



Source: SD1

Elijahs Creek Watershed Characterization Report

Prepared for: Sanitation District No. 1 of Northern Kentucky



January 2009

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1. WATERSHED SUMMARY

Watershed characterization reports are being developed for sixteen watersheds located in Northern Kentucky that lie within Sanitation District No. 1's (SD1's) service area. The purpose of the watershed characterization reports is to describe the physical and natural features, land cover, infrastructure, waterbody conditions, potential pollutant sources and other features in each watershed. This information will allow SD1 and other interested parties to develop an understanding of important features, pollutant sources and water quality in the watersheds. This information will also assist SD1 and others in goal-setting, prioritization of improvement projects, and assessment of the effectiveness of these projects. The watershed characterization reports meet the system characterization element for the receiving water that is required for a combined sewer overflow (CSO) Long-Term Control Plan (LTCP). Additionally, the Consent Decree requires that the Watershed Plans include elements of a LTCP.

The Elijahs Creek watershed is located in Boone County, in the North Study Basin (Figure 1). Elijahs Creek is one of the smaller watersheds in the study area but has the highest percent imperviousness. Developed lands comprise 68% of the watershed, with the Cincinnati/Northern Kentucky International Airport located in the headwaters area.

Elijahs Creek and its tributaries are designated for warm water aquatic habitat, primary contact recreation, secondary contact recreation and domestic water supply (at applicable points of withdrawal). This creek does not appear on the 303(d) list of impaired waterbodies (KDOW, 2008); however, airport runoff containing deicing fluids has historically impacted dissolved oxygen levels in this creek. In 1998, a TMDL was completed and in 2005 a more stringent permit was issued to the airport for storm water runoff.

Water quality data have been collected in the Elijahs Creek watershed since 1992. A comparison of recent water quality data to the applicable water quality criteria revealed bacteria exceedances. Violations of dissolved oxygen and pH have historically been observed at the USGS continuous monitoring station, but recent data from this location are still being reviewed and are not yet included in this assessment.

The most recent macroinvertebrate and benthic algae data indicate poor to very poor biological conditions in this watershed and aquatic habitat has been assessed as not supporting.

Potential pollutant sources in this watershed include: sanitary sewer overflows (SSOs), KPDES-permitted dischargers of storm water, storm water runoff, and septic systems. The potential for these sources to generate fecal coliform bacteria has been assessed using a Watershed Assessment Tool (WAT!)¹. The WAT! identifies the potential sources within a watershed and estimates their possible impact. It also allows SD1 to compare and rank the 16 different Northern Kentucky watersheds.

The WAT! calculated an average fecal coliform loading potential for year-round conditions and a very low fecal coliform loading potential for base flow conditions for

¹ The WAT! is still under development. All results presented here are for illustrative purposes only. The results are subject to change and should therefore not be relied on or considered definitive.

the Elijahs Creek watershed. Overland runoff is predicted to be the dominant source under year-round conditions and septic systems are predicted to be the dominant source under base flow conditions.

The WAT! ranking is one of several factors that should be considered when prioritizing watersheds for improvement projects. Other factors include moderate-high public interest, and the absence of threatened and endangered species, drinking water intakes and special designations in this watershed.

There is significant data collection planned or ongoing in this watershed, therefore no additional biological, habitat or chemical monitoring is recommended at this time.

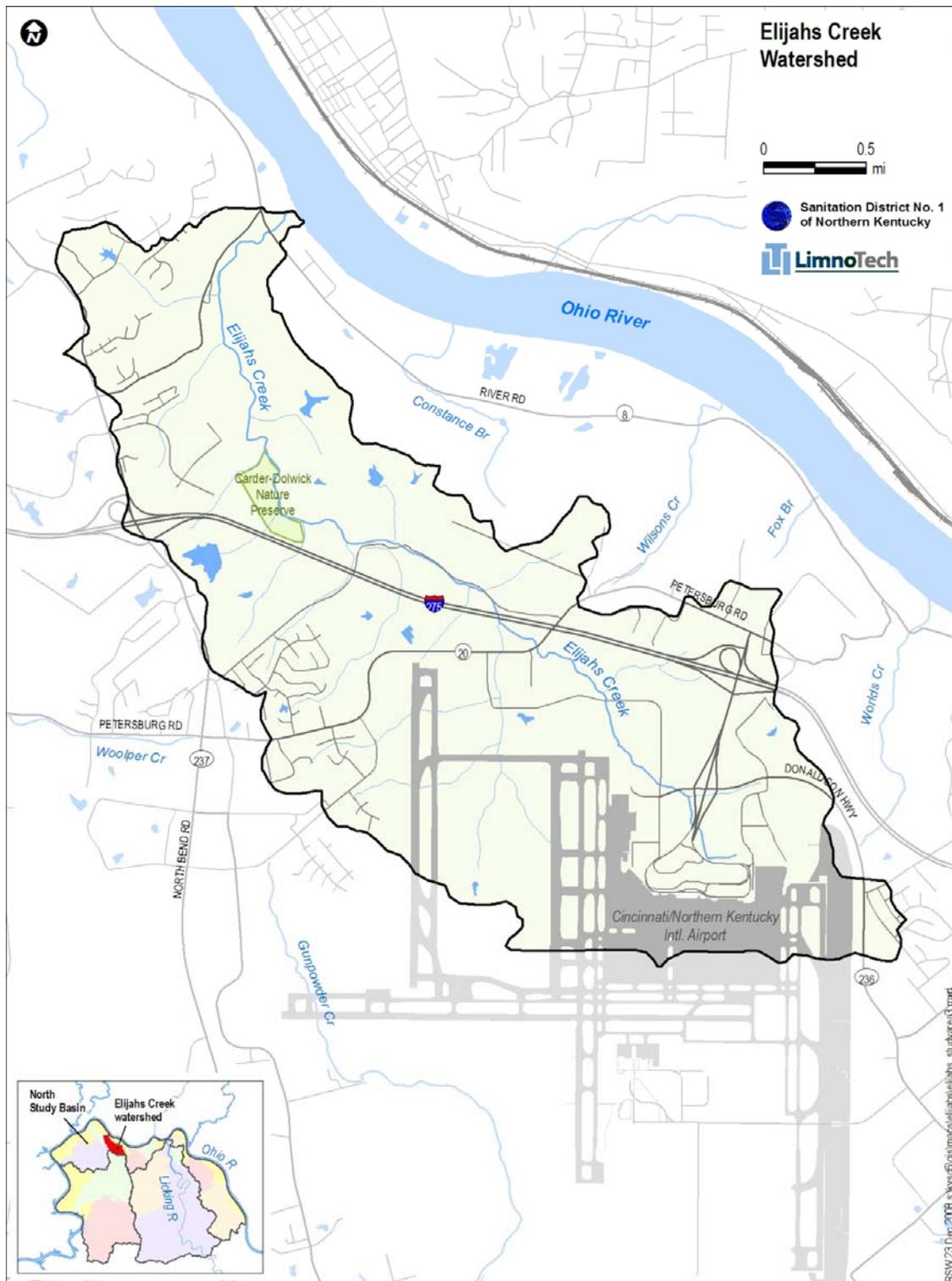


Figure 1. Elijahs Creek Watershed

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2. WATERSHED FEATURES

Elijahs Creek is located in Boone County and the watershed area for this creek is 6.7 square miles. The headwaters of Elijahs Creek are located north of the Cincinnati/Northern Kentucky International Airport. The 5.1 mile long creek flows northwest and is joined by several unnamed tributaries before it empties into the Ohio River.

2.1 PHYSICAL AND NATURAL FEATURES

The following sections describe key features of the watershed and creek, including hydrology, geology, topography, soils, climate, and habitat. These features are important because they affect land uses, and shape the chemical, biological, and hydrological characteristics of Elijahs Creek.

2.1.1 Hydrology

An active USGS continuous monitoring station (03260100) is located on Elijahs Creek at Elijahs Creek Road. The watershed area draining to the station is 3.9 square miles², comprising approximately 60% of the Elijahs Creek watershed. Daily discharge measurements are available at the station from April 1999 to the present³. The average flow at the station is 7.2 cfs (4/9/1999 - 9/30/2007), and 95% of flows are less than 32 cfs. Base flows at this location have been measured at less than 0.5 cfs, with flows increasing by up to three orders of magnitude during a storm event. The maximum flow recorded at the USGS station is 365 cfs. The periods of high flow tend to be very brief and only last one to two days. In contrast, during extended periods of dry weather, flows at the station become intermittent. Between April 1999 and September 2007 there were 60 days with zero flow.

The 100-year floodplain extends up Elijahs Creek less than ¼ mile from the mouth. According to the Boone County Comprehensive Plan, portions of the Elijahs Creek watershed experiences frequent flooding (BCPC, 2005).

2.1.2 Geology

The Elijahs Creek watershed is located in the Outer Bluegrass Physiographic⁴ Region, which is underlain primarily by Ordovician-age interbedded limestone and shale (Ray et al., 1994). Although roughly half of this watershed is underlain by bedrock with a moderate potential for karst development (Paylor and Currens, 2002), rocks in this region generally contain higher percentages of shale layers and do not develop extensive karst features (Ray et al., 1994)⁵.

² This drainage area was calculated using a detailed watershed delineation developed for this project; the reported drainage area differs slightly from that reported by the USGS.

³ This analysis only uses approved data from USGS, and at the time of the analysis data was approved through 9/30/2007.

⁴ Physiographic regions are based on differences in geology, topography and hydrologic regime. The State of Kentucky is divided into five physiographic regions.

⁵ In areas with karst, an almost immediate connection between groundwater and surface water can exist, short-circuiting any attenuation of pollutant loads that might otherwise occur.

The headwaters of this watershed are underlain by glacial deposits, and nearer the mouth, steeper banks are found where creek cuts through the erodible shale found in the Kope formation. Groundwater yield in this watershed varies depending on geological formation, and is generally much less available on hilltops and hillsides. Wells in the valley bottoms can yield 100-500 gallons per day; however, water is hard and may contain salt and hydrogen sulfide (Carey and Stickney, 2004).

2.1.3 Topography

Higher elevations are found in the southwest and near the far eastern edges of this watershed. The high point (931 feet) is at the far southeast corner of the watershed near Donaldson Highway, on the east side of the Cincinnati/Northern Kentucky International Airport. The lowest elevation in the watershed (453.6 feet at normal Ohio River pool) is at the confluence of Elijahs Creek with the Ohio River.

2.1.4 Soils

The nature of soils and topography in a watershed plays an important role in both the amount of runoff generated and the amount of soil erosion that can occur. Most (77%) of the soils in the Elijahs Creek watershed are classified as hydrologic soil group C (NRCS, 2006), meaning they have slow infiltration rates when thoroughly wetted. Another 19% of the soils are classified as hydrologic soil group D meaning water movement through the soil is restricted or very restricted. Soils in this group have a high runoff potential when thoroughly wet.

Most (97%) of the soils in the watershed are ranked “highly erodible” as indicated by an index for erodibility (NRCS, 2006). The erodibility of soils is important when soils are disturbed through activities such as land clearing for new development. Portions of this watershed are anticipated to undergo significant development in the future (Section 2.2).

2.1.5 Climate

The temperatures in this area are generally lowest in January and highest in July. Precipitation averages 41.2 inches annually, with the wettest months observed between March and July. Minimum precipitation is recorded in the fall and late winter as shown in Figure 2 (NCDC, 2008).

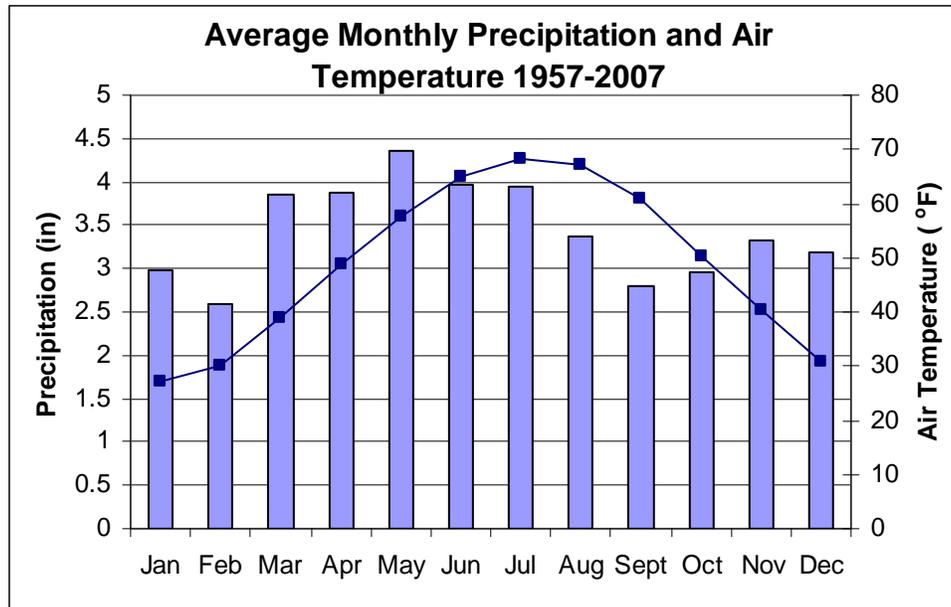


Figure 2. Average Monthly Precipitation and Air Temperature at the Cincinnati Northern Kentucky Airport (1957-2007)

2.1.6 Habitat

The Elijahs Creek watershed lies within the Outer Bluegrass ecoregion⁶, which is characterized by sinkholes, springs, entrenched rivers and intermittent and perennial streams (Woods et al. 2002). Wetlands are not common in this ecoregion and within this watershed comprise less than an acre. Streams typically have relatively high levels of suspended sediment and nutrients. Glacial outwash, which tends to be highly erodible, exists in a few areas.

Pre-settlement conditions in this ecoregion consisted of open woodlands with barren openings, and vegetation was mostly oak-hickory, with some white oak, maple-oak-ash and American beech-sugar maple forests (Woods et al. 2002). As described in Section 2.2.1, natural habitats have been altered from pre-settlement conditions.

Elijahs Creek is steep in some areas and has limited riparian areas. Some underlying bedrock occurs within the stream margins, but fine sediments are common instream (Figure 3).

In the past, runoff from the airport contained deicing fluids which promoted oxygen-consuming bacteria in the creek. The high concentrations of biochemical oxygen demand (BOD) and nuisance growths of *Sphaerotilus* (KDOW, 1998) impacted the stream and habitat.

⁶ Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources (Woods et al., 2002).

Aquatic habitat assessments⁷ were conducted at two sites in Elijahs Creek in 2004, and both sites were rated as not supporting of aquatic habitats (Table 1).

A more stringent permit was issued to the airport in April 2005 and recently, a new treatment facility was built to treat storm water from the airport before it reaches Elijahs Creek. Aquatic habitats may improve concurrent with this improvement in the quality of water reaching the creek from the airport.



Figure 3. Elijahs Creek

Table 1. Aquatic Habitat and Biological Sampling

Stream	River mile	Monitoring					
		Habitat		Macroinvertebrates		Diatoms	
		Year	Ranking	Year(s)	Ranking ^b	Year(s)	Result
Elijahs Creek	1.0	2004	Not supporting	1993, 1994, 1995, 2004	Fair, Very Poor, Poor, Very Poor	1993	Poor
Elijahs Creek	3.6	2004	Not supporting	1993 (Mar, Nov), 1994, 1995, 2004	Poor	1993	Poor
Unnamed Tributary of Elijahs Creek at River Mile 3.4	0.1			1993 (Mar, Nov), 1994, 1995	Poor	1993	Poor

^a When ranking remained the same between sampling periods, the ranking is only shown once.

⁷ This assessment was conducted using EPA-established protocols. KDOW rated several components of physical habitat within the stream such as epifaunal substrate, embeddedness, sediment deposition, channel flow status, bank stability and riparian vegetation zone width, among others.

2.2 LAND COVER CHARACTERISTICS

Land cover and land use play an important role in the quantity and quality of runoff into receiving waters. Current and future land cover in the Elijahs Creek watershed are described below.

2.2.1 Current Land Cover

The Kentucky Division of Geographic Information, Commonwealth Office of Technology provided a GIS dataset showing 2005 Kentucky land cover. This dataset was updated and improved to approximate 2007 land cover conditions (Figure 4) using a variety of other datasets that represent current impervious conditions (roads, parking lots, buildings), open space lands (including parks), and surface waters.

Currently, 68% of the Elijahs Creek watershed is developed and 25% is covered with impervious surfaces. Forest and pasture/hay comprise the majority of the undeveloped land covers.

There are no incorporated areas in this watershed. Interstate 275 traverses the watershed north of the Cincinnati/Northern Kentucky International airport. Development in this watershed is primarily located near the airport and in the western portion of the watershed along Petersburg Road and north of I-275. Much of the steep land adjacent to the creek and north of I-275 is forested. The Hillside Trust owns one preserve, the 35-acre Carder-Dolwick Nature Preserve in the Elijahs Creek watershed.

2.2.1.a Animal operations

There are no permitted concentrated animal feeding operations (CAFOs) or animal feeding operations (AFOs) in the watershed (Kentucky Geographic Network, 2008 and 2008a). It is not known if there are any other livestock in this watershed.

2.2.1.b Septic Systems

SD1 estimates that approximately 3% of all parcels in the Elijahs Creek watershed are potentially serviced by septic systems (Figure 8). Properties potentially served by septic systems are found between I-275 and Petersburg Road and are also scattered in the western part of the watershed between I-275 and KY-20.

The Northern Kentucky Health Department does not currently have estimates of septic system failure rates Boone Counties. Anecdotal reports from Health Department inspectors suggest that 10% of the septic systems in Northern Kentucky may be operating improperly due to incorrect installation, lack of maintenance or age of the system (NKHD, 2008).

2.2.2 Future Conditions

The Elijahs Creek watershed is predicted to become even more intensely developed in the future. Some areas near the airport are predicted to remain less developed or undeveloped, as the Cincinnati/Northern Kentucky Airport has worked with the Boone County Planning Commission to discourage residential development in some areas and has implemented a voluntary property acquisition program to reduce the impact of aircraft activity on residential areas.

Several transportation projects are planned for I-275 near the airport. One involves construction of a new interchange at the I-275 and Petersburg Road (KY-20), and the other is reconstruction of the existing I-275/KY-212 and KY-20 interchanges (Kentucky Transportation Cabinet, 2006).

The Boone County Comprehensive Plan mentions that development in the area of developmentally sensitive hillsides should be planned carefully, with great care taken in preserving and protecting existing vegetation (BCPC, 2005).

2.2.2.a Future land cover

Future land cover was developed by modifying 2007 land cover to reflect potential future conditions (roughly 2030) obtained from SD1 and the Northern Kentucky Area Planning Commission (NKAPC). Development is predicted to primarily replace forest and pasture lands (Figure 5). If development occurs as predicted, this will become the most developed of the 16 watersheds (83% developed land). Impervious surfaces in the watershed are predicted to increase from 25% to 31%.

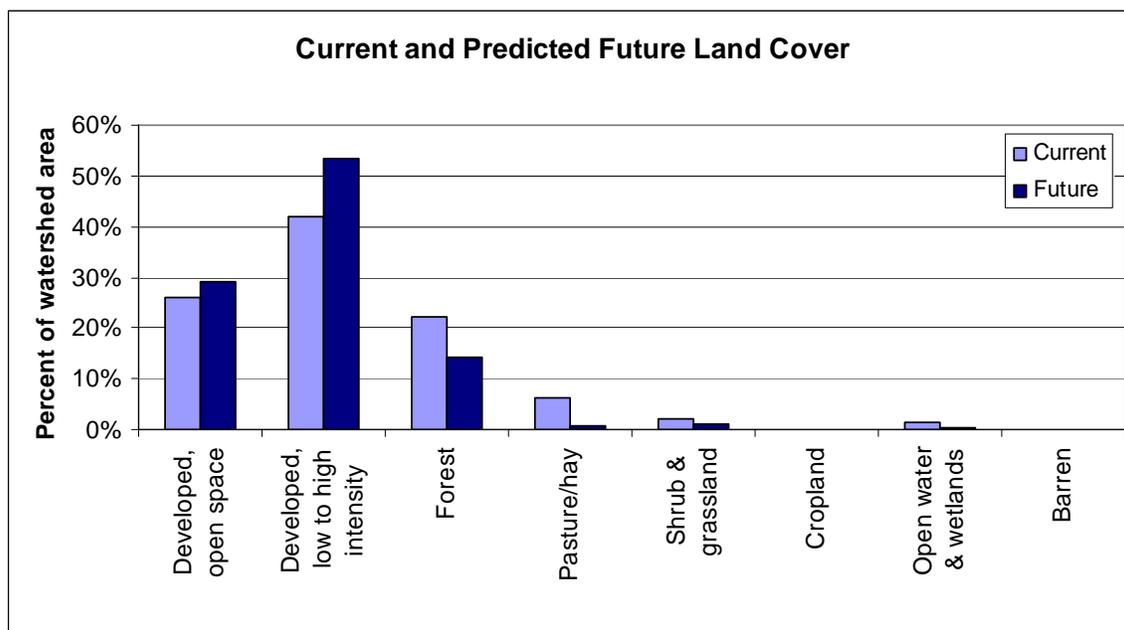


Figure 5. Current and Predicted Future Land Cover

2.3 INFRASTRUCTURE FEATURES

This section summarizes infrastructure features for the Elijahs Creek watershed⁸. The entire watershed lies within SD1's sanitary sewer service area. This area contains approximately 28 miles of separate sewer lines. The sanitary sewer infrastructure is primarily located in the western portion of the watershed and along the mid- to downstream portion of Elijahs Creek itself.

The entire watershed lies within SD1's storm water service area. The storm water system is comprised of approximately 91.1 miles of streams and channels and approximately 12.9 miles of pipes.

There is no combined sewer system area in this watershed. The extent of the sanitary and storm water service area within this watershed is shown in Figure 6.

⁸ SD1 is undertaking a characterization and assessment of the sewer system, and overflows identified herein are subject to change. Information on the sanitary and storm water system in Section 2.3 was queried from SD1's geodatabase accessed on November 21, 2008.

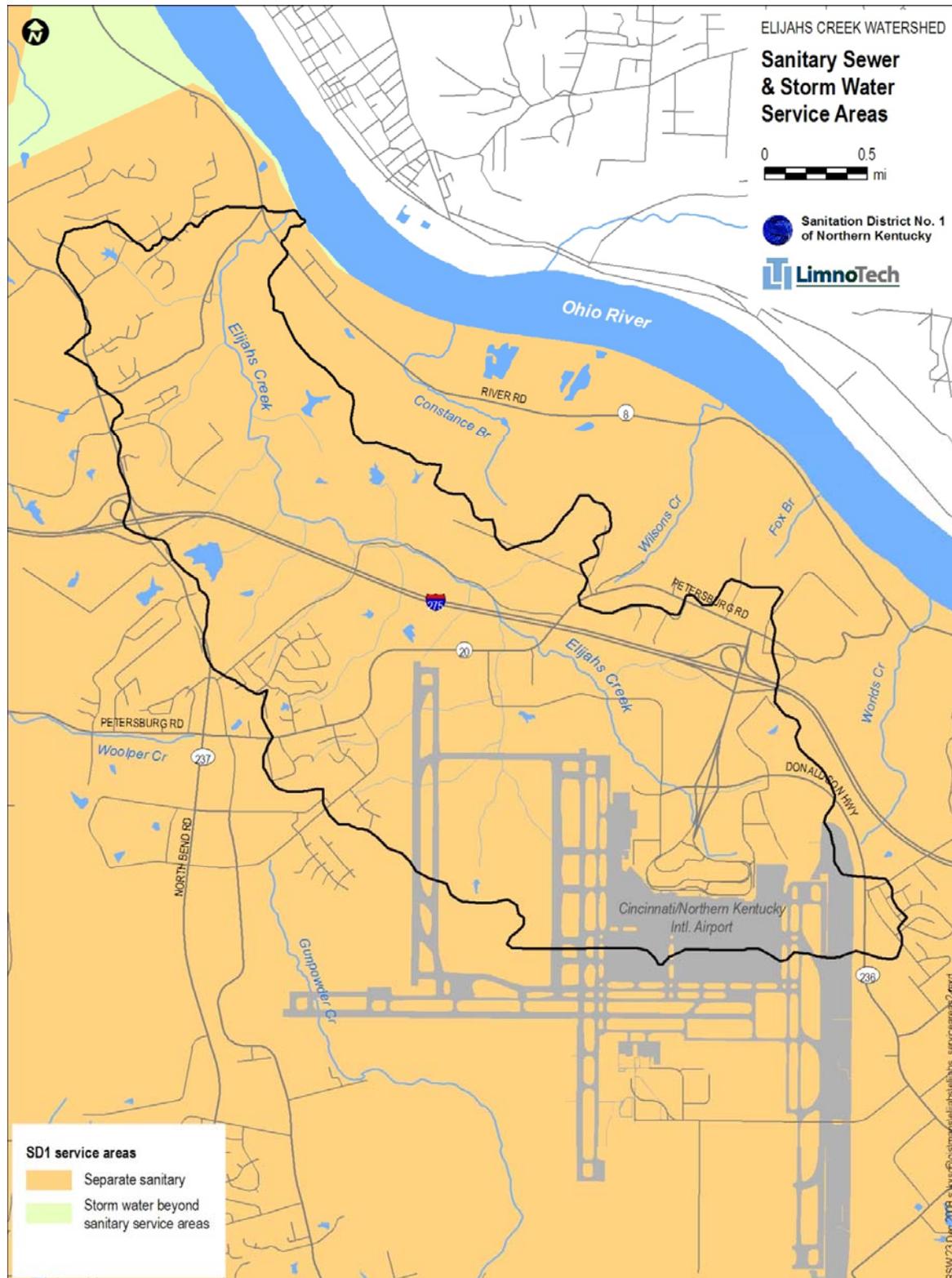


Figure 6. Sanitary Sewer and Storm Water Service Areas

2.3.1 Point Sources and Infrastructure

The occurrence of KPDES-permitted dischargers, sewer overflows and storm water discharges are discussed below.

2.3.1.a KPDES dischargers

There are two KPDES-permitted dischargers in the Elijahs Creek watershed. Both of these dischargers are individual permits for storm water discharges. Based on a review of recent effluent monitoring data (January 2007 to June 2008), it was observed that both of the permitted dischargers have violated permit limits for at least one of the following parameters: 5-day biochemical oxygen demand (BOD₅), total suspended solids (TSS), dissolved oxygen (DO), pH, or oil and grease. Permitted dischargers are presented in Table 2.

Table 2. Permitted Dischargers

Receiving Water	KPDES ID	Facility Name	Permit Type	Outfall	Outfall Description	Currently Permitted? ^a	Permit Violations
Elijahs Creek	KY0063339	Cincinnati/Northern KY Intl Airport (CVG)	Minor	002A	Storm water runoff	Y	BOD ₅ , TSS
Elijahs Creek	KY0082864	Cincinnati/Northern KY Intl Airport (CVG)	Minor	003A	Storm water	Y	DO, oil and grease, pH, TSS

^a Discharge is permitted as of June 2008

2.3.1.b Sewer overflows

There are no combined sewer overflows (CSOs) in the Elijahs Creek watershed, however, there are three sanitary sewer overflows (SSOs) (Table 3). All of the SSOs are at pump stations: the Taylorsport pump station, South Park Industrial pump station and Cardinal Cove pump station. The Taylorsport pump station SSO (2360PS1) has been greatly reduced through recent pump station improvements, and will be further abated through the installation of the new conveyance system and Western Region Water Reclamation Facility as part of the Watershed Plans currently under development by SD1. The South Park Industrial pump station SSO (2360PS3) has been documented as extremely infrequent, with only a single recorded occurrence due to power failure. The Cardinal Cove pump station (2360PS2) has a history of overflows due to lack of capacity, as well as power outage issues.

Table 3. Sanitary Sewer Overflow Points

Manhole ID	Direct Discharge to Waterbody?	Typical Year Spill Frequency (Number) ^a	Typical Year Volume (MG) ^a
2360PS1 (Taylorsport PS)	Elijahs Creek	0	0
2360PS3 (South Park Industrial)	Tributary to Elijahs Creek	0	0
2360PS2 (Cardinal Cove)	Tributary to Elijahs Creek	0	0

^a The results presented were generated by models based on SD1's current understanding of the collection system infrastructure. 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 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 therefore not be relied on or considered definitive.

2.3.1.c Storm water discharges

Storm water outfalls are located in the highest concentration along the western and eastern edges of the watershed and along the I-275 corridor. In addition to storm water outfalls, there are also approximately seven suspected illicit activity points (SIAs) in the Elijahs Creek watershed. SIAs are locations where there was possible evidence of illicit discharges during SD1's storm water mapping project (2001-2002). These locations are being further investigated to determine if they are recurring. SIAs are located on the western edge of the watershed as well as along I-275. KPDES-permitted storm water discharges also exist in this watershed and were discussed previously in Section 2.3.1.a.

2.3.2 Recently Completed Infrastructure Projects

SD1 has recently implemented several infrastructure projects in the Elijahs Creek watershed or in watersheds tributary to the Elijahs Creek infrastructure:

- Taylorsport Pump Station. Elimination of a constructed bypass in approximately 2004.
- Airport Office Pump Station. Elimination of the pump station and associated constructed bypass in approximately 2005.
- Hart Drive Sewer Assessment Project. Completed in 2005, this project involved extending sewer lines, giving 57 properties the opportunity to connect to sewer service.
- Allen Fork Collection System Phase I Improvements. Completed in January 2007, this project included the installation of approximately 2,700 linear feet of new 24-inch gravity sewer to replace existing deteriorated 8-inch and 12-inch gravity sewers. The installation of the replacement sewer directly reduced wet weather flows at the Taylorsport PS, because some infiltration and inflow generated in the deteriorated existing sewers was eliminated from the system.

In addition, SD1 recently completed one infrastructure assessment project that included sewers in this watershed:

- Phase III of the Large Diameter Sewer Assessment Program. This investigation program helped identify opportunities to increase capacity and/or reduce rainfall-dependent infiltration and inflow, which would help to reduce wet-weather collection system overflows in the watershed.

2.3.3 Ongoing or Planned Infrastructure Improvement Projects

SD1 has two planned infrastructure projects for this watershed:

- Pump Station Backup Power Program. This program will minimize the risk of pump station overflow by ensuring that the three pump stations without backup power in this watershed have backup power in place by no later than December 31,

2015. These pump stations are: Cardinal Cove, South Park and Ridgefield. Cardinal Cove has a history of overflows due to capacity as well as power outage issues. South Park has a single overflow due to a power failure, and Ridgefield does not have a history of overflows.

- Pump Station Overflow Elimination Program. This program will address bypasses at pump stations identified in Exhibit E of the Consent Decree. South Park Industrial Pump Station is included in this program. While this pump station does not have a constructed bypass, the improvement plan will address historical overflows per the requirements of Exhibit E.

Project information is provided in Table 4.

Table 4. Planned Infrastructure Improvement Projects

Capital Improvement Project Title	Goals	Anticipated Start Date	Anticipated Completion Date	Project Total
Pump Station Backup Power Program	Ensure that all pump stations have backup power or other appropriate measures for addressing power outages. This includes 3 pump stations in this watershed.	2008	2015	\$508,000
Pump Station Overflow Elimination Program	Ensure that pump stations identified in Exhibit E of the Consent Decree have remedial measures implemented to eliminate known overflows. This includes the South Park Industrial Pump Station in this watershed.	2009	2010	To be determined

2.4 SENSITIVE AREAS

The federal CSO Control Policy (USEPA, 1994) states EPA's expectation that a permittee's Long-Term Control Plan (LTCP) give the highest priority to controlling CSOs in sensitive areas. The CSO Control Policy indicates that sensitive areas include:

- Waters designated as Outstanding National Resource Waters (ONRW);
- Waters with threatened or endangered species and their habitat;
- Waters with primary contact recreation, such as bathing beaches;
- Public drinking water intakes and their designated protected areas;
- National Marine Sanctuaries (NMS); and
- Shellfish beds.

These six criteria were evaluated individually. None of the waterbodies in the Elijahs Creek watershed have been designated as Outstanding National Resource Waters (401 KAR 10:030) and there are no National Marine Sanctuaries in the watershed (NOAA, 2008). Additionally, there are no threatened or endangered species or known commercial shellfish beds within the Elijahs Creek watershed, nor is shellfish harvest for consumption by private individuals known to occur. Therefore these criteria were determined not to be

relevant to the identification of sensitive waters in the Elijahs Creek watershed. The remaining two criteria are discussed below. A discussion of species of concern is also included only for potential relevance for ranking watersheds.

2.4.1 Threatened & Endangered Species or Their Designated Critical Habitat

The Kentucky State Nature Preserves Commission (KSNPC) did not identify any threatened or endangered species in this watershed, but did identify two terrestrial species of concern in this watershed (KSNPC, 2007). These are the redback salamander (*Plethodon cinereus*) and the upland sandpiper (*Bartramia longicauda*). The redback salamander is dependent upon woodland habitats (NatureServe, 2007) and the upland sandpiper is likely to inhabit marshes, beaches and rocky shores and travels through Kentucky during spring and/or fall migration (Sibley, 2000). The upland sandpiper is also considered a historic species within this watershed (KSNPC, 2007), with the last recorded sighting in 1950. Historic species are of interest to KSNPC because they may be rediscovered within the areas where they were previously found (KSNPC, 2007a).

2.4.2 Primary Contact Recreation Waters

Kentucky does not have a tiered approach for primary contact recreation (PCR). This means that the State has designated that all PCR waters should be suitable for full body contact recreation during the recreation season of May 1 through October 31 (401 KAR 10:001E). However, the State water quality standards do not define full body contact recreation, so the bacteria criteria that have been developed are based on the presumption that people will ingest the water and could therefore become ill if the water was sufficiently contaminated with bacteria.

Elijahs Creek and its tributaries are designated for PCR. It is not clear whether or not swimming activity occurs in the creeks, as public surveys regarding that information are unavailable. No public swimming beaches were identified in the watershed. Additional data will be gathered about uses of the creek.

2.4.3 Public Drinking Water Intakes or their Designated Protection Areas

There are no public drinking water intakes from surface waters or groundwater wells in this watershed. The nearest public drinking water intake from surface waters is located on the Ohio River near Louisville, Kentucky.

Source Water Assessment and Protection (SWAPP) Zones for the Ohio River intakes are determined by the Ohio River Valley Water Sanitation Commission (ORSANCO). SWAPP zones are not used in a regulatory sense, but are delineated to identify potential contaminants upstream of water intakes and are used to support identification of sources potentially impacting the intakes. ORSANCO has determined that this entire watershed lies within SWAPP Zone 2, reflecting the fact that this watershed is more than 25 miles upstream of the Louisville intake.

Drinking water supply features are shown in Figure 7.

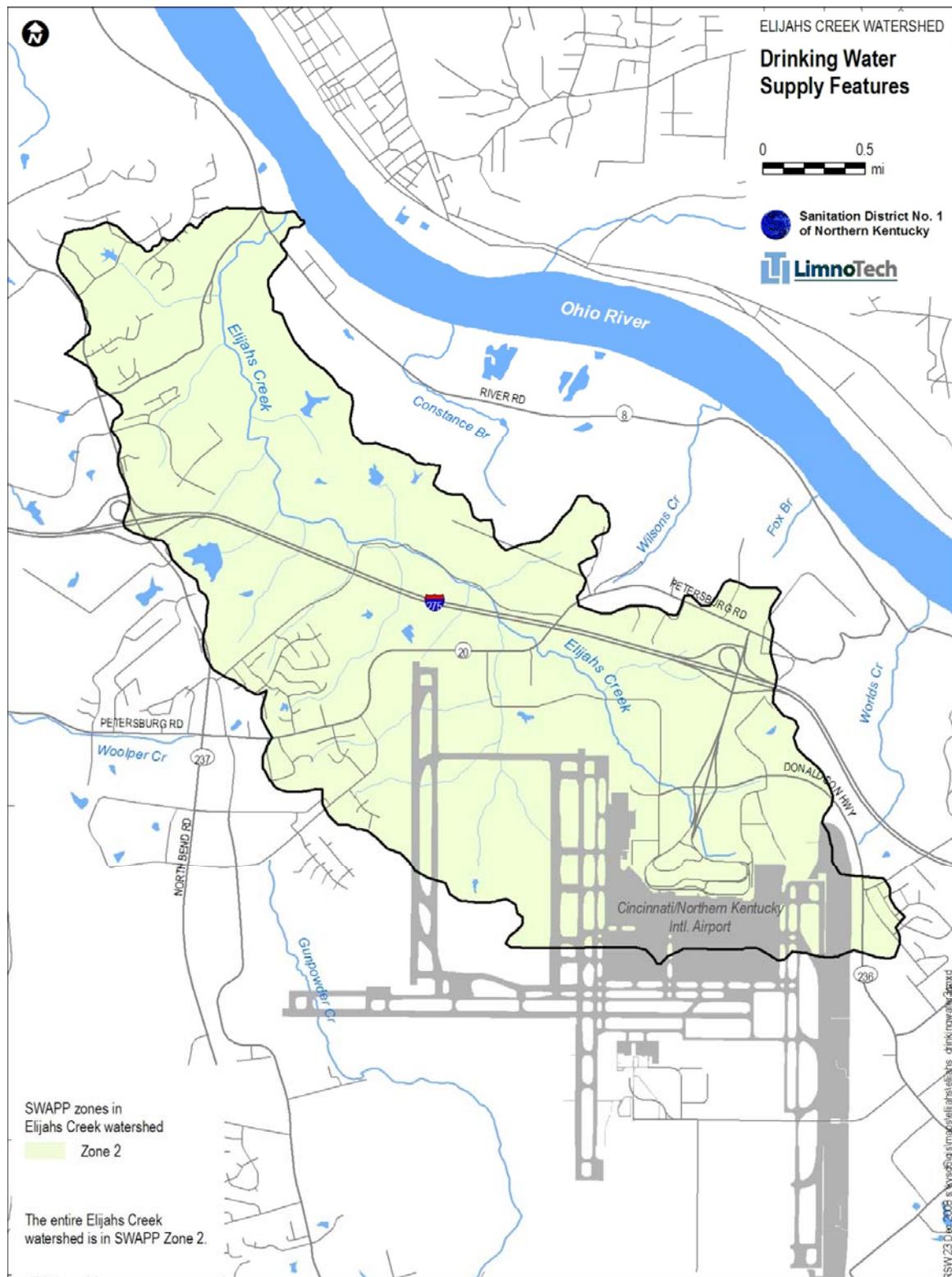


Figure 7. Drinking Water Supply Features

2.5 PUBLIC INTEREST/WATERSHED GROUP ACTIVITIES

Public interest in this watershed is moderately high due to interest in reducing deicing fluid runoff to the creek, and past sampling by the Kentucky Division of Water, USGS and SD1.

In 1998, the Kentucky Division of Water developed a Total Maximum Daily Load (TMDL) for Elijahs Creek to address impacts from deicing fluid runoff from the Cincinnati/Northern Kentucky International airport. These impacts included high concentrations of biochemical oxygen demand (BOD) and nuisance growths of *Sphaerotilus* (KDOW, 1998). The TMDL specified allowable loads of oxygen-demanding substances (ammonia and biochemical oxygen demand), and also outlined implementation actions to ensure that deicing fluids do not continue to create water quality problems in the creek. The airport agreed to install more than \$50 million in pollution controls, which included a recycling system for deicing fluids. Additionally, the state of Kentucky issued the airport a more stringent discharge permit designed to eliminate the impairment of Elijahs Creek. This permit includes monitoring requirements designed to assess compliance with water quality standards. The airport's storm water treatment plant is currently online.

The Sierra Club appears to have shown much interest in improving water quality in Elijahs Creek and their efforts to stop deicing fluid from entering Elijahs (and Gunpowder) Creek are highlighted on their website (Sierra Club, 2005).

Another organization with a presence in the watershed is the Hillside Trust, which owns the 35 acre nature preserve along Elijahs Creek near I-275.

Additionally, the Elijahs Creek valley has been mentioned, along with others, as having future potential as a greenbelt pathway system but the completed Boone County Greenways Plan was not available at the time of this report (BCPC, 2005).

3. WATERBODY USES

This section describes designated and current uses for Elijahs Creek and its tributaries.

3.1 DESIGNATED USES

Elijahs Creek and its tributaries are designated for warm water aquatic habitat, primary contact recreation, secondary contact recreation and domestic water supply, applicable at existing points of public water supply withdrawal (401 KAR 10:026). These uses are defined below.

- **Warm water aquatic habitat** means any surface water and associated substrate capable of supporting indigenous warm water aquatic life.
- **Primary contact recreation** waters means those waters suitable for full body contact recreation during the recreation season of May 1 through October 31.
- **Secondary contact recreation** waters means those waters that are suitable for partial body contact recreation, with minimal threat to public health due to water quality.
- **Domestic water supply** means surface waters that with conventional domestic water supply treatment are suitable for human consumption through a public water system as defined in 401 KAR 8:010, culinary purposes, or for use in any food or beverage processing industry; and meet state and federal regulations under the Safe Drinking Water Act, as amended, 42 U.S.C. 300f - 300j.

3.2 CURRENT USES

Available information on current uses in the watershed is presented below.

- Biological data collected in 2004 suggest poor to very poor conditions in this watershed.
- Aquatic habitat ratings in 2004 indicate that available habitat cannot support a diverse or productive ecosystem.
- A statewide fish consumption advisory was issued on April 11, 2000 due to low levels of organic mercury found in fish taken from Kentucky waters (KDOW, 2007).
- There are currently no swimming advisories for Elijahs Creek. However, KDOW and the Division of Public Health Protection and Safety recommend against swimming or other full-body contact with surface waters immediately following heavy rainfall events, especially in dense residential, urban and livestock production areas (KDOW, 2007a).
- No fishing access sites were found in the watershed (<http://kygeonet.ky.gov/kdfwr/viewer.htm>).
- There are no surface drinking water intakes in the watershed.
- There are no active public water supply groundwater wells in this watershed (KDOW, 2008a; KDOW, 2007b).

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4. WATERBODY CONDITIONS

This section describes monitoring programs and water quality and biological conditions in this watershed.

4.1 303(d) STATUS AND POLLUTANTS OF CONCERN

KDOW has previously identified Elijahs Creek (River Mile 0.0 – 5.2) as being impaired, and an ethylene glycol TMDL has been developed (see Section 2.5). This creek does not appear on the 2008 303(d) list (KDOW, 2008). It is, however, categorized as category 4A in the 305(b) report (KDOW, 2008b), indicating that this segment had an EPA approved or established TMDL, however, it has still not achieved the warm water aquatic habitat use.

4.2 MONITORING PROGRAMS

Water quality data have been collected in this watershed by KDOW, USGS and SD1. Data currently compiled by SD1 from known monitoring programs are presented in Table 5, however, only data which have been fully analyzed are discussed in Section 4.3 Water Quality Data Analysis. Available data exist for the main stem of Elijahs Creek, as well as an unnamed tributary to Elijahs Creek.

Data not included in this report will be reviewed and included in subsequent updates.

Table 5. Summary of Water Quality Monitoring Data

Entity	Dates	Parameters Sampled	Sampling Locations ^b	Sampling Frequency
KDOW	1993	Alkalinity, chloride, hardness, pH, conductivity, turbidity, Total dissolved solids (TDS), total suspended solids (TSS), nutrients	Elijahs Cr. RM 1.0, 3.6, 3.9; Unnamed Tribs. RM 0.1	1 sample (3/10/1993)
KDOW	1992-1996	Ethylene glycol, biochemical oxygen demand (BOD), dissolved oxygen (DO), pH, temperature, total organic carbon (TOC), TSS, nutrients	Elijahs Cr. RM 3.8, 5.3; Unnamed Tribs. RM 0.0, 0.1	17 samples for RM 3.8, 9 samples for RM 5.3, 14 samples for RM 0.0, 12 samples for RM 0.1
USGS	1999-present ^a	Gage height, discharge, precipitation, DO, DO % saturation, DO equilibrium, pH, conductivity, turbidity, temperature	Elijahs Cr. RM 2.8; station Number 03260100	15-minute intervals
SD1	2006	Fecal coliform, E. coli, DO, pH, conductivity, turbidity, temperature	Elijahs Cr. RM 0.3, 2.8	2 samples from baseline survey (10/3/2006 & 10/23/2006)
SD1	2007	Fecal coliform, E. coli, carbonaceous biological oxygen demand (5-day), DO, pH, conductivity, turbidity, TSS, temperature, turbidity, nutrients	Elijahs Cr. RM 0.3, 2.8	1 sample (8/15/2007)
SD1	2008 ^a	Fecal coliform, E. coli, carbonaceous biological oxygen demand (5-day), DO, pH, conductivity, turbidity, TSS, temperature, turbidity, nutrients	Elijahs Cr. RM 0.3, 2.8	1 sample (8/28/2008)

^aData not analyzed in Section 4.3, including USGS data collected after WY 2005

^bRM = River mile

4.2.1 Future Sampling

Additional sampling in this watershed is planned by SD1, the USGS (at the existing station) and the Cincinnati/Northern Kentucky International Airport. These programs are described briefly below.

SD1 plans to continue monitoring Elijahs Creek at RM 0.3 and 2.8 during base flow conditions with at least one survey per year. Typical analyses will include bacteria, nutrients, solids, oxygen-demanding constituents and physical parameters.

SD1 is planning to collect wet weather data at RM 0.3 and RM 2.8 in 2009. Attempts will be made to collect data during three discrete storm events of varying characteristics (total rainfall, maximum intensity). Samples may be analyzed for bacteria, nutrients, solids, oxygen-demanding constituents and physical parameters. Within each event, samples will be collected near hour 0, 2, 4, 6, 12, 24, 36 and 48 of the start of the storm, though these intervals are dependent on the storm characteristics and may be changed if necessary.

SD1 also plans to conduct biological monitoring within this watershed in 2009 at RM 0.3 and 2.8. This will include habitat surveys along with fish and macroinvertebrate population assessments. Additionally, surveys to assess the degree of stream hydromodification are currently underway.

The USGS will continue to operate the stage gage and measure flow and water quality (physical parameters) at RM 2.8 (station 03260100). This station is operated and funded via a cooperative agreement between USGS and SD1.

The airport conducts biological monitoring as a requirement of their KPDES permit. For monitoring, they've hired an environmental consultant to conduct macroinvertebrate and fish (number and species) monitoring (personal communication, airport environmental coordinator). In the Elijahs Creek watershed, monitoring is conducted at a station on Elijahs Creek at RM 3.4. These data are provided to KDOW.

4.3 WATER QUALITY DATA ANALYSIS

Historical water quality data (1992-2005) have been analyzed to identify past water quality problems in this watershed. Historical dissolved oxygen, unionized ammonia and pH violations were identified. The pH violations were only observed at the USGS continuous monitoring station.

Recent data (2006-present) have been analyzed in more detail to describe current stream conditions, because these data better reflect the effect of existing sources on instream water quality. Recent data did reflect elevated *E. coli*; however, no dissolved oxygen or pH violations were identified. It should be noted that the data collected at the USGS station are not included in this assessment of recent data. These data are still being reviewed will be included in the next update of this report.

4.3.1 Historical Data

Both discrete measurements and the continuous water quality data were analyzed to identify historical water quality problems. The 15-minute data collected at the USGS station through water year 2005 have been previously analyzed and documented in report

by Cumberland Environmental Group (2007). This report is used to as the basis for the continuous data analysis.

Historical data reveal three dissolved oxygen violations at two sampling locations (Table 6). Violations were not observed at any of the other data locations.

Table 6. Historical Dissolved Oxygen Violations

Stream	River Mile	Parameters violating criteria	
		Dissolved oxygen ^a	
		# measurements	% of measurements in violation
Elijahs Creek	3.8	33	6%
Unnamed tributary entering Elijahs Creek at RM 4.7	0.1	8	13%

^a The dissolved oxygen criterion is 4 mg/l.

Numerous dissolved oxygen violations have also been observed at the USGS station. Dissolved oxygen concentrations less than 4 mg/l were present in all five water years (WY) that have been analyzed (WY 2001-2005). These violations have generally been observed between March and September, although violations were also observed in November. The periods of low dissolved oxygen appear to be associated most commonly with algal respiration; though high upstream oxygen demand has also been observed at times.

pH violations were identified through a review of analyses presented in the Continuous Monitoring Network Synthesis Report (CEG, 2007). The pH in Elijahs Creek at RM 2.8 was observed to change more than 1 su in a 24-hour period in WY 2001, 2002 and 2003. pH was also observed to be greater than 9.0 su in WY 2001, and less than 6.0 su in WY 2004.

A single violation of the unionized ammonia criteria was observed in the historical data (Table 7).

Table 7. Historical Unionized Ammonia Violations

Stream	River Mile	Parameters violating criteria	
		Unionized ammonia ^a	
		# samples	% of samples in violation
Unnamed tributary entering Elijahs Creek at RM 4.6	0.0	2	50%

^a The unionized ammonia criteria is 0.05 mg/l

4.3.2 Recent Data

Recent water quality data were available for two locations along the mainstem of Elijahs Creek (RM 0.3 and 2.8). Of the three *E. coli* measurements made at each location, only one was observed to exceed water quality criteria (Table 8). Measurements for parameters not shown met water quality criteria. Recent data collected at the USGS station are being reviewed and will be included in the next update of this report.

Table 8. Recent Bacteria Exceedances

Stream	River Mile	Parameters exceeding criteria	
		<i>E. coli</i> bacteria ^a	
		# samples	% of samples exceeding criteria
Elijahs Creek	0.3	3	33%

^a There are no instances where 5 samples were collected from a single location within a 30-day period. Therefore the comparison to the geometric mean portion of the *E. coli* criteria, which requires a minimum of 5 samples taken during a 30-day period, is not possible. Comparisons were, however, made to the part of the criteria that reads, "Content shall not exceed 240 colonies/100ml in 20 percent or more of all samples taken during a 30-day period for *E. coli*." Even this comparison, however, is conservative, as the criterion is meant to be applied to a dataset of 5 or more samples collected over a 30-day period.

4.3.2.a Bacteria

E. coli data were available for base flow conditions. As shown in Figure 8, one of the six samples exceeded the applicable criteria for *E. coli*. A base flow *E. coli* concentration of 362 cfu/100 ml was observed at RM 0.3 on August 15, 2007. None of the fecal coliform samples exceeded applicable criteria.

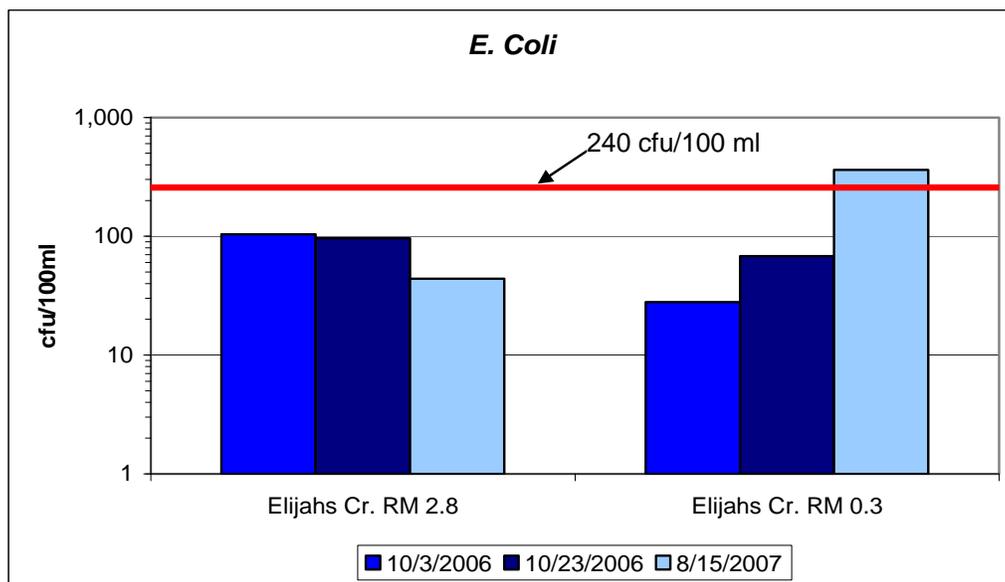


Figure 8. 2006-07 Base Flow *E. Coli* Concentrations Compared to 240 cfu/100 ml Criterion

4.4 BIOLOGICAL CONDITIONS

KDOW assessed biological conditions at two sites in Elijahs Creek and at one site on an unnamed tributary to Elijahs Creek (Table 1). All three of these sites were sampled three times in the mid-1990s and two of the sites were sampled again in 2004 for macroinvertebrates.

Both macroinvertebrate and benthic algae samples revealed that conditions within this watershed are poor. In fact, the biological samples indicate that Elijahs Creek is one of Northern Kentucky's most disturbed watersheds. The poor biological scores are consistent with the "not supporting" habitat scores found at two of the same sites (Table 1).

Macroinvertebrate communities are susceptible to water quality and habitat degradation, and data from these communities are used as a tool changes in habitat and water quality and assessing stream health (KDOW, 2008c). All MBI scores⁹ for these sites were ranked as "fair" or worse in all sampling periods (Table 1). The site at Tanner Road Bridge (RM 1.0) ranked fair in 1993. However, in subsequent years, this site ranked poor and very poor. The other two sites that were assessed consistently ranked poor for all sampling periods. These macroinvertebrate scores indicate a severely degraded aquatic system.

Benthic algae are useful biological indicators of water quality because they are sensitive to changes in water quality and are the primary producers within aquatic ecosystems. Diatoms are benthic algae that are useful indicators of biological integrity because at least a few can be found under almost any condition, and they are identifiable to species (KDOW, 2008c). In 1993, all three assessed sites received a "poor" rating based on diatom measurements (Table 1).

4.5 STREAM METABOLISM

Stream metabolism can be used as a measure of ecosystem health because it responds to the complex interactions between instream conditions (physical, biological and chemical) and watershed conditions. It can be assessed by looking at the ratio of primary production (P), which is influenced by instream conditions (light and nutrient inputs), to respiration (R), which is influenced by watershed conditions (other nutrient and detritus inputs). This ratio can be calculated using continuous instream dissolved oxygen measurements, because dissolved oxygen responds to both instream and watershed inputs. Smaller ratios (e.g., P:R less than 1) suggest that stream system health is more strongly affected by watershed inputs than by instream and near stream processes.

Stream metabolism has been analyzed at the eight USGS continuous monitoring stations which deploy multi-parameter sondes. These stations are located in watersheds that have varying levels of watershed impacts; however, none are located in an unimpacted or reference watershed. For the 2000-2005 period, all eight sites have ratios that indicate the health of these streams is more strongly affected by watershed inputs than instream and near stream inputs.

For the period 2000 to 2005, Elijahs Creek (RM 2.8) has the highest average P/R ratio among all monitored sites, with a generally decreasing P/R trend unlike other monitored sites. For example, in the first three years of metabolism monitoring (2001-2003) Elijahs Creek had the highest metabolism measures of all sites, while 2004 and 2005 found decreasing metabolism measures. Because this creek has the highest average P/R ratio for the monitoring period, this suggests that stream metabolism at this site is less dominated by organic consumption processes than the other monitored sites, although the site appears to

⁹ The macroinvertebrate data were used to calculate the Kentucky macroinvertebrate biotic index (MBI). The MBI compiles attributes of the macroinvertebrate community such as taxa richness, pollution tolerant species and pollution intolerant species. Additional metrics are added depending on the stream size and/or ecoregion.

have moved towards the average for all monitored sites over the last two years. Continued evaluation of stream metabolism at the Elijahs Creek station will help to understand the natural variability of metabolism and the potential of changes within this watershed impacting the production/respiration balance at this site.

5. SOURCE ANALYSIS

This section summarizes potential pollutant sources in the Elijahs Creek watershed for comparison to the recent (2006-2007) observed impairments. Conclusions are based on the watershed characterization and recent water quality data.

5.1 WATERSHED SOURCE ANALYSIS

Potential sources of bacteria were identified within the Elijahs Creek watershed, based on the watershed characterization information discussed previously. Although only base flow samples were available for the recent analysis (Section 4.3.2), all potential sources of bacteria in this watershed are listed. These sources are summarized in Table 9 and their locations are shown in Figure 9.

Table 9. Summary of Potential Sources

	Elijahs Creek
<i>Recent observed impairment =></i>	<i>Bacteria^b</i>
SSO at pump station ^a	3
Septic systems	Few
KPDES dischargers – storm water outfalls	2
Storm water runoff	Urban
Watershed improvements	<p>New airport treatment facility to address deicing fluid in runoff</p> <p>Recent improvements have reduced Taylorsport pump station SSO; this SSO will be further abated as part of Watershed Planning Process</p> <p>Pump station overflow elimination program will address SSO at South Park Industrial pump station.</p> <p>Pump station back up power program will provide back-up power to 3 pump stations, 2 of which have had overflows due to power failure.</p>

^a SD1 is undertaking a characterization and assessment of the sewer system, and sources are subject to change.

^b DO and pH violations have historically been observed at the USGS station, but recent data are being reviewed and are not yet available.

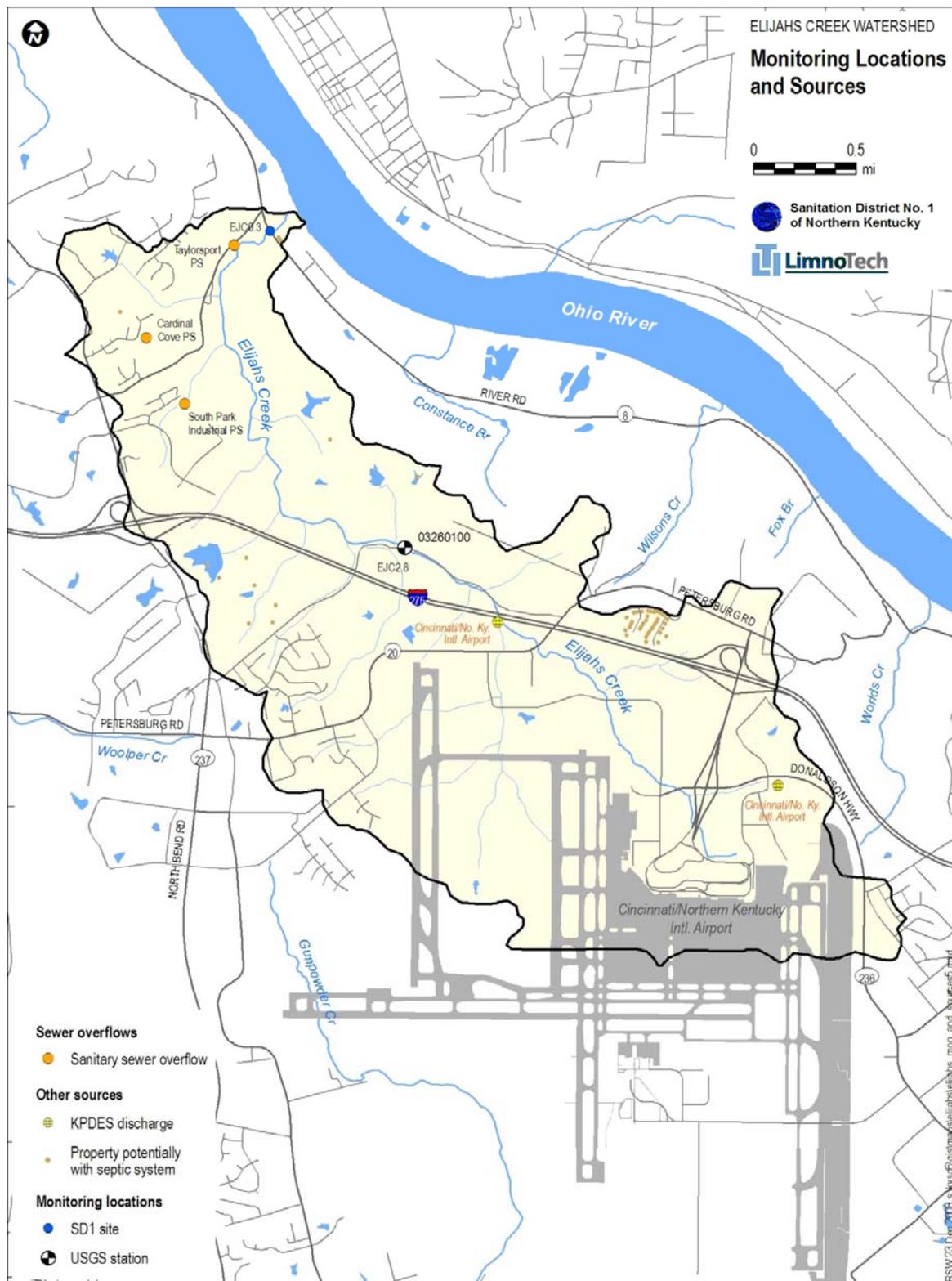


Figure 9. Monitoring Locations and Sources

6. RANKING

6.1 RESULTS

The WAT! is a tool that assesses the potential for point and nonpoint sources to generate fecal coliform, total solids and total phosphorus pollutant loads. WAT! was developed for these three pollutants because data to support modeling were readily available and they are representative indicators of potential water quality conditions. Calibration of the WAT! tool for total solids and total phosphorus is planned, and results should be available in future reports. Results for fecal coliform are discussed below.

This analysis was conducted for each of the sixteen watersheds located within SD1's study area. In addition to assessing pollutant loading potential by source, the WAT! also assesses pollutant loading potential by watershed, which allows for ranking and comparisons among the sixteen watersheds.

WAT! results¹⁰ indicate that under year-round conditions, the Elijahs Creek watershed has an average ranking (analogous to load) for fecal coliform, relative to the sixteen identified watersheds in SD1's jurisdictional area.

In addition to WAT! results, other factors such as presence of public drinking water features, presence of aquatic-dependent threatened and endangered (T&E) species, special designations, and public interest may affect watershed prioritization. These and other ranking considerations are summarized in Table 10.

Table 10. Watershed Ranking Considerations

CSO (#)	SSO (#)	SWAPP Zone	Aquatic-dependent T&E Species ^a (#)	Special Designations	Public interest	WAT! Rank, year-round conditions ^b
						Bacteria
0	3	Zone 2 due to Louisville intake	0	None	Moderate-High	8 of 16

^a There are two terrestrial State species of special concern in this watershed but neither species is threatened or endangered (T&E).

^b The WAT! is still under development. All results presented here are for illustrative purposes only. The results are subject to change and should therefore not be relied on or considered definitive.

6.2 SCREENING TO DETERMINE IF ADDITIONAL DATA ARE NEEDED

Elijahs Creek has been sampled since 1992. The USGS continuous monitoring station on Elijahs Creek provides a good record of flow, DO, temperature, pH and a few other parameters beginning in 1999. Habitat and biological assessments have been previously conducted at several locations in the watershed, however, information on fish communities is absent from the previous biological assessments. Fish communities are an

¹⁰ WAT is still under development. All results presented here are for illustrative purposes only. The results are subject to change and should therefore not be relied on or considered definitive.

indicator of overall stream health and provide insight into vertebrate community conditions within a stream.

SD1 has plans to conduct additional base flow and wet weather sampling in this watershed, and to also complete biological (fish and macroinvertebrate) and habitat assessments. The flow and water quality measurements collected at the USGS station are also planned to continue in the future.

6.2.1 Data Gap Analysis

No data gaps were identified, and no additional biological, habitat or chemical monitoring is recommended for this watershed beyond that already planned.

6.3 SOURCE PRIORITIZATION

The sources identified through the process of watershed characterization have been quantified using the WAT!. WAT! has been applied for a five-year period (1992-1996 climatological conditions), to quantify fecal coliform contributions by source. Together the characterization and WAT! results help inform source prioritization for improvement or elimination.

6.3.1 WAT! Results

The relative fecal coliform load generated by source is shown in Figure 10. These WAT! results incorporate predicted sewer overflow volumes from infrastructure model simulations for 1992-1996 climatological conditions¹¹. CSOs were not a factor in the WAT! results, as none occur in the watershed; however, flow estimates were available for one of the SSOs in this watershed.

Under year-round conditions, the largest source of fecal coliform bacteria is storm water runoff. Septic systems are not a significant contributor to the total annual bacteria load; however, during base flow conditions they are estimated to contribute the majority of the fecal coliform load.

¹¹ The results presented were generated by models based on SD1's current understanding of the collection system infrastructure. 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 therefore not be relied on or considered definitive.

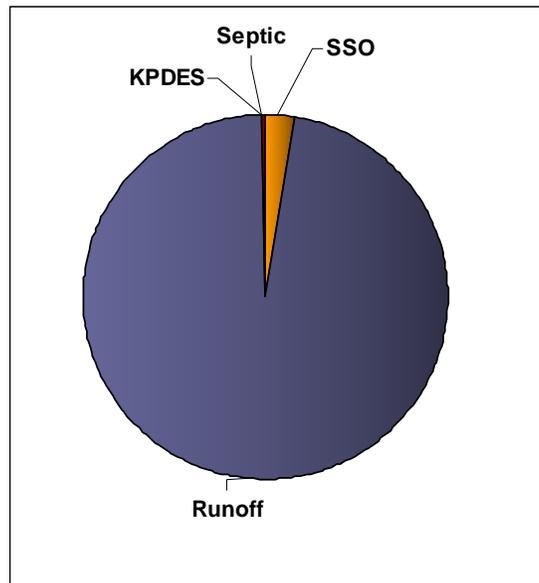


Figure 10. Initial Year-Round WAT! Results for Fecal Coliform

WAT! is still under development. All results presented here are for illustrative purposes only. The results are subject to change and should therefore not be relied on or considered definitive.

WAT! results should be considered preliminary as ongoing work may affect the WAT! source analysis and rankings. Work is currently ongoing to refine the bacteria contribution from septic systems.

6.4 WATERSHED RANKING

The WAT! produced a ranking by watershed, for sixteen watersheds based on their potential to generate fecal coliform loads over a 1-year period. The water quality impact score (analogous to load) for each of the sixteen watersheds was used as a ranking metric. Additional detail on the ranking is available in the WAT! documentation.

The WAT! produces rankings of the watersheds for both base flow and year-round conditions. By separating base flow conditions, the impacts of dry weather sources on stream conditions can be differentiated from the combined impact of dry and wet weather sources. The ranking of the Elijahs Creek watershed during year-round and base flow conditions is provided in Table 11.

Table 11. WAT! Watershed Rankings

	Rank for Year-Round Conditions ^{a,b}	Rank for Base flow Conditions ^{a,b}
Fecal coliform	8	13

^a Rank ranges from 1 to 16. A rank of 1 indicates a high water quality impact score, which is analogous to load. The lowest rank possible is 16.

^b WAT is still under development. All results presented here are for illustrative purposes only. The results are subject to change and should therefore not be relied on or considered definitive.

The WAT! analysis for both total solids and total phosphorus will be presented in future reports upon completion of the WAT! calibration. Future monitoring programs will further populate and refine WAT! results and rankings, aiding in characterization of potential sources.

7. REFERENCES

- Boone County Planning Commission (BCPC), 2005. 2005 Boone County Comprehensive Plan A Blueprint for the Year 2030. Adopted October 19, 2005.
- Carey, D. I. and J.F. Stickney, 2004. Groundwater Resources of Boone County, Kentucky. Kentucky Geological Survey County Report 8, Series XII, ISSN 0075-5567.
- Cincinnati/Northern Kentucky International Airport. Personal communication with Environmental Coordinator for the airport. December 2007.
- Cumberland Environmental Group (CEG), 2007. Continuous Monitoring Network Synthesis Report Water Years 2001-2005. Prepared for Sanitation District No. 1 of Northern Kentucky. December 6, 2007.
- Grace, M. and S. Imberger, 2006. Stream Metabolism: Performing & Interpreting Measurements. New South Wales Department of Environmental Conservation Stream metabolism workshop. May 2004, Sydney Australia. Workshop developed technical manual. Accessed at <http://www.sci.monash.edu.au/wsc/docs/tech-manual-v3.pdf>
- Kentucky Administrative Regulations (KAR). 2008. Title 401 Natural Resources and Environmental Protection Cabinet Department for Environmental Protection. Chapter 10. Regulation 001E. Statement of Emergency Regulation. Definitions for 401 KAR Chapter 10.
- Kentucky Administrative Regulations (KAR). 2008. Title 401 Natural Resources and Environmental Protection Cabinet Department for Environmental Protection. Chapter 10. Regulation 026. Designation of Uses of Surface Waters. Administrative Register of Kentucky.
- Kentucky Administrative Regulations (KAR). 2008. Title 401 Natural Resources and Environmental Protection Cabinet Department for Environmental Protection. Chapter 10. Regulation 030. Antidegradation Policy Implementation Methodology.
- Kentucky Commonwealth Office of Technology, 2005. 2005 Kentucky Land Cover. Obtained in November, 2007.
- Kentucky Division of Fish and Wildlife Resources. Fishing access site viewer [online] <http://kygeonet.ky.gov/kdfwr/viewer.htm>
- Kentucky Division of Water (KDOW), 1998. Impacts of Deicing Fluid on Elijahs and Gunpowder Creeks Boone County, Kentucky.
- Kentucky Division of Water, 2007. Fish Consumption Advisories in Kentucky. www.water.ky.gov/sw/advisories/fish.htm Last modified 7/25/2007. Accessed 2/24/2008.
- Kentucky Division of Water. 2007a. Swimming Advisories in Kentucky. URL: <http://www.water.ky.gov/sw/advisories/swim.htm>. Last modified 11/8/07.

- Kentucky Division of Water, 2007b. Personal communication on status of domestic and public water wells. December 2007.
- 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.
- Kentucky Division of Water (KDOW), 2008a. Kentucky Drinking Water Watch Database Version 1.2. Accessed March 2008.
- Kentucky Division of Water (KDOW), Kentucky Environmental and Public Protection Cabinet. 2008b. 2008 Integrated Report to Congress on Water Quality in Kentucky. Volume 1, 305(b) Report. April 1, 2008.
- Kentucky Division of Water (KDOW), 2008c. Standard Methods for Assessing Biological Integrity of Surface Waters in Kentucky. February.
- Kentucky Geographic Network, 2008. April 9, 2008.
<http://kygeonet.ky.gov/geographicexplorer/explorer.jsf>
- Kentucky Geographic Network, 2008a. August 11, 2008.
<http://kygeonet.ky.gov/geographicexplorer/explorer.jsf>
- Kentucky State Nature Preserves Commission (KSNPC), 2007. Natural Heritage Program Database Review. Data Request 08-007. July 23.
- Kentucky State Nature Preserves Commission (KSNPC), 2007a. Personal communication with KSNPC Species Data Manager. September 14.
- Kentucky Transportation Cabinet. 2006. Boone County Six-Year Plan Projects. FY-2006 thru FY-2012.
- McTammany, M.E., E.F. Benefeld and J.R. Webster. 2007. Recovery of stream ecosystem metabolism from historical agriculture. *Journal of the North American Benthological Society* 26(3):532-545.
- National Climatic Data Center (NCDC), NOAA Satellite and Information Service. 2008. Data obtained for Cincinnati Northern KY Airport, Covington/Cincinnati, KY, United States. WBAN 93814.
- National Oceanic and Atmospheric Administration (NOAA). 2008. National Marine Sanctuaries. <http://sanctuaries.noaa.gov/welcome.html>. Revised February 7, 2008. Accessed February 11, 2008.
- Natural Resources Conservation Service (NRCS), 2006. SSURGO/GIS format. [online]
<http://datagateway.nrcs.usda.gov/>
- NatureServe. 2007. NatureServe Explorer: An online encyclopedia of life [web application]. Version 6.1. NatureServe, Arlington, Virginia. Available <http://www.natureserve.org/explorer>. (Accessed: September 5, 2007).
- Northern Kentucky Health Department (NKHD), 2008. Personal communication, February 2008.

- Odum, E.P. 1956. Primary production in flowing waters. *Limnology and Oceanography*. 1:102-117.
- Paylor, R.L. and J.C. Currens. *Karst Occurrence in Kentucky*. University of Kentucky, Kentucky Geological Survey. 2002.
http://kgsweb.uky.edu/olops/pub/kgs/mc33_12.pdf. Accessed on May 21, 2007.
- Ray, J.A., Webb, J.S., O'Dell, P.W. (Kentucky Department of Environmental Protection, Division of Water, Groundwater Branch), 1994. Groundwater Sensitivity Regions of Kentucky.
- Sibley, D. 2000. *The Sibley Guide to Birds*. Alfred A. Knopf, Inc. New York. 544 pg.
- Sierra Club. 2005. Sentinels Score a Victory to Stop Deicing Fluid Pollution [online] http://www.sierraclub.org/watersentinels/no_kentucky/AirportVictory.pdf
- United States Environmental Protection Agency (USEPA). April 19, 1994. Combined Sewer Overflow (CSO) Policy. *Fed. Regist.* Vol. 59 pg. 18688.
- Woods, A.J., J.M. Omernik, W.H. Martin, G.J. Pond, W.M. Andrews, S.M. Call, J.A. Comstock, and D.D. Taylor. 2002. Ecoregions of Kentucky. Color poster with map, descriptive text, summary tables, and photographs, U.S. Geological Survey (map scale 1:1,000,000), Reston, VA.