	$60	$983	$67,000	$82,200	$60,400	$60,900	$41,600	$45,600	1.6%	1.3%	1.7%	1.7%	2.5%	2.3%
11	FY-2018	15.0%	$61	$1,131	$68,600	$84,100	$61,800	$62,300	$42,600	$46,700	1.7%	1.4%	1.9%	1.9%	2.8%	2.6%
12	FY-2019	15.0%	$62	$1,300	$70,200	$86,000	$63,200	$63,700	$43,600	$47,800	1.9%	1.6%	2.2%	2.1%	3.1%	2.9%
13	FY-2020	15.0%	$64	$1,495	$71,800	$88,000	$64,700	$65,200	$44,600	$48,900	2.2%	1.8%	2.4%	2.4%	3.5%	3.2%
14	FY-2021	15.0%	$65	$1,720	$73,500	$90,000	$66,200	$66,700	$45,600	$50,000	2.4%	2.0%	2.7%	2.7%	3.9%	3.6%
15	FY-2022	12.5%	$66	$1,934	$75,200	$92,100	$67,700	$68,200	$46,700	$51,200	2.7%	2.2%	3.0%	2.9%	4.3%	3.9%
16	FY-2023	12.5%	$68	$2,176	$76,900	$94,200	$69,300	$69,800	$47,800	$52,400	2.9%	2.4%	3.2%	3.2%	4.7%	4.3%
17	FY-2024	5.0%	$69	$2,285	$78,700	$96,400	$70,900	$71,400	$48,900	$53,600	3.0%	2.4%	3.3%	3.3%	4.8%	4.4%
18	FY-2025	4.5%	$70	$2,388	$80,500	$98,600	$72,500	$73,100	$50,000	$54,800	3.1%	2.5%	3.4%	3.4%	4.9%	4.5%
19	FY-2026	0.0%	$72	$2,388	$82,400	$100,900	$74,200	$74,800	$51,200	$56,100	3.0%	2.4%	3.3%	3.3%	4.8%	4.4%

[1]Estimated rate increase as projected by the Sanitation District.

[2]Rates calculated by the Sanitation District based on estimated quarterly stormwater rate.

[3]Estimated annual residential customer costs based on quarterly consumption of 27 ccf billed in 2007 and 2008; 24 ccf in 2009; and 21 ccf thereafter. Reduction reflects actual billing usage reduction of residential customers.

[4]MHI for 2007, 2008, and 2009 based on U.S. Census Amerian Community. MHI escalated by CPI of 2.31% per year rounded to nearest $100.

[5]MHI escalated by CPI of 2.31% per year, rounded to nearest $100.

[6]MHI escalated by CPI of 2.31% per year, rounded to nearest $100. 2007 MHI escalated by select populations from tri-county 2000 MHI ($33,031) using the CPI of 2.31%.

As shown in Table 5-2 above, and in Figures 5-1 through 5-6, below, it is anticipated that the cost per residential customer for each of the communities will exceed the 2.0 percent affordability threshold as summarized below:

- Median Household Income within SD1 service area - exceeds 2.0% of MHI in FY-2020
- Boone County - exceeds 2.0% of MHI in FY-2021
- Campbell County - exceeds 2.0% of MHI in FY-2019
- Kenton County - exceeds 2.0% of MHI in FY-2019
- Newport - exceeds 2.0% of MHI in FY-2015
- Low Income Communities - exceeds 2.0% of MHI in FY-2016

Figures 5-1 to 5-6 below graphically represent the cost for wastewater utility services, in the identified service area, as a percentage of that service area's projected MHI.

Figure 5-1
Affordability of Residential Wastewater Rates
Areawide - Sanitation District #1 of Northern Kentucky

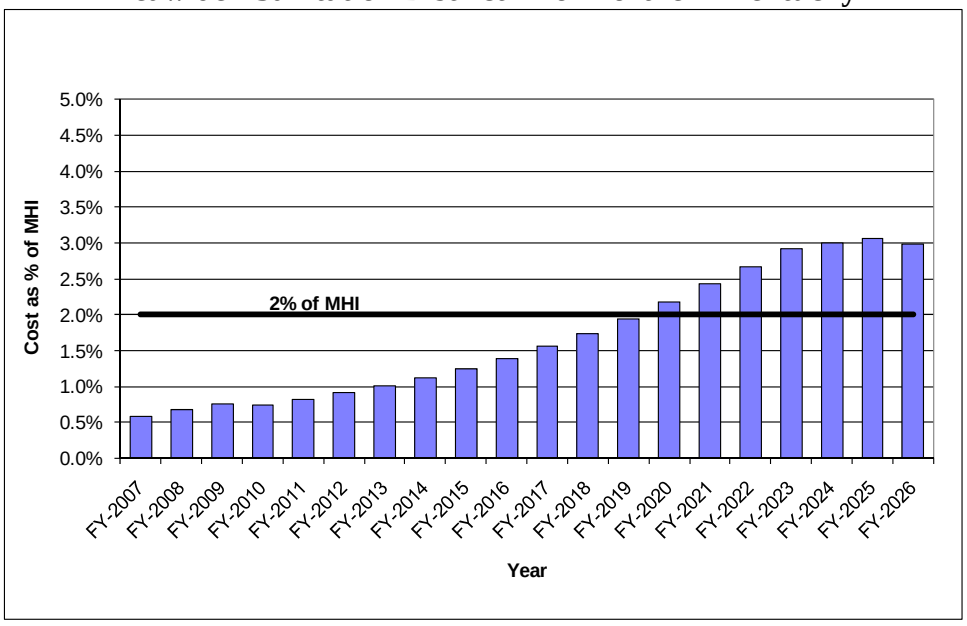


Figure 5-2
Affordability of Residential Wastewater Rates
Boone County

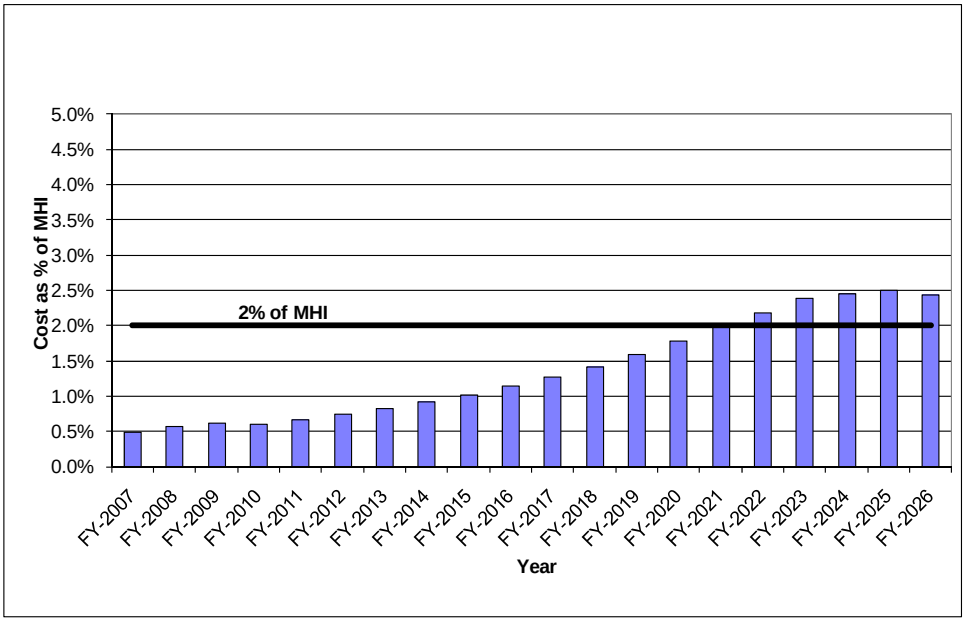


Figure 5-3
Affordability of Residential Wastewater Rates
Campbell County

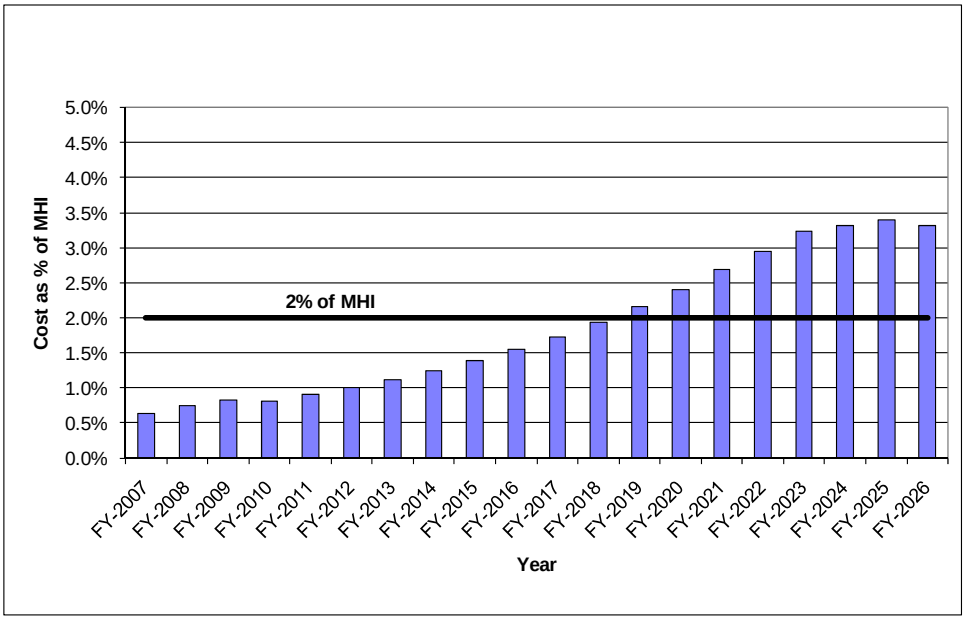


Figure 5-4
Affordability of Residential Wastewater Rates
Kenton County

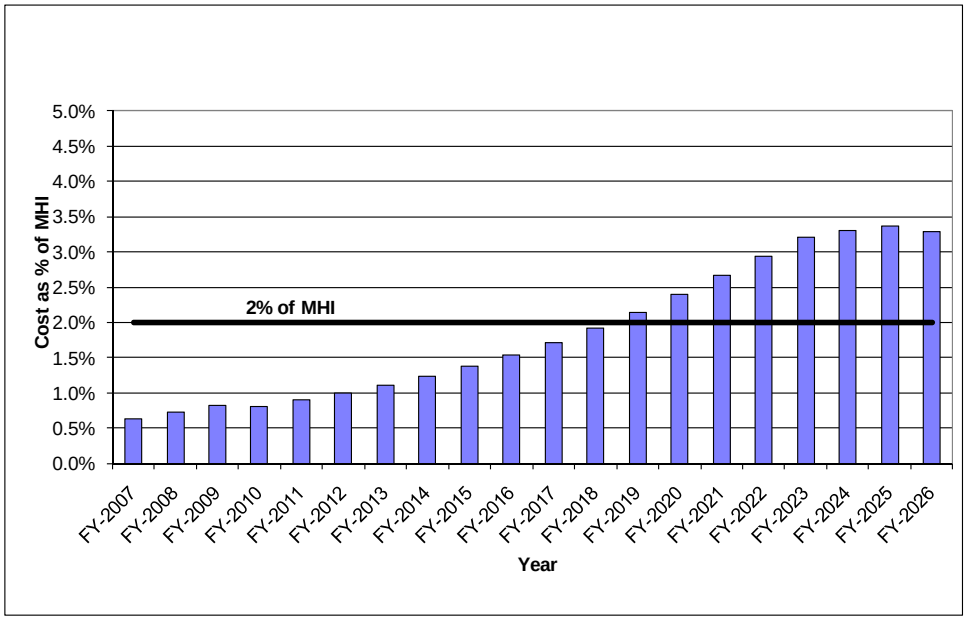


Figure 5-5
Affordability of Residential Wastewater Rates
City of Newport

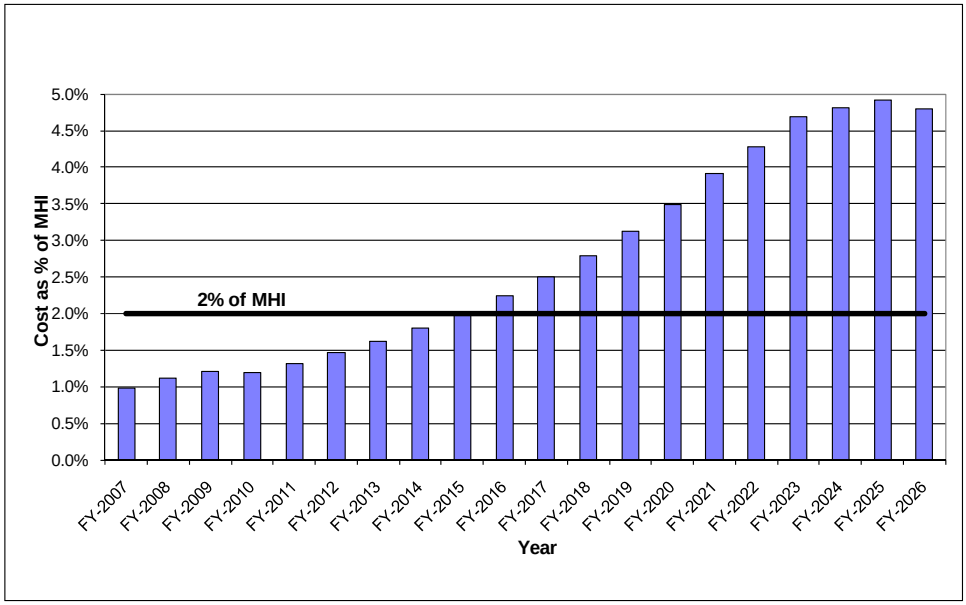
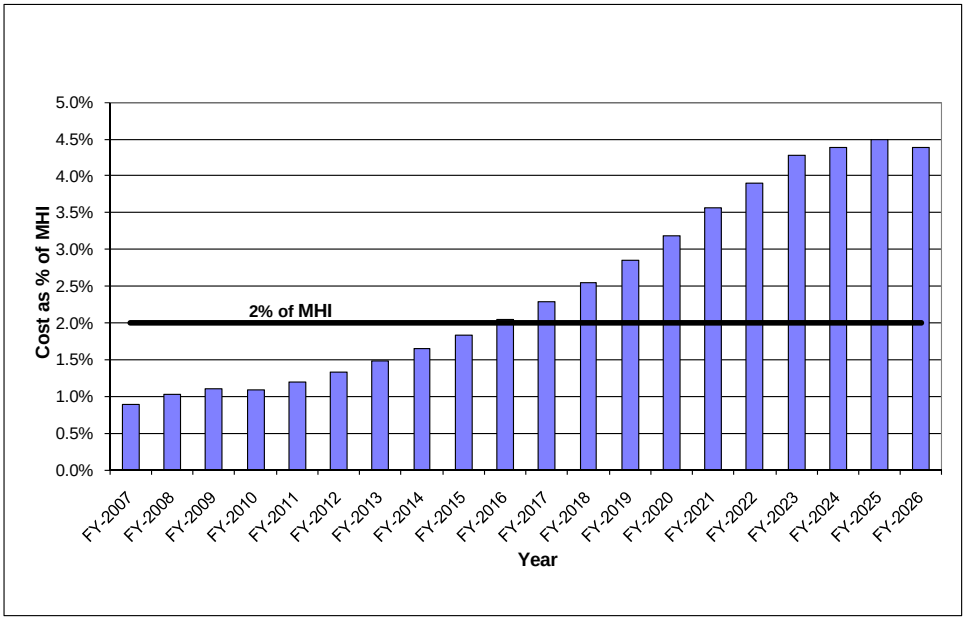


Figure 5-6
Affordability of Residential Wastewater Rates
Low Income Communities



Attachment 1

Financial Capability Assessment
Backup Information

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Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ASSESSMENT - PHASE 1 THE RESIDENTIAL INDICATOR
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 1: CALCULATION OF COST PER HOUSEHOLD

Description			Amount	Backup Reference	EPA Line No.	Source
Current and Projected Wastewater Treatment and Wet-Weather Control Costs:						
Current WWT and Wet-Weather Control Costs:						
Annual O&M Expense (excluding Depreciation)			$ 24,945,851	*A*	100	SD1's FY-2009 budgeted Expenditures.
Annual Debt Service (Principal & Interest)			18,793,350	*B*	101	2009 Debt service from schedule provided by the SD1
Subtotal			$ 43,739,201		102	Calculation
Projected WWT and Wet-Weather Control Costs:						
Annual Incremental O&M Expense			$ 26,562,893	*C*	103	Annual cost of O&M for Western Regional, Integrated Solution, and potential future effluent limits.
Capital Cost of WWT, CSO Controls, SSO Controls, Asset Management	$2,417,000,000			*D*		Capital costs of projects from 2010 through 2026 expressed in 2009 dollars. Future costs deflated to current dollars using a deflation rate of 3% per year
Annual Debt Service (Principal & Interest)			$175,592,419		104	Calculation assuming debt is funded at an interest rate 6.0% for 30 years according to SD1.
Subtotal			$ 202,155,312		105	Calculation
Total Current and Projected WWT and Wet-Weather Control Costs			$ 245,894,513		106	
Allocaton of WWT and Wet-Weather Costs to City Customers:						
Wastewater Flow Statistics:						
Total Flow	12,339,551.00	CCF	100.0%			Information based off of records provided by SD1
Total Allocation of WWT and Wet-Weather Control Costs to District Customers			$ 245,894,513			Calculation
Allocaton of WWT and Wet-Weather Costs to District Customers:						
Residential district Flow as a Percentage of Total District Flow			61.6%	*E*		
Residential Share of Total District WWT and Wet-Weather Control Costs			$ 151,509,830		107	Calculation
Determination of WWT and Wet-Weather Cost Per Household:						
Total Number of Residential Accounts in Service Area			89,971	*F*	108	2009 SD1 billed residential accounts
Cost Per Household			**$1,684**		109	

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ASSESSMENT - PHASE 1 THE RESIDENTIAL INDICATOR
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 2: CALCULATION OF THE RESIDENTIAL INDICATOR

Description	Amount	Backup Reference	EPA Line No.	Source
Adjusted Median Household Income Levels				
Using Weighted Average MHI:				
Census Year MHI	$55,839	*G*	201	2009 U.S. Census, American Community Survey Weighted MHI for Boone, Campbell & Kenton Counties
Adjustment Factor	NA		202	Adjustment Calculation (Not Applicable since Census year is 2009)
Adjusted MHI	$55,839		203	2009 Calculation
Annual WWT and Wet-Weather Control Cost Per Household (CPH)	$1,684		204	Calculation
Residential Indicator: (CPH as % of MHI)	**3.02%**		205	Calculation

Analysis of the Residential Indicator **High**

Financial Impact	Residential Indicator (CPH as % MHI)
Low	Less than 1.0 Percent of MHI
Mid-Range	1.0-2.0 Percent of MHI
High	**Greater than 2.0 Percent of MHI**

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ANALYSIS - PHASE 2 - FINANCIAL CAPABILITY INDICATORS
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 3: BOND RATING INDICATOR

Description	Amount	EPA Line No.	Source
Date:	2010		
Rating Agency:	Standard & Poors		SD1 2010 Bond Statements
Rating:	AA	301	
Date:	2010		
Rating Agency:	Moody's		SD1 2010 Bond Statements
Rating:	Aa2	302	
Summary Bond Rating: (Select Most Recent Rating)	AA	303	

Analysis of the Bond Rating Indicator

Bond Rating Indicator	Bond Rating
Strong	**AAA, Aaa, AA, A**
Mid-Range	BBB, Baa
Weak	BB, Ba, B, CCC, Caa, CC, Ca, C, D

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ANALYSIS - PHASE 2 - FINANCIAL CAPABILITY INDICATORS
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 4: OVERALL NET DEBT AS A % OF FULL MARKET PROPERTY VALUE

Description	Amount	Backup Reference	EPA Line No.	Source
Direct Net Debt (Excludes Revenue and Double Barrel bonds)	$ 267,330,968	*H*	401	Source: 2005-2007 CAFR of selected communities. Used an average debt per customer for several communities without direct net debt info.
Debt of Overlapping Entities				
Total Debt of Overlapping Entities	$ -		402	None
Overall Net Debt	$ 267,330,968		403	
Market Value of Property	$ 16,185,436,998	*I*	404	(Full Market Value of Property Within Communities in Kenton, Campbell and Boone County). Info from Property Valuation Administration (PVA) office in Kenton and Campbell County and the Florence CAFR. Excludes: Walton, Union, Latonia Lakes, Mentor, Fairview, Kenton Vale, Ryland Heights, Visalia Includes Taxable Property only.
Overall Net Debt as a % of Full Market Property Value	1.7%		405	

Analysis of the Net Debt Indicator Strong

Net Debt Indicator	Net Debt as % of Full Market Property Value
Strong	**Less than 2% Net Debt**
Mid-Range	Between 2% and 5% Net Debt
Weak	Greater than 5% Net Debt

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ANALYSIS - PHASE 2 - FINANCIAL CAPABILITY INDICATORS
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 5: UNEMPLOYMENT RATE ANALYSIS

Description	Amount	Backup Reference	EPA Line No.	Source
			EPA Line No.	
Unemployment Rate for Areas Served:	9.30%	*J*	501	Bureau of Labor Statistics, Cincinnati - Middletown (N. KY), 2009 Unemployment Rate (Information is not exclusive to SD1's service area, best information available)
State Unemployment Rate:	10.70%	*K*	502	Bureau of Labor Statistics, Kentucky, 2009 Unemployment Rate
Average National Unemployment Rate:	9.30%	*L*	503	Bureau of Labor Statistics, National, 2009 Unemployment Rate
Area Rate Difference From National Average	0.00%			Calculation
Analysis of the Unemployment Rate Indicator	Mid-Range			

Unemployment Rate Indicator	Unemployment Rate Deviation From National Average
Strong	More Than 1% Below the National Average
Mid-Range	**Within 1% of the National Average**
Weak	More Than 1% Above the National Average

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ANALYSIS - PHASE 2 - FINANCIAL CAPABILITY INDICATORS
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 6: MEDIAN HOUSEHOLD INCOME

Description	Amount	Backup Reference	EPA Line No.	Source
Adjusted Median Household Income:	$ 55,839		601	2009 U.S. Census, American Community Survey Weighted MHI for Boone, Campbell & Kenton Counties
Benchmark: Census Year National MHI:	$ 50,221	*M*	602	2009 U.S. Census, American Community Survey
MHI Adjustment Factor:	NA		603	Adjustment not applicable since Census data is 2009
Adjusted National MHI:	$ 50,221		604	Calculation to adjust National data to 2009.
Area MHI as a % of Adjusted National Average:	111.2%			
Analysis of the Median Household Income Indicator	Mid-Range			

Median Household Income Indicator	MHI Rate as % of National Average
Strong	More Than 25% Above the Adjusted National MHI
Mid-Range	**Within 25% of the Adjusted National MHI**
Weak	More Than 25% Below the Adjusted National MHI

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ANALYSIS - PHASE 2 - FINANCIAL CAPABILITY INDICATORS
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 7: PROPERTY TAX REVENUES AS A PERCENTAGE OF FULL MARKET PROPERTY VALUE

Description	Amount	Backup Reference	EPA Line No.	Source
Full Market Value of Real Property:	$16,185,436,998	*I*	701	2007 Property Tax information provided by County Property Valuation Administration (PAV) in select communities in Kenton, Campbell and Boone County
Total Property Tax Revenues (current year' property tax revenues):	$184,505,860	*N*	702	2006 Residential tax rates from County websites and 2006/2007 Assessed Property Value (APV) (town, county and school district)
Property Tax Revenue as a % of Full Market Property Value:	1.14%		703	Calculation
Analysis of the Property Tax Revenue as % of Property Value Indicator	Strong			

Property Tax Indicator	Property Tax as % of Real Property Value
Strong	**Below 2% of the Market Value of Real Property**
Mid-Range	Between 2% and 4% of the Market Value of Real Property
Weak	Above 4% of the Market Value of Real Property

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ANALYSIS - PHASE 2 - FINANCIAL CAPABILITY INDICATORS
March 31, 2011 Affordability Study for the Watershed Plans
WORKSHEET 8: PROPERTY TAX REVENUE COLLECTION RATE

Description	Amount	Backup Reference	EPA Line No.	Source
Property Tax Revenue Collected:	$22,326,379	*O*	801	2006 Residential tax rates from County websites and 2006/2007 Assessed Property Value (APV)
Property Tax Levied	$23,391,299	*P*	802	Obtained from CAFR information 2005-2007 of available communities
Property Tax Revenue Collection Rate	95.4%		803	

Analysis of the Property Tax Revenue Collection Rate Indicator Mid-Range

Property Tax Indicator	Property Tax Collection Rate
Strong	Greater Than 98%
Mid-Range	**Between 94% and 98%**
Weak	Below 94%

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ASSESSMENT
March 31, 2011 Affordability Study for the Watershed Plans
SUMMARY OF FINANCIAL CAPABILITY ASSESSMENT RESULTS

Indicator	Actual Value	Indicator Range	Score	EPA Line No.
Summary of Community Financial Capability Indicators				
Bond Rating	AA	**Strong**	3	901
Overall Net Debt as a Percent of Full Market Property Value	1.7%	**Strong**	3	902
Unemployment Rate	9.30%	**Mid-Range**	2	903
Median Household Income	$55,839	**Mid-Range**	2	904
Property Tax Revenues as a % of Full Market Property Value	1.14%	**Strong**	3	905
Property Tax Revenue Collection Rate	95.4%	**Mid-Range**	2	906
Overall Financial Capability Indicators Score (Average)		**Mid-Range**	**2.50**	907
Financial Capability Matrix Score				
Residential Indicator Score:	3.02%			1001
Residential Indicator Range:		**High**		
Financial Capibility Indicator Score	2.50			1002
Financial Capability Matrix Category (Financial Impact)		**High Burden**		1003

Sanitation District No. 1 of N. Kentucky
EPA CSO FINANCIAL CAPABILITY ASSESSMENT
March 31, 2011 Affordability Study for the Watershed Plans
FINANCIAL CAPABILITY MATRIX (EPA TABLE 3)

Permittee Financial Capability Indicators Score (Socioeconomic, Debt and Financial Indicators)	**Residential Indicator (Cost Per Household as a % of MHI)**		
	Low (Below 1%)	Mid-Range (Between 1.0 and 2.0%)	High (Above 2.0%)
Weak (Below 1.5)	Medium Burden	High Burden	High Burden
Mid-Range (Between 1.5 and 2.5)	Low Burden	Medium Burden	**High Burden**
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

CSO SCHEDULE DEVELOPMENT GUIDELINES -
BASED ON FINANCIAL CAPABILITY (EPA TABLE 5)

Financial Capability Matrix Category	Implementation Period
Low Burden	Normal Engineering/Construction
Medium Burden	Up to 10 Years
High Burden	**Up to 15 Years***

*Schedule up to 20 years based on negotiation with EPA and state NPDES authorities.

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans

Historical and Budgeted Operating Expenses

Breakdown of O&M Categories	**FY 2005 ACTUAL**	**FY 2006 ACTUAL**	**FY 2007 ACTUAL**	**FY 2008 ACTUAL**	**FY 2009 ACTUAL**		**FY 2010 ACTUAL**
Personnel	11,703,405	12,479,142	14,329,129	16,314,623	17,221,552		18,076,356
Contract Services	(646,401)	(3,058,929)	(3,324,263)	(2,952,716)	(2,967,393)		(2,652,888)
Administrative & Office Operations	772,719	903,437	959,657	1,301,430	1,347,221		1,743,400
Utilities, Fuel Oil & Chemicals	4,414,529	5,564,287	5,929,620	6,595,897	6,551,355		7,198,146
Vehicle Operations	627,341	842,508	932,181	1,216,855	1,037,133	***Backup***	1,096,655
Miscellaneous	1,487,583	2,313,736	1,637,978	8,008,645	1,755,983	***Reference***	2,655,675
Total O&M Expenses:	$ 18,359,175	$ 19,044,181	$ 20,464,302	$ 30,484,734	**$ 24,945,851**	***A***	$ 28,117,344

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans

Determination of Debt Service Allocable to Utility System

Data Source: SD1 2010 Proforma v3.4 2-10-2011 spreadsheet

Line No.	Description	Percent Wastewater	Percent Other	Fiscal Year Ending June 2005	2006	2007	2008	2009
	EXISTING DEBT SERVICE							
1	Series 1998 A Revenue Bonds	100%	0%	4,422,300	2,661,244	2,656,638	2,656,806	2,651,513
	Series 2001 A Revenue Bonds	100%	0%	3,440,650	3,418,713	3,413,938	3,407,363	3,398,988
	Series 2005 A Revenue Bonds (1998A Refinance)	100%	0%	-	826,700	1,647,500	1,647,900	1,647,900
	Series 2006 A Revenue Bonds	100%	0%	-	-	721,318	2,163,954	3,025,034
	FY 2007 A Series Bonds	100%	0%	-	-	-	837,458	5,843,050
	KY Infrastructure Auth.- Melbourne	100%	0%	57,060	56,904	345,785	-	-
	GE Capital Corp - Cresent Spring	100%	0%	3,937	43,000	-	-	-
	KIA Eastern Regional WRF	100%	0%	7,218	133,190	481,952	1,437,283	2,226,866
	KIA Western Regional WRF	100%	0%	-	-	-	-	-
	Total			$ 7,931,165	$ 7,139,750	$ 9,267,130	$ 12,150,763	$ 18,793,350
	SRF Western Regional Plant Construction Loan	100%	0%	-	-	-	-	-
	DCWWTP Clarifier Construction Loan	100%	0%	-	-	-	-	-
		100%	0%	-	-	-	-	-
	Total			$ -	$ -	$ -	$ -	$ -
	PROPOSED DEBT SERVICE							
	FY 2010 Series Bonds	100%	0%	-	-	-	-	-
	FY 2011 Series Bonds	100%	0%	-	-	-	-	-
	FY 2012 Series Bonds	100%	0%	-	-	-	-	-
	FY 2013 Series Bonds	100%	0%	-	-	-	-	-
	FY 2014 Series Bonds	100%	0%	-	-	-	-	-
	FY 2015 Series Bonds	100%	0%	-	-	-	-	-
				$ -	$ -	$ -	$ -	$ -
	TOTAL DEBT SERVICE			$ 7,931,165	$ 7,139,750	$ 9,267,130	$ 12,150,763	**$ 18,793,350**
								B

Backup Reference

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans

Incremental O&M Cost (Annual)

Western Regional O&M	$	3,807,154		Annualized to FY-2009
CSO Control Projects				
Green Tier 1 Projects	$	2,570,549		
Green Programs in CSS	$	839,182		
Gray Projects to meet targeted LOC	$	5,316,728		
SSO Control Projects				
Gray Projects to meet 2-yr LOS	$	2,150,693		
Potential Future Effluent Limits - Dry Creek	$	3,860,000		
Potential Future Effluent Limits - Eastern Regional	$	105,000		
Potential Future Effluent Limits - Western Regional	$	980,000		
Watershed and Programmatic Projects				
Source Identification Program Decentralized Projects	$	232,044		
Green Programs and Projects in SSS	$	166,455		
Stormwater BMPs in RDII Basins	$	3,566,178		
Facility Planning Projects	$	2,968,910		
Total for Calculation	$	26,562,893	**C**	***Backup Reference***

Capital Improvement Program Summary

Line No.	Project	Fiscal Year Ending June 2010	2011	2012	2013	2014
1	High Priority Sewer Projects (Van Deren, Covert Run, Highland Pike)	6,498,572	817,000	2,750,000	-	-
2	Pump Station Back-up Power	1,114,241	450,000	646,000	678,000	801,000
3	Solids & Floatables Control Program	925,948	300,000	300,000	300,000	300,000
4	Capacity Management Operation Maintenance Program	1,002,203	1,455,000	1,528,000	1,604,000	1,684,000
5	Consent Decree Planning, Implementation & Management	2,496,599	1,592,000	1,444,000	1,922,000	4,764,000
6	Improvements at Dry Creek Wastewater Treatment Plant and Other Plant	8,130,458	8,550,000	1,842,000	1,637,000	8,592,000
7	Pump Station Projects	3,454,145	3,561,000	4,415,000	2,511,000	945,000
8	On-going Sewer Rehabilitation/Repair Projects	12,925,325	10,477,000	7,908,000	8,048,000	7,828,000
9	Storm Sewer Rehabilitation/Repair	1,542,169	4,679,000	1,988,000	1,400,000	1,400,000
10	Capital Purchases (vehicles, construction equipment, etc.)	1,130,363	1,718,000	1,801,000	1,020,000	903,000
11	Western Regional Projects	111,231,075	91,803,000	40,810,000	14,605,000	15,000
12	Eastern Regional Projects	249,553	450,000	300,000	1,723,000	-
13	5-Year System-wide and Basin Projects (including RWI)	4,318,291	14,412,000	30,617,000	28,015,000	23,726,000
14	CSO Control Projects	-	-	-	-	-
15	SSO Control Projects	-	-	-	-	-
16	Potential Future Effluent Limits	-	-	-	-	-
17	Watershed and Programmatic Projects	-	-	-	-	-
18	Public Structural Rehabilitation	-	-	-	-	-
19	Facility Planning Projects	-	-	-	-	-
20	SD1 Adjustments for FY-10 Actual CIP	(8,860,067)	-	-	-	-
	TOTAL CAPITAL IMPROVEMENT COSTS	**$ 146,158,873**	**$ 140,264,000**	**$ 96,349,000**	**$ 63,463,000**	**$ 50,958,000**

Current Value of FY-2010 to FY-2026 = $2,417,000,000 *D*

Backup Reference

Inflation/Deflation Rate: 3.00%

Sanitation District No. 1 of N. Kentucky
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Capital Improvement Program Summary

Line No.	Project	2015	2016	2017	2018	2019
1	High Priority Sewer Projects (Van Deren, Covert Run, Highland Pike)	-	-	-	-	-
2	Pump Station Back-up Power	888,000	-	-	-	-
3	Solids & Floatables Control Program	300,000	318,000	328,000	338,000	348,000
4	Capacity Management Operation Maintenance Program	1,768,000	1,787,000	1,841,000	1,896,000	1,953,000
5	Consent Decree Planning, Implementation & Management	2,894,000	1,845,000	1,674,000	2,228,000	5,523,000
6	Improvements at Dry Creek Wastewater Treatment Plant and Other Plant	1,690,000	1,803,000	1,857,000	1,912,000	2,251,000
7	Pump Station Projects	1,495,000	1,030,000	1,061,000	1,093,000	1,126,000
8	On-going Sewer Rehabilitation/Repair Projects	2,228,000	2,295,000	2,364,000	2,435,000	2,508,000
9	Storm Sewer Rehabilitation/Repair	1,400,000	1,442,000	1,485,000	1,530,000	1,576,000
10	Capital Purchases (vehicles, construction equipment, etc.)	441,000	800,000	820,000	850,000	870,000
11	Western Regional Projects	15,000	-	-	-	-
12	Eastern Regional Projects	-	-	-	-	-
13	5-Year System-wide and Basin Projects (including RWI)	6,863,000	1,601,000	2,142,000	1,927,000	1,776,000
14	CSO Control Projects	2,070,000	19,541,000	64,498,000	58,672,000	49,844,000
15	SSO Control Projects	41,447,000	42,690,000	58,011,000	48,446,000	37,372,000
16	Potential Future Effluent Limits	-	-	10,958,000	26,226,000	88,900,000
17	Watershed and Programmatic Projects	27,330,000	28,150,000	39,164,000	38,952,000	34,013,000
18	Public Structural Rehabilitation	28,330,000	29,180,000	47,415,000	34,649,000	29,445,000
19	Facility Planning Projects	-	-	-	-	-
20	SD1 Adjustments for FY-10 Actual CIP	-	-	-	-	-
	TOTAL CAPITAL IMPROVEMENT COSTS	**$ 119,159,000**	**$ 132,482,000**	**$ 233,618,000**	**$ 221,154,000**	**$ 257,505,000**

Capital Improvement Program Summary

Line No.	Project	2020	2021	2022	2023	2024
1	High Priority Sewer Projects (Van Deren, Covert Run, Highland Pike)	-	-	-	-	-
2	Pump Station Back-up Power	-	-	-	-	-
3	Solids & Floatables Control Program	358,000	369,000	380,000	391,000	403,000
4	Capacity Management Operation Maintenance Program	2,011,000	2,072,000	2,134,000	2,198,000	2,264,000
5	Consent Decree Planning, Implementation & Management	3,355,000	2,139,000	1,940,000	2,582,000	6,403,000
6	Improvements at Dry Creek Wastewater Treatment Plant and Other Plant	2,319,000	2,388,000	2,460,000	2,534,000	2,610,000
7	Pump Station Projects	1,159,000	1,194,000	1,230,000	1,267,000	1,305,000
8	On-going Sewer Rehabilitation/Repair Projects	2,583,000	2,660,000	2,740,000	2,822,000	2,907,000
9	Storm Sewer Rehabilitation/Repair	1,623,000	1,672,000	1,722,000	1,774,000	1,827,000
10	Capital Purchases (vehicles, construction equipment, etc.)	900,000	930,000	960,000	980,000	1,010,000
11	Western Regional Projects	-	-	-	-	-
12	Eastern Regional Projects	-	-	-	-	-
13	5-Year System-wide and Basin Projects (including RWI)	-	-	-	-	-
14	CSO Control Projects	22,147,000	18,820,000	21,527,000	104,461,000	162,814,000
15	SSO Control Projects	38,158,000	147,609,000	152,841,000	48,304,000	18,613,000
16	Potential Future Effluent Limits	98,973,000	73,284,000	16,448,000	-	-
17	Watershed and Programmatic Projects	36,333,000	45,242,000	7,476,000	1,569,000	1,616,000
18	Public Structural Rehabilitation	30,341,000	37,889,000	22,469,000	-	-
19	Facility Planning Projects	-	-	6,995,000	46,379,000	158,442,000
20	SD1 Adjustments for FY-10 Actual CIP	-	-	-	-	-
	TOTAL CAPITAL IMPROVEMENT COSTS	**$ 240,260,000**	**$ 336,268,000**	**$ 241,322,000**	**$ 215,261,000**	**$ 360,214,000**

Capital Improvement Program Summary

Line No.	Project	2025	2026	Total
1	High Priority Sewer Projects (Van Deren, Covert Run, Highland Pike)	-	-	10,065,572
2	Pump Station Back-up Power	-	-	4,577,241
3	Solids & Floatables Control Program	415,000	428,000	6,501,948
4	Capacity Management Operation Maintenance Program	2,332,000	2,402,000	31,931,203
5	Consent Decree Planning, Implementation & Management	3,890,000	2,480,000	49,171,599
6	Improvements at Dry Creek Wastewater Treatment Plant and Other Plant	2,688,000	2,768,000	56,031,458
7	Pump Station Projects	1,344,000	1,384,000	29,574,145
8	On-going Sewer Rehabilitation/Repair Projects	2,994,000	3,084,000	78,806,325
9	Storm Sewer Rehabilitation/Repair	1,882,000	1,938,000	30,880,169
10	Capital Purchases (vehicles, construction equipment, etc.)	1,040,000	1,080,000	17,253,363
11	Western Regional Projects	-	-	258,479,075
12	Eastern Regional Projects	-	-	2,722,553
13	5-Year System-wide and Basin Projects (including RWI)	-	-	115,397,291
14	CSO Control Projects	135,213,000	44,982,000	704,589,000
15	SSO Control Projects	2,449,000	3,436,000	639,376,000
16	Potential Future Effluent Limits	-	-	314,789,000
17	Watershed and Programmatic Projects	1,664,000	1,714,000	263,223,000
18	Public Structural Rehabilitation	-	-	259,718,000
19	Facility Planning Projects	124,879,000	64,313,000	401,008,000
20	SD1 Adjustments for FY-10 Actual CIP	-	-	(8,860,067)
	TOTAL CAPITAL IMPROVEMENT COSTS	**$ 280,790,000**	**$ 130,009,000**	**$ 3,265,234,873**

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans

Residential Flow as a Percentage of Total Flow

TOTAL Consumption of District Customers 2006/2007 (CCF)

City	First 65000 Records	Records 65001-99568	Total Consumption
ALEXANDRIA	252,619.00	16,873.00	**269,492.00**
BELLEVUE	209,689.00	-	**209,689.00**
Blank City	139.00	2,938.00	**3,077.00**
BOONE	-	108.00	**108.00**
BROMLEY	-	24,100.00	**24,100.00**
BURLINGTON	-	473,551.00	**473,551.00**
CALIFORNIA	19.00	-	**19.00**
COLD SPRING	206,710.00	502.00	**207,212.00**
COVINGTON	1,420,737.00	239,775.00	**1,660,512.00**
CRESCENT SPRINGS	163,698.00	411.00	**164,109.00**
CRESTVIEW	-	929.00	**929.00**
CRESTVIEW HILLS	156,255.00	-	**156,255.00**
DAYTON	184,721.00	-	**184,721.00**
EDGEWOOD	325,595.00	-	**325,595.00**
ELSMERE	208,979.00	-	**208,979.00**
ERLANGER	705,042.00	96,776.00	**801,818.00**
FLORENCE	375,151.00	2,126,760.00	**2,501,911.00**
FT MITCHELL	313,246.00	-	**313,246.00**
FT THOMAS	557,499.00	-	**557,499.00**
FT WRIGHT	256,914.00	-	**256,914.00**
HEBRON	-	896,693.00	**896,693.00**
HIGHLAND HEIGHTS	209,029.00	12,065.00	**221,094.00**
INDEPENDENCE	437,681.00	129,857.00	**567,538.00**
LAKESIDE PARK	125,580.00	-	**125,580.00**
LUDLOW	44.00	146,733.00	**146,777.00**
MELBOURNE	20,395.00	-	**20,395.00**
NEWPORT	644,795.00	-	**644,795.00**
PARK HILLS	110,972.00	-	**110,972.00**
RICHWOOD	-	1,314.00	**1,314.00**
SILVER GROVE	28,802.00	-	**28,802.00**
SOUTHGATE	114,847.00	-	**114,847.00**
TAYLOR MILL	17,316.00	259,287.00	**276,603.00**
UNION	-	326,049.00	**326,049.00**
VILLA HILLS	279,431.00	94.00	**279,525.00**
WALTON	125.00	135,651.00	**135,776.00**
WILDER	115,032.00	-	**115,032.00**
WOODLAWN	8,023.00	-	**8,023.00**
GRND TOTAL	**7,449,085.00**	**4,890,466.00**	**12,339,551.00**

Residential **7,603,111**

Backup Reference

% residential ***61.6%*** ***E***

Sanitation District No.1 of N. Kentucky
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Sanitary Sewer (SN) Revenue Summary

Charges only for FY 2006					Approximate Averages		
RIC Code	* Accnts	%	Revenues	%	HCF/Qtr.	Rev Acct/Qtr.	Rev Acct/Yr.
R	83,937	88.8%	$ 16,934,235	67.7%	22.8	$ 50.44	$ 201.75
I	1,147	1.2%	$ 761,783	3.0%	79.0	$ 166.02	$ 664.08
C	5,247	5.5%	$ 4,838,508	19.3%	112.0	$ 230.52	$ 922.06
Other	1,515	1.6%	$ 1,988,614	8.0%	162.1	$ 328.17	$ 1,312.66
Blank	2,723	2.9%	$ 486,416	1.9%	20.1	$ 44.65	$ 178.62
Totals:	**94,570**	**100.0%**	**$ 25,009,556**	**100.0%**			

Note: Assumes Blank equals RES

*** Accounts Estimate based on FY 2008 Distribution**

Charges only for FY 2007					Approximate Averages		
RIC Code	* Accnts	%	Revenues	%	HCF/Qtr.	Rev Acct/Qtr.	Rev Acct/Yr.
R	85,246	88.8%	$ 19,054,191	68.1%	21.9	$ 55.88	$ 223.52
I	1,165	1.2%	$ 881,644	3.2%	78.1	$ 189.19	$ 756.76
C	5,329	5.5%	$ 5,218,067	18.7%	102.9	$ 244.78	$ 979.12
Other	1,539	1.6%	$ 2,284,201	8.2%	159.4	$ 371.16	$ 1,484.62
Blank	2,766	2.9%	$ 537,342	1.9%	19.0	$ 48.57	$ 194.29
Totals:	**96,045**	**100.0%**	**$ 27,975,446**	**100.0%**			

Note: Assumes Blank equals RES

*** Accounts Estimate based on FY 2008 Distribution**

Partial Charges only for FY 2008					Approximate Averages		
RIC Code	Accounts	%	Revenues	%	HCF/Qtr.	Rev Acct/Qtr.	Rev Acct/Yr.
R	86,489	88.8%	$ 23,724,844	69.7%		$ 68.58	$ 274.31
I	1,182	1.2%	$ 1,073,355	3.2%		$ 227.02	$ 908.08
C	5,407	5.5%	$ 6,135,360	18.0%		$ 283.68	$ 1,134.71
Other	1,561	1.6%	$ 2,483,871	7.3%		$ 397.80	$ 1,591.20
Blank	2,806	2.9%	$ 615,394	1.8%		$ 54.83	$ 219.31
Totals:	**97,445**	**100.0%**	**$ 34,032,824**	**100.0%**			

Note: Assumes Blank equals RES

Residential 89,295
(Residential + Blank = 89,295)

Revised Methodology for residential customers for 2010 according to SD1
90,646

Estimated 2009 Residential Accounts 89,971 ***F*** Calculated average of 2008 and 2010 accounts

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans
US Census & Bureau of Labor Statistics Data:

MHI Year 2009

Backup Reference

City/County	# Households	% of Total Households	2009 MHI
Boone	41,683	30%	$68,369
Campbell	34,544	25%	$50,282
Kenton	63,770	46%	$50,660
Total	139,997	100%	N/A

Weighted average of Boone, Kenton and Campbell Counties from 2009 American Community Survey 1-Year Estimates data set MHI and occupied households at http://factfinder.census.gov, (Information is not exclusive to the service area, but of the entire three counties; best information available).

Weighted Average MHI $55,839 *G* 2009 Weighted calculation

National MHI: $50,221 *M* 2009 Median Household Income (MHI) from 2009 American Community Survey 1-Year Estimates data set at http://factfinder.census.gov
Source US Census Bureau

Bureau of Labor Statistics:

Average Unemployment Rate for Areas Served:
Northern Kentucky SD 1 9.30% *J* Bureau of Labor Statistics 2009 Unemployment Rate, see below

Min Unemployment Rate for Areas Served: 9.30%

State Unemployment Rate: 10.70% *K* Bureau of Labor Statistics 2009 Unemployment Rate, see below

Average National Unemployment Rate: 9.30% *L* Bureau of Labor Statistics 2009 Unemployment Rate, see below

Source Bureau of Labor Statistics

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans
US Census & Bureau of Labor Statistics Data:

Historic Inflation (CPI-U)

United States			OH, KY, IN			South		
Year	Index Point	% Change	Year	Index Point	% Change	Year	Index Point	% Change
1998	163.0		1998	155.1		1998	158.9	
1999	166.6	2.21%	1999	159.2	2.64%	1999	162.0	1.95%
2000	172.2	3.36%	2000	164.8	3.52%	2000	167.2	3.21%
2001	177.1	2.85%	2001	167.9	1.88%	2001	171.1	2.33%
2002	179.9	1.58%	2002	170.0	1.25%	2002	173.3	1.29%
2003	184.0	2.28%	2003	173.4	2.00%	2003	177.3	2.31%
2004	188.9	2.66%	2004	176.5	1.79%	2004	181.8	2.54%
2005	195.3	3.39%	2005	181.6	2.89%	2005	188.3	3.58%
2006	201.6	3.23%	2006	188.8	3.96%	2006	194.7	3.40%
2007	207.342	2.85%	2007	193.892	2.70%	2007	200.361	2.91%
2008	215.303	3.84%	2008	201.543	3.95%	2008	208.681	4.15%
2009	214.537	-0.36%	2009	200.587	-0.47%	2009	207.845	-0.40%
2010	218.056	1.64%	2010	204.729	2.06%	2010	211.338	1.68%
AVERAGE†		**2.56%**			**2.31%**			**2.50%**

Source: US http://data.bls.gov/cgi-bin/surveymost?cu
N. KY region http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?series_id=CUUSA213SA0&data_tool=XGtable
South http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?data_tool=dropmap&series_id=CUUR0300SA0,CUUS0300SA0

Note †: The average takes the last 10 years (2001 to 2010) % change, removes the highest and lowest % change (yellow highlighted values) and averages the remaining eight numbers.

Historic Unemployment

United States		Kentucky		Cincinnati-Middletown (N. KY)	
Year	Rate	Year	Rate	Year	Rate
2001	4.7%	2001	5.2%	2001	4.1%
2002	5.8%	2002	5.7%	2002	5.1%
2003	6.0%	2003	6.3%	2003	5.4%
2004	5.5%	2004	5.5%	2004	5.3%
2005	5.1%	2005	6.0%	2005	5.3%
2006	4.6%	2006	5.7%	2006	5.2%
2007	4.6%	2007	5.5%	2007	5.0%
2008	5.8%	2008	6.5%	2008	5.8%
2009	9.3%	2009	10.7%	2009	9.3%
2010	9.6%	2010	10.4%	2010	9.9%
AVERAGE	**6.78%**		**7.77%**		**7.04%**
Backup Reference	***L***		***K***		***J***

Avg. taken from 2006 to 2010 (5 yr Avg.)

Source: US http://stats.bls.gov/cps/prev_yrs.htm
KY http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?series_id=LASST21000003&data_tool=XGtable
N. KY region http://data.bls.gov/PDQ/servlet/SurveyOutputServlet?series_id=LAUMT39171403&data_tool=XGtable

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans

Taxes Assessed

	2000 Census	Population	Total Assessed property value (APV)	Population x Assessed Property Value (APV)	Real Estate Property Tax	County Tax	School Tax	Total Debt	Net Debt†
	BOONE								
1	Florence	23,551	2,286,422,911	53,847,545,976,961	6,312,539	4,801,488	11,980,856	32,867,659	32,867,659
	CAMPBELL								
2	Alexandria	8,286	536,623,766	4,446,464,525,076	959,483	1,184,865	2,687,948	1,280,311	1,280,311
3	Bellevue	6,480	277,665,147	1,799,270,152,560	767,021	613,085	1,865,910	6,198,312	6,198,312
4	California	86	2,649,173	227,828,878	2,649	5,849	13,484		97,303
5	Cold Spring	3,806	512,764,169	1,951,580,427,214	933,231	1,132,183	2,609,970		4,306,206
6	Crestview	471	18,849,800	8,878,255,800	29,971	41,620	95,945		532,901
7	Dayton	5,966	144,006,511	859,142,844,626	934,966	317,966	1,255,737	447,016	447,016
8	Fort Thomas	16,495	1,012,752,251	16,705,348,380,245	3,180,042	2,236,157	8,375,461		18,662,865
9	Highland Heig	6,554	287,298,685	1,882,955,581,490	481,513	634,355	1,462,350		7,415,363
10	Melbourne	457	21,346,090	9,755,163,130	51,231	47,132	108,652		517,061
11	Newport	17,048	611,464,410	10,424,245,261,680	1,419,361	1,350,113	5,362,543	83,436,169	83,436,169
12	Silver Grove	1,215	71,268,909	86,591,724,435	114,743	157,362	615,763	45,611	45,611
13	South Gate	3,472	164,852,572	572,368,129,984	602,910	363,994	1,203,424	475,831	475,831
14	Wilder	2,624	258,710,580	678,856,561,920	791,092	571,233	1,316,837	3,125,000	3,125,000
15	Woodlawn	268	8,611,800	2,307,962,400	15,932	19,015	43,834	69,478	69,478
	KENTON								
16	Bromley	838	31,626,000	26,502,588,000	82,228	88,237	175,841		948,135
17	Covington	43,370	2,476,103,895	107,388,625,926,150	5,656,394	6,908,330	22,829,678	43,196,326	43,196,326
18	Crescent Sprin	3,931	329,078,210	1,293,606,443,510	829,277	918,128	1,829,675	3,394,220	1,769,220
19	Crestview Hills	2,889	400,259,531	1,156,349,785,059	610,396	1,116,724	2,225,443	2,585,224	2,585,224
20	Edgewood	9,400	982,577,549	9,236,228,960,600	2,515,399	2,741,391	5,463,131	6,007,252	6,007,252
21	Elsmere	8,139	366,009,903	2,978,954,600,517	823,522	1,021,168	2,035,015		9,208,673
22	Erlanger	16,676	1,166,841,941	19,458,256,208,116	3,068,794	3,255,489	7,817,841	7,365,000	7,365,000
23	Fort Mitchell	8,089	628,114,838	5,080,820,924,582	885,642	1,752,440	3,492,318	707,244	707,244
24	Fort Wright	5,681	513,490,299	2,917,138,388,619	1,037,250	1,432,638	2,855,006		6,427,629
25	Independence	14,982	1,324,982,943	19,850,894,452,026	2,345,220	3,696,702	7,366,905		16,951,018
26	Lakeside Park	2,869	228,115,696	654,463,931,824	597,435	636,443	1,268,323		3,246,060
27	Ludlow	4,409	225,806,840	995,582,357,560	383,872	630,001	1,379,680	599,631	599,631
28	Park Hills	2,977	268,176,530	798,361,529,810	600,715	748,213	1,491,062	303,656	303,656
29	Taylor Mills	6,913	402,698,091	2,783,851,903,083	896,260	1,123,528	2,239,001	55,387	55,387
30	Villa Hills	7,498	626,267,958	4,695,757,149,084	1,333,951	1,747,288	3,482,050		8,483,429
	Sum	**235,440**	**16,185,436,998**	**272,590,933,924,939**	**38,263,038**	**41,293,139**	**104,949,683**	**192,159,327**	**267,330,968**
	AVG	**7,848**	**539,514,567**	**9,086,364,464,165**	**1,275,435**	**1,376,438**	**3,498,323**	**10,675,518**	**8,911,032**
									10,585,240
	TOTAL WTD AVG								
	Backup Reference		***I***		***N***	***N***	***N***		***H***

Notes:

†: For communites that did not report a total debt, the net debt was calculated as the weighted average of the debt for the communities that did report, multipled by the "non-reporting" communitie's population.

Sanitation District No. 1 of N. Kentucky
March 31, 2011 Affordability Study for the Watershed Plans

Real Estate Property Tax Collected

Community	Real Estate Property Tax	Tax collected (CAFR)	Reference
Florence	6,312,539	6,312,539	Tax rate from CAFR
Alexandria	767,021	767,021	Tax rate from CAFR
Dayton	934,966	934,966	Tax rate from CAFR
Newport	1,419,361	1,424,659	Tax rate from CAFR
South Gate	602,910	602,910	Tax rate from CAFR
Wilder	791,092	791,092	Tax rate from CAFR
Woodlawn	15,932	14,810	Tax rate calculated
Covington	5,656,394	5,469,125	Tax rate from CAFR
Crescent Springs	829,277	782,068	Tax rate calculated
Crestview Hills	610,396	468,223	Tax rate calculated
Erlanger	3,068,794	2,692,000	Tax rate calculated
Fort Mitchell	885,642	747,424	Tax rate calculated
Park Hills	600,715	423,282	Tax rate calculated
Taylor Mills	896,260	896,260	Tax rate from CAFR
	23,391,299	**22,326,379**	***O***
	1,670,807	**1,594,741**	
		95%	

Backup Reference ***P***

Note:
Not all of the CAFRs collected from the communities contained the level of information needed for the analysis, or the available information was outdated.

Note:

These 13 communities form the "subset" of all communities serviced by SD1 and are the only communities that provided this level of information.

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Appendix 5-A

Response to Public Comments

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Response to Public Comments

Introduction
Sanitation District No. 1 (SD1) conducted a public comment period for the *Watershed Plans for Northern Kentucky: Draft Plan for Public Comment* from May 7, 2009 to June 8, 2009. SD1 received written comments on the plan from four individuals, which are included in Attachment A.

The following provides key comments and SD1's responses to the issues raised during the public comment period.

Commenter: Ms. Barbara A. Manning
Written comments submitted at May 14, 2009 Boone County Draft Watershed Plans Public Workshop.

> "We are located in Hearthstone Subdivision…Sleeping at night is a problem. We can't keep windows open due to the constant humming of pump which is running at the creek…Please see what can be done to alleviate this problem so we can sleep with the windows open."

Response: SD1 is in the process of upgrading the Gunpowder interceptor sewer to convey flow to the new Western Regional Water Reclamation Facility. This project, which is located near the Hearthstone Subdivision, was commenced in September in 2007 and it is anticipated that construction should be completed in November 2009. This upgrade required crews to pump the wastewater flow in the existing line around the construction of the new line. This bypass pumping will need to continue until the project is complete and every effort will be made to minimize the noise from these pumps. The project also crossed through Gunpowder Creek, which required crews to pump the creek flow around the construction site. This portion of the project is complete, which has helped reduce the impact of the construction noise in this portion of the project area.

> "…concern regarding trucks in the subdivision and on Pleasant Valley speeding. Please address this."

Response: SD1 has notified the contractors and on-site consultants about this matter and have requested that the issue be addressed with the companies providing the hauling services.

Commenter: Ms. Sharon Tepe
Written comment submitted June 5, 2009 via email.

> I do applaud the implementation of many "green" initiatives to reduce storm water runoff and improve the quality of water that does eventually wind up in our streams. However, I was wondering if we could also implement green initiatives at the source to reduce the amount of runoff and improve water quality. The implementation of rain gardens and the use of rain barrels for residents and public buildings are two that come quickly to mind. Promotion of the use of permeated pavement in new construction of roads/driveways, etc., is another.

Response: The Watershed Plans present a discussion of system-wide green infrastructure program in Section 7.3.2. These programs include: downspout disconnection, rain barrels, rain gardens, vegetated roofs, and urban reforestation. All of these programs will be developed and implemented over the first five-year Watershed Plan cycle. These programs will not only provide SD1 with great opportunities to educate the public on the goals of the Watershed Plan and the Consent Decree, but also on the role of individuals in helping to protect Northern Kentucky's streams and rivers.

SD1 has allocated nearly $2 Million to implement these green programs and has already begun work on a number of projects with partner organizations. For example, SD1 recently partnered with the City of Covington and KYTC in the incorporation of green street elements into the 12th Street reconstruction project. SD1 also partnered with St. Elizabeth Medical Center in the design and construction a regional bioretention basin retrofit project at their new facility in Covington. On a smaller scale, SD1 has developed a Rain Barrel Program in which local citizens can currently purchase Raintainers through SD1's website: http://www.sd1.org/rainbarrels/.

> Also, I read that the study is concerned about bacteria in the streams, which they should be. But one of the leaders of water pollution is the chemicals and pesticides that people use on their lawns.
>
> Are there any educational efforts or funding planned towards the items I mentioned above. If not, I would like to see that included in the plan. Is there some money that could be set aside for grants to help local residents/communities deal with issues of storm water runoff and water quality?
>
> If these items were mentioned in the plan, I apologize. Thank you for the opportunity to comment.

Response: While these Watershed Plans are focused on bacteria in streams, SD1 maintains other programs that address public education and outreach on nonpoint source pollutants. These programs, associated with SD1's storm water management plan, reach out to Northern Kentucky residents in a variety of ways in order to educate them about the impact that storm water pollution has on local waterways. Bill inserts, the distribution of brochures, website content, presentations to community groups, messages printed on give-aways and tours of Public Service Park are all education efforts that encourage pollution prevention behaviors.

SD1 provides tips on how residents can be the solution to storm water pollution. Key messages relating to household hazardous waste include following directions when applying fertilizers and pesticides, using the proper amount of chemicals and not during

or right before a rain storm, as well as properly disposing of unwanted chemicals. SD1 has circulated a Solid Waste Resource Guide that city officials can use to help answer questions that they receive about lawn care products and other household hazardous waste. This resource, and SD1's other educational efforts, have proven to be valuable and have allowed others to share in spreading the message.

As for available funding or grants to support storm water runoff, SD1 is investigating cost-sharing and other incentives to support and encourage residential green infrastructure improvements. Those programs will be developed and implemented over the first five-year Watershed Plan cycle.

Commenter: Mr. Gurney C. Clancy
Written comment submitted June 5, 2009 via email.

> Page: ES-5 "SD1 will seek mechanisms to implement controls that extend beyond current authorities"
>
> Throughout the document, references and calculations of some of these controls are used that are not currently in place. Some factions of the community and maybe our organization might oppose some of these controls. These controls might not be adopted or not adopted as envisioned. This would open you and us as citizens, the ultimate payers, to lawsuits that would be ultimately costly and not productive.

Response: SD1 believes that the watershed-based approach of its Consent Decree program offers a better opportunity to develop cost-effective improvements that will provide better public health and water quality benefits as compared to traditional combined sewer overflow (CSO) and sanitary sewer overflow (SSO) control plans. The assessment of Northern Kentucky's watersheds showed that, in many cases, sewer overflows are not the dominant source of water quality impairment. Any work towards implementing controls beyond SD1's current authority would be made within the context of maintaining a cost-effective program that is supported by local ratepayers and helps SD1 meet the objectives of the Consent Decree.

> Page: ES-12 "It should be noted that cost estimates for watershed controls are inherently less accurate than gray infrastructure cost."
>
> This statement is understandable especially in light as mentioned in the opening paragraphs and your conclusion that this agreement is different than anything else in the United States. Don't take this as negative, but the above statement begs the question, "What is the degree of reliability of this document and the actual costs of these controls? Could a management technique like game theory when the variables are unknown and a probability factor applied be appropriate in making these critical choices?" This would increase the probability of success.

Response: The use of watershed controls and green infrastructure in a wet weather Consent Decree program is an approach that has developed rapidly over the last few years. In addition, there are a relatively small number these projects in this region that have been constructed and in service for a significant period of time. Lastly, the cost and performance of watershed controls and green infrastructure projects can be more sensitive to local site characteristics (such as soil conditions) than traditional gray approaches.

The end result of these factors is that cost estimates and predicted performance levels for watershed controls and green infrastructure are not as well defined as gray infrastructure at this time. That is why SD1's Watershed Plans are based on the phased development of new programs, demonstration projects, and full-scale projects. The intent of this approach is that information gathered through the first Watershed Plan cycle will inform future decisions and led to more reliable estimates of cost and performance.

Page: ES-13 "Riparian Buffers"

A favorite topic of ours. First are you using a 50' and 100' buffer to be on each side of the stream? If so, that would make the swath 100' or 200' wide, plus the width of the stream. We view these buffers as taking of property rights, if not freely given or fairly purchased from the land owners. Because of the topography of Northern Kentucky, hills and valleys, much valuable real estate will be consumed by these buffers. This will drive up the effective cost of land for developers to the point, in our opinion, not much land in Northern Kentucky can be left for development. Who will own and maintain these buffers? A land owner may be willing to sell or give you the land, but not an easement. He can no longer use the land, but until eternity has to pay taxes on it. Because of our topography, this is a contentious issue for developers and farmers in our area. If not properly addressed, the burden of this control can fall on a few. If given or purchased, loss of tax revenue to the counties could mount up. Additionally, the construct of these zone producing documents must be well though out. Utilities and roads need to be allowed to cross these zones. If not crafted correctly, the intent of the documents can be artfully altered to growth limiting or stopping instruments, used to prevent growth past a point, such as stopping growth in Boone County.

Response: Unlike many other watershed controls and green infrastructure features, stream buffers have been relatively well researched and tested over a number of years. That work has typically shown that a riparian buffer can provide significant instream benefits such as reductions in streambank erosion and improved water quality. SD1 included an analysis of stream buffers in the water quality modeling efforts of the Watershed Plan development to evaluate their potential benefits as compared to typical gray infrastructure improvements. The Watershed Plans do not include a specific recommendation or proposed regulation regarding the protection or restoration of stream buffers. The establishment of a local stream buffer regulation for Northern Kentucky could only be established through the appropriate regulatory agencies and would involve significant public involvement.

With respect to the question of property taking, the re-establishment of riparian buffers, as described in the plan, would only be implemented with the full cooperation of the

landowner. In these cases, it is expected that the landowner would receive compensation for the land committed to buffers, either through purchase of easements or through outright purchase of the property. In either case, the landowner's rights will be fully protected. A third option is the donation of the land by the owner for conservation purposes, which has occurred recently in the Banklick watershed.

Although the protection of existing buffers or restoration of buffers will occupy land that is, in some cases, otherwise developable, the amount of land is relatively small. The total area of land covered by all the riparian buffer opportunities in the Banklick Creek watershed, assuming a 100-foot buffer width, is approximately 390 acres, which represents about 1% of the total land area in the watershed. And in many cases riparian buffers occupy areas such as floodplains or floodways that could not easily be developed.

SD1 recognizes that environmental protection must be managed in a balance with the economic growth of the region. That is why SD1 takes great efforts to engage the public in the discussion of these issues.

Page: ES-19 Personal Peeves and Questions:
"Urban Reforestation"

This term implies trees are being sacrificed for development. Reforest to what? The time when Christopher Columbus discovered America, then get the chain saws out. There are more trees on the continent today than when Columbus discovered America. Today, June 4th, 2009, there are 5 trees planted for everyone cut down in the United States. Using misleading terms like this degrades the intent of the document.

Response: Urban reforestation was included within the larger "Green Programs" project category because SD1's evaluations indicated a potential benefit of improved tree cover, particularly within the urbanized combined sewer areas of Northern Kentucky (Covington, Newport, Bellevue, Dayton, etc.). Along with improved air quality and cooler temperatures, tree canopy can provide storm water benefits through rainfall interception, which leads to a reduction in runoff. SD1's evaluation indicated that 14% of the combined sewer area is currently covered by tree canopy. According to the American Forests, recommended canopy coverage for typical central business districts is approximately 25%.

The enhancement of Northern Kentucky's urban forest has the potential to reduce storm water runoff and the resulting CSO volumes. One goal of SD1's work over the first five-year Watershed Plan cycle is to better quantify the benefits and costs associated with reforestation efforts through the pilot programs and demonstration projects.

"Disconnecting Downspouts"

Do this in Newport or Covington with no means of capturing the water and it runs into the street catch basins and back into the combined sewers. Most 50's and 60's developments had downspouts to storm drains that go over the hill. Disconnect these and watch the city streets erode. Developers quit the expense of connecting downspouts to storm drains in the 70's.

Response: As correctly noted in this comment, in order for a downspout disconnection program to be an effective means of CSO control, downspouts should re-directed to rain barrels, small rain gardens, green space, or other receiving areas. As SD1 develops the downspout disconnect program, several factors will need to be considered such as: size of the lots, housing density, available green space, soil conditions, and potential discharge locations.

For homes in densely developed, small-lot neighborhoods, the disconnection of those downspouts and routing of flow into driveways or sidewalks will generally not provide CSO reduction benefits. In those areas, any downspout disconnections would likely need to include additional measures such as rain barrels or small rain gardens. In some cases, downspout disconnection simply may not be feasible. In areas with larger lots, more green space, and favorable soil conditions, re-routing downspouts into existing lawns or planted areas may be a useful approach for mitigating CSO volume and engaging the public.

Not mentioned, but sure to contribute to pollution are the local, county, state and federal transportation systems. As they expand, they will surely increase the shear magnitude of the problem with each improvement of traffic. The expansion of the I 75 corridor is a huge example of this. If the additional run off is not mitigated at the source, all money spent and effort made by SD1 won't come up to the impact this one project will have on this area, complying with the Clean Water Act. EPA needs to be made aware that one federal agency is causing Northern Kentucky not to comply with the law and allowance for that need to be made.

Response: In developing the Watershed Plans, SD1 analyzed the distribution of impervious area throughout Northern Kentucky with an emphasis in the combined sewer areas. Based on that GIS analysis, it was estimated that 36% of the impervious area in the combined sewer system of Northern Kentucky is public roadway. Clearly, storm water runoff from roads is a significant contributor to SD1's total CSO volume.

In recognition of this fact, SD1 has worked with the Kentucky Transportation Cabinet (KYTC) on a number of potential partnership opportunities. That work has included the inclusion of green street features into the 12th St reconstruction project (Covington), the development of green infrastructure retrofit projects along I-71/75, and discussions on the storm water / CSO impact of the different proposed alignments for I-71/75 reconstruction. SD1 will continue to develop this relationship with KYTC in order to help reduce the impact from this large source of impervious area. In addition, SD1 initiated discussions with various cities located within SD1's combined sewer system regarding potential green street improvements during the development of the Watershed Plans.

SD1 plans to continue those discussions and work with cities to implement green infrastructure demonstration projects in local streets and evaluate their effectiveness.

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Attachment A

Public Comments Received on Draft Watershed Plans

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QUESTION AND COMMENT SHEET
Sanitation District No. 1
Draft Watershed Plans Public Workshop
May 14, 2009

Please Print

Name: BARBARA A. MANNING (MRS. THOMAS J.)
Street Address: 2145 BLANKENBECKER DR., HEARTHSTONE SUBDIVISION
City/State/Zip: FLORENCE, KY 41042
E-mail Address: bamanning@fuse.net

Questions and Comments:

1. We are located in Hearthstone subdivision which is off Pleasant Valley road. Our house is on a cul-de-sac, and the back of the house faces the big construction area (BIG equipment, pipes, gravel, etc) next to the creek. We have become accustomed to the construction noise during the day (M-F, sometimes part of Saturday. Sleeping at night is a problem — we can't keep windows open due to constant HUMMM of pump which is running at the creek. I spoke with Mr. Wilson at SD#1 a couple of weeks ago and he said why the pump has to keep running. We understand that. Nonetheless, the thought of not being able to sleep with windows open for the next 7 months is difficult to deal with. (7 months is based on Mr. Wilson's sharing that the project should be done in November. Please see what can be done to alleviate this problem so we can sleep with windows open. Thank you.
2. Our subdivision has a web page and a number of families have shared their concern re: trucks in the subdivision and on Pleasant Valley speeding. Please address this. Thank you

Signature: Barbara Manning (Mrs. Tom) **Date:** 5/14/09

Return to: Sanitation District No. 1
Attention: Peggy Casey
1045 Eaton Drive
Ft. Wright, Kentucky 41017
859-331-2436 (fax)
pcasey@sd1.org (email)

Thank you for offering this public meeting on this necessary project.

QUESTION AND COMMENT SHEET
Sanitation District No. 1
Draft Watershed Plans Public Workshop
May 14, 2009

Please Print
Name: JAMES D AUGHBERRY
Street Address: 7094 CLAUDE LANE
City/State/Zip: FLORENCE 41042-6304
E-mail Address:

Questions and Comments:

WELL STAFFED AND PRESENTED. ESPECIALLY FOR FIRST PRESENTATION.

VIDEO CLIP AT START PROVIDES A GOOD INTRODUCTION AND PROVIDES GOOD CONTEXT AS A WORST CASE SCENARIO (CATASTROPHE)

PRESENTERS AND CONSULTANTS SEEMED KNOWLEDGEABLE AND INTERESTED IN LISTENING TO AND EDUCATING PUBLIC WITH AMENABLE.

GOOD JOB EXPLAINING HOW SD1'S APPROACH DIFFERS FROM TYPICAL APPROACH AND THE IMPROVED RESULTS THAT ARE PROMISED.

Signature: James D Daugherty **Date:** 5-14-09

Return to: Sanitation District No. 1
Attention: Peggy Casey
1045 Eaton Drive
Ft. Wright, Kentucky 41017
859-331-2436 (fax)
pcasey@sd1.org (email)

Diane Bielo - Comments on Plans

From: "Sharon Tepe" <sharon.tepe@fuse.net>
To: <info@sd1.org>
Date: 6/5/2009 6:14 PM
Subject: Comments on Plans

I have to admit that I didn't get completely through all the documentation. And even some of the things I read, I didn't completely understand.

I do applaud the implementation of many "green" initiatives to reduce storm water runoff and improve the quality of water that does eventually wind up in our streams. However, I was wondering if we could also implement green initiatives at the source to reduce the amount of runoff and improve water quality. The implementation of rain gardens and the use of rain barrels for residents and public buildings are two that come quickly to mind. Promotion of the use of permeated pavement in new construction of roads/driveways, etc., is another.

Also, I read that the study is concerned about bacteria in the streams, which they should be. But one of the leaders of water pollution is the chemicals and pesticides that people use on their lawns.

Are there any educational efforts or funding planned towards the items I mentioned above. If not, I would like to see that included in the plan. Is there some money that could be set aside for grants to help local residents/communities deal with issues of storm water runoff and water quality?

If these items were mentioned in the plan, I apologize. Thank you for the opportunity to comment.

Sharon Tepe
859-781-1741
Go Green
Working towards a healthier and greener home, community and environment throughout Campbell County.

Diane Bielo - comments to watershed approach

From: <Jrcca@aol.com>
To: <info@sd1.org>
Date: 6/5/2009 7:01 AM
Subject: comments to watershed approach
Attachments: CAMPBELL SD! WATERSHED LETTER.doc

attached is a letter

signed by JR Roth also

We found the real 'Hotel California' and the 'Seinfeld' diner. What will you find? Explore **WhereItsAt.com**.

June 4, 2009

Sanitation District Number One
1045 Eaton Drive
Fort Wright, KY 41017

Gentlemen,

RE: Draft Watershed Plans for Northern Kentucky

The enormity of the document pails to the financial ramification our Northern Kentucky community faces trying to deal with the unfunded mandate of the Clean Water Act. Our hope is that you now and continue to make the county elected officials aware of the costs associated with this task and to provide them a cost/impact (moving closer to compliance) analysis updated annually. Our county officials need to be continually apprized of this undertaking. You're integrated approach should, if the decisions are made wisely, produce the most cost-effective (most bang for the buck) solution. At some point, we see that the citizen's financial well being (cost) will trump the impact. At that point, our elected officials will have some hard decisions to make. They need to know now that down the road that decision will be facing them.

We, as an organization and some of our members individually, have raised a few questions, concerns and frustrations. We would ask you to consider these.

Page: ES-5 "SD1 will seek mechanisms to implement controls that extend beyond current authorities"

Throughout the document, references and calculations of some of these controls are used that are not currently in place. Some factions of the community and maybe our organization might oppose some of these controls. These controls might not be adopted or not adopted as envisioned. This would open you and us as citizens, the ultimate payers, to lawsuits that would be ultimately costly and not productive.

Page: ES-11 Last paragraph, Banklick Creek example and
Page: ES-12 Second paragraph, last sentence.

Some members noted that if you eliminated all CSO's, the water quality would

only increase by 7%. Their point is that the EPA has asked SD1 to perform a magic trick, remove all human bacteria CSO's and non-human bacteria sources. I am sure when Buffalo herds roamed the Midwest; they numbered more than the farm animals now residing in the area. Before EPA or humans existed here the water quality did not meet EPA requirements. They are asking you to do better than God, on the backs of the Northern Kentucky citizens.

Page: ES-12 "It should be noted that cost estimates for watershed controls are inherently less accurate than gray infrastructure cost."

This statement is understandable especially in light as mentioned in the opening paragraphs and your conclusion that this agreement is different than anything else in the United States. Don't take this as negative, but the above statement begs the question, "What is the degree of reliability of this document and the actual costs of these controls? Could a management technique like game theory when the variables are unknown and a probability factor applied be appropriate in making these critical choices?" This would increase the probability of success.

Page: ES-13 "Riparian Buffers"

A favorite topic of ours. First are you using a 50' and 100' buffer to be on each side of the stream? If so, that would make the swath 100' or 200' wide, plus the width of the stream. We view these buffers as taking of property rights, if not freely given or fairly purchased from the land owners. Because of the topography of Northern Kentucky, hills and valleys, much valuable real estate will be consumed by these buffers. This will drive up the effective cost of land for developers to the point, in our opinion, not much land in Northern Kentucky can be left for development. Who will own and maintain these buffers? A land owner may be willing to sell or give you the land, but not an easement. He can no longer use the land, but until eternity has to pay taxes on it. Because of our topography, this is a contentious issue for developers and farmers in our area. If not properly addressed, the burden of this control can fall on a few. If given or purchased, loss of tax revenue to the counties could mount up. Additionally, the construct of these zone producing documents must be well though out. Utilities and roads need to be allowed to cross these zones. If not crafted correctly, the intent of the documents can be artfully altered to growth limiting or stopping instruments, used to prevent growth past a point, such as stopping growth in Boone County.

Page: ES-16 "Rate Discussions"

From what is presented, minimum rate increases for 2012 – 2014 will be 12.5%, 10% and 10%. The suggested annual rate increase of 15% would generate an additional 79 million of borrowing power. One would expect these earlier higher rates to mitigate rate increase in the future.

Page: ES-19 Personal Peeves and Questions:
"Urban Reforestation"

This term implies trees are being sacrificed for development. Reforest to what? The time when Christopher Columbus discovered America, then get the chain saws out. There are more trees on the continent today than when Columbus discovered America. Today, June 4th, 2009, there are 5 trees planted for everyone cut down in the United States. Using misleading terms like this degrades the intent of the document.

"Disconnecting Downspouts"

Do this in Newport or Covington with no means of capturing the water and it runs into the street catch basins and back into the combined sewers. Most 50's and 60's developments had downspouts to storm drains that go over the hill. Disconnect these and watch the city streets erode. Developers quit the expense of connecting downspouts to storm drains in the 70's.

Not mentioned, but sure to contribute to pollution are the local, county, state and federal transportation systems. As they expand, they will surely increase the shear magnitude of the problem with each improvement of traffic. The expansion of the I 75 corridor is a huge example of this. If the additional run off is not mitigated at the source, all money spent and effort made by SD1 won't come up to the impact this one project will have on this area, complying with the Clean Water Act. EPA needs to be made aware that one federal agency is causing Northern Kentucky not to comply with the law and allowance for that need to be made.

Hopefully you will take this comment letter in the intent it is meant, as constructive criticism. Honestly, I spent most of a week reviewing this document and only got through appendix 4-B. Clearly a lot of effort has been made in preparing it. In summary, the financial well being of the community will be impacted greatly. Yes, employees of SD1, our neighbors, will be impacted almost the same as the rest of the community. The difference lies in that the SD1 employees will have jobs, while some

jobs will be lost in the community because of this. Yes, you are doing the best you can to comply, but don't fall into the "me too" trap that government agencies do from time to time. YYZ city has an increased rate, that's justification for us doing the same?

Thanks for you attention.

Gurney C. Clancy
President
859 428 0201

CC: Judge Executives

Appendix 7-A

Dry Creek WWTP - No Feasible Alternatives Analysis

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1 Introduction and Purpose

The Dry Creek WWTP serves a vital role in the wet weather strategies included in the Watershed Plans Plan, originally submitted on June 30, 2009. In the 2009 plan, significant improvements were proposed to the Dry Creek WWTP to increase secondary capacity from the current flow of 55 MGD to a maximum capacity of 100 MGD. Increase in influent flow to the plant of up to 160 MGD was also included in the plan. Because separation of separate and combined flows are possible at the plant, all separate flows were to be accommodated by secondary treatment under peak wet weather conditions. Under all other conditions, portions of the combined sewer flow could be treated through secondary treatment up to 100 MGD, when totaled with separate flow.. The solutions included a total flow of 160 MGD to Dry Creek, based on limitations in the conveyance system, the hydraulic capacity of the existing plant outfall under the Ohio River, and the economics of the general solutions considered.

In the strategy, combined flows above 100 MGD would be treated in the existing primary clarifiers, diverted around secondary treatment, and disinfected before being combined with secondary effluent for discharge. USEPA has requested that SD1 evaluate whether it is feasible to provide additional secondary treatment capacity above the 100 MGD originally stipulated in the plans. This document is intended to summarize the analysis of alternatives to increase secondary treatment capacity above 100 MGD.

2 Summary of Existing Dry Creek Capacity

2.1 Existing Process

The Dry Creek WWTP was constructed in the late 1970s and was placed into operation in early 1979. Over the years, capacity expansion and process technology modifications have been made to increase capacity and/or achieve operational efficiencies. The last improvement that provided additional process tankage was in 1991 that included additional primary and secondary treatment units. These improvements were designed to increase the average daily flow capacity of the plant to 46.5 MGD with a peak hour flow of 93 MGD. The maximum sustained secondary capacity as designed was 55.5 MGD. Currently, flows above 55 MGD receive primary treatment and then are routed around the secondary system and combined with secondary effluent prior to disinfection. All flow is then disinfected prior to discharge. Routing is achieved via a motorized gate and Parshall flume.

A summary of the major unit treatment processes and associated equipment is shown in **Table 2.1**, and a schematic of major liquid stream unit processes is shown in **Figure 2.1**.

Table 2.1

Summary of Major Liquid Stream Processes at the Dry Creek WWTP

Unit Process	Description of equipment	Number of Process Units
Influent Screening	• Mechanically cleaned, continuous cleaning field • Aquaguard (Parkson Corp). • 3 mm slotted opening, 4 ft screening field width	3
Influent Flow Measurement	• Lakeview Outfall – 5 ft Parshall flume throat width • Influent – 10 ft Parshall flume throat width	1 each
Grit Removal	*Vortex* • 20 ft diameter *Rectangular* • Dimensions: 84.5 ft long, 11 ft wide (top); 4 ft 8 inches (bottom), 5 ft avg. depth	*Vortex – 2* *Rectangular* (Not in service – equipment removed)
Primary Clarifiers	• Rectangular clarifiers with chain and flight mechanism • Sludge withdrawal at influent end • Dimensions: 178 ft long, 48 ft wide, 12 ft avg. depth	6
Aeration Basins	• Two pass plug flow with fine bubble diffusers • Dimensions: 195 ft long, 40 ft wide (total), 25 ft depth • Tank volume – 1.46 Mgal / tank	6
Aeration System	• Roots horizontal split case multi-stage blowers • 2 @ 40,000 scfm • 1 @ 20,000 scfm	3 total
Secondary Clarifiers	• Circular – suction type sludge withdrawal • 131 ft diameter • 14 ft side water depth	6
Effluent Disinfection	• Sodium hypochlorite for chlorination / sulfur dioxide for dechlorination • 66-inch outfall pipe used for disinfection contact time	1 outfall pipe

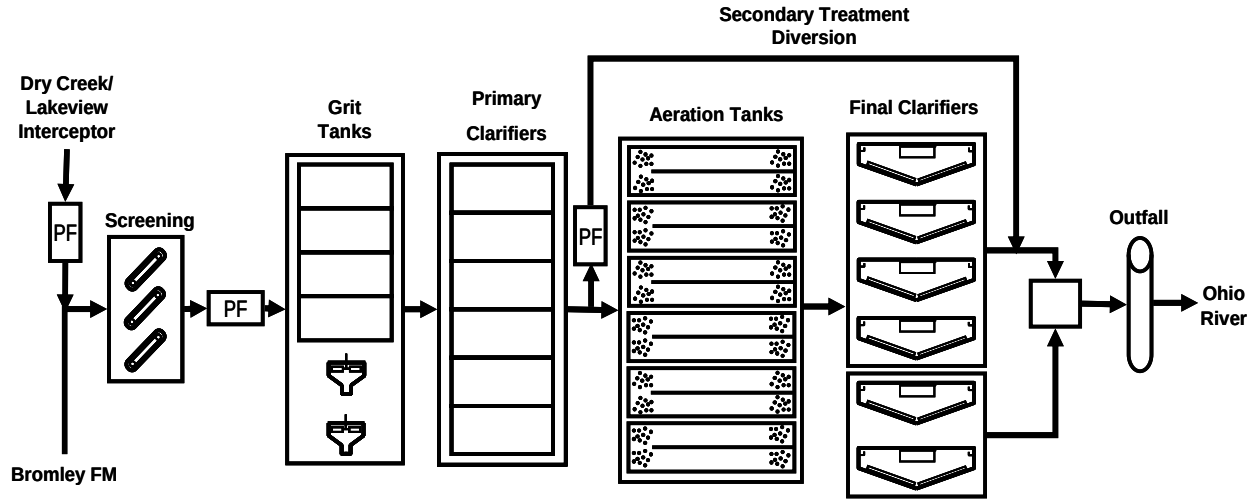

Figure 2.1 Simplified Liquid Stream Process Schematic for the Dry Creek WWTP

Preliminary Treatment:

Influent flow to the plant comes from two sources: the Bromley force main and the Lakeview Outfall / Dry Creek Interceptor. The flow from the Bromley force main includes flow from Bromley Pump Station and the Taylorsport Pump Station. The flow from the Lakeview Outfall / Dry Creek Interceptor includes pumped flow from the Lakeview Pump Station and gravity collection systems. Flow from the Bromley Pump station is derived from combined sewer systems, while flows from the Lakeview system and the Taylorsport Pump Station are derived from separate sewer systems. The influent to the plant is screened with three mechanically cleaned bar screens. Flow is then metered through a single influent Parshall flume, and grit is removed from the flow through two vortex grit removal units.

Primary Treatment:

Screened and degritted flow from the preliminary treatment process enters six rectangular primary clarifiers with chain and flight mechanisms for primary treatment. Primary sludge is pumped to the solids treatment system. Routing of wet weather flow around the secondary treatment system is achieved by operating a motorized gate in the aeration basin influent channel, such that all flows greater than 55 MGD are diverted using a Parshall flume for flow measurement.

Secondary Treatment:

Primary effluent flows to the plant aeration basins, consisting of 6 two-pass tanks with fine bubble diffused aeration. Mix Liquor Suspended Solids (MLSS) is settled in six circular final clarifiers prior to disinfection. Return activated sludge (RAS) pumps return biomass to the head of the aeration basins and waste activated sludge (WAS) is pumped to the gravity belt thickener prior to the centrifuges (March 2008 replaced Zimpro system). Secondary effluent and any primary effluent routed around secondary treatment during high wet weather flow conditions are combined prior to disinfection. Sodium hypochlorite is added to the flow in neat form (i.e. 12.5% solution) using tubular diaphragm pumps. Contact time for the plant effluent is achieved in the 66-inch diameter outfall pipe prior to dechlorination

with sulfur dioxide. Plant effluent is discharged to the Ohio River through an underwater effluent diffuser.

Solids Handling:

Sludge is currently treated using centrifuges, which replaced the thermal conditioning Zimpro process in March 2008. Primary sludge is combined and stored with thickened waste activated sludge (TWAS) prior to feeding the centrifuges. Dewatered solids from the process as well as the preliminary treatment screenings and grit are trucked to a landfill for final disposal.

2.2 Current Process Capacity

The current capacities for each liquid unit process are shown in **Figure 2.2**.

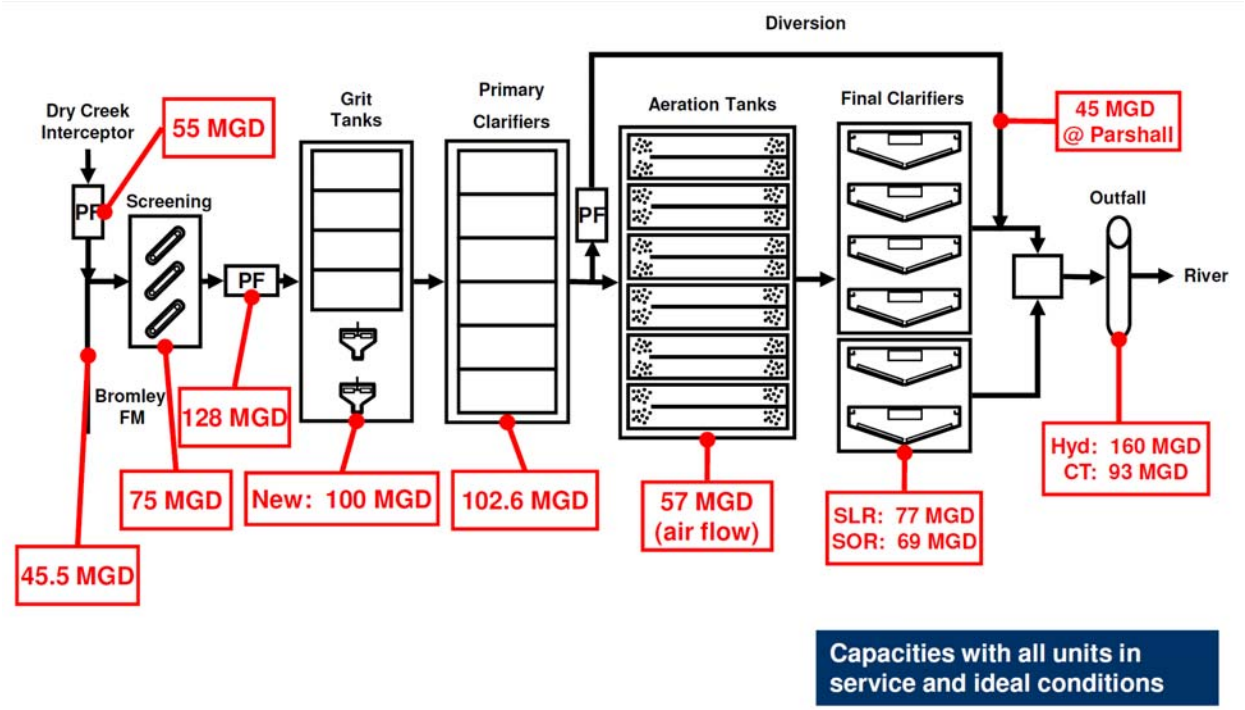

Figure 2.2 Schematic of the Current Liquid Stream Unit Process Capacities (with all units in service)

The capacities shown above are peak capacities with all units in service. The two vortex grit units were installed in 2003. Primary clarifier capacity was based on peak surface overflow rate (SOR) of 2,000 gpd/ft2. The Secondary/Final clarifier capacity is based on a SOR of 850 gpd/ft2 from a study prior to March 2008.

There are two process capacity improvements ongoing at this time: retrofit / rehabilitation of the existing secondary/final clarifiers and design and construction of a new 100 MGD preliminary treatment facility for the Dry Creek Interceptor. Rehabilitation of the six existing final clarifiers is intended to replace aging mechanisms and return activated sludge pumps. The retrofit / rehabilitation was performed

consistent with future plans to increase secondary treatment capacity, based on the long term control plan. Similarly, the new preliminary treatment facility for the Dry Creek interceptor and Bromley force main is part of the improvements planned for future increases in wet weather capacity at the facility and will alleviate overflows that occur now due to bottlenecks in the existing headworks.

2.3 Effluent Permit Limits

The existing plant permit limits are shown in **Table 2.3**.

Table 2.3

Existing Effluent Permit Limits for the Dry Creek WWTP

Parameter	Monthly Average	Weekly Average
CBOD5 (mg/L)	25	37.5
TSS (mg/L)	30	45
NH3-N (mg/L)	20	30
DO > 2 (mg/L), (daily)		
pH [6,9], daily		
Total Residual Chlorine (mg/L)	---	0.076
Fecal Coliform (cts/100 mL)[1]	200	400
Fecal Coliform (cts/100 mL)[2]	1000	2000

[1] Effective May 1 - October 31

[2] Effective November 1 - April 30

The current permit is based on a design flowrate of 46.5 MGD and allows for diversion of flow above 55 MGD around the aeration basins.

3 Summary of Previous Evaluation of Increases in Wet Weather Capacity

The previous collection system alternative evaluation showed that peak flows from the separate system at Dry Creek WWTP would reach a maximum value of 100 MGD under future buildout conditions and capacity increases in the collection system to alleviate current bottlenecks and wet weather overflows. Therefore, the improvements necessary to accommodate an increase in secondary treatment capacity to 100 MGD was investigated. Biowin biological process modeling, clarifier stress testing, and computational fluid dynamics modeling was performed as part of the development of the Long Term Control Plan presented in the 2009 Watershed Plans. The purpose of these evaluations was to determine the feasibility of increasing secondary capacity to 100 MGD and to aid in the planning of improvements needed to achieve this capacity.

3.1 Plant Process Model

In late 2008, BioWin™ simulations for the Dry Creek WWTP were performed. BioWin™ (BioWin) is a full plant biological process simulator developed by EnviroSim Associates Limited (www.envirosim.com) that is widely used in the wastewater industry for simulation of existing facilities and for process design. The version available and used at the time was 3.01.

The process flow diagram of the plant that was developed for the simulations is shown in Figure 3.1.

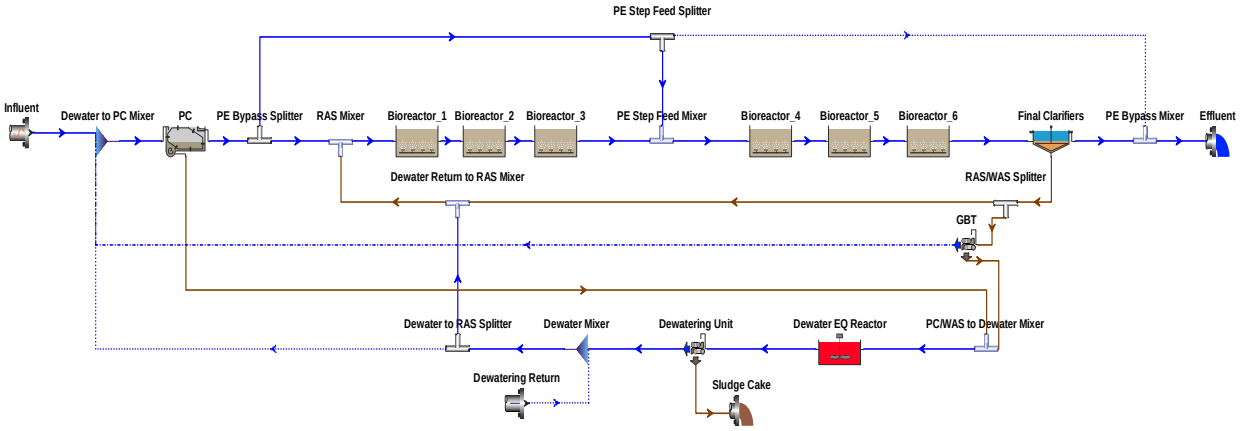

Figure 3.1 BioWin Process Flow Diagram for the Dry Creek WWTP

Historical plant data from 2006 through October 2008 was reviewed during development of the model. The full data set was used for development of influent fractions. Because of a major change in the solids treatment at the plant in early 2008, the period from March 2008 through October 2010 was used for calibration of the model. For calibration, daily transient / dynamic input were used and simulated results were compared to the historical plant data. Adjustments were made in the model to various parameters to provide predicted solids concentrations in all processes to within 10% of historical values.

The calibrated model was used to simulate potential solids loading conditions to the plant clarifiers under selected scenarios. The base solids concentrations were developed in the model prior to the wet weather routing simulations using maximum month flows and loads. This means that simulated solids levels were based on plant capacity conditions.

For storm events, transient/dynamic simulation was applied by increasing plant secondary flow to 100 MGD in four equal hourly intervals from the maximum month flow condition. Dewatering operations were held constant and RAS flow rates of 40 and 50 MGD were held constant. The 100 MGD peak flow rate was held constant for a two day period. Simulations were performed for cases with and without step feed. During step feed, aeration basin influent was transitioned to the second pass of the aerations basin once the flow reached 55 MGD. An overview of simulated results is shown in **Table 3.1.**

Table 3.1

Overview of Process Model Simulation Results

Influent Flow Rate / Scenario	Step Feed?	RAS Rate (MGD)	Predicted MLSS Concentration in Aeration Basin Effluent	Predicted Effluent NH3 (mg/l)
46.5 MGD No Step Feed,	No	23.2 MGD	2970	0.6
63.2 MGD No Step Feed	No	31.6 MGD	3210	1.4
100 MGD No Step Feed	No	50 MGD	3270	4.0
100 MGD Step Feed	Yes	50 MGD	2000	6.2
NOTES: Simulations run at 20 deg C. Steady state prior to storm events included aerobic SRT of 5.2 days				

Simulation results indicate that use of step feed during wet weather can significantly reduce the solids loading rate to the clarifiers. With step feed, predicted MLSS at the end of the aeration basins is 2000 mg/l and without step feed the predicted effluent is approximately 3,300 mg/L. Use of step feed will allow the first pass of the aeration basins to be used as biological solids storage during peak flow events.

3.2 Clarifier Stress Testing and CFD Analysis

Clarifier stress testing and CFD analysis was used to evaluate the peak capacity of the final clarifiers. The CFD model used is known as 2Dc, which is a quasi-three-dimensional clarifier model that was developed at the University of New Orleans. Field sampling, settleability testing, and clarifier stress testing was performed in October 2008. An aerial view of the plant Final Clarifiers is shown in Figure 3.2.

Figure 3.2 Aerial View of the Final Clarifiers at Dry Creek WWTP

During stress testing, clarifiers were taken out of service one at a time to increase both solids and hydraulic loading rates to the clarifiers. As clarifiers were taken out of service, effluent suspended solids and sludge blankets within the clarifiers were documented. At peak loading conditions, three of the six clarifiers were in service and a peak SOR of approximately 1,100 gpd/ft2 was maintained for a period of time. After a brief period at this loading rate, clarifiers were brought back on due to excessive sludge blankets (approaching 10 ft) and increases in effluent suspended solids.

Data collected during final clarifier sampling and stress testing was used to calibrate the CFD model for the plant clarifiers. In addition to simulation of peak flow conditions for future wet weather planning, the CFD model was used to determine optimum dimensions of the influent feed well and baffle, effluent launder location, and optimum location of density baffles for the clarifier rehabilitation project.

Performance of the final clarifiers at a peak flow of 100 MGD was simulated under several different conditions:

- MLSS concentrations of 2000 mg/l (with step feed) and 3000 mg/l (without step feed)
- Numbers of clarifiers in service – 6 (all existing units) and 7 (all existing units plus one additional)
- Sludge Volume Index levels of 115 mg/l (average value from 3/13 – 7/31/08), 147 (90th percentile value from 3/13 – 7/31/08), and 165 (95th percentile from 3/13 – 7/31/08)

A summary of simulation results is shown in Table 3.2.

Table 3.2

Simulation Results of the 2Dc CFD Model Under Various 100 MGD Conditions

Q (MGD)	Units in Service	SOR (gpd/ft^2)	RAS (%)	Q RAS (MGD)	ESS (mg/L)	RAS TSS (mg/L)	Observations
SVI = 115 mL/g, MLSS = 3,000 mg/L							
100	6	1237	40.00%	40	54	10020	Sludge blanket is high ~ 10 ft
100	6	1237	50.0%*	50	59	8810	
100	7	1060	50.0%*	50	45	8830	
SVI = 115 mL/g, MLSS = 2,000 mg/L							
100	6	1237	40.00%	40	70	6840	ESS is high
100	7	1060	40.00%	40	57	6880	
SVI = 147 mL/g, MLSS = 3,000 mg/L							
100	6	1237	40.00%	40	> 100		Thickening Failure
100	6	1237	50.0%*	50	> 100		Thickening Failure
100	7	1060	50.0%*	50	> 100		Thickening Failure
SVI = 147 mL/g, MLSS = 2,000 mg/L							
100	6	1237	40.00%	40	74	6840	ESS is high
100	6	1237	50.0%*	50	74	5870	ESS is high
100	7	1060	50.0%*	50	69	5870	ESS is high
SVI = 167 mL/g, MLSS = 3,000 mg/L							
100	6	1237	40.00%	40	> 100		Thickening Failure
100	7	1060	50.0%*	50	> 100		Thickening Failure
SVI = 167 mL/g, MLSS = 2,000 mg/L							
100	6	1237	40.00%	40	67	6830	ESS is high
100	7	1060	50.0%*	50	69	5890	ESS is high

*Total RAS flow capacity increased to 50 mgd

When sludge settling characteristics are favorable, performance of six clarifiers in service without step feed is satisfactory under peak conditions (note that an effluent suspended solids concentration of 1.5 times the monthly limit was deemed acceptable for brief periods associated with wet weather flows), but hydraulic loading conditions exceed ten states standards. When sludge settling characteristics deteriorate (i.e. higher SVI), a minimum of seven clarifiers is required and step feed is necessary to prevent solids washout. Based on these simulation results, construction of a seventh clarifier is necessary to reliably meet 100 MGD peak capacity.

3.3 Recommended Improvements

The evaluation indicated that 100 MGD secondary treatment capacity was possible with the addition of a seventh secondary clarifier and improvements to the aeration system to allow for reliable step feed. Additional improvements to accommodate increases in plant flow up to 160 MGD influent flow and 100 MGD through secondary treatment were then evaluated. At 160 MGD, 60 MGD would be expected from the combined system (i.e. Bromley) and 100 MGD would be expected from the separate system (i.e. Dry Creek Interceptor and Taylorsport Force Main). A conceptual level schematic of the improvements necessary to accommodate 160 MGD of plant flow to Dry Creek is shown in **Figure 3.3**. Improvements

originally proposed as part of the long term control plan presented in the 2009 Watershed Plans are discussed below.

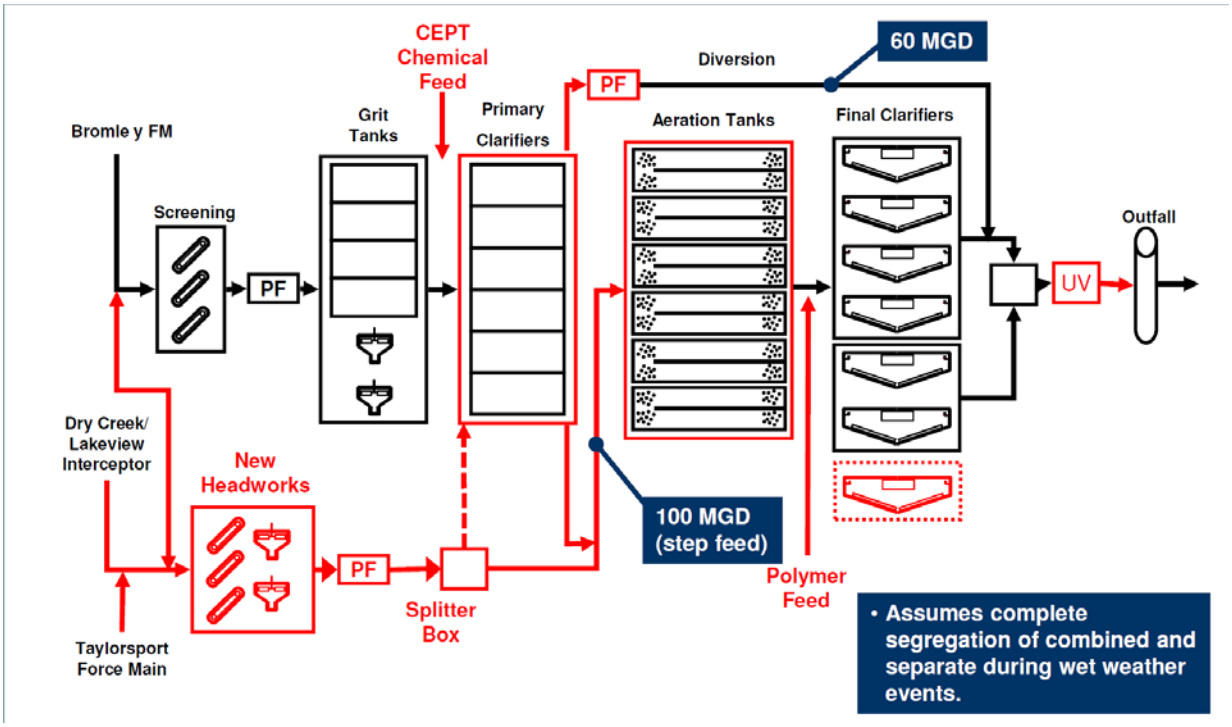

Figure 3.3 Dry Creek WWTP Conceptual Process Flow Schematic for 160 MGD (100 Secondary / 60 MGD Diverted)

Preliminary Treatment

Improvements included addition of a new 100 MGD preliminary treatment system constructed on the Lakeview / Dry Creek Interceptor and operation in parallel with the existing headworks. In this system, all separate flows would enter the new headworks and all combined flows would be handled in the existing headworks. The new headworks will consist of screening and grit removal, screenings and grit conveyance and handling, Parshall flume for flow monitoring, and associated supporting items for the process. Interconnection between the new and existing facilities will also be further considered in the future for additional operational flexibility.

Primary Clarifiers

Based on previous stress testing and typical loading rates, the existing six primary clarifiers have a capacity of 100 MGD (i.e. 102 at SOR of 2,000 gpd/ft2). The originally recommended improvements included placement of gates in the primary clarifier influent channel to allow for separation of combined and separate flows through the primaries. During peak wet weather flow, incoming separate flow would be bypassed around the primary clarifiers and go directly to the aeration basins. With this arrangement, only four of the existing six primary clarifiers would be required to handle combined system flows and the remainder could be used for flow equalization. Implementation of provisions for chemically enhanced primary treatment were also recommended to increase the performance of the primary clarifiers.

Aeration Basins

At 100 MGD, step feed of all aeration basin influent (including effluent from the new headworks) would proceed to the end of the first pass, which would provide approximately one hour of contact time during peak flow conditions. This is sufficient to provide rapid BOD uptake and to produce good settling floc. Improvements included as part of the original Long Term Control Plan included replacement of the existing diffusers and air delivery piping to the basins to allow for tapered aeration and the feed of all primary effluent at the end of the first pass of the aeration basins. In addition, provisions would be included to operate the step feed zone and the first zone in the first pass as anoxic selectors to improve sludge settleability.

Final Clarifiers

The addition of a seventh clarifier, including modifications to the existing final clarifier distribution box, influent and effluent piping, and return activated sludge / waste activated sludge improvements were recommended as part of the improvements. Construction of a seventh clarifier will require the construction of an extensive retaining wall and relocation of the existing plant entrance road. A polymer storage and feed system was also included in the improvements to allow for feed of polymer in the event of poor settling conditions.

Disinfection

The plant effluent outfall is currently used to provide contact time for chlorine disinfection. A maximum flow of 93 MGD is possible while maintaining the Ten States Standards requirement for 15 minutes of contact time at peak flow. Therefore, installation of a UV disinfection system was included in the originally recommended improvements. During final design, retaining part of the existing sodium hypochlorite disinfection system for supplemental disinfection of high solids effluent will also be evaluated.

Solids

No improvements to the solids handling processes were recommended as part of the Long Term Control Plan strategy. However, provisions were made in previous projects to allow for the addition of more dewatering centrifuges if higher throughput becomes necessary in the future.

3.4 Cost Estimates

The conceptual level capital cost estimate for capital improvements associated with increasing total flow capacity to 160 MGD and secondary capacity to 100 MGD is summarized in Table 3.4. These capital costs include engineering, construction and contingency.

Table 3.4
Conceptual Level Cost Estimate for 160 MGD Peak Plant Flow, 100 MGD Peak Secondary Capacity

Description	CIP Total ($Millions)
Preliminary Treatment	18.7
Primary Treatment	9.2
Aeration Basins	11.1
Final Clarifier Modifications (including new 7th clarifier)	32.3
UV System - 160 MGD	9.2
Total Estimated Capital Cost	80.4

4 Evaluation of Additional Alternatives for Increased Wet Weather Capacity

In order to evaluate the feasibility of increasing secondary capacity beyond 100 MGD, two other cases were considered for increases in secondary capacity: 130 MGD or 160 MGD. 160 MGD was chosen as an alternative because this flow represents the maximum hydraulic capacity of the existing outfall and also represents the maximum feasible influent flow rate to the plant from the collection system. 130 MGD was chosen based on the potential capacity of the secondary system associated with placement of two additional clarifiers near the existing six. For purposes of this analysis, the influent modifications associated with the proposed new headworks would not change. Similarly, effluent disinfection and outfall capacity would also not require changes from those discussed above as part of increasing secondary capacity to 100 MGD. Changes to the secondary treatment system including final clarifiers and aeration basins and changes to the primary treatment system will be discussed.

Secondary Treatment Capacity

160 MGD

In order to increase secondary capacity to 160 MGD, the step feed strategy of feeding 100% of the aeration basin influent (including effluent from the new headworks) to the first pass of the aeration basins would be maintained. The contact time provided in the basins is approximately 30 minutes. Capability to feed some influent to the last half of the second pass would also be provided. This is a minimum contact time that would be recommended for rapid BOD uptake and for production of a good settling floc. Construction of new aeration basins was considered to increase contact time, but there is no feasible area in the vicinity of the existing basins. Additionally, additional basins would not be operated during dry weather conditions.

The number of secondary clarifiers required for this flowrate was determined by using a peak surface overflow rate of 1,200 gpd/ft2. At this overflow rate, a total of 10 final clarifiers (4 additional) are required. This is an aggressive approach based on the findings of the previous analysis (see previous

section). At this aggressive overflow rate, polymer feed and very good settling sludge will be necessary to maintain permit limits and to retain biological solids during wet weather events.

Additional modifications will be required to the aeration system to provide the required oxygen transfer during peak flow conditions. Additional diffusers and larger aeration piping will be necessary under these peak conditions. The influent channel will need to be raised on all basins to prevent overflows during this flow and larger conveyance piping will be needed from the primary clarifiers to the aeration basins.

130 MGD

Similar to the 160 MGD case, step feed must be employed at peak wet weather to provide treatment and to ensure consistent process performance. Aeration basin influent (including effluent from the new headworks) would be fed to the first pass of the aeration basins. This configuration would provide over 45 minutes of detention time at peak flow.

A total of 8 final clarifiers at a surface overflow rate of 1,200 gpd/ft are required to provide a peak wet weather capacity of 130 MGD. The two additional clarifiers would be constructed near the existing six clarfiers. Similar to the 160 MGD case, a polymer system and relatively low SVIs will be required to provide good settling during peak conditions.

Additional modifications will be required to the aeration system to provide the required oxygen transfer during peak flow conditions. Additional diffusers and larger aeration piping will be necessary under these conditions.

4.1 Primary Treatment

In the originally proposed strategy for wet weather flows, 100 MGD of separate system flows would be bypassed around the primary clarifiers and sent to secondary treatment during peak wet weather flow events. The remaining flow of 60 MGD would be treated in the existing primary clarifiers, disinfected, combined with secondary effluent, and discharged. In the 130 MGD and 160 MGD cases, it is recommended that all flows be treated through primary treatment prior to either secondary treatment or disinfection. Primary clarification will reduce the BOD and TSS load to the secondary system under these conditions.

Three different options were considered for increasing primary treatment capacity for total flows of up to 160 MGD:

- Addition of 4 primary clarifiers to provide conventional primary treatment of 160 MGD at a loading rate of 2,000 gpd/ft2.
- Retrofit of all primary clarifiers for chemically enhanced primary treatment and addition of one primary clarifier to provide primary treatment of 160 MGD at a loading rate of 3,000 gpd/ft2.
- Installation of 60 MGD of chemical high rate treatment for flows above 100 MGD.

The addition of one additional primary clarifier and retrofit of all clarifiers for chemically enhanced primary treatment was found to be the most feasible based on available land area and capital costs.

4.2 Recommended Improvements and Site Layout

Schematics of recommended improvements for treating 130 MGD and 160 MGD through secondary treatment are shown in Figures 4.1 and 4.2.

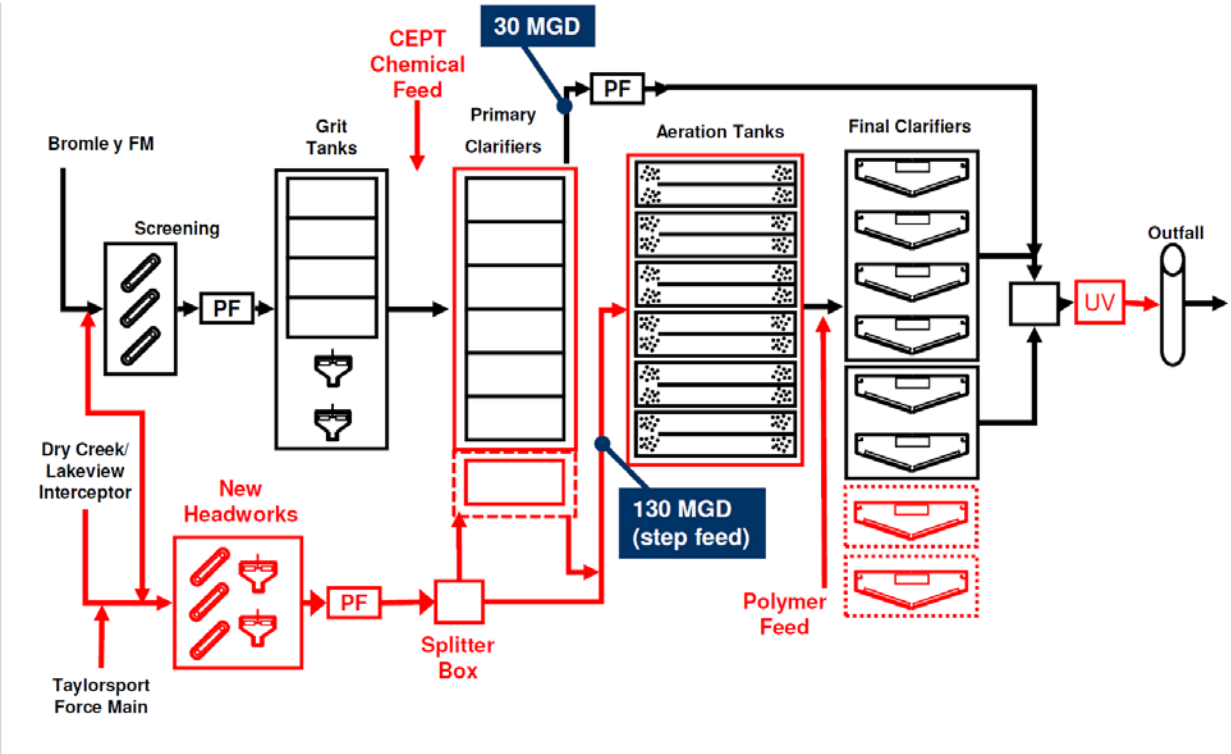

Figure 4. 1 Dry Creek WWTP Conceptual Process Flow Schematic for 160 MGD Total Flow and 130 MGD Secondary Treatment Capacity

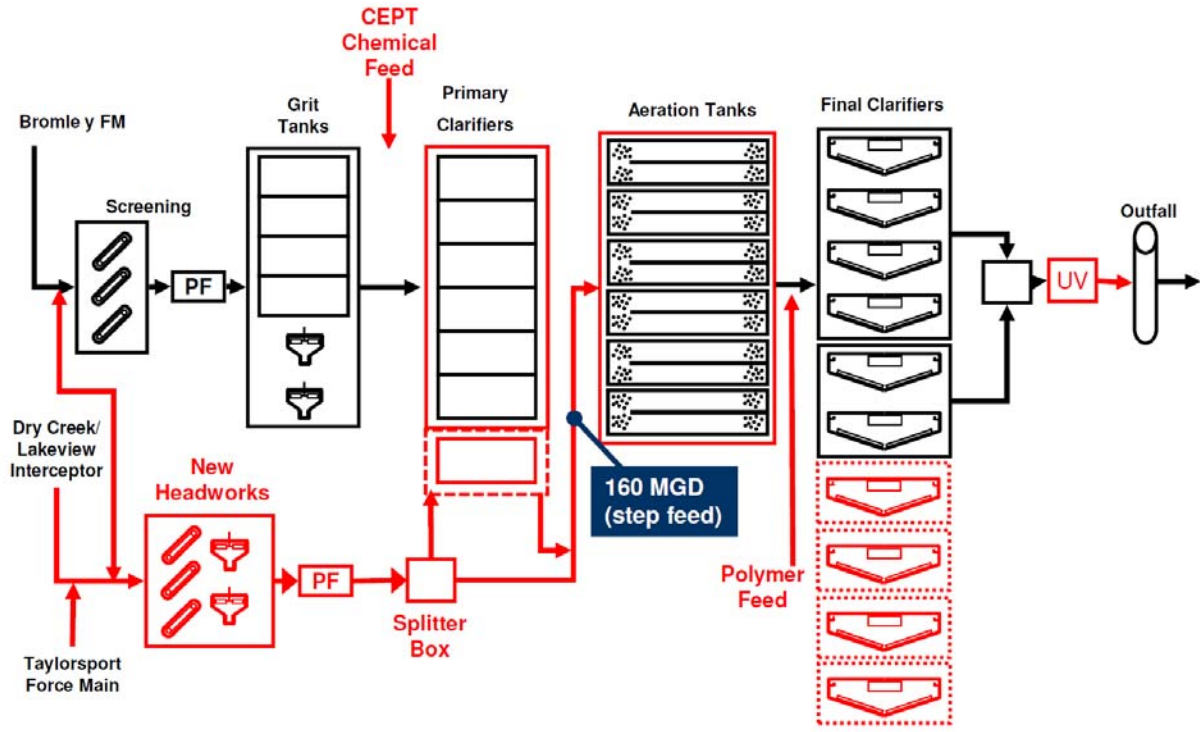

Figure 4. 2 Dry Creek WWTP Conceptual Process Flow Schematic for 160 MGD Total Flow and 160 MGD Secondary Treatment Capacity

As was discussed previously, the improvements proposed at the influent and effluent of the plant remain the same as was initially proposed for 100 MGD secondary treatment capacity. Improvements to both the secondary treatment system and primary treatment system were discussed in the previous section. During wet weather, operation would be similar except that less flow would be diverted in the 130 MGD secondary capacity case and all flow would be sent through secondary treatment in the 160 MGD case. In the 130 MGD secondary capacity case, complete segregation of combined and separate flows will not be possible if primary treatment is maintained for all flow entering the plant.

A site layout showing the potential locations of clarifiers for the 130 MGD secondary capacity case and the 160 MGD secondary capacity are shown in Figure 4.3.

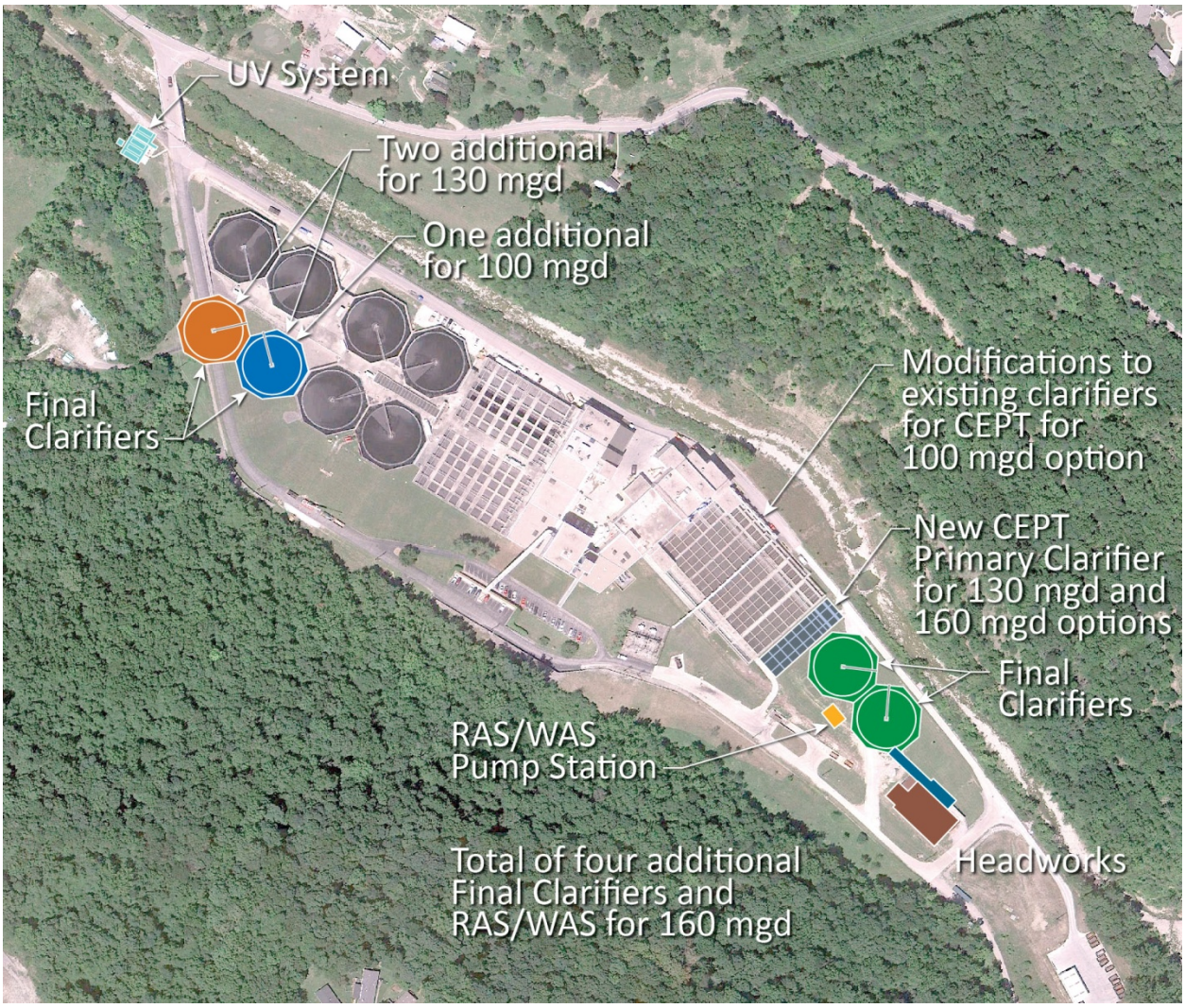

Figure 4.3 Dry Creek WWTP Conceptual Site Aerial/Plan of the 130 MGD and 160 MGD Capacity Scenarios.

As can be seen from the conceptual site layout, the available land area on the site is extremely limited. Areas outside the existing roadways surrounding the plant have extremely large slopes, ranging from 22 to 40%. Construction of the eighth clarifier for 130 MGD secondary capacity would require extensive modifications to the existing plant influent access road and additional retaining wall installation beyond that required for adding the seventh clarifier (for the 100 MGD secondary case). Construction of the ninth and tenth clarifier to provide 160 MGD of secondary capacity would require construction of these clarifiers near the primary clarifiers on the influent side of the plant. Area in this location of the plant is also extremely limited and would require construction of the new clarifiers very near the other proposed facilities. Operation of the ninth and tenth clarifiers on this side of the plant would also be extremely difficult. Mixed liquor from the aeration basins would need to be split and transported across the site to the ninth and tenth clarifiers, RAS and WAS would similarly need to be pumped back across the site. In addition, this system would need to be taken out of operation and drained after every rain event.

4.3 Summary of Cost Estimates

A summary of estimated capital costs for the 130 MGD and 160 MGD Secondary Capacity alternatives are shown in **Tables 4.1** and **4.2** below.

Table 4.1

Summary of Conceptual Level Capital Cost Estimate for 130 MGD Secondary Capacity

Description	CIP Total ($Millions)
Preliminary Treatment (new Headworks)	18.7
Primary Treatment (CEPT + 1 Add. PC)	14.7
Aeration Basins (Step feed, diffusers, hydraulics)	16.6
Final Clarifier Modifications (including two new clarifiers)	44.6
UV System - 160 MGD	10.1
Total Estimated Costs	104.8

Table 4.2

Summary of Conceptual Level Capital Cost Estimate for 160 MGD Secondary Capacity

Description	CIP Total ($Millions)
Preliminary Treatment (new Headworks)	18.7
Primary Treatment (CEPT + 1 Add. PC)	14.7
Aeration Basins (Step feed, diffusers, hydraulics)	19.3
Final Clarifier Modifications (including four new clarifiers and new RAS/WAS PS)	86.6
UV System - 160 MGD	10.1
Total Estimated Costs	149.5

5 Summary and Conclusions

The original Long-Term Control Plan included a plan at Dry Creek WWTP to increase the influent flow to 160 MGD and to increase secondary treatment capacity to 100 MGD. The 160 MGD influent flow rate represents that maximum practicable flowrate possible to the plant, based on collection system analysis and alternatives included in the Long-Term Control Plan as part of the 2009 Watershed Plans. In the original evaluation, proposed improvements to the secondary system were evaluated based on the use of a biological treatment system model and clarifier stress testing and computational fluid dynamics modeling.

The improvements proposed to increase the secondary treatment capacity to 100 MGD included additional unit processes that maximized the use of the existing plant area.

Two additional scenarios were evaluated to determine if increase in secondary treatment capacity was feasible at the Dry Creek WWTP:

- 130 MGD secondary treatment capacity
- 160 MGD secondary treatment capacity (all flows treated through secondary system)

Proposed improvements, as well as potential site layouts and conceptual level capital costs were determined for each alternative.

Even though capital costs were developed for each option, implementation of either alternative is not feasible or practical based on the following:

- **130 MGD Secondary Treatment Capacity**
  - Requires construction of an eighth final clarifier, required extensive additional retaining wall construction and reroute of existing plant influent road on the hillside slope.
  - Segregation of combined and separate flows would be difficult and not cost-effective.
  - Site limitations near the existing secondary clarifiers make construction extremely costly in order to add additional secondary clarifiers for additional capacity. Therefore, secondary clarifiers were sized aggressively and operation during peak wet weather would pose risk for solids washout due to high loading rates on the clarifiers. This would increase the risk of poor performance during dry weather conditions subsequent to rain events.
- **160 MGD Secondary Treatment Capacity**
  - Requires construction of four total secondary clarifiers with two of the secondary clarifiers needing to be located on the influent side of the plant due to site limitations. Splitting and transport of flow to the secondary clarifiers near the influent and return of RAS and WAS would be extremely difficult. This would increase the risk of process failure during wet weather and potential issues with dry weather operation after rain events.
  - Site limitations near the existing secondary clarifiers make construction extremely costly in order to add additional secondary clarifiers for additional capacity. Therefore, secondary clarifiers were sized aggressively and operation during peak wet weather would pose risk for solids washout due to high loading rates on the clarifiers. This would increase the risk of poor performance during dry weather conditions subsequent to rain events.

Both alternatives pose a significant risk for solids washout during peak conditions and also pose significant operational challenges. In addition, since all flows are being disinfected prior to discharge, neither alternative provides additional water quality benefit. Based on the above, 100 MGD through secondary treatment represents the maximum feasible capacity at the Dry Creek WWTP and provides for full secondary treatment of all separate flows as well as providing the opportunity to treat an additional

470 MG of flow in a typical year through secondary treatment over the current peak secondary capacity of 55 MGD. The following table shows incremental increase in secondary treatment of flow at the Dry Creek WWTP in a typical year based on a conveyance capacity of 160 MGD to the Dry Creek WWTP.

Table 4.3

Incremental Increase in Secondary Treatment

Peak Secondary Capacity Increase (MGD)	Incremental Increase in Typical Year Secondary Treatment (MG per Year)	Differential in CIP ($ Millions)	Incremental Cost per additional gallon through secondary ($M)
From 55 to 100	276	80.4 (base)	$0.29
From 100 to 130	3	24.4 (additional)	$8.13
From 130 to 160	0	69.1 (additional)	NA

Note: Peak flow is less than 160 MGD in the typical year

As Table 4.3 shows, there is an enormous increase in secondary treatment of flows with the expansion from 55 MGD to 100 MGD but the benefit drops dramatically when looking at increasing to 130 MGD and further to 160 MGD where the flow will not reach that level in the typical year based on the current Integrated Plan for 2025 and the resulting additional costs to achieve this higher capacity does not justify the benefits. This analysis further demonstrates that the highest feasible peak sustained secondary capacity at the Dry Creek WWTP is 100 MGD and no feasible and cost-effective alternative exists to increase the secondary treatment capacity beyond 100 MGD.

It is important to note that SD1 properly maintains and operates its equipment to sustain target capacity. Regular maintenance schedules are followed and tracked within the Lucity Asset Management software program.