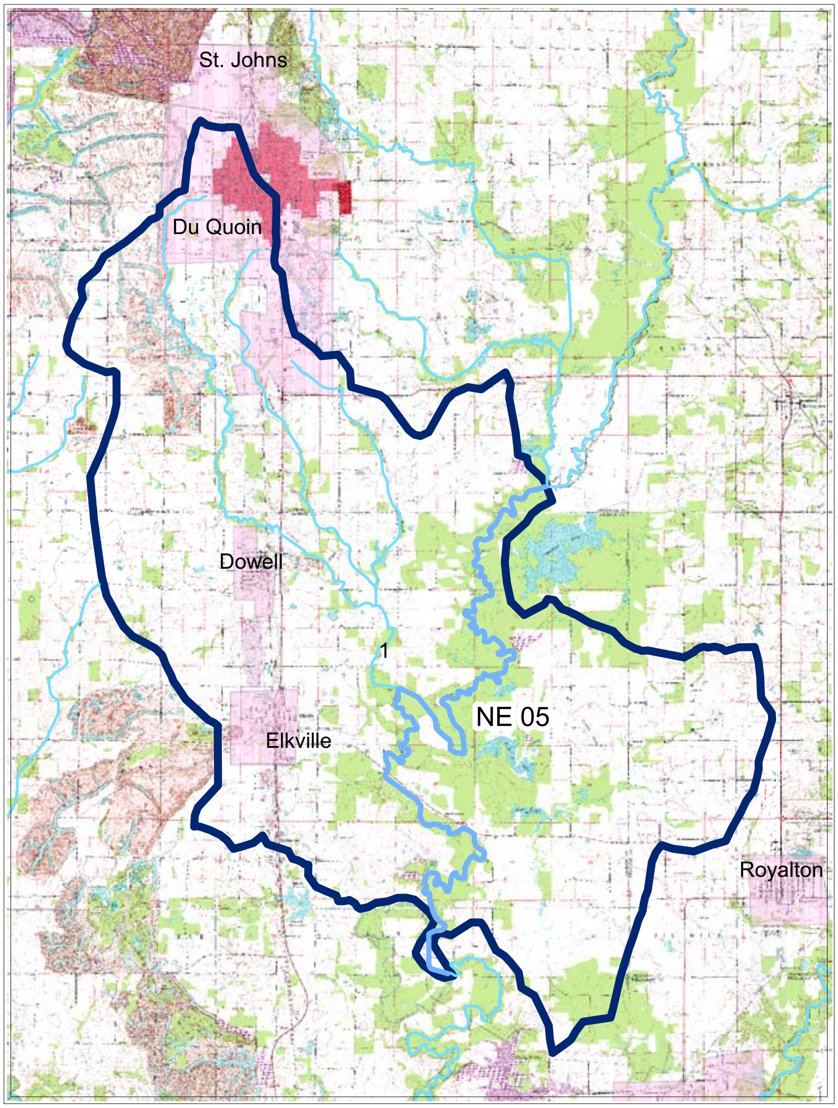
Illinois
Environmental
Protection Agency

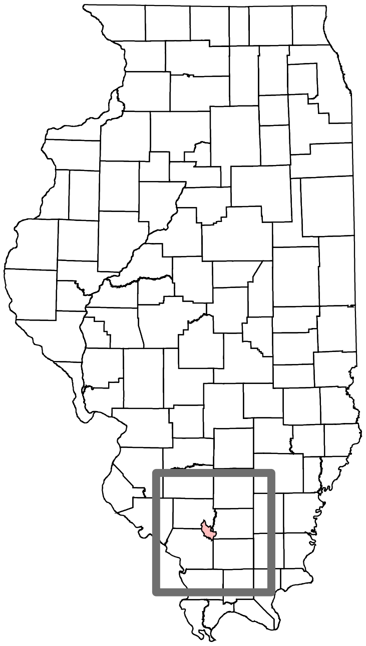
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

June 2004

IEPA/BOW/04-016

LITTLE MUDDY RIVER TMDL REPORT





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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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REPLY TO THE ATTENTION OF:

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09 JUN 2004

Ms. Marcia T. Willhite
IEPA Bureau of Water
1021 North Grand Avenue East
Springfield, IL 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Load (TMDL) submittal for the Little Muddy River Watershed, including supporting documentation and follow up information. IEPA's submitted TMDLs address one stream segment impaired for General Use. Based on this review, U.S. EPA has determined that Illinois' TMDLs for manganese, sulfates, and Total Dissolved Solids (TDS) meets the requirements of Section 303(d) of the Clean Water Act (CWA) and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves Illinois' 3 TMDLs for the Little Muddy River Watershed. The statutory and regulatory requirements, and U.S. EPA's review of Illinois' compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois' effort in this submitted TMDL, and look forward to future TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Watersheds and Wetlands Branch at 312-886-4448.

Sincerely yours,

Jo Lynn Traub
Director, Water Division

Enclosure

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Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDLs) for Little Muddy River. In the 1998 Section 303(d) List, Little Muddy River was listed as impaired for the following parameters: manganese, sulfates, nitrogen, pH, siltation, low dissolved oxygen (DO), total dissolved solids (TDS), other habitat alterations, and total suspended solids (TSS). Since then, new data assessed in 2002 showed that Little Muddy River is currently impaired for manganese, sulfates, pH, low DO, TDS, pathogens, and TSS.

Illinois EPA has since determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards. These numeric water quality standards will serve as the target endpoints for TMDL development and provide a greater degree of clarity and certainty about the TMDL and implementation plans. As a result, this TMDL will only focus on the parameters of manganese, sulfates, pH, low DO, and TDS, for which numeric water quality standards exist.

The listing of pathogens as a cause was based on the criteria published in the 2002 305(b) Water Quality Report. The current General Use water quality standard for pathogens specifies that during the months of May through October, based on a minimum of five samples taken over not more than a 30-day period, fecal coliform bacteria counts shall not exceed a geometric mean of 200/100 mL, nor shall more than 10 percent of the samples during any 30-day period exceed 400/100 mL. The frequency of water sampling at Ambient Water Quality Monitoring Network sites (i.e., approximately once every six weeks throughout the year) does not meet the frequency necessary to apply the Illinois standard; therefore, surrogate assessment guidelines, closely reflecting the standard, are used to assess attainment of the primary contact (swimming) use.

For Little Muddy segment NE05, 24 measurements of fecal coliform bacteria were taken during May-October in 1996-2000. Thus the sampling frequency was less than one sample per month, much less than the five samples in 30 days required in order for the numeric water quality standard to apply, and no month had the requisite five samples taken. Using the surrogate assessment guidelines, two of the 12 samples were greater than 400/100 mL when TSS was less than or equal to the 50th percentile value of TSS, indicating partial support of primary contact use. A TMDL was not developed for pathogens. The Agency is instead recommending that additional monitoring be conducted to verify pathogen concentrations and sources consistent with the specifications of the water quality standard. If the monitoring results indicate water quality standard violations, a TMDL for pathogens will be conducted at a later time. To learn more about this process, see page 40 of Illinois EPA's Illinois Water Quality Report 2002.

Causes of impairment not based on numeric water quality standards will be assigned a lower priority for TMDL development. Pending the development of numeric water quality standards for these parameters, as may be proposed by the Agency and adopted by the Illinois Pollution Control Board, Illinois EPA will continue to work toward improving water quality throughout the state by promoting and administering existing programs and working toward creating new methods for treating these potential causes of impairment.

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Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
µS/cm	microSiemens per centimeter
ALMP	Ambient Lake Monitoring Program
AMLRD	Abandoned Mined Lands Reclamation Division
AWQMN	Ambient Water Quality Monitoring Network
BMP	best management practices
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
CBOD	carbonaceous biochemical oxygen demand
$CBOD_5$	5-day carbonaceous biochemical oxygen demand
CCC	Commodity Credit Corporation
cfs	cubic feet per second
CPP	Conservation Practices Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	dissolved oxygen
EMC	event mean concentration
EQIP	Environmental Quality Incentive Program
FSA	Farm Service Agency
GIS	geographic information system
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
KDEP	Kentucky Department of Environmental Protection
LA	Load Allocation
LC	Loading Capacity
LTA	long-term average
MBI	Macroinvertebrate Biotic Index
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MOS	Margin of Safety
NCDC	National Climate Data Center
NCSU	North Carolina State University

NPDES	National Pollutant Discharge Elimination System
PDEP	Pennsylvania Department of Environmental Protection
SOD	sediment oxygen demand
SSRP	Streambank Stabilization and Restoration Practice
STORET	Storage and Retrieval
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TSS	total suspended solids
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WASCOB	water and sediment control basin
WERF	Water Environment Research Foundation
WHIP	Wildlife Habitat Incentives Program
WLA	Waste Load Allocation
WMM	Watershed Management Model
WRP	Wetlands Reserve Program

Executive Summary
Little Muddy River Watershed

TMDL Fact Sheet

Watershed Name:	Little Muddy River
Segment Name	Little Muddy River
Impaired Segments:	NE05
Location:	Jackson County, Illinois
Size:	15.5 miles
Primary Watershed Land Uses:	Agriculture, grassland, and forest land
Criteria of Concern:	Manganese (Mn), sulfates, TDS, pH, and dissolved oxygen (DO)
Designated Uses Affected:	General use
Environmental Indicators:	Mn, sulfates, TDS, pH, and DO monitoring
Major Sources:	Potentially contaminated groundwater, stagnant stream conditions, elevated instream temperatures, and nonpoint source loading from agriculture
Loading Capacity:	Mn = 178 lbs/day Sulfate = 68,805 lbs/day TDS = 459,698 lbs/day pH = No Allocation DO = No allocation
Waste Load Allocation:	No Allocation
Margin of Safety:	Implicit through data selected for development of TMDL; additional explicit of 10 percent

This Total Maximum Daily Load (TMDL) assessment for impaired water bodies in the Little Muddy River Watershed addresses the sources of water body impairments, reductions in source loading necessary to comply with water quality standards, and the implementation of procedures to mitigate the impairment.

The TMDLs for manganese, sulfates, and TDS in Little Muddy River segment NE05 were based on analyses performed in a Monte Carlo simulation. Segment NE05 was listed for TDS impairments due to noncompliant conductivity measurements, so the TDS analysis was based on a relationship between TDS and conductivity. The Monte Carlo simulation for manganese, sulfates, and TDS showed a reduction of 88 percent, 89 percent, and 52 percent, respectively, necessary to achieve water quality standards. The potential source of manganese, sulfates, and TDS in the Little Muddy River Watershed is contaminated groundwater. The groundwater is potentially contaminated by active and abandoned coal mines; however, further source identification is recommended. Confirmation that abandoned mines are a source of manganese, sulfates, and TDS in the watershed would require reclamation of the mines. Passive treatment for mine reclamation is recommended. If active mines are confirmed as a source of impairments, permit reductions may be required.

The TMDL analysis for DO in Little Muddy River segment NE05 was made through investigation of the relationship between DO, total organic carbon (TOC), 5-day biochemical oxygen demand (BOD_5), and reaeration in the creek. The likely source of DO impairments in the segment is primarily a lack of aeration and elevated instream temperatures. BOD loadings in runoff from nonpoint source loads may also contribute to DO impairments. However, examination of BOD in the stream segment showed that the concentrations of BOD are low and likely represent ambient conditions in the stream; therefore, reductions in BOD concentrations are not recommended at this time. Due to data limitations and technical considerations of implementation difficulties, a load allocation cannot be developed for reaeration or temperature, so allocations were not developed for segment NE05. Procedures to alleviate low DO caused by slow-moving waters can be addressed with in-stream mitigation methods, such as reaeration. Additionally, riparian buffer strips aid in decreasing instream temperatures, which could help to alleviate the DO impairment. Excess nutrients can cause excessive algal growth that can also deplete DO in streams; however, analytical tools were not used to assess nutrients, algae, and DO as no algal data was available for Little Muddy River segment NE05. Methods to control nutrients were still included in the implementation plan, such as buffer strips along the stream banks, which are similar to filter strips in their ability to remove nutrients from surface runoff. The potential contributions to BOD from nonpoint source loads are attributed to agricultural land uses requiring mitigation methods to control nutrients in sediment erosion and surface runoff from the land contributing to segment NE05. These methods include filter strips, wetlands, conservation tillage, and nutrient management plans as discussed above.

The analysis for pH was based on hydrogen ion concentrations and the three-year flow observed in Little Muddy River segment NE05. Analysis showed that the existing average hydrogen ion concentration was below the allowable loading, so allocations were not developed for pH in segment NE05 at this time. Although an allocation was not developed, mitigation measures for manganese, sulfates, TDS, and DO will help control pH in Little Muddy River segment NE05.

Section 1
Goals and Objectives for Little Muddy River Watershed (ILNE05)

1.1 Total Maximum Daily Load (TMDL) Overview

A Total Maximum Daily Load, or TMDL, is a calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards. TMDLs are a requirement of Section 303(d) of the Clean Water Act (CWA). To meet this requirement, the Illinois Environmental Protection Agency (Illinois EPA) must identify water bodies not meeting water quality standards and then establish TMDLs for restoration of water quality. Illinois EPA lists water bodies not meeting water quality standards every two years. This list is called the 303(d) list and water bodies on the list are then targeted for TMDL development.

In general, a TMDL is a quantitative assessment of water quality problems, contributing sources, and pollution reductions needed to attain water quality standards. The TMDL specifies the amount of pollution or other stressor that needs to be reduced to meet water quality standards, allocates pollution control or management responsibilities among sources in a watershed, and provides a scientific and policy basis for taking actions needed to restore a water body (U.S. Environmental Protection Agency [USEPA] 1998).

Water quality standards are laws or regulations that states authorize to enhance water quality and protect public health and welfare. Water quality standards provide the foundation for accomplishing two of the principal goals of the CWA. These goals are:

- restore and maintain the chemical, physical, and biological integrity of the nation's waters;
- where attainable, to achieve water quality that promotes protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water.

Water quality standards consist of three elements:

- the designated beneficial use or uses of a water body or segment of a water body;
- the water quality criteria necessary to protect the use or uses of that particular water body;
- an antidegradation policy.

Examples of designated uses are swimming, recreation, and protection of aquatic life. Water quality criteria describe the quality of water that will support a designated use. Water quality criteria can be expressed as numeric limits or as a narrative statement.

Antidegradation policies are adopted so that water quality improvements are conserved, maintained, and protected.

1.2 TMDL Goals and Objectives for Little Muddy River Watershed

The TMDL goals and objectives for the Little Muddy River Watershed include developing TMDLs for all impaired water bodies within the watershed, describing all of the necessary elements of the TMDL, developing an implementation plan for each TMDL, and gaining public acceptance of the process. Following is the impaired water body segment in the Little Muddy River Watershed, which is also shown in Figure 1-1:

- Little Muddy River (NE05)

The TMDL for each of the segments listed above will specify the following elements:

- Loading Capacity (LC) or the maximum amount of pollutant loading a water body can receive without violating water quality standards;
- Waste Load Allocation (WLA) or the portion of the TMDL allocated to existing or future point sources;
- Load Allocation (LA) or the portion of the TMDL allocated to existing or future nonpoint sources and natural background;
- Margin of Safety (MOS) or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality.

These elements are combined into the following equation:

$$\mathbf{TMDL} = \mathbf{LC} = \sum \mathbf{WLA} + \sum \mathbf{LA} + \mathbf{MOS}$$

Each TMDL developed must also take into account the seasonal variability of pollutant loads so that water quality standards are met during all seasons of the year. Also, reasonable assurance that the TMDLs will be achieved is described in the implementation plan. The implementation plan for the Little Muddy River Watershed describes how water quality standards will be attained. This implementation plan includes recommendations for implementing best management practices (BMP), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and time frame for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Little Muddy River Watershed Description** provides a description of the impaired water body and general watershed characteristics.

- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development.
- **Section 4 Little Muddy River Watershed Water Quality Standards** defines the water quality standards for the impaired water bodies. Pollution sources will also be discussed in this section.
- **Section 5 Little Muddy River Watershed Data Review** provides an overview of available data for the Little Muddy River Watershed.
- **Section 6 Methodologies to Complete TMDLs for the Little Muddy River Watershed** discusses the models and analyses needed for TMDL development.
- **Section 7 Methodology Development for Little Muddy River** describes the analytical procedures used to examine Little Muddy River.
- **Section 8 Total Maximum Daily Load for the Little Muddy River Watershed** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 9 Implementation Plan for Little Muddy River Watershed** provides methods to reduce loadings to impaired water bodies.
- **Section 10 References** lists references used in this report.

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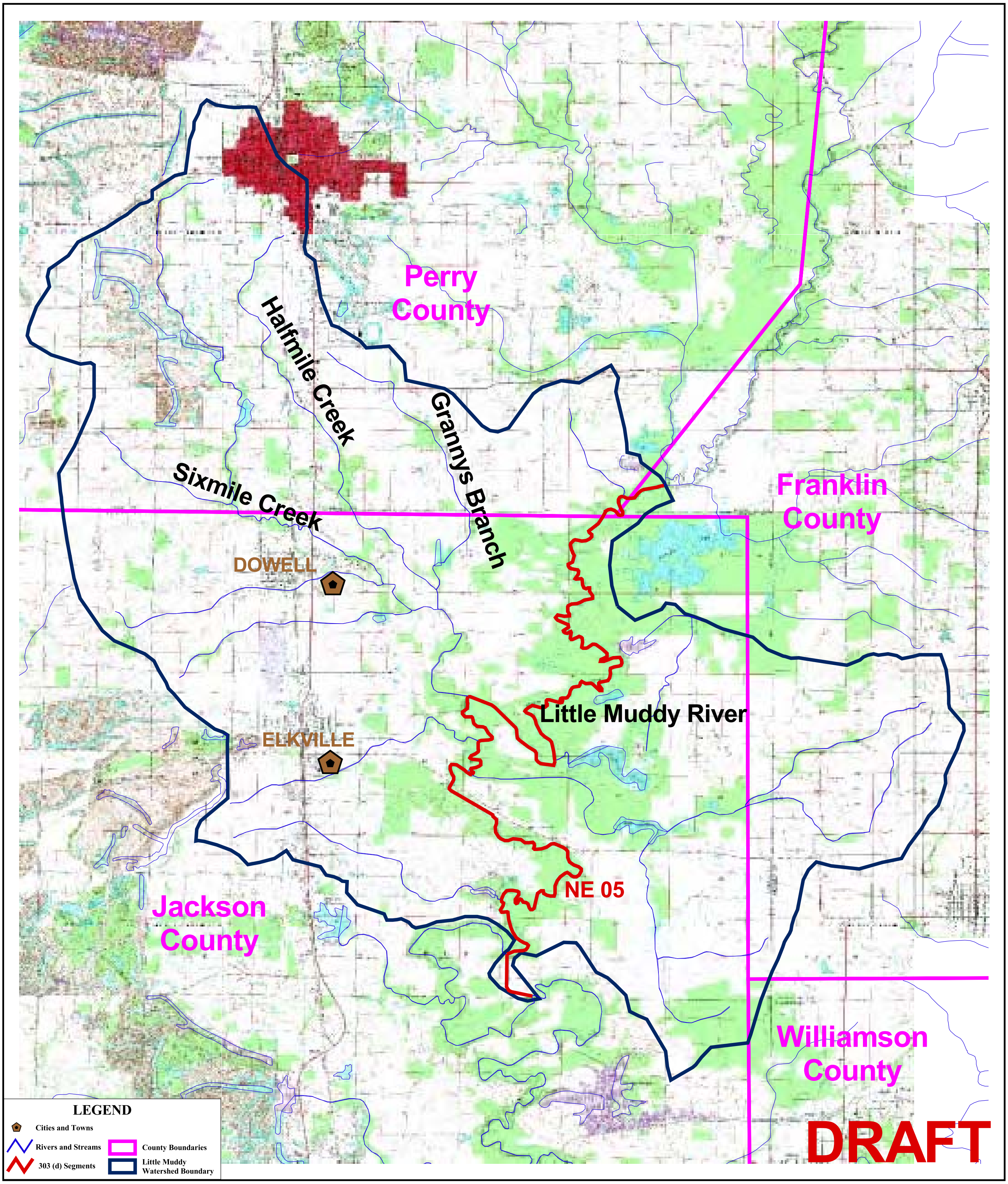

Figure 1-1
Little Muddy River Watershed (ILNE05)
Impaired Water Bodies

CDM

densvr01/projects/IEPA/gis_data/apr/little_muddy.apr 041003 MJF

Section 2
Little Muddy River Watershed Description

2.1 Little Muddy River Watershed Overview

The Little Muddy River Watershed originates in the northeastern portion of Jackson County and flows southward towards its confluence with the Big Muddy River. The watershed encompasses an area of approximately 270 square miles and is located within U.S. Geological Survey (USGS) Big Muddy Basin (Hydrologic Unit Code [HUC] 07140106). Figure 1-1 shows the impaired river segment within the watershed. The impaired segment is shown in red. Table 2-1 lists the water body segment, water body size, and potential causes of impairment. Illinois EPA has determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards; therefore, several parameters listed for the Little Muddy River watershed in the 1998 and 2002 303(d) lists, such as total suspended sediments and pathogens, will not be addressed with this TMDL.

Table 2-1 Impaired Water Body in Little Muddy River Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
NE05	Little Muddy River	15.5 miles	Manganese, sulfates, pH, dissolved oxygen (DO)

Land use data was obtained from the Critical Trends Assessment Land Cover Database of Illinois (Illinois Department of Natural Resources [IDNR] 1996). Land use in the watershed is predominantly agricultural followed by rural grassland and deciduous forest land use. Strip mining also is a land use type found within the watershed. Farmers in the area primarily raise cash crops, such as corn, soybeans, and alfalfa.

Soils within the Little Muddy River Watershed are primarily of silty soils over clayey sediment. The surface layer is typically seven inches of dark grayish brown silt loam. The subsurface layer is about five inches of light brownish silt loam. The subsoil is a grayish silty clay loam that extends to a depth of more than 60 inches. Permeability is slow and the available water capacity is moderate to high (U.S. Department of Agriculture [USDA] 1979).

The climate in Little Muddy River watershed is cold in the winter and warm in the summer. There is no published temperature data available through the National Climate Data Center (NCDC) for Jackson County; hence, temperature data presented below is for Perry County. In the winter, October through March, the average temperature is 43 degrees Fahrenheit (°F) and the average daily minimum temperature is 32°F according to data collected at DuQuoin, Illinois. Summer temperatures are typically 70°F with an average daily maximum of 82°F. Annual precipitation is 45 inches, of which 25 inches, approximately 55 percent, usually falls in April through September (NCDC 2002).

2.2 Stream Segments Site Reconnaissance of Little Muddy River Watershed


Little Muddy River looking north from the Hwy 14 bridge near the Perry/Franklin county line.

The project team conducted a site reconnaissance of the Little Muddy River Watershed on June 18, 2001. This section briefly describes the stream segments and the site reconnaissance.

Table 2-1 lists the impaired stream segment in the Little Muddy River Watershed. Based on the 1998 and 2002 303(d) lists, Illinois EPA determined that one segment of the Little Muddy River was impaired, Segment NE05. This segment is shown in Figure 1-1. Segment NE05 was observed from Illinois Route 14 west of the Perry/Franklin County line near DuQuoin, Illinois, and from County Road 2400N east of Elkville, Illinois.


Little Muddy River looking north-northeast from Illinois Rt. 2400N bridge east of Elkville, Illinois.

The upper portion of the Little Muddy appeared silty or turbid and, on the north side of the bridge, was full of branches and other debris. The bank appeared muddy and barren closest to the river, but mature trees were present at the tops of the banks. The surrounding land was planted with row crops to the east and was wooded to the west.

The lower portion of the Little Muddy was broader and slower flowing.

Section 3
Public Participation and Involvement

3.1 Little Muddy River Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It was important to involve the public as early in the process as possible to achieve maximum cooperation, counter concerns as to the purpose of the process, and the regulatory authority to implement the recommendations. Two public meetings were held to discuss the Little Muddy River Watershed at 3:00 p.m. and 6:20 p.m. on December 12, 2001 at the Davis McCann Center in Murphysboro, Illinois. A total of 44 interested citizens, including public officials and organizations other than Illinois EPA, attended the public meeting.

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Section 4
Little Muddy River Watershed Water Quality Standards

4.1 Illinois Water Quality Standards

Water quality standards are developed and enforced by the state to protect the "designated uses" of the state's waterways. In the state of Illinois, setting the water quality standards is the responsibility of the Illinois Pollution Control Board (IPCB). Illinois is required to update water quality standards every three years in accordance with the CWA. The standards requiring modifications are identified and prioritized by Illinois EPA, in conjunction with USEPA. New standards are then developed or revised during the three-year period.

Illinois EPA is also responsible for developing scientifically based water quality criteria and proposing them to the IPCB for adoption into state rules and regulations. The Illinois water quality standards are established in the Illinois Administrative Rules Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards.

4.2 Designated Uses

The waters of Illinois are classified by designated uses, which include: General Use, Public and Food Processing Water Supplies, Lake Michigan, and Secondary Contact and Indigenous Aquatic Life Use (Illinois EPA 2000). The only designated uses applicable to Little Muddy River are General Use.

The General Use classification provides for the protection of indigenous aquatic life, primary and secondary contact recreation (e.g., swimming or boating), and agricultural and industrial uses. The General Use classification is applicable to the majority of Illinois streams and lakes (Illinois EPA 2000).

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations, Illinois EPA compares collected data for the water body to the available water quality standards developed by Illinois EPA for assessing water body impairment. Table 4-1 presents the water quality standards of the potential causes of impairment for TMDLs that will be developed in the Little Muddy River Watershed. These water quality standards are further discussed in the remainder of the section.

Table 4-1 Summary of General Use Water Quality Standards for Little Muddy River

Parameter	General Use Water Quality Standard
pH	6.5 to 9.0
DO	Greater than 5.0 milligrams per liter (mg/L) Greater than 6.0 mg/L (16 hours of any 24-hour period
Manganese	1.0 mg/L
Sulfates	500 mg/L
TDS	1,000 mg/L

4.3.1 pH

The General Use water quality standard for pH is a range with a minimum of 6.5 and maximum of 9.0. This is with the exception of pH levels outside this range due to natural causes.

The pH parameter is listed as a cause of less than full support use attainment in streams, if there is at least one General Use water quality violation based on the last three years of Ambient Water Quality Monitoring Network (AWQMN) data, or at least one violation determined from the most recent basin survey or facility survey data. The AWQMN is a series of fixed stations throughout Illinois streams that are sampled every six weeks for a minimum of 55 parameters. Segments without AWQMN stations are sampled as part of the intensive basin survey, which occurs every five years.

4.3.2 Dissolved Oxygen

DO is listed as a cause of impairment for Little Muddy River. The General Use water quality standard for DO is based on a minimum value of 5.0 mg/L. Therefore, DO levels shall not be less than 5.0 mg/L at any time. In addition, DO levels should not be less than 6.0 mg/L for more than 16 hours of any 24-hour period.

DO is listed as a cause of less than full support use attainment in streams, if there is at least one General Use water quality violation based on the last three years of AWQMN data or at least one violation determined from the most recent basin survey or facility survey data.

4.3.3 Manganese

The General Use water quality standard for manganese is 1.0 mg/L and is based on total manganese. Manganese is listed as a cause of less than full support use attainment in streams, if there is at least one General Use water quality violation based on the last three years of AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Manganese is also listed as a cause of less than full support, if there have been fish advisory reports due to manganese or the manganese concentration in the sediment is 2,800 milligrams per kilogram (mg/kg) or higher (Muir et al. 1997).

4.3.4 Sulfates

The General Use water quality standard for sulfates is 500 mg/L. Sulfate is listed as a cause of a less than full support use attainment in streams, if there is at least one General Use water quality violation based on the last three years of AWQMN data or at least one violation from the most recent basin survey or facility survey data.

4.3.5 TDS

Total dissolved solids (TDS) is listed as a cause of impairment in the Little Muddy River. The General Use water quality standard for TDS is 1,000 mg/L. TDS is listed as a cause of less than full support use attainment in streams, if there is at least one General Use water quality violation of TDS in the last three years based on AWQMN data or at least one violation determined from the most recent basin survey or facility survey data. Conductivity measurements are used to determine the relative TDS level. If conductivity levels are greater than 1,667 microSiemens per centimeter (µS/cm), TDS is estimated to be a cause of impairment.

4.3.6 Parameters without Numeric Water Quality Standards

It should be noted that, although formal TMDLs will not be developed for parameters without water quality standards in the Little Muddy River Watershed, many of the management measures discussed in Section 9 of this report will result in reductions of the parameters listed in the 1998 and 2002 303(d) lists that do not currently have adopted water quality standards. For example, many of the management measures that will be discussed in Section 9 address the other parameters of concern for the watershed. For total suspended sediments (TSS), management measures that control erosion, such as filter strips and wetlands, will reduce sediment from entering the waterways, thereby reducing TSS caused by eroding stream banks.

4.4 Pollution Sources

As part of the Illinois EPA use assessment presented in the annual Illinois Water Quality Report, the causes of the pollutants resulting in a less than full support use attainment are associated with a potential source, based on data, observations, and other existing information. The following is a summary of the sources associated with the listed causes for the TMDL listed segments in this watershed. They are summarized in Table 4-2.

Table 4-2 Summary of Potential Sources of Pollutants

Potential Source	Cause of Impairment
Municipal Point Source	DO
Agriculture Nonirrigated crop production Pasture Lane Animal Holding/Management Areas	DO
Resource Extraction Mining Mine Tailings	Sulfates pH Manganese
Contaminated Sediments	Manganese DO
Urban Runoff/Storm Sewers	DO

4.4.1 Municipal Point Sources

Municipal point sources include wastewater treatment plants (WWTP) operated by municipalities to treat municipal wastewater generated by the community. A National Pollutant Discharge Elimination System (NPDES) permit issued by Illinois EPA regulates the discharge. The NPDES permit sets limits that must be met at the discharge to the receiving stream.

Historically, these point sources have impacted water quality of the receiving streams, particularly during low flow conditions. Many municipal WWTPs have upgraded the facilities through grant and low-interest loan programs, thereby improving effluent quality and reducing impacts to the receiving stream.

Municipal point source effluents are typically regulated for ammonia nitrogen and biochemical oxygen demand (BOD). BOD is associated with oxygen demand. The higher the BOD, the more likely the effluent is to reduce the DO levels in the stream.

A total of 186 NPDES permits are issued to dischargers in the Big Muddy River basin. Within the Little Muddy watershed NE05, there is one point source from a wastewater treatment plant and one permitted mine discharge.

4.4.2 Agriculture

The southern Illinois area is largely agriculture land use. Row crop agriculture is the largest single category land use in the basin. Agricultural land uses can potentially contribute sediment, TSS, nutrients, and pesticides to the stream loading. The amount that is contributed is a function of the soil type, slope, crop management, precipitation, total amount of cropland, and the distance to the water resource (Muir et al. 1997).

Erosion of the land and streambanks carries sediment to the stream, resulting in higher levels of TSS and siltation. This can be also be caused by livestock on pastures and feedlots. Wastes from livestock can enter streams and impact DO.

4.4.3 Resource Extraction

Resource extraction consists of both active mining and abandoned mine lands. Runoff and discharges from mines can contain sulfates, TDS, metals, TSS, and can affect the pH of the stream. There are currently 47 permitted coal mines with 169 authorized discharges in the Big Muddy River basin. In addition, 1,177 inactive or abandoned mines have been identified. Although there are many permitted mines within the Big Muddy River Basin, there is only one permitted, active coal mine located in the Little Muddy River Watershed. Mining is most concentrated in Beaucoup Creek, Galum Creek, Little Muddy River, Pond Creek, Hurricane Creek, and Rend Lake watersheds (Muir et al. 1997).

Drainage from the mines can be impacted by contact with exposed soil, spoil piles, or pumped water from pits. Acid mine drainage occurs when water and oxygen come in contact with iron pyrite material. This combination makes ferrous iron and sulfuric acid, creating acidic runoff and impacting the stream pH. Although acid mine drainage may come from active mines, most acid mine drainage entering streams is from abandoned mine lands.

4.4.4 Contaminated Sediments

Sediments are carried to streams during runoff conditions and are generally deposited in streambeds or lake bottoms. Constituents contained in sediment may include metals and nutrients. Contaminated sediments containing metals can originate from urban areas or mining locations. Both agricultural lands and urban areas contribute to the nutrient loading in the sediment.

Suspended sediments settle out to stream bottoms during periods of low flow. During periods of high flow, sediments are resuspended and carried downstream to be deposited in another location. Once the sediment reaches a lake or reservoir, the sediments are deposited and typically accumulate in these areas. The source of the contaminated sediment can therefore be located much farther upstream than the location detected. Contaminated sediments can slowly leach contaminants to the water column, thereby being a continual source of impact to the water body.

4.4.5 Urban Runoff/Storm Sewers

Urban areas in the Little Muddy River Watershed constitute a small percentage of land use in the watershed; however, polluted runoff from urban sections can be significant. Runoff from urban areas reaches streams or lakes either by sheet flow runoff or through storm sewer discharges. The runoff can originate from any number of areas including highways; roadways; parking lots; industrial, commercial, or residential areas; or undeveloped lands. Phosphorous, which can influence BOD loads, can originate from fertilizer use, natural phosphorous levels in sediment, and from sanitary waste where combined sewer overflows are present.

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Section 5
Little Muddy River Watershed Data Review

5.1 Existing Data Review

The following data sources were reviewed for model selection and analysis:

- mapping data
- topography data
- flow data
- precipitation data
- temperature data
- existing water quality data
- land use
- point sources
- dairy and animal confinement locations
- septic systems

5.1.1 Mapping Data

USGS quadrangle maps (scale 1:24,000) were collected for the watershed in paper and electronic form. These were utilized for base mapping.

5.1.2 Topography Data

A Digital Elevation Model (DEM) was used to delineate watersheds in a geographic information system (GIS) for Little Muddy River impaired segment NE05. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the *BASINS* database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic water quality gages for the Little Muddy Watershed and the boundary for the segment NE05 subwatershed. The watershed boundaries define the area investigated for causes of impairments in segment NE05.

The watershed for segment NE05 only represents the area that drains directly to segment NE05. All segments upstream and downstream of segment NE05 on the main stem of the Little Muddy River, as well as all tributaries to segment NE05, are listed as full support. Therefore, the sources of impairments in segment NE05 will focus on areas draining directly to the segment.

5.1.3 Flow Data

Analyses of the Little Muddy Watershed require an understanding of flow through the Little Muddy River segment NE05. There is no active stream gage within the Little

Muddy Watershed. Therefore, the drainage area ratio method, represented by the following equation, was used to estimate flows within the segment NE05 subwatershed.

$$\mathbf{Q_{gaged}}\left(\frac{\mathbf{Area_{ungaged}}}{\mathbf{Area_{gaged}}}\right)=\mathbf{Q_{ungaged}}$$

where Q_{gaged} = Streamflow of the gaged basin
$Q_{ungaged}$ = Streamflow of the ungaged basin
$Area_{gaged}$ = Area of the gaged basin
$Area_{ungaged}$ = Area of the ungaged basin

The assumption behind the equation is that the flow per unit area is equivalent in watersheds with similar characteristics. Therefore, the flow per unit area in the gaged watershed times the area of the ungaged watershed will result in a flow for the ungaged watershed.

An assessment of the flow gages within HUC 07140106, which contains the Little Muddy River, revealed three gages with flow data through 2001. Of these three gages, two are downstream of a reservoir, Rend Lake, on the Big Muddy River and the third represents a drainage area of only 37 square miles. USGS gage 05597000 (Big Muddy River at Plumfield, Illinois) was chosen as an appropriate gage from which to compute flows within the Little Muddy Watershed. Although the gage is downstream of a reservoir, it was the most suitable for use within the HUC due to its proximity to the Little Muddy Watershed and availability of recent data. Additionally, a comparison of average annual flows prior to the construction of the reservoir in 1971 and after the construction showed little variation, as shown in Figure 5-2. Gage 05597000 captures flow from a drainage area of approximately 794 square miles in the Big Muddy River Watershed and is located about 10 miles east of segment NE05. Daily streamflow data for the gage were downloaded from the USGS NWIS for the entire period of record from January 1, 1972 to September 30, 2000 (USGS 2002a). Figure 5-3 at the end of this section shows the seasonal patterns of stream flow through segment NE05 over the period of record. Flows are higher in the spring months of March through May. For Little Muddy River segment NE05, average monthly flows range from 37 to 529 cubic feet per second (cfs) with a mean annual flow of 256 cfs. The 7Q10 flow (lowest average seven consecutive day low flow with an average recurrence frequency of once in 10 years) is typically utilized as the critical low flow for NPDES permitting and is estimated to be zero for segment NE05 (ISWS 2000).

5.1.4 Precipitation and Temperature Data

As discussed in Section 2.1, the Little Muddy Watershed is located within Jackson County. Two sites with historical precipitation data were identified in Jackson County through the NCDC database. No historical temperature data records for Jackson County were identified through the NCDC database. Additionally, the precipitation and temperature gage for Perry County is located closer to the watershed. Therefore, data from the Perry County gage were used for analysis. Two months of data were missing from the Perry County gage over the period from 1985 to 2001. Missing data were supplemented with data from a gage in neighboring Franklin County. Table 5-1 lists the station details for the Jackson County, Perry County, and Franklin County gages.

Table 5-1 Historical Precipitation and Temperature Gages for the Little Muddy Watershed (NCDC 2002)

NCDC Gage Number	Station Location (Name)	Period Record
5983	Jackson County (Murphysboro 2SW)	1948 to present
1265	Jackson County (Carbondale Sewage Plant)	1970 to present
2483	Perry County (Du Quoin)	1901 to present
0608	Franklin County (Benton 2 N)	1948 to present

Table 5-2 Average Monthly Precipitation Developed for the Little Muddy Watershed from 1985 to 2000

Month	Average Precipitation (in)
January	3.2
February	2.8
March	3.5
April	4.3
May	4.7
June	5.1
July	3.8
August	3.2
September	3.5
October	3.1
November	4.5
December	3.0
Average Annual Precipitation	**44.7**

Table 5-2 shows the average monthly precipitation of the dataset developed for the Little Muddy Watershed for the years 1985 to 2001. The average annual precipitation over the same period is approximately 45 inches for the watershed.

5.1.5 Water Quality Data

Two historic water quality stations exist within the Little Muddy River segment NE05 subwatershed and are presented in Table 5-3. This table provides the location, station identification number, and the agency that collected the water quality data. Location and station identification number are also shown in Figure 5-1.

Table 5-3 Historic Water Quality Stations for the Little Muddy River Watershed

Location	Station Identification Number	Data Collection Agency
Little Muddy River	05597280	USGS
Little Muddy River	NE05	Illinois EPA

The impaired water body segments in the Little Muddy River Watershed were presented in Section 2. For Little Muddy River segment NE05 there are two historic water quality stations listed in Table 5-3 and shown in Figure 5-1. The two stations in segment NE05 are located in the same place, but have different sampling periods. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA Storage and Retrieval (*STORET*) database associated with impairments discussed in Section 2 for the segment NE05.

Table 5-4 Summary of Constituents Associated with Potential Impairments Listed for Little Muddy River Segment NE05 (USEPA 2002b and Illinois EPA 2002)

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Little Muddy River Segment NE05; Sample Location 05597280		
Manganese	1/10/90-4/2/97	52
Sulfates	1/10/90-4/2/97	52
PH	1/10/90-4/2/97	52
DO	1/10/90-4/2/97	53
TDS	7/17/95-3/5/96	2
Conductivity (µS/cm)	1/10/90-4/2/97	65
Little Muddy River Segment NE05; Sample Location NE05		
Manganese	10/22/97-8/22/00	29
Sulfates	10/22/97-8/22/00	29
PH	10/22/97-8/22/00	29
DO	10/22/97-8/22/00	29
TDS	7/19/00-8/22/00	2
Conductivity (µS/cm)	5/20/97-8/22/00	31

5.1.5.1 Little Muddy River Water Quality Data

The water quality station data for the two stations in segment NE05 were downloaded from the *STORET* online database for the years of 1990 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in the Little Muddy River segment NE05, as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

5.1.5.1.1 Manganese, Sulfates, and TDS

Table 5-5 summarizes historical manganese, sulfates, TDS, and conductivity data since 1990 from the USEPA *STORET* database and recent data, not yet entered into the *STORET* database, for segment NE05 in the Little Muddy River Watershed. The raw historical water quality data is contained in Appendix A. Although the average manganese, sulfates, and conductivity values for some stations are below the water quality standard, the maximum observed values exceed the endpoints. Segment NE05 is impaired for TDS although the water quality data shows that no sample points exceed the endpoint; however, the impairment for TDS is based on conductivity, which does exceed the endpoint. The historical water quality samples were also taken during months with historically varying flow conditions.

Table 5-5 Existing Water Quality Data and TMDL Endpoints for Segment NE05 (USEPA 2002b)

Sample Location and Parameter	Endpoint	Period of Record Examined for Samples and Number of Data Points	Mean	Maximum	Minimum
Little Muddy River Segment NE05; Sample Location 05597280					
Manganese (mg/L)	1.0	1/10/90-4/2/97; 52	1.1	4.2	0.1
Sulfates (mg/L)	500	1/10/90-4/2/97; 52	363	1,620	38
TDS (mg/L)	1,000	7/17/95-3/5/96; 2	740	866	614
Conductivity (µS/cm)	1,667	1/10/90-4/2/97; 65	856	2,780	193
Little Muddy River Segment NE05; Sample Location NE05					
Manganese (mg/L)	1.0	10/22/97-8/22/00; 29	0.7	2.0	0.04
Sulfates (mg/L)	500	10/22/97-8/22/00; 29	499	1,940	23
TDS (mg/L)	1,000	7/19/00-8/22/00; 2	520	724	316
Conductivity (µS/cm)	1,667	5/20/97-8/22/00; 31	1,025	3,440	147

Figures 5-4 through 5-6 (at the end of this section) show concentrations of manganese, sulfates, and TDS, respectively, with corresponding flows in segment NE05. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this analysis, about 68 percent of manganese and sulfate samples and 25 percent of TDS samples were taken at below average monthly flow conditions. This suggests that most historical samples were taken under low flow conditions in segment NE05 of the Little Muddy River Watershed. Analysis of impaired sample dates showed that more than 80 percent of the impaired samples for manganese, sulfates, and conductivity were taken at below average flows.

5.1.5.1.2 DO and TOC

Table 5-6 summarizes the available historic DO and total organic carbon (TOC) data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database, for Little Muddy River segment NE05 (raw data contained in Appendix A). TOC data are presented here because they are used in the DO analysis. The average DO concentration for segment NE05 is above the water quality standard of 6.0 mg/L (16 hours of any 24-hour period), but the minimum values observed are less than the water quality standard of 6.0 mg/L.

Table 5-6 Existing DO and TOC Water Quality Data and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Little Muddy River Segment NE05; Sample Location 05597280					
DO	6.0 (16 hours of any 24-hour period)	1/10/90-4/2/97; 53	7.1	12.6	2.5
Little Muddy River Segment NE05; Sample Location NE05					
DO	6.0 (16 hours of any 24-hour period)	10/22/97-8/22/00; 28	6.3	15.5	2.2
TOC	–	7/17/95-8/22/00; 4	7.7	8.7	7.2

Historical flow data were presented in Section 5.1.3. The flow values during historical sampling events for DO that had corresponding TOC measurements are presented in

Table 5-7. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this comparison, over half of the impaired samples were taken at below average flows. Low flows within the stream segment result in slow-moving waters, which could decrease the amount of aeration occurring in the stream. In addition, 17 of the 20 days with DO impairments occurred between May and September, which are typically considered warm weather months. Elevated stream temperatures affect the aquatic environment by limiting the concentration of DO in the water column. For example, the DO concentration for 100 percent air saturated water at sea level is 14.6 mg O_2/L at 0 degrees Celsius (°C) (32°F) and decreases to 8.6 mg O_2/L at 25°C (77°F) (Brown and Brazier 1972).

Table 5-7 DO Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	DO (mg/L)
NE05	7/17/95	160	3.0
NE05	3/5/96	18	12.6
NE05	7/19/00	235	4.0
NE05	8/22/00	139	4.8

5.1.5.1.3 pH

Table 5-8 summarizes the available historic pH data from 1990 to 2001 from the USEPA *STORET* database and recent data, not yet entered into the *STORET* database, for Little Muddy River segment NE05 (raw data contained in Appendix A). The average pH concentration for the segment is within the water quality boundaries of 6.5 and 9.0, but the minimum value observed is less than the water quality standard of 6.5. TDS concentrations are used in the pH calculations and were included previously in Table 5-5.

Table 5-8 Existing pH Water Quality Data and TMDL Endpoints (USEPA 2002b and Illinois EPA 2002)

Sample Location and Parameter	Endpoint (s.u.)	Period of Record Examined and Number of Data Points	Mean (s.u.)	Maximum (s.u.)	Minimum (s.u.)
Little Muddy River Segment NE05; Sample Location NE05					
pH	6.5 - 9	10/22/97-8/22/00; 29	7.1	8.1	6.0
Little Muddy River Segment NE05; Sample Location 05597280					
pH	6.5 - 9	1/10/90-4/2/97; 52	7.4	8.4	6.8

Figure 5-7 shows a histogram of pH values in segment NE05 of the Little Muddy River. This histogram illustrates that, based on historic data, 1.2 percent (one sample) of the measured pH values in segment NE05 violated the pH standard. The violation occurred on June 20, 2000.

5.1.6 Land Use

The Illinois Natural Resources Geospatial Clearinghouse distributes the Critical Trends Assessment Land Cover Database of Illinois. This database represents 23 land use classes created by satellite imagery captured between 1991 and 1995. The data were published in 1996 and are distributed by county in grid format for use in GIS. The GIS-delineated watershed for Little Muddy River segment NE05 was used to obtain the land use from the Critical Trends Assessment Land Cover grid. Tables 5-9 lists the land uses contributing to the segment NE05 subwatershed as well as each land use area and percent of total area.

Table 5-9 Land Use for Segment NE05 Subwatershed

Land Use	Area (Acres)	Percent of Total
Row Crop	16,235	50%
Rural Grassland	4,138	13%
Deciduous	4,102	13%
Forested Wetland	2,846	9%
Small Grains	2,427	7%
Medium Density	971	3%
Urban Grassland	376	1%
Shallow Water Wetland	359	1%
Open Water	318	1%
Shallow Marsh/Wetland	296	1%
High Density	166	1%
Deep Marsh	89	0%
Swamp	74	0%
Low Density	40	0%
TOTAL	**32,437**	**100%**

5.1.7 Point Sources and Animal Confinement Operations

5.1.7.1 Coal Mines and Oil and Gas Fields

Acid mine drainage from coal mines could contribute to manganese, sulfates, and TDS concentrations and high conductivity levels in a watershed. Data from the Illinois Natural Resources Geospatial Data Clearinghouse was reviewed for coal mines, oil fields, and non-coal mines within the Little Muddy River Watershed from the following references (full citation provided in Section 10):

- Chenoweth, Cheri, 1998, Areas Mined for the Springfield (No. 5) Coal in Illinois
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 1
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 2
- Coal Section, Illinois State Geological Survey, 1991, Point Locations of Active and Abandoned Coal Mines in Illinois
- Illinois Office of Mines and Minerals, 1998, Coal Mine Permits Boundaries in Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois

- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois - Points
- Illinois State Geological Survey, not published, Oil and Gas Fields in Illinois

Figure 5-8 presents the findings from these databases for extraction operations in the segment NE05 watershed. Multiple coal mines were identified within the watershed and labeled on Figure 5-8. The mine names and dates of operation are listed in Appendix B. Figure 5-8 also shows which coal mines are permitted. A comparison of the existing and permitted mine databases suggests that non-permitted mines are likely abandoned or closed. No oil or gas fields or non-coal mines were located in the segment NE05 subwatershed; however, the non-coal mine database contains only 20 percent of the non-coal mines in Illinois due to the lack of a legal filing requirement.

Figure 5-8 shows one permitted coal mine (#967) in the segment NE05 watershed. The discharge permit ID number for this mine is IL0038512 and is held by the Consolidation Coal Company. The original permit was granted June 6, 1975 and the current permit expired October 31, 2002. The facility is still operating under the old permit until a new one is completed. According to the data provided in Appendix B, Mine 967 was only operational until 1990; however, data from the USEPA's Permit Compliance System states that pipe outfalls associated with this permit are active as of October 2002 (USEPA 2002c).

Manganese and sulfate data are not reported on the available discharge monitoring reports for permit IL038512; however, iron data, which can be used as a surrogate for manganese, and pipe outflow data are available for one pipe outfall. These data are summarized in Table 5-10.

Table 5-10 Iron Pipe Outfall Concentrations

Permit ID and Sample Dates	Pipe Outfall	Flow (cfs)				Iron (mg/L)			
		# of Samples	Minimum	Maximum	Average	# of Samples	Minimum	Maximum	Average
IL0038512 05/00 – 09/01	Outfall 6-015	15	0.00	3.01	0.38	15	1.84	13.90	4.99

Permitted discharges are regulated by Title 35 of the Illinois Administrative Code (IPCB 1999b). The effluent standards for mine discharges are listed in Table 5-11.

Table 5-11 Effluent Standards for Mine Discharges in Illinois (IPCB 1999b)

Constituent	Limit
Acidity	Shall not exceed total alkalinity
Iron (total)	3.5 mg/L
Lead (total)	1 mg/L
Ammonia Nitrogen (as N)	5 mg/L
pH	6 - 9 s.u.
Zinc (total)	5 mg/L
Fluoride (total)	15 mg/L
Total Suspended Solids	35 mg/L
Manganese	2 mg/L[a]
Sulfate	3,500 mg/L[a]
Chloride	1,000 mg/L[a]
TDS	– – –[a]

[a] Utilize good mining practices to minimize discharge of pollutant.

The average iron concentration of the effluent data exceeds the effluent standards listed in Table 5-11. This data will be further discussed in Section 7 as part of a loading analysis.

Both Illinois EPA and IDNR Office of Mines and Minerals have responsibilities relating to the permitting of active coal mines and the regulation of mine drainage. Mine drainage is any groundwater, surface water, or rainwater that flows through, or in any way contacts, an area affected by mining. Mine drainage from sites in Illinois is either non-acid drainage or acid drainage and can be classified as pre-law and post-law. Pre-law mines are those mines operated prior to 1977, which are abandoned and not permitted and are typically acid drainage mines (Muir et al. 1997).

Acid mine drainage is formed when three essential components combine: iron pyrite material, oxygen, and water. Pyritic material may come in several different forms, some of which are very stable and difficult to break down while others are very reactive and break down readily. Iron pyrite is commonly found associated with coal and coal refuse materials. As water contacts iron pyrite in the presence of oxygen, a chemical reaction occurs that forms ferrous iron and sulfuric acid. The ferrous iron then undergoes oxidation to form ferric iron. With the presence of ferrous iron, ferric iron, pyrite, oxygen, and water, several chemical reactions occur that produce additional acidity, further lowering the pH of the water. The formation of new acid is practically continuous when erosion of the refuse material exposes unreacted pyrite in the presence of oxygen and water. The negative impacts of acid mine drainage are high levels of dissolved solids, especially iron, sulfates, chlorides, and manganese associated with the mine drainage (Muir et al. 1997).

As mentioned previously, the sampling data for manganese, sulfates, and TDS, shown in Figures 5-4 and 5-5, respectively, were taken primarily under low-flow conditions. The figures for manganese and sulfates show a decrease in concentrations with increases in flow indicating that groundwater is the potential source of these constituents. If the source of manganese or sulfates was due to surface runoff, an increase in concentrations would be expected with increased flows. Figure 5-6, which shows the sampling data for TDS, only contains four data points from which a conclusion cannot be drawn. The absence of exceedences of the water quality standards for manganese, sulfates, or TDS, at higher flows in the figures, supports the conclusion that manganese, sulfates, and TDS could have leached into the groundwater from pools within the mine sites and be the source of manganese, sulfates, and TDS concentrations in segment NE05. In addition, no data is available to assess the natural background of manganese, sulfates, and TDS in the watershed. Natural background concentrations typically are attributed to what occurs naturally in groundwater due to mineral conditions of the soils (Water Environment Research Foundation [WERF] 1997).

5.1.7.2 Animal Confinement Operations

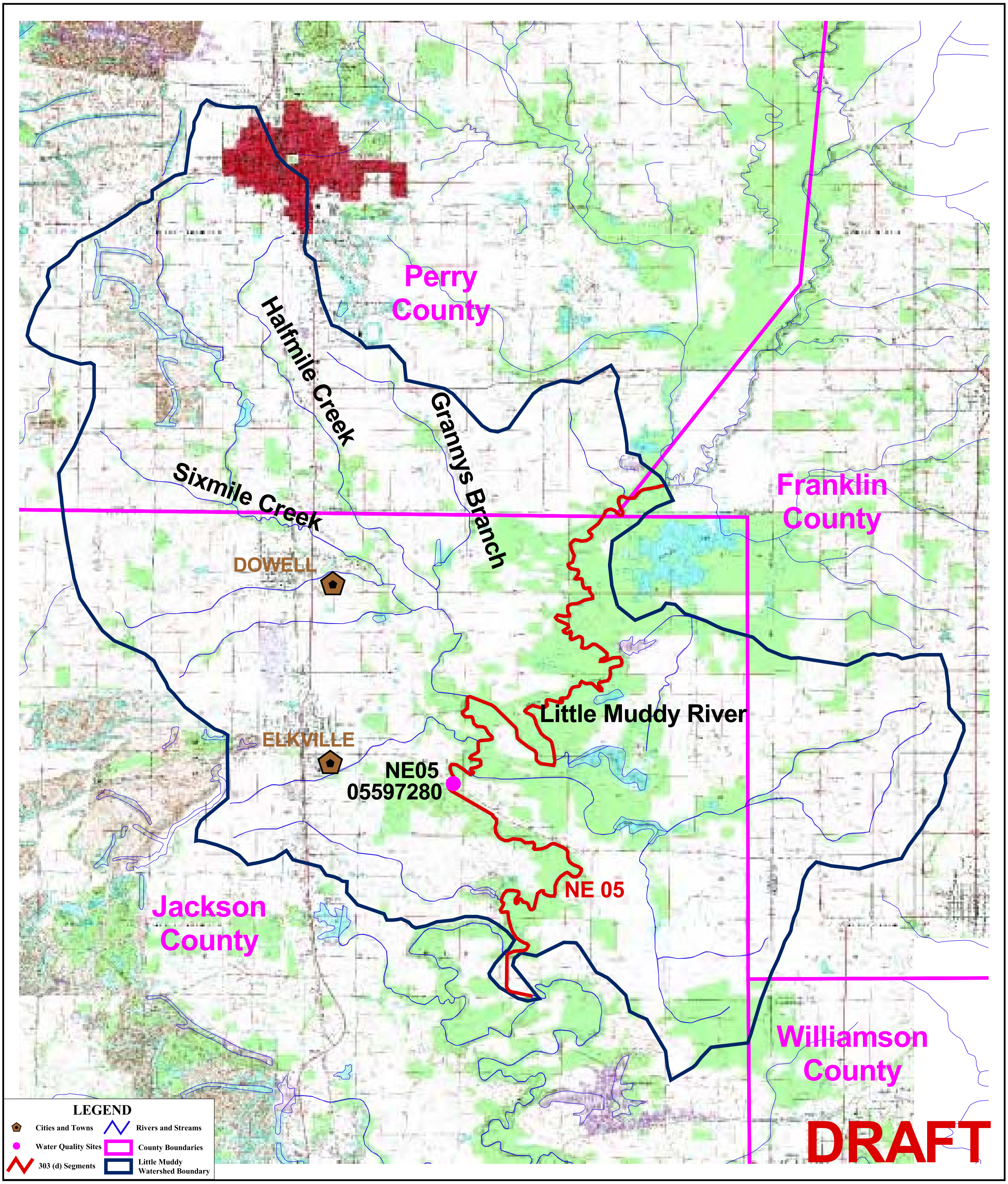
The Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Big Muddy River Basin, which contains the Little Muddy Watershed. The Illinois EPA assessed the potential impact of each facility on water quality with regard to the size of the facility, the site condition and management, pollutant transport efficiency, and water resources vulnerability. Four animal management operations were located in the segment NE05 subwatershed. Of the four operations, one (feedlot) is designated as potentially having no impact on receiving waters, one (animal management area) as potentially having a slight impact on receiving waters, and the last two (dairy and animal management area) were not assessed. Figure 5-9 shows the animal management operations within the segment NE05 subwatershed.

5.1.8 Septic Systems

Typically, septic systems near lake waters have greater potential for impacting water quality than systems near streams due to their proximity to the water body of concern. The number of septic systems within the watersheds could not be confirmed from available data sources. It is anticipated that failing septic systems are a negligible source of pollutant loads in this watershed.

5.1.9 Aerial Photography

Aerial photographs of the Little Muddy River Watershed were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse. The photographs were used to supplement the USGS quadrangle maps when locating facilities.



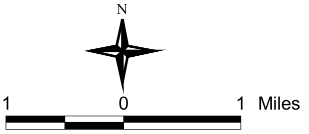


Figure 5-1
Little Muddy Watershed
and Historic Sampling Locations

CDM

densvr01/projects/IEPA/gis_data/apr/little_muddy.apr 041003 MJF

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Figure 5-2: Annual Average Flows at Gage 05597000 on the Big Muddy River

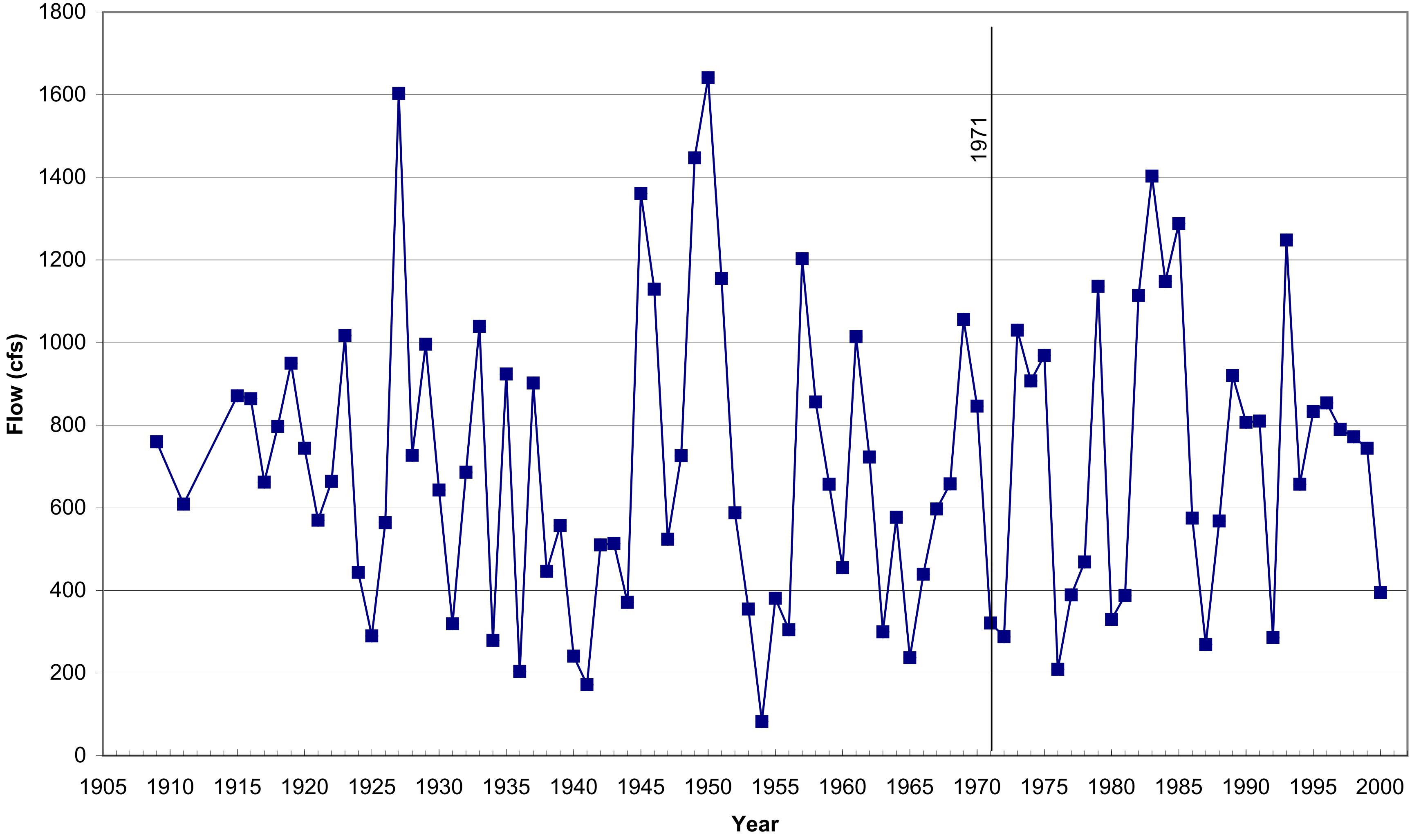

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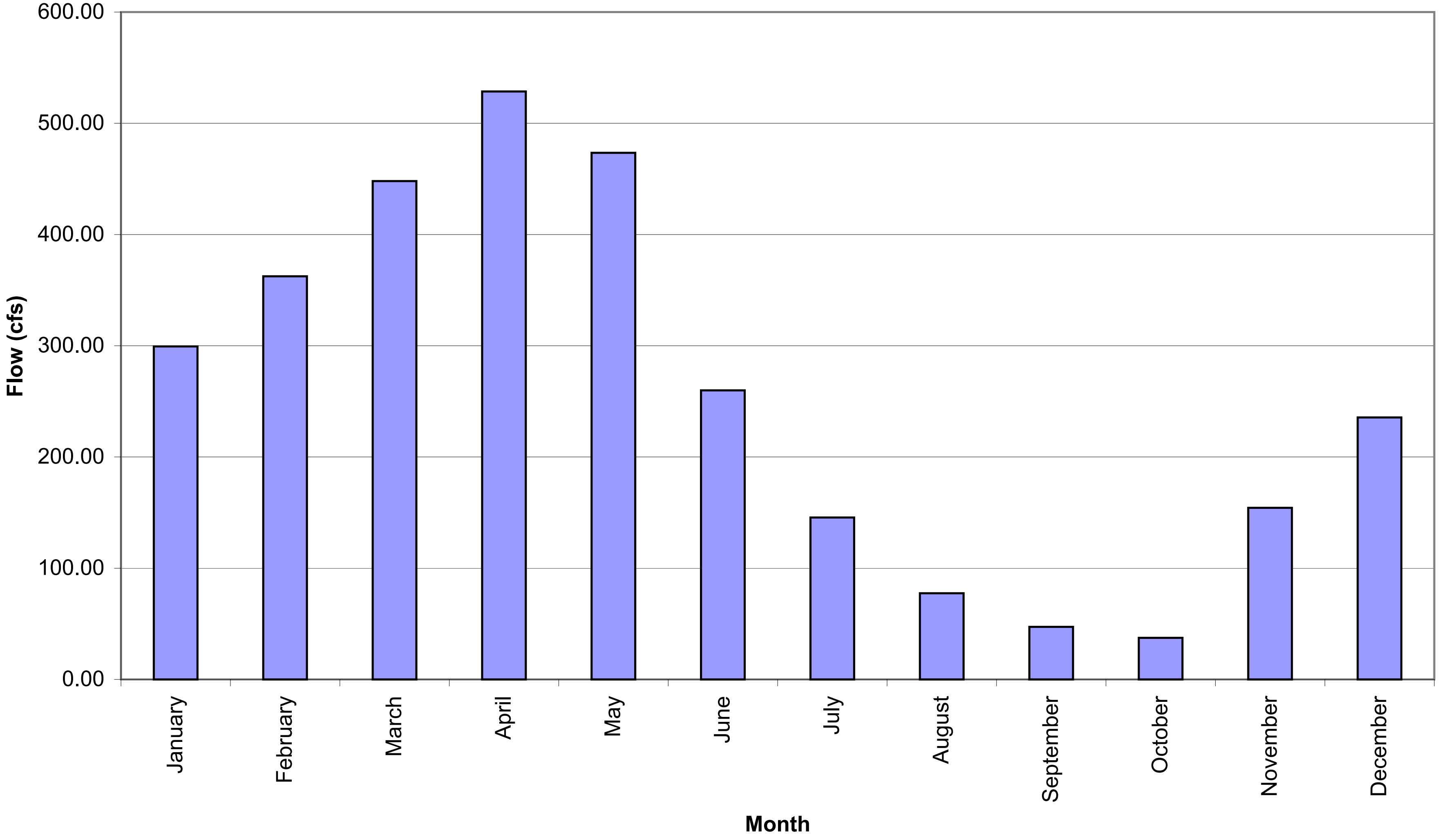
Figure 5-3: Estimated Streamflows in the Little Muddy Watershed Calculated from Gage 05597000



Period of Record
January 1, 1972 - September 30, 2001

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Figure 5-4: Manganese Concentrations and Flows within Little Muddy River Segment NE05

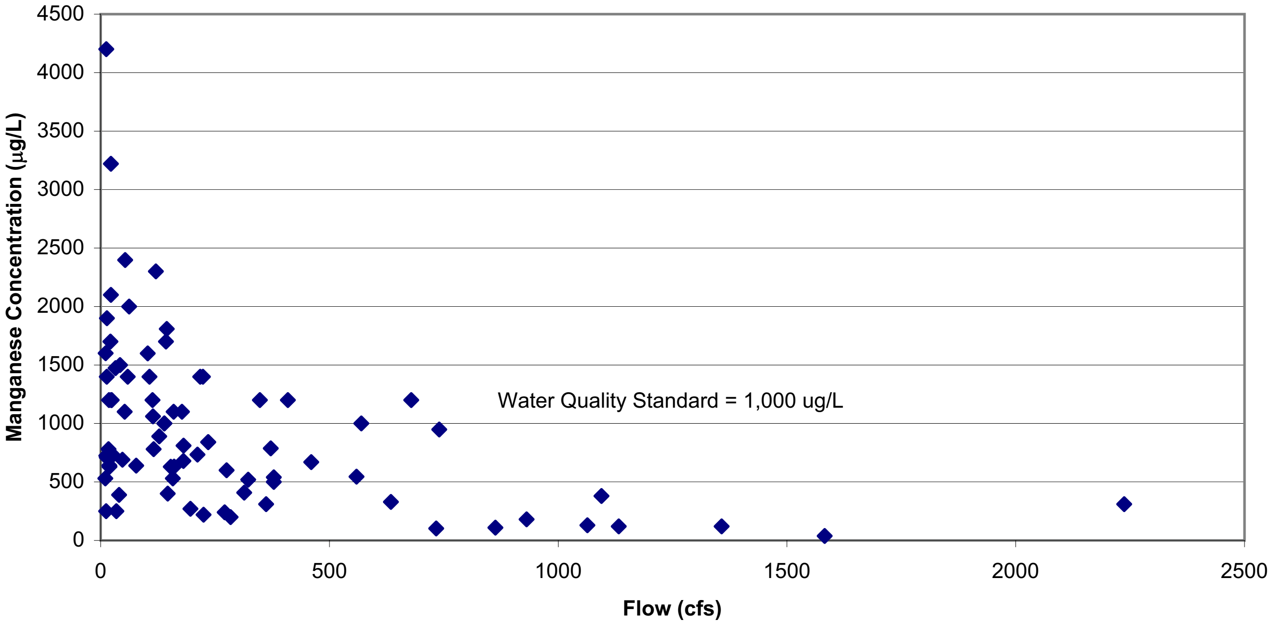

Figure 5-5: Sulfates Concentrations and Flows within Little Muddy River Segment NE05

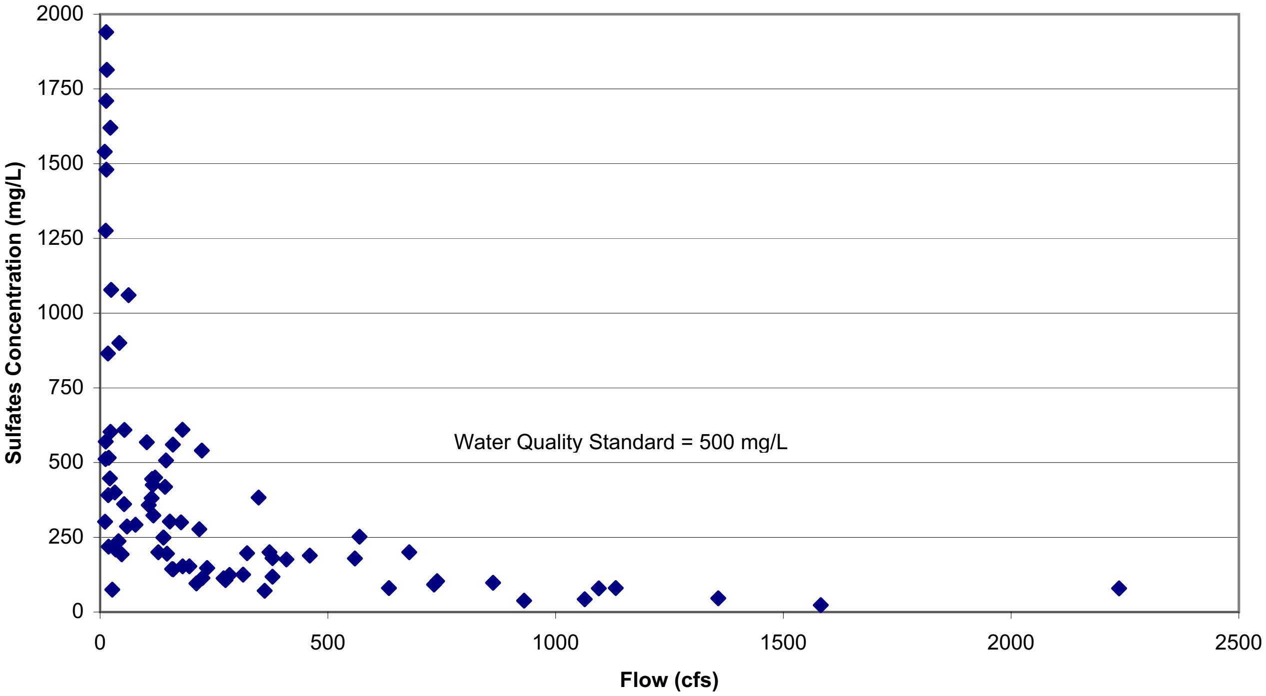

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Figure 5-6: TDS Concentrations and Flows within Little Muddy River Segment NE05

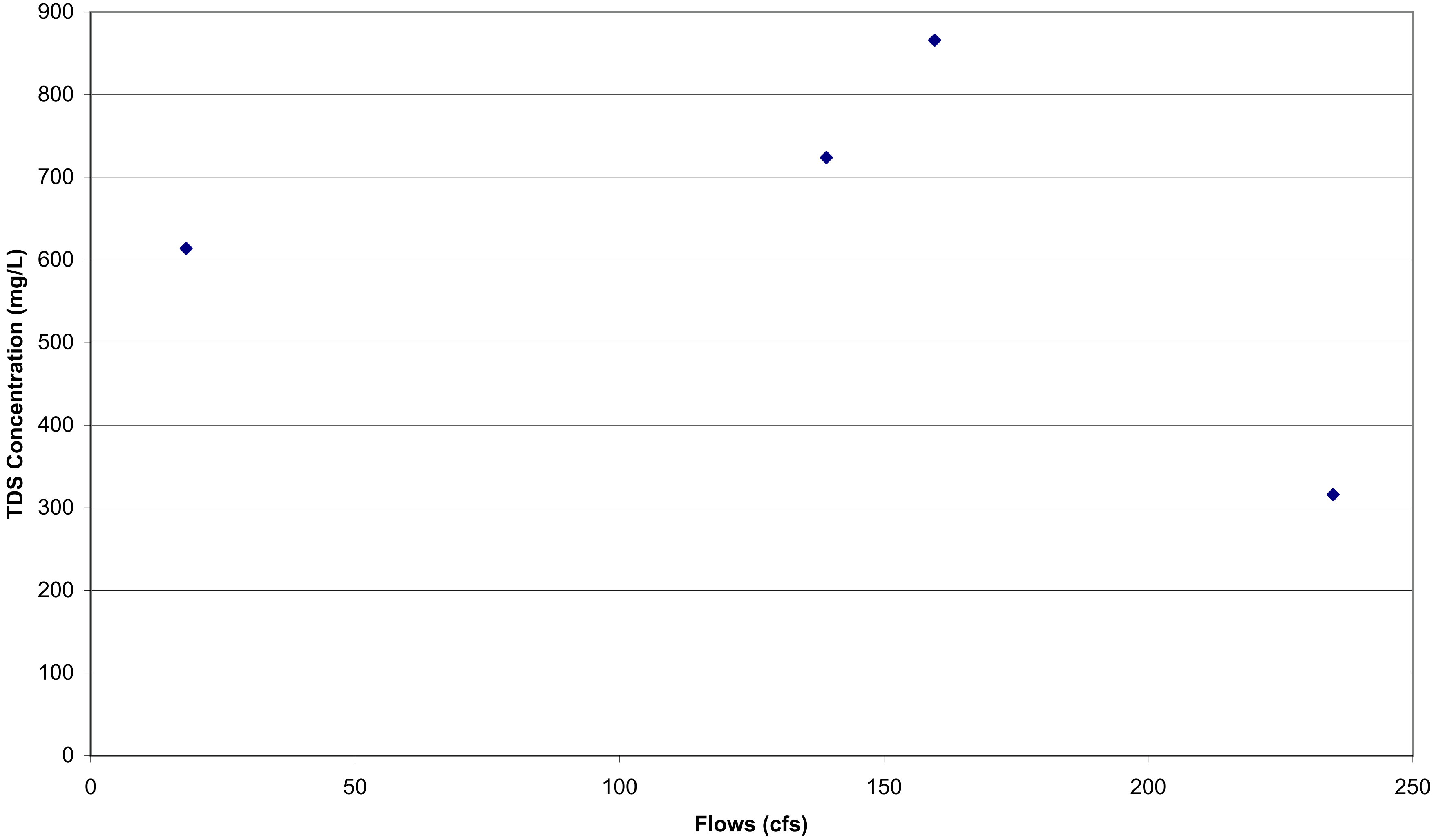

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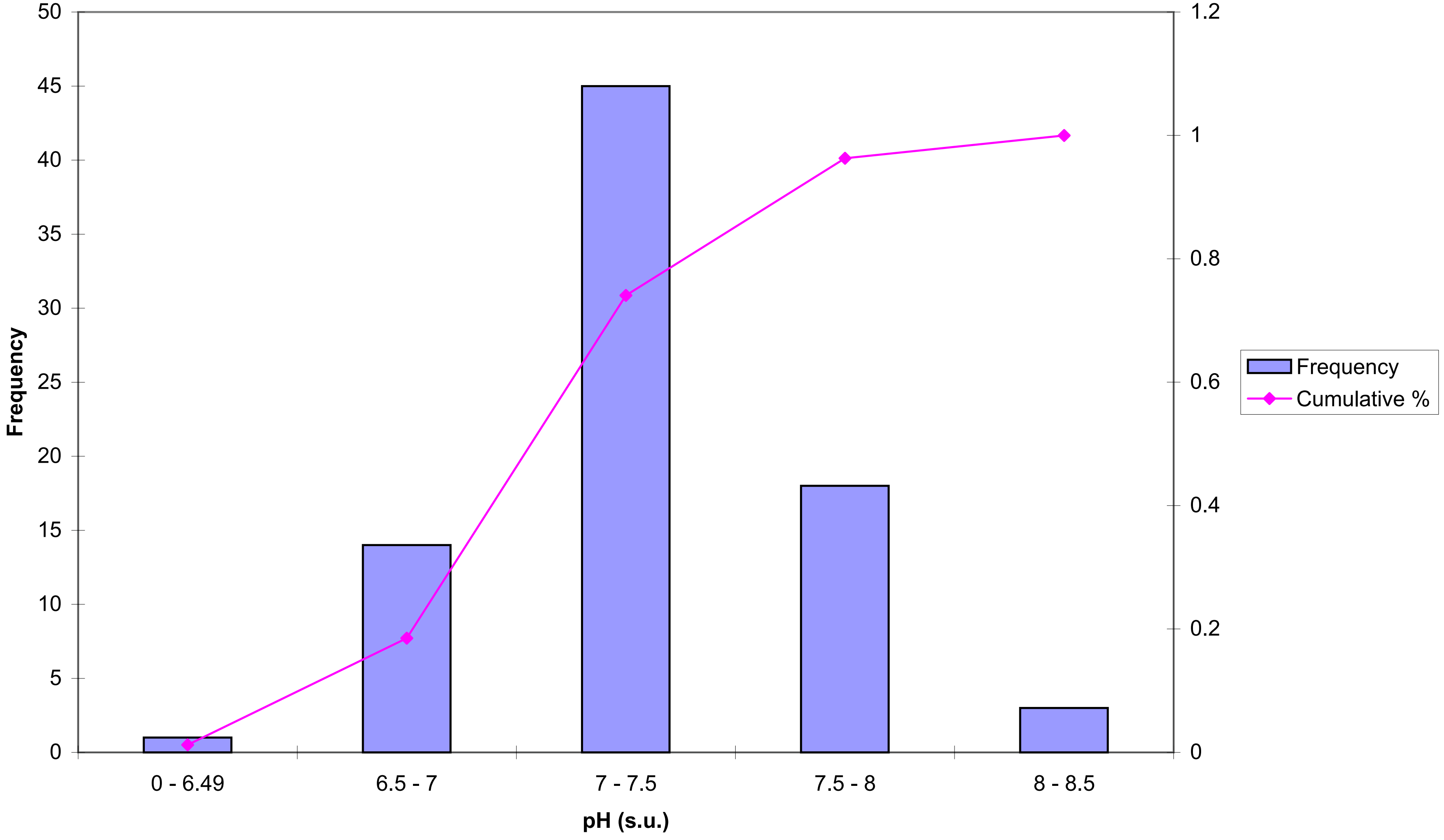
Figure 5-7: pH Histogram for Little Muddy River Segment NE05



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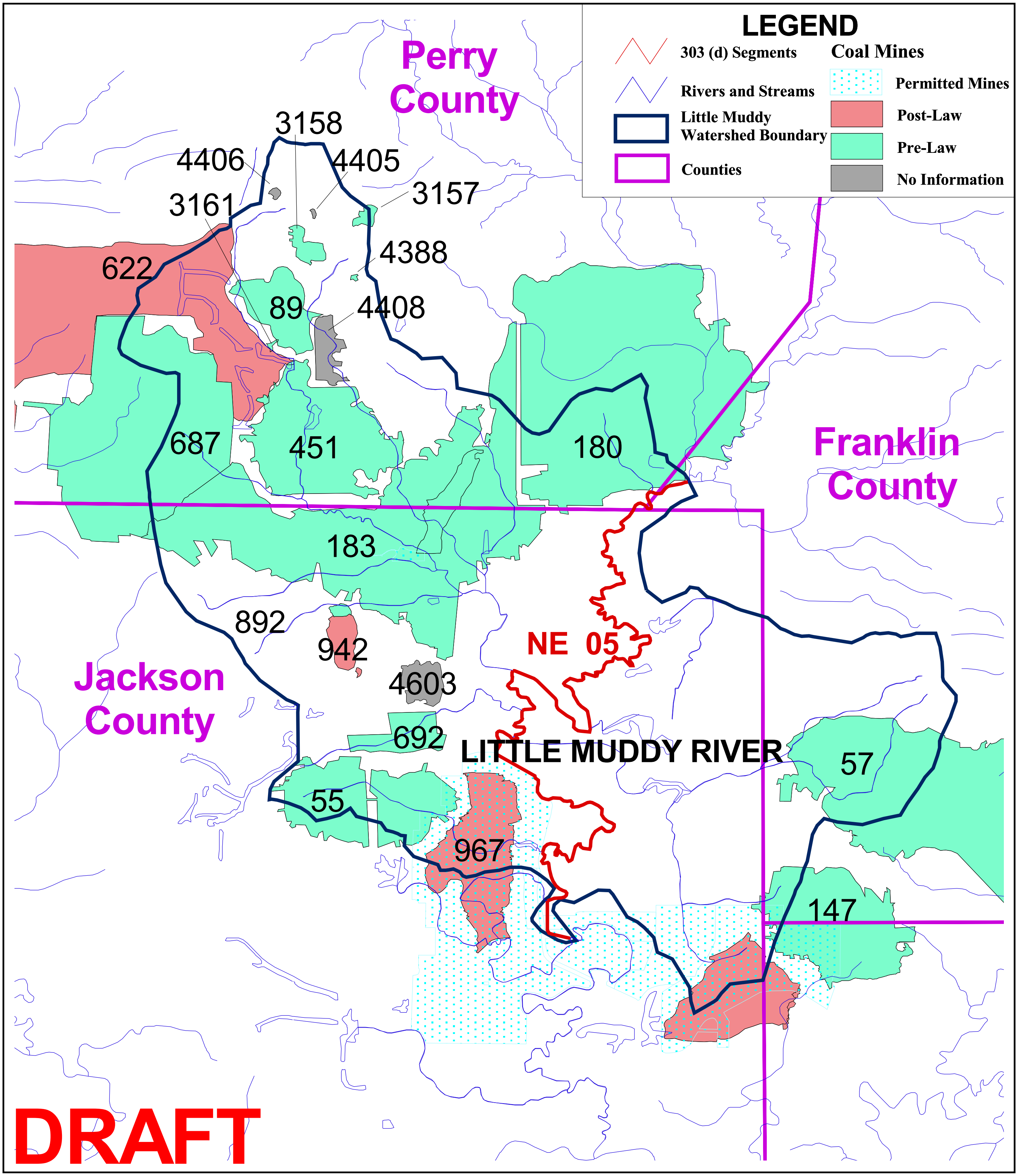

Figure 5-8
Coal Mines in the
Little Muddy Watershed
CDM

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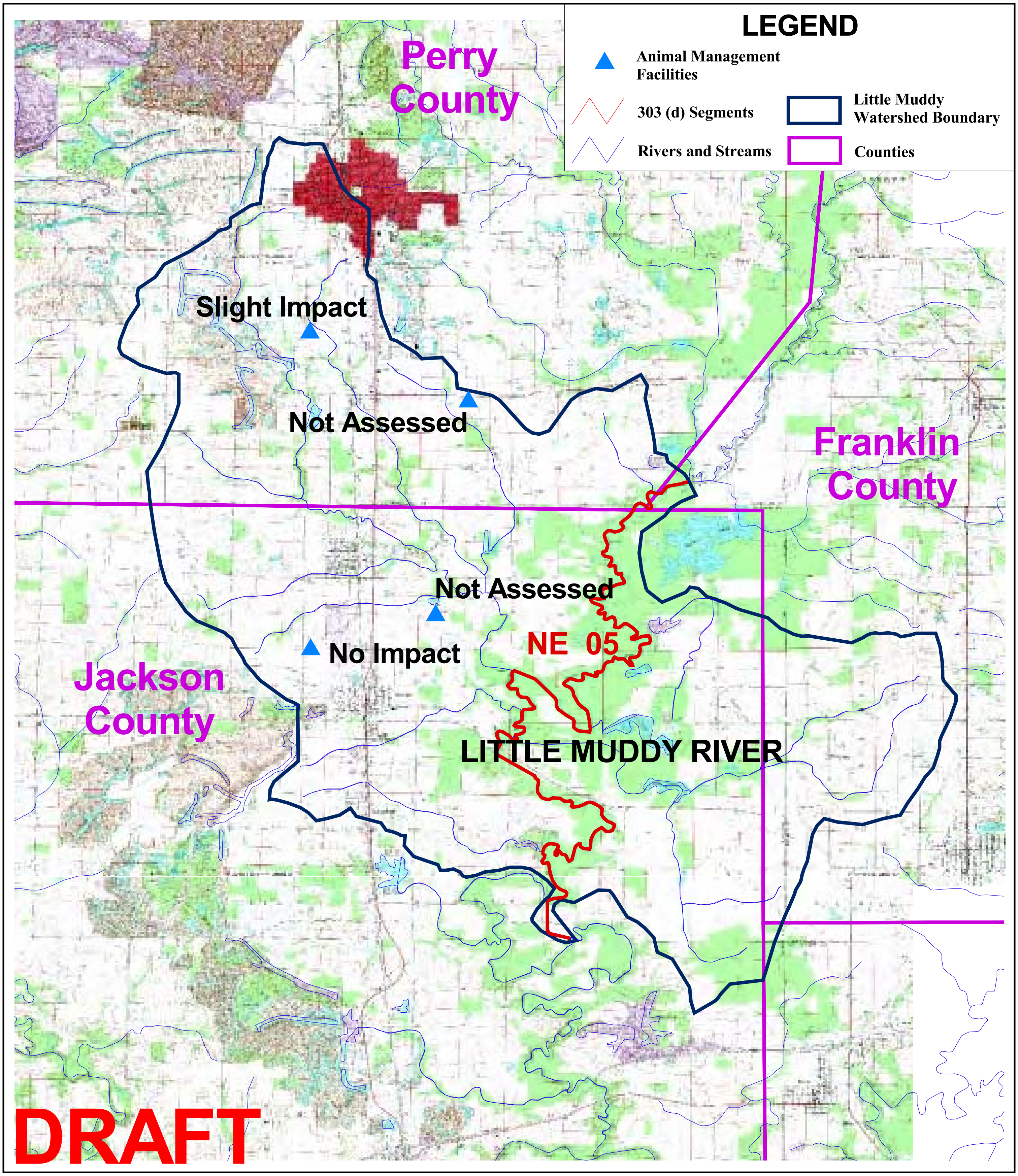

Figure 5-9
Animal Management Facilities
in the Little Muddy Watershed

CDM

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Section 6

Methodologies and Models to Complete TMDLs for the Little Muddy River Watershed

6.1 Set Endpoints for TMDLs

TMDLs are used to define the total amount of pollutants that may be discharged into a particular water body within any given day based on a particular use of that water body. Developing TMDLs must, therefore, account for both present and future stream users, habitat, flow variability, and current and future point and nonpoint pollutant loadings that may impact the water body. Defining a TMDL for any particular stream segment must take into account not only the science related to physical, chemical, and biological processes that may impact water body water quality, but must also be responsive to temporal changes in the watershed and likely influences of potential solutions to water quality impairments on entities that reside in the watershed.

Stream water quality standards were presented in Section 4, specifically in Table 4-1. Biological data, such as the Index of Biotic Integrity (IBI) and the Macroinvertebrate Biotic Index (MBI), are used to support 305(b) and 303(d) listing decisions; however, TMDLs were not developed specifically to meet biological endpoints for the Little Muddy River Watershed. The endpoints presented in Section 4, which are chemical and physical endpoints of the following constituents, were targeted: manganese, sulfates, TDS, pH, and DO.

6.2 Methodologies and Models to Assess TMDL Endpoints

Methodologies and models were examined to assess their applicability for addressing TMDL endpoints for the Little Muddy River Watershed. Model development is more data intensive than using simpler methodologies or mathematical relationships for the basis of TMDL development. In situations where only limited or qualitative data exist to characterize impairments, methodologies were used to develop TMDLs and implementation plans as appropriate.

In addition to methodologies, watershed and receiving water computer models are available for TMDL development. Most models have similar overall capabilities but operate at different time and spatial scales and were developed for varying conditions. The available models range between empirical and physically based. However, all existing watershed and receiving water computer models simplify processes and often include obviously empirical components that omit the general physical laws. They are, in reality, a representation of data.

Each model has its own set of limitations on its use, applicability, and predictive capabilities. For example, watershed models may be designed to project loads within annual, seasonal, monthly, or storm event time scales with spatial scales ranging from large watersheds to small subbasins to individual parcels such as construction sites. With regard to time, receiving water models can be steady state, quasi-dynamic, or fully dynamic. As the level of temporal and spatial detail increases, the data requirements and level of modeling effort increase.

6.2.1 Watershed Models

Watershed or loading models can be divided into categories based on complexity, operation, time step, and simulation technique. USEPA has grouped existing watershed-scale models for TMDL development into three categories based on the number of processes they incorporate and the level of detail they provide (USEPA 1997a):

- Simple models
- Mid-range models
- Detailed models

Simple models primarily implement empirical relationships between physiographic characteristics of the watershed and pollutant runoff. A list of simple category models with an indication of the capabilities of each model is shown in Table 6-1. Simple models may be used to support an assessment of the relative significance of different nonpoint sources, guide decisions for management plans, and focus continuing monitoring efforts. Generally, simple models aggregate watershed physiographic data spatially at a large-scale and provide pollutant loading estimates on large time-scales. Although they can easily be adopted to estimate storm event loading, their accuracy decreases since they cannot capture the large fluctuations of pollutant concentrations observed over smaller time-scales.

Table 6-1 Evaluation of Watershed Model Capabilities - Simple Models (USEPA 1997a)

Criteria		USEPA Screening[1]	Simple Method[1]	Regression Method[1]	SLOSS-PHOSPH[2]	Watershed	FHWA	WMM
Land Uses	Urban	○	◒	◒	–	◒	○[3]	●
	Rural	◒	–	○	◒	◒	○	●
	Point Sources	–	–	–	–	○	–	○
Time Scale	Annual	●	●	●	●	●	●	●
	Single Event	○	○	○	–	–	○	–
	Continuous	–	–	–	–	–	–	–
Hydrology	Runoff	–[4]	◒	–	–	–	○	○
	Baseflow	–	–	–	–	–	–	○
Pollutant Loading	Sediment	◒	◒	◒	◒	◒	–	–
	Nutrients	◒	◒	◒	◒	◒	◒	◒
	Others	○	◒	◒	–	◒	◒	◒
Pollutant Routing	Transport	–	–	–	–	–	–	–
	Transformation	–	–	–	–	–	–	○
Model Output	Statistics	–	–	–	–	◒	○	○
	Graphics	–	–	–	–	◒	–	○
	Format Options	–	–	–	–	◒	–	○
Input Data	Requirements	○	○	○	○	○	○	○
	Calibration	–	–	–	○	◒	–	◒
	Default Data	●	●	◒	◒	○	◒	◒
	User Interface	–	–	–	–	◒	○	◒
BMPs	Evaluation	○	○	–	○	◒	◒	◒
	Design Criteria	–	–	–	–	–	–	–
Documentation		●	●	●	●	●	●	◒

[1] Not a computer program
[2] Coupled with GIS
[3] Highway drainage basins
[4] Extended Versions recommended use of SCS-curve number method for runoff estimation

● High ◒ Medium ○ Low – Not Incorporated

Mid-range models attempt a compromise between the empiricism of the simple models and complexity of detailed mechanistic models. Mid-range models are designed to estimate the importance of pollutant contributions from multiple land uses and many individual source areas in a watershed. Therefore, they require less aggregation of the watershed physiographic characteristics than the simple models. Mid-range models may be used to define large areas for pollution migration programs on a watershed basis and make qualitative evaluations of BMP alternatives. A list of models within the mid-range category and their capabilities is shown in Table 6-2.

Table 6-2 Evaluation of Watershed Model Capabilities - Mid-Range Models (USEPA 1997a)

Criteria		**SITEMAP**	**GWLF**	**P8-UCM**	**Auto-QI**	**AGNPS**	**SLAMM**
Land Uses	Urban	●	●	●	●	–	●
	Rural	●	●	–	–	●	–
	Point Sources	◒	◒	●	–	●	●
Time Scale	Annual	–	–	–	–	–	–
	Single Event	○	–	●	–	●	–
	Continuous	●	●	●	●	–	●
Hydrology	Runoff	●	●	●	●	●	●
	Baseflow	○	●	○	○	–	○
Pollutant Loading	Sediment	–	●	●	●	●	●
	Nutrients	●	●	●	●	●	●
	Others	–	–	●	●	–	●
Pollutant Routing	Transport	○	○	○	◒	●	◒
	Transformation	–	–	–	–	–	–
Model Output	Statistics	◒	○	–	–	–	○
	Graphics	◒	◒	●	–	●	○
	Format Options	●	●	●	○	●	●
Input Data	Requirements	◒	◒	◒	◒	◒	◒
	Calibration	○	○	○	◒	○	◒
	Default Data	●	●	◒	○	◒	◒
	User Interface	●	●	●	◒	◒	●
BMPs	Evaluation	○	○	●	◒	◒	◒
	Design Criteria	–	–	●	◒	◒	○
Documentation		●	●	●	◒	●	◒

● High ◒ Medium ○ Low – Not Incorporated

Detailed models use storm event or continuous simulation to predict flow and pollutant concentrations for a range of flow conditions. These models explicitly simulate the physical processes of infiltration, runoff, pollutant accumulation, instream effects, and groundwater/surface water interaction. These models are complex and were not designed with emphasis on their potential use by the typical state or local planner. Many of these models were developed for research into the fundamental land surface and instream processes that influence runoff and pollutant generation, rather than to communicate information to decision makers faced with planning watershed management (USEPA 1997a). Although detailed or complex models provide a comparatively high degree of realism in form and function, complexity does not come without a price of data requirements for model construction, calibration, verification, and operation. If the necessary data are not available, and many inputs must be based upon professional judgment or taken from literature, the resulting uncertainty in predicted values undermine the potential benefits from greater realism. Based on the available data for the Little Muddy River Watershed, a detailed model could not be constructed, calibrated, and verified with certainty and the watershed model selection should focus on the simple or mid-range models.

6.2.1.1 Watershed Model Recommendation

For the Little Muddy River Watershed, the Watershed Management Model (WMM) will be utilized in screening mode for the DO TMDLs in the watershed. For manganese, sulfates, and TDS, a Monte Carlo simulation will be utilized as discussed in Section 7.

6.2.2 Receiving Water Quality Models

Receiving water quality models differ in many ways, but some important dimensions of discrimination include conceptual basis, input conditions, process characteristics, and output. Table 6-3 presents extremes of simplicity and complexity for each condition as a point of reference. Most receiving water quality models have some mix of simple and complex characteristics that reflect tradeoffs made in optimizing performance for a particular task.

Table 6-3 General Receiving Water Quality Model Characteristics

Model Characteristic	Simple Models	Complex Models
Conceptual Basis	Empirical	Mechanistic
Input Conditions	Steady State	Dynamic
Process	Conservative	Nonconservative
Output Conditions	Deterministic	Stochastic

The concept behind a receiving water quality model may reflect an effort to represent major processes individually and realistically in a formal mathematical manner (mechanistic), or it may simply be a "black-box" system (empirical) wherein the output is determined by a single equation, perhaps incorporating several input variables, but without attempting to portray constituent processes mechanistically.

In any natural system, important inputs, such as flow in the river, change over time. Most receiving water quality models assume that the change occurs sufficiently slowly so that the parameter (for example, flow) can be treated as a constant (steady state). A dynamic receiving water quality model, which can handle unsteady flow conditions, provides a more realistic representation of hydraulics, especially those conditions associated with short duration storm flows, than a steady-state model. However, the price of greater realism is an increase in model complexity that may be neither justified nor supportable.

The manner in which input data are processed varies greatly according to the purpose of the receiving water quality model. The simplest conditions involve conservative substances where the model need only calculate a new flow-weighted concentration when a new flow is added (conservation of mass). Such an approach is unsatisfactory for constituents such as DO or labile nutrients, such as nitrogen and phosphorus, which will change in concentration due to biological processes occurring in the stream.

Whereas the watershed nonpoint model's focus is the generation of flows and pollutant loads from the watershed, the receiving water models simulate the fate and transport of the pollutant in the water body. Table 6-4 presents the steady-state (constant flow and loads) models applicable for this watershed. The steady-state models are less complex than the dynamic models. Also, as discussed above, the dynamic models require significantly more data to develop and calibrate an accurate simulation of a water body.

Table 6-4 Descriptive List of Model Components - Steady-State Water Quality Models

Model	Water Body Type	Parameters Simulated	Process Simulated	
			Physical	Chemical/Biological
USEPA Screening Methods	River, lake/ reservoir, estuary, coastal	Water body nitrogen, phosphorus, chlorophyll "a," or chemical concentrations	Dilution, advection, dispersion	First order decay - empirical relationships between nutrient loading and eutrophication indices
EUTROMOD	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
BATHTUB	Lake/reservoir	DO, nitrogen, phosphorus, chlorophyll "a"	Dilution	Empirical relationships between nutrient loading and eutrophication indices
QUAL2E	Rivers (well mixed/shallow lakes or estuaries)	DO, carbonaceous biochemical oxygen demand (CBOD), arbitrary, nonconservative substances, three conservative substances	Dilution, advection, dispersion	First order decay, DO-BOD cycle, nutrient-algal cycle
EXAMSII	Rivers	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, process kinetics, daughter products, exposure assessment
SYMPTOX3	River/reservoir	Conservative and nonconservative substances	Dilution, advection, dispersion	First order decay, sediment exchange
STREAMDO	Rivers	DO, CBOD, and ammonium	Dilution	First order decay, BOD-DO cycle, limited algal component

6.2.2.1 Receiving Water Model Recommendation

Because of the lack of spatial data sets for the stream segments within the Little Muddy River Watershed, methodologies based on the USEPA Screening Methods and Monte Carlo simulations will be utilized for stream TMDL development as discussed in the following section.

6.2.3 Stream TMDLs for the Little Muddy River Watershed

Because of limited data available for watershed and receiving water model development for the Little Muddy River Watershed, TMDLs for the following constituents will be completed using methodologies: TDS, DO, sulfates, and manganese. For DO, a Streeter-Phelps analysis based on the USEPA Screening Procedures was developed. In addition, a screening level WMM analysis was conducted. These analyses are described in Section 7. For TDS, sulfates, and manganese a Monte Carlo simulation was conducted, and the description of this analysis is also contained in Section 7. For pH, an analysis based on recurrence interval and pH was created and this discussion is also included in Section 7.

6.2.4 Calibration and Validation of Models

The results of loading and receiving water simulations are more meaningful when they are accompanied by some sort of confirmatory analysis. The capability of any model to accurately depict water quality conditions is directly related to the accuracy of input data and the level of expertise required to operate the model. It is also largely dependent on the amount of data available. Calibration involves minimization of deviation between measured field conditions and model output by adjusting parameters of the model. Data required for this step are a set of known input values along with corresponding field observation results. Validation involves the use of a second set of independent information to check the model calibration. The data used for validation should consist of field measurements of the same type as the data output from the model. Specific features such as mean values, variability, extreme values, or all predicted values may be of interest to the modeler and require testing. Models are tested based on the levels of their predictions, whether descriptive or predictive. More accuracy is required of a model designed for absolute versus relative predictions. If the model is calibrated properly, the model predictions will be acceptably close to the field predictions. Because methodologies will be utilized for the Little Muddy River Watershed, a detailed calibration and verification cannot be completed for the watershed.

6.2.5 Seasonal Variation

Consideration of seasonal variation, such that water quality standards for the allocated pollutant will be met during all seasons of the year, is a requirement of a TMDL submittal. TMDLs must maintain or attain water quality standards throughout the year and consider variations in the water body's assimilative capacity caused by seasonal changes in temperature and flow (USEPA 1999). Seasonal variation for the Little Muddy River Watershed is discussed in Section 8.

6.2.6 Allocation

Establishing a TMDL requires the determination of the LC of each stream segment. The models or methodologies were used to establish what the LC is for each segment for each pollutant. The next step was to determine the appropriate MOS for each segment. After setting the MOS, WLA of point sources and LA from the nonpoint sources were set.

The MOS can be set explicitly as a portion of the LC or implicitly through applying conservative assumptions in data analysis and modeling approaches. Data analyses and modeling limitations were taken into account when recommending a MOS. The allocation scheme (both LA and WLA) demonstrates that water quality standards will be attained and maintained and that the load reductions are technically achievable. The allocation is the foundation for the implementation and monitoring plan. Further discussion on the allocation is presented in Section 8.

6.2.7 Implementation and Monitoring

For the Little Muddy River Watershed, a plan of implementation was produced to support the developed TMDL. The plan of implementation has reasonable assurance of being achieved. The plan provides the framework for the identification of the actions that must be taken on point and nonpoint sources to achieve the desired TMDLs. The accomplishment of the necessary actions to reach these targets may involve substantial efforts and expenditures by a large number of parties within the watershed. Depending upon the specific issues and their complexity in the Little Muddy River Watershed, the time frame for achieving water quality standards has been developed.

The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. Also, reductions from point sources through waste stream management, which involves the treatment of point source waste streams in order to decrease potential water quality impacts; pretreatment controls; and other structural and nonstructural programs, were identified as applicable. The implementation plan for the Little Muddy River Watershed is presented in Section 9.

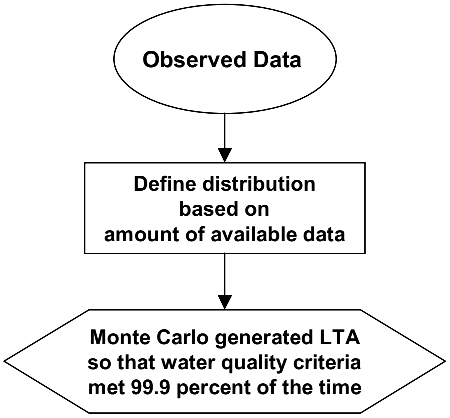
Section 7
Methodology Development for the Little Muddy River

7.1 Basis for TDS TMDL

The TMDL for TDS will be based on conductivity. There is a relationship between the two constituents as shown in Figure 7-1 at the end of this section. A Monte Carlo analysis will be performed on conductivity to determine the reduction required to meet water quality standards. The relationship in Figure 7-1 will be used to establish the TMDL for TDS.

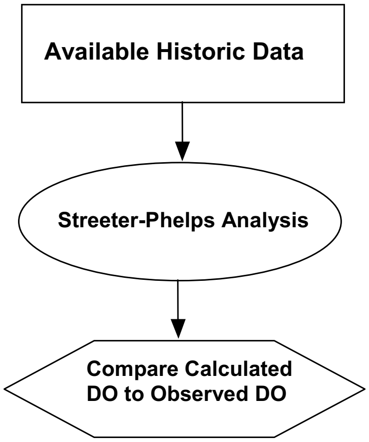
7.2 Methodology Overview

Methodologies were utilized in the TMDL analysis of the Little Muddy River Watershed. For manganese, sulfates, and conductivity, a Monte Carlo simulation was utilized to estimate a long-term average instream concentration needed to meet water quality standards. Investigation of DO required a Streeter-Phelps analysis.



Schematic 1

The schematic to the left shows how the Monte Carlo analysis was utilized to analyze manganese, sulfates, and conductivity. A distribution based on existing data is entered in the Monte Carlo simulation program. This distribution is based on the amount of existing data available. Using this defined distribution, the computer simulation program randomly generates values to determine what long-term average (LTA) would be needed so that water quality criteria are met 99.9 percent of the time or so that water quality criteria are exceeded less than once every three years. The TMDL for manganese, sulfates, and conductivity will be based on this LTA. The randomly generated values generated by the Monte Carlo simulation are available in Appendix C.



Schematic 2

The Streeter-Phelps analysis was conducted as illustrated in the schematic to the right. Observed data were utilized to set up a Streeter-Phelps analysis to predict stream coefficients that would be required to result in observed DO concentrations. This Streeter-Phelps analysis was based on USEPA's Screening Procedures (Mills et al. 1985). The 5-day biochemical oxygen demand (BOD_5) load and reaeration coefficient

(k_a) utilized in the Streeter-Phelps analysis were examined in the TMDL for DO for segment NE05.

The procedure used to develop the TMDL for pH was based on an analytical procedure (Kentucky Department of Environmental Protection [KDEP] 2001). The procedure calculates a maximum allowable hydrogen ion loading in the water column to maintain pH standards.

7.3 Watershed Delineation

A watershed for the area contributing directly to Little Muddy River segment NE05 was delineated with GIS analyses through use of the DEM, as discussed in Section 5.1.2. The delineation suggests that segment NE05 captures flows from a directly contributing watershed of approximately 51 square miles. The entire watershed upstream of segment NE05 is approximately 271 square miles. Figure 7-2 at the end of this section shows the location of the water quality stations in the Little Muddy River segment NE05 and the boundary of the GIS-delineated watershed contributing to segment NE05.

7.4 Methodology Development and Results

This section discusses the methodologies utilized to examine manganese, sulfates, conductivity, DO, and pH levels in the Little Muddy River Watershed.

7.4.1 Monte Carlo Analysis Development and Results

For each constituent exceeding water quality standards, the available data was analyzed and an appropriate distribution was chosen to represent the data. A lognormal distribution, defined as a distribution of random variables whose logarithm is normally distributed, was chosen to analyze segment NE05, since sufficient data for this site was available to utilize this distribution.

Each constituent was evaluated separately using @RISK, which is a Microsoft® *Excel*® add-in for the Monte Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the required percent reduction such that the water quality criteria would be met at least 99.9 percent of the time. The 99.9 percent of time value matches the Illinois EPA's 303(d) listing criteria of less than once in a three-year allowable excursion of water quality standards. For each simulation, the required percent reduction is:

$$\mathbf{PR = maximum\ \{0, (1-Cc/Cd)\}}$$

where: PR = required percent reduction for the current iteration
Cc = water quality criterion in mg/L
Cd = randomly generated pollutant source concentration in mg/L based on the lognormal distribution

An allowable LTA instream concentration was determined for each impaired constituent. The Monte Carlo simulation analysis is designed to identify a LTA value that will meet the water quality criterion for that parameter 99.9 percent of the time. The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a concentration, Cd, is randomly generated according to a specified distribution determined by observed data. For each concentration generated, a percent reduction was calculated, if necessary, to meet water quality criteria. The mean concentration value is multiplied by the inverse of the required percent reduction to compute the long-term daily average concentration that needs to be met to achieve the water quality standard.

The overall percent reduction required is the 99.9th percentile value of the probability distribution generated by the 10,000 iterations, so that the allowable LTA concentration is:

$$\mathbf{LTA = Mean * (1 - PR99.9)}$$

7.4.1.1 Monte Carlo Results for Little Muddy River Segment NE05

Observed manganese values in segment NE05 ranged from 0.04 to 4.2 mg/L, sulfates samples ranged from 23 to 1,940 mg/L, and conductivity values ranged from 147 to 3,440 μS/cm as shown in Table 5-5. Two of the output model concentrations are significant to the TMDL analysis of segment NE05. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 7-1 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed, so that water quality standards will be achieved in Little Muddy River segment NE05. Calculation details are presented in Appendix C.

Table 7-1 LTA Concentrations Determined through Analysis to Meet Water Quality Standards in Little Muddy River Segment NE05

Constituent	Average Concentration Calculated from Distribution	LTA Concentration (mg/L)
Manganese (mg/L)	0.94	0.13
Sulfates (mg/L)	411	50
Conductivity (μS/cm)	913	293

Table 7-1 shows that the concentration determined by analysis to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese, sulfates, and conductivity; therefore, the TMDL for segment the Little Muddy River at NE05 requires that a load reduction be made for manganese, sulfates, and TDS (conductivity) based upon the available data. The TMDL will be discussed in Section 8.

7.4.1.2 Loading Analysis from Permitted Mines

Because the analyses presented in the previous sections focus on total load reduction needed and does not focus on the sources of the load (point or nonpoint), a loading analysis based on available discharge mine data was completed. The goal of the analyses was to determine whether permitted discharges from mining activity could be causing water body impairments, and, if so, what appropriate reductions would be needed to be incorporated in the mine permits.

To assess the relative loading from the mines, in relation to loading in the stream, the average loading in stream versus loading from the mine was estimated. Results for Little Muddy River segment NE05 are shown in Table 7-2. The discharge monitoring data for IL0038512 report discharge for iron, but not manganese or sulfates. None of the data reported by the DMRs provided an acceptable surrogate for sulfates; however, iron was used as an acceptable surrogate constituent for calculation of manganese loading. Table 7-2 shows that the percent of manganese loading from the mine is likely insignificant in comparison to nonpoint sources or background loads of manganese.

Table 7-2 Comparison of Loadings for Stream vs. Permitted Mine for Manganese*

Mine	Average River Flow (cfs)	Average River Concentration (mg/L)	Average River Manganese Load (lb/day)	Average Mine Flow (cfs)	Average Mine Manganese* Concentration (mg/L)	Average Mine Manganese* Load (lb/day)	Percent of Manganese Load from Mine (%)
IL0038512	217	0.9	1053	0.4	5.0	10	1

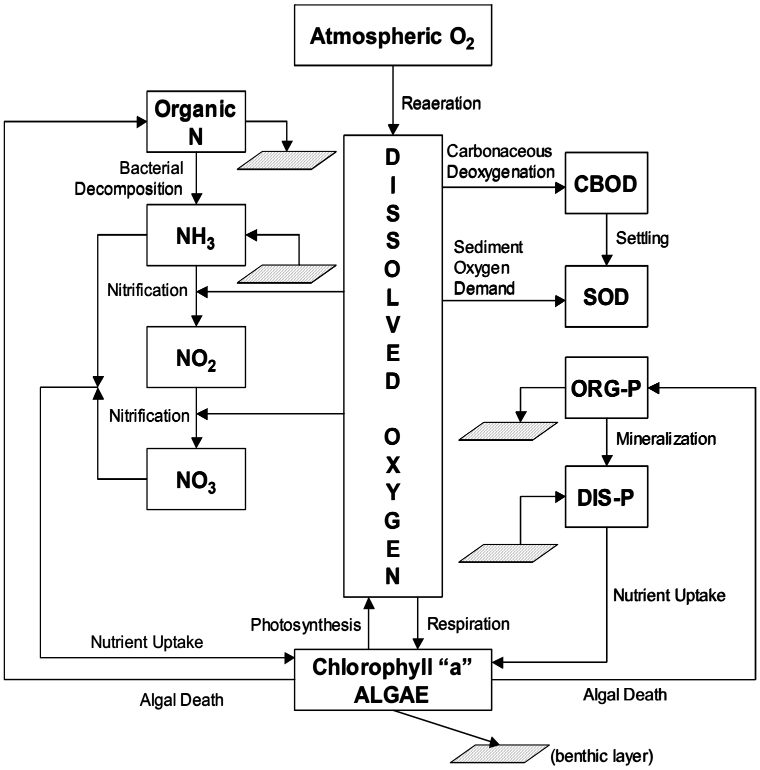
Manganese* - Iron used as surrogate

7.4.2 DO Analysis Development and Results

A Streeter-Phelps analysis was utilized for investigation of DO in the Little Muddy River segment NE05 subwatershed. Data availability, useful for analyzing DO for this watershed, is described in Table 7-3. The historic water quality data were investigated from 1990 to 2000.

Table 7-3 Data Availability from 1990 to 2000

Model Parameter	Historic data available (yes/no)
Flow	Yes
Stream temperature	Yes
DO	Yes
5-day carbonaceous biochemical oxygen demand ($CBOD_5$)	No
BOD_5	No
Total nitrogen	Yes
Total organic carbon	Yes
Ammonia	Yes
Nitrate + Nitrite	Yes
Total Kjeldahl nitrogen	Yes
Total phosphorus	Yes
Dissolved phosphorus	Yes
Orthophosphate	No
PH	Yes
$CBOD_{20}$	No
Daily minimum and maximum DO	No
Chlorophyll "a"	No
Stream depth	Yes



The lack of various constituent samples from historic data sites in the Little Muddy River Watershed limits the modeling tools available for DO. Therefore, a Streeter-Phelps analysis was developed to examine the DO relationship with BOD_5 in the Little Muddy River. The diagram on the following page shows the interactions of DO with different processes within the water column of the stream (USEPA 1997b). The consumers of DO include:

- deoxygenation of biodegradable organics whereby bacteria and fungi (decomposers) utilize oxygen in the bioxidation-decomposition process,
- sediment oxygen demand (SOD), where oxygen is utilized by organisms inhabiting the upper layers of the bottom sediment deposits,
- nitrification, in which oxygen is utilized during oxidation of ammonia and organic nitrogen to nitrates,

- respiration by algae and aquatic vascular plants that use oxygen during night and early morning hours to sustain their living processes.

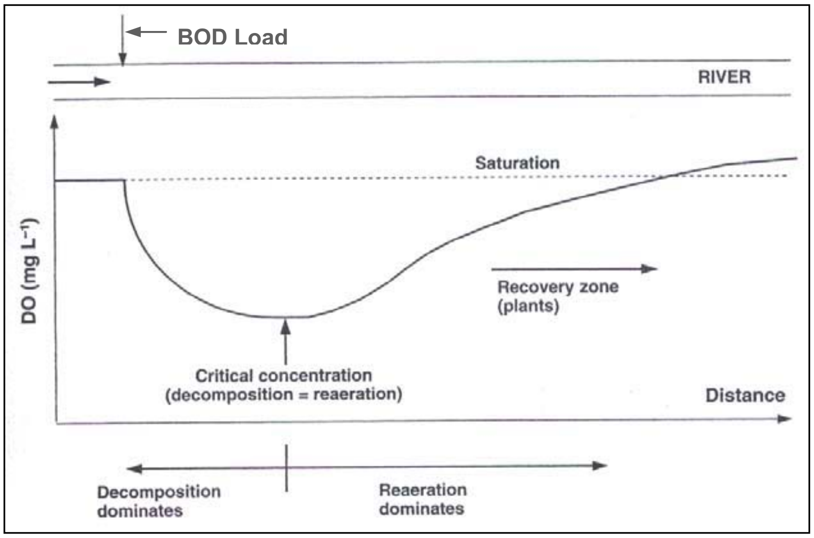
Major oxygen sources are:

- atmospheric reaeration, where oxygen is transported from the air into the water through turbulence at the air-water interface;

- photosynthesis, where chlorophyll-containing organisms (producers such as algae and aquatic plants) convert carbon dioxide to organic matter with a consequent production of oxygen.

Streeter and Phelps (1925) proposed the basic concept of the DO balance in streams. The Streeter-Phelps equation predicts the DO "sag" that occurs after biodegradable constituents are discharged into streams. A biodegradable constituent is anything that can be broken down by microorganisms. BOD is the measure of the quantity of oxygen consumed by microorganisms during the decomposition of organic matter. When nutrients, such as nitrate and phosphate, are released into the water, growth of algae and aquatic plants is stimulated. The result is an increase in microbial populations, higher levels of BOD, and increased oxygen demand from the photosynthetic organisms during the dark hours. This results in a reduction in DO concentrations, especially during the early morning hours just before dawn.

In addition to natural sources of BOD, such as leaf fall from vegetation near the water's edge and aquatic plants, there are also anthropogenic (human) sources of organic matter. Point sources, which may contribute high levels of BOD, include wastewater treatment facilities, pulp and paper mills, and meat and food processing plants. Organic matter also comes from nonpoint sources, such as agricultural runoff, urban runoff, and livestock operations. Both point and nonpoint sources can contribute significantly to the oxygen demand in a water body. The DO sag is shown in the following figure (Chapra 1997):



Water quality models have built upon the Streeter-Phelps equation to evaluate the DO balance in streams. The analysis for segment NE05 is based on BOD_5 and reaeration only. There is not enough coincident nutrient and algal historical data from this site to assess impacts of nutrient loads on algal growth that also impact DO levels. Free floating and attached algae, as well as aquatic plants are of concern. The extent to which algae impacts the DO resources of a river is dependent on many factors, such as turbidity, which can decrease light transmittance through the water column. Additionally, the photosynthetic rate constantly changes in response to variations in sunlight intensity and is not constant. This results in diurnal fluctuations in DO levels (Mills et al. 1985). In addition, there is not enough data available to estimate the impacts of SOD at these sites.

The Streeter-Phelps analysis was based on the following equation (Mills et al. 1985):

$$\mathbf{DO_o = D_S - \left[D_o \exp\left[\frac{-k_a\,x}{v}\right] + \frac{L_0 k_d}{k_a - k_d}\left[\exp\left(\frac{-k_d\,x}{v}\right) - \exp\left(\frac{-k_a\,x}{v}\right)\right]\right]}$$

where: DO_o = calculated DO concentration (mg/L)
D_S = DO at saturation (mg/L)
D_o = Initial DO deficit (mg/L)
k_a = reaeration rate (1/day)
k_d = BOD_5 decay rate (1/day)
x = distance downstream of discharge (ft)
v = stream velocity (ft/day)
L_0 = initial BOD_5 (mg/L) at $x = 0$

The initial BOD_5 concentration (L_o) was calculated from observed TOC data. Literature states that the ratio of BOD_5 to TOC is typically between 1.0 and 1.6 (Metcalf and Eddy, Inc. 1991). For analysis, a ratio of 1.3 was used to calculate BOD_5 for each sample date.

Literature provides equations to calculate both the BOD_5 decay rate coefficient (k_d) and reaeration rate coefficient (k_a). The decay rate coefficient is dependent on stream depth, and the reaeration coefficient is dependent on depth and velocity. Due to the limits of the data set shown in Table 7-3, the decay rate coefficient was calculated from either known depths or rating curves allowing the reaeration coefficient to be calculated from the Streeter-Phelps equation presented above as the only unknown variable. The rating curves used to determine depths are available in Appendix D.

The BOD_5 decay rate coefficient (k_d) at 20°C was calculated based on the following equation (USEPA 1997b):

$$\begin{aligned} k_{d20} &= 0.3\left[\frac{H}{8}\right]^{-0.434} \quad \text{for } 0 < H < 8 \\ &= 0.3 \text{ for } H > 8 \end{aligned}$$

The BOD_5 decay rate coefficient was corrected for temperature with the following equation (Novotny and Olem 1994):

$$k_{dT} = k_{d20}\theta^{(T-20)}$$

where k_{dT} = BOD_5 decay rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) in the above equation has an accepted value of 1.047 for the BOD_5 decay rate coefficient (Novotny and Olem 1994). The decay rate coefficient typically falls between 0.02 and 3.4 day^{-1}. The reaeration rate coefficient typically ranges between 0 and 100 day^{-1} (USEPA 1997b).

For comparison purposes, the reaeration coefficient (k_a) was calculated based on the following equation (USEPA 1997b):

$$k_a = \frac{12.9\ v^{0.5}}{H^{1.5}} \text{ at } 20^{\circ}C$$

where: v = Stream velocity (feet/s)
H = Stream depth (feet)

Like the BOD_5 decay rate coefficient, the reaeration coefficient is corrected for temperature with the following equation (Novotny and Olem 1994):

$$k_{aT} = k_{a20}\theta^{(T-20)}$$

where: k_{dT} = Reaeration rate coefficient at temperature T; T in °C
θ = Thermal factor

The thermal factor (θ) for the reaeration coefficient has an accepted value of 1.025 (Novotny and Olem 1994).

Since no point sources were identified as contributing significant loads to either segment, it was assumed that the BOD_5 load from all nonpoint sources is evenly distributed throughout each segment as shown in the following figure:

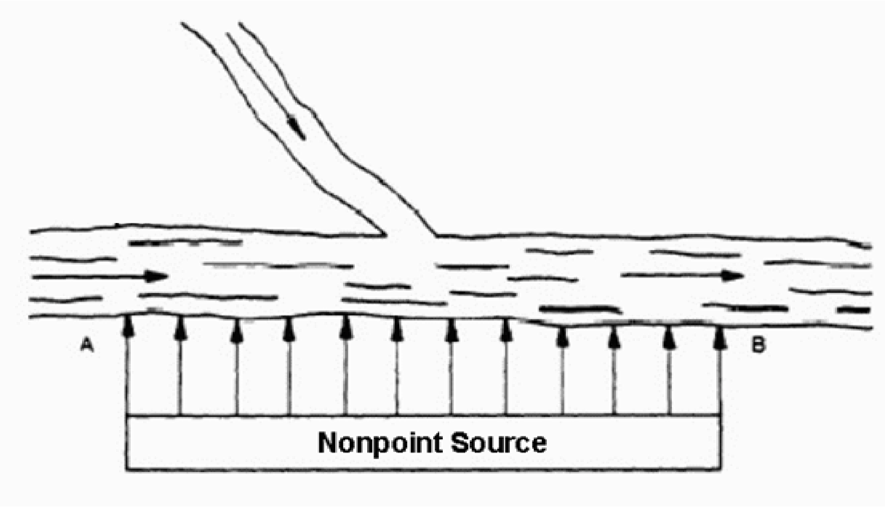


Table 7-4 shows the observed TOC data and the BOD_5 concentrations (L_0) calculated from observed TOC data. BOD loads were not calculated for March 5, 1996 because the observed DO was above saturation. Table 7-4 also shows the k_a and k_d coefficients calculated with the above equations. In addition, the estimated BOD_5 load was calculated based on the calculated BOD_5 concentration and average daily flow on the day the sample was taken. Revised k_a and k_d values are also shown in Table 7-4. These values were utilized in the Streeter-Phelps equation described above, and the resulting calculated DO was compared to observed DO readings. If there was not a match between the calculated DO and observed DO, k_a and k_d were revised within their accepted ranges so that calculated DO more closely matched observed DO. If possible, only k_a was revised as it was calculated based on estimated depth and flow, while k_d was based on estimated depth. Table 7-4 also includes precipitation values near or on the sampling date so that estimates of pollutant loads from runoff can be compared to loads estimated based on the BOD_5/TOC ratio. Analysis details are contained in Appendix E.

Table 7-4 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations

Sample Location and Date	**NE05 7/17/95**	**NE05 3/5/96**	**NE05 7/19/00**	**NE05 8/22/00**
Measured DO (mg/L)	3.0	12.6	4.0	4.8
Measured TOC (mg/L)	7.2	8.7	7.4	7.3
Calculated BOD_5 Concentration (mg/L)	9.4	11.3	9.6	9.5
Calculated BOD_5 Load (lb/day)	8,088	–	12,160	7,126
Calculated k_a (1/day)	4.2	12.5	2.9	3.1
Revised k_a (1/day)	0.10	–	0.12	2.8
Calculated k_d (1/day)	0.73	0.46	0.58	0.58
Revised k_d (1/day)	1.6	–	0.58	0.58
Precipitation (in)	0.78	–	1.10	0.72
Dates Precipitation Occurred	12 days before sample date	–	On sample date and two days prior	On sample date and two and three days prior
Flow (cfs)	160	–	235	139

The sample date that measured the lowest DO concentration in the dataset, July 17, 1995, required that both k_a and k_d be revised to obtain a match between the calculated and observed DO. In this case, k_a was reduced to the minimum of the literature range, 0.1/day, and k_d was revised to match the calculated and observed DO for the sample date. The value of k_a for the second lowest DO concentration in the dataset, July 19, 2000, was revised to a value near the lower end of the literature range. The need to reduce the aeration coefficient, k_a, to its minimum suggests that lack of aeration is a primary contributor to DO impairments. An error analysis was run on the literature ranges of values for k_a and k_d for each sample date to validate their use for the Streeter-Phelps analysis. This analysis is contained in Appendix F.

As discussed in Section 6.2.1.1, the WMM model was run as a screening tool to assess the BOD_5 loads that are typically generated annually for the watershed. The major inputs to the model are land use, precipitation, and event mean concentration (EMC). Land use for the watershed was presented in Table 5-9. The average monthly and annual precipitation for the Little Muddy Watershed was presented in Table 5-2. The EMCs used for each land use type are shown in Table 7-5.

Table 7-5 EMC by Land Use Type for Segment NE05 Watershed

Land Use	Area (acres)	Percent of Total	BOD EMC (mg/L)	Source
Row Crop	16,235	50%	8.0	2
Deciduous	4,102	13%	2.0	1
Rural Grassland	4,138	12%	2.0	1
Forested Wetland	2,846	10%	0.0	1
Small Grains	2,427	7%	8.0	2
Medium Density	971	2%	14.1	1
Shallow Water/Wetlands	359	2%	0.0	1
Urban Grassland	376	1%	2.0	1
Open Water	318	1%	0.0	1
Shallow Marsh/Wetlands	296	1%	0.0	1
Swamp	74	1%	0.0	1
High Density	166	0%	14.1	1
Deep Marsh	89	0%	0.0	1
Low Density	40	0%	14.1	1

1 Smullen (1999)
2 Denison and Tilton (1998)

Results of the WMM screening are shown in Table 7-6. The results are for the watershed contributing directly to segment NE05, not the entire upstream watershed. Results shown are an estimate of annual loads and loads from the precipitation events provided in Table 7-4. The loads estimated from WMM generated based on precipitation events near the sampling events are all greater than those shown in Table 7-4. The WMM model files are contained in Appendix G. This analysis indicates that loading from runoff events is not the sole source of DO impairments. Other factors that could contribute to low DO levels include stagnant flow conditions occurring during low flows, elevated stream temperatures during summer months, and nutrient loads from nonpoint sources in the watershed. The implementation plan in Section 9 will address other factors that could also cause decreased DO levels in the Little Muddy Watershed.

Table 7-6 Results of WMM Screening Analysis for the Segment NE05 Subwatershed

Event	Precipitation (inches)	Total BOD (lb/event)
Annual	44.7	311,948
7/17/95	0.78	5,443
7/19/00	1.10	7,677
8/22/00	0.72	5,025

The estimated BOD_5 loads in Table 7-4 are low in comparison to the WMM loads predicted suggesting that they represent loadings occurring during ambient conditions. Therefore, it is likely that further reductions in BOD concentrations could be achieved. The WMM results represent loadings from precipitation events shown in Table 7-4 that, in some cases, occurred before the sample date. For the July 17, 1995 sample, precipitation occurred 12 days prior to the sampling date, and it is likely that the loads from the event passed through the stream system before the sample was taken. The remaining two dates had precipitation occurring on and before the sample date and had slightly higher TOC measurements than the other impaired date. This also suggests that a portion of the BOD_5 loading may be from runoff events. Therefore, the TMDL described in Section 8 and the implementation plan outlined in Section 9 will focus on increases in reaeration needed to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period). The implementation plan in Section 9 will also address methods to reduce the BOD_5 loading to the stream and other factors that could also cause decreased DO levels in the Little Muddy River segment NE05 Watershed, such as elevated stream temperatures during summer months and nutrient loads from nonpoint sources in the watershed.

7.4.3 pH Analysis Development and Results

An analytical method was used to analyze pH in segment NE05 of the Little Muddy River. The method incorporates TDS concentrations, ionic strength, an activity coefficient, and flows to calculate a maximum hydrogen ion loading that will maintain a pH of 6.5 within segment NE05.

The ionic strength is calculated with the following equation:

$$\mu = (2.5 \times 10^{-5}) \times TDS$$

where: μ = ionic strength
TDS = 95th percentile concentration, mg/L or ppm

The 95th percentile concentration of TDS is used to provide a conservative estimate (Snoeyink and Jenkins 1980).

Activity coefficients are used to convert measured H^+ ion activity to molar H^+ ion concentration. The coefficient is dependent on ionic strength and is determined from literature (Snoeyink and Jenkins 1980). The maximum hydrogen ion loading for a particular flow and pH can then be calculated with the following equation:

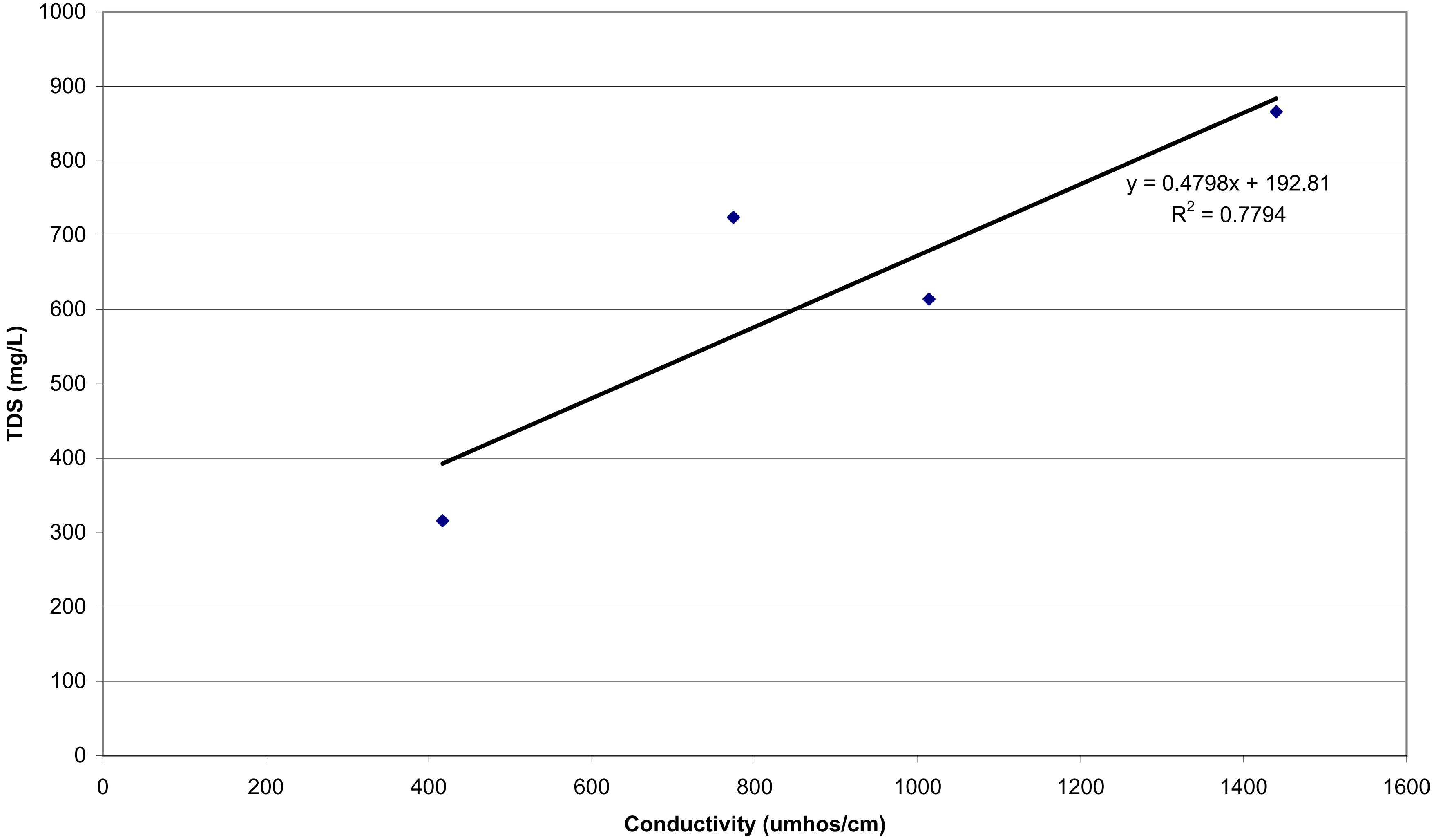
$$[\mathbf{H}^{+}] = \frac{\mathbf{10^{-pH} \times 1\,gram/mole \times 28.37L/ft^{3} \times Q \times 86400\ s/day}}{\gamma}$$

where: $[H^{+}]$ = ion load, lb/d
Q = flow, cfs
γ = activity coefficient

This equation can be used to develop the maximum allowable hydrogen ion concentration for a specific pH and varying flow regimes. Figure 7-3 shows the maximum allowable H^{+} ion loading at a pH of 6.5 for various flows. Using a pH of 6.5 and the three-year peak flow in the above equation will result in the maximum hydrogen ion concentration allowed to maintain a pH of at least 6.5. The three-year peak flow is utilized because the water quality standard requires a less than once in three-year allowable excursion (IPCB 1999a).

The 95th percentile of the TDS concentrations in segment NE05 is 913 mg/L resulting in an ionic strength of 0.02. An activity coefficient of 0.9 was determined from literature for segment NE05. The chart used to determine the activity coefficient is provided in Appendix H. As mentioned in Section 5.1.3, flows for segment NE05 were obtained from USGS gage 05597000. A lognormal distribution was used to develop the three-year peak flow through segment NE05 of 2,919 cfs. Using this flow in the above equation, a maximum allowable hydrogen ion concentration of 2,469 g/day or 5.4 lb/day was calculated. Analysis details are contained in Appendix I.

Figure 7-1: Relationship between Conductivity and TDS within Little Muddy River Segment NE05



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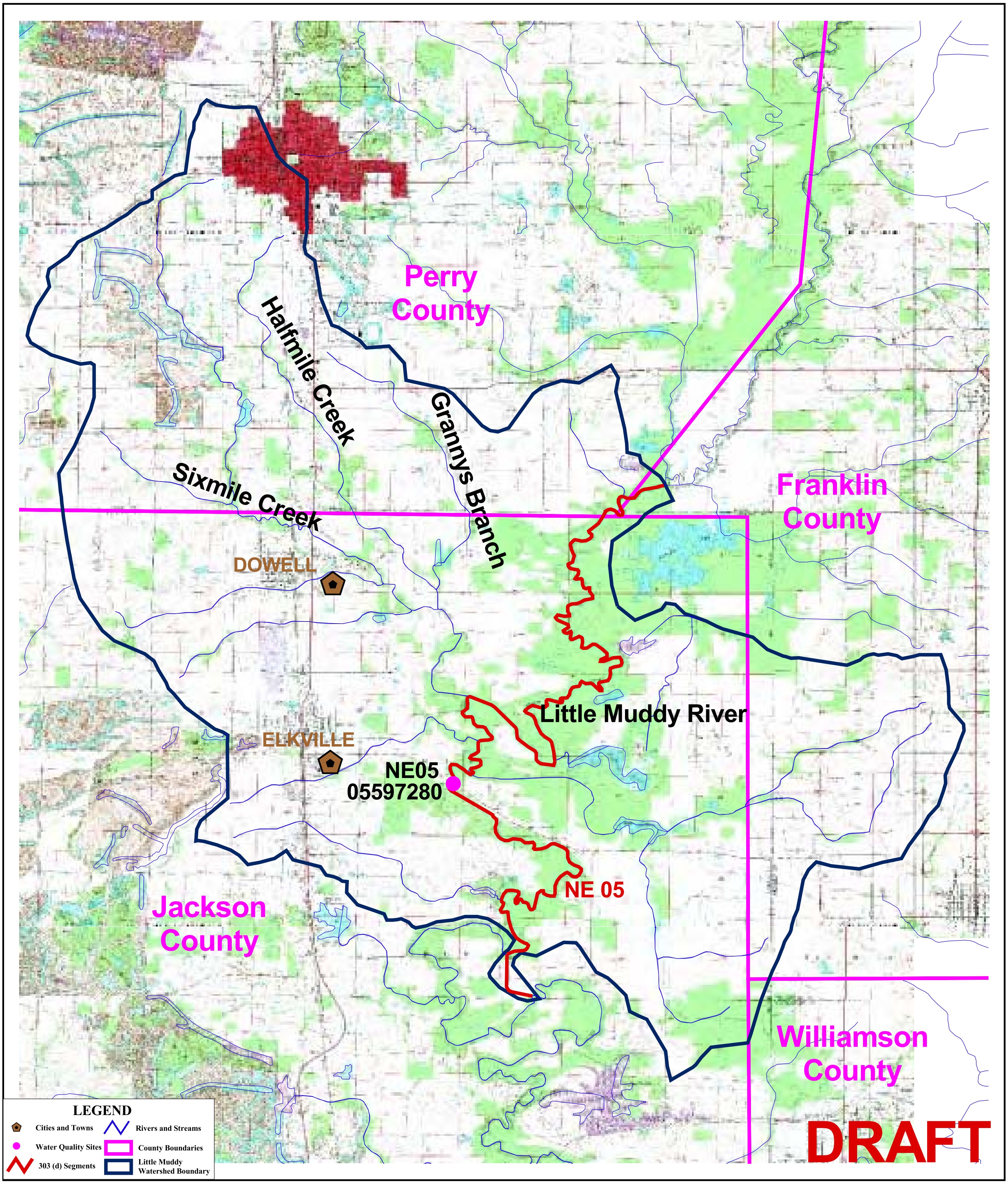

Figure 7-2
Little Muddy Watershed
and Historic Sampling Locations

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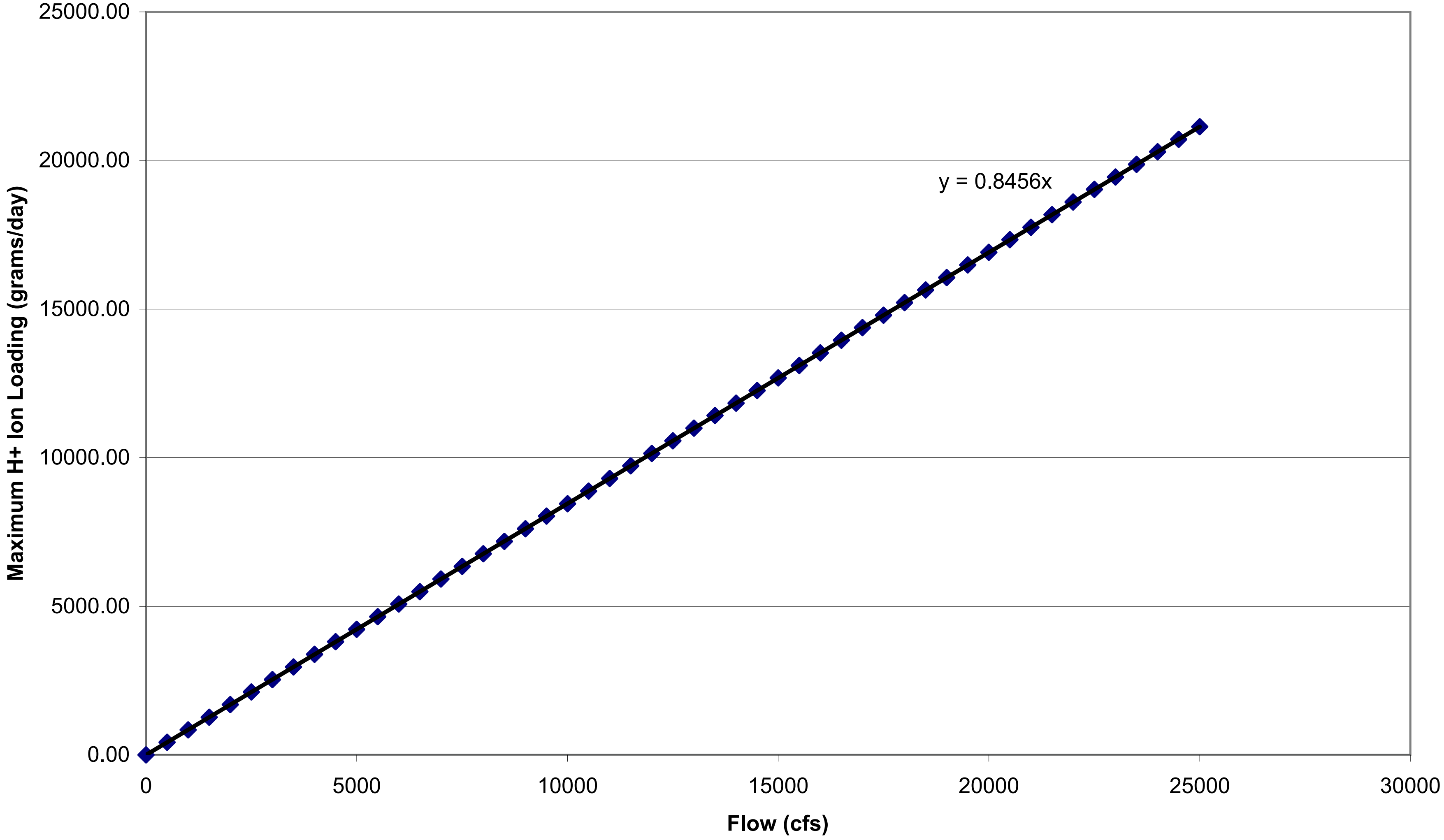
Figure 7-3: Flow versus Maximum H^+ Ion Loading at a Constant pH of 6.5



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Section 8
Total Maximum Daily Load for the Little Muddy River Watershed

8.1 TMDL Endpoints for the Little Muddy River

The TMDL endpoints for manganese, sulfates, TDS, conductivity, DO, and pH are summarized in Table 8-1. For manganese, sulfates, TDS, and conductivity, the concentration is below the TMDL endpoint. For DO, concentrations must be greater than 6.0 mg/L for 16 hours of any 24-hour period. For pH, the desired measurement is between the endpoint limits. These endpoints are based on protection of aquatic life in the Little Muddy River and its tributaries. Some of the average concentrations in Table 8-1, which are based on a limited data set, meet the desired endpoints. However, for those constituents, the data set has maximum or minimum values, presented in Sections 5.1.5.1.1 and 5.1.5.1.2, that do not meet the desired endpoints, and this was the basis for TMDL analysis. As mentioned in Sections 5.1.5.1.1 and 7.1, although the data do not show impairments for TDS, the impairment is based on conductivity, which does exceed the endpoint. Further monitoring, as outlined in the monitoring plan presented in Section 9, will help further define when impairments are occurring in the watershed and support the TMDL allocations outlined in the remainder of this section.

Table 8-1 TMDL Endpoints and Average Observed Concentrations for Impaired Constituents in the Little Muddy River Watershed

Constituent	TMDL Endpoint	Average Observed Value for NE05
Manganese	1.0 mg/L	0.9
Sulfates	500 mg/L	412
TDS	1,000 mg/L	630
Conductivity	1,667 µS/cm	911
DO	6.0 mg/L (16 hours of any 24-hour period)	6.8
pH	6.5 - 9 s.u.	7.3

8.2 Pollutant Source and Linkages

Pollutant sources for the Little Muddy River were identified through the existing data review described in Section 5. Based on the data review, the source of manganese, sulfates, and TDS in the impaired Little Muddy River segment NE05 is groundwater potentially contaminated by active and abandoned coal mines. The likely source of oxygen demanding constituents is primarily factors occurring during low flow conditions, such as slow-moving waters and increased water temperatures promoting algal growth. Nonpoint source loads in the watershed, such as urban or agricultural stormwater runoff, may also contribute to low DO in the stream. Sources of low pH include acid mine drainage and fluctuations due to algal growth in aquatic systems.

8.3 Allocation

As explained in Section 1, the TMDL for Little Muddy River segment NE05 will address the following equation:

$$\mathbf{TMDL = LC = \Sigma WLA + \Sigma LA + MOS}$$

where: LC = maximum amount of pollutant loading a water body can receive without violating water quality standards
WLA = the portion of the TMDL allocated to existing or future point sources
LA = portion of the TMDL allocated to existing or future nonpoint sources and natural background
MOS = an accounting of uncertainty about the relationship between pollutant loads and receiving water quality

Each of these elements will be discussed in this section as well as consideration of seasonal variation in the TMDL calculation.

8.3.1 Manganese, Sulfates, and TDS TMDL

8.3.1.1 Loading Capacity

The loading capacity for manganese, sulfates, and conductivity for impaired segment NE05 was based on the Monte Carlo analysis described in Section 7. The LTA, determined by analysis to meet water quality standards generated from the Monte Carlo analysis, is the basis for loading capacity for segment NE05. This LTA was multiplied by average flow in each segment to determine an average load. The LTA for conductivity was converted into a TDS concentration using the relationship in Figure 7-1. These average loads are shown in Table 8-2.

Table 8-2 Average Loads Based on LTA for Manganese, Sulfates, and TDS

Constituent	LTA Concentration (mg/L)	Allowable Load (lb/day)
Manganese	0.13	178
Sulfates	50	68,805
TDS	333	459,698

8.3.1.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Little Muddy River segment NE05 TMDL as conditions were investigated during all seasons of the year. Section 5.1.3 discusses the flow data available for segment NE05, and Section 5.1.5 and Appendix 1 contain the water quality data available for manganese, sulfates, and TDS. A review of the flow data and water quality data (Figures 5-4 through 5-6) show that the water quality data was gathered at various times during the year, thus capturing seasonal variations in loadings into the river. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., spring run-off loads), the loadings for this TMDL will focus on a LTA loading rather than specifying different loadings by season. As more data is gathered, further refinement of the seasonal variation may be possible.

8.3.1.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. An explicit MOS of 10 percent is recommended for manganese, sulfates, and TDS in the Little Muddy River segment NE05 Watershed because of the limited data set available for analysis and because Monte Carlo analysis incorporates uncertainty to some degree into the LTA.

Uncertainty in water quality is accounted for in the Monte Carlo analysis based upon how the analysis is done. The distribution of the water quality data is estimated and numerous iterations are run to determine the reduction needed to meet the target of one exceedence in three years. A data set with significant variation will result in a final target (LTA) that is significantly lower than the water quality standard, as compared to a data set with little variation that would likely result in a LTA being slightly lower than the water quality standard. By this process, uncertainty in the data is addressed. For these reasons, an explicit 10 percent MOS is considered appropriate based upon the data available. As more data become available, such as a regression analysis between flow and in-stream concentrations, the MOS could be revisited and revised if appropriate.

8.3.1.4 Waste Load Allocation

Mine effluent from one permitted mine (IL038512) is discharged into Little Muddy River segment NE05. However, the loads from the mine is negligible in comparison to loading in the river from nonpoint sources or background loads. Hence, no WLA is recommended at this time.

8.3.1.5 Load Allocation and Summary TMDLs

Table 8-3 shows a summary of the TMDL for manganese, sulfates, and TDS in the segment NE05 subwatershed. The calculated allowable loads (LC) necessary to maintain the water quality standard are reduced by the MOS, representing the uncertainty in the data analysis, to determine the allowable loading from the watershed, the LA. As mentioned previously, the average conductivity calculated from the Monte Carlo simulation was converted to a TDS concentration with the relationship in Figure 7-1. The LC was calculated from the LTA presented in Section 8.3.1.1.

Table 8-3 TMDL Summary for Manganese, Sulfates, and TDS

Constituent	LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Reduction Needed (lb/day)	Reduction Needed (percent)
Manganese	178	0	160	18	1,134	88%
Sulfates	68,805	0	61,924	6,880	505,446	89%
TDS	459,698	0	413,729	4,5970	456,701	52%

The required LTAs presented in Section 7 and in Table 8-2 were reduced because of the applied MOS and are presented in Table 8-4. The recalculated LTA represents the LA in Table 8-3. Methods to meet these LTAs will be outlined in Section 9.

Table 8-4 LTAs Adjusted by TMDL MOS

Constituent	Monte Carlo LTA (mg/L)	Recalculated LTA (mg/L)
Manganese	0.13	0.10
Sulfates	50	45
TDS	333	300

Based on the relationship provided in Figure 7-1, between TDS concentration and conductivity and LTA required for conductivity, exceedences of the TDS and conductivity water quality standards should be avoided. Therefore, the TMDL for the Little Muddy River will focus on TDS, as explained throughout the remainder of this section.

8.3.2 DO TMDL

8.3.2.1 Loading Capacity

As discussed in Section 7.4.2, the analysis suggests that the principle cause of DO impairments in segment NE05 is a lack of aeration. Table 8-5 shows the aeration coefficient calculated from the observed DO in Section 7.4.2 for sample dates that did not meet the TMDL endpoint, and the coefficient that would be required to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period) for sampling events that had DO measurements less than 6.0 mg/L. Increasing aeration in the stream is not a parameter for which a TMDL can be developed. Therefore, no TMDL will be developed at this time. Methods to achieve elevated reaeration coefficients will be outlined in Section 9.

Table 8-5 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Little Muddy River Segment NE05 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Modeled k_a (1/day)	Required k_a (1/day)
NE05	7/17/95	3.0	0.10	17.1
NE05	7/19/00	4.0	0.12	10.4
NE05	8/22/00	4.8	2.8	9.4

Based on the data analysis, increases of aeration would be required in summer months but not during winter conditions. Monitoring data to make the analysis more robust will be discussed in Section 9, as well as management measures to increase aeration and reduce nonpoint source loads contributing to non-attainment of the DO water quality standard.

To confirm that reductions in BOD_5 loads to meet the water quality standard are not an appropriate measure for controlling DO in this watershed, the Streeter-Phelps equations presented in Section 7.4.2 were used to estimate the BOD_5 loading required to meet the water quality standard on each sample date impaired for DO. Table 8-6 shows the BOD_5 loads estimated from TOC as discussed in Section 7.4.2 and the BOD_5 loading that would be necessary to meet water quality standards.

Table 8-6 Calculated BOD_5 Loads and Required Loads in the Little Muddy River Segment NE05 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Calculated BOD_5 (lb/d)	Required BOD_5 (lb/d)
NE05	7/17/95	3.0	8,088	0
NE05	7/19/00	4.0	12,160	0
NE05	8/22/00	4.8	7,126	0

8.3.3 pH TMDL

Figure 8-1 shows the existing maximum hydrogen ion concentration versus flow using hydrogen concentrations calculated from the pH sample data for segment NE05 and the equation presented in Section 7.4.3. From this figure, the maximum hydrogen ion load for the three-year peak flow of 2,919 cfs was determined as 5.4 lb/day. The allowable maximum hydrogen ion load calculated in Section 7.4.3 is 3.7 lb/day. The existing hydrogen ion concentration is below the allowable hydrogen ion concentration indicating that no allocations are necessary at this time to meet the TMDL endpoint for pH in Little Muddy River segment NE05. Because the relationship between hydrogen ion concentration and pH is an inverse log-arithmetic function, since the maximum load is greater than the allowable load, no allocations are needed to increase the pH within the watershed. Although no TMDL is recommended, the implementation strategies outlined in Section 9 will also help control pH in the Little Muddy River segment NE05 Watershed.

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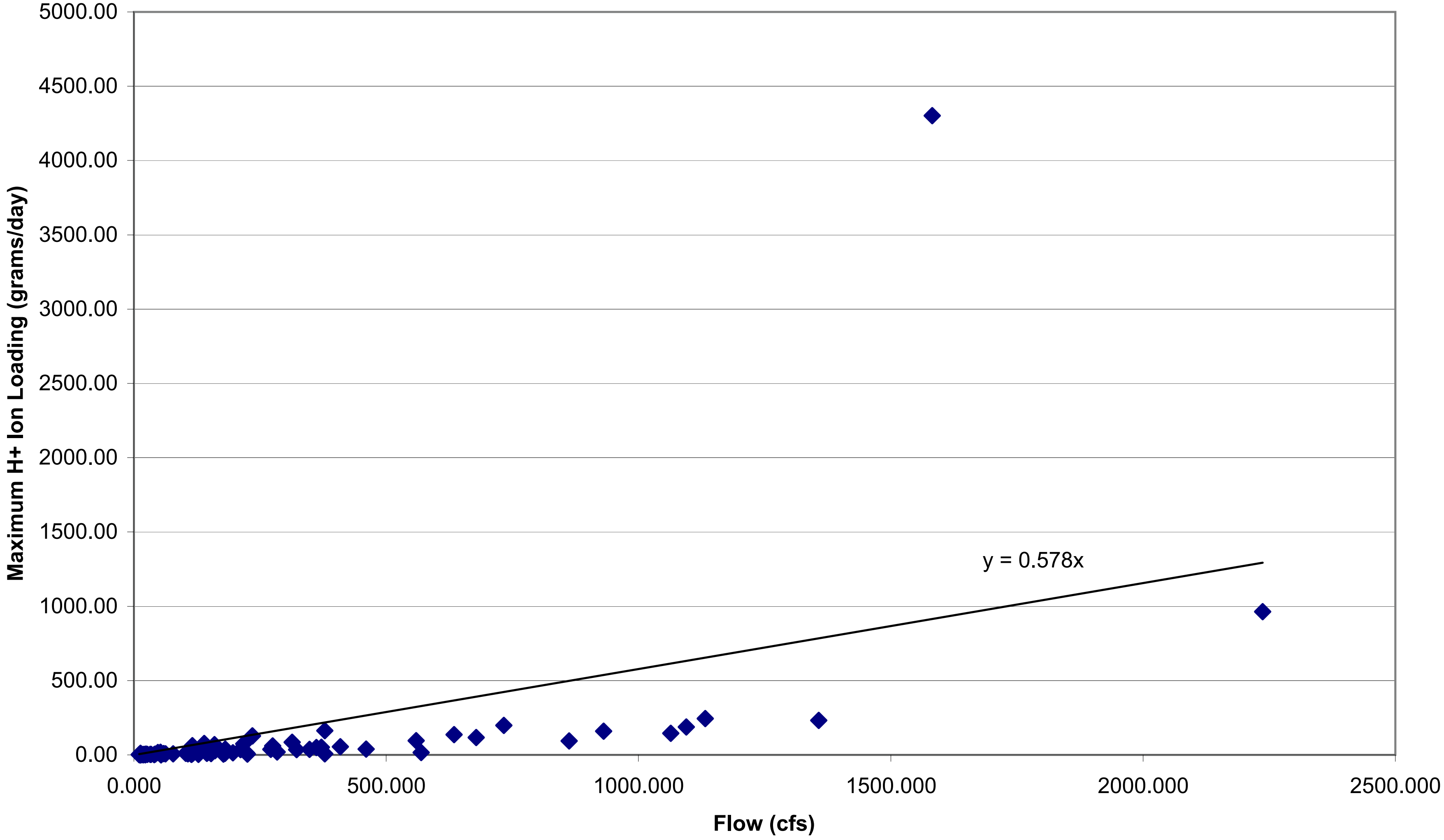
Figure 8-1: Flow versus Maximum H^+ Ion Loading for Little Muddy River Segment NE05



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Section 9
Implementation Plan for the Little Muddy River Watershed

9.1 Implementation Actions and Management Measures for Manganese, Sulfates, and TDS

An adaptive management or phased approach is recommended for the manganese, sulfates, and TDS TMDL for this watershed because of the limited amount of longitudinal data available for the TMDL analysis of segment NE05 in the Little Muddy River Watershed. Longitudinal data would be represented by multiple sampling locations in segment NE05. Adaptive management is a systematic process for continually improving management policies and practices through learning from the outcomes of operational programs. Some of the differentiating characteristics of adaptive management are:

- acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue;
- thoughtful selection of the policies or practices to be applied (the assessment and design stages of the cycle);
- careful implementation of a plan of action designed to reveal the critical knowledge that is currently lacking;
- monitoring of key response indicators;
- analysis of the management outcomes in consideration of the original objectives, and incorporation of the results into future decisions (British Columbia Ministry of Forests 2000).

Based on existing data review, presented in Section 5, the likely sources of manganese, sulfates, and TDS in the segment NE05 watershed are from groundwater potentially contaminated by active and abandoned mining activity. Further source identification is required as outlined in the next section. Acid mine drainage and excessive algal growth could cause pH impairments, but as explained in Section 8, no TMDL for pH is recommended at this time. BMPs recommended for manganese, sulfates, TDS, and DO should also help mitigate pH impairments.

9.1.1 Source Identification for Manganese, Sulfates, and TDS

It is recommended that further source identification activities take place within the watershed because the current data, regarding sources of manganese, sulfates, and TDS in the segment NE05 subwatershed, is limited. The GIS data and mapping provided in Section 5 (Figure 5-8) should be the basis for the start of the source investigation. Collection of data during various flow conditions may also be beneficial in determining the source of these constituents. For the segment NE05 watershed, the location of the potential discharge from the abandoned coal mines should be identified, in addition to other mining activity. Once potential sources are identified and located, sampling stations should be placed in appropriate locations to assess water quality downstream of these sources. The potential source identification and station sampling placement should be the result of field investigations. Data from the permitted coal mine within the segment NE05 subwatershed should be collected from the discharge effluent during various flow conditions to assess the impact of the mine drainage on receiving waters.

9.1.2 Manganese, Sulfates, and TDS Management Measures

For the active mine site, current NPDES permits were examined to confirm current effluent limitations are being met and if the effluent limits are appropriate. Mine effluent limitations are provided in Part 406 of the Illinois Administrative Code Section 406.202 states:

> In addition to the other requirements of this Part, no mine discharge or non-point source mine discharge shall, alone or in combination with other sources, cause a violation of any water quality standards of 35 Ill. Adm. Code 302 or 303. When the Agency finds that a discharge which would comply with effluent standards contained in this Part would cause or is causing a violation of water quality standards, the Agency shall take appropriate action under Section 31 or 39 of the Environmental Protection Act to require the discharge to meet whatever effluent limits are necessary to ensure compliance with the water quality standards. When such a violation is caused by the cumulative effect of more than one source, several sources may be joined in an enforcement or variance proceeding and measures for necessary effluent reductions will be determined on the basis of technical feasibility, economic reasonableness and fairness to all discharges (IPCB 1999b).

It is likely that the main contributors to impairments within the watershed are abandoned mine sites. If the major source of manganese, sulfates, and TDS in the segment NE05 subwatershed is attributed to abandoned mining, active chemical treatment methods, passive treatment methods, and mine reclamation are available. Active chemical treatment typically involves the addition of alkaline chemicals, such as calcium carbonate, sodium hydroxide, sodium bicarbonate, and anhydrous ammonia to acid mine drainage. These chemicals raise the pH to acceptable levels and decrease the solubility of dissolved metals. Metal precipitates form and settle out of the solution. Active chemical treatment is not a viable option for the Little Muddy River Watershed because the chemicals are expensive, and the treatment system requires additional costs associated with operation and maintenance, as well as the disposal of metal-laden sludge.

Reclamation of abandoned mines is another method of controlling pollutants. Reclamation of abandoned mine land involves clearing site vegetation, removing contaminated topsoil and coal, and restoring functionality of the site for recreational, agricultural, or wildlife habitat purposes. The environmental benefits realized from abandoned mine reclamation projects are numerous and significant, including restoring land for future use and improving water quality. Restoration of the land can result in increased and enhanced pasture land, recreational areas, or wildlife habitat (Pennsylvania Department of Environmental Protection [PDEP] 2002). However, reclamation projects tend to be costly and resource intensive and may not be appropriate for abandoned mine sites in Little Muddy River Watershed.

Passive methods could be utilized until full reclamation of a mine occurs. Chemical addition and energy consuming treatment processes are virtually eliminated with passive treatment systems. The operation and maintenance requirements of passive systems are considerably less than active treatment systems (PDEP 2002). Therefore, passive treatment systems would be the best solution for controlling manganese, sulfates, and TDS from abandoned coal mines in segment NE05 of the Little Muddy River Watershed.

Following are examples of the passive treatment technologies:

- Aerobic wetland
- Compost or anaerobic wetland
- Open limestone channels
- Diversion wells
- Anoxic limestone drains
- Vertical flow reactors
- Pyroclastic process

The remainder of this section discusses these technologies.

9.1.2.1 Aerobic Wetland

An aerobic wetland consists of a large surface area pond with horizontal surface flow. The pond may be planted with cattails and other wetland species. Aerobic wetlands can only effectively treat water that is net alkaline (pH greater than 7). In aerobic wetland systems, metals are precipitated through oxidation reactions to form oxides and hydroxides. A typical aerobic wetland will have a water depth of 6 to 18 inches (PDEP 2002).

9.1.2.2 Compost or Anaerobic Wetland

Compost wetlands, or anaerobic wetlands as they are sometimes called, consist of a large pond with a lower layer of organic substrate. The flow is horizontal within the substrate layer of the basin. Piling the compost a little higher than the free water surface can encourage the flow within the substrate. Typically, the compost layer consists of spent mushroom compost that contains about 10 percent calcium carbonate. Other compost materials include peat moss, wood chips, sawdust, or hay. A typical compost wetland will have 12 to 24 inches of organic substrate and be planted with cattails or other emergent vegetation (PDEP 2002).

9.1.2.3 Open Limestone Channels

Open limestone channels may be the simplest passive treatment method. Open limestone channels are constructed in two ways. In the first method, a drainage ditch constructed of limestone collects contaminated acid mine drainage water. The other method consists of placing limestone fragments directly in a contaminated stream. Dissolution of the limestone adds alkalinity to the water and raises the pH. This treatment requires large quantities of limestone for long-term success (PDEP 2002).

9.1.2.4 Diversion Wells

Diversion wells are another simple way to increase the alkalinity of contaminated waters. Acidic water is conveyed by a pipe to a downstream "well," which contains crushed limestone aggregate. The hydraulic force of the pipe flow causes the limestone to turbulently mix and abrade into fine particles preventing armoring (PDEP 2002).

9.1.2.5 Anoxic Limestone Drains

An anoxic limestone drain is a buried bed of limestone constructed to intercept subsurface mine water flow and prevent contact with atmospheric oxygen. Keeping oxygen out of the water prevents oxidation of metals and armoring of the limestone. An anoxic limestone drain can be considered a pretreatment step to increase alkalinity and raise pH before the water enters a constructed aerobic wetland (PDEP 2002).

9.1.2.6 Vertical Flow Reactors

Vertical flow reactors were conceived as a way to overcome the alkalinity producing limitations of anoxic limestone drains and the large area requirements of compost wetlands. The vertical flow reactor consists of a treatment cell with an underdrained limestone base topped with a layer of organic substrate and standing water. The water flows vertically through the compost and limestone and is collected and discharged through a system of pipes. The vertical flow reactor increases alkalinity by limestone dissolution and bacterial sulfate reduction (PDEP 2002).

9.1.2.7 Pyrolusite Process

This is a patented process, which utilizes site-specific cultured microbes to remove iron, manganese, and aluminum from acid mine drainage. The treatment process consists of a shallow bed of limestone aggregate inundated with acid mine drainage. After laboratory testing determines the proper combination, microorganisms are introduced to the limestone bed by inoculation ports located throughout the bed. The microorganisms grow on the surface of the limestone chips and oxidize the metal contaminants while etching away limestone, which in turn increases the alkalinity and raises the pH of water. This process has been used on several sites in western Pennsylvania with promising results (PDEP 2002).

9.2 Implementation Actions and Management Measures for Dissolved Oxygen

DO impairments are addressed by focusing on organic loads that consume oxygen through decomposition and nutrient loads that can cause algal growth, which can also deplete DO. Analysis provided in Section 7 established a relationship between BOD_5 and DO concentrations in Little Muddy River segment NE05, so management measures for the Little Muddy River Watershed will focus on increasing reaeration and decreasing BOD_5 loads to increase DO concentrations. Although it was shown that based on current data, BOD_5 loads do not need to be reduced, it is likely that during storm events, high BOD_5 loads are transported to the stream, and therefore reducing these loads will also help increase DO concentrations.

DO impairments in Little Muddy River segment NE05 are mostly attributed to low flow or stagnant conditions within the creek. Runoff from nonpoint sources may also contribute a BOD_5 load in segment NE05. An additional contributor to low DO is increased water temperatures. Therefore, management measures for segment NE05 will focus on reducing nonpoint source loading through sediment and surface runoff controls, reducing stream temperatures, and reducing stagnant conditions through reaeration.

Implementation actions, management measures, or BMPs are used to control the generation or distribution of pollutants. BMPs are either structural, such as wetlands, sediment basins, fencing, reaeration structures or filter strips; or managerial, such as conservation tillage, nutrient management plans, or crop rotation. Both types require good management to be effective in reducing pollutant loading to water resources (Osmond et al. 1995).

It is generally more effective to install a combination of BMPs or a BMP system. A BMP system is a combination of two or more individual BMPs that are used to control a pollutant from the same critical source. In other words, if the watershed has more than one identified pollutant, but the transport mechanism is the same, then a BMP system that establishes controls for the transport mechanism can be employed. (Osmond et al. 1995).

Implementation actions and management measures are described for each nonpoint source in the watershed. Nonpoint sources include cropland and rural grassland.

9.2.1 Nonpoint Source DO Concentration Management

The sources of nonpoint source pollution in the Little Muddy River TMDL are divided between agricultural cropland, rural grasslands, and animal management facilities. BMPs evaluated for treatment of these nonpoint sources are:

- filter strips
- wetlands

- nutrient management
- reaeration

Organic and nutrient loads originating from cropland is most efficiently treated with a combination of riparian buffer or grass filter strips and wetlands. Nutrient management focuses on source control of nonpoint source contributions to Little Muddy River. Instream management measures for DO focus on reaeration techniques. The Streeter-Phelps equations presented in Section 7 utilizes a reaeration coefficient. Increasing the reaeration coefficient by physical means will increase DO in Little Muddy River segment NE05.

9.2.1.1 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to Little Muddy River segment NE05. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff, help reduce stream water temperatures thereby increasing the water body DO saturation level, and provide bank stabilization decreasing erosion and deposition. The following paragraphs focus on the implementation of filter strips in Little Muddy River segment NE05 watershed. Finally, design criteria and size selection of filter strips are detailed.

Organic debris in topsoil contributes to the BOD_5 load to water bodies (USEPA 1997b). Increasing the length of stream bordered by grass and riparian buffer strips will decrease the amount of BOD_5 and nutrient load associated with sediment loads to Little Muddy River segment NE05. Nutrient criteria, currently being developed and expected to be adopted around 2007 by the Illinois EPA, will assess the instream nutrient concentrations required for the watershed. As stated previously, excess nutrients in streams can cause excessive algal growth, which can deplete DO in streams. Adoption of nutrient criteria will affect this DO TMDL and would be expected to also help control exceedences of DO water quality criteria in Little Muddy River segment NE05.

Filter strips will help control BOD_5 levels by removing organic loads associated with sediment from runoff; however, no studies were identified as providing an estimate of removal efficiency. Grass filter strips can remove as much as 75 percent of sediment and 45 percent of total phosphorus from runoff, so it is assumed that the removal of BOD_5 falls within this range (North Carolina State University [NCSU] 2000). Riparian buffer strips also help reduce water temperatures increasing the water body DO saturation level as explained in Section 7.

Riparian vegetation, specifically shade, plays a significant role in controlling stream temperature change. The shade provided will reduce solar radiation loading to the stream. Furthermore, riparian vegetation provides bank stability that reduces sediment loading to the stream and the stream width-to-depth ratio. Research in California (Ledwith 1996), Washington (Dong et al. 1998), and Maine (Hagan and Whitman 2000) show that riparian buffers effect microclimate factors such as air temperature and relative humidity proximal to the stream. Ledwith (1996) found that a 500-foot buffer had an air temperature decrease of 12°F at the stream over a zero-foot buffer. The greatest change occurred in the first 100 feet of the 500-foot buffer where the temperature decreased 2°F per 30 feet from the stream bank. A decrease in the air temperature proximal to the stream would result in a smaller convective flux to the stream during the day.

Filter strip widths for the Little Muddy River TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on slope estimates near tributaries within the watershed, filter strips widths of 72 to 234 feet could be incorporated in locations throughout the watershed. The total acreage examined was 460 acres.

Table 9-1 Filter Strip Flow Lengths Based on Land Slope

Percent Slope	**0.5%**	**1.0%**	**2.0%**	**3.0%**	**4.0%**	**5.0% or greater**
Minimum	36	54	72	90	108	117
Maximum	72	108	144	180	216	234

The acreages provided above are used to calculate an approximation of BMP cost in Section 9.3 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips according to the NRCS guidance presented in Table 9-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.3.

9.2.1.2 Wetlands

Wetlands can be used as a structural control to treat loads from animal management operations located in the Little Muddy River Watershed. One of the four animal management facilities in the segment NE05 watershed has been designated as potentially having no impact on receiving waters; the second has been designated as potentially having a slight impact on receiving waters, and the remaining two have not been assessed. Wetlands are an effective BMP for sediment, nutrient, and organic load control because they function to:

- prevent floods by temporarily storing water, allowing the water to evaporate or percolate into the ground;
- improve water quality through natural pollution control such as plant nutrient uptake;
- filter sediment;
- slow overland flow of water thereby reducing soil erosion (USDA 1996).

While constructed wetlands have been demonstrated to effectively reduce nitrogen and sediment, literature shows mixed results for phosphorus removal. Studies have shown that artificial wetlands designed and constructed specifically to remove pollutants from surface water runoff have removal rates for suspended solids of greater than 90 percent, for total phosphorus of 0 to 90 percent, and for nitrogen species from 10 to 75 percent (Johnson, Evans, and Bass 1996; Moore 1993; USEPA 1993; Kovosic et al. 2000). In some cases, wetlands can be sources of phosphorus. Over the long term, it is generally thought that wetlands are neither sources nor sinks of phosphorus (Kovosic et al. 2000).

Efficiency of pollutant removal in wetlands can be addressed in the design and maintenance of the constructed wetland. Location, hydraulic retention time and space requirements should be considered in design. To maintain removal efficiency, sheet flow should be maintained and substrate should be monitored to assess whether the wetland is operating optimally. Sediment or vegetation removal may be necessary if the wetland removal efficiency is lessened over a period of time (USEPA 1993; NCSU 1994).

It is recommended that further investigation take place within the watershed to determine the impact of animal management facilities on Little Muddy River segment NE05. Due to the lack of data on the impacts of nonpoint source runoff from these facilities, wetlands were not analyzed as a treatment for this TMDL. However, it is recommended that animal control facility managers consider wetlands to treat nonpoint source runoff from control facilities.

9.2.1.3 Nutrient Management

Nutrient management could result in reduced nutrient loads to segment NE05. Crop management of nitrogen and phosphorus can be accomplished through Nutrient Management Plans, which focus on increasing the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and groundwater. In the past, nutrient management focused on application rates designed to meet crop nitrogen requirements but avoid groundwater quality problems created by excess nitrogen leaching. This results in buildup of soil phosphorus above amounts sufficient for optimal crop yields. Illinois, along with most Midwestern states, demonstrates high soil test phosphorus in greater than 50 percent of soil samples analyzed (Sharpley et al. 1999).

The overall goal of nutrient reduction from agriculture should increase the efficiency of phosphorus use by balancing phosphorus inputs in feed and fertilizer with intakes of crops and animal produce as well as managing the level of phosphorus in the soil. Reducing nutrient loss in agricultural runoff may be brought about by source and transport control measures, such as filter strips or grassed waterways. The Nutrient Management Plans account for all inputs and outputs of phosphorus to determine reductions. Elements of a Nutrient Management Plan include:

- plan summary,
- manure summary, including annual manure generation, use, and export,
- nutrient application rates by field and crop,

- summary of excess manure utilization procedures
- implementation schedule
- manure management and stormwater BMPs

In Illinois, Nutrient Management Plans have successfully reduced phosphorus application to agricultural lands by 36-lb/acre. National reductions range from 11- to 106-lb/acre, with an average of 35-lb/acre (NCSU 2000).

9.2.1.4 Reaeration

The purpose of reaeration is to increase DO concentrations in streams. Physical measures that will assist in increasing reaeration of a stream include bank stabilization, channel modifications, and the addition of riprap or pool and riffle sequences. Bank stabilization reduces erosion by planting vegetation along the bank or modification of the channel to decrease the slope of the bank. Riprap or pool and riffle sequences would increase reaeration by increasing turbulence. Turbulence creates an increase in the interaction between air and water, which draws air into the river increasing aeration. Expanding monitoring to several locations along the impaired segments could help identify reaches that would benefit the most from an increase of turbulence.

9.2.2 Implementation Actions and Management Measures Summary

Mitigations to DO impairments in the Little Muddy River segment NE05 Watershed should focus on reducing stream temperatures and nonpoint source loads. Evaluation of land near streams and lakes and creation of grass or hardwood filter strips, according to the NRCS guidance presented in Table 9-1 will help reduce stream temperatures and may potentially reduce the organic loads thereby reducing the BOD_5 loading. Adaptive management principles will be utilized to assess further management measures in the future.

9.3 Reasonable Assurance

Reasonable assurance means that a demonstration is given that the pollutant reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Sections 9.1 and 9.2 provided a means for obtaining the reductions necessary. The remainder of this section discusses the programs available to assist with funding and an estimate of costs to the watershed for implementing these practices.

9.3.1 Available Programs for Manganese, Sulfates, and TDS TMDL

The state agency primarily responsible for reclamation of pre-law coal mine areas is the IDNR, Office of Mines and Minerals, Abandoned Mined Lands Reclamation Division (AMLRD). The AMLRD contracts or oversees reclamation of pre-law mine sites utilizing funds from a "reclamation fee" (tax) on every ton of coal mined in Illinois, since the implementation of the Surface Mining Control and Reclamation Act of 1977. The fee monies are sent to the U.S. Department of Interior and are then partially reallocated back to the states for several purposes, which include the reclamation of pre-law abandoned mined lands. This reclamation fee funds almost all of the reclamation of pre-law mine sites in Illinois. The AMLRD also has the responsibility to reclaim permitted mine sites where the operator has deserted the site and all of the bond money has been forfeited. This adds to the overall number of projects that the AMLRD has to complete (Muir et al. 1997).

Abandoned mine sites are reclaimed through the ALMRD according to a priority list as monies become available. Because the federally designated first priority for ALMRD projects is safety, most of the early reclamation projects were not environmentally oriented. Even so, the AMLRD has completed a large number of environmentally oriented reclamation projects (Muir et al. 1997). Due to the uncertainty of sources of manganese and sulfates in the Little Muddy River Segment NE05 Watershed, no cost estimates were developed for mitigation of the potential sources provided in this report. If the abandoned mines in the segment NE05 watershed are shown to contribute to impairment of segments within the watershed, funds from the ALMRD focused on environmental projects should be directed towards water bodies with TMDLs.

9.3.2 Available Programs for DO TMDL

Approximately 58 percent of the Little Muddy River segment NE05 watershed is classified as rural grassland (pasture land, CRP, waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill that encourage landowners to implement resource-conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following sections.

9.3.2.1 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project

The Illinois Department of Agriculture (IDA) and Illinois EPA are presently co-sponsoring a cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 18,241 acres of cropland have been targeted in the Little Muddy segment NE05 subwatershed. This voluntary project will supply incentive payments to producers to have Nutrient Management Plans developed and implemented. Additionally, if sediments or phosphorus has been identified as a cause for impairment in the watershed, then traditional erosion control practices will be eligible for cost-share assistance through the Nutrient Management Plan project as well.

9.3.2.2 Clean Water Act Section 319 Grants

Section 319 was added to the CWA to establish a national program to address nonpoint sources of water pollution. Through this program, each state is allocated section 319 funds on an annual basis according to a national allocation formula based on the total annual appropriation for the section 319 grant program. The total award consists of two categories of funding; incremental funds and base funds. A state is eligible to receive EPA 319(h) grants upon USEPA's approval of the state's Nonpoint Source Assessment Report and Nonpoint Source Management Program. States may reallocate funds through subawards (e.g., contracts, subgrants) to both public and private entities, including local governments, tribal authorities, cities, counties, regional development centers, local school systems, colleges and universities, local nonprofit organizations, state agencies, federal agencies, watershed groups, for-profit groups, and individuals. Subawards to individuals are limited to demonstration projects (USEPA 2003, 2002).

USEPA designates incremental funds, a $100-million award, for the restoration of impaired water through the development and implementation of watershed-based plans and TMDLs for impaired waters. Base funds, funds other than incremental funds, are used to provide staffing and support to manage and implement the state Nonpoint Source Management Program. Section 319 funding can be used to implement activities which improve water quality, such as filter strips, streambank stabilization, etc (USEPA 2003, 2002).

9.3.2.3 Streambank Stabilization and Restoration Practice

The Streambank Stabilization and Restoration Practice (SSRP) was established to address problems associated with streambank erosion; such as loss or damage to valuable farmland, wildlife habitat, roads; stream capacity reduction through sediment deposition; and degraded water quality, fish, and wildlife habitat. The primary goals of the SSRP are to develop and demonstrate vegetative, stone structure and other low-cost bio-engineering techniques for stabilizing streambanks and to encourage the adoption of low-cost streambank stabilization practices by making available financial incentives, technical assistance, and educational information to landowners with critically eroding streambanks. A cost share of 75 percent is available for approved project components; such as willow post installation, bendway weirs, rock riffles, stream barbs/rock, vanes, lunker structures, gabion baskets, and stone toe protection techniques. There is no limit on the total program payment for cost-share projects that a landowner can receive in a fiscal year. However, maximum cost per foot of bank treated is used to cap the payment assistance on a per foot basis and maintain the program's objectives of funding low-cost techniques (IDA 2000).

9.3.2.4 Conservation Reserve Program (CRP)

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. CRP is the USDA's single largest environmental improvement program and one of its most productive and cost efficient. It is administered through the FSA by USDA's Commodity Credit Corporation (CCC). The program was initially established in the Food & Security Act of 1985. The duration of the contracts under CRP range from 10 to 15 years.

Eligible land must be one of the following:

1. cropland that is planted or considered planted to an agricultural commodity two of the five most recent crop years (including field margins); Must be physically and legally capable of being planted in a normal manner to an agricultural commodity.

2. certain marginal pastureland enrolled in the Water Bank Program.

The CCC bases rental rates on the relative productivity of soils within each county and the average of the past three years of local dryland cash rent or cash-rent equivalent. The maximum rental rate is calculated in advance of enrollment. Producers may offer land at the maximum rate or at a lower rental rate to increase likelihood of offer acceptance. In addition, the CCC provides cost-share assistance for up to 50 percent of the participant's costs in establishing approved conservation practices. CCC also encourages restoration of wetlands by offering a one-time incentive payment equal to 25 percent of the costs incurred. This incentive is in addition to the 50 percent cost share provided to establish cover (USDA 1999).

Finally, CCC offers additional financial incentives of up to 20 percent of the annual payment for certain continuous sign-up practices. Continuous sign-up provides management flexibility to farmers and ranchers to implement certain high-priority conservation practices on eligible land. The land must be determined by NRCS to be eligible and suitable for any of the following practices:

- riparian buffers,
- filter strips,
- grass waterways,
- shelter belts,
- field windbreaks,
- living snow fences,
- contour grass strips,
- salt tolerant vegetation,
- shallow water areas for wildlife,
- eligible acreage within an USEPA-designated wellhead protection area (FSA 1997).

9.3.2.5 Wetlands Reserve Program (WRP)

The Wetlands Reserve Program (WRP) is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (2002a).

The 2002 Farm Bill reauthorized the program through 2007, increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. The program offers three enrollment options: permanent easements, 30-year conservation easements, and 10-year restoration cost-share agreements. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs, and the average project size is 177 acres. The costs for each enrollment option follow in Table 9-2 (USDA 1996).

Table 9-2 Costs for Enrollment Options of WRP Program

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value	75% Agricultural Value	NA
Payment Options	Lump Sum	Lump Sum if less than $50,000	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

9.3.2.6 Environmental Quality Incentive Program (EQIP)

The Environmental Quality Incentive Program (EQIP) is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watershed, regions, or areas of special environmental sensitivity that have significant soil, water, or natural resource related concerns. The program goal is to maximize environmental benefits per dollar expended and provides "(1) flexible technical and financial assistance to farmers and ranchers that face the most serious natural resource problems; (2) assistance to farmers and ranchers in complying with federal, state, and tribal environmental laws, and encourage environmental enhancement; (3) assistance to farmers and ranchers in making beneficial, cost-effective changes to measures needed to conserve and improve natural resources; and (4) for the consolidation and simplification of the conservation planning process." As of 2001, 379,000 acres have been protected in Illinois using EQIP (NRCS 2002c,d).

Landowners, with the assistance of a local NRCS or other service provider, are responsible for development of a site-specific conservation plan that addresses the primary natural resource concerns of the priority area. Conservation practices include but are not limited to erosion control, filter strips, buffers, and grassed waterways. If the plan is approved by NRCS, a five- to 10-year contract that provides cost-share and incentive payments is developed.

Cost-share assistance may pay landowners up to 75 percent of the costs of conservation practices, such as grassed waterways, filter strips, manure management, capping abandoned wells, and other practices important to improving and maintaining the health of natural resources in the area. Total incentive and cost-share payments are limited to $10,000 per person per year and $50,000 over the life of the contract.

9.3.2.7 Conservation Practices Program (CPP)

The Conservation Practices Program (CPP) is a 10-year program. The practices consist of waterways, water and sediment control basins (WASCOBs), pasture/hayland establishment, critical area, terrace system, no-till system, diversions, and grade stabilization structures. The CPP is state-funded through the Department of Agriculture. There is a project cap of $5,000 per landowner and costs per acre vary significantly from project to project.

9.3.2.8 Wildlife Habitat Incentives Program (WHIP)

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan that becomes the basis of the cost-share agreement between NRCS and the participant. Most contracts are five to 10 years in duration, depending upon the practices to be installed. However, longer term contracts of 15 years or greater may also be funded. Under the agreement:

- The landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.
- NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002b).

The Farm Service Agency (FSA) administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Jackson County are listed in Table 9-3 below.

Table 9-3 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
W. Scott Martin	1213 N. 14th Street Murphysboro, Illinois 62966	618-684-3064 x 3
Local FSA Office		
Murphysboro Service Center	1213 N. 14th Street Murphysboro, Illinois 62966	618-684-3471 x 3

9.3.3 Cost Estimates for BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 9-4 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Little Muddy River segment NE05 Watershed are presented in Section 9.3.3.5 and Table 9-5.

9.3.3.1 Streambank Stabilization

Cost information of streambank stabilization was taken from Johnson County NRCS. Johnson County NRCS estimates an average cost per foot to implement streambank stabilization measures at $40.00/foot. This price includes grading and shaping of the bank and critical area and dormant stub planting.

9.3.3.2 Filter Strips and Riparian Buffers

The Jackson County NRCS estimates an average cost per acre to install a grass filter strip with a 15-year life span at $90/acre. A riparian buffer strip established with bare root stock has a life span of 15 years and an installation cost of $384/acre. Based on this preliminary estimate, it appears that grass filter strips would be a more cost-effective way to control BOD and nutrient loads in the watershed.

9.3.3.3 Nutrient Management Plan − NRCS

Generally, agricultural land in Jackson County is comprised of cropland and rural grassland. The Jackson County Extension Service estimates the average plan to cost $10/acre.

9.3.3.4 Nutrient Management Plan − IDA and Illinois EPA

The costs associated with development of Nutrient Management Plans co-sponsored by the IDA and the Illinois EPA is estimated as $5/acre paid to the producer and $2/acre for a third party vendor who develops the plans. The total plan development cost is estimated at $7/acre.

9.3.3.5 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 9-4. The column labeled *Program* lists the financial assistance program available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 9-4 Cost Estimate of Various BMP Measures in the Segment NE05 Watershed

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	CRP	Grass Filter Strips	15	$90.00	$9.00
	CRP	Riparian Buffer	10	$384.00	$38.40
	319 or SSRP	Streambank Stabilization*	10	$280.00	$4.00
	NRCS	Nutrient Management Plan		$10.00	
	IDA and Illinois EPA	Nutrient Management Plan		$7.00	

* Streambank Stabilization cost calculated on linear foot basis.

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $249,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 9-5 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 9-5 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle.

Table 9-5 Cost Estimate of Implementation Measures for Segment NE05 Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	**Watershed $**	**$/ac/yr**	**Watershed $/yr**
Grass Filter Strips	460	$90.00	$41400.00	$9.00	$4140.000
Nutrient Management Plan	18,241	$7.00	$128,000.00		
Streambank Stabilization*	81,840	$40.00	$3,273,600.00	$4.00	$327,360.00
Total			**$3,443,000**		**$331,500**

* Streambank Stabilization cost calculated on linear foot basis.

9.6 Monitoring Plan

The purpose of the monitoring plan for the Little Muddy River segment NE05 subwatershed is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

- track implementation of management measures in the watershed,
- estimate effectiveness of management measures,
- continued ambient monitoring,
- monitoring of permitted mine discharge.

Tracking the implementation of management measures can be used to address the following goals (NCSU 2000):

- determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints;
- establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts;
- measure the extent of voluntary implementation efforts;
- support workload and cost analysis for assistance or regulatory programs;
- determine the extent to which management measures are properly maintained and operated.

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems, such as a constructed wetland. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency.

Illinois EPA monitors segment NE05 yearly through the Ambient Water Quality Network, and every five years through the Intensive Basin Survey program. Continuation of this monitoring will assess instream water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the watershed are being attained. To further support DO modeling and to plan for future nutrient criteria in the watershed, the following parameters should be added to the monitoring list:

- BOD_5,
- BOD_{20},
- Chlorophyll 'a' or algae monitoring.

Monitoring to assess groundwater concentrations of manganese should be conducted to determine source locations of subsurface abandoned mine activity. Location of groundwater contamination would help prioritize areas that will require remediation, so that water quality standards can be achieved in the future.

Monitoring discharge from the permitted mine in the segment NE05 subwatershed will help further assess the sources of contaminants in the watershed. Permit limits should be reviewed based on source identification and mine discharge concentrations. Permit discharges may need to be decreased to maintain water quality standards. Decreases in discharges may result only after further review and study.

9.7 Implementation Time Line

Implementing the actions outlined in this section for the Little Muddy River segment NE05 subwatershed should occur in phases, and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to one to two years for further source identification in the watershed. It is also assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. The length of time required to meet water quality standards will be based on the types of BMPs implemented in the watershed. In summary, meeting water quality standards in the Little Muddy River segment NE05 subwatershed may take 15 to 20 years to complete.

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Section 10
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Appendix A
Historic Water Quality Data

Primary Station ID	Start Date	Parameter Long Name	Result Value
5597280	1/10/1990	MANGANESE, TOTAL (UG/L AS MN)	641
5597280	2/13/1990	MANGANESE, TOTAL (UG/L AS MN)	409
5597280	3/26/1990	MANGANESE, TOTAL (UG/L AS MN)	1061
5597280	5/9/1990	MANGANESE, TOTAL (UG/L AS MN)	540
5597280	6/11/1990	MANGANESE, TOTAL (UG/L AS MN)	949
5597280	7/18/1990	MANGANESE, TOTAL (UG/L AS MN)	1808
5597280	8/27/1990	MANGANESE, TOTAL (UG/L AS MN)	2398
5597280	10/10/1990	MANGANESE, TOTAL (UG/L AS MN)	632
5597280	11/14/1990	MANGANESE, TOTAL (UG/L AS MN)	1601
5597280	1/23/1991	MANGANESE, TOTAL (UG/L AS MN)	110
5597280	2/13/1991	MANGANESE, TOTAL (UG/L AS MN)	545
5597280	3/20/1991	MANGANESE, TOTAL (UG/L AS MN)	103
5597280	4/24/1991	MANGANESE, TOTAL (UG/L AS MN)	788
5597280	5/30/1991	MANGANESE, TOTAL (UG/L AS MN)	1700
5597280	7/16/1991	MANGANESE, TOTAL (UG/L AS MN)	1474
5597280	9/5/1991	MANGANESE, TOTAL (UG/L AS MN)	3220
5597280	10/8/1991	MANGANESE, TOTAL (UG/L AS MN)	725
5597280	12/4/1991	MANGANESE, TOTAL (UG/L AS MN)	310
5597280	1/9/1992	MANGANESE, TOTAL (UG/L AS MN)	240
5597280	3/11/1992	MANGANESE, TOTAL (UG/L AS MN)	1400
5597280	5/20/1992	MANGANESE, TOTAL (UG/L AS MN)	1600
5597280	6/18/1992	MANGANESE, TOTAL (UG/L AS MN)	1400
5597280	8/6/1992	MANGANESE, TOTAL (UG/L AS MN)	1700
5597280	9/8/1992	MANGANESE, TOTAL (UG/L AS MN)	1200
5597280	4/1/1993	MANGANESE, TOTAL (UG/L AS MN)	520
5597280	10/27/1993	MANGANESE, TOTAL (UG/L AS MN)	1200
5597280	1/19/1994	MANGANESE, TOTAL (UG/L AS MN)	680
5597280	3/1/1994	MANGANESE, TOTAL (UG/L AS MN)	500
5597280	4/5/1994	MANGANESE, TOTAL (UG/L AS MN)	1100
5597280	5/10/1994	MANGANESE, TOTAL (UG/L AS MN)	1000
5597280	6/1/1994	MANGANESE, TOTAL (UG/L AS MN)	1400
5597280	7/14/1994	MANGANESE, TOTAL (UG/L AS MN)	890
5597280	9/19/1994	MANGANESE, TOTAL (UG/L AS MN)	2100
5597280	11/1/1994	MANGANESE, TOTAL (UG/L AS MN)	1900
5597280	12/15/1994	MANGANESE, TOTAL (UG/L AS MN)	270
5597280	2/1/1995	MANGANESE, TOTAL (UG/L AS MN)	200
5597280	3/9/1995	MANGANESE, TOTAL (UG/L AS MN)	180
5597280	4/19/1995	MANGANESE, TOTAL (UG/L AS MN)	2300
5597280	5/9/1995	MANGANESE, TOTAL (UG/L AS MN)	734
5597280	6/14/1995	MANGANESE, TOTAL (UG/L AS MN)	1200
5597280	7/17/1995	MANGANESE, TOTAL (UG/L AS MN)	1100
5597280	9/28/1995	MANGANESE, TOTAL (UG/L AS MN)	1200
5597280	11/6/1995	MANGANESE, TOTAL (UG/L AS MN)	4200
5597280	12/20/1995	MANGANESE, TOTAL (UG/L AS MN)	530
5597280	2/1/1996	MANGANESE, TOTAL (UG/L AS MN)	250
5597280	3/5/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5597280	4/10/1996	MANGANESE, TOTAL (UG/L AS MN)	640
5597280	5/7/1996	MANGANESE, TOTAL (UG/L AS MN)	310
5597280	6/19/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5597280	7/24/1996	MANGANESE, TOTAL (UG/L AS MN)	1400
5597280	3/5/1997	MANGANESE, TOTAL (UG/L AS MN)	120

5597280	4/2/1997	MANGANESE, TOTAL (UG/L AS MN)	670
NE05	10/22/1997	MANGANESE, TOTAL (UG/L AS MN)	780
NE05	12/3/1997	MANGANESE, TOTAL (UG/L AS MN)	630
NE05	2/2/1998	MANGANESE, TOTAL (UG/L AS MN)	390
NE05	3/4/1998	MANGANESE, TOTAL (UG/L AS MN)	220
NE05	4/22/1998	MANGANESE, TOTAL (UG/L AS MN)	380
NE05	5/21/1998	MANGANESE, TOTAL (UG/L AS MN)	1200
NE05	6/18/1998	MANGANESE, TOTAL (UG/L AS MN)	330
NE05	8/12/1998	MANGANESE, TOTAL (UG/L AS MN)	810
NE05	9/8/1998	MANGANESE, TOTAL (UG/L AS MN)	2000
NE05	10/15/1998	MANGANESE, TOTAL (UG/L AS MN)	730
NE05	12/3/1998	MANGANESE, TOTAL (UG/L AS MN)	730
NE05	1/5/1999	MANGANESE, TOTAL (UG/L AS MN)	400
NE05	2/9/1999	MANGANESE, TOTAL (UG/L AS MN)	130
NE05	4/8/1999	MANGANESE, TOTAL (UG/L AS MN)	120
NE05	5/19/1999	MANGANESE, TOTAL (UG/L AS MN)	600
NE05	7/7/1999	MANGANESE, TOTAL (UG/L AS MN)	780
NE05	8/16/1999	MANGANESE, TOTAL (UG/L AS MN)	1500
NE05	9/30/1999	MANGANESE, TOTAL (UG/L AS MN)	1400
NE05	10/26/1999	MANGANESE, TOTAL (UG/L AS MN)	530
NE05	12/7/1999	MANGANESE, TOTAL (UG/L AS MN)	710
NE05	1/27/2000	MANGANESE, TOTAL (UG/L AS MN)	250
NE05	2/24/2000	MANGANESE, TOTAL (UG/L AS MN)	630
NE05	4/5/2000	MANGANESE, TOTAL (UG/L AS MN)	1100
NE05	5/25/2000	MANGANESE, TOTAL (UG/L AS MN)	690
NE05	6/20/2000	MANGANESE, TOTAL (UG/L AS MN)	38
NE05	7/19/2000	MANGANESE, TOTAL (UG/L AS MN)	840
NE05	7/19/2000	MANGANESE, TOTAL (UG/L AS MN)	840
NE05	8/22/2000	MANGANESE, TOTAL (UG/L AS MN)	1000

Primary Station ID	Start Date	Parameter Long Name	Result Value
5597280	1/10/1990	SULFATE, TOTAL (MG/L AS SO4)	219
5597280	2/13/1990	SULFATE, TOTAL (MG/L AS SO4)	125
5597280	3/26/1990	SULFATE, TOTAL (MG/L AS SO4)	445
5597280	5/9/1990	SULFATE, TOTAL (MG/L AS SO4)	118
5597280	6/11/1990	SULFATE, TOTAL (MG/L AS SO4)	103
5597280	7/18/1990	SULFATE, TOTAL (MG/L AS SO4)	507
5597280	8/27/1990	SULFATE, TOTAL (MG/L AS SO4)	609
5597280	10/10/1990	SULFATE, TOTAL (MG/L AS SO4)	143
5597280	11/14/1990	SULFATE, TOTAL (MG/L AS SO4)	302
5597280	1/23/1991	SULFATE, TOTAL (MG/L AS SO4)	98
5597280	2/13/1991	SULFATE, TOTAL (MG/L AS SO4)	179
5597280	3/20/1991	SULFATE, TOTAL (MG/L AS SO4)	92
5597280	4/24/1991	SULFATE, TOTAL (MG/L AS SO4)	200
5597280	5/30/1991	SULFATE, TOTAL (MG/L AS SO4)	419
5597280	7/16/1991	SULFATE, TOTAL (MG/L AS SO4)	400
5597280	10/8/1991	SULFATE, TOTAL (MG/L AS SO4)	570
5597280	12/4/1991	SULFATE, TOTAL (MG/L AS SO4)	71
5597280	1/9/1992	SULFATE, TOTAL (MG/L AS SO4)	113
5597280	3/11/1992	SULFATE, TOTAL (MG/L AS SO4)	358
5597280	4/16/1992	SULFATE, TOTAL (MG/L AS SO4)	323
5597280	5/20/1992	SULFATE, TOTAL (MG/L AS SO4)	568
5597280	6/18/1992	SULFATE, TOTAL (MG/L AS SO4)	286
5597280	8/6/1992	SULFATE, TOTAL (MG/L AS SO4)	447
5597280	9/8/1992	SULFATE, TOTAL (MG/L AS SO4)	603
5597280	4/1/1993	SULFATE, TOTAL (MG/L AS SO4)	197
5597280	10/27/1993	SULFATE, TOTAL (MG/L AS SO4)	381
5597280	1/19/1994	SULFATE, TOTAL (MG/L AS SO4)	610
5597280	3/1/1994	SULFATE, TOTAL (MG/L AS SO4)	180
5597280	4/5/1994	SULFATE, TOTAL (MG/L AS SO4)	300
5597280	5/10/1994	SULFATE, TOTAL (MG/L AS SO4)	252
5597280	6/1/1994	SULFATE, TOTAL (MG/L AS SO4)	540
5597280	7/14/1994	SULFATE, TOTAL (MG/L AS SO4)	200
5597280	9/19/1994	SULFATE, TOTAL (MG/L AS SO4)	1620
5597280	11/1/1994	SULFATE, TOTAL (MG/L AS SO4)	1480
5597280	12/15/1994	SULFATE, TOTAL (MG/L AS SO4)	153
5597280	2/1/1995	SULFATE, TOTAL (MG/L AS SO4)	124
5597280	3/9/1995	SULFATE, TOTAL (MG/L AS SO4)	38
5597280	4/19/1995	SULFATE, TOTAL (MG/L AS SO4)	450
5597280	5/9/1995	SULFATE, TOTAL (MG/L AS SO4)	96
5597280	6/14/1995	SULFATE, TOTAL (MG/L AS SO4)	200
5597280	7/17/1995	SULFATE, TOTAL (MG/L AS SO4)	560
5597280	9/28/1995	SULFATE, TOTAL (MG/L AS SO4)	1078
5597280	11/6/1995	SULFATE, TOTAL (MG/L AS SO4)	1276
5597280	12/20/1995	SULFATE, TOTAL (MG/L AS SO4)	144
5597280	2/1/1996	SULFATE, TOTAL (MG/L AS SO4)	209
5597280	3/5/1996	SULFATE, TOTAL (MG/L AS SO4)	391
5597280	4/10/1996	SULFATE, TOTAL (MG/L AS SO4)	292
5597280	5/7/1996	SULFATE, TOTAL (MG/L AS SO4)	79.3
5597280	6/19/1996	SULFATE, TOTAL (MG/L AS SO4)	176
5597280	7/24/1996	SULFATE, TOTAL (MG/L AS SO4)	277

5597280	3/5/1997	SULFATE, TOTAL (MG/L AS SO4)	80.4
5597280	4/2/1997	SULFATE, TOTAL (MG/L AS SO4)	189
NE05	10/22/1997	SULFATE, TOTAL (MG/L AS SO4)	865
NE05	12/3/1997	SULFATE, TOTAL (MG/L AS SO4)	516
NE05	2/2/1998	SULFATE, TOTAL (MG/L AS SO4)	237
NE05	3/4/1998	SULFATE, TOTAL (MG/L AS SO4)	114
NE05	4/22/1998	SULFATE, TOTAL (MG/L AS SO4)	79
NE05	5/21/1998	SULFATE, TOTAL (MG/L AS SO4)	383
NE05	6/18/1998	SULFATE, TOTAL (MG/L AS SO4)	80
NE05	8/12/1998	SULFATE, TOTAL (MG/L AS SO4)	153
NE05	9/8/1998	SULFATE, TOTAL (MG/L AS SO4)	1060
NE05	10/15/1998	SULFATE, TOTAL (MG/L AS SO4)	75
NE05	12/3/1998	SULFATE, TOTAL (MG/L AS SO4)	1814
NE05	1/5/1999	SULFATE, TOTAL (MG/L AS SO4)	195
NE05	2/9/1999	SULFATE, TOTAL (MG/L AS SO4)	42.6
NE05	4/8/1999	SULFATE, TOTAL (MG/L AS SO4)	45.8
NE05	5/19/1999	SULFATE, TOTAL (MG/L AS SO4)	107
NE05	7/7/1999	SULFATE, TOTAL (MG/L AS SO4)	425
NE05	8/16/1999	SULFATE, TOTAL (MG/L AS SO4)	900
NE05	9/30/1999	SULFATE, TOTAL (MG/L AS SO4)	1940
NE05	10/26/1999	SULFATE, TOTAL (MG/L AS SO4)	1540
NE05	12/7/1999	SULFATE, TOTAL (MG/L AS SO4)	1710
NE05	1/27/2000	SULFATE, TOTAL (MG/L AS SO4)	512
NE05	2/24/2000	SULFATE, TOTAL (MG/L AS SO4)	303
NE05	4/5/2000	SULFATE, TOTAL (MG/L AS SO4)	361
NE05	5/25/2000	SULFATE, TOTAL (MG/L AS SO4)	193
NE05	6/20/2000	SULFATE, TOTAL (MG/L AS SO4)	23.1
NE05	7/19/2000	SULFATE, TOTAL (MG/L AS SO4)	147
NE05	8/22/2000	SULFATE, TOTAL (MG/L AS SO4)	249

Primary Station ID	Start Date	Parameter Long Name	Result Value
5597280	7/17/1995	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	866
5597280	3/5/1996	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	614
NE 05	7/19/2000	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	316
NE 05	8/22/2000	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	724

Primary Station ID	Start Date	Parameter Long Name	Result Value
5597280	01/10/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	786
5597280	02/13/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	425
5597280	03/26/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1151
5597280	05/09/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	451
5597280	06/11/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	412
5597280	07/18/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1269
5597280	08/27/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1441
5597280	10/10/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	513
5597280	11/14/90	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	931
5597280	01/23/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	365
5597280	02/13/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	584
5597280	03/20/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	383
5597280	04/24/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	578
5597280	05/30/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1174
5597280	07/16/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1051
5597280	09/05/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1016
5597280	10/08/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1187
5597280	12/04/91	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	284
5597280	01/09/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	398
5597280	03/11/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1038
5597280	04/16/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	961
5597280	05/20/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1394
5597280	06/18/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1064
5597280	08/06/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1225
5597280	09/08/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1500
5597280	11/09/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1710
5597280	12/15/92	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	742
5597280	02/17/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	738
5597280	04/01/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	688
5597280	05/10/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	474
5597280	06/07/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	946
5597280	07/29/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	422
5597280	09/07/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	279
5597280	10/27/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1024
5597280	12/21/93	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	959
5597280	01/19/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1359
5597280	03/01/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	642
5597280	04/05/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	957
5597280	05/10/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	768
5597280	06/01/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1460
5597280	07/14/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	700
5597280	09/19/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	307
5597280	11/01/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	2780
5597280	12/15/94	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	524
5597280	02/01/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	443
5597280	03/09/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	193
5597280	04/19/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1244
5597280	05/09/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	405
5597280	06/14/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	747
5597280	07/17/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1440
5597280	09/28/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	2470

5597280	11/06/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	902
5597280	12/20/95	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	562
5597280	02/01/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	687
5597280	03/05/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1014
5597280	04/10/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	830
5597280	05/07/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	313
5597280	06/19/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	613
5597280	07/24/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	813
5597280	09/25/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1459
5597280	11/12/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	704
5597280	12/23/96	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	656
5597280	02/05/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	283
5597280	03/05/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	321
5597280	04/02/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	480
5597280	05/20/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1175
5597280	06/19/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	279
5597280	07/17/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1251
5597280	09/29/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1325
5597280	10/22/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	2010
5597280	12/03/97	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1378
5597280	02/02/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	710
5597280	03/04/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	414
5597280	04/22/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	318
5597280	05/21/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1025
5597280	06/18/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	358
5597280	08/12/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	543
5597280	09/08/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	763
5597280	10/15/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1720
5597280	12/03/98	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	2380
NE 05	01/05/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	607
NE 05	02/09/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	147
NE 05	04/08/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	231
NE 05	08/19/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	397
NE 05	07/07/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1012
NE 05	08/16/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1910
NE 05	09/30/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	3440
NE 05	10/26/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	287
NE 05	12/07/99	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	2980
NE 05	01/27/00	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	1291
NE 05	02/24/00	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	815
NE 05	04/05/00	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	941
NE 05	05/25/00	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	716
NE 05	06/20/00	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	169
NE 05	07/19/00	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	417
NE 05	08/22/00	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)	774

Primary Station ID	Start Date	Parameter Long Name	Result Value
5597280	1/10/1990	OXYGEN, DISSOLVED MG/L	7.8
5597280	2/13/1990	OXYGEN, DISSOLVED MG/L	7.1
5597280	3/26/1990	OXYGEN, DISSOLVED MG/L	10.1
5597280	5/9/1990	OXYGEN, DISSOLVED MG/L	5.1
5597280	6/11/1990	OXYGEN, DISSOLVED MG/L	4
5597280	7/18/1990	OXYGEN, DISSOLVED MG/L	4.2
5597280	8/27/1990	OXYGEN, DISSOLVED MG/L	7.2
5597280	10/10/1990	OXYGEN, DISSOLVED MG/L	6.3
5597280	11/14/1990	OXYGEN, DISSOLVED MG/L	3.8
5597280	1/23/1991	OXYGEN, DISSOLVED MG/L	9.7
5597280	2/13/1991	OXYGEN, DISSOLVED MG/L	9.3
5597280	3/20/1991	OXYGEN, DISSOLVED MG/L	7.9
5597280	4/24/1991	OXYGEN, DISSOLVED MG/L	7
5597280	5/30/1991	OXYGEN, DISSOLVED MG/L	5.1
5597280	7/16/1991	OXYGEN, DISSOLVED MG/L	3.2
5597280	9/5/1991	OXYGEN, DISSOLVED MG/L	3.8
5597280	10/8/1991	OXYGEN, DISSOLVED MG/L	5.4
5597280	12/4/1991	OXYGEN, DISSOLVED MG/L	10.9
5597280	1/9/1992	OXYGEN, DISSOLVED MG/L	10
5597280	3/11/1992	OXYGEN, DISSOLVED MG/L	9.3
5597280	4/16/1992	OXYGEN, DISSOLVED MG/L	6.7
5597280	5/20/1992	OXYGEN, DISSOLVED MG/L	3.4
5597280	6/18/1992	OXYGEN, DISSOLVED MG/L	3.9
5597280	8/6/1992	OXYGEN, DISSOLVED MG/L	2.5
5597280	9/8/1992	OXYGEN, DISSOLVED MG/L	3.5
5597280	4/1/1993	OXYGEN, DISSOLVED MG/L	6.6
5597280	10/27/1993	OXYGEN, DISSOLVED MG/L	5.2
5597280	1/19/1994	OXYGEN, DISSOLVED MG/L	8.2
5597280	3/1/1994	OXYGEN, DISSOLVED MG/L	11.6
5597280	4/5/1994	OXYGEN, DISSOLVED MG/L	8.3
5597280	5/10/1994	OXYGEN, DISSOLVED MG/L	7.1
5597280	6/1/1994	OXYGEN, DISSOLVED MG/L	9.3
5597280	7/14/1994	OXYGEN, DISSOLVED MG/L	3.7
5597280	9/19/1994	OXYGEN, DISSOLVED MG/L	6.8
5597280	11/1/1994	OXYGEN, DISSOLVED MG/L	10.8
5597280	12/15/1994	OXYGEN, DISSOLVED MG/L	10.9
5597280	2/1/1995	OXYGEN, DISSOLVED MG/L	11.1
5597280	3/9/1995	OXYGEN, DISSOLVED MG/L	11.1
5597280	4/19/1995	OXYGEN, DISSOLVED MG/L	6.4
5597280	5/9/1995	OXYGEN, DISSOLVED MG/L	6.9
5597280	6/14/1995	OXYGEN, DISSOLVED MG/L	5
5597280	7/17/1995	OXYGEN, DISSOLVED MG/L	3
5597280	9/28/1995	OXYGEN, DISSOLVED MG/L	4.2
5597280	11/6/1995	OXYGEN, DISSOLVED MG/L	6.1
5597280	12/20/1995	OXYGEN, DISSOLVED MG/L	10.2
5597280	2/1/1996	OXYGEN, DISSOLVED MG/L	10.6
5597280	3/5/1996	OXYGEN, DISSOLVED MG/L	12.6
5597280	4/10/1996	OXYGEN, DISSOLVED MG/L	9.8
5597280	5/7/1996	OXYGEN, DISSOLVED MG/L	5.2
5597280	6/19/1996	OXYGEN, DISSOLVED MG/L	3.8
5597280	7/24/1996	OXYGEN, DISSOLVED MG/L	4

5597280	3/5/1997	OXYGEN, DISSOLVED MG/L	9
5597280	4/2/1997	OXYGEN, DISSOLVED MG/L	9.2
NE05	10/22/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	6.1
NE05	12/3/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	5.4
NE05	2/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	9.8
NE05	3/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	8.3
NE05	4/22/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	6.5
NE05	5/21/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	3.7
NE05	6/18/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	4.5
NE05	8/12/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	3.9
NE05	9/8/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	3.2
NE05	10/15/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	6.3
NE05	12/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	10
NE05	1/5/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	10.8
NE05	2/9/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	8.4
NE05	4/8/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	5.9
NE05	5/19/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	4
NE05	7/7/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	2.2
NE05	8/16/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	5.9
NE05	9/30/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	5.1
NE05	10/26/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	8
NE05	12/7/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	6.6
NE05	1/27/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	15.5
NE05	2/24/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	7.4
NE05	4/5/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	7.6
NE05	5/25/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	4.6
NE05	6/20/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	4.9
NE05	7/19/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	4
NE05	8/22/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	4.8

Primary Station ID	Start Date	Parameter Long Name		Result Value
5597280	1/10/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
5597280	2/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7
5597280	3/26/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8
5597280	5/9/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8
5597280	7/18/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
5597280	8/27/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
5597280	10/10/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
5597280	11/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
5597280	1/23/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
5597280	2/13/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
5597280	3/20/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7
5597280	4/24/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
5597280	5/30/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
5597280	7/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
5597280	9/5/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
5597280	10/8/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
5597280	12/4/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
5597280	1/9/1992	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
5597280	3/11/1992	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
5597280	4/16/1992	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
5597280	5/20/1992	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
5597280	6/18/1992	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
5597280	8/6/1992	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
5597280	9/8/1992	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
5597280	4/1/1993	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
5597280	10/27/1993	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
5597280	1/19/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
5597280	3/1/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
5597280	4/5/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8
5597280	5/10/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8
5597280	6/1/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
5597280	7/14/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
5597280	9/19/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8
5597280	11/1/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8
5597280	12/15/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
5597280	2/1/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
5597280	3/9/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
5597280	4/19/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
5597280	5/9/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
5597280	6/14/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
5597280	7/17/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8
5597280	9/28/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
5597280	11/6/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
5597280	12/20/1995	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
5597280	2/1/1996	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
5597280	3/5/1996	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
5597280	4/10/1996	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
5597280	5/7/1996	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8
5597280	6/19/1996	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
5597280	7/24/1996	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9
5597280	3/5/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1

5597280	4/2/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
NE05	7/19/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7
NE05	8/22/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7
NE05	10/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
NE05	12/3/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
NE05	2/2/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
NE05	3/4/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
NE05	4/22/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
NE05	5/21/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
NE05	6/18/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
NE05	8/12/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
NE05	9/8/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
NE05	10/15/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
NE05	12/3/1998	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
NE05	1/5/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
NE05	2/9/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
NE05	4/8/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
NE05	5/19/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
NE05	7/7/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7
NE05	8/16/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
NE05	9/30/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.5
NE05	10/26/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
NE05	12/7/1999	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
NE05	1/27/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
NE05	2/24/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
NE05	4/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9
NE05	5/25/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9
NE05	6/20/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6
NE05	7/19/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7
NE05	8/22/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7

Appendix B
Directory of Selected Coal Mines for Jackson and Perry Counties, Illinois (IDNR 2000)

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON AND PERRY COUNTIES, ILLINOIS (IDNR 2000)

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
55	MUDDY VALLEY MNG & MFG	HALLIDAYBORO	1	SHAFT	RPP	1889-15	HERRIN	JACKSON	7S	1W	29
55	JACKSON C C	MUDDY VALLEY		SHAFT		1915-25	HERRIN	JACKSON	7S	1W	29
57	BIG MUDDY & CARTERVILLE C C	BIG MUDDY	1	SHAFT	RPP	1907-14	HERRIN	FRANKLIN	7S	1E	28
89	HORN, HENRY C C	HORN		SHAFT	MRP	1889-05	HERRIN	PERRY	6S	1W	19
89	DUQUOIN PITT COAL & COKE CO	HORN		SHAFT		1905-06	HERRIN	PERRY	6S	1W	19
89	BRILLIANT COAL & COKE C	HORN		SHAFT		1906-15	HERRIN	PERRY	6S	1W	19
147	WESTERN C C	BUSH	2	SHAFT	RPP	1917-28	HERRIN	FRANKLIN	7S	1E	31
180	EQUITABLE C C	MAJESTIC	14	SHAFT	RPP	1905-06	HERRIN	PERRY	6S	12	23
180	EQUITABLE C C	MAJESTIC	14	SHAFT	RPP	1905-06	HERRIN	PERRY	6S	1W	23
180	MAJESTIC C C	MAJESTIC	1	SHAFT		1906-18	HERRIN	PERRY	6S	1W	23
180	EQUITABLE COAL & MNG CO	MAJESTIC		SHAFT		1918-23	HERRIN	PERRY	6S	1W	23
180	CRERAR-CLINCH C C	MAJESTIC	14	SHAFT		1924-37	HERRIN	PERRY	6S	1W	23
180	PEABODY C C IDLE:23-34	PEABODY	14	SHAFT		1937-54	HERRIN	PERRY	6S	1W	23
183	UNION COLLIERY CO	KATHLEEN		SHAFT	RP	1918-47	HERRIN	JACKSON	7S	1W	5
183	UNION COLLIERY CO	KATHLEEN		SHAFT	RP	1918-47	HERRIN	JACKSON	7S	1W	5
451	SECURITY C C	SECURITY	1	SHAFT	RPP	1911-31	HERRIN	PERRY	6S	1W	29
622	UNITED ELECTRIC C C	FIDELITY	11	STRIP		1929-74	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
687	UNION COLLIERY CO	NEW KATHLEEN		SLOPE	MRP	1946-58	HERRIN	PERRY	6S	2W	36
687	UNION COLLIERY CO	NEW KATHLEEN		SLOPE	MRP	1946-58	HERRIN	PERRY	6S	2W	36
687	TRUAX TRAER C C	NEW KATHLEEN		SLOPE		1958-58	HERRIN	PERRY	6S	2W	3631
692	MCCORMICK, PATRICK	MCCORMICK		SHAFT	RPP	1936-39	HERRIN	JACKSON	7S	1W	20
692	HALLIDAYBORO C C	HALLIDAYBORO		SHAFT		1939-50	HERRIN	JACKSON	7S	1W	20
692	JOLIANA MNG CO	JOLIANA		SHAFT		1950-54	HERRIN	JACKSON	7S	1W	20
692	ELK C C	ELK		SHAFT		1954-64	HERRIN	JACKSON	7S	1W	20
892	ROYAL C C	ROYAL		STRIP		1969-72	HERRIN	JACKSON	7S	1W	8
942	ELK C C	ELK		STRIP		1972-74	SPRINGFIELD	JACKSON	7S	1W	17
942	CENTRAL STATES MINING CO	ELK		STRIP		1974-77	SPRINGFIELD	JACKSON	7S	1W	17
967	CONSOLIDATION C C	BURNING STAR	5	STRIP		1976-89	HERRIN	JACKSON	8S	1W	12
967	CONSOLIDATION C C	BURNING STAR	5	STRIP		1976-89	HERRIN	JACKSON	8S	1E	6
967	CONSOLIDATION C C	BURNING STAR	5	STRIP		1976-89	HERRIN	JACKSON	8S	1W	12
967	CONSOLIDATION C C	BURNING STAR	5	STRIP		1976-89	HERRIN	JACKSON	8S	1W	9
967	CONSOLIDATION C C	BURNING STAR	5	STRIP		1976-90	HERRIN	JACKSON	7S	1W	21
3157	ENTERPRIZE C C	ENTERPRIZE #2				1875-76	HERRIN	PERRY	6S	1W	17
3157	WALL C C	ENTERPRIZE #2		SHAFT	RP	1934	HERRIN	PERRY	6S	1W	17

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON AND PERRY COUNTIES, ILLINOIS (IDNR 2000)

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
3158	HARVEY BROS	HARVEY		SHAFT	RPP	1917-18	HERRIN	PERRY	6S	1W	18
3158	JEWEL C C	JEWEL	1	SHAFT		1918-25	HERRIN	PERRY	6S	1W	18
3161	PATRICK C C	PATRICK				1925-26	HERRIN	PERRY	6S	1W	19
3161	LEMON, L L	LEMON				1926-27	HERRIN	PERRY	6S	1W	19
3161	PATRICK C C	PATRICK				1927-37	HERRIN	PERRY	6S	1W	19
3161	LITTLE WHITE ASH C C	LITTLE ASH				1937-43	HERRIN	PERRY	6S	1W	19
3161	MCCORMICK & GEORGE	MCCORMICK & GEORGE				1942-43	HERRIN	PERRY	6S	1W	19
4388	NEW JEWEL C C	NEW JEWEL	3	SLOPE		1935-47	HERRIN	PERRY	6S	1W	17
4405								PERRY	6S	1W	18
4406	JACOB'S MINE	JACOB						PERRY	6S	1W	7
4408	ENTERPRISE COAL & COKE	ENTERPRIZE #5						PERRY	6S	1W	20
4603	CASTELON LAND BEFORE 1908			SHAFT				JACKSON	7S	1W	17

Appendix C
Monte Carlo Analyses

IEPA
Watershed Load Reductions
7/11/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : NE 05

Manganese

Cc (Mn)	1	mg/L	- Water quality criterion
Cd (Mn)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 74.3% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.9378008 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.240605 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 86.3% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 0.937801 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.128758 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NE 05

Sulfate

Cc (Sulfate) 500 mg/L - Water quality criterion
Cd (Sulfate) #NAME? mg/L - Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 76.1% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 411.2166 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 98.26158 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 87.9% percent

Long Term Average
LTA = allowable LTA source concentration in mg/L

mean 411.2166 mg/L

LTA = mean * (1 - PR99.9)

LTA (Sulfate) 49.86811 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NE 05

Conductivity

Cc (Cond)	1667	US/CM	- Water quality criterion
Cd (Cond)	#NAME?	US/CM	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

PR = Max{ 0, (1-Cc/Cd)}

PR (Cond) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Cond) 49.6% percent

Long Term Average
LTA = allowable LTA source concentration in US/CM

mean 913.0626 US/CM

LTA = mean * (1 - PR99)

LTA (Cond) 460.5701 US/CM

Percent reduction at the 99.9th percentile

PR99.9 (Cond) 68.0% percent

Long Term Average
LTA = allowable LTA source concentration in US/CM

mean 913.0626 US/CM

LTA = mean * (1 - PR99.9)

LTA (Cond) 292.5571 US/CM

Simulation Results for Book1

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 3
Sampling Type= Monte Carlo
Runtime= 00:00:21
Run on 7/12/2002, 1:59:15 PM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B18	PR (Mn)	0.00E+00	0.1102899	0.9170313
B56	PR (Sulfate)	0	0.09138039	0.9279916
B18	PR (Cond)	0.00E+00	0.02438871	0.8194739
B12	(Input) Cd (Mn)	0.05129259	0.9378008	12.05274
B50	(Input) Cd (Sulfate)	9.456059	411.2166	6943.632
B12	(Input) Cd (Cond)	52.55287	913.0626	9234.124

@RISK Simulation of	Run on 7/12/2002, 1:59:15 PM	Simulations= 1	Iterations= 10000			
Name	PR (Mn)	PR (Sulfate)	PR (Cond)	Cd (Mn)	Cd (Sulfate)	Cd (Cond)
Description	Output	Output	Output	Lognorm(0.94,0.79)	Lognorm(411.56,440.12)	Lognorm(913.16,644.07)
Cell	B18	B56	B18	B12	B50	B12
Minimum =	0.00E+00	0	0.00E+00	0.05129259	9.456059	52.55287
Maximum =	0.9170313	0.9279916	0.8194739	12.05274	6943.632	9234.124
Mean =	0.1102899	0.09138039	0.02438871	0.9378008	411.2166	913.0626
Std Deviation =	0.1987049	1.92E-01	0.09155224	0.7904344	426.7439	6.45E+02
Variance =	3.95E-02	3.69E-02	8.38E-03	0.6247865	182110.3	4.16E+05
Skewness =	1.751706	2.119643	4.399069	3.236393	3.82E+00	2.417713
Kurtosis =	4.953621	6.438054	23.34044	24.28912	30.2472	14.11303
Errors Calculated =	0	0	0	0	0	0
Mode =	0	0	0	0.6562068	113.3308	415.0804
5% Perc =	0	0	0	0.2182146	67.68984	257.7308
10% Perc =	0	0	0	0.2820227	92.50745	326.6453
15% Perc =	0	0	0	0.3382358	115.3455	384.7296
20% Perc =	0	0	0	0.3882285	136.3684	433.2219
25% Perc =	0	0	0	0.4407323	157.4693	484.7229
30% Perc =	0	0	0	0.4924223	180.2202	533.8644
35% Perc =	0	0	0	0.5431075	204.9253	585.5309
40% Perc =	0	0	0	0.5959478	228.764	640.1046
45% Perc =	0	0	0	0.6547544	254.7296	692.54
50% Perc =	0	0	0	0.7183177	284.6493	751.1619
55% Perc =	0	0	0	0.7866059	318.2729	811.9827
60% Perc =	0	0	0	0.8655798	356.0056	884.4093
65% Perc =	0	0	0	0.9557394	396.173	958.4983
70% Perc =	0.05493084	0	0	1.058124	446.6583	1039.563
75% Perc =	0.1453485	0.01428163	0	1.170068	507.2443	1141.489
80% Perc =	0.2497771	0.1418252	0	1.332937	582.6319	1269.679
85% Perc =	0.3505346	0.2789322	0	1.539728	693.4161	1433.905
90% Perc =	0.4542265	0.4221018	0.004451739	1.832262	865.2043	1674.454
95% Perc =	0.578712	0.5719736	0.2078675	2.373673	1168.152	2104.446
Filter Minimum =						
Filter Maximum =						
Type (1 or 2) =						
# Values Filtered =	0	0	0	0	0	0
Scenario #1 =	>75%	>75%	>75%			
Scenario #2 =	<25%	<25%	<25%			
Scenario #3 =	>90%	>90%	>90%			
Target #1 (Value)=	0.743436933	0.761046648	0.49557662	3.897676945	2092.458496	3304.763428
Target #1 (Perc%)=	99%	99%	99%	99%	99%	99%
Target #2 (Value)=	0.862702429	0.878730297	0.679587007	7.28345108	4033.038574	5202.660156
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Mn) in Cell B18

(From @RISK Simulation of Book1- Run on 7/12/2002, 1:59:15 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.8205904)	Rank Correlation Coefficient
#1	B12	Cd (Mn)	0.9058644	0.8355587
#2	B50	Cd (Sulfate)	0	-1.01E-02
#3	B88	Cd (TDS)	0	8.24E-03

Simulation Sensitivities for PR (Sulfate) in Cell B56

(From @RISK Simulation of Book1- Run on 7/12/2002, 1:59:15 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0.8026364)	Rank Correlation Coefficient
#1	B50	Cd (Sulfate)	0.8958998	0.766163
#2	B12	Cd (Mn)	0	-6.57E-03
#3	B88	Cd (TDS)	0	3.92E-03

Simulation Sensitivities for PR (TDS) in Cell B94

(From @RISK Simulation of Book1- Run on 7/12/2002, 1:59:15 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity (RSqr=0)	Rank Correlation Coefficient
#1	B12	Cd (Mn)	0	0
#2	B50	Cd (Sulfate)	0.00E+00	0.00E+00
#3	B88	Cd (TDS)	0.00E+00	0.00E+00

Simulation Variables for Book1
(From @RISK Simulation of Book1- Run on 7/12/2002, 1:59:15 PM, Simulations= 1, Iterations= 10000)
Outputs:

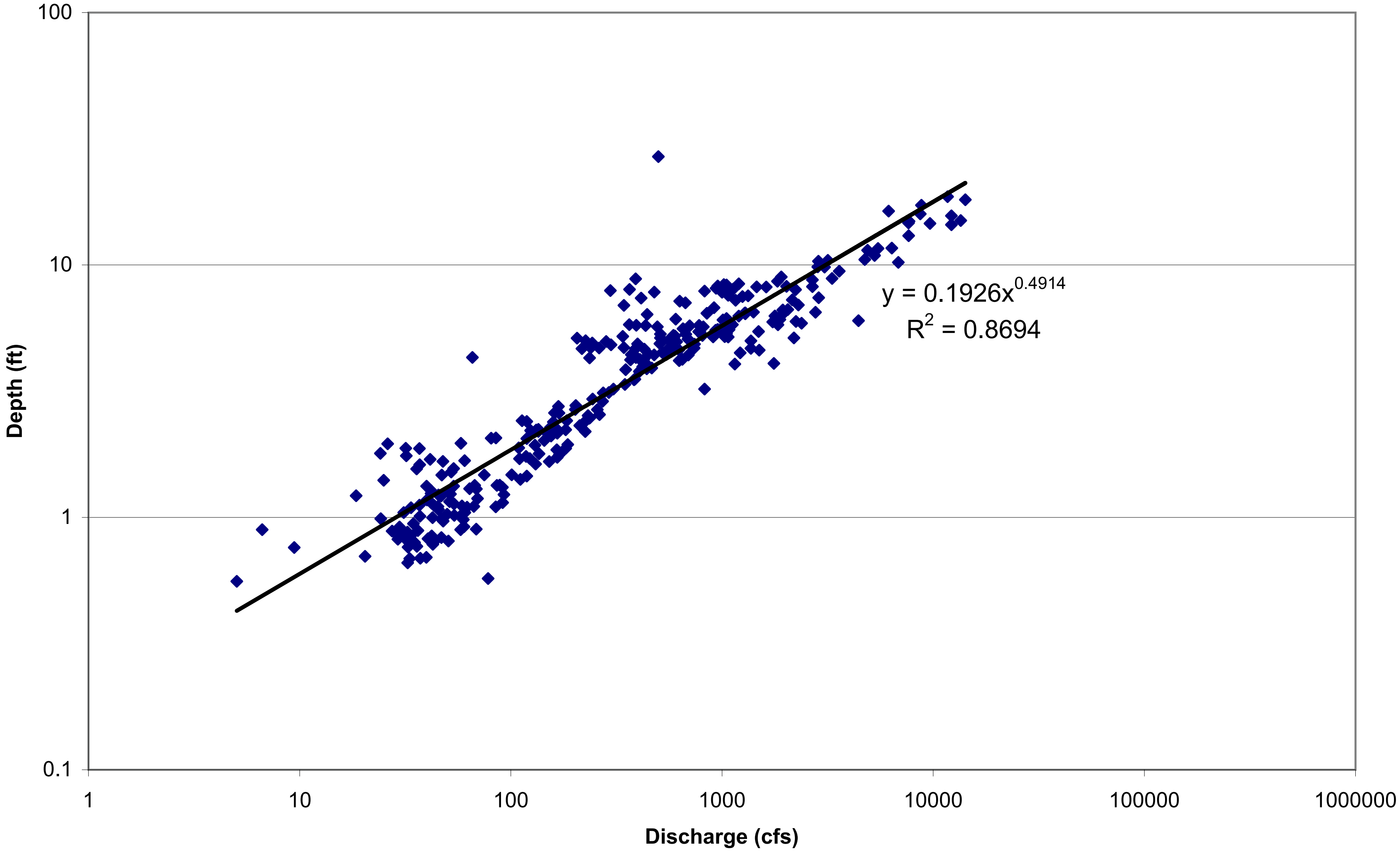
Cell	Name	Current
B18	PR (Mn)	0.333333333
B56	PR (Sulfate)	0
B18	PR (Cond)	0

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Lognorm(0.94,0.79)	[IEPA_Monte_Carlo_NE05.xls]NE05	'=RiskLognorm(0.94,0.79)
! B50	Cd (Sulfate)	Lognorm(411.56,440.12)	[IEPA_Monte_Carlo_NE05.xls]NE05	'=RiskLognorm(411.56,440.12)
! B12	Cd (Cond)	Lognorm(913.16,644.07)	[IEPA_Monte_Carlo_NE05b.xls]NE05	'=RiskLognorm(913.16,644.07)

Appendix D
Rating Curve for Stream Depth

Depth Curve for Little Muddy Watershed



Appendix E
Streeter-Phelps Analyses

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Little Muddy River Watershed
Aeration Coefficient Summary

Location	**Date**	**DO observed**	**BOD @ DO observed**	**Ka @ DO observed**	**Ka at DO = 6 mg/L**
NE05	7/17/1995	3	9.4	0.1	17.1
NE05	7/19/2000	4	9.6	0.12	10.4
NE05	8/22/2000	4.8	9.5	2.8	9.3

Definitions

D	DO Deficit = DO at saturation minus observed DO
$\mathbf{D_o}$	Initial DO deficit
$\mathbf{k_a}$	Reaeration rate
$\mathbf{k_d}$	BOD5 decay rate
x	Distance downstream of discharge
U	Stream velocity
$\mathbf{L_o}$	Initial BOD5 at x=0
$\mathbf{C_s}$	DO at saturation
C	Observed DO
H	Stream depth
T	Stream temperature
Q	Streamflow

Used Q from USGS Derived Flows and H calculated from Q. *Ka is lowest possible and Kd is calculated from that.*

		20 °C	**@ T**									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
4.89	4	3.53	0.1	1.6	5280	0.9	9.4	7.9	3	2.3	27.6	160
4.89												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.0

x	y	m	b
0	7.6	-0.00025	7.6
2000	7.1		

Elevation	375	feet
DO @ Elev.	7.5	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	7.9	mg/L

Used Q from USGS Derived Flows and H calculated from Q. *Ka is lowest possible and Kd is calculated from that.*

		20 °C	**@ T**									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
1.89	4	3.53	17.06	1.6	5280	0.9	9.4	7.9	6	2.3	27.6	160
1.89												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp	8.0

x	y	m	b
0	7.6	-0.00025	7.6
2000	7.1		

Elevation	375	feet
DO @ Elev.	7.5	mg/L
DO Elev Factor	0.99	

DO @ Temp/Elev	7.9	mg/L

Used Q from USGS Derived Flows and H determined from Transect Data. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
4.32	4	2.62	0.12	0.58	5280	1.0	9.6	8.3	4	2.9	24.8	235
4.32												

x	y	m	b
20	9.2	-0.16	12.4
25	8.4		

DO @ Temp	8.4	

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	375	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.3	mg/L

Used Q from USGS Derived Flows and H determined from Transect Data. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.32	4	2.62	10.42	0.58	5280	1.0	9.6	8.3	6	2.9	24.8	235
2.32												

x	y	m	b
20	9.2	-0.16	12.4
25	8.4		

DO @ Temp	8.4

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	375	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.3	mg/L

Used Q from USGS Derived Flows and H determined from Transect Data. Kd is temp corrected and Ka is calibrated.

		20 °C	**@ T**									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
3.65	4	2.86	2.80	0.58	5280	0.9	9.5	8.4	4.8	2.7	24	139
3.66												

x	y	m	b
20	9.2	-0.16	12.4
25	8.4		

DO @ Temp 8.6

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	375	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.4	mg/L

Used Q from USGS Derived Flows and H determined from Transect Data. Kd is temp corrected and Ka is calibrated.

		20 °C	**@ T**									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
2.45	4	2.86	9.35	0.58	5280	0.9	9.5	8.4	6	2.7	24	139
2.45												

x	y	m	b
20	9.2	-0.16	12.4
25	8.4		

DO @ Temp	8.6

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	375	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.4	mg/L

Appendix F
Error Analyses

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F.1 Monte Carlo Analysis Development and Results

This appendix provides the results of the Monte-Carlo DO error analysis. The analysis was run on the range of possible values for the BOD_5 decay rate coefficient (k_d) and the reaeration rate coefficient (k_a). The Monte-Carlo program requires a distribution of k_a and k_d values. For each impaired DO sample date, a triangle distribution was chosen to analyze segment NE05 since data for this site was extremely limited.

Each impaired DO sample date was evaluated separately using @RISK, which is a Microsoft® *Excel* Add-in for the Monte-Carlo analysis. The @RISK analysis package performed 10,000 iterations to determine the range of possible DO predictions over 10,000 combinations of randomly selected k_a and k_d values.

A triangular distribution assumes that the values of a given data set are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. Water quality data were not available to determine the actual k_a and k_d, so the estimated values discussed in Section 7.3 and shown in Table 7-6 were used as the mode for each sample date.

In order to define a more appropriate distribution than triangular, more data needs to be collected. In the absence of any drift, or non-random error, 10 samples can be used to define a distribution. As the data set increases, so does the ability to define an appropriate distribution, such a lognormal, normal, etc. The number of samples needed to define the true data distribution depends upon the severity of the drift.

The Monte Carlo simulation was run using 10,000 iterations with the triangular distribution. For each iteration, a DO concentration is randomly generated according to random sampling of the triangular distribution of k_a and k_d. The output of the Monte-Carlo simulation is a population of 10,000 DO concentrations that could be observed across the literature range of k_a and k_d values. Statistics were performed on the Monte-Carlo output to determine the 95th and 99.9th percentile confidence intervals. A confidence interval means that the stated percent of the simulated concentrations fall within the low and high concentrations of the interval.

This appendix shows the set-up for the Monte-Carlo simulation for each impaired sample date, a summary of the output, and the 95th and 99.9th percentile confidence intervals for each impaired sample date.

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.9	9.4	7.9	3	160	=RiskTriang(0.01,0.1,100)	=RiskTriang(0.02,1.6,3.4)

DO= `=$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))`

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	2.18	0.04	0.04
Maximum =	7.85	99.19	3.38
Mean =	6.35	32.83	1.67
Std Deviation =	1.33	23.54	0.69
Variance =	1.76	554.25	0.47
Skewness =	-0.97	0.61	0.07
Kurtosis =	2.87	2.47	2.40
Errors Calculated =	0.00	0.00	0.00
Mode =	5.10	31.58	1.35

95th Percent Confidence Interval

3.7	8.9

99.9th Percent Confidence Interval

2.0	10.7

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	1.0	9.6	8.3	4	235	=RiskTriang(0.01,0.12,100)	=RiskTriang(0.02,0.584,3.4)

DO= `=$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))`

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	2.59	0.02	0.03
Maximum =	8.30	99.20	3.40
Mean =	6.88	33.27	1.33
Std Deviatio	1.28	23.52	0.74
Variance =	1.64	553.36	0.54
Skewness =	-1.01	0.58	0.51
Kurtosis =	3.01	2.43	2.42
Errors Calcu	0.00	0.00	0.00
Mode =	5.87	42.31	0.76

95th Percent Confidence Interval

4.4	9.4

99.9th Percent Confidence Interval

2.6	11.1

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.9	9.5	8.4	4.8	139	=RiskTriang(0.01,2.8,100)	=RiskTriang(0.02,0.579,3.4)

DO= `=$F$3-(($B$3*EXP((-$I$3*$C$3)/($D$3*86400)))+($E$3*$J$3/($I$3-$J$3))*(EXP(-$J$3*$C$3/($D$3*86400))-EXP(-$I$3*$C$3/($D$3*86400))))`

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	3.07	0.22	0.04
Maximum =	8.43	99.33	3.40
Mean =	7.11	34.16	1.33
Std Deviation =	1.19	23.21	0.74
Variance =	1.41	538.58	0.54
Skewness =	-1.03	0.58	0.51
Kurtosis =	3.08	2.43	2.41
Errors Calculated =	0.00	0.00	0.00
Mode =	5.38	11.79	1.47

95th Percent Confidence Interval

4.8 9.4

99.9th Percent Confidence Interval

3.2 11.0

Appendix G
Watershed Management Model (WMM) Analyses

G.1 Watershed Management Model (WMM)

As discussed in Sections 6.2.1.1 and 7.4.3, the WMM model was run as a screening tool to assess the BOD_5 loads that are typically generated annually for the watershed. This appendix provides the output files from the WMM analysis for each sampled date in the Bonnie Creek Watershed and for the average annual precipitation event.

The output tables in this appendix use the following column headings. They are defined as follows:

Baseflow - Annual dry weather flow (cfs/sq. mile)
Point Source - Wastewater Treatment Plant or industrial process wastewater discharge
ISDS – Individual septic disposal system
Agriculture - Agriculture or pasture land
COM - Office or commercial land
Extractive - Mining type land use
Farm - Small or medium farm land
IND - Light to heavy industrial land
Institutional - University, school, or institution
Roads - Highways or surface roads
Water - Rivers, lakes, or wetlands
Forest - Forest land
Res High - High density residential land
Res Med - Medium density residential land
Urban Open - Urban open space
Vacant – Urban land with no development
LU1 - User defined land use
LU2 - User defined land use

TABLE 1-A
LITTLE MUDDY WATERSHED
AVERAGE LITTLE MUDDY LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Little Muddy	Perry	0	0	0	10,774	0	0	0	0	0	0	13,375	5,062	181	1,124	0	0	0	0	30,517
BOD	(lbs/yr)	Little Muddy	Perry	0	0	0	234,387	0	0	0	0	0	0	0	27,529	6,949	43,083	0	0	0	0	311,948
COD	(lbs/yr)	Little Muddy	Perry	0	0	0	1,494,219	0	0	0	0	0	0	0	701,994	40,904	253,607	0	0	0	0	2,490,724
TSS	(lbs/yr)	Little Muddy	Perry	0	0	0	9,375,490	0	0	0	0	0	0	0	1,200,272	15,455	95,821	0	0	0	0	10,687,038
TDS	(lbs/yr)	Little Muddy	Perry	0	0	0	2,929,841	0	0	0	0	0	0	0	1,376,458	49,282	305,551	0	0	0	0	4,661,133
Total-P	(lbs/yr)	Little Muddy	Perry	0	0	0	75,004	0	0	0	0	0	0	1,490	1,656	99	385	0	0	0	0	78,634
Dissolved-P	(lbs/yr)	Little Muddy	Perry	0	0	0	2,637	0	0	0	0	0	0	1,455	413	133	825	0	0	0	0	5,463
Total-N	(lbs/yr)	Little Muddy	Perry	0	0	0	269,545	0	0	0	0	0	0	37,342	17,817	741	2,919	0	0	0	0	328,364
TKN	(lbs/yr)	Little Muddy	Perry	0	0	0	135,945	0	0	0	0	0	0	21,559	4,950	494	2,114	0	0	0	0	165,062
NO2+NO3	(lbs/yr)	Little Muddy	Perry	0	0	0	133,601	0	0	0	0	0	0	15,783	12,867	246	804	0	0	0	0	163,302
Lead	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	45	461	15	82	0	0	0	0	603
Copper	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	51	174	4	16	0	0	0	0	246
Zinc	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	1,945	1,170	65	198	0	0	0	0	3,378
Manganese	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
LITTLE MUDDY WATERSHED
AVERAGE LITTLE MUDDY LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Little Muddy	Perry	0	0	0	188	0	0	0	0	0	0	233	88	3	20	0	0	0	0	533
BOD	(lbs/yr)	Little Muddy	Perry	0	0	0	4,090	0	0	0	0	0	0	0	480	121	752	0	0	0	0	5,443
COD	(lbs/yr)	Little Muddy	Perry	0	0	0	26,074	0	0	0	0	0	0	0	12,250	714	4,425	0	0	0	0	43,462
TSS	(lbs/yr)	Little Muddy	Perry	0	0	0	163,599	0	0	0	0	0	0	0	20,944	270	1,672	0	0	0	0	186,485
TDS	(lbs/yr)	Little Muddy	Perry	0	0	0	51,125	0	0	0	0	0	0	0	24,019	860	5,332	0	0	0	0	81,335
Total-P	(lbs/yr)	Little Muddy	Perry	0	0	0	1,309	0	0	0	0	0	0	26	29	2	7	0	0	0	0	1,372
Dissolved-P	(lbs/yr)	Little Muddy	Perry	0	0	0	46	0	0	0	0	0	0	25	7	2	14	0	0	0	0	95
Total-N	(lbs/yr)	Little Muddy	Perry	0	0	0	4,703	0	0	0	0	0	0	652	311	13	51	0	0	0	0	5,730
TKN	(lbs/yr)	Little Muddy	Perry	0	0	0	2,372	0	0	0	0	0	0	376	86	9	37	0	0	0	0	2,880
NO2+NO3	(lbs/yr)	Little Muddy	Perry	0	0	0	2,331	0	0	0	0	0	0	275	225	4	14	0	0	0	0	2,850
Lead	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	1	8	0	1	0	0	0	0	11
Copper	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4
Zinc	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	34	20	1	3	0	0	0	0	59
Manganese	(lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
LITTLE MUDDY WATERSHED
AVERAGE LITTLE MUDDY LOADS BY SUBBASIN
ANNUAL

Constituent (units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff (ac-ft/yr)	Little Muddy	Perry	0	0	0	265	0	0	0	0	0	0	329	125	4	28	0	0	0	0	751
BOD (lbs/yr)	Little Muddy	Perry	0	0	0	5,768	0	0	0	0	0	0	0	677	171	1,060	0	0	0	0	7,677
COD (lbs/yr)	Little Muddy	Perry	0	0	0	36,770	0	0	0	0	0	0	0	17,275	1,007	6,241	0	0	0	0	61,293
TSS (lbs/yr)	Little Muddy	Perry	0	0	0	230,717	0	0	0	0	0	0	0	29,537	380	2,358	0	0	0	0	262,992
TDS (lbs/yr)	Little Muddy	Perry	0	0	0	72,099	0	0	0	0	0	0	0	33,873	1,213	7,519	0	0	0	0	114,703
Total-P (lbs/yr)	Little Muddy	Perry	0	0	0	1,846	0	0	0	0	0	0	37	41	2	9	0	0	0	0	1,935
Dissolved-P (lbs/yr)	Little Muddy	Perry	0	0	0	65	0	0	0	0	0	0	36	10	3	20	0	0	0	0	134
Total-N (lbs/yr)	Little Muddy	Perry	0	0	0	6,633	0	0	0	0	0	0	919	438	18	72	0	0	0	0	8,081
TKN (lbs/yr)	Little Muddy	Perry	0	0	0	3,345	0	0	0	0	0	0	531	122	12	52	0	0	0	0	4,062
NO2+NO3 (lbs/yr)	Little Muddy	Perry	0	0	0	3,288	0	0	0	0	0	0	388	317	6	20	0	0	0	0	4,019
Lead (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	1	11	0	2	0	0	0	0	15
Copper (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	6
Zinc (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	48	29	2	5	0	0	0	0	83
Manganese (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
LITTLE MUDDY WATERSHED
AVERAGE LITTLE MUDDY LOADS BY SUBBASIN
ANNUAL

Constituent (units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff (ac-ft/yr)	Little Muddy	Perry	0	0	0	174	0	0	0	0	0	0	215	82	3	18	0	0	0	0	492
BOD (lbs/yr)	Little Muddy	Perry	0	0	0	3,775	0	0	0	0	0	0	0	443	112	694	0	0	0	0	5,025
COD (lbs/yr)	Little Muddy	Perry	0	0	0	24,068	0	0	0	0	0	0	0	11,307	659	4,085	0	0	0	0	40,119
TSS (lbs/yr)	Little Muddy	Perry	0	0	0	151,015	0	0	0	0	0	0	0	19,333	249	1,543	0	0	0	0	172,140
TDS (lbs/yr)	Little Muddy	Perry	0	0	0	47,192	0	0	0	0	0	0	0	22,171	794	4,922	0	0	0	0	75,079
Total-P (lbs/yr)	Little Muddy	Perry	0	0	0	1,208	0	0	0	0	0	0	24	27	2	6	0	0	0	0	1,267
Dissolved-P (lbs/yr)	Little Muddy	Perry	0	0	0	42	0	0	0	0	0	0	23	7	2	13	0	0	0	0	88
Total-N (lbs/yr)	Little Muddy	Perry	0	0	0	4,342	0	0	0	0	0	0	601	287	12	47	0	0	0	0	5,289
TKN (lbs/yr)	Little Muddy	Perry	0	0	0	2,190	0	0	0	0	0	0	347	80	8	34	0	0	0	0	2,659
NO2+NO3 (lbs/yr)	Little Muddy	Perry	0	0	0	2,152	0	0	0	0	0	0	254	207	4	13	0	0	0	0	2,630
Lead (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	1	7	0	1	0	0	0	0	10
Copper (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4
Zinc (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	31	19	1	3	0	0	0	0	54
Manganese (lbs/yr)	Little Muddy	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix H

Chart of Activity Coefficients versus Ionic Strength

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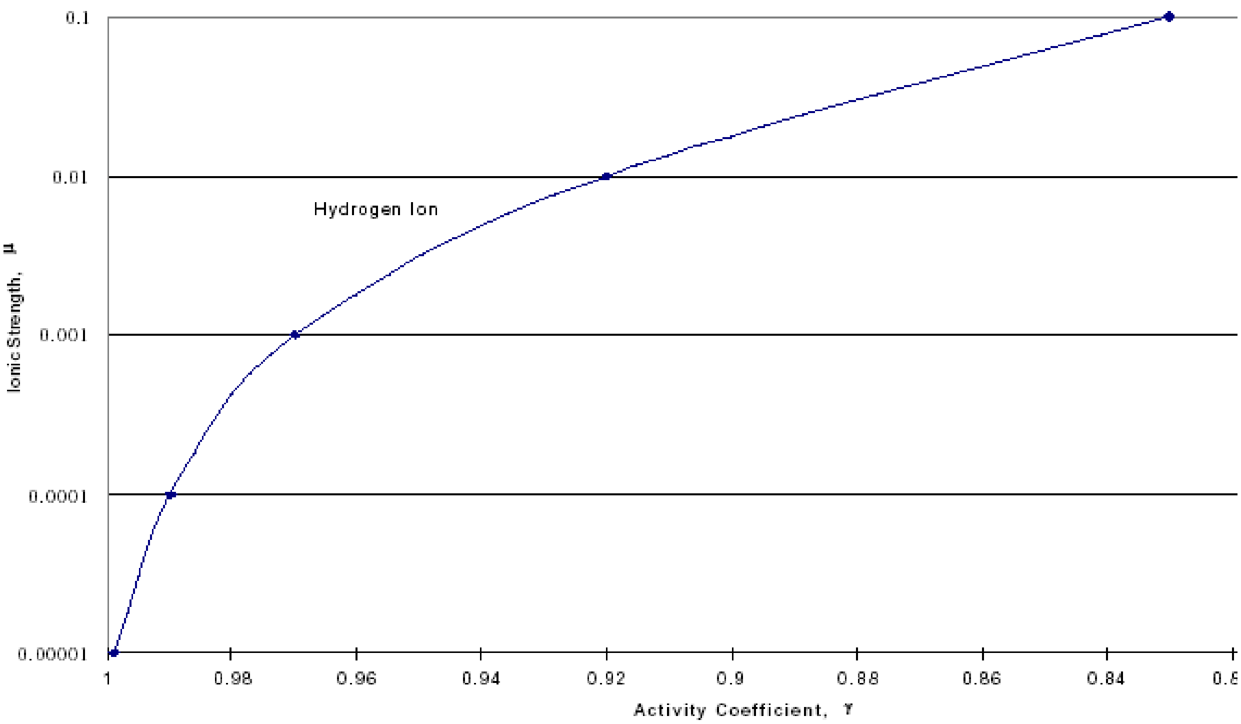
Ionic Strength versus Activity Coefficient (Snoeyink 1980)



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Appendix I
pH Analyses

IEPA
pH TMDL
9/12/2002

Watershed	Segment	TDS 95 percentile (mg/L)	Ionic Strength (μ)	Activity CorrectionFactor
Little Muddy River	NE05	913	0.02283	0.9

- Activity Correction factor computed from Figure 5, Brier Creek Watershed, KY Report
- TDS 95 percentile is computed from observed data in IEPA_Data_for_pH_Analysis.xls

Watershed	**Segment**	**Area (miles^2)**	**3 yr-Flow (cfs)**	**Max H+ Ion Loading @ pH of 6.5 (g/day)**	**Max H+ Ion Loading @ pH of 6.5 (lbs/day)**	**Actual H+ Ion Loading (g/day)**	**Actual H+ Ion Loading (lbs/day)**	**Reduction in H+ Ion Loading (lbs/day)**
Little Muddy River	NE05	270.76	2,919.43	2,468.67	5.44	1,687.43	3.72	(1.72)

Additional Notes:

1) 3-yr flow calculated by the Log Normal
2) Max H+ concentration @ pH of 6.5 is determined by relationship in QvsLoading_g (6.5)
3) Actual H+ concentration for Little Muddy @ 3 yr flow is determined by relationship in QvsLoading_g (NE05)

Water Quality pH Standard = 6.5
Activity CorrectionFactor (NE05) = 0.9 * based upon the TDS concentrations observed in the watershed

	NE05	
Flow (cfs)	**Max Ion Loading (g/day)**	**Max Ion Loading (lbs/day)**
0	0.00	0.000
500	422.78	0.932
1000	845.55	1.864
1500	1268.33	2.796
2000	1691.10	3.728
2500	2113.88	4.660
3000	2536.65	5.592
3500	2959.43	6.524
4000	3382.20	7.456
4500	3804.98	8.388
5000	4227.76	9.320
5500	4650.53	10.252
6000	5073.31	11.185
6500	5496.08	12.117
7000	5918.86	13.049
7500	6341.63	13.981
8000	6764.41	14.913
8500	7187.18	15.845
9000	7609.96	16.777
9500	8032.74	17.709
10000	8455.51	18.641
10500	8878.29	19.573
11000	9301.06	20.505
11500	9723.84	21.437
12000	10146.61	22.369
12500	10569.39	23.301
13000	10992.17	24.233
13500	11414.94	25.165
14000	11837.72	26.097
14500	12260.49	27.029
15000	12683.27	27.961
15500	13106.04	28.893
16000	13528.82	29.825
16500	13951.59	30.757
17000	14374.37	31.690
17500	14797.15	32.622
18000	15219.92	33.554
18500	15642.70	34.486
19000	16065.47	35.418
19500	16488.25	36.350
20000	16911.02	37.282
20500	17333.80	38.214
21000	17756.57	39.146
21500	18179.35	40.078
22000	18602.13	41.010
22500	19024.90	41.942
23000	19447.68	42.874
23500	19870.45	43.806
24000	20293.23	44.738
24500	20716.00	45.670
25000	21138.78	46.602

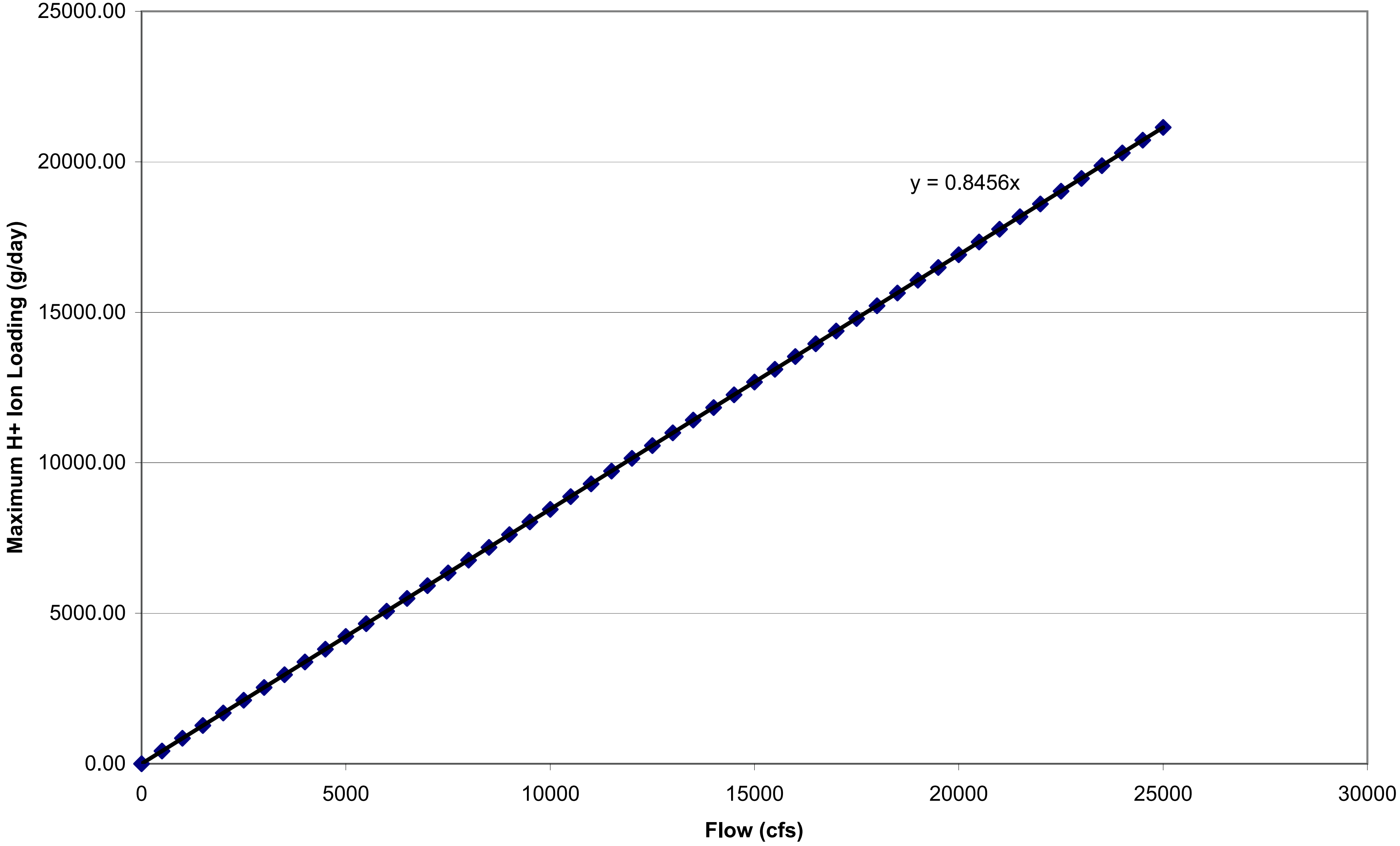
Little Muddy River (NE05)

Water Quality pH Standard = 6.5
Activity CorrectionFactor = 0.9

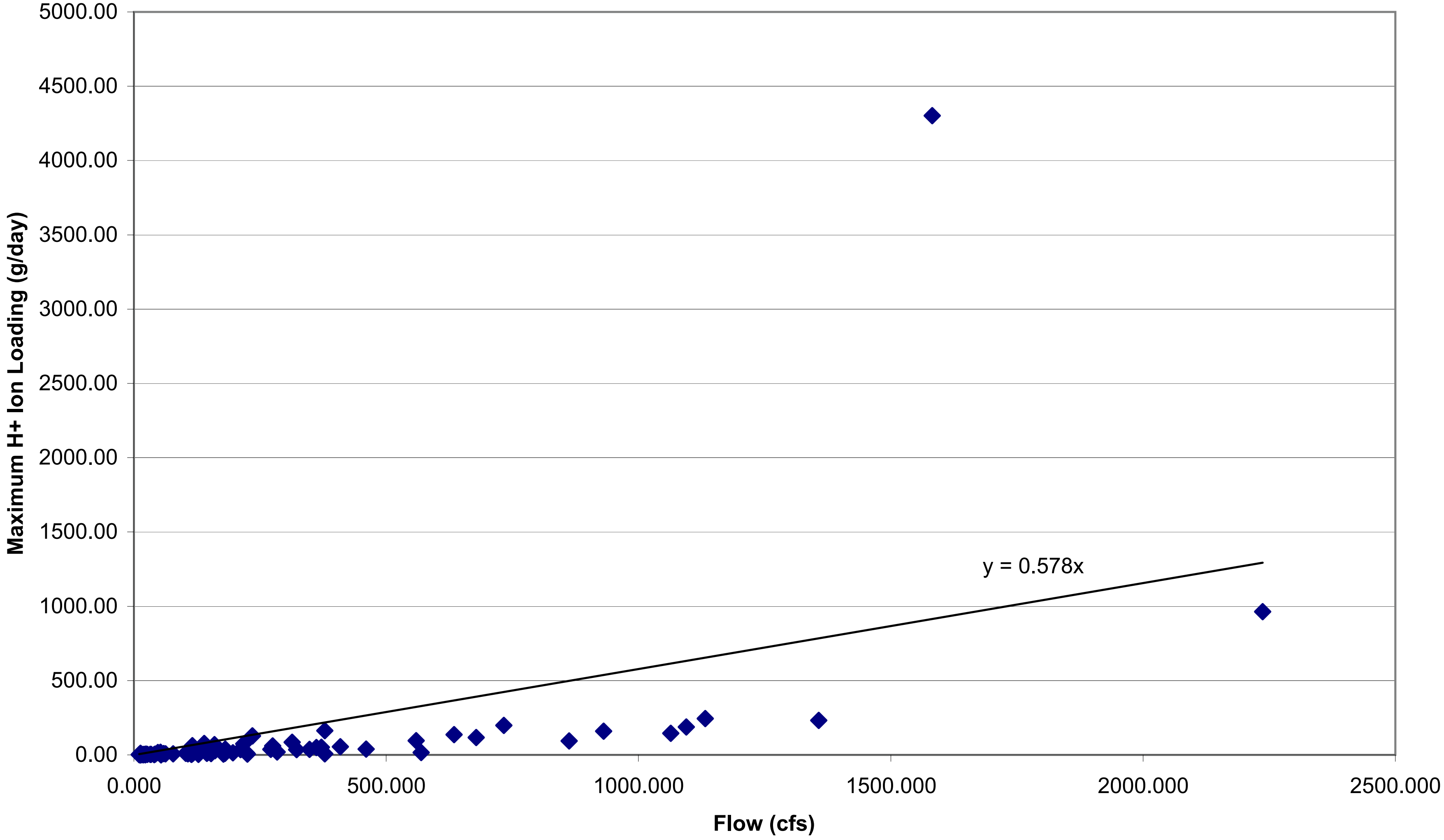
Max Ion Loading (g/day)	Max Ion Loading (lbs/day)	pH (measured)	Flow (cfs)
1.28	0.003	7.600	18.756
85.29	0.188	7.000	313.729
3.11	0.007	8.000	114.238
163.08	0.360	6.800	378.521
9.87	0.022	7.600	144.588
0.58	0.001	8.400	53.539
27.55	0.061	7.200	160.616
1.18	0.003	7.400	10.912
93.37	0.206	7.400	862.756
95.92	0.211	7.200	559.257
199.31	0.439	7.000	733.172
50.64	0.112	7.300	371.701
19.42	0.043	7.300	142.542
3.51	0.008	7.400	32.396
1.93	0.004	7.500	22.507
0.67	0.001	7.700	12.276
49.25	0.109	7.300	361.471
36.94	0.081	7.300	271.103
7.29	0.016	7.600	106.736
10.05	0.022	7.500	116.966
11.11	0.024	7.400	102.644
8.04	0.018	7.300	58.995
2.93	0.006	7.300	21.484
1.96	0.004	7.500	22.848
34.91	0.077	7.400	322.596
6.14	0.014	7.700	113.215
9.80	0.022	7.700	180.735
6.49	0.014	8.200	378.521
4.83	0.011	8.000	177.666
15.48	0.034	8.000	569.487
12.12	0.027	7.700	223.362
4.38	0.010	7.9	127.879
0.97	0.002	7.8	22.507
0.59	0.001	7.8	13.640
13.39	0.030	7.6	196.081
19.40	0.043	7.6	284.061
159.68	0.352	7.2	930.958
20.71	0.046	7.2	120.718
36.26	0.080	7.2	211.426
116.40	0.257	7.2	678.610
68.76	0.152	6.8	159.593
5.23	0.012	7.1	24.212
2.11	0.005	7.2	12.276
34.09	0.075	7.1	157.888
3.69	0.008	7.4	34.101
1.96	0.004	7.4	18.074
6.68	0.015	7.5	77.750
963.81	2.125	6.8	2237.027
55.75	0.123	7.3	409.212
74.46	0.164	6.9	217.564
244.47	0.539	7.1	1132.154
39.57	0.087	7.5	460.364
127.44	0.281	6.7	234.956
75.47	0.166	6.7	139.132
1.16	0.003	7.6	17.051
2.07	0.005	7.4	19.097
1.38	0.003	7.9	40.239
4.85	0.011	8.1	224.726
187.75	0.414	7.2	1094.643
37.64	0.083	7.4	347.830
136.96	0.302	7.1	634.279
39.10	0.086	7.1	181.076
6.75	0.015	7.4	62.405
3.62	0.008	7.3	26.599
3.17	0.007	7.1	14.663
15.87	0.035	7.4	146.634
144.96	0.320	7.3	1063.952
232.79	0.513	7.2	1357.220
59.42	0.131	7.1	275.195
62.70	0.138	6.7	115.602
5.76	0.013	7.3	42.285
11.43	0.025	6.5	13.299
1.39	0.003	7.3	10.230
2.28	0.005	7.2	13.299
1.63	0.004	7.3	11.935
8.30	0.018	7.7	153.114
17.97	0.040	6.9	52.516
16.22	0.036	6.9	47.400
4301.34	9.483	6	1582.287
127.44	0.281	6.7	234.956
75.47	0.166	6.7	139.132

Gage	Date	pH (S.U.)	Flow (cfs)
5597280	1/10/1990	7.6	18.75556
5597280	2/13/1990	7	313.7294
5597280	3/26/1990	8	114.2384
5597280	5/9/1990	6.8	378.5213
5597280	7/18/1990	7.6	144.5883
5597280	8/27/1990	8.4	53.5386
5597280	10/10/1990	7.2	160.6158
5597280	11/14/1990	7.4	10.91233
5597280	1/23/1991	7.4	862.7557
5597280	2/13/1991	7.2	559.2567
5597280	3/20/1991	7	733.1719
5597280	4/24/1991	7.3	371.7011
5597280	5/30/1991	7.3	142.5423
5597280	7/16/1991	7.4	32.39597
5597280	9/5/1991	7.5	22.50667
5597280	10/8/1991	7.7	12.27637
5597280	12/4/1991	7.3	361.4708
5597280	1/9/1992	7.3	271.1031
5597280	3/11/1992	7.6	106.7362
5597280	4/16/1992	7.5	116.9665
5597280	5/20/1992	7.4	102.6441
5597280	6/18/1992	7.3	58.99476
5597280	8/6/1992	7.3	21.48364
5597280	9/8/1992	7.5	22.84768
5597280	4/1/1993	7.4	322.5956
5597280	10/27/1993	7.7	113.2154
5597280	1/19/1994	7.7	180.7354
5597280	3/1/1994	8.2	378.5213
5597280	4/5/1994	8	177.6663
5597280	5/10/1994	8	569.487
5597280	6/1/1994	7.7	223.3617
5597280	7/14/1994	7.9	127.8788
5597280	9/19/1994	7.8	22.50667
5597280	11/1/1994	7.8	13.64041
5597280	12/15/1994	7.6	196.0808
5597280	2/1/1995	7.6	284.0615
5597280	3/9/1995	7.2	930.9578
5597280	4/19/1995	7.2	120.7176
5597280	5/9/1995	7.2	211.4263
5597280	6/14/1995	7.2	678.6102
5597280	7/17/1995	6.8	159.5928
5597280	9/28/1995	7.1	24.21172
5597280	11/6/1995	7.2	12.27637
5597280	12/20/1995	7.1	157.8877
5597280	2/1/1996	7.4	34.10102
5597280	3/5/1996	7.4	18.07354
5597280	4/10/1996	7.5	77.75032
5597280	5/7/1996	6.8	2237.027
5597280	6/19/1996	7.3	409.2122
5597280	7/24/1996	6.9	217.5645
5597280	3/5/1997	7.1	1132.154
5597280	4/2/1997	7.5	460.3637
NE05	7/19/2000	6.7	234.956
NE05	8/22/2000	6.7	139.1321
NE05	10/22/1997	7.6	17.05051
NE05	12/3/1997	7.4	19.09657
NE05	2/2/1998	7.9	40.2392
NE05	3/4/1998	8.1	224.7257
NE05	4/22/1998	7.2	1094.643
NE05	5/21/1998	7.4	347.8304
NE05	6/18/1998	7.1	634.2789
NE05	8/12/1998	7.1	181.0764
NE05	9/8/1998	7.4	62.40486
NE05	10/15/1998	7.3	26.59879
NE05	12/3/1998	7.1	14.66344
NE05	1/5/1999	7.4	146.6344
NE05	2/9/1999	7.3	1063.952
NE05	4/8/1999	7.2	1357.22
NE05	5/19/1999	7.1	275.1952
NE05	7/7/1999	6.7	115.6024
NE05	8/16/1999	7.3	42.28526
NE05	9/30/1999	6.5	13.2994
NE05	10/26/1999	7.3	10.23031
NE05	12/7/1999	7.2	13.2994
NE05	1/27/2000	7.3	11.93536
NE05	2/24/2000	7.7	153.1136
NE05	4/5/2000	6.9	52.51557
NE05	5/25/2000	6.9	47.40041
NE05	6/20/2000	6	1582.287
NE05	7/19/2000	6.7	234.956
NE05	8/22/2000	6.7	139.1321

Flow vs. Maximum H^+ Ion Loading



Flow vs. Maximum H^+ Ion Loading
(Little Muddy NE05)



AppendixI-pHAnalyses.xls, 'QvsLoading_g (NE05)'

Appendix J
Responsiveness Summary

Appendix J
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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from January 23 to March 29, 2004 postmarked, including those from the February 26, 2004 public meeting discussed below.

What is a TMDL?

A Total Maximum Daily Load (TMDL) is the sum of the allowable amount of a pollutant that a water body can receive from all contributing sources and still meet water quality standards or designated uses. The Little Muddy River TMDL report contains a plan detailing the actions necessary to reduce pollutant loads to the impaired water bodies and ensure compliance with applicable water quality standards. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations thereunder.

Background

The watershed targeted for TMDL development is Little Muddy River (ILNE05), which originates in the northeast portion of Jackson County, Illinois. The watershed encompasses an area of approximately 270 square miles. Land use in the watershed is predominately agriculture followed by rural grassland and deciduous forestland. TMDLs developed for impaired water bodies in the Little Muddy River watershed include Little Muddy River segment NE05. In the 1998 Section 303(d) List, Little Muddy River (NE05) was listed as impaired for manganese, sulfates, nitrogen, pH, siltation, low dissolved oxygen (DO), total dissolved solids (TDS), other habitat alterations, and total suspended solids (TSS). Since then, new data assessed in 2002, showed that Little Muddy River (NE05) is currently impaired for manganese, sulfates, pH, low DO, TDS, pathogens, and TSS. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were only developed for the following: manganese, sulfates, pH, low DO, and TDS. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Little Muddy River watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001 and in the city of Murphysboro on December 12, 2001 and February 26, 2004. The Illinois EPA provided public notice for the February 26, 2004 meeting by placing display ads in the Southern Illinoisan on January 27, 2004, and the Carbondale Times and The Spokesman on January 25, 2004. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 34 individuals and organizations were also sent the public notice by first class mail. The draft TMDL

Report was available for review at the Murphysboro Township office and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 8:00 p.m. on Thursday, February 26, 2004. The meeting concluded at 8:30 p.m. There were no attendees. The meeting record remained open until midnight, March 29, 2004. No comments were received.

DISTRIBUTION OF RESPONSIVENESS SUMMARY

Additional copies of this responsiveness summary are available from Mark Britton, Illinois EPA Office of Community Relations, phone 217-524-7342 or email Mark.Britton@epa.state.il.us

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Public Relations	Mark Britton	217-524-7342

Questions regarding the public record and access of the exhibits should be directed to Hearing Officer Sanjay Sofat, 217-782-5544.

Written requests can be mailed to:

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Bureau of Water, Watershed Management Section
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Springfield, IL 62794-9276