Illinois
Environmental
Protection Agency

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

June 2008

IEPA/BOW/07-018

Shoal Creek Watershed TMDL Report

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TMDL Development for the Shoal Creek Watershed, Illinois

This file contains the following documents:

1) U.S. EPA Approval letter for Stage Three TMDL Report

2) Stage One Report: Third Quarter Draft

3) Stage Two Report: Data Report

This report is available as a separate document- www.epa.state.il.us/water/tmdl

4) Stage Three Report: TMDL Development

5) Implementation Plan

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Shoal

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

SEP 20 2007

REPLY TO THE ATTENTION OF:

WW-16J

RECEIVED
SEP 27 2007
Watershed Management Section
BUREAU OF WATER

Marcia T. Willhite, Chief
Bureau of Water
Illinois Environmental Protection Agency
P.O. Box 19276
Springfield, IL 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Loads (TMDLs) from the Illinois Environmental Protection Agency (IEPA) for the Shoal Creek Watershed in Illinois. The TMDLs are for fecal coliform, manganese, silver, ammonia, copper, and TDS that impair the Primary Contact, Public Water Supply, and Aquatic Life uses.

Based on this review, U.S. EPA has determined that Illinois' TMDLs for fecal coliform, manganese, silver, ammonia, copper, and TDS meet the requirements of Section 303(d) of the Clean Water Act and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves 8 TMDLs (see Table 2 of the Enclosure). 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 submitting this TMDL and look forward to future TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Dean Maraldo, TMDL Program Manager at 312-353-2098.

Sincerely yours,

Kevin M. Pierard
Acting Director, Water Division

Enclosure

cc: Bruce Yurdin, IEPA

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Illinois Environmental Protection Agency

Shoal Creek Watershed TMDL
Stage One
Third Quarter Draft Report

April 2006

Draft Report

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Contents

Figures

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Acronyms

°F	degrees Fahrenheit
BMP	best management practice
BOD	biochemical oxygen demand
$CBOD_5$	5-day carbonaceous biochemical oxygen demand
cfs	cubic feet per second
CRP	Conservation Reserve Program
cfu	Coliform forming units
CWA	Clean Water Act
DMR	Discharge Monitoring Reports
DO	dissolved oxygen
ft	Foot or feet
GIS	geographic information system
HUC	Hydrologic Unit Code
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
IL-GAP	Illinois Gap Analysis Project
ILLCP	Illinois Interagency Landscape Classification Project
Illinois EPA	Illinois Environmental Protection Agency
INHS	Illinois Natural History Survey
IPCB	Illinois Pollution Control Board
LA	load allocation
LC	loading capacity
lb/d	pounds per day
mgd	Million gallons per day
mg/L	milligrams per liter
MHP	mobile home park
mL	milliliter
MOS	margin of safety
NA	Not applicable
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NED	National Elevation Dataset
NPDES	National Pollution Discharge Elimination System
NRCS	National Resource Conservation Service

PCBs	polychlorinated biphenyl
PCS	Permit Compliance System
SOD	sediment oxygen demand
SSURGO	Soil Survey Geographic Database
STORET	Storage and Retrieval
STP	Sanitary Treatment Plant
SWCD	Soil and Water Conservation District
TMDL	total maximum daily load
TSS	total suspended solids
ug/L	Micrograms per liter
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	waste load allocation
WTP	Water Treatment Plant

Section 1
Goals and Objectives for Shoal Creek Watershed (0714020306, 0714020303)

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.

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 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 Shoal Creek Watershed

The Illinois EPA has a three-stage approach to TMDL development. The stages are:

- Stage 1 – Watershed Characterization, Data Analysis, Methodology Selection
- Stage 2 – Data Collection (optional)
- Stage 3 – Model Calibration, TMDL Scenarios, Implementation Plan

This report addresses Stage 1 TMDL development for the Shoal Creek Watershed. Stage 2 and 3 will be conducted upon completion of Stage 1. Stage 2 is optional as data collection may not be necessary if additional data is not required to establish the TMDL.

Following this process, the TMDL goals and objectives for the Shoal Creek Watershed will 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 are the impaired water body segments in the Shoal Creek Watershed for which a TMDL will be developed:

- Shoal Creek (OI 05)
- Shoal Creek (OI 08)
- Locust Fork (OIC 02)
- Chicken Creek (OIO 09)
- Cattle Creek (OIP 10)
- Shoal Creek (OI 09)
- Sorento Reservoir (ROZH)

These impaired water body segments are shown on Figure 1-1. There are seven impaired segments within the Shoal Creek Watershed. Table 1-1 lists the water body segment, water body size, and potential causes of impairment for the water body.

Table 1-1 Impaired Water Bodies in Shoal Creek Watershed

Water Body Segment ID	Water Body Name	Size	Causes of Impairment with Numeric Water Quality Standards	Causes of Impairment with Assessment Guidelines
OI 05	Shoal Creek	12.39 miles	Dissolved oxygen	Sedimentation/siltation, total suspended solids (TSS), total phosphorus
OI 08	Shoal Creek	13.11 miles	Manganese, total fecal coliform	
OIC 02	Locust Fork	4.24 miles	Manganese, dissolved oxygen	Sedimentation/siltation, TSS, total phosphorus
OIO 09	Chicken Creek	1.92 miles	Silver, dissolved oxygen	Total nitrogen, sedimentation/siltation, TSS, total phosphorus
OIP 10	Cattle Creek	2.71 miles	Copper, dissolved oxygen, total dissolved solids (TDS), ammonia	Sedimentation/siltation, TSS, total phosphorus
OI 09	Shoal Creek	29.75 miles	Manganese, total fecal coliform	
ROZH	Sorento Reservoir	11 acres	Manganese, total phosphorus(1)	TSS, excess algal growth

(1) The total phosphorus standard applies to reservoirs greater than 20 acres in size. Therefore, this impairment will not be analyzed in the following sections of this report.

Illinois EPA is currently only developing TMDLs for parameters that have numeric water quality standards, and therefore the remaining sections of this report will focus on the dissolved oxygen, manganese, total fecal coliform, silver, copper, and TDS impairments in the Shoal Creek watershed. For potential causes that do not have numeric water quality standards as noted in Table 1-1, TMDLs will not be developed at this time. However, in the implementation plans completed during Stage 3 of the TMDL, many of these potential causes may be addressed by implementation of controls for the pollutants with water quality standards.

The TMDL for 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:

$$TMDL = LC = \Sigma WLA + \Sigma LA + MOS$$

The 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 TMDL will be achieved will be described in the implementation plan. The implementation plan for the Shoal Creek Watershed will describe how water quality standards will be attained. This implementation plan will include recommendations for implementing best management practices (BMPs), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and timeframe for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Shoal Creek Watershed Characteristics** provides a description of the watershed's location, topography, geology, land use, soils, population, and hydrology
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development
- **Section 4 Shoal Creek Watershed Water Quality Standards** defines the water quality standards for the impaired water body
- **Section 5 Shoal Creek Watershed Characterization** presents the available water quality data needed to develop TMDLs, discusses the characteristics of the impaired reservoirs in the watershed, and also describes the point and non-point sources with potential to contribute to the watershed load.
- **Section 6 Approach to Developing TMDL and Identification of Data Needs** makes recommendations for the models and analysis that will be needed for TMDL development and also suggests segments for Stage 2 data collection.

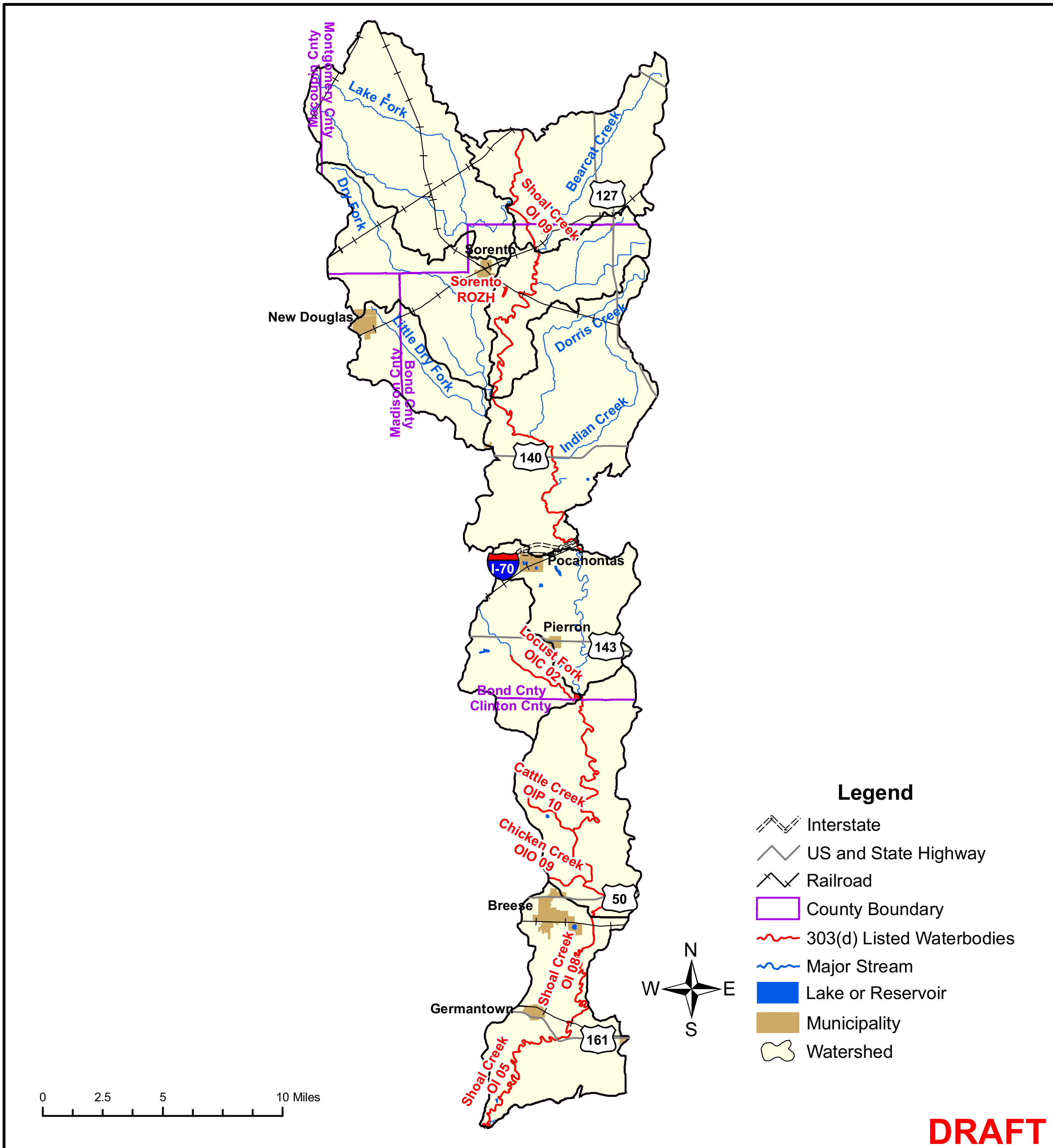

Figure 1-1
Shoal Creek Watershed

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Section 2
Shoal Creek Watershed Description

2.1 Shoal Creek Watershed Location

The Shoal Creek watershed (Figure 1-1) is located in southern Illinois, flows in a southerly direction, and drains approximately 198,861 acres within the state of Illinois. Approximately 55,180 acres lie in southwestern Montgomery County, 1,045 acres lie in southeastern Macoupin County, 90,835 acres lie in western Bond County, 6,015 acres lie in northeastern Madison County, and 45,780 acres lie in western Clinton County.

2.2 Topography

Topography is an important factor in watershed management because stream types, precipitation, and soil types can vary dramatically by elevation. National Elevation Dataset (NED) coverages containing 30-meter grid resolution elevation data are available from the USGS for each 1:24,000-topographic quadrangle in the United States. Elevation data for the Shoal Creek watershed was obtained by overlaying the NED grid onto the GIS-delineated watershed. Figure 2-1 shows the elevations found within the watershed.

Elevation in the Shoal Creek watershed ranges from 699 feet above sea level in the headwaters of Shoal Creek to 394 feet at its most downstream point in the southern end of the watershed. The absolute elevation change is 147 feet over the approximately 77-mile stream length of Shoal Creek, which yields a stream gradient of approximately 1.9 feet per mile.

2.3 Land Use

Land use data for the Shoal Creek watershed were extracted from the Illinois Gap Analysis Project (IL-GAP) Land Cover data layer. IL-GAP was started at the Illinois Natural History Survey (INHS) in 1996, and the land cover layer was the first component of the project. The IL-GAP Land Cover data layer is a product of the Illinois Interagency Landscape Classification Project (IILCP), an initiative to produce statewide land cover information on a recurring basis cooperatively managed by the United States Department of Agriculture National Agricultural Statistics Service (NASS), the Illinois Department of Agriculture (IDA), and the Illinois Department of Natural Resources (IDNR). The land cover data was generated using 30-meter grid resolution satellite imagery taken during 1999 and 2000. The IL-GAP Land Cover data layer contains 23 land cover categories, including detailed classification in the vegetated areas of Illinois. Appendix A contains a complete listing of land cover categories. (Source: IDNR, INHS, IDA, USDA NASS's 1:100,000 Scale Land Cover of Illinois 1999-2000, Raster Digital Data, Version 2.0, September 2003.)

The land use of the Shoal Creek watershed was determined by overlaying the IL-GAP Land Cover data layer onto the GIS-delineated watershed. Table 2-1 contains the land uses contributing to the Shoal Creek watershed, based on the IL-GAP land cover categories and also includes the area of each land cover category and percentage of the watershed area. Figure 2-2 illustrates the land uses of the watershed.

The land cover data reveal that approximately 143,822 acres, representing nearly 72 percent of the total watershed area, are devoted to agricultural activities. Corn and soybeans farming accounts for about 25 percent and 27 percent of the watershed area, respectively; winter wheat/soybeans farming accounts for about 7 percent; and rural grassland accounts for about 7 percent. Upland forests and wetlands cover approximately 14 and 9 percent of the watershed, respectively. Other land cover categories represent less that 3 percent of the watershed area.

Table 2-1 Land Use in Shoal Creek Watershed

Land Cover Category	Area (Acres)	Percentage
Corn	50,174	25.2%
Soybeans	54,177	27.2%
Winter Wheat	4,757	2.4%
Other Small Grains and Hay	4,630	2.3%
Winter Wheat/Soybeans	14,503	7.3%
Other Agriculture	1,881	0.9%
Rural Grassland	13,700	6.9%
Upland	28,618	14.4%
Forested Areas	2,941	1.5%
High Density	1,278	0.7%
Low/Medium Density	2,438	1.2%
Urban Open Space	869	0.5%
Wetlands	18,320	9.2%
Surface Water	356	0.2%
Barren and Exposed Land	217	0.1%
Total	**198,859**	**100%**

1. Forested areas include partial canopy/savannah upland.
2. Wetlands include shallow marsh/wet meadow, deep marsh, seasonally/ temporally flooded, floodplain forest, and shallow water.

2.4 Soils

Two types of soil data are available for use within the state of Illinois through the National Resource Conservation Service (NRCS). General soils data and map unit delineations for the entire state are provided as part of the State Soil Geographic (STATSGO) database. Soil maps for the database are produced by generalizing detailed soil survey data. The mapping scale for STATSGO is 1:250,000. More detailed soils data and spatial coverages are available through the Soil Survey Geographic (SSURGO) database for a limited number of counties. For SSURGO data, field mapping methods using national standards are used to construct the soil maps. Mapping scales generally range from 1:12,000 to 1:63,360 making SSURGO the most detailed level of soil mapping done by the NRCS.

The Shoal Creek watershed falls within Montgomery, Macoupin, Bond, Madison, and Clinton Counties. At this time, SSURGO data is only available for Macoupin County. STATSGO data has been used in lieu of SSURGO data for the portion of the watershed that lies within the remaining counties. Figure 2-3 displays the STATSGO soil map units as well as the SSURGO soil series in the Shoal Creek watershed. Attributes of the spatial coverage can be linked to the STATSGO and SSURGO databases, which provide information on various chemical and physical soil characteristics for each map unit and soil series. Of particular interest for TMDL development are the hydrologic soil groups as well as the K-factor of the Universal Soil Loss Equation. The following sections describe and summarize the specified soil characteristics for the Shoal Creek Watershed.

2.4.1 Shoal Creek Watershed Soil Characteristics

Appendix B contains the STATSGO Map Unit IDs (MUIDs) for the Shoal Creek Watershed as well as the SSURGO soil series. The table also contains the area, dominant hydrologic soil group, and K-factor range. Each of these characteristics is described in more detail in the following paragraphs. The predominant soil type in the watershed are soils categorized as a fine-grained and made up of silts and clays with a liquid limit of less than 50 percent that tend toward a lean clay.

Hydrologic soil groups are used to estimate runoff from precipitation. Soils are assigned to one of four groups. They are grouped according to the infiltration of water when the soils are thoroughly wet and receive precipitation from long-duration storms. Hydrologic soil groups B, C, and D are found within the Shoal Creek watershed with the majority of the watershed falling into category C. Category C soils are defined as "soils having a slow infiltration rate when thoroughly wet." C soils consist "chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture." These soils have a slow rate of water transmission (NRCS, 2005).

A commonly used soil attribute is the K-factor. The K-factor:

> *Indicates the susceptibility of a soil to sheet and rill erosion by water.* (The K-factor) *is one of six factors used in the Universal Soil Loss Equation (USLE) to predict the average annual rate of soil loss by sheet and rill erosion. Losses are expressed in tons per acre per year. These estimates are based primarily on percentage of silt, sand, and organic matter (up to 4 percent) and on soil structure and permeability. Values of K range from 0.02 to 0.69. The higher the value, the more susceptible the soil is to sheet and rill erosion by water (NRCS 2005).*

The distribution of K-factor values in the Shoal Creek Watershed range from 0.17 to 0.55.

2.5 Population

Population data were retrieved from Census 2000 TIGER/Line Data from the U.S. Bureau of the Census. Geographic shape files of census blocks were downloaded for every county containing any portion of the watersheds. The block files were clipped to each watershed so that only block populations associated with the watershed would be counted. The census block demographic text file (PL94) containing population data was downloaded and linked to each watershed and summed. City populations were taken from the US Bureau of the Census. For municipalities that are located across watershed borders, the population was estimated based on the percentage of area of municipality within the watershed boundary.

Approximately 15,837 people reside in the watershed. The major municipalities in the Shoal Creek watershed are shown in Figure 1-1. The city of Breese is the largest population center in the watershed and contributes an estimated 4,048 people to total watershed population.

2.6 Climate and Streamflow

2.6.1 Climate

Southern Illinois has a temperate climate with hot summers and cold, snowy winters. Monthly precipitation and temperature data from Hillsboro (station id. 4108) in Montgomery County were extracted from the NCDC database for the years of 1901 through 2004. The data station in Hillsboro, Illinois is just north of the watershed and was chosen to be representative of precipitation throughout the Shoal Creek watershed which is lacking an active weather station within its boundary.

Table 2-2 contains the average monthly precipitation along with average high and low temperatures for the period of record. The average annual precipitation is approximately 39 inches.

Table 2-2 Average Monthly Climate Data in the Shoal Creek Watershed

Month	Total Precipitation (inches)	Maximum Temperature (degrees F)	Minimum Temperature (degrees F)
January	2.3	38	21
February	2	43	24
March	3.3	54	33
April	4	66	43
May	4.5	76	53
June	4.2	85	62
July	3.4	89	66
August	3.5	88	64
September	3.4	81	56
October	3.1	70	45
November	3	54	34
December	2.5	42	25
Total	**39.2**		

2.6.2 Streamflow

Analysis of the Shoal Creek Watershed requires an understanding of flow throughout the drainage area. USGS gage 05594000 (Shoal Creek near Breese, Illinois) is the only available data gage within the watershed with current data (Figure 2-4). The gage is located on the OI 08 segment of Shoal Creek.

Data was available for the gage from the USGS for the years 1909 through 2004. The average monthly flows recorded at the gage range from 138 cubic feet per second (cfs) in September to 978 cfs in March with a mean annual monthly flow of 548 cfs (Figure 2-5).

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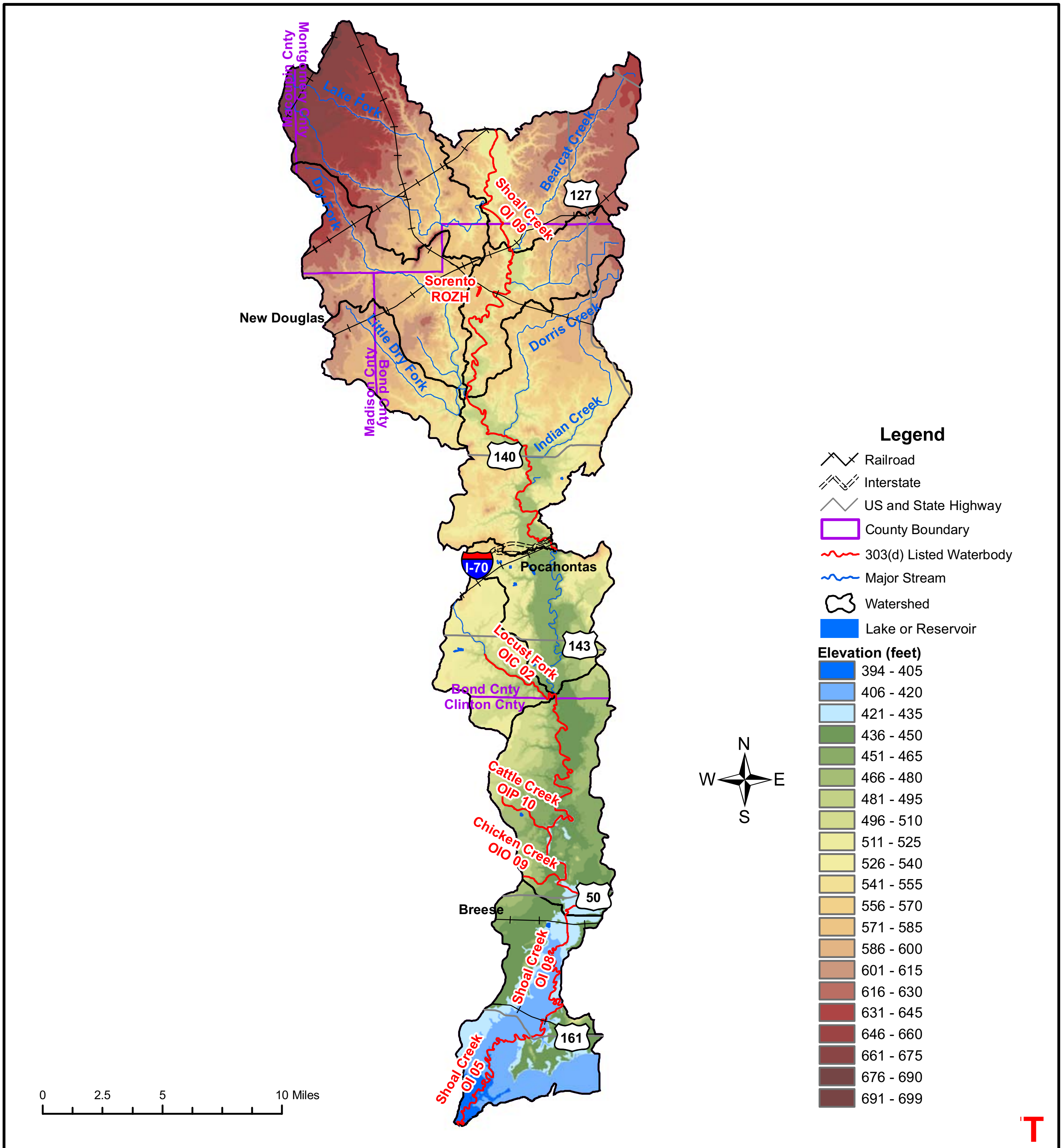

Figure 2-1
Shoal Creek Watershed
Elevation

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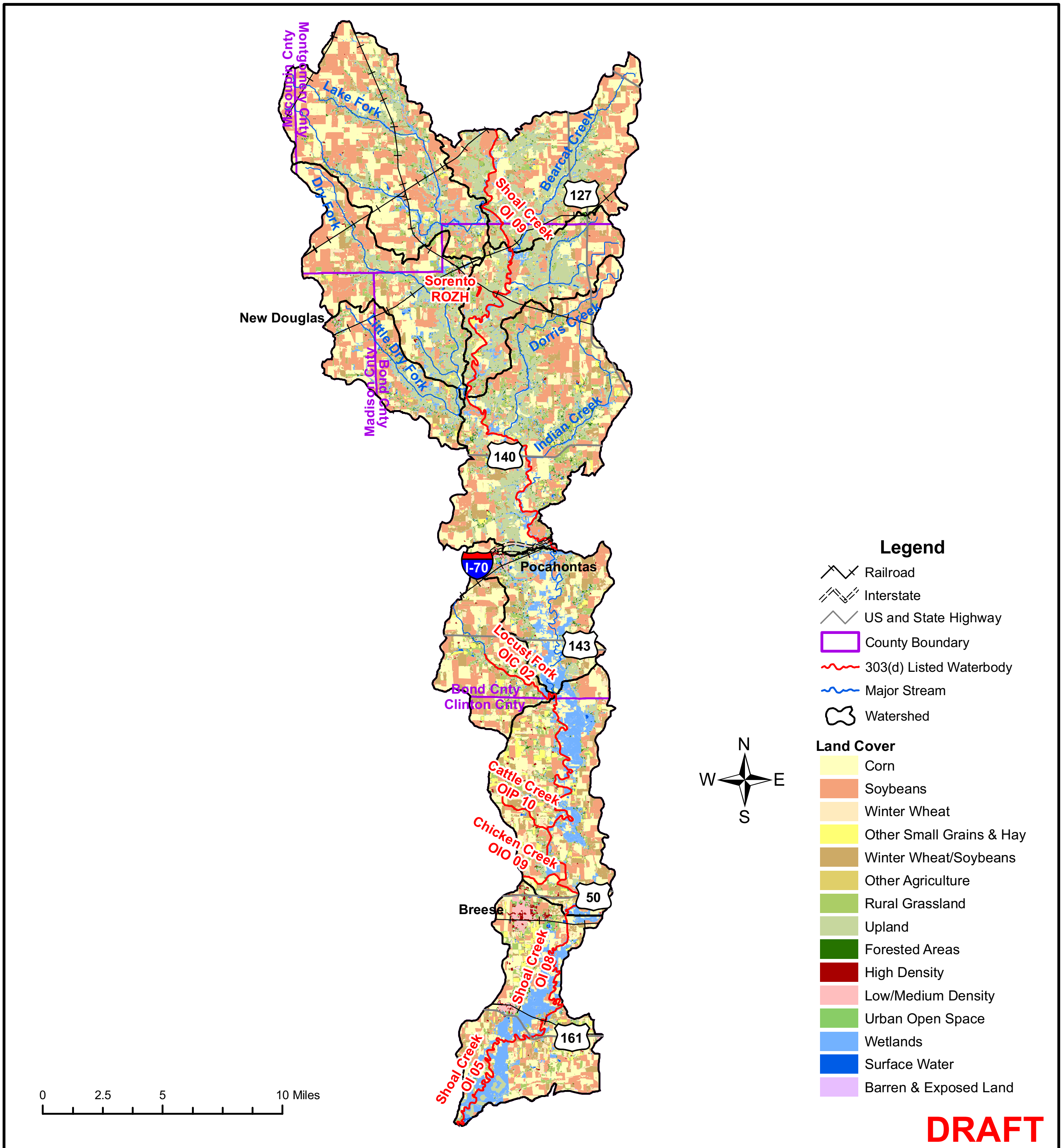

Figure 2-2
Shoal Creek Watershed
Land Use

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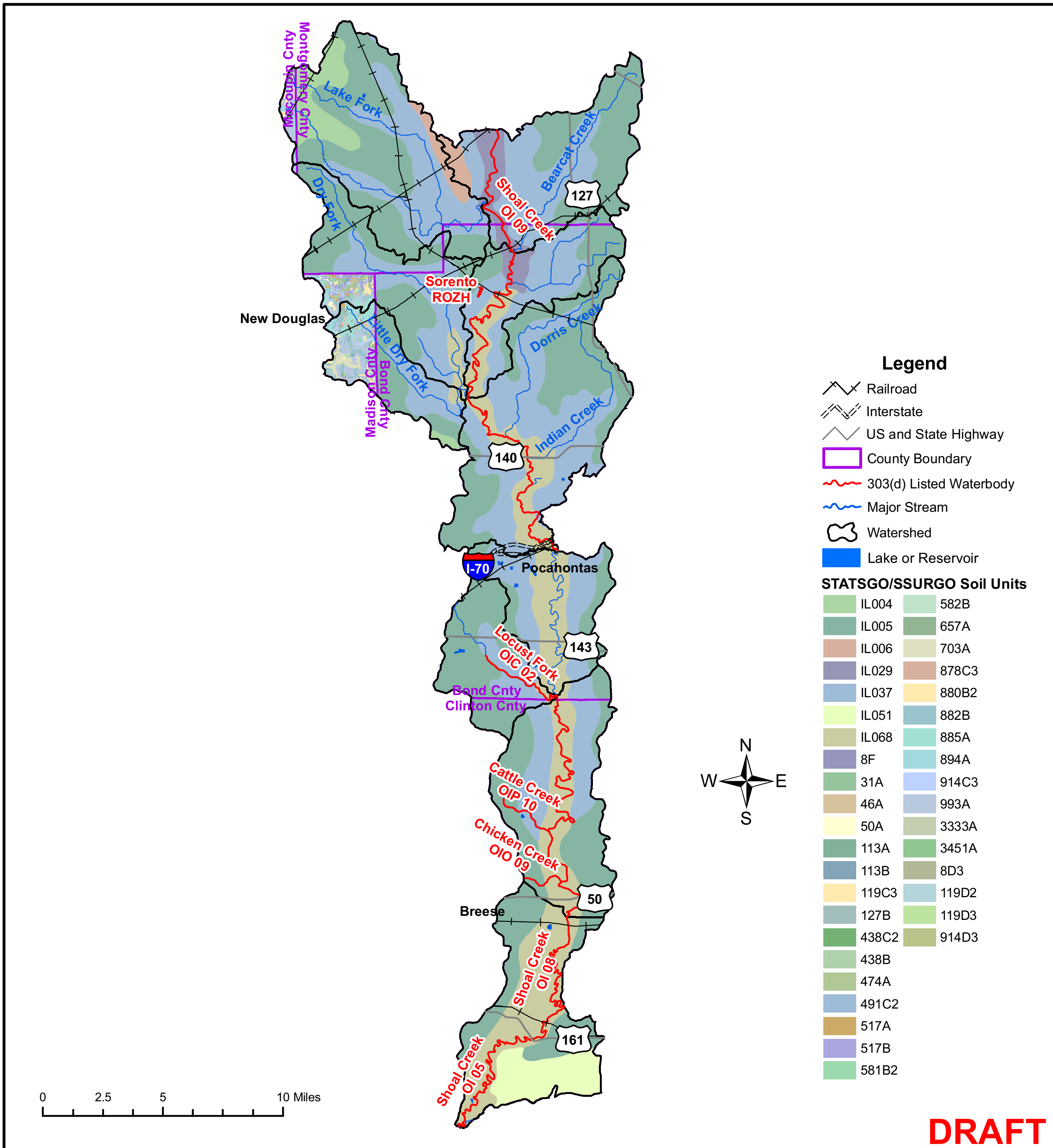

Figure 2-3
Shoal Creek Watershed
Soils

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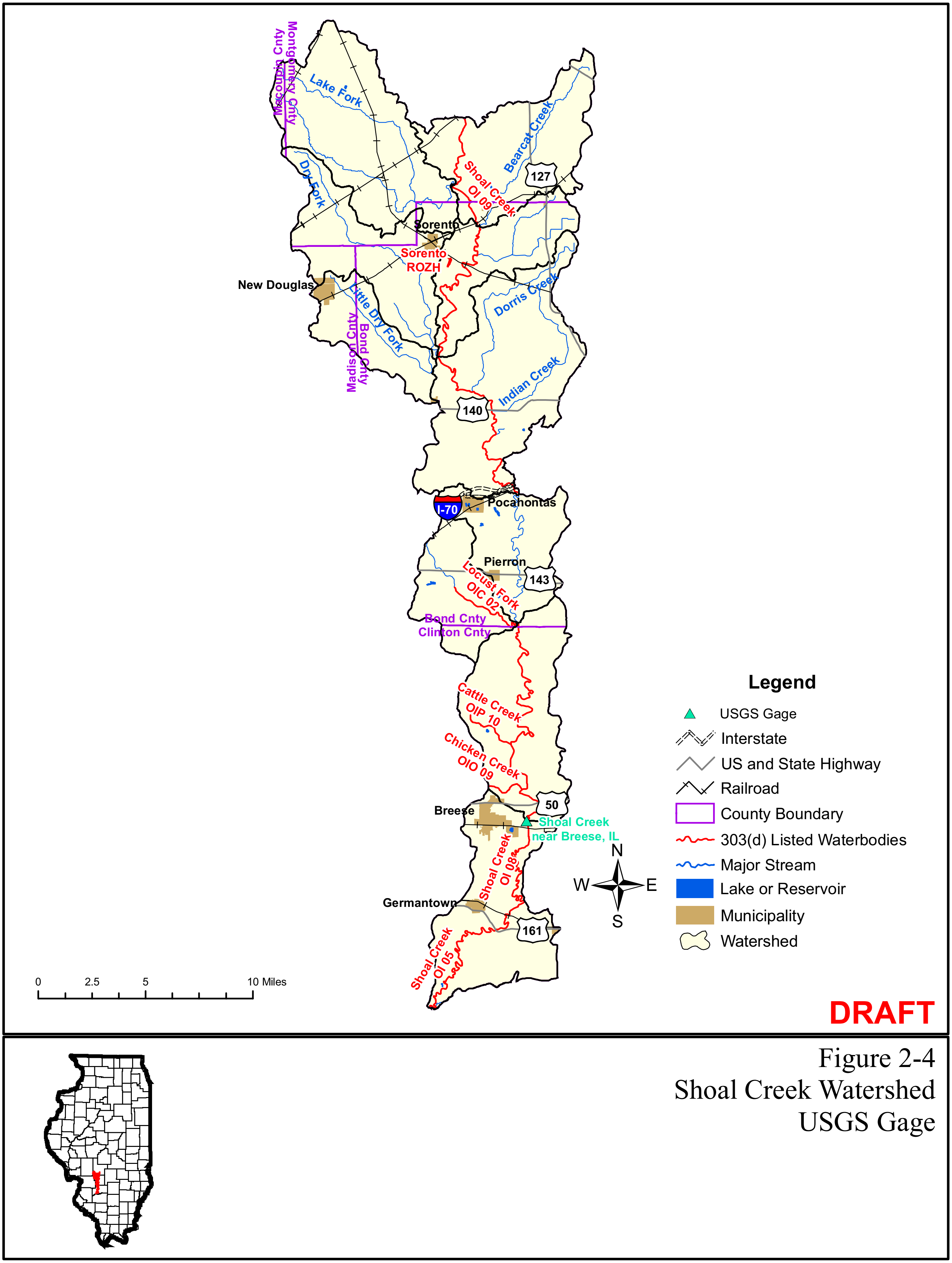

Figure 2-4
Shoal Creek Watershed
USGS Gage

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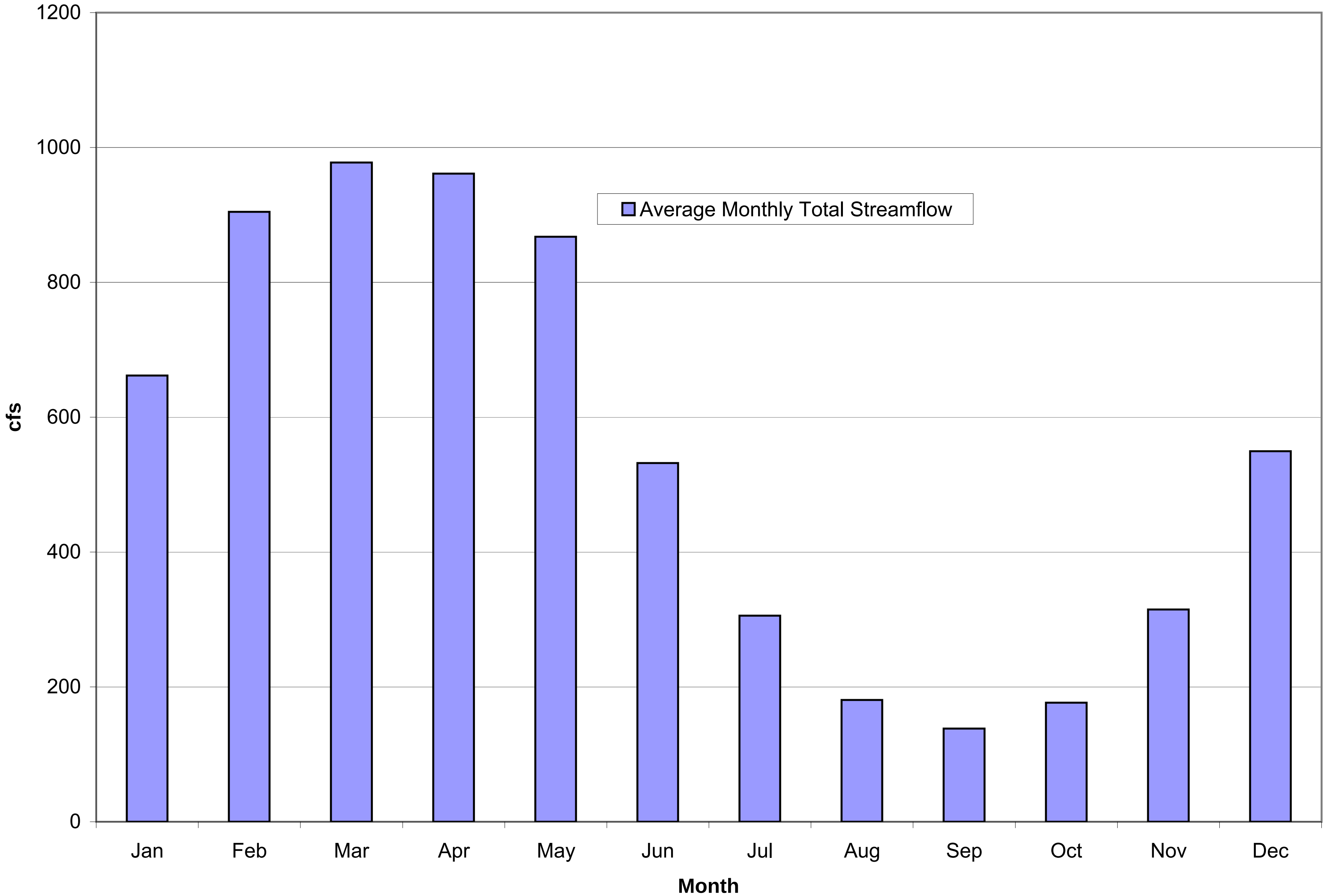

Figure 2-5:
Average Total Monthly Streamflow
at USGS gage 05594000
Shoal Creek near Breese, IL

CDM

T:\GIS\WRITEUP\8 Shoal Creek\Data\Shoal_precip-temp-flow.xlsflowchart

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Section 3
Public Participation and Involvement

3.1 Shoal Creek Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It is important to involve the public as early in the process as possible to achieve maximum cooperation and counter concerns as to the purpose of the process and the regulatory authority to implement any recommendations.

Illinois EPA, along with CDM, will hold up to four public meetings within the watershed throughout the course of the TMDL development. This section will be updated once public meetings have occurred.

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Section 4
Shoal Creek 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 2005). The designated uses applicable to the Shoal Creek Watershed are the General Use and Public and Food Processing Water Supplies Use.

4.2.1 General Use

The General Use classification is defined by IPCB as: The General Use standards will protect the state's water for aquatic life, wildlife, agricultural use, secondary contact use and most industrial uses and ensure the aesthetic quality of the state's aquatic environment. Primary contact uses are protected for all General Use waters whose physical configuration permits such use.

4.2.2 Public and Food Processing Water Supplies

The Public and Food Processing Water Supplies Use is defined by IPCB as: These are cumulative with the general use standards of Subpart B and must be met in all waters designated in Part 303 at any point at which water is withdrawn for treatment and distribution as a potable supply or for food processing.

4.3 Illinois Water Quality Standards

To make 303(d) listing determinations for aquatic life uses, Illinois EPA first collects biological data and if this data suggests that impairment to aquatic life is occurring, then a comparison of available water quality data with water quality standards occurs.

For public and food processing water supply waters, Illinois EPA compares available data with water quality standards to make impairment determinations. Tables 4-1 and 4-2 present the water quality standards of the potential causes of impairment for both lakes and streams within the Shoal Creek Watershed. Only constituents with numeric water quality standards will have TMDLs developed at this time.

Table 4-1 Summary of Water Quality Standards for Potential Shoal Creek Watershed Lake Impairments

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies
Excess Algal Growth	NA	No numeric standard	No numeric standard
Manganese	µg/L	1000	150
Total Phosphorus	mg/L	0.05(1)	No numeric standard
Total Suspended Solids	NA	No numeric standard	No numeric standard

(1) Standard applies in particular inland lakes and reservoirs (greater than 20 acres) and in any stream at the point where it enters any such lake or reservoir. Sorento Reservoir is less than 20 acres.
µg/L = micrograms per liter mg/L = milligrams per liter NA = Not Applicable

Table 4-2 Summary of Water Quality Standards for Potential Shoal Creek Watershed Stream Impairments

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies
Copper	µg/L	Acute standard(1) = (exp[-1.464+0.9422 x ln(H)]) x 0.960* Chronic standard(2) = (exp[-1.465+0.8545 x ln(H)]) x 0.960*	No numeric standard
Manganese	µg/L	1000	150
Nitrogen, ammonia (Total)	mg/L	15(3)	No numeric standard
Oxygen, Dissolved	mg/L	5.0 instantaneous minimum; 6.0 minimum during at least 16 hours of any 24 hour period	No numeric standard
Sedimentation/ Siltation	NA	No numeric standard	No numeric standard
Silver	µg/L	5	No numeric standard
Total Dissolved Solids	µg/L	1000	500

Table 4-2 Summary of Water Quality Standards for Potential Shoal Creek Watershed Stream Impairments (continued)

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies
Total Fecal Coliform	Count/ 100 mL	May through Oct – 200(4), 400(5) Nov though Apr – no numeric standard	2000(4)
Total Nitrogen as N	NA	No numeric standard	No numeric standard
Total Phosphorus - Statistical Guideline	NA	No numeric standard	No numeric standard
Total Suspended Solids	NA	No numeric standard	No numeric standard

µg/L = micrograms per liter exp(x) = base natural logarithms raised to the x- power

mg/L = milligrams per liter ln(H) = natural logarithm of hardness of the receiving water in mg/L

NA = Not Applicable * = conversion factor for multiplier for dissolved metals

(1) Not to be exceeded except as provided in 35 Ill. Adm. Code 302.208(d).

(2) Not to be exceeded by the average of at least four consecutive samples collected over any period of at least four days except as provided in 35 Ill. Adm. Code 302.208(d). The samples used to demonstrate attainment or lack of attainment with a chronic standard must be collected in a manner that assures an average representative of the sampling period. To calculate attainment status of chronic metals standards, the concentration of the metal in each sample is divided by the calculated water quality standard for the sample to determine a quotient. The water quality standard is attained if the mean of the sample quotients is less than or equal to one for the duration of the averaging period.

(3) The allowable concentration varies in accordance with water temperature and pH values. 15 mg/L is the maximum total ammonia nitrogen value allowed. In general, as both temperature and pH decrease, the allowable value of total ammonia nitrogen increases. For example, when the pH is 8.0 and the temperature is 20 degrees C, the acute standard is 8.4 mg/L, the chronic standard is 1.7 mg/L, and the subchronic standard is 4.3 mg/L. See 35 Ill. Adm. Code 302.212 for the formulae by which the standards are calculated.

(4) Geometric mean based on a minimum of 5 samples taken over not more than a 30 day period.

(5) Standard shall not be exceeded by more than 10% of the samples collected during any 30 day period.

4.4 Potential Pollutant Sources

In order to properly address the conditions within the Shoal Creek watershed, potential pollution sources must be investigated for the pollutants where TMDLs will be developed. The following is a summary of the potential sources associated with the listed causes for the 303(d) listed segments in this watershed. They are summarized in Table 4-3.

Table 4-3 Summary of Potential Sources for Shoal Creek Watershed

Segment ID	Segment Name	Potential Causes	Potential Sources
OI 05	Shoal Creek	Sedimentation/siltation, dissolved oxygen, total suspended solids, total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, intensive animal feeding operations
OI 08	Shoal Creek	Manganese, total fecal coliform	Source unknown
OIC 02	Locust Fork	Manganese, sedimentation/siltation, dissolved oxygen, total suspended solids, total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, intensive animal feeding operations, source unknown
OIO 09	Chicken Creek	Silver, total nitrogen as N, sedimentation/siltation, dissolved oxygen, total suspended solids, total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, pasture grazing – riparian and/or upland, intensive animal feeding operations, source unknown
OIP 10	Cattle Creek	Copper, ammonia nitrogen (total), sedimentation/siltation, dissolved oxygen, total dissolved solids, total suspended solids, total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, pasture grazing – riparian and/or upland, intensive animal feeding operations, source unknown
OI 09	Shoal Creek	Manganese, total fecal coliform	Source unknown
ROZH	Sorento Reservoir	Manganese, total suspended solids, excess algal growth, total phosphorus	Agriculture, crop-related sources, nonirrigated crop production, source unknown

Section 5
Shoal Creek Watershed Characterization

Data was collected and reviewed from many sources in order to further characterize the Shoal Creek watershed. Data has been collected in regards to water quality, reservoirs, and both point and nonpoint sources. This information is presented and discussed in further detail in the remainder of this section.

5.1 Water Quality Data

There are nine historic water quality stations within the Shoal Creek watershed that were used for this report. Figure 5-1 shows the water quality data stations within the watershed that contain data relevant to the impaired segments.

The impaired water body segments in the Shoal Creek watershed were presented in Section 1. Refer to Table 1-1 for impairment information specific to each segment. The following sections address both stream and lake impairments. Data is summarized by impairment and discussed in relation to the relevant Illinois numeric water quality standard. Data analysis is focused on all available data collected since 1990. STORET data is available for stations sampled prior to January 1, 1999 while Illinois EPA data (electronic and hard copy) are available for stations sampled after that date. The following sections will first discuss Shoal Creek watershed stream data followed by Shoal Creek watershed reservoir data.

5.1.1 Stream Water Quality Data

The Shoal Creek watershed has six impaired stream segments within its drainage area that are addressed in this report. There is one active water quality station on each impaired segment (see Figure 5-1). The data summarized in this section include water quality data for impaired constituents as well as parameters that could be useful in future modeling and analysis efforts. All historic data is available in Appendix C.

5.1.1.1 Fecal Coliform

Shoal Creek segments OI 08 and OI 09 are listed as impaired for total fecal coliform. Table 5-1 summarizes available historic fecal coliform data on the segment. The general use water quality standard for fecal coliform states that the standard of 200 per 100 mL not be exceeded by the geometric mean of at least five samples, nor can 10 percent of the samples collected exceed 400 per 100 mL in protected waters, except as provided in 35 Ill. Adm. Code 302.209(b). Samples must be collected over a 30 day period or less during peak fecal coliform application periods (May through October).The public water supply water quality standard states that the standard of 2,000 per 100 mL not be exceeded by the geometric mean of at least five samples.

Table 5-1 Existing Fecal Coliform Data for Shoal Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Period of Record and Number of Data Points	Geometric mean of all samples	Maximum	Minimum	Number of samples > 200 (1)	Number of samples > 400 (1)	Number of samples > 2000
Shoal Creek Segment OI 08; Sample Location OI 08							
Total Fecal Coliform (cfu/100 mL)	2000-2005; 39	401	22,000	2	13	10	4
Shoal Creek Segment OI 09; Sample Location OI 09							
Total Fecal Coliform (cfu/100 mL)	2000-2002; 18	449	38,600	10	6	4	1

(1) Samples collected during the months of May through October

There are no instances since 1990 where at least five samples have been collected during a 30-day period. The summary of data presented in Table 5-1 reflects single samples compared to the standards during the appropriate months. Figure 5-2 shows the total fecal coliform samples collected over time at OI 08 and OI 09.

5.1.1.2 Dissolved Oxygen

In the Shoal Creek watershed, Shoal Creek segment OI 05, Locust Fork segment OIC 02, Chicken Creek segment OIO 09, and Cattle Creek segment OIP 10 are listed as impaired for dissolved oxygen (DO). Table 5-2 summarizes the available historic DO data since 1990 for the impaired stream segments (raw data contained in Appendix C). The table also shows the number of violations for each segment. A sample was considered a violation if it was below 5.0 mg/L. The average DO concentration is below the standard (5.0 mg/L instantaneous minimum) on two of the four impaired segments. Minimum values for all segments are below the DO standard.

Table 5-2 Existing Dissolved Oxygen Data for Shoal Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Illinois WQ Standard (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Shoal Creek Segment OI 05; Sample Location OI 05						
DO	5.0(1)	2002; 3	5.4	6.5	4.0	1
Locust Fork Segment OIC 02; Sample Locations OIC 02						
DO	5.0(1)	1991; 3	4.4	9.3	1.7	1
Chicken Creek Segment OIO 09; Sample Location OIO 09						
DO	5.0(1)	1991; 2	5.0	6.7	3.3	1
Cattle Creek Segment OIP 10; Sample Location OIP 10						
DO	5.0(1)	1991; 3	4.2	8.4	0.1	2

(1) Instantaneous Minimum

Table 5-3 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts for DO. Where available, all nutrient, biological oxygen demand (BOD), and total organic carbon data has been collected for possible use in future analysis.

Table 5-3 Data Availability for DO Data Needs Analysis and Future Modeling Efforts

Sample Location and Parameter	Available Period of Record Post 1990	Number of Samples
Shoal Creek Segment OI 05; Sample Location OI 05		
Nitrogen Kjeldahl Total Bottom Dep Dry Wt (mg/kg)	1996	1
Phosphorus, Total, Bottom Deposit (mg/kg-P Dry Wgt)	1996	1
Locust Fork Segment OIC 02; Sample Locations OIC 02		
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1991	3
Ammonia, Unionized (mg/L as N)	1991	3
BOD, 5 Day, 20 Deg C (mg/L)	1991	3
BOD, Carbonaceous, 5 Day, 20 Deg C (mg/L)	1991	3
COD, .025N K2CR2O7 (mg/L)	1991	3
COD, Bottom Deposits, Dry Weight (mg/kg)	1991	1
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1991	3
Nitrogen Kjeldahl Total Bottom Dep Dry Wt (mg/kg)	1991	1
Nitrogen, Ammonia, Total (mg/L as N)	1991	3
Nitrogen, Kjeldahl, Total (mg/L as N)	1991	3
Phosphorus, Total (mg/L as P)	1991	3
Phosphorus, Total, Bottom Deposit (mg/kg-P Dry Wgt)	1991	1
Chicken Creek Segment OIO 09; Sample Location OIO 09		
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1991	2
Ammonia, Unionized (mg/L as N)	1991	2
BOD, 5 Day, 20 Deg C (mg/L)	1991	2
BOD, Carbonaceous, 5 Day, 20 Deg C (mg/L)	1991	2
COD, .025N K2CR2O7 (mg/L)	1991	2
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1991	2
Nitrogen, Ammonia, Total (mg/L as N)	1991	2
Nitrogen, Kjeldahl, Total (mg/L as N)	1991	2
Phosphorus, Total (mg/L as P)	1991	2
Cattle Creek Segment OIP 10; Sample Location OIP 10		
Ammonia, Unionized (Calc Fr Temp-pH-NH4) (mg/L)	1991	3
Ammonia, Unionized (mg/L as N)	1991	3
BOD, 5 Day, 20 Deg C (mg/L)	1991	3
BOD, Carbonaceous, 5 Day, 20 Deg C (mg/L)	1991	3
COD, .025N K2CR2O7 (mg/L)	1991	3
Nitrite plus Nitrate, Total 1 Det. (mg/L as N)	1991	3
Nitrogen, Ammonia, Total (mg/L as N)	1991	3
Nitrogen, Kjeldahl, Total (mg/L as N)	1991	3
Phosphorus, Total (mg/L as P)	1991	3

5.1.1.3 Total Ammonia

Table 5-4 Total Ammonia Samples Collected on Cattle Creek segment OIP10

Sample Location	Sample Date	Total Ammonia (mg/L)
OIP 10	4/15/91	0.38
OIP 10	9/18/91	24
OIP 10	10/28/91	3.0

Segment OIP10 of Cattle Creek is listed as impaired for total ammonia nitrogen. The allowable concentration of total ammonia varies as it is calculated using water temperature and pH values. Regardless of temperature and pH variation, the State sets 15 mg/L as the maximum total ammonia nitrogen value allowed. There have been three samples collected on the segment since 1990. Table 5-4 contains the sampling results. The sample collected in September of 1991 exceeded the maximum allowable concentration.

5.1.1.4 Metals: Silver and Copper

Chicken Creek segment OIO 09 is impaired for silver and Cattle Creek segment OIP 10 is impaired for copper. Table 5-5 contains a summary of metal data collected on impaired segments. The applicable water quality standard for silver is a maximum total silver concentration of 5.0 µg/L. The applicable copper water quality standard is dependent on water hardness. Hardness data has been collected in conjunction with copper data. The number of violations presented in Table 5-5 for copper represents violations of the general use chronic standard. There were not enough available total silver or dissolved copper data for time series plots. Table 5-5 shows that one of the two total silver samples and two of three dissolved copper samples violated the corresponding water quality standards.

Table 5-5 Existing Metals Data (Silver and Copper) for Shoal Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Illinois WQ Standard (µg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Chicken Creek Segment OIO 09; Sample Location OIO 09						
Total Silver (µg/L)	General Use: 5.0	1991; 2	8	13	3	1
Cattle Creek Segment OIP 10; Sample Location OIP 10						
Dissolved Copper (µg/L)	Hardness Dependent	1991; 3	502	1,461	10	2

5.1.1.5 Other Constituents: Manganese and Total Dissolved Solids

Shoal Creek segments OI 08 and OI 09 and Locust Fork segment OIC 02 are impaired for manganese. The applicable water quality standard is a maximum total manganese concentration of 1,000 µg/L for general use and 150 µg/L for public water supply. Cattle Creek segment OIP 10 is impaired for total dissolved solids (TDS). The applicable water quality standard for TDS is a maximum TDS concentration of 1,000 mg/L for general use and 500 mg/L for public water supply. Standards for the general use waters cannot be exceeded except where mixing is allowed as provided in 35 Ill. Adm. Code 302.102.

Table 5-6 summarizes the available historic manganese and TDS data since 1990 for the impaired stream segments. This includes dissolved and bottom deposit manganese samples where available. The table also shows the number of violations for each segment. Figure 5-3 shows total manganese concentrations over time on Shoal Creek segments OI 08 and OI 09. There is limited manganese and TDS data for segments OIC 02 and OIP 10. These impaired segments have only three data points each.

Table 5-6 Existing Chemical Constituents Data (Manganese and Total Dissolved Solids) for Shoal Creek Watershed Impaired Stream Segments

Sample Location and Parameter	Illinois WQ Standard |(µg/L or mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum	Number of Violations
Shoal Creek Segment OI 08; Sample Location OI 08						
Total Manganese (µg/L)	General Use: 1000	1990-2003; 41	269	680	76	0
	Public Water Supply: 150					35
Dissolved Manganese (µg/L)	NA	1990-2003; 41	131	570	15	NA
Shoal Creek Segment OI 09; Sample Location OI 09						
Total Manganese (µg/L)	General Use: 1000	1990-2002; 26	214	370	71	0
	Public Water Supply: 150					18
Locust Fork Segment OIC 02; Sample Locations OIC 02						
Total Manganese (µg/L)	General Use: 1000	1991; 3	1,557	4,202	164	1
	Public Water Supply: 150					3
Manganese Sediments (mg/kg)	NA	1991; 1	624	624	624	NA
Cattle Creek Segment OIP 10; Sample Location OIP 10						
TDS (µg/L)	General Use: 1000	1991; 3	719	1,220	304	1
	Public Water Supply: 150					2

5.1.2 Reservoir Water Quality Data

The Shoal Creek watershed has one impaired reservoir within its drainage area that is addressed in this report. There are three monitoring stations on the impaired reservoir (see Figure 5-1). The data summarized in this section include water quality data for the impaired constituent as well as parameters that could be useful in future modeling and analysis efforts. All historic data is available in Appendix C.

5.1.2.1 Sorento Reservoir

Sorento Reservoir is impaired for total manganese. Although there are three monitoring stations in Sorento Reservoir, manganese data is only available from sampling location ROZH-1. An inventory of all available manganese data is presented in Table 5-7.

Table 5-7 Sorento Reservoir Data Inventory for Impairments

Sorento Reservoir Segment ROZH; Sample Locations ROZH-1		
ROZH-1	**Period of Record**	**Number of Samples**
Total Manganese	2001	5
Manganese Bottom Deposits	2001	1

The applicable water quality standard for manganese is a maximum concentration of 1,000 µg/L for general use and 150 µg/L for public water supplies. Table 5-8 summarizes available manganese data for Sorento Reservoir. Three of the five samples taken in 2001 violated the public water supply standard.

Table 5-8 Average Total Manganese Concentrations in Sorento Reservoir

Year	ROZH-1			
	Water Quality Standard (mg/L)	**Data Count**	**Number of Violations**	**Average**
2001	General Use: 1000	5	0	269
	Public Water Supply: 150		3	

Table 5-9 contains information on data availability for other parameters that may be useful in data needs analysis and future modeling efforts. DO at varying depths has been collected where available.

Table 5-9 Sorento Reservoir Data Availability for Data Needs Analysis and Future Modeling Efforts

Sorento Reservoir Segment ROZH; Sample Locations ROZH-1, ROZH-2, and ROZH-3		
ROZH-1	**Period of Record**	**Number of Samples**
Total Depth	1996-1998	17
Dissolved Oxygen	2001	44
Temperature	2001	44
ROZH-2		
Total Depth	1990-1998	16
ROZH-3		
Total Depth	1990-1998	17

5.2 Reservoir Characteristics

There is one impaired reservoir in the Shoal Creek watershed. Reservoir information that can be used for future modeling efforts was collected from GIS analysis, Illinois EPA, the U.S. Army Corps of Engineers, and USEPA water quality data. The following sections will discuss the available data for Sorento Reservoir.

5.2.1 Sorento Reservoir

Sorento Reservoir has a surface area of 11 acres. Water from the lake is supplied to the Village of Sorento for drinking water from an intake in Sorento Reservoir and Shoal Creek at a rate of approximately 70,000 gallons per day (Source Water Assessment Program, Illinois EPA 2002). Table 5-10 contains dam information for the reservoir while table 5-11 contains depth information for each sampling location on the reservoir. The average maximum depth in Sorento Reservoir is 21.1 feet.

Table 5-10 Sorento Reservoir Dam Information (U.S. Army Corps of Engineers)

Dam Length	270 feet
Dam Height	27 feet
Maximum Discharge	1,025 cfs
Maximum Storage	162 acre-feet
Normal Storage	101 acre-feet
Spillway Width	53 feet
Outlet Gate Type	U

Table 5-11 Average Depths (ft) for Sorento Reservoir (Illinois EPA 2002 and USEPA 2002a)

Year	ROZH-1	ROZH-2	ROZH-3
1996	17.2	10.0	4.6
1997	23.1	9.6	7.2
1998	27.5	11.2	4.0
2001	16.5	–	–
Average	**21.1**	**10.3**	**5.3**

5.3 Point Sources

Point sources for the Shoal Creek watershed have been separated into municipal/ industrial sources and mining discharges. Available data has been summarized and are presented in the following sections.

5.3.1 Municipal and Industrial Point Sources

Permitted facilities must provide Discharge Monitoring Reports (DMRs) to Illinois EPA as part of their NPDES permit compliance. DMRs contain effluent discharge sampling results, which are then maintained in a database by the state. There are 10 point sources located within the Shoal Creek watershed. Figure 5-4 shows all NPDES permitted facilities in the watershed. In order to assess point source contributions to the watershed, the data has been examined by receiving water and then by the downstream impaired segment that has the potential to receive the discharge. Receiving waters were determined through information contained in the USEPA Permit Compliance System (PCS) database. Maps were used to determine downstream impaired receiving water information when PCS data was not available. The impairments for each segment or downstream segment were considered when reviewing DMR data. Data has been summarized for any sampled parameter that is associated with a downstream impairment (i.e., all available nutrient and biological oxygen demand data was reviewed for segments that are impaired for dissolved oxygen). This will help in future model selection as well as source assessment and load allocation.

5.3.1.1 Shoal Creek Segment OI 05

There are two point sources with the potential to contribute discharge to Shoal Creek segment OI 05. Segment OI 05 is listed as impaired for DO. Table 5-12 contains a summary of available and pertinent DMR data for these point sources.

Table 5-12 Effluent Data from Point Sources Discharging Upstream of Shoal Creek Segment OI 05 (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Western Gardens MHP 1996-2004 ILG551030	NA/Shoal Creek Segment OI 05	Average Daily Flow	0.0187 mgd	NA
		BOD, 5-Day	191.3 mg/L	
		CBOD, 5-Day	87.9 mg/L	4.31
Germantown STP 1998-2005 ILG580186	Shoal Creek/Shoal Creek Segment OI05	Average Daily Flow	0.135 mgd	NA
		BOD, 5-Day	49.0 mg/L	
		CBOD, 5-Day	14.0 mg/L	15.1

5.3.1.2 Shoal Creek Segment OI 08

There are four permitted facilities whose discharge has the potential to reach Shoal Creek segment OI 08. Shoal Creek segment OI 08 is listed for manganese and total fecal coliform impairments. Table 5-13 contains a summary of available DMR data for these point sources. Total fecal coliform data was available for only one discharger.

Table 5-13 Effluent Data from Point Sources Discharging to Shoal Creek Segment OI 08 (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Pierron East STP 2001-2005 ILG580237	Unnamed Tributary to Shoal Creek/Shoal Creek Segment OI 08	Average Daily Flow	0.0206 mgd	NA
Breese STP 1989-2004 IL0022772	Unnamed Tributary to Shoal Creek/Shoal Creek Segment OI 08	Average Daily Flow	0.629 mgd	NA
		Total Fecal Coliform	44.4 mg/L	
Louisville STP 1994-2004 ILG580081	NA/Shoal Creek Segment OI 08	Average Daily Flow	0.15 mgd	NA
Pocahontas STP 1993-2005 ILG580010	Shoal Creek/Shoal Creek Segment OI 08	Average Daily Flow	0.125 mgd	NA

5.3.1.3 Shoal Creek Segment OI 09

There are three point sources with the potential to contribute discharge to Shoal Creek segment OI 09 directly or through tributaries. Shoal Creek segment OI 09 is listed as impaired for manganese and total fecal coliform. Table 5-14 contains a summary of available DMR data for these point sources. No manganese or total fecal coliform data were available because the permits do not require sampling for these constituents.

Table 5-14 Effluent Data from Point Sources Discharging Upstream of Shoal Creek Segment OI 09 (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Panama STP 1994-2004 IL0048992	Bearcat Creek/Shoal Creek Segment OI 09	Average Daily Flow	0.0525 mgd	NA
New Douglas STP 1992-2005 IL0074292	NA/Shoal Creek Segment OI 09	Average Daily Flow	0.055 mgd	NA
Sorento STP 1974-2004 ILG580049	Dry Fork Creek/Shoal Creek Segment OI 09	Average Daily Flow	0.07 mgd	NA

5.3.1.4 Sorento Reservoir Segment ROZH

There is one point source with the potential to contribute discharge to Sorento Reservoir segment ROZH. Sorento Reservoir segment ROZH is impaired for manganese. Table 5-15 contains a summary of available DMR data for these point sources. No manganese data is available because it is not required by the facility's permit.

Table 5-15 Effluent Data from Point Sources Discharging above Sorento Reservoir (Illinois EPA 2005)

Facility Name Period of Record Permit Number	Receiving Water/ Downstream Impaired Waterbody	Constituent	Average Value	Average Loading (lb/d)
Sorento WTP 1996-2003 ILG640149	NA/Sorento Segment ROZH	Average Daily Flow	0.017 mgd	NA

5.3.1.5 Other

There are no permitted facilities that discharge directly to Chicken Creek segment OIO 09 or Cattle Creek segment OIP 10.

5.3.2 Mining Discharges

There are no permitted mine sites or recently abandoned mines within the Shoal Creek watershed. If other mining data becomes available, it will be reviewed and considered during Stage 3 of TMDL development.

5.4 Nonpoint Sources

There are many potential nonpoint sources of pollutant loading to the impaired segments in the Shoal Creek watershed. This section will discuss site-specific cropping practices, animal operations, and area septic systems. Data was collected through communication with local NRCS, Soil and Water Conservation District (SWCD), Public Health Department, and County Tax Department officials.

5.4.1 Crop Information

The majority of the land found within the Shoal Creek watershed is devoted to crops. Corn and soybean farming account for approximately 25 percent and 27 percent of the watershed respectively. Tillage practices can be categorized as conventional till, reduced till, mulch-till, and no-till. The percentage of each tillage practice for corn, soybeans, and small grains by county are generated by the Illinois Department of Agriculture from County Transect Surveys. The most recent survey was conducted in 2004. Data specific to the Shoal Creek watershed were not available; however, the Montgomery, Macoupin, Bond, Madison, and Clinton County practices were available and are shown in the following tables.

Table 5-16 Tillage Practices in Macoupin County

Tillage System	Corn	Soybean	Small Grain
Conventional	72%	8%	100%
Reduced - Till	19%	18%	0%
Mulch - Till	8%	26%	0%
No - Till	2%	47%	0%

Table 5-17 Tillage Practices in Bond County

Tillage System	Corn	Soybean	Small Grain
Conventional	94%	27%	77%
Reduced - Till	0%	43%	0%
Mulch - Till	0%	6%	0%
No - Till	6%	24%	23%

Table 5-18 Tillage Practices in Madison County

Tillage System	Corn	Soybean	Small Grain
Conventional	68%	8%	6%
Reduced - Till	21%	35%	21%
Mulch - Till	7%	22%	23%
No - Till	4%	35%	49%

Table 5-19 Tillage Practices in Clinton County

Tillage System	Corn	Soybean	Small Grain
Conventional	66%	30%	10%
Reduced - Till	5%	4%	0%
Mulch - Till	21%	26%	62%
No - Till	7%	40%	28%

Table 5-20 Tillage Practices in Montgomery County

Tillage System	Corn	Soybean	Small Grain
Conventional	76%	6%	0%
Reduced - Till	9%	23%	0%
Mulch - Till	8%	38%	0%
No - Till	7%	33%	100%

Estimates on tile drainage were provided by the Clinton County NRCS office. It is estimated that farms near waterways have an average of 1,000 feet of tile drains. The total drainage for Clinton County in the Shoal Creek watershed is estimated to be 5,000 feet. The Madison County NRCS office also provided local information. They indicated that subsurface tile drainage is not practical in the Madison County portion of the watershed due to the lack of adequate outlets. Information on tile drainage was not available from other county offices in the watershed. Site-specific data will be incorporated if it becomes available. Without local information, soils data will be reviewed for information on hydrologic soil group in order to provide a basis for tile drain estimates.

5.4.2 Animal Operations

Watershed specific animal numbers were not available for the Shoal Creek watershed. Data from the National Agricultural Statistics Service was reviewed and is presented below to show countywide estimates of livestock numbers.

Table 5-21 Bond County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	10,413	11,378	9%
Beef	2,885	2,930	2%
Dairy	2,534	3,284	30%
Hogs and Pigs	18,334	10,810	-41%
Poultry	668	597	-11%
Sheep and Lambs	409	521	27%
Horses and Ponies	NA	294	NA

Table 5-22 Madison County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	17,690	15,809	-11%
Beef	5,890	5,931	1%
Dairy	1,774	1,683	-5%
Hogs and Pigs	46,331	29,844	-36%
Poultry	1,517	NA	NA
Sheep and Lambs	1,047	1,013	-3%
Horses and Ponies	NA	1,226	NA

Table 5-23 Clinton County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	37,735	36,849	-2%
Beef	5,095	2,242	-56%
Dairy	14,830	15,080	2%
Hogs and Pigs	93,190	177,880	91%
Poultry	552,992	514,945	-7%
Sheep and Lambs	473	430	-9%
Horses and Ponies	NA	402	NA

Table 5-24 Montgomery County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	13,301	11,053	-17%
Beef	4,395	4,212	-4%
Dairy	1,082	889	-18%
Hogs and Pigs	67,031	58,861	-12%
Poultry	2,165	485	-78%
Sheep and Lambs	475	388	-18%
Horses and Ponies	NA	344	NA

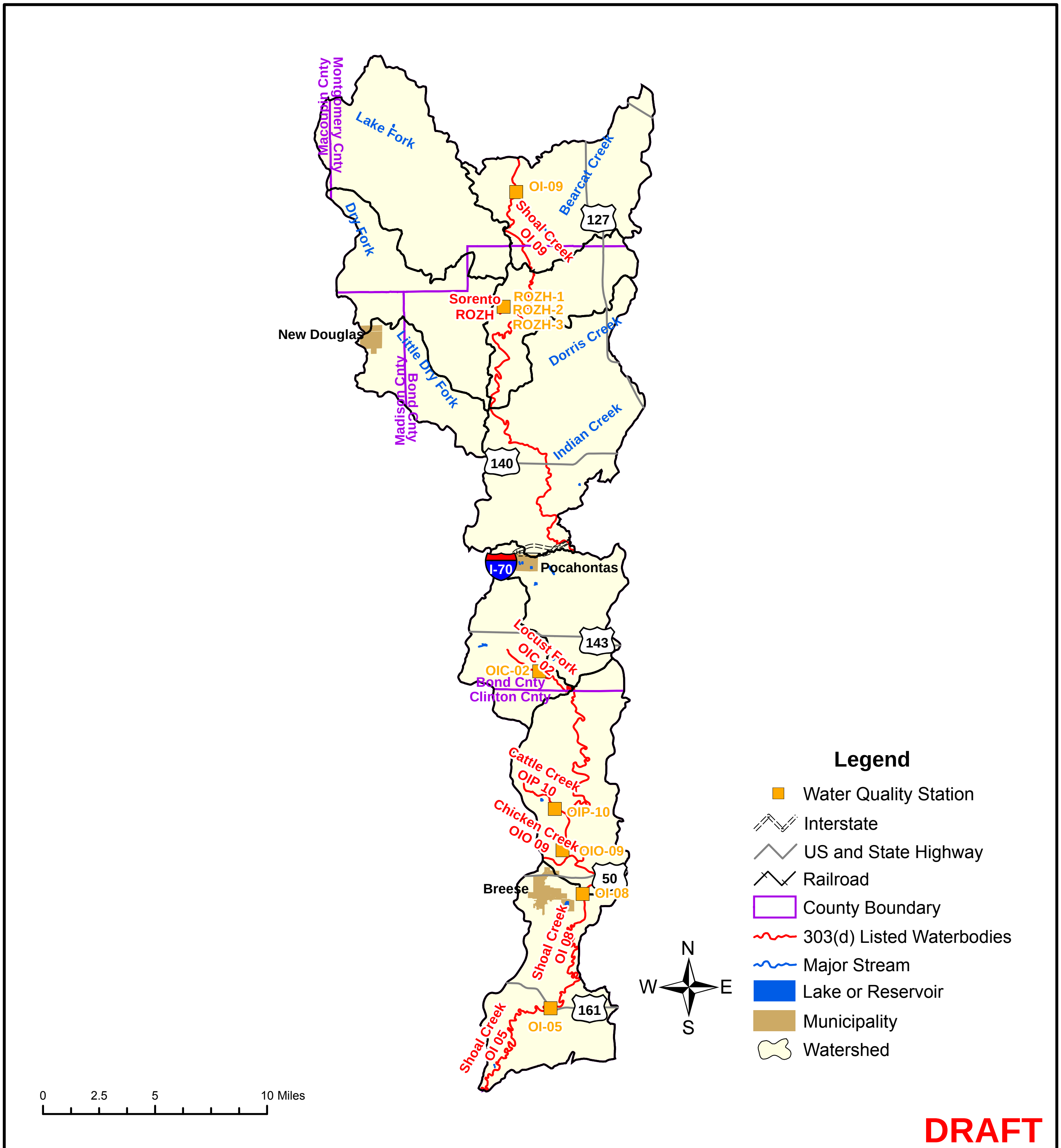
Table 5-24 Macoupin County Animal Population (2002 Census of Agriculture)

	1997	2002	Percent Change
Cattle and Calves	32,393	26,961	-17%
Beef	11,188	8,001	-28%
Dairy	1,502	1,161	-23%
Hogs and Pigs	91,755	68,030	-26%
Poultry	1,061	628	-41%
Sheep and Lambs	2,190	1,461	-33%
Horses and Ponies	NA	640	NA

Communications with local NRCS officials have provided more watershed-specific animal information. Clinton County indicated that within the Clinton County portion of the watershed, it is estimated that 21 dairies, seven beef farms, and five hog operations exist. It is estimated that the dairies have an average of 75 to 100 cows while the beef farms range from 25 to 50 head. The hog operations in the area are all likely associated with Mashoff Pork Production. Bond County estimated that three large hog operations existed within that portion of the watershed. In the portion of the watershed located in Montgomery County, it is estimated that there are 11 animal operations. They mostly consist of beef operations and are spread out across that area of the watershed. Madison County estimates that few, if any, animal operations exist in the Madison County area of the watershed.

5.5 Watershed Information

Previous planning efforts have been conducted within the Shoal Creek watershed. In 1990, a water quality project was completed through Illinois EPA for the Upper Shoal Creek. Communications with local NRCS offices indicated the watershed has been involved in some aspect of EQIP, ERP and State CPP cost-share projects. A 319 water quality project dealing with animal waste projects is also being conducted in the watershed. Further investigation will be performed to determine more information regarding these activities and other watershed groups. Data collected will be reviewed for possible use during Stage 3 of TMDL development.



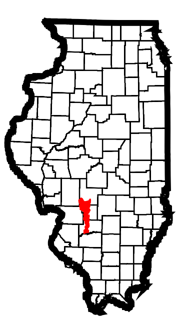


Figure 5-1
Water Quality Stations
Shoal Creek Watershed

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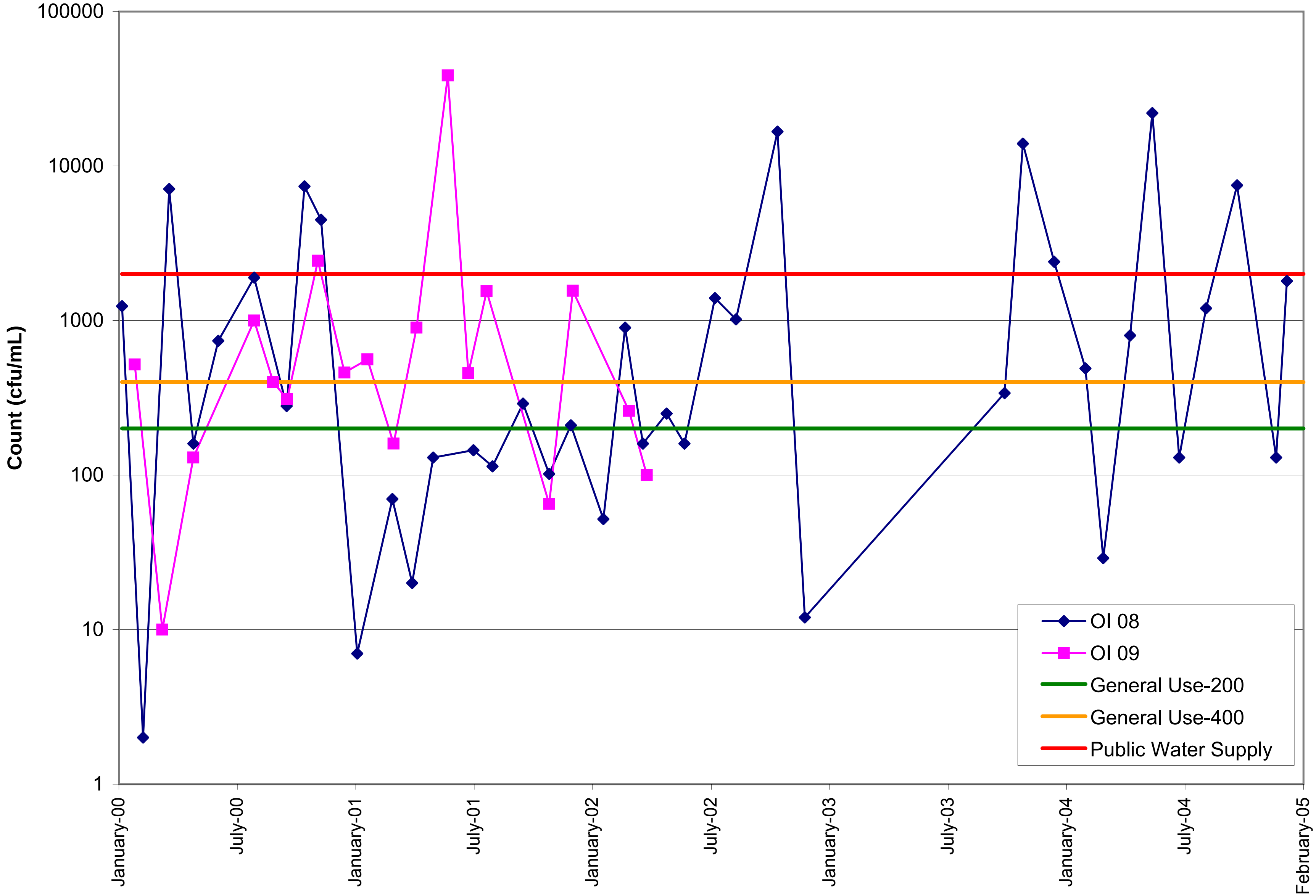

CDM

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Figure 5-2:
Shoal Creek Segments OI08 and OI09
Fecal Coliform Samples

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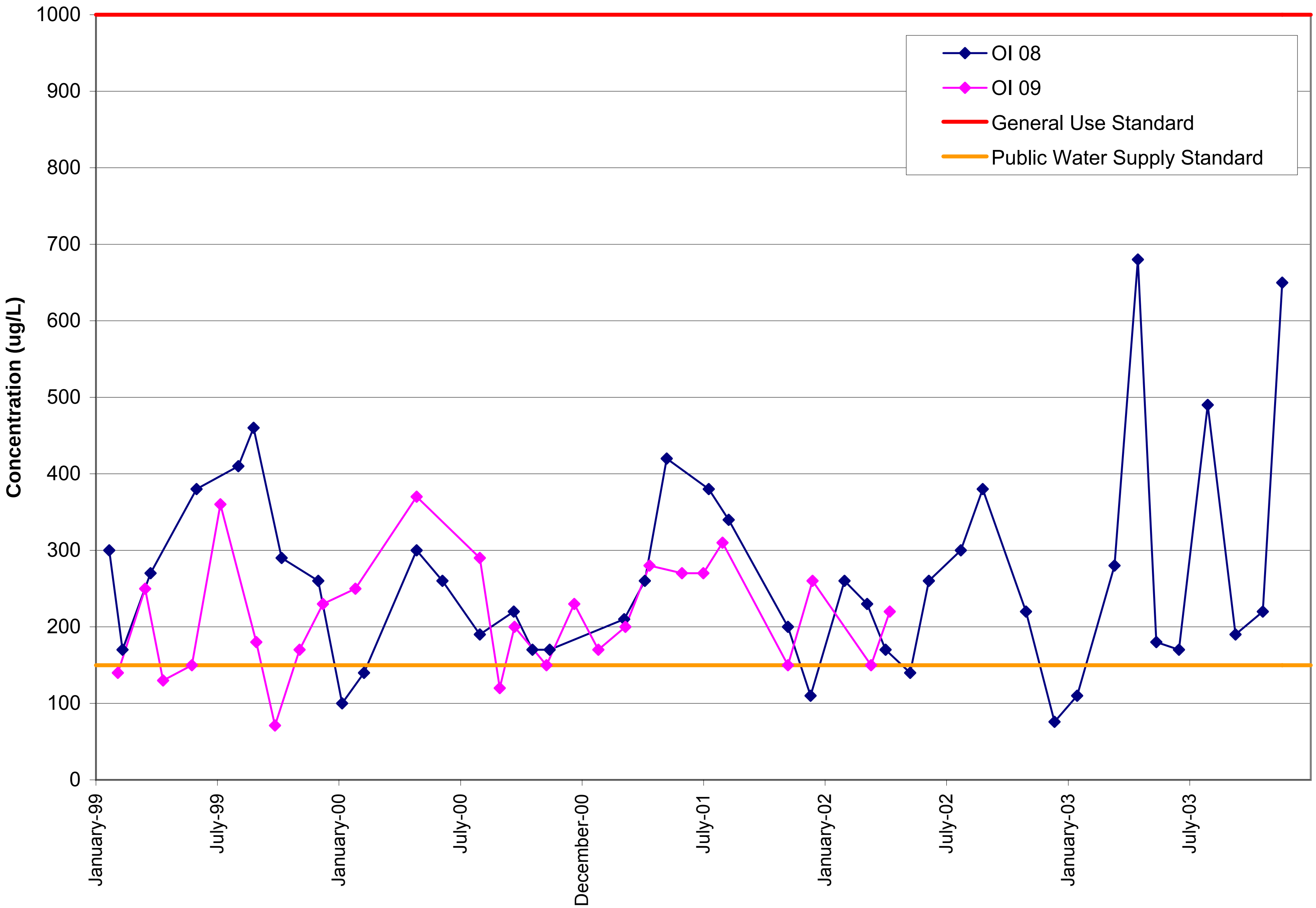

CDM

N:\8 Shoal Creek\Data\ShoalCrk Mang&TDS Summary.xlsPLT OI08&09

Figure 5-3:
Shoal Creek Segments OI08 and OI09
Total Manganese Samples

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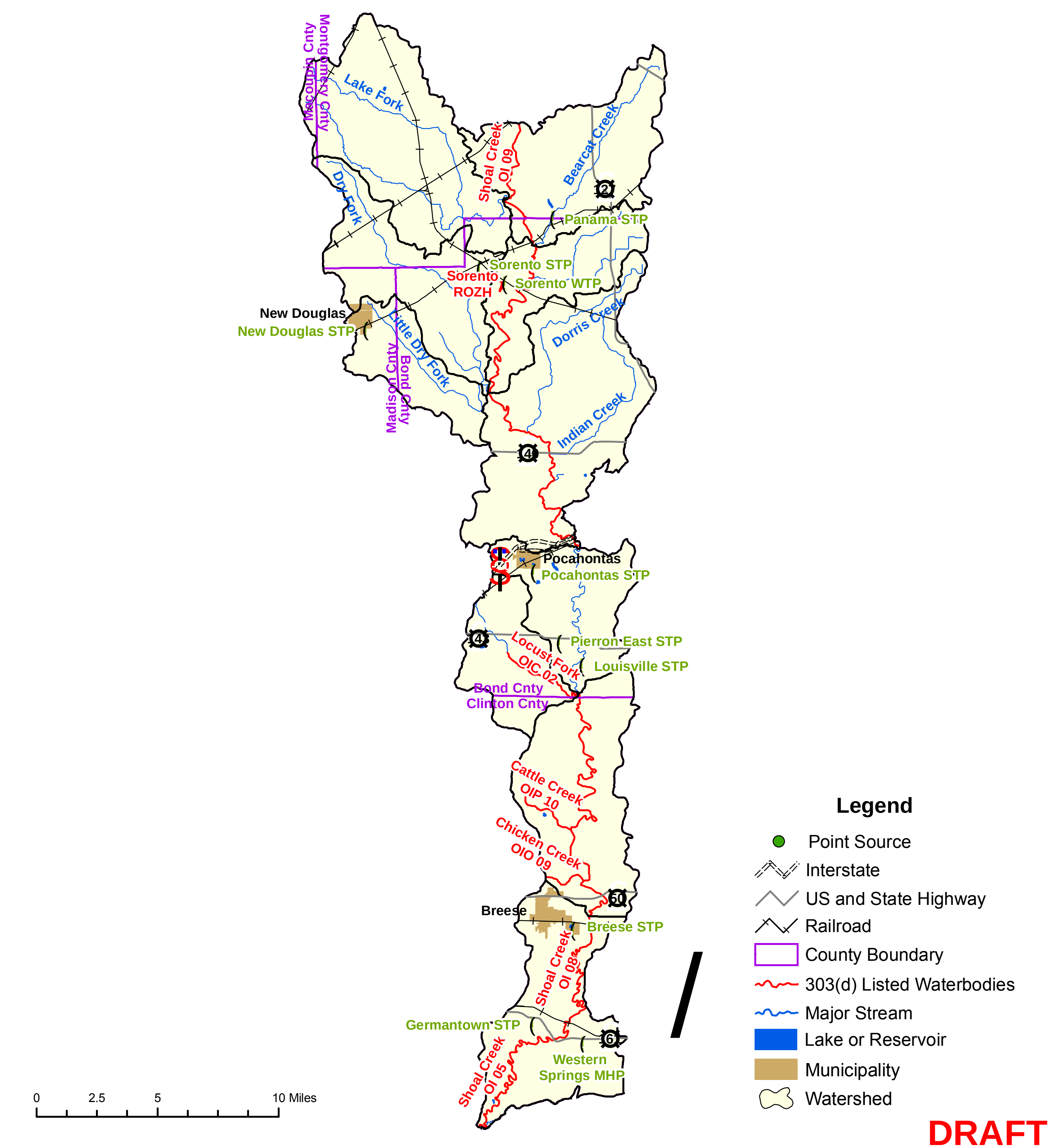

Figure 5-4
NPDES Permits
Shoal Creek Watershed

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Section 6
Approach to Developing TMDL and Identification of Data Needs

Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Of the pollutants impairing stream segments in the Shoal Creek watershed, DO, fecal coliform, manganese, TDS, silver and copper are all of the parameters with numeric water quality standards. For Sorento Reservoir, manganese is the only parameter with a numeric water quality standard for which a TMDL is being developed. Illinois EPA believes that addressing these impairments should lead to an overall improvement in water quality due to the interrelated nature of the other listed pollutants. Recommended technical approaches for developing TMDLs for streams and lakes are presented in this section. Additional data needs are also discussed.

6.1 Simple and Detailed Approaches for Developing TMDLs

The range of analyses used for developing TMDLs varies from simple to complex. Examples of a simple approach include mass-balance, load-duration, and simple watershed and receiving water models. Detailed approaches incorporate the use of complex watershed and receiving water models. Simple approaches typically require less data than detailed approaches and therefore these are the analyses recommended for the Shoal Creek watershed except for stream segments with major point sources whose NDPES permit may be affected by the TMDL's WLA. Establishing a link between pollutant loads and resulting water quality is one of the most important steps in developing a TMDL. As discussed above, this link can be established through a variety of techniques. The objective of the remainder of this section is to recommend approaches for establishing these links for the constituents of concern in the Shoal Creek watershed.

6.2 Approaches for Developing TMDLs for Stream Segments in the Shoal Creek Watershed

Stream segments with major point sources (those discharging greater than 0.1 million gallons per day) in the Shoal Creek watershed are segments OI08 and OI05 of Shoal Creek. The remaining impaired segments do not have major point sources discharging to them. Approaches for developing TMDLs for areas with and without major point sources are described below.

6.2.1 Recommended Approach for DO TMDLs for Stream Segments without Major Point Sources

Locust Creek, Cattle Creek, and Chicken Creek do not have major point sources discharging to them and are all listed as impaired for DO. Cattle Creek is also listed as impaired for total ammonia nitrogen. The data for these segments are limited and it is suggested that these segments proceed to Stage 2 in order to obtain more information for modeling. Once data collection has occurred, a simplified approach that involves simulating pollutant oxidation and stream reaeration only within a spreadsheet model is recommended for these TMDLs. The model simulates steady-state stream DO as a function of carbonaceous and nitrogenous pollutant oxidation and atmospheric reaeration. The model allows for non-uniform stream hydraulics, hydrology, and pollutant loadings at any level of segmentation. It is also free of numerical dispersion as it relies on well-known analytical solutions rather than numerical approximations of the fundamental equations. The model assumes plug flow (no hydrodynamic dispersion), which is likely an acceptable assumption for most small to medium sized streams. The model also does not incorporate the impacts of stream plant life, which generally require site-specific data for meaningful parameterization. A toxicitiy component will be incorporated for the total ammonia calculations. A watershed model will not be used for these segments. Using the spreadsheet model iteratively, the BOD loads causing the impairments and that are required to maintain a DO concentration of 5.0 mg/L will be calculated. These calculated loads will become the basis for recommending TMDL reductions if necessary.

6.2.2 Recommended Approach for DO TMDLs for Segments with Major Point Sources

The Germantown STP discharges above Shoal Creek segment OI05. For this segment a more complicated approach that would also incorporate the impacts of stream plant activity, and possibly sediment oxygen demand (SOD), and would require a more sophisticated numerical model and an adequate level of measured data to aide in model parameterization is recommended.

Available instream water quality data for this segement are limited to three samples. Data are also very limited spatially. Therefore, additional data collection is recommended for this segment. Specific data requirements include a synoptic (snapshot in time) water quality survey of this reach with careful attention to the location of the point source dischargers. This survey should include measurements of flow, hydraulics, DO, temperature, nutrients, and CBOD. The collected data will be used to support the model development and parameterization and will lend significant confidence to the TMDL conclusions.

This newly collected data could then be used to support the development and parameterization of a more sophisticated DO model for this stream and therefore, the use of the QUAL2E model (Brown and Barnwell 1985) could be utilized to accomplish the TMDL analysis for Shoal Creek. QUAL2E is well-known and USEPA-supported. It simulates DO dynamics as a function of nitrogenous and carbonaceous oxygen demand, atmospheric reaeration, SOD, and phytoplankton photosynthesis and respiration. The model also simulates the fate and transport of nutrients and BOD and the presence and abundance of phytoplankton (as chlorophyll-a). Stream hydrodynamics and temperature are important controlling parameters in the model. The model is essentially only suited to steady-state simulations.

In addition to the QUAL2E model, a simple watershed model such as PLOAD, Unit Area Loads or the Watershed Management Model is recommended to estimated BOD and nutrient loads from non-point sources in the watershed. This model will allow for allocation between point and nonpoint source loads and provide an understanding of percentage of loadings from point sources and nonpoint sources in the watershed.

6.2.3 Recommended Approach for Fecal Coliform TMDLs

Segments OI08 and OI09 of Shoal Creek are listed as impaired for total fecal coliform. The recommend approach for developing a TMDL for these segments is use of the load-duration curve method. The load-duration methodology uses the cumulative frequency distribution of streamflow and pollutant concentration data to estimate the allowable loads for a waterbody.

6.2.4 Recommended Approach for Manganese, TDS, and Metal TMDLs in Non-Mining Impacted Areas

Segments OI08 and OI09 of Shoal Creek and OIC02 of Locust Creek are impaired for manganese. Cattle Creek is impaired for TDS and copper while Chicken Creek is impaired for silver. Segments OI08 and OI09 of Shoal Creek have adequate manganese data for TMDL development, however, limited data are available for the remaining segments and parameters. It is recommended that more data be collected on Locust, Cattle, and Chicken Creeks. No apparent sources of manganese, TDS, or metals have been identified to date. Once adequate data is available for each of the parameters and segments, an empirical loading and spreadsheet analysis will be utilized to calculate these TMDLs.

6.3 Approaches for Developing a TMDL for Sorento Reservoir

The recommended TMDL approach for Sorento Reservoir will be discussed in this section. It is assumed that enough data exists to develop a simple model for use in TMDL development.

6.3.1 Recommended Approach for Manganese TMDL

The applicable water quality standard for manganese is 150 µg/L. The reservoir is also listed for a phosphorus impairment, but the standard does not apply to reservoirs with a surface area less than 20 acres. However, it is assumed that development of a phosphorus TMDL will control the manganese concentrations. The manganese target is maintenance of hypolimnetic DO concentrations above zero, because the only controllable source of manganese to the lake is the release of manganese from lake sediments during periods when there is no DO in lake bottom waters. The lack of DO in lake bottom waters is presumed to be due to the effects of nutrient enrichment, as there are no significant sources of oxygen demanding materials to the lake. For this reason, attainment of the total phosphorus standard is expected to result in oxygen concentrations that will reduce sediment manganese flux to natural background levels. The TMDL target is therefore set as a total phosphorus concentration of 0.050 mg-P/l.

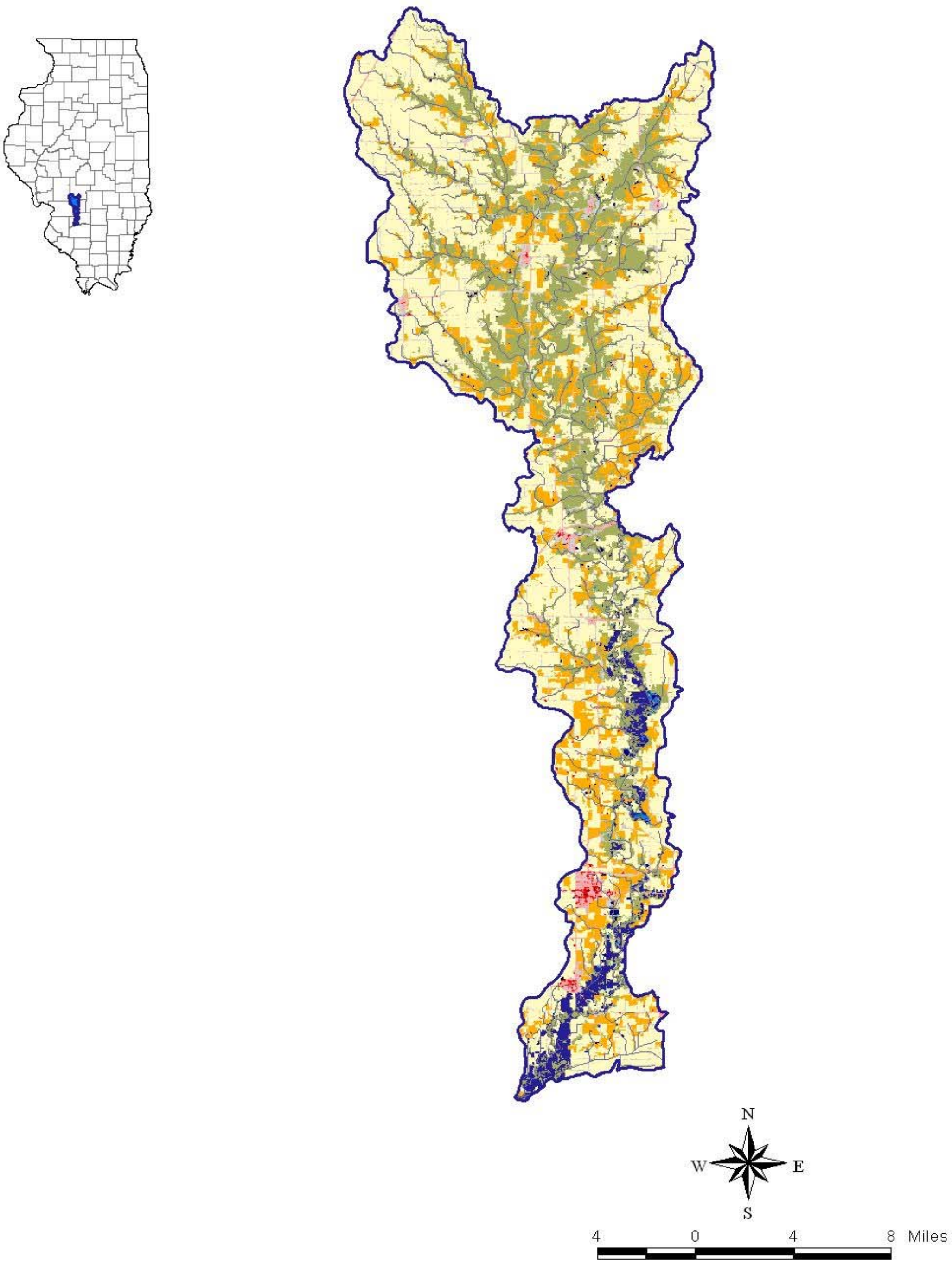
The BATHTUB model is recommended for lake phosphorus assessments. The BATHTUB model performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport and nutrient sedimentation. The model relies on empirical relationships to predict lake trophic conditions and subsequent DO conditions as functions of total phosphorus and nitrogen loads, residence time, and mean depth. (USEPA 1997). Oxygen conditions in the model are simulated as meta and hypolimnetic depletion rates, rather than explicit concentrations.

Watershed loadings to the lakes will be based on empirical data or tributary data available in the lake watersheds.

TMDL Development for the Shoal Creek Watershed, Illinois

FINAL REPORT FOR USEPA APPROVAL

August 30, 2007



TETRA TECH

Illinois Environmental Protection Agency

TMDL Development for the Shoal Creek Watershed, Illinois

FINAL REPORT FOR USEPA APPROVAL

August 30th, 2007

Submitted to:
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62702

Submitted by:
Tetra Tech, Inc.
Water Resources TMDL Center

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1.0 INTRODUCTION

A TMDL is defined as "the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background" such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. A TMDL is also required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. The overall goals and objectives in developing TMDLs for the above listed waterbodies include:

- Assess the water quality of the impaired waterbodies and identify key issues associated with the impairments and potential pollutant sources.
- Use the best available science and available data to determine the maximum load the waterbodies can receive and fully support all of their designated uses.
- Use the best available science and available data to determine current loads of pollutants to the impaired waterbodies.
- If current loads exceed the maximum allowable load, determine the load reduction that is needed.
- Identify feasible and cost-effective actions that can be taken to reduce loads.
- Inform and involve the public throughout the project to ensure that key concerns are addressed and the best available information is used.
- Submit a final TMDL report to USEPA for review and approval.

The Illinois Environmental Protection Agency (IEPA) has a three-stage approach to total maximum daily load (TMDL) development. The stages are:

- Stage 1 was completed by the consulting firm Camp Dresser and McKee (CDM) in October 2006 and involved characterization of the watershed, assessment of the available water quality data, identification of additional data needs for the development of credible TMDLs and recommendation of potential technical approaches for TMDL development (Appendix E).
- Stage 2 was also completed by the CDM consulting firm in March 2007 and involved collecting additional chemical water quality data, continuous dissolved oxygen measurements, channel morphology and discharge measurements at twenty-five monitoring locations (Figure 1 and Appendix F).
- Stage 3 was completed by the Tetra Tech consulting firm and involves model development and calibration, TMDL scenarios, and implementation planning.

This report documents the modeling and TMDL components of Stage 3. The specific pollutant sources were not a focus of this report and will be the subject of a forthcoming Implementation Plan, along with a description of alternatives for achieving the desired load reductions.

2.0 BACKGROUND

The Shoal Creek watershed has a drainage area of approximately 921 square miles and is an 8 digit hydrologic unit code (07140203) as defined by USGS Geological Survey (USGS). The watershed is located in south-central Illinois and the portion of the watershed addressed in this report has a drainage area of 310 square miles and encompasses five counties with Bond County covering 46 percent of the watershed followed by Montgomery (28%), Clinton (23%), Madison (3%), and Macoupin (0.05%)(Figure 1). The Shoal Creek headwaters begin in north-eastern Montgomery County and continue south towards the Kaskaskia River. Major tributaries to Shoal Creek include the West, Middle, and East Forks of Shoal Creek and Beaver Creek. Agriculture is the dominant land use in this watershed (Figure 2).

Table 1 lists the Shoal Creek watershed Section 303(d) listing information along with an identification of the TMDLs presented in this report. IEPA is currently developing TMDLs only for pollutants that have numeric water quality standards. However, best management practices identified for pollutants with numeric water quality standards (e.g., copper, silver) might include the control of other pollutants (e.g., suspended solids) that do not have water quality standards. Information on these potential best management practices will be forthcoming in the implementation plan.

Several segments have been de-listed since the Stage 1 report due to newer ambient data or data collected during Stage 2. Shoal Creek was originally listed as impaired for dissolved oxygen. However, additional data collected in 2006 indicated no exceedances of the dissolved oxygen water quality standard (Appendix F). USEPA has therefore already approved a de-listing of dissolved oxygen for segment OI05 of Shoal Creek and no TMDL has been developed.

Locust Fork was originally listed as impaired for manganese. However, additional data collected in 2006 indicated no exceedances of the manganese water quality standard. USEPA has therefore already approved a de-listing of manganese for the OIC01 segment of Locust Fork and no TMDL has been developed.

Sorento Lake was originally listed as impaired for manganese but it was later determined that was in error due to the fact the lake is not designated as a public water supply. No TMDL has therefore been developed for Sorento Lake.

Table 1. Section 303(d) listed waterbodies within the Shoal Creek watershed addressed within this report.

Waterbody Name	Waterbody Segment	Segment Size (Miles)	Cause of Impairment	Impaired Designated Use
Shoal Creek	OI-08	13.11	**Fecal Coliform**	Primary Contact Recreation
			Manganese	Public Water Supplies
Shoal Creek	OI-09	29.75	**Fecal Coliform**	Primary Contact Recreation
			Manganese	Public Water Supplies
Locust Fork	OIC-02	4.24	**Dissolved Oxygen**	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Chicken Creek	OIO-09	1.92	**Dissolved Oxygen**	Aquatic Life
			Silver	Aquatic Life
			Total Nitrogen	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Cattle Creek	OIP-10	2.71	**Ammonia**	Aquatic Life
			Copper	Aquatic Life
			Dissolved Oxygen	Aquatic Life
			TDS	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life

Note: Bold font indicates cause will be addressed in this report because there are numeric water quality criteria.

Figure 1. Location of the Shoal Creek Watershed

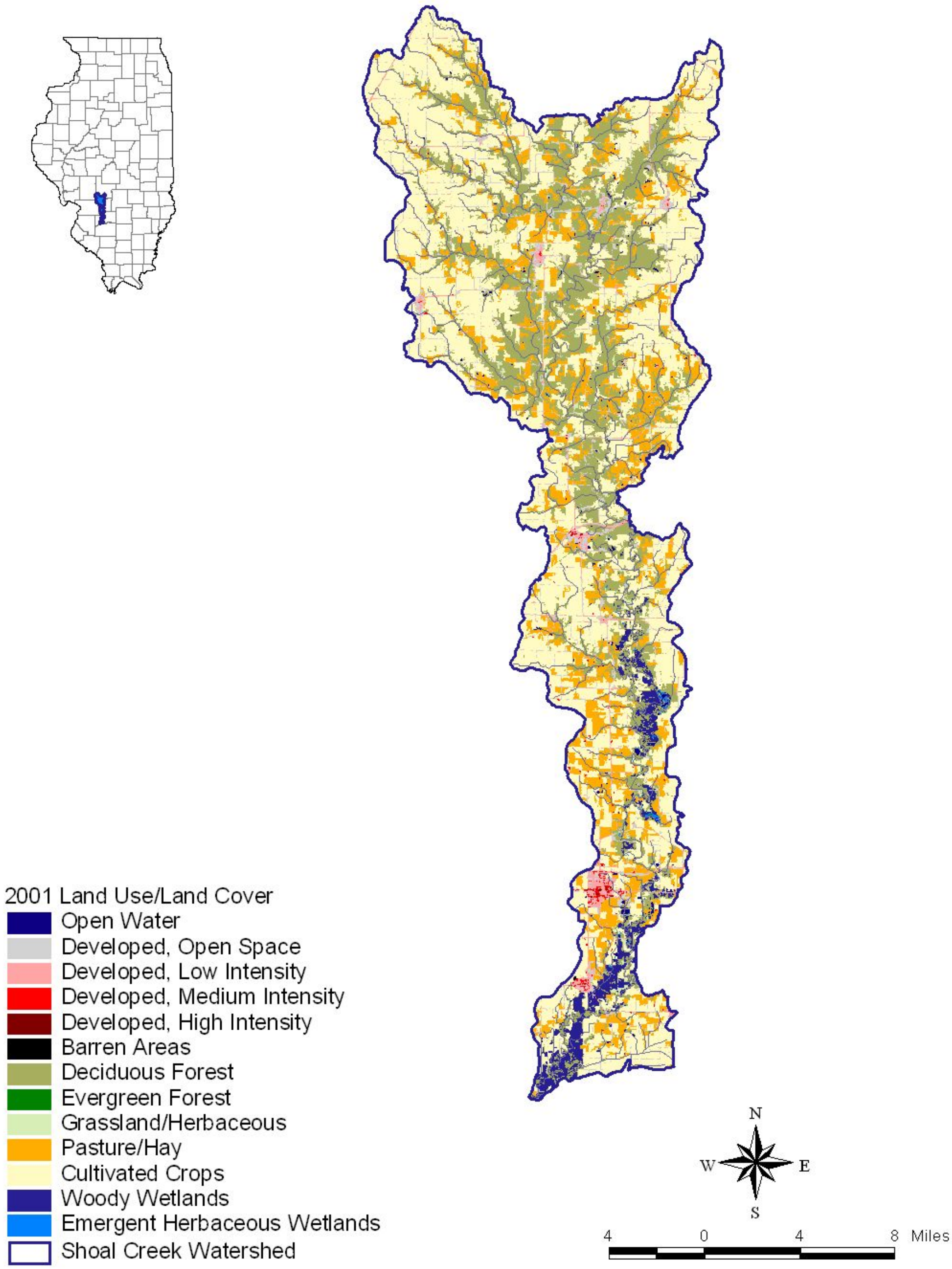

Figure 2. Land Use in the Shoal Creek Watershed

3.0 APPLICABLE WATER QUALITY STANDARDS

The purpose of developing a TMDL is to identify the pollutant loading that a waterbody can receive and still achieve water quality standards. Under the Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters. These standards represent a level of water quality that will support the Clean Water Act's goal of "swimmable/fishable" waters. Water quality standards consist of three components: designated uses, numeric or narrative criteria, and an antidegradation policy. A description of the water quality standards that apply to this TMDL is presented below and detailed comparisons of the available water quality data to the standards are provided in Appendix E and Appendix F.

3.1 Use Support Guidelines

IEPA uses rules and regulations adopted by the Illinois Pollution Control Board (IPCB) to assess the designated use support for Illinois waterbodies. The following are the use support designations provided by the IPCB that apply to water bodies in the Shoal Creek watershed:

General Use Standards - These standards protect for aquatic life, wildlife, agricultural, primary contact (where physical configuration of the waterbody permits it, any recreational or other water use in which there is prolonged and intimate contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard, such as swimming and water skiing), secondary contact (any recreational or other water use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal, such as fishing, commercial and recreational boating, and any limited contact incident to shoreline activity), and most industrial uses. These standards are also designed to ensure the aesthetic quality of the state's aquatic environment.

Public and food processing water supply standards – These standards are cumulative with the general use standards and apply to waters of the state at any point at which water is withdrawn for treatment and distribution as a potable supply to the public or for food processing.

Water quality standards used for TMDL development in the Shoal Creek watershed are listed below in Table 2.

Table 2. Summary of Water Quality Standards for the Shoal Creek Watershed Stream Impairments.

Parameter	Units	General Use Water Quality Standard	Public and Food Processing Water Supplies	Regulatory Citation
Nitrogen, ammonia (Total)	mg/L	15[1]	No numeric standard	302.212
Copper	µg/L	Acute standard[2] =(exp[-1.464+0.9422 x ln(H)]) x 0.960* Chronic standard[3] =(exp[-1.465+0.8545 x ln(H)]) x 0.960*	No numeric standard	302.208
Dissolved Oxygen	mg/L	5.0 instantaneous minimum	No numeric standard	302.206
		6.0 minimum during at least 16 hours of any 24 hour period		
Fecal coliform[4]	#/100 mL	400 in <10% of samples[5]	Geomean[6] <2,000	General use: 302.209 Public Water Supply: 302.306
		Geomean < 200[6]		
Manganese	µg/L	1,000	150	General use: 302.208 Public Water Supply: 302.304
Silver	µg/L	5	No numeric standard	302.208
Total Dissolved Solids (TDS)	mg/L	1,000	500	General use: 302.208 Public Water Supply: 302.304

Notes:
All IEPA water quality standards are published by the Illinois Pollution Control Board under Title 35: Environmental Protection Subtitle C: Water Pollution Chapter I: Pollution Control Board. Part 302. Water Quality Standards. Subpart A: General Water Quality Provisions.
* = conversion factor for multiplier for dissolved metals
[1] The allowable concentration varies in accordance with water temperature and pH values. 15 mg/L is the maximum total ammonia nitrogen value allowed. In general, as both temperature and pH decrease, the allowable value of total ammonia nitrogen increases. For example, when the pH is 8.0 and the temperature is 20 degrees C, the acute standard is 8.4 mg/L, the chronic standard is 1.7 mg/L, and the subchronic standard is 4.3 mg/L. See 35 Ill. Adm. Code 302.212 for the formulae by which the standards are calculated.
[2]Not to be exceeded except as provided in 35 Ill. Adm. Code 302.208(d).
[3]Not to be exceeded by the average of at least four consecutive samples collected over any period of at least four days except as provided in 35 Ill. Adm. Code 302.208(d). The samples used to demonstrate attainment or lack of attainment with a chronic standard must be collected in a manner that assures an average representative of the sampling period. To calculate attainment status of chronic metals standards, the concentration of the metal in each sample is divided by the calculated water quality standard for the sample to determine a quotient. The water quality standard is attained if the mean of the sample quotients is less than or equal to one for the duration of the averaging period.
[4] Fecal coliform standards are for the recreation season only (May through October)
[5] Standard shall not be exceeded by more than 10% of the samples collected during a 30 day period
[6] Geometric mean based on minimum of 5 samples taken over not more than a 30 day period

4.0 TECHNICAL ANALYSIS

This section of the report addresses the technical approaches applied to calculate TMDLs for fecal coliform, manganese, atrazine, pH and dissolved oxygen. Load duration curves were used to estimate the current and allowable loads of atrazine, fecal coliform, and manganese loads for impaired streams in the Shoal Creek watershed. QUAL2K modeling was used to simulate instream dissolved oxygen concentrations for impaired streams in the Shoal Creek watershed and pollutant load reductions that are needed to meet the water quality standards. Table 3 presents the listed water bodies and the corresponding modeling approach used to address each TMDL.

Table 3. 303(d) List Information and Modeling Approaches for the Shoal Creek Watershed

Waterbody Name	Segment	Cause of Impairment	Modeling Approach
Shoal Creek	OI-08	Fecal Coliform	Load Duration Curve
		Manganese	Load Duration Curve
Shoal Creek	OI-09	Fecal Coliform	Load Duration Curve
		Manganese	Load Duration Curve
Locust Fork	OIC-02	Dissolved Oxygen	QUAL2K
Chicken Creek	OIO-09	Dissolved Oxygen	QUAL2K
		Silver	Load Duration Curve
Cattle Creek	OIP-10	Ammonia	Load Duration Curve
		Copper	Load Duration Curve
		Dissolved Oxygen	QUAL2K
		TDS	Load Duration Curve

4.1 Load Duration Curves

Load reductions for fecal coliform, manganese, silver, ammonia, and TDS were determined through the use of load duration curves. The load duration curve demonstrates the allowable loadings of a pollutant at different flow regimes expected to occur in the impaired segment and still maintain the water quality standard. The following steps are taken:

1. A flow duration curve for the stream is developed by generating a flow frequency table and plotting the data points. It should be noted that the Illinois fecal coliform standard is designated for the months of May to October and so only flow data collected during these months were used for the load duration analysis.

2. The flow curve is translated into a load duration (or TMDL) curve. To accomplish this, each flow value is multiplied by the water quality standard and by a conversion factor. The resulting points are graphed. It should be noted that both the geometric mean (200 cfu/100 mL) and the not-to-exceed (400 cfu/100 mL) components of Illinois's water quality standard were evaluated as part of this study. The TMDL results presented below are based on the more restrictive geometric mean standard of 200 cfu/100 mL because it is more restrictive and ensures both standards will be met. The not-to-exceed 400 cfu/100 mL standard results are presented in Appendix A for information purposes.

3. Each water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected and a conversion factor. Then, the individual loads are plotted on the TMDL graph.

4. Points plotting above the curve represent deviations from the water quality standard and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load.

5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet water quality standards.

Fecal coliform and total manganese loadings were calculated for Shoal Creek segments OI08 and OI09. Segment OI08 starts at the confluence of Shoal Creek and Cattle Creek and ends at the confluence of Beaver Creek. Segment OI09 begins downstream of the confluence of the West and Middle Forks of Shoal Creek and ends at the confluence with the East Fork of Shoal Creek (Figure 3). Allowable silver loads were calculated for Chicken Creek segment OIO09 that covers the entire length of Chicken Creek from the headwaters to the mouth (Figure 3). Ammonia, copper and TDS loadings were calculated for the OIP10 segment of Cattle Creek. This segment covers the entire mainstem of Cattle Creek from the headwaters to the mouth (Figure 3).

Fecal coliform and total manganese data for sampling stations OI08 and OI09 were used to assess loadings to segments OI08 and OI09, silver data for sampling station OIO09 were used to assess loadings to segment OIO09, and ammonia, copper, and TDS data for sampling station OIP10 were used to assess loadings to segment OIP10. The pollutant reductions necessary to achieve the applicable water quality standards are presented in Section 5.1.

The stream flows displayed on a load duration curve may be grouped into various flow regimes to aid with interpretation of the load duration curves. The flow regimes are typically divided into 10 groups, which can be further categorized into the following five "hydrologic zones" (Cleland, 2005):

- High flow zone: stream flows that plot in the 0 to 10-percentile range, related to flood flows.
- Moist zone: flows in the 10 to 40-percentile range, related to wet weather conditions.
- Mid-range zone: flows in the 40 to 50 percentile range, median stream flow conditions;
- Dry zone: flows in the 60 to 90-percentile range, related to dry weather flows.
- Low flow zone: flows in the 90 to 100-percentile range, related to drought conditions.

The load duration approach helps to identify the issues surrounding the impairment and to roughly differentiate between sources. Table 4 summarizes the relationship between the five hydrologic zones and potentially contributing source areas.

The load reduction approach also considers critical conditions and seasonal variation in the TMDL development as required by the Clean Water Act and EPA's implementing regulations. Because the approach establishes loads based on a representative flow regime, it inherently considers seasonal variations and critical conditions attributed to flow conditions.

Table 4. Relationship Between Load Duration Curve Zones and Contributing Sources.

Contributing Source Area	Duration Curve Zone				
	High	Moist	Mid-Range	Dry	Low
Point source				M	H
Livestock direct access to streams				M	H
On-site wastewater systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Stormwater: Impervious		H	H	H	
Combined sewer overflow (CSO)	H	H	H		
Stormwater: Upland	H	H	M		
Field drainage: Natural condition	H	M			
Field drainage: Tile system	H	H	M-H	L-M	
Bank erosion	H	M			
Note: Potential relative importance of source area to contribute loads under given hydrologic condition (H: High; M: Medium; L: Low)					

4.1.1 Stream Flow Estimates

Daily stream flows are needed to apply the load duration curve. There is one USGS gage station with continuous flow data in the Shoal Creek watershed (Figure 3). USGS station 05594000 is located near Breese, Illinois on the OI08 segment of Shoal Creek.

Stream flows for all monitoring stations (OI08, OI09, OIO09, and OIP10) were extrapolated from the USGS station 05594000, using a multiplier based upon a comparison of the two drainage areas. For example, the drainage area upstream of the OI08 monitoring station is 725.82 square miles and the drainage area upstream of the USGS gage station is 735 square miles. The drainage area ratio therefore equals 0.9875 and the daily flows at the flow gage were multiplied by 0.9875 to estimate the daily flows at station OI08.

A further modification to the flow estimates was made to ensure that they accounted for the design flows of any upstream point sources (because the TMDL WLAs are based on design flows). In cases where the minimum estimated flows were less than the cumulative design flows of upstream point sources, the design flows were added to the flow record.

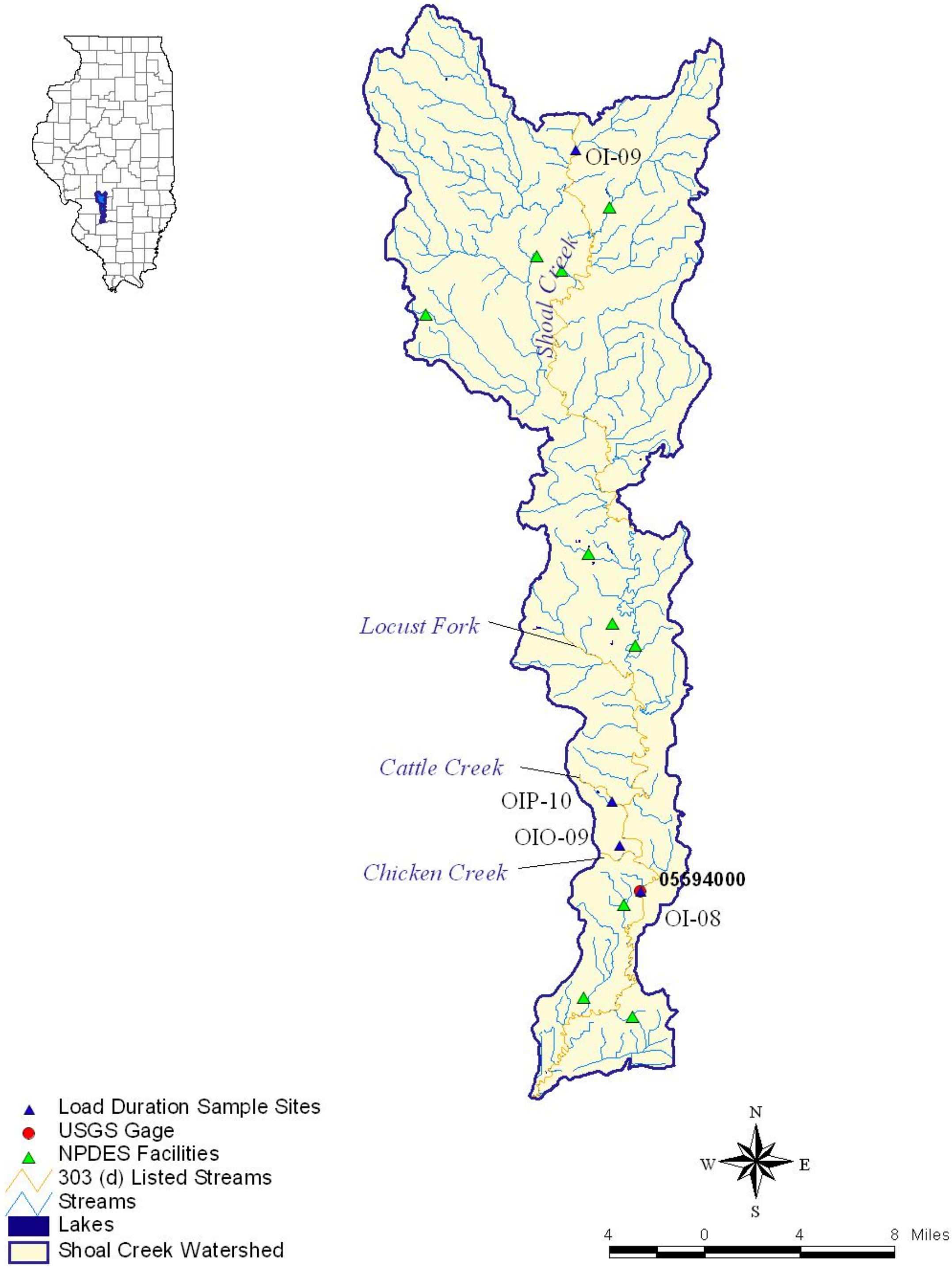

Figure 3. USGS and Load Duration Stations in the Shoal Creek Watershed

4.2 QUAL2K Model

The QUAL2K water quality model was used to assess dissolved oxygen concentrations in Locust Fork, Cattle Creek, and Chicken Creek. QUAL2K is supported by U.S. EPA and has been used extensively for TMDL development and point source permitting issues across the country, especially for issues related to dissolved oxygen concentrations. The QUAL2K model is suitable for simulating hydraulics and water quality conditions of a small river. It is a one-dimensional model with the assumption of a completely mixed system for each computational cell. QUAL2K assumes that the major pollutant transport mechanisms, advection and dispersion, are significant only along the longitudinal direction of flow. The model allows for multiple waste discharges, water withdrawals, tributary flows, and incremental inflows and outflows. The processes employed in QUAL2K address nutrient cycles, algal growth, and dissolved oxygen dynamics.

5.0 TMDL

A TMDL is the total amount of a pollutant that can be assimilated by the receiving water while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are composed of the sum of individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources (including natural background levels). In addition, the TMDL must include a margin of safety (MOS), either implicitly or explicitly, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this is defined by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

A summary of the TMDL allocations for the Shoal Creek watershed is presented in this section of the report, organized according to pollutants and modeling analysis.

5.1 Loading Capacity for Fecal Coliform, Manganese, Silver, Ammonia, Copper, and TDS in the Shoal Creek Watershed

A TMDL must identify the loading capacity of a waterbody for the applicable pollutant. USEPA regulations define loading capacity as the greatest amount of a pollutant that a waterbody can receive without violating water quality standards. The loading capacity is often referred to as the "allowable" load. The following sections provide load duration curve analysis for Segments OI08, OI09, OIO09, and OIP10 of Shoal Creek. Table 5 lists the fecal coliform and manganese load reductions needed at Shoal Creek segment OI08, Table 6 lists the fecal coliform and manganese load reductions needed at Shoal Creek segment OI09, Table 7 lists the silver load reductions needed in Chicken Creek, and Table 8 lists the ammonia, copper, and TDS load reductions needed in Cattle Creek. Appendix A presents the detailed load duration analyses performed for Shoal Creek at stations OI08, OI09, OIO09, and OIP10.

5.1.1 Loading Capacity of Shoal Creek Segment OI08

Existing and allowable fecal coliform and manganese loads were calculated for Shoal Creek segment OI08 at station OI08 located at the Route 50 bridge, 1.4 miles east of Breese. This location drains 726 square miles and land use/land cover consists primarily of cultivated crops, deciduous forest, and pasture/hay. Numerous livestock operations are located within the Shoal Creek watershed upstream of and adjacent to this segment. A total of 39 fecal coliform samples and 41 manganese samples were available for the load duration analysis (Appendix B).

The TMDL summary for Shoal Creek segment OI08 is presented in Table 5. Current observed loads for each flow regime are based on the median observed flow in each regime and the results indicate that fecal coliform observations exceed the loading limit most frequently between very high and mid range flows. Manganese loadings are above the threshold loadings throughout the entire flow range with 46 percent or greater needed reductions.

Table 5. Fecal Coliform and Manganese TMDL Summary for Stream Segment OI08

OI08 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Fecal Coliform (Million/day)	Current Load	125,343,030	4,899,685	486,344	124,123	No Data
	TMDL= LA+WLA+MOS	**7,972,860**	**995,400**	**285,090**	**111,137**	**40,589**
	LA	7,945,378	967,918	257,608	97,903	27,355
	WLA: Pierron East STP	156	156	156	156	156
	WLA: Breese STP	23,772	23,772	23,772	9,524	9,524
	WLA: Louisville STP	1,136	1,136	1,136	1,136	1,136
	WLA: Pocahontas STP	946	946	946	946	946
	WLA: Panama STP	397	397	397	397	397
	WLA: New Douglas STP	416	416	416	416	416
	WLA: Sorento STP	530	530	530	530	530
	WLA Sorento WTP	129	129	129	129	129
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	WLA: Total Point Sources	27,482	27,482	27,482	13,234	13,234
	MOS (Implicit)	Implicit	Implicit	Implicit	Implicit	Implicit
	TMDL Reduction (%)	94%	80%	41%	10%	No Data
Manganese (kg/day)	Current Load	3,182.6	330.7	71.0	30.2	7.6
	TMDL= LA+WLA+MOS	**1,080.0**	**156.6**	**42.4**	**13.4**	**3.6**
	LA	972.0	140.9	38.2	12.1	3.2
	Future Growth Reserve (0%)	0.0	0.0	0.0	0.0	0.0
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	108.0	15.7	4.2	1.3	0.4
	TMDL Reduction (%)	69%	57%	46%	60%	57%

The following sewage treatment plants (STP) are located in the Shoal Creek watershed upstream of monitoring station OI08:

- Pierron East STP (permit number ILG580237)
- Breese STP (permit number IL0022772)
- Louisville STP (permit number ILG580081)
- Pocahontas STP(permit number ILG580010)
- Panama STP (permit number IL0048992)
- New Douglas STP (permit number IL0074292)
- Sorento STP (permit number ILG580049)
- Sorento WTP (permit number ILG640149)

Sewage from treatment plants treating domestic and/or municipal waste contains fecal coliform–it is indigenous to sanitary sewage. All facilities addressed by this TMDL, with the exception of the Breese STP, have applied for and received disinfection exemptions which allow the facility to discharge wastewater water without disinfection. All of these treatment facilities are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water. The WLAs shown Table 5 were therefore calculated based on the facility design flows multiplied by 200 cfu/100 mL for the facilities with disinfection exemptions. Facilities with year-round disinfection exemptions may be required to provide the Agency with updated information to demonstrate compliance with these requirements. Facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions.

The WLAs for the Breese STP facility were determined by multiplying the facility's design maximum flow (DMF) by its permit limit (400/100 mL) during high to mid range flows and by multiplying the design average flow (DAF) by the permit limit during low flows and moist conditions. Monitoring data from this facility indicate that the effluent is well within its permit limits (Appendix C).

Other potential sources of fecal coliform in this segment include livestock, private sewage systems, discharges from permitted point sources, and wildlife. Livestock and animal feeding operations are prevalent throughout the Clinton, Bond, and Montgomery County portions of the watershed (IEPA, 2006) and are potential contributors of fecal coliform to segment OI08. Private surface sewage systems are also common in the area and if not treated properly can release untreated sewage to local waterways. It has been estimated that statewide between 20 and 60 percent of surface discharging systems are failing or have failed (IEPA, 2004) suggesting that such systems may be a significant source of pollutants.

None of the permitted point sources discharging to stream segment OI08 are required to monitor or control for manganese as none of them would be expected to have high concentrations of this parameter. The high manganese levels are attributed to natural background conditions. Many of the soils in the Shoal Creek watershed contain naturally-occurring manganese concentrations or accumulations and most soils in the watershed are acidic (pH of 6.6). Low pH accelerates the manganese movement into solution and its transportation through baseflow and or/runoff. Release of manganese from river bottom sediments is also a potential source of manganese. Therefore, the observed manganese levels are likely due to the natural geochemical environment and most likely reflect natural background conditions.

5.1.2 Loading Capacity of Shoal Creek Stream Segment OI09

Existing and allowable loads of fecal coliform and manganese were calculated for segment OI09 along Shoal Creek at station OI09 located at the County Road bridge, 3 miles north of Panama and 3 miles east of Walshville in Montgomery County. This sample station drains 276.43 square miles and land use/land cover is primarily cultivated crops, deciduous forest, and pasture hay. A total of 52 fecal coliform samples and 26 manganese samples were available for the load duration analysis (Appendix B).

Table 6 presents the TMDL summary for this assessment location. Results of the load duration analysis indicate that fecal coliform observations exceed the loading limit during all flow conditions resulting in needed reductions of 23 to 94 percent. Manganese loadings are above the threshold loadings across all flow conditions, with the exception of low flows, displaying the highest needed reductions during mid-range and dry flow conditions.

The greatest needed reductions for fecal coliform occur during high and moist flow conditions (94 and 85 percent, respectively). Livestock and animal feeding operations were identified as potential sources of fecal coliform (IEPA, 2006), and fecal coliform located in the streambed might also be re-suspended during these high flow periods. Wildlife, including waterfowl and terrestrial animals, could also be significant sources of fecal coliform as well.

The high manganese levels are attributed to natural background conditions, similar to segment OI08.

Table 6. Fecal Coliform and Manganese TMDL Summary for Stream Segment OI09

OI09 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Fecal Coliform (Million/day)	Current Load	47,273,391	2,307,725	146,303	49,182	45,699
	TMDL= LA+WLA+MOS	**3,036,480**	**379,100**	**108,577**	**42,327**	**15,458**
	LA	3,032,770	375,390	104,867	38,617	11,748
	WLA: Pierron East STP	156	156	156	156	156
	WLA: Louisville STP	1,136	1,136	1,136	1,136	1,136
	WLA: Pocahontas STP	946	946	946	946	946
	WLA: Panama STP	397	397	397	397	397
	WLA: New Douglas STP	416	416	416	416	416
	WLA: Sorento STP	530	530	530	530	530
	WLA Sorento WTP	129	129	129	129	129
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	WLA: Total Point Sources	3,710	3,710	3,710	3,710	3,710
	MOS (Implicit)	Implicit	Implicit	Implicit	Implicit	Implicit
	TMDL Reduction (%)	94%	84%	26%	14%	66%
Manganese (kg/day)	Current Load	505.0	79.6	35.4	11.2	0.7
	TMDL= LA+WLA+MOS	**411.3**	**59.6**	**16.1**	**5.1**	**1.4**
	LA	370.2	53.6	14.5	4.6	1.3
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	41.1	6.0	1.6	0.5	0.1
	TMDL Reduction (%)	27%	33%	59%	59%	0%

5.1.3 Loading Capacity of Chicken Creek Stream Segment OIO09

Existing and allowable silver loads were calculated for Chicken Creek segment OIO09 at station OIO09 located 1.6 miles north-northeast of Breese in Clinton County. This location drains 2.21 square miles and land use/land cover is primarily of cultivated crops and pasture/hay. A total of 2 silver samples obtained in 1991 were available for the load duration analysis (Appendix B). Stage 2 sampling of Chicken Creek was not able to be completed due to dry streams, therefore the only available data are from 1991. There are no point source facilities that discharge directly to Chicken Creek. No potential sources of silver were identified in either the Stage 1 or Stage 2 report. However, silver is naturally found in soils and this is one potential source that will be further investigated during development of the implementation plan.

Table 7 presents the TMDL summary for this assessment location. Data were only available for high and mid-range flow conditions. Results of the load duration analysis indicate that silver observations exceed the loading limit during mid range flow conditions resulting in a needed 49 percent reduction in silver loads.

Table 7. Silver TMDL Summary for Stream Segment OIO09

OIO09 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
Silver (kg/day)	Current Load	0.0633	No Data	0.0076	No Data	No Data
	TMDL= LA+WLA+MOS	**0.1096**	**0.0159**	**0.0043**	**0.0014**	**0.0004**
	LA	0.0986	0.0143	0.0039	0.0013	0.0004
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	0.0110	0.0016	0.0004	0.0001	0.0000
	TMDL Reduction (%)	0%	No Data	49%	No Data	No Data

5.1.4 Loading Capacity of Cattle Creek Stream Segment OIP10

Existing and allowable loads of TDS, copper, and ammonia were calculated for Cattle Creek (segment OIP10) at station OIP10, located 3.1 miles north of Breese. This location drains 3.32 square miles and land use/land cover is primarily of cultivated crops and pasture/hay. A total of 4 ammonia samples, 4 copper samples, and 4 TDS samples were available for the load duration analysis (Appendix B). There are no point source facilities discharging upstream of sample station OIP10.

Potential sources of ammonia in this segment include animal feeding operations (NPS) and livestock (grazing or feeding operations). Livestock and animal feeding operations are prevalent throughout the Clinton, Bond, and Montgomery County portions of the watershed (IEPA, 2006) and are potential contributors of ammonia to segment OIP10. Private surface sewage systems are also common in the area and if not treated properly can release untreated sewage to local waterways. It has been estimated that statewide between 20 and 60 percent of surface discharging systems are failing or have failed (IEPA, 2004) suggesting that such systems may be a significant source of pollutants.

TDS sources include animal feeding operations (NPS), livestock (grazing or feeding operations), and crop production (crop land or dry land) (IEPA, 2006). Sources of copper loads in Cattle Creek were not identified in the Stage 1 or Stage 2 reports and are listed as unknown. Copper is naturally found in soils and this is one potential source that will be further investigated during development of the implementation plan.

Table 8 presents the TMDL summary for this assessment location. Results of the load duration analysis indicate that no reductions are needed during high flows for all three parameters. The TDS results show no needed reductions at mid-range flows and needed reductions of 39 and 21 percent at dry and low flows. Needed copper load reductions increase as flows decrease displaying 20 to 99 percent reductions from mid-range to low flows. Ammonia loads show similar results with no needed reductions at mid-range flows, 18 percent at dry flows, and 66 percent needed reductions at low flows.

Table 8. TDS, Copper, and Ammonia TMDL Summary for Stream Segment OIP10

OIP10 TMDL		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
Pollutant	**TMDL Component**	**0-10**	**10-40**	**40-60**	**60-90**	**90-100**
TDS (kg/day)	Current Load	9.64	No Data	0.55	0.61	0.13
	TMDL= LA+WLA+MOS	**32.93**	**4.77**	**1.29**	**0.41**	**0.11**
	LA	29.64	4.29	1.16	0.37	0.10
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	3.29	0.48	0.13	0.04	0.01
	TMDL Reduction (%)	0%	No Data	0%	39%	21%
Copper (kg/day)	Current Load	0.317	No Data	0.030	0.014	0.150
	TMDL= LA+WLA+MOS	**0.672**	**0.097**	**0.026**	**0.008**	**0.002**
	LA	0.605	0.087	0.023	0.007	0.002
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	0.067	0.010	0.003	0.001	0.000
	TMDL Reduction (%)	0%	No Data	20%	45%	99%
Ammonia (kg/day)	Current Load	12.1	No Data	2.6	3.8	2.5
	TMDL= LA+WLA+MOS	**277.0**	**40.2**	**10.9**	**3.4**	**0.9**
	LA	249.3	36.2	9.8	3.1	0.8
	WLA: facility	n/a	n/a	n/a	n/a	n/a
	WLA: MS4	n/a	n/a	n/a	n/a	n/a
	MOS (10%)	27.7	4.0	1.1	0.3	0.1
	TMDL Reduction (%)	0%	No Data	0%	18%	66%

5.1.5 Waste Load Allocations

The results of this analysis indicate that fecal coliform is a concern in Shoal Creek during all flow conditions. There are eight NPDES entities that are allowed to discharge fecal coliform in the Shoal Creek watershed upstream of OI-08 and OI-09. Information on these dischargers is shown in Table 9. The WLAs for the Breese STP facility were determined by multiplying the facility's design maximum flow (DMF) by its permit limit (400/100 mL) during high to mid range flows and by multiplying the design average flow (DAF) by the permit limit during low flows and moist conditions. The WLAs for each of the remaining facilities with disinfection exemptions were determined by multiplying the design average flows by 200 cfu/100 mL during all flow ranges. As discussed previously the facilities with disinfection exemptions are required to meet the geometric mean standard at the nearest point downstream where recreational use occurs in the receiving water, not at the pipe outfall.

No NPDES facilities discharge to the segments impaired due to silver and ammonia and therefore no WLAs were developed for these parameters.

None of the permitted point sources discharging to streams impaired due to manganese are required to monitor or control for manganese as none of them would be expected to have high concentrations of this parameter. No manganese WLAs were therefore developed as part of the development of these TMDLs.

There are no Municipal Separate Stormwater System (MS4) communities in the Shoal Creek watershed so no WLAs were assigned for MS4s. Furthermore, IEPA does not have information on confined animal feeding operations (CAFOs) at this time. In the event IEPA obtains information on CAFOs in the future, the TMDL strategy may be amended to better account for contributing sources.

Table 9. Fecal Coliform Limits and WLA for NPDES Facilities in the Shoal Creek watershed

WLA Summary		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
NPDES Permit	Parameter	0-10	Oct-40	40-60	60-90	90-100
Pierron East STP	Flow (MGD)	0.0206	0.0206	0.0206	0.0206	0.0206
	Fecal Coliform WLA (Million/day)	156	156	156	156	156
Breese STP	Flow (MGD)	1.57	1.57	1.57	0.629	0.629
	Fecal Coliform WLA (Million/day)	23,772	23,772	23,772	9,524	9,524
Louisville STP	Flow (MGD)	0.15	0.15	0.15	0.15	0.15
	Fecal Coliform WLA (Million/day)	1,136	1,136	1,136	1,136	1,136
Pocahontas STP	Flow (MGD)	0.125	0.125	0.125	0.125	0.125
	Fecal Coliform WLA (Million/day)	946	946	946	946	946
Panama STP	Flow (MGD)	0.0525	0.0525	0.0525	0.0525	0.0525
	Fecal Coliform WLA (Million/day)	397	397	397	397	397
New Douglas STP	Flow (MGD)	0.055	0.055	0.055	0.055	0.055
	Fecal Coliform WLA (Million/day)	416	416	416	416	416
Sorento STP	Flow (MGD)	0.07	0.07	0.07	0.07	0.07
	Fecal Coliform WLA (Million/day)	530	530	530	530	530
Sorento WTP	Flow (MGD)	0.017	0.017	0.017	0.017	0.017
	Fecal Coliform WLA (Million/day)	129	129	129	129	129

5.1.6 Load Allocation

The load allocations presented above are based on subtracting the allocations for WLAs and the MOS from allowable loads and are presented in Table 5 through 8. The control of fecal coliform, manganese, silver, TDS, ammonia, and copper loadings from nonpoint sources such as wildlife and agriculture will be explored during the development of the implementation plan.

5.1.7 Margin of Safety

The Clean Water Act requires that a TMDL include a margin of safety (MOS) to account for uncertainties in the relationship between pollutants loads and receiving water quality. USEPA guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS). A 10 percent explicit MOS has been applied as part of this TMDL for manganese, silver, TDS, ammonia, and copper. A moderate MOS was specified because the use of the load duration curves is expected to provide accurate information on the loading capacity of the stream (because the loading capacity is simply calculated by multiplying the daily flows by the appropriate water quality criteria), but this estimate of the loading capacity may be subject to potential error due to estimating flows for ungaged locations within the watershed (i.e., daily flows are not measured at each and every point where a TMDL was to be calculated and therefore had to be estimated).

The MOS for fecal coliform is an implicit one because (1) the TMDL is based on meeting the more restrictive geometric mean standard of 200 cfu/100 mL and (2) the load duration analysis does not account for the known die-off of fecal coliform.

5.1.8 Critical Conditions and Seasonality

TMDLs should also take into account critical conditions and seasonal variations. Critical conditions refer to the periods when greatest reductions of pollutants are needed. The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. From the load duration approach it has been determined that critical conditions for fecal coliform occur during high flow conditions; for manganese the critical conditions occur during both high and low flow regimes. Both point and nonpoint sources are believed to contribute to fecal coliform loads during these critical periods and the specific sources will be further evaluated during the preparation of an implementation plan. The allocation of point source loads (i.e., the WLA) also takes into account critical conditions by assuming that the facilities will discharge at their respective maximum design flows during moist to high flow conditions and at their average design flow during low flow and dry conditions..

The Clean Water Act also requires that TMDLs be established with consideration of seasonal variations. Seasonal variations for fecal coliform TMDL are addressed by only assessing conditions during the season when the water quality standard applies (May through October). Unlike for fecal coliform, there is no manganese, silver, TDS, ammonia, or copper standards set for a particular season i.e., the standard is set for the whole year. The load duration approach also accounts for seasonality by evaluating allowable loads on a daily basis over the entire range of observed flows and presenting daily allowable loads that vary by flow.

5.2 Dissolved Oxygen in the Shoal Creek Watershed

Three streams in the Shoal Creek watershed are listed as impaired due to low dissolved oxygen concentrations. No TMDLs are being developed for these three streams at this time due to the considerations described below.

5.2.1 Dissolved Oxygen Analysis in Locust Fork

Locust Fork is listed as impaired due to low dissolved oxygen. The original listing was made based on three samples collected in 1991, one of which was 1.7 mg/L. The impairment was confirmed based on the Stage 2 sampling in October 2006 which resulted in one additional sample below the water quality standard (refer to Stage 1 and Stage 2 reports for details). The QUAL2K model was setup and calibrated to the 2006 sampling data in Locust Fork to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Based upon the results of the Stage 1 study, the Stage 2 sampling, and the QUAL2K modeling the low dissolved oxygen conditions in Locust Fork appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools. For example, the most upstream station on Locust Fork could not be sampled in either August 2006 due to a lack of flow. To further investigate this issue three separate analyses were conducted to evaluate the potential for meeting the dissolved oxygen water quality standard in Locust Fork:

- Point and nonpoint source loads were reduced until both components of the dissolved oxygen water were met.
- The average dissolved oxygen re-aeration coefficient derived from the QUAL2K calibration was increased until both components of the dissolved oxygen water quality standard were met.
- The sediment oxygen demand derived from the QUAL2K calibration was decreased until both components of the dissolved oxygen water quality standard were met.

Table 10 indicates that significant load reductions from nonpoint sources would be needed to achieve the dissolved oxygen water quality standard. It is unknown at this time whether the nonpoint source load reductions are even feasible, given that much of this load is associated with natural background sources during these low flow periods when the dissolved oxygen problem is most prevalent. For example, leaf fall from vegetation near the water's edge, aquatic plants, and drainage from organically rich areas like swamps and bogs are all natural sources of material that consumes oxygen.

The modeling analysis also suggests that the water quality standards cannot be met even with the complete elimination of sediment oxygen demand (some of which is also expected to be natural). Although the water quality standards could be met if the average re-aeration rate is increased from 6.42/day to 12/day, increasing aeration in the stream would be technically difficult and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDL will be developed at this time and instead methods to reduce pollutant loadings and increase in-stream re-aeration will be outlined in the Implementation Plan.

Table 10. Pollutant load reductions needed for Locust Fork to achieve dissolved oxygen criteria.

Pollutant	Existing Nonpoint Sources (lbs/day)	Reduced Nonpoint Sources (lbs/day)	Nonpoint Source Percent Reduction
CBOD	506.6	202.1	60
TKN	23.33	12.19	48

5.2.2 Dissolved Oxygen Analysis in Cattle Creek

Cattle Creek is listed as impaired due to low dissolved oxygen. The original listing was made based on three samples collected in 1991, two of which were below the 5 mg/L water quality standard. The impairment was confirmed based on the Stage 2 sampling in October 2006 which resulted in one additional sample below the water quality standard (refer to Stage 1 and Stage 2 reports for details). The QUAL2K model was setup and calibrated to the 2006 sampling data in Cattle Creek to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Similar to Locust Fork, the low dissolved oxygen conditions in Cattle Creek appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools. For example, both sampling stations on Cattle Creek could not be sampled in August 2006 due to a lack of flow and one station could not be sampled in October 2006. To further investigate this issue three separate analyses were conducted to evaluate the potential for meeting the dissolved oxygen water quality standard in Locust Fork:

- Point and nonpoint source loads were reduced until both components of the dissolved oxygen water were met.
- The average dissolved oxygen re-aeration coefficient derived from the QUAL2K calibration was increased until both components of the dissolved oxygen water quality standard were met.
- The sediment oxygen demand derived from the QUAL2K calibration was decreased until both components of the dissolved oxygen water quality standard were met.

Table 11 indicates that significant load reductions from nonpoint sources would be needed to achieve the dissolved oxygen water quality standard. It is unknown at this time whether the nonpoint source load reductions are even feasible, given that much of this load is associated with natural background sources. The modeling analysis also suggests that the water quality standards cannot be met even with the complete elimination of sediment oxygen demand (some of which is also expected to be natural). Although the water quality standards could be met if the average re-aeration rate is increased from 35/day to 80/day, increasing aeration in the stream would be technically difficult and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDL will be developed at this time and instead methods to reduce pollutant loadings and increase in-stream re-aeration will be outlined in the Implementation Plan.

Table 11. Pollutant load reductions needed for Cattle Creek to achieve dissolved oxygen criteria.

Pollutant	Existing Nonpoint Sources (lbs/day)	Reduced Nonpoint Sources (lbs/day)	Nonpoint Source Percent Reduction
CBOD	83.8	25.2	70
TKN	0.63	0.19	70

5.2.3 Dissolved Oxygen Analysis in Chicken Creek

Chicken Creek is listed as impaired due to low dissolved oxygen. The original listing was made based on three samples collected in 1991, two of which were below the 5 mg/L water quality standard. The impairment could not be confirmed based on the Stage 2 sampling because the creek was dry on both September 1, 2006 and October 17, 2006. The QUAL2K model was therefore setup and calibrated to the 1991 sampling data to further investigate the dissolved oxygen issues as explained in Section 4.2. Details of the QUAL2K modeling are provided in Appendix C.

Similar to Locust Fork and Cattle Creek, the low dissolved oxygen conditions in Chicken Creek appear to be strongly related to sediment oxygen demand and a lack of aeration caused by low flows and stagnant pools. Table 12 indicates that significant load reductions from nonpoint sources would be needed to achieve the dissolved oxygen water quality standard. It is unknown at this time whether the nonpoint source load reductions are even feasible, given that much of this load is associated with natural background sources. The modeling analysis suggests that the water quality standards could be met with the complete elimination of sediment oxygen demand, but some of this is also expected to be natural. Although the water quality standards could be met if the average re-aeration rate is increased from 15/day to 30/day, increasing aeration in the stream would be technically difficult and is not a parameter for which a TMDL can be developed. Based on these considerations no TMDL will be developed at this time and instead methods to reduce pollutant loadings and increase in-stream re-aeration will be outlined in the Implementation Plan.

Table 12. Pollutant load reductions needed for Chicken Creek to achieve dissolved oxygen criteria.

Pollutant	Existing Nonpoint Sources (lbs/day)	Reduced Nonpoint Sources (lbs/day)	Nonpoint Source Percent Reduction
CBOD	32.6	14.7	55
TKN	8.36	3.76	55

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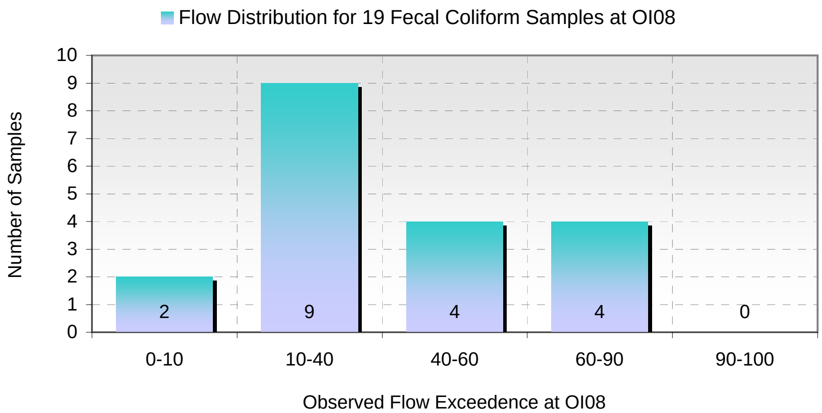
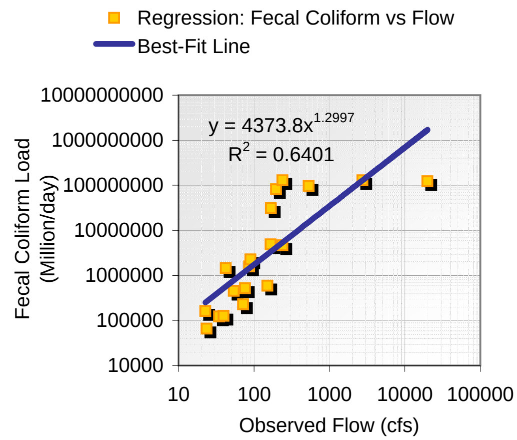
Appendix A : Load Duration Analysis

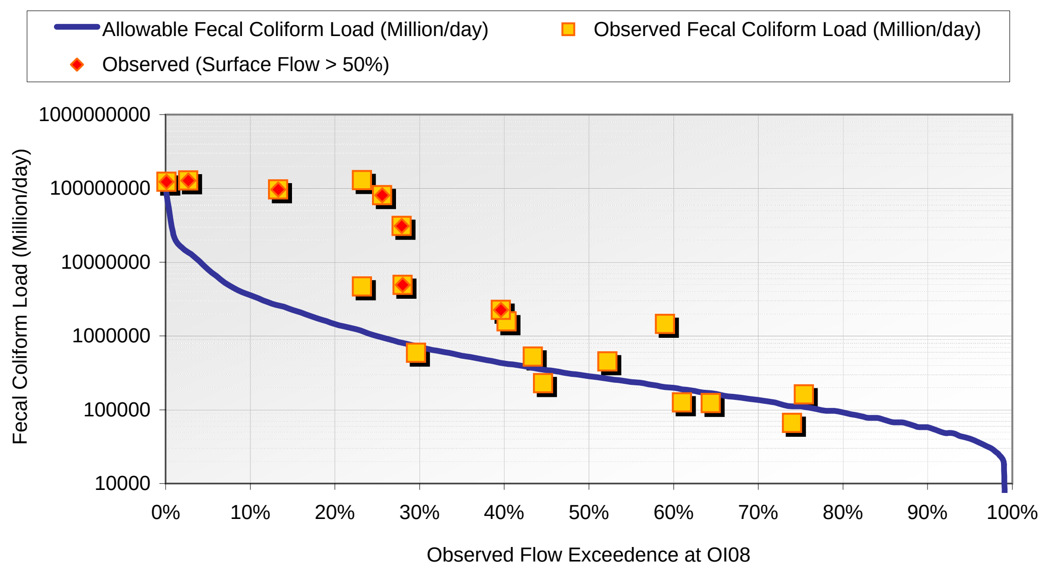
[2: Fecal Coliform at OI08 (MPN/100mL)] -vs- [5: Flow at OI08 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

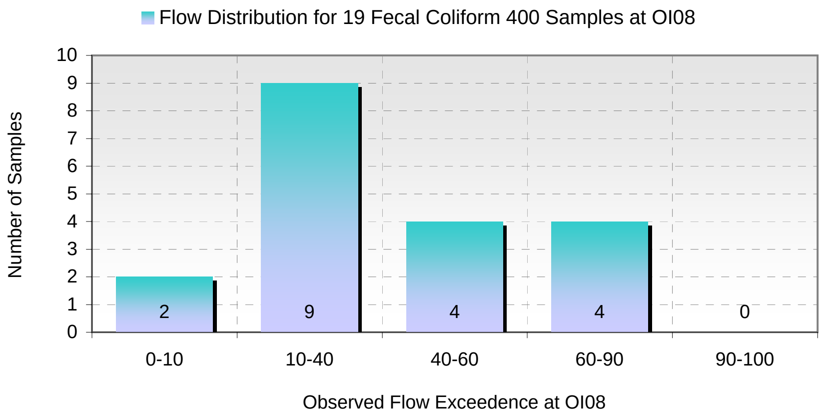


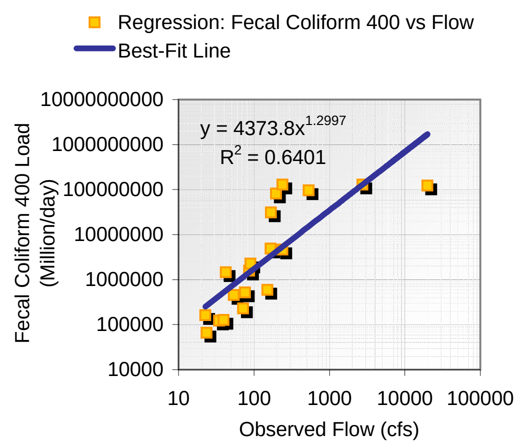
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	19-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (Million/day)	Observed Load (Million/day)	Estimated Reduction (%)
0-10	2	1629.39	7,972,860	125,343,030	93.6%
10-40	9	203.43	995,400	4,899,685	79.7%
40-60	4	58.26	285,090	486,344	41.4%
60-90	4	22.71	111,137	124,123	10.5%
90-100	0	8.30	40,589	No Data	No Data

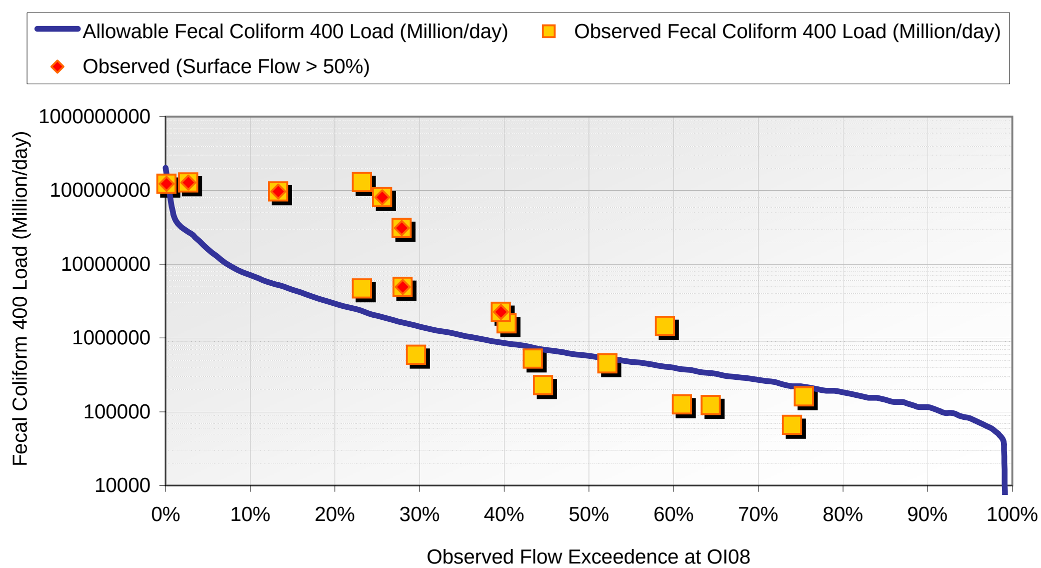
[14: Fecal Coliform 400 at OI08 (MPN/100mL)] -vs- [5: Flow at OI08 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

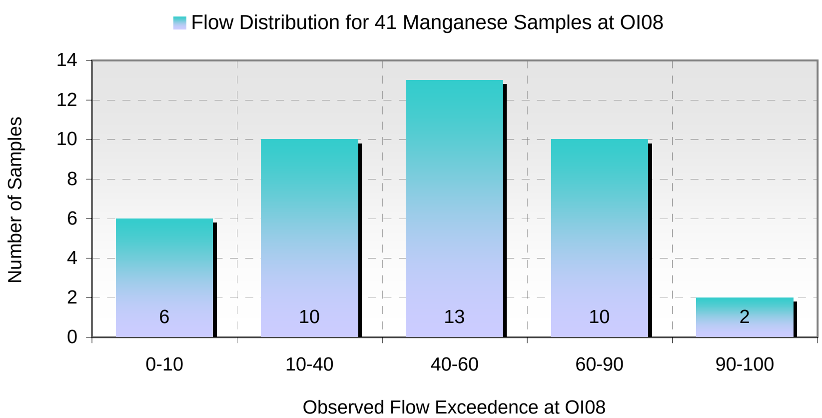


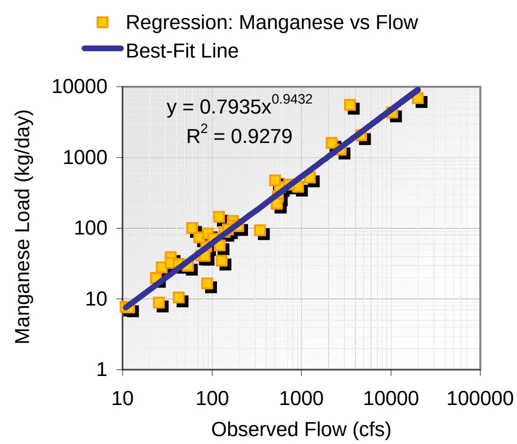
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	19-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (Million/day)	Observed Load (Million/day)	Estimated Reduction (%)
0-10	2	1629.39	15,945,721	125,343,030	87.3%
10-40	9	203.43	1,990,799	4,899,685	59.4%
40-60	4	58.26	570,180	486,344	0.0%
60-90	4	22.71	222,274	124,123	0.0%
90-100	0	8.30	81,178	No Data	No Data

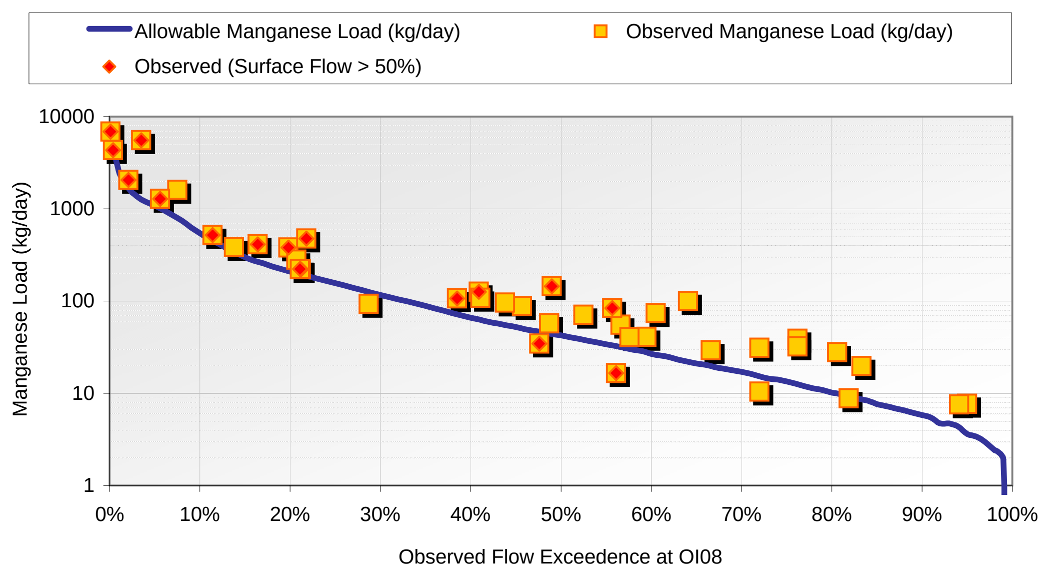
[3: Manganese at OI08 (mg/L)] -vs- [1: Flow at OI08 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

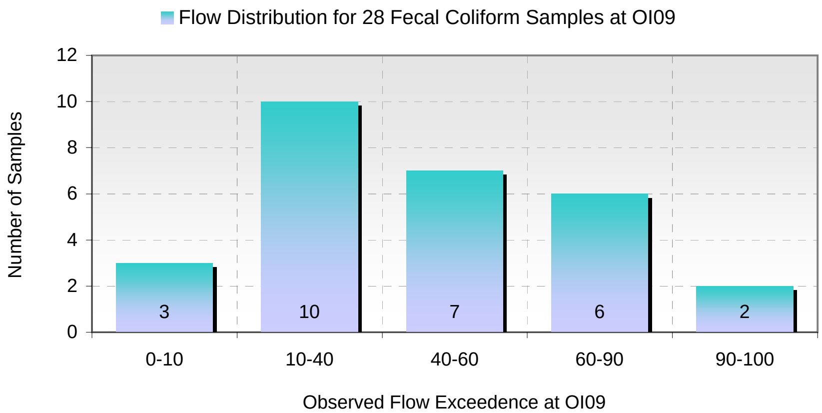


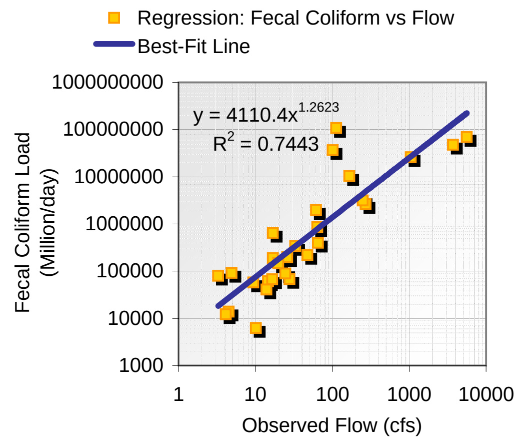
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	41-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (kg/day)	Observed Load (kg/day)	Estimated Reduction (%)
0-10	6	2942.78	1,080.0	3,182.6	66.1%
10-40	10	426.60	156.6	330.7	52.7%
40-60	13	115.54	42.4	71.0	40.3%
60-90	10	36.54	13.4	30.2	55.6%
90-100	2	9.88	3.6	7.6	52.5%

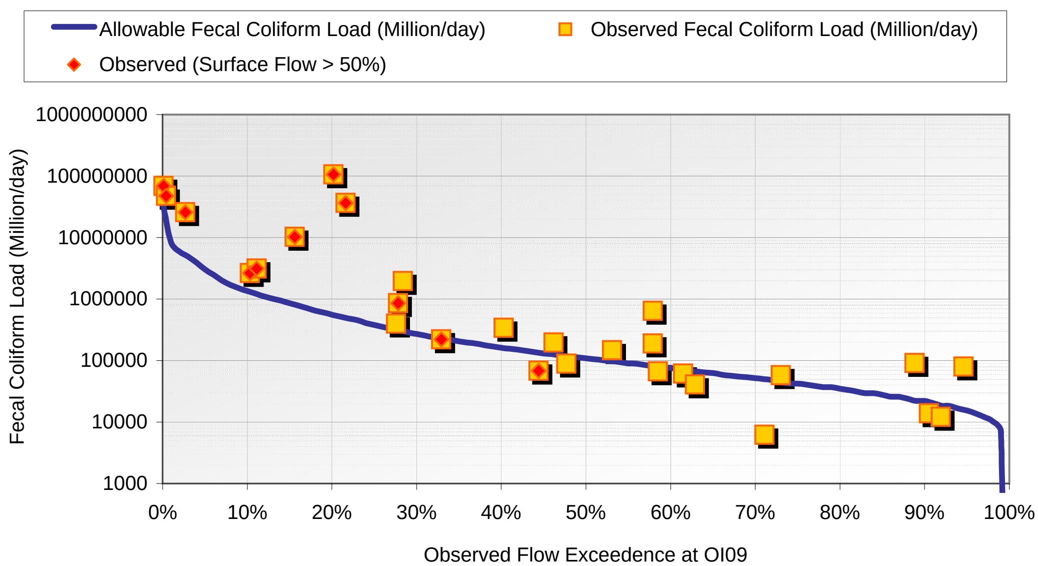
[6: Fecal Coliform at OI09 (MPN/100mL)] -vs- [6: Flow at OI09 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

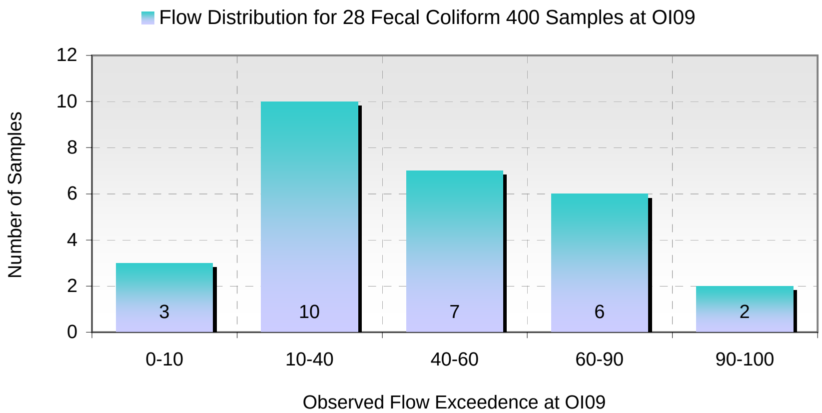


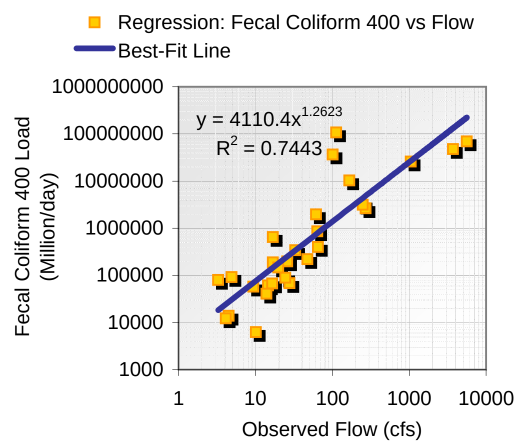
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	28-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (Million/day)	Observed Load (Million/day)	Estimated Reduction (%)
0-10	3	620.56	3,036,480	47,273,391	93.6%
10-40	10	77.48	379,100	2,307,725	83.6%
40-60	7	22.19	108,577	146,303	25.8%
60-90	6	8.65	42,327	49,182	13.9%
90-100	2	3.16	15,458	45,699	66.2%

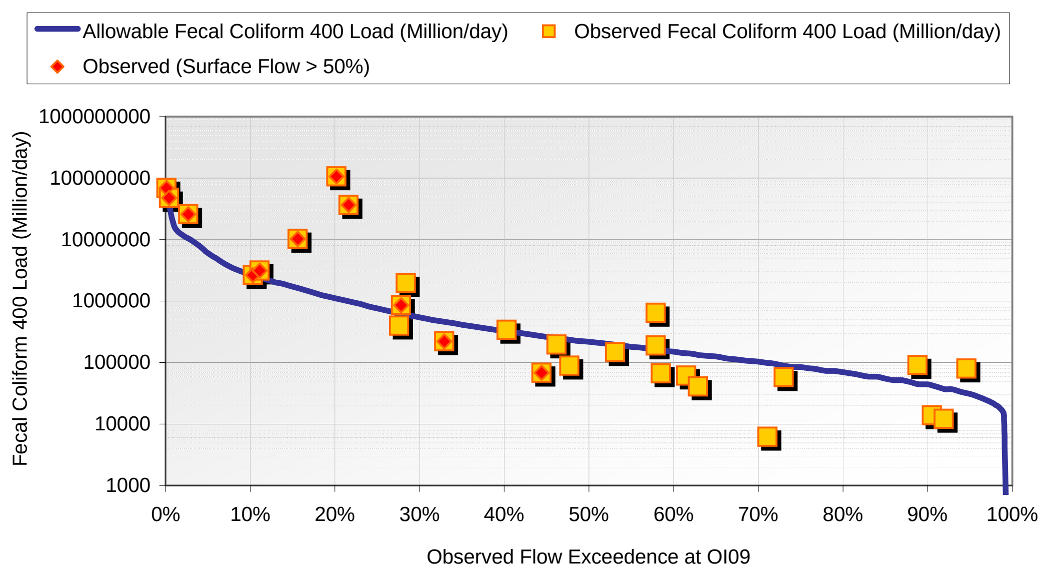
[15: Fecal Coliform 400 at OI09 (MPN/100mL)] -vs- [6: Flow at OI09 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

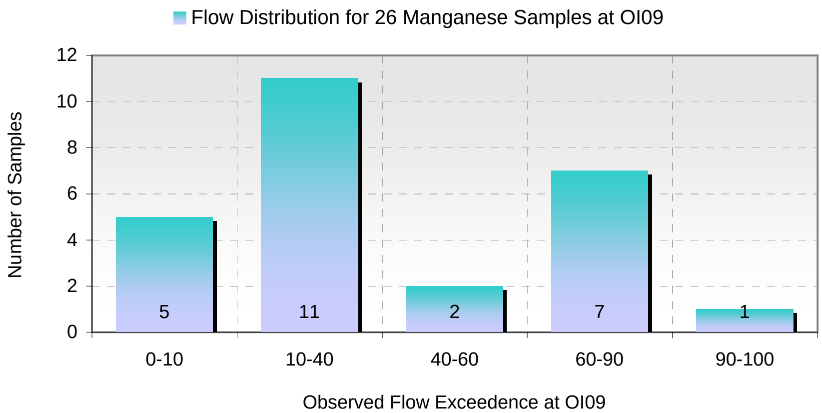


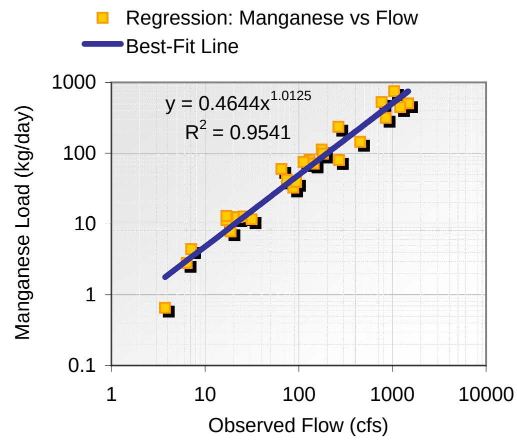
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	28-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (Million/day)	Observed Load (Million/day)	Estimated Reduction (%)
0-10	3	620.56	6,072,960	47,273,391	87.2%
10-40	10	77.48	758,200	2,307,725	67.1%
40-60	7	22.19	217,154	146,303	0.0%
60-90	6	8.65	84,653	49,182	0.0%
90-100	2	3.16	30,917	45,699	32.3%

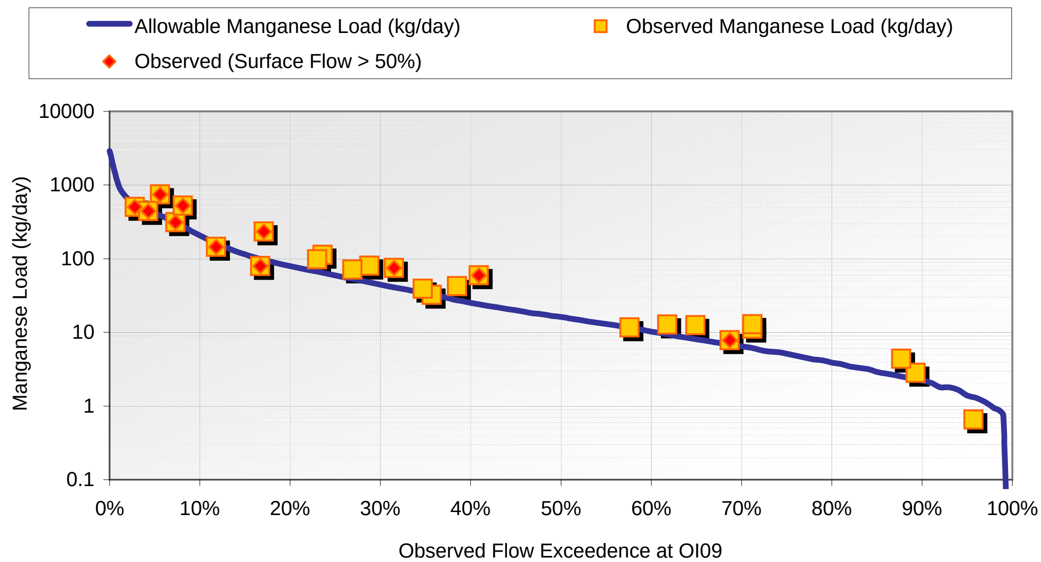
[7: Manganese at OI09 (mg/L)] -vs- [2: Flow at OI09 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

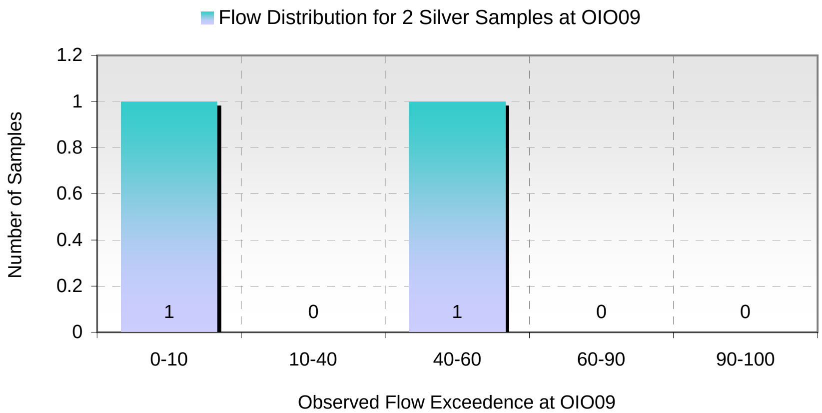


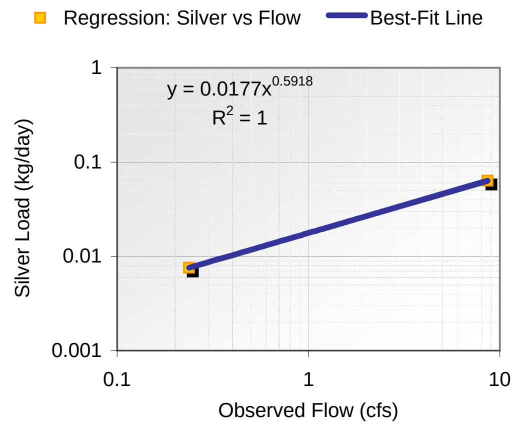
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	26-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (kg/day)	Observed Load (kg/day)	Estimated Reduction (%)
0-10	5	1120.76	411.3	505.0	18.5%
10-40	11	162.47	59.6	79.6	25.1%
40-60	2	44.00	16.1	35.4	54.4%
60-90	7	13.92	5.1	11.2	54.3%
90-100	1	3.76	1.4	0.7	0.0%

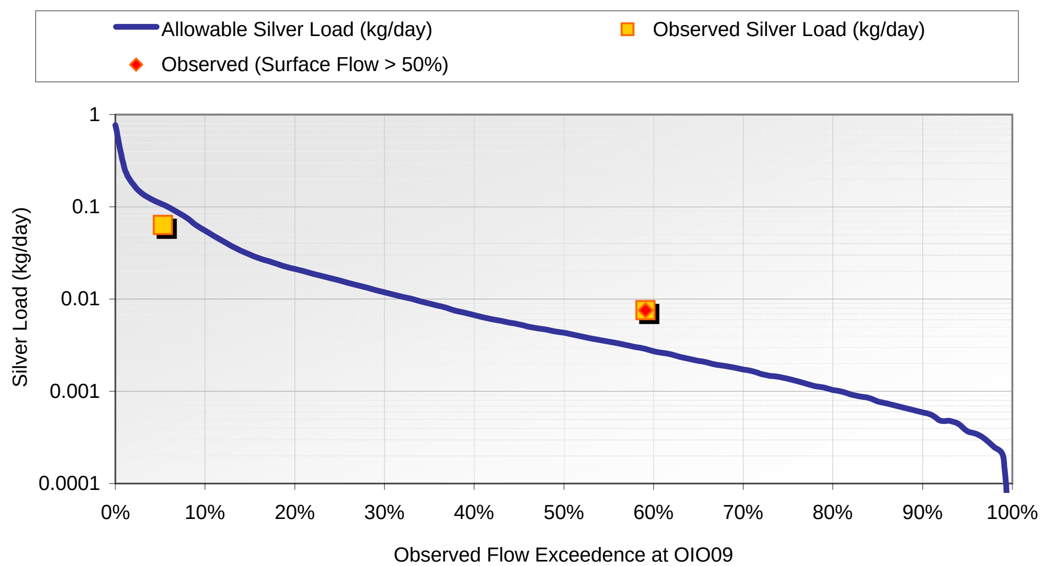
[9: Silver at OIO09 (mg/L)] -vs- [3: Flow at OIO09 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

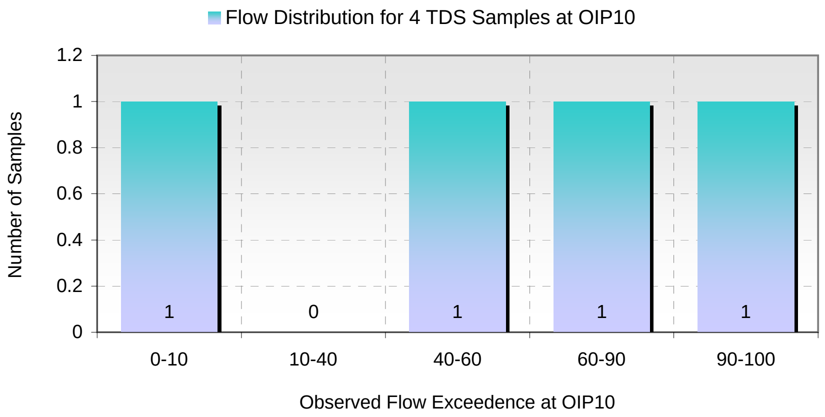


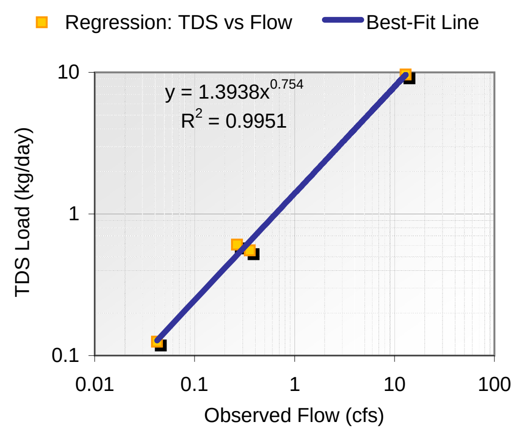
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	2-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (kg/day)	Observed Load (kg/day)	Estimated Reduction (%)
0-10	1	8.96	0.1096	0.0633	0.0%
10-40	0	1.30	0.0159	No Data	No Data
40-60	1	0.35	0.0043	0.0076	43.0%
60-90	0	0.11	0.0014	No Data	No Data
90-100	0	0.03	0.0004	No Data	No Data

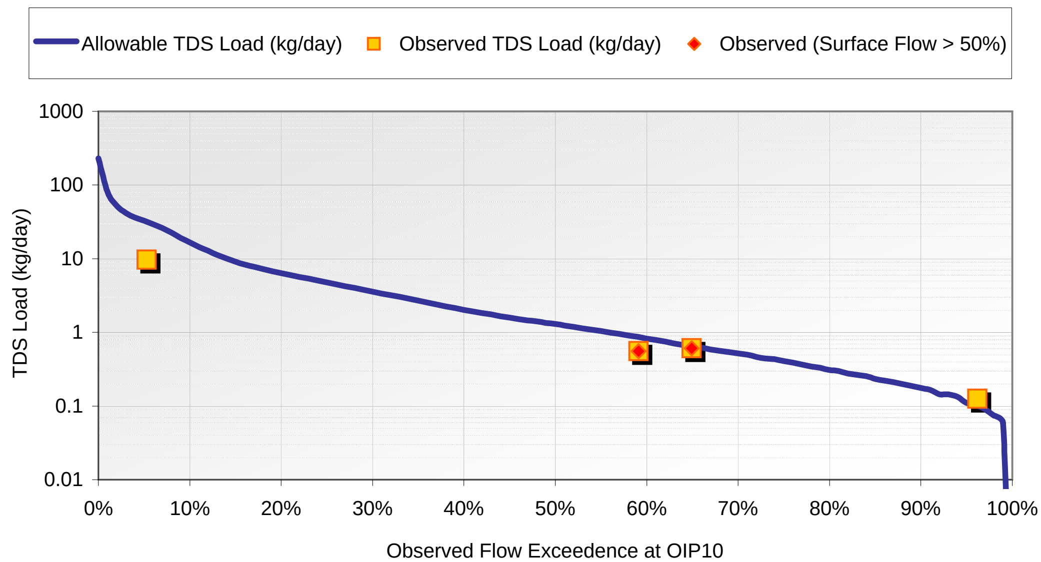
[10: TDS at OIP10 (mg/L)] -vs- [4: Flow at OIP10 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

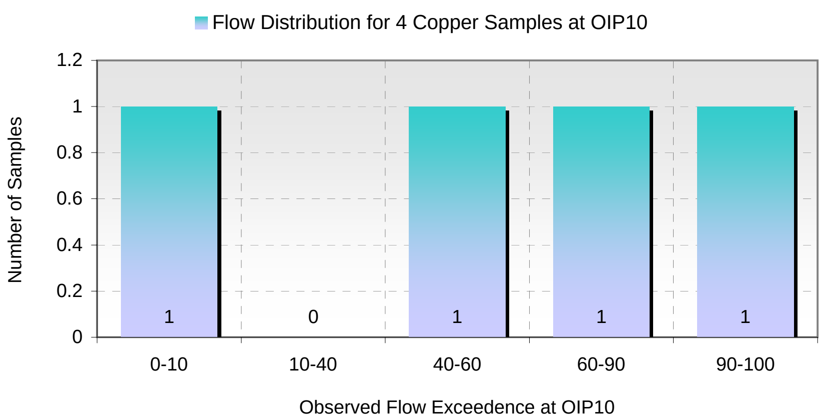


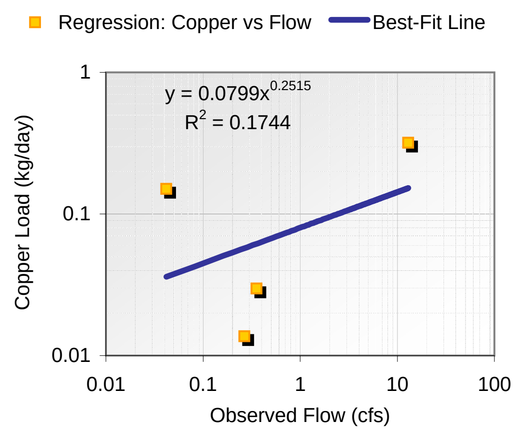
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	4-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (kg/day)	Observed Load (kg/day)	Estimated Reduction (%)
0-10	1	13.46	32.93	9.64	0.0%
10-40	0	1.95	4.77	No Data	No Data
40-60	1	0.53	1.29	0.55	0.0%
60-90	1	0.17	0.41	0.61	32.4%
90-100	1	0.05	0.11	0.13	11.9%

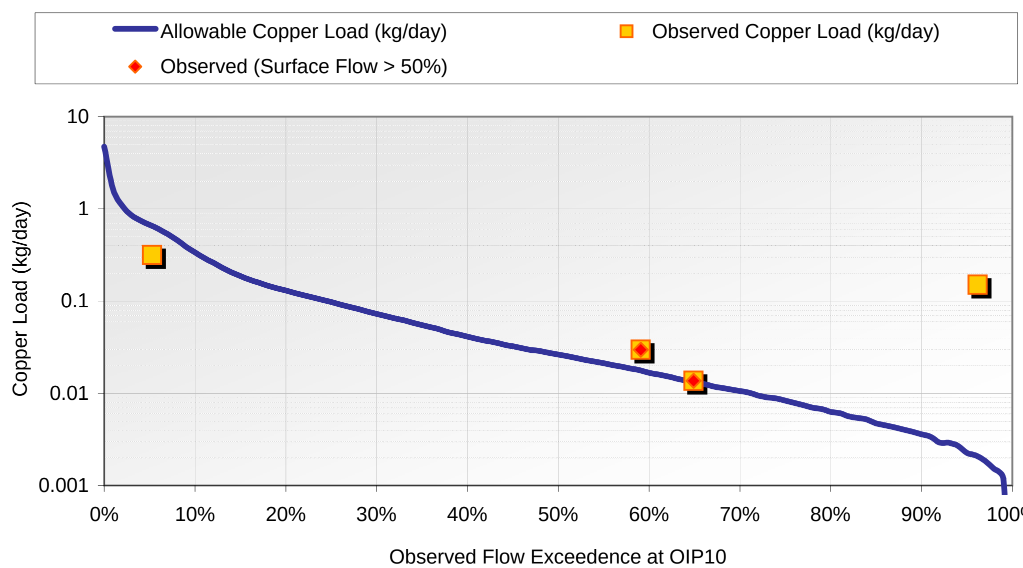
[12: Copper at OIP10 (mg/L)] -vs- [4: Flow at OIP10 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis

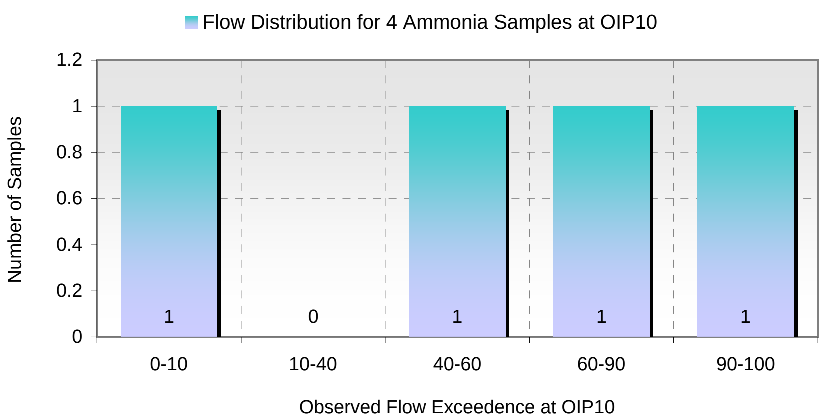


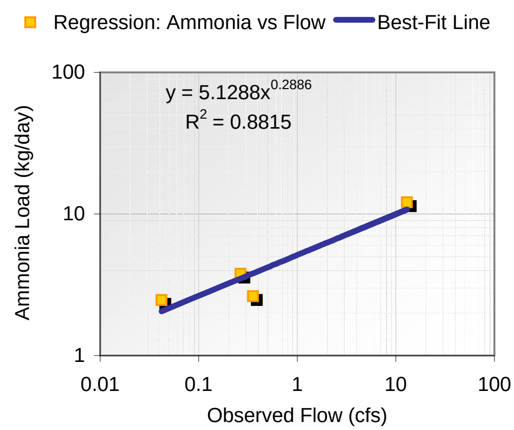
3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	4-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (kg/day)	Observed Load (kg/day)	Estimated Reduction (%)
0-10	1	13.46	0.6718	0.3172	0.0%
10-40	0	1.95	0.0974	No Data	No Data
40-60	1	0.53	0.0264	0.0297	11.1%
60-90	1	0.17	0.0083	0.0137	39.1%
90-100	1	0.05	0.0023	0.1502	98.5%

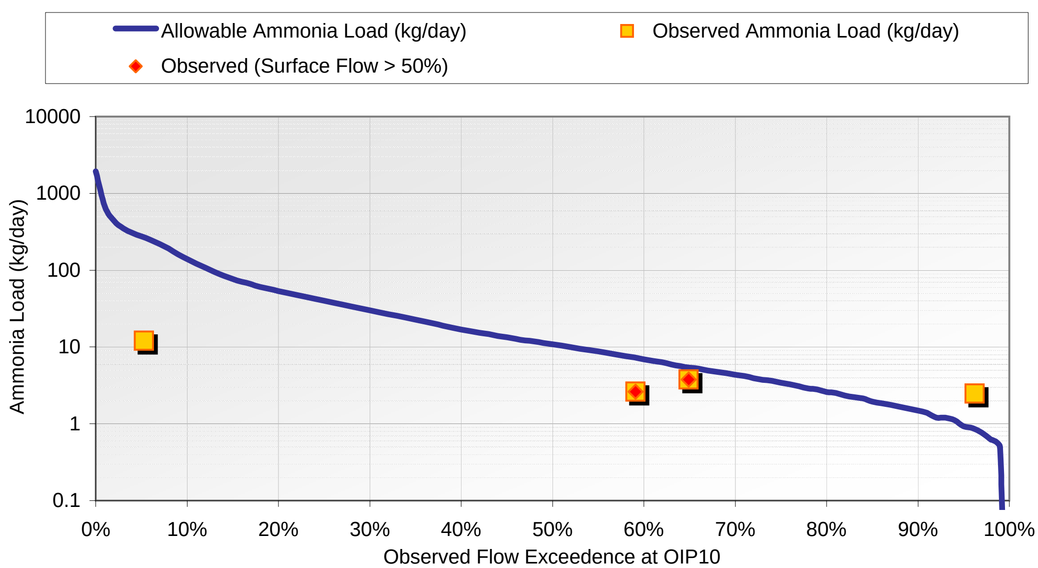
[13: Ammonia at OIP10 (mg/L)] -vs- [4: Flow at OIP10 (cfs)]

1. Data Assessment and Trend Confirmation





2. Load Exceedence Analysis



3. Estimated TMDL Loads by Flow Exceedence Range

Flow Exceedence Ranges	4-Sample Distribution	Median Observed Flow (cfs)	Allowable Load (kg/day)	Observed Load (kg/day)	Estimated Reduction (%)
0-10	1	13.46	276.96	12.05	0.0%
10-40	0	1.95	40.15	No Data	No Data
40-60	1	0.53	10.87	2.62	0.0%
60-90	1	0.17	3.44	3.78	9.1%
90-100	1	0.05	0.93	2.47	62.3%

Appendix B : Fecal Coliform, Manganese, Silver, TDS, Copper, and Ammonia Data for Load Duration Analysis

Table B-1. Available Fecal Coliform Data for Segment OI08

Date	Fecal Coliform at station OI08 (cfu/100ml)
1/6/2000	1,240
2/8/2000	2
3/20/2000	7,100
4/27/2000	160
6/5/2000	740
7/31/2000	1,900
9/20/2000	280
10/18/2000	7,400
11/13/2000	4,500
1/9/2001	7
3/5/2001	70
4/5/2001	20
5/8/2001	130
7/10/2001	145
8/9/2001	114
9/26/2001	290
11/6/2001	102
12/10/2001	210
1/30/2002	52
3/5/2002	900
4/2/2002	160
5/9/2002	250
6/6/2002	160
7/24/2002	1,400
8/26/2002	1,020
10/30/2002	16,700
12/12/2002	12
10/21/2003	340
11/19/2003	14,000
1/7/2004	2,400
2/25/2004	490
3/24/2004	29
5/5/2004	800
6/9/2004	22,000
7/21/2004	130
9/1/2004	1,200
10/20/2004	7,500
12/20/2004	130
1/6/2005	1,800

Table B-2. Available Manganese Data for Segment OI08

Date	Manganese at Station OI08 (µg/L)
1/21/1999	300
2/10/1999	170
3/24/1999	270
6/1/1999	380
8/3/1999	410
8/26/1999	460
10/7/1999	290
12/1/1999	260
1/6/2000	100
2/8/2000	140
4/27/2000	300
6/5/2000	260
7/31/2000	190
9/20/2000	220
10/18/2000	170
11/13/2000	170
3/5/2001	210
4/5/2001	260
5/8/2001	420
7/10/2001	380
8/9/2001	340
11/6/2001	200
12/10/2001	110
1/30/2002	260
3/5/2002	230
4/2/2002	170
5/9/2002	140
6/6/2002	260
7/24/2002	300
8/26/2002	380
10/30/2002	220
12/12/2002	80
1/15/2003	110
3/12/2003	280
4/16/2003	680
5/14/2003	180
6/17/2003	170
7/30/2003	490
9/10/2003	190
10/21/2003	220
11/19/2003	650

Table B-3. Available Fecal Coliform data for Segment OI09

Date	Fecal Coliform Data at Station OI09 (cfu/100ml)
1/26/2000	520
3/9/2000	10
4/27/2000	130
6/5/2000	420
7/31/2000	1,000
8/30/2000	400
9/21/2000	310
11/8/2000	2,440
12/20/2000	460
1/25/2001	560
3/7/2001	160
4/12/2001	900
5/31/2001	38,600
7/2/2001	455
7/31/2001	1,550
9/18/2001	250
11/6/2001	65
12/13/2001	1,560
1/24/2002	120
3/11/2002	260
4/8/2002	100
5/16/2002	500
7/9/2002	300
8/12/2002	190
9/19/2002	100
10/28/2002	25
12/10/2002	30
12/10/2002	30
1/30/2003	25
3/5/2003	40
4/7/2003	180
5/22/2003	510
7/8/2003	170
8/12/2003	165
9/18/2003	120
11/5/2003	230
12/10/2003	80
3/16/2004	200
4/14/2004	160
6/1/2004	520
6/22/2004	1,300
8/30/2004	2,500
9/27/2004	125
11/9/2004	140

Date	Fecal Coliform Data at Station OI09 (cfu/100ml)
12/29/2004	120
5/25/2005	149
8/10/2005	990
9/26/2005	14,600
5/17/2006	250
6/26/2006	545
8/30/2006	760
9/25/2006	120

Table B-4. Available Manganese Data for Segment OI09

Date	Manganese at station OI09 (µg/L)
2/3/1999	140
3/16/1999	250
4/12/1999	130
5/25/1999	150
7/7/1999	360
8/30/1999	180
9/27/1999	70
11/3/1999	170
12/8/1999	230
1/26/2000	250
4/27/2000	370
7/31/2000	290
8/30/2000	120
9/21/2000	200
11/8/2000	150
12/20/2000	230
1/25/2001	170
3/7/2001	200
4/12/2001	280
5/31/2001	270
7/2/2001	270
7/31/2001	310
11/6/2001	150
12/13/2001	260
3/11/2002	150
4/8/2002	220

Table B-5. Available Silver Data for Segment OIO09

Date	Silver Data at Station OIO09 (µg/L)
4/15/1991	3
10/28/1991	13

Table B-6. Available TDS Data for Segment OIP10

Date	TDS at station OIP10 (mg/L)
4/15/1991	304
9/18/1991	1,220
10/28/1991	634
10/17/2006	928

Table B-7. Available Copper Data for Segment OIP10

Date	TDS at station OIP10 (µg/L)
4/15/1991	10
9/18/1991	1,461
10/28/1991	34
10/17/2006	21

Table B-8. Available Ammonia Data for Segment OIP10

Date	Ammonia at station OIP10 (mg/L)
4/15/1991	0.38
9/18/1991	24.00
10/28/1991	3.00
10/17/2006	5.80

Appendix C : NPDES Fecal Coliform Counts

Table C-1. Fecal Coliform Counts from Breese STP (IL0022772)

Date	Fecal Count (cfu/100 mL)	Average Flow (MGD)	Max Flow (MGD)	Rec Season
5/31/2005	52	0.392	0.878	Yes
6/30/2005	23	0.36	1.42	Yes
7/31/2005	12	0.429	1.25	Yes
8/31/2005	2	0.369	1.08	Yes
7/31/2006	2	0.541	0.775	Yes

Appendix D : QUAL2K Modeling

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Headwater and Downstream Boundary Data:

Headwater Flow	0.000	m3/s
Prescribed downstream boundary?	No	
Headwater Water Quality	*Units*	*12:00 AM*
Temperature	C	20.00
Conductivity	umhos	0.00
Inorganic Solids	mgD/L	0.00
Dissolved Oxygen	mg/L	8.00
CBODslow	mgO2/L	1.00
CBODfast	mgO2/L	1.00
Organic Nitrogen	ugN/L	10.00
NH4-Nitrogen	ugN/L	10.00
NO3-Nitrogen	ugN/L	0.00
Organic Phosphorus	ugP/L	0.00
Inorganic Phosphorus (SRP)	ugP/L	0.00
Phytoplankton	ugA/L	0.00
Detritus (POM)	mgD/L	0.00
Pathogen	cfu/100 mL	0.00
Generic constituent	user defined	0.00
Alkalinity	mgCaCO3/L	200.00
pH	s.u.	7.33

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Reach Data:

Reach for diel plot:	17							
			Reach			Downstream	Elevation	
Reach	Downstream		length	Downstream		location	Upstream	Downstream
Label	end of reach label	Number	(km)	Latitude	Longitude	(km)	(m)	(m)
	Headwater	0		38.59	89.54	4.250		149.250
		1	0.25	38.59	89.54	4.000	149.000	147.750
		2	0.25	38.59	89.54	3.750	147.750	146.500
		3	0.25	38.59	89.54	3.500	146.500	145.250
		4	0.25	38.59	89.54	3.250	145.250	144.000
		5	0.25	38.59	89.54	3.000	144.000	142.750
		6	0.25	38.59	89.54	2.750	142.750	141.500
		7	0.25	38.59	89.54	2.500	141.500	140.250
		8	0.25	38.59	89.54	2.250	140.250	139.000
		9	0.25	38.59	89.54	2.000	139.000	137.750
		10	0.25	38.59	89.54	1.750	137.750	136.500
		11	0.25	38.59	89.54	1.500	136.500	135.250
		12	0.25	38.59	89.54	1.250	135.250	134.000
		13	0.25	38.59	89.54	1.000	134.000	133.000
		14	0.25	38.59	89.54	0.750	133.000	132.000
		15	0.25	38.59	89.54	0.500	132.000	131.000
		16	0.25	38.59	89.54	0.250	131.000	130.000
		17	0.25	38.59	89.54	0.000	130.000	129.000

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Reach Data:

							Hydraulic Model (Weir Overrides Rating Curves; Rating Curv					
	Downstream						Weir		Rating Curves			
	Latitude			Longitude			Height	Width	Velocity		Depth	
Number	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds	(m)	(m)	Coefficient	Exponent	Coefficient	Exponent
0	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
1	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
2	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
3	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
4	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
5	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
6	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
7	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
8	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
9	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
10	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
11	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
12	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
13	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
14	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
15	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
16	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
17	38.00	35	0	89.00	32	0	0.0000	0.0000	0.0000	0.000	0.0000	0.000

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Reach Data:

	es Override Manning Formula)										
	Manning Formula					*Prescribed*	*Bottom*	*Bottom*	*Prescribed*	*Prescribed*	*Prescribed*
	Channel	*Manning*	*Bot Width*	*Side*	*Side*	*Dispersion*	*Algae*	*SOD*	*SOD*	*CH4 flux*	*NH4 flux*
Number	*Slope*	*n*	*m*	*Slope*	*Slope*	*m2/s*	*Coverage*	*Coverage*	*gO2/m2/d*	*gO2/m2/d*	*mgN/m2/d*
0	0.000050	0.0550	0.37	2.00	2.00	0.00					
1	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
2	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
3	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
4	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
5	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
6	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
7	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
8	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
9	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
10	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
11	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
12	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
13	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
14	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
15	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
16	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000
17	0.000050	0.0550	0.37	2.00	2.00	0.00	0%	100%	3.00	0.0000	0.0000

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Reach Data:

Number	Prescribed Inorg P flux mgP/m2/d	Sediment thermal cond (W/m/degC)	Sediment thermal diff (cm^2/sec)	Sediment/hyporheic zone thickness (cm)	Hyporheic exchange flow (fraction of stream flow)	Hyporheic sediment porosity (fraction of volume)
0						
1	0.0000	1.6	0.0064	10	5%	40%
2	0.0000	1.6	0.0064	10	5%	40%
3	0.0000	1.6	0.0064	10	5%	40%
4	0.0000	1.6	0.0064	10	5%	40%
5	0.0000	1.6	0.0064	10	5%	40%
6	0.0000	1.6	0.0064	10	5%	40%
7	0.0000	1.6	0.0064	10	5%	40%
8	0.0000	1.6	0.0064	10	5%	40%
9	0.0000	1.6	0.0064	10	5%	40%
10	0.0000	1.6	0.0064	10	5%	40%
11	0.0000	1.6	0.0064	10	5%	40%
12	0.0000	1.6	0.0064	10	5%	40%
13	0.0000	1.6	0.0064	10	5%	40%
14	0.0000	1.6	0.0064	10	5%	40%
15	0.0000	1.6	0.0064	10	5%	40%
16	0.0000	1.6	0.0064	10	5%	40%
17	0.0000	1.6	0.0064	10	5%	40%

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Air Temperature Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Hourly air temperature for each reach (degrees C)				
Label	Label	Label	Number	km	km	(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)				
Headwater			1	4.25	4.00	13.00	14.00	16.00	16.00	14.00
			2	4.00	3.75	13.00	14.00	16.00	16.00	14.00
			3	3.75	3.50	13.00	14.00	16.00	16.00	14.00
			4	3.50	3.25	13.00	14.00	16.00	16.00	14.00
			5	3.25	3.00	13.00	14.00	16.00	16.00	14.00
			6	3.00	2.75	13.00	14.00	16.00	16.00	14.00
			7	2.75	2.50	13.00	14.00	16.00	16.00	14.00
			8	2.50	2.25	13.00	14.00	16.00	16.00	14.00
			9	2.25	2.00	13.00	14.00	16.00	16.00	14.00
			10	2.00	1.75	13.00	14.00	16.00	16.00	14.00
			11	1.75	1.50	13.00	14.00	16.00	16.00	14.00
			12	1.50	1.25	13.00	14.00	16.00	16.00	14.00
			13	1.25	1.00	13.00	14.00	16.00	16.00	14.00
			14	1.00	0.75	13.00	14.00	16.00	16.00	14.00
			15	0.75	0.50	13.00	14.00	16.00	16.00	14.00
			16	0.50	0.25	13.00	14.00	16.00	16.00	14.00
			17	0.25	0.00	13.00	14.00	16.00	16.00	14.00

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Air Temperature Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
2	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
3	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
4	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
5	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
6	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
7	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
8	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
9	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
10	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
11	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
12	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
13	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
14	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
15	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
16	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
17	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Air Temperature Data:

Reach Number	*3:00 PM*	*4:00 PM*	*5:00 PM*	*6:00 PM*	*7:00 PM*	*8:00 PM*	*9:00 PM*	*10:00 PM*	*11:00 PM*
1	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
2	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
3	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
4	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
5	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
6	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
7	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
8	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
9	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
10	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
11	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
12	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
13	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
14	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
15	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
16	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
17	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Dew Point Temperature Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Hourly dewpoint temperature for each reach (degrees C)				
Label	Label	Label	Number	km	km	(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)				
Headwater			1	4.25	4.00	12.00	13.00	15.00	14.00	12.00
			2	4.00	3.75	12.00	13.00	15.00	14.00	12.00
			3	3.75	3.50	12.00	13.00	15.00	14.00	12.00
			4	3.50	3.25	12.00	13.00	15.00	14.00	12.00
			5	3.25	3.00	12.00	13.00	15.00	14.00	12.00
			6	3.00	2.75	12.00	13.00	15.00	14.00	12.00
			7	2.75	2.50	12.00	13.00	15.00	14.00	12.00
			8	2.50	2.25	12.00	13.00	15.00	14.00	12.00
			9	2.25	2.00	12.00	13.00	15.00	14.00	12.00
			10	2.00	1.75	12.00	13.00	15.00	14.00	12.00
			11	1.75	1.50	12.00	13.00	15.00	14.00	12.00
			12	1.50	1.25	12.00	13.00	15.00	14.00	12.00
			13	1.25	1.00	12.00	13.00	15.00	14.00	12.00
			14	1.00	0.75	12.00	13.00	15.00	14.00	12.00
			15	0.75	0.50	12.00	13.00	15.00	14.00	12.00
			16	0.50	0.25	12.00	13.00	15.00	14.00	12.00
			17	0.25	0.00	12.00	13.00	15.00	14.00	12.00

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Dew Point Temperature Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
2	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
3	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
4	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
5	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
6	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
7	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
8	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
9	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
10	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
11	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
12	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
13	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
14	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
15	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
16	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00
17	11.00	11.00	11.00	11.00	11.00	12.00	12.00	12.00	12.00	13.00

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Dew Point Temperature Data:

Reach Number	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
2	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
3	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
4	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
5	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
6	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
7	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
8	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
9	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
10	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
11	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
12	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
13	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
14	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
15	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
16	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
17	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Wind Speed Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Wind speed for each reach 7m above water surface (m/s)				
Label	Label	Label	Number	km	km	(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)				
Headwater			1	4.25	4.00	4.02	4.02	3.58	7.15	8.94
			2	4.00	3.75	4.02	4.02	3.58	7.15	8.94
			3	3.75	3.50	4.02	4.02	3.58	7.15	8.94
			4	3.50	3.25	4.02	4.02	3.58	7.15	8.94
			5	3.25	3.00	4.02	4.02	3.58	7.15	8.94
			6	3.00	2.75	4.02	4.02	3.58	7.15	8.94
			7	2.75	2.50	4.02	4.02	3.58	7.15	8.94
			8	2.50	2.25	4.02	4.02	3.58	7.15	8.94
			9	2.25	2.00	4.02	4.02	3.58	7.15	8.94
			10	2.00	1.75	4.02	4.02	3.58	7.15	8.94
			11	1.75	1.50	4.02	4.02	3.58	7.15	8.94
			12	1.50	1.25	4.02	4.02	3.58	7.15	8.94
			13	1.25	1.00	4.02	4.02	3.58	7.15	8.94
			14	1.00	0.75	4.02	4.02	3.58	7.15	8.94
			15	0.75	0.50	4.02	4.02	3.58	7.15	8.94
			16	0.50	0.25	4.02	4.02	3.58	7.15	8.94
			17	0.25	0.00	4.02	4.02	3.58	7.15	8.94

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Wind Speed Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
2	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
3	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
4	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
5	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
6	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
7	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
8	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
9	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
10	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
11	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
12	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
13	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
14	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
15	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
16	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34
17	3.58	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13	1.34

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Wind Speed Data:

	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Reach									
Number									
1	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Cloud Cover Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Hourly cloud cover shade for each reach (Percent)				
Label	Label	Label	Number	km	km	(Percent of sky that is covered by clouds. The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)				
Headwater			1	4.25	4.00	95.0%	95.0%	95.0%	95.0%	95.0%
			2	4.00	3.75	95.0%	95.0%	95.0%	95.0%	95.0%
			3	3.75	3.50	95.0%	95.0%	95.0%	95.0%	95.0%
			4	3.50	3.25	95.0%	95.0%	95.0%	95.0%	95.0%
			5	3.25	3.00	95.0%	95.0%	95.0%	95.0%	95.0%
			6	3.00	2.75	95.0%	95.0%	95.0%	95.0%	95.0%
			7	2.75	2.50	95.0%	95.0%	95.0%	95.0%	95.0%
			8	2.50	2.25	95.0%	95.0%	95.0%	95.0%	95.0%
			9	2.25	2.00	95.0%	95.0%	95.0%	95.0%	95.0%
			10	2.00	1.75	95.0%	95.0%	95.0%	95.0%	95.0%
			11	1.75	1.50	95.0%	95.0%	95.0%	95.0%	95.0%
			12	1.50	1.25	95.0%	95.0%	95.0%	95.0%	95.0%
			13	1.25	1.00	95.0%	95.0%	95.0%	95.0%	95.0%
			14	1.00	0.75	95.0%	95.0%	95.0%	95.0%	95.0%
			15	0.75	0.50	95.0%	95.0%	95.0%	95.0%	95.0%
			16	0.50	0.25	95.0%	95.0%	95.0%	95.0%	95.0%
			17	0.25	0.00	95.0%	95.0%	95.0%	95.0%	95.0%

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Cloud Cover Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
2	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
3	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
4	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
5	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
6	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
7	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
8	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
9	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
10	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
11	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
12	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
13	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
14	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
15	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
16	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%
17	72.5%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Cloud Cover Data:

Reach Number	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
2	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
3	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
4	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
5	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
6	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
7	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
8	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
9	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
10	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
11	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
12	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
13	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
14	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
15	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
16	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
17	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Shade Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Integrated hourly effective shade for each reach (Percent)				
Label	Label	Label	Number	km	km	(Percent of solar radiation that is blocked because of shade from topography and vegetation. Hourly values are applied as integrated values for each hour, e.g. the value at 12:00 AM is applied from 12:00 to 1:00 AM)				
Headwater			1	4.25	4.00	15.0%	15.0%	15.0%	15.0%	15.0%
			2	4.00	3.75	15.0%	15.0%	15.0%	15.0%	15.0%
			3	3.75	3.50	15.0%	15.0%	15.0%	15.0%	15.0%
			4	3.50	3.25	15.0%	15.0%	15.0%	15.0%	15.0%
			5	3.25	3.00	15.0%	15.0%	15.0%	15.0%	15.0%
			6	3.00	2.75	15.0%	15.0%	15.0%	15.0%	15.0%
			7	2.75	2.50	15.0%	15.0%	15.0%	15.0%	15.0%
			8	2.50	2.25	15.0%	15.0%	15.0%	15.0%	15.0%
			9	2.25	2.00	15.0%	15.0%	15.0%	15.0%	15.0%
			10	2.00	1.75	15.0%	15.0%	15.0%	15.0%	15.0%
			11	1.75	1.50	15.0%	15.0%	15.0%	15.0%	15.0%
			12	1.50	1.25	15.0%	15.0%	15.0%	15.0%	15.0%
			13	1.25	1.00	15.0%	15.0%	15.0%	15.0%	15.0%
			14	1.00	0.75	15.0%	15.0%	15.0%	15.0%	15.0%
			15	0.75	0.50	15.0%	15.0%	15.0%	15.0%	15.0%
			16	0.50	0.25	15.0%	15.0%	15.0%	15.0%	15.0%
			17	0.25	0.00	15.0%	15.0%	15.0%	15.0%	15.0%

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Shade Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
2	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
3	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
4	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
5	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
6	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
7	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
8	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
9	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
10	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
11	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
12	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
13	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
14	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
15	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
16	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
17	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Shade Data:

Reach Number	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
2	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
3	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
4	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
5	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
6	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
7	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
8	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
9	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
10	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
11	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
12	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
13	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
14	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
15	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
16	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
17	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Light Parameters and Surface Heat Transfer Models:

Parameter	*Value*	*Unit*	
Photosynthetically Available Radiation	0.47		
Background light extinction	0.2	*/m*	k_{eb}
Linear chlorophyll light extinction	0.0088	*1/m-(ugA/L)*	α_p
Nonlinear chlorophyll light extinction	0.054	*1/m-(ugA/L)$^{2/3}$*	α_{pn}
ISS light extinction	0.052	*1/m-(mgD/L)*	α_i
Detritus light extinction	0.174	*1/m-(mgD/L)*	α_o
Macrophyte light extinction	0.015	*1/m-(gD/m^3)*	α_{mac}
Solar shortwave radiation model			
Atmospheric attenuation model for solar	Ryan-Stolzenbach		
Bras solar parameter (used if Bras solar model is selected)			
atmospheric turbidity coefficient (2=clear, 5=smoggy, default=2)	2		n_{fac}
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)			
atmospheric transmission coefficient (0.70-0.91, default 0.8)	0.8		a_{tc}
Downwelling atmospheric longwave IR radiation			
atmospheric longwave emissivity model	Brunt		
Evaporation and air convection/conduction			
wind speed function for evaporation and air convection/conduction	Brady-Graves-Geyer		

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Diffuse Source Data:

			Diffuse	Diffuse		Spec	Inorg	Diss	CBOD	CBOD
			Abstraction	Inflow	Temp	Cond	SS	Oxygen	slow	fast
Name	Up (km)	Down (km)	m3/s	m3/s	C	umhos	mgD/L	mg/L	mgO2/L	mgO2/L
1.00	4.2500	1.0000	0.00	0.0007	27.00	0.00	0.00	3.50	300.0	250.0
1.00	1.0000	0.0000		0.0001	27.00	0.00	0.00	3.50	300.0	250.0

Organic N ugN/L	Ammon N ugN/L	Nitrate N ugN/L	Organic P ugP/L	Inorganic P ugP/L	Phyto plankton ug/L	Detritus mgD/L	Pathogen cfu/100 mL	Generic constituent user defined	Alk mgCaCO3/L	pH
3800.0	330.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	7.0
3800.0	330.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	7.0

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Global rate parameters

Fitness:
#DIV/0!

Parameter	Value	Units	Symbol	Auto-calibration inputs		
				Auto-cal	Min value	Max value
Stoichiometry:						
Carbon	40	gC	gC	No	30	50
Nitrogen	7.2	gN	gN	No	3	9
Phosphorus	1	gP	gP	No	0.4	2
Dry weight	100	gD	gD	No	100	100
Chlorophyll	1	gA	gA	No	0.4	2
Inorganic suspended solids:						
Settling velocity	0.00236	m/d	v_i	Yes	0	2
Oxygen:						
Reaeration model	O'Connor-Dobbins			f(u h)		
Temp correction	1.024		θ_a			
Reaeration wind effect	None					
O2 for carbon oxidation	2.69	gO_2/gC	r_{oc}			
O2 for NH4 nitrification	4.57	gO_2/gN	r_{on}			
Oxygen inhib model CBOD oxidation	Exponential					
Oxygen inhib parameter CBOD oxidation	0.60	L/mgO2	K_{socf}	No	0.60	0.60
Oxygen inhib model nitrification	Exponential					
Oxygen inhib parameter nitrification	0.60	L/mgO2	K_{sona}	No	0.60	0.60
Oxygen enhance model denitrification	Exponential					
Oxygen enhance parameter denitrification	0.60	L/mgO2	K_{sodn}	No	0.60	0.60
Oxygen inhib model phyto resp	Exponential					
Oxygen inhib parameter phyto resp	0.60	L/mgO2	K_{sop}	No	0.60	0.60
Oxygen enhance model bot alg resp	Exponential					
Oxygen enhance parameter bot alg resp	0.60	L/mgO2	K_{sob}	No	0.60	0.60
Slow CBOD:						
Hydrolysis rate	0.5	/d	k_{hc}	Yes	0	5
Temp correction	1.047		θ_{hc}	No	1	1.07
Oxidation rate	0.1	/d	k_{dcs}	Yes	0	5
Temp correction	1.047		θ_{dcs}	No	1	1.07
Fast CBOD:						

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Global rate parameters

Fitness:
#DIV/0!

Parameter	Value	Units	Symbol	Auto-calibration inputs		
				Auto-cal	Min value	Max value
Oxidation rate	3.4	/d	k_{dc}	Yes	0	5
Temp correction	1.047		θ_{dc}	No	1	1.07
Organic N:						
Hydrolysis	0.5	/d	k_{hn}	Yes	0	5
Temp correction	1.07		θ_{hn}	No	1	1.07
Settling velocity	0.05	m/d	v_{on}	Yes	0	2
Ammonium:						
Nitrification	1	/d	k_{na}	Yes	0	10
Temp correction	1.07		θ_{na}	No	1	1.07
Nitrate:						
Denitrification	0.1	/d	k_{dn}	Yes	0	2
Temp correction	1.07		θ_{dn}	No	1	1.07
Sed denitrification transfer coeff	0.01	m/d	v_{di}	Yes	0	1
Temp correction	1.07		θ_{di}	No	1	1.07
Organic P:						
Hydrolysis	0	/d	k_{hp}	Yes	0	5
Temp correction	1.07		θ_{hp}	No	1	1.07
Settling velocity	0.84512	m/d	v_{op}	Yes	0	2
Inorganic P:						
Settling velocity	0	m/d	v_{ip}	Yes	0	2
Sed P oxygen attenuation half sat constant	0.65786	mgO_2/L	k_{spi}	Yes	0	2
Phytoplankton:						
Max Growth rate	0	/d	k_{gp}	No	1.5	3
Temp correction	1.07		θ_{gp}	No	1	1.07
Respiration rate	0	/d	k_{rp}	No	0	1
Temp correction	1.07		θ_{rp}	No	1	1.07
Death rate	0	/d	k_{dp}	No	0	1
Temp correction	1		θ_{dp}	No	1	1.07
Nitrogen half sat constant	15	ugN/L	k_{sPp}	No	0	150
Phosphorus half sat constant	2	ugP/L	k_{sNp}	No	0	50

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Global rate parameters

Fitness:
#DIV/0!

Parameter	Value	Units	Symbol	Auto-calibration inputs		
				Auto-cal	Min value	Max value
Inorganic carbon half sat constant	1.30E-05	moles/L	k_{sCp}	No	1.30E-06	1.30E-04
Phytoplankton use HCO3- as substrate	Yes					
Light model	Half saturation					
Light constant	57.6	langleys/d	K_{Lp}	No	28.8	115.2
Ammonia preference	25	ugN/L	k_{hnxp}	No	25	25
Settling velocity	0.15	m/d	v_a	No	0	5
Bottom Plants:						
Growth model	Zero-order					
Max Growth rate	0	mgA/m^2/d or /d	C_{gb}	Yes	0	500
Temp correction	1.07		θ_{gb}	No	1	1.07
First-order model carrying capacity	1000	mgA/m^2	$a_{b,max}$	No	1000	1000
Respiration rate	0	/d	k_{rb}	Yes	0	0.5
Temp correction	1.07		θ_{rb}	No	1	1.07
Excretion rate	0	/d	k_{eb}	Yes	0	0.5
Temp correction	1.07		θ_{db}	No	1	1.07
Death rate	0	/d	k_{db}	Yes	0	0.5
Temp correction	1.07		θ_{db}	No	1	1.07
External nitrogen half sat constant	0	ugN/L	k_{sPb}	Yes	0	300
External phosphorus half sat constant	0	ugP/L	k_{sNb}	Yes	0	100
Inorganic carbon half sat constant	2.50E-06	moles/L	k_{sCb}	Yes	1.30E-06	1.30E-04
Bottom algae use HCO3- as substrate	Yes					
Light model	Half saturation					
Light constant	3.58588	langleys/d	K_{Lb}	Yes	1	100
Ammonia preference	22.48993	ugN/L	k_{hnxb}	Yes	1	100
Subsistence quota for nitrogen	0.63189468	mgN/mgA	q_{0N}	Yes	0.0072	7.2

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Global rate parameters

Fitness:
#DIV/0!

				Auto-calibration inputs		
Parameter	*Value*	*Units*	*Symbol*	*Auto-cal*	*Min value*	*Max value*
Subsistence quota for phosphorus	0.03389707	mgP/mgA	q_{0P}	Yes	0.001	1
Maximum uptake rate for nitrogen	72.64143	mgN/mgA/d	ρ_{mN}	Yes	35	150
Maximum uptake rate for phosphorus	15.03188	mgP/mgA/d	ρ_{mP}	Yes	5	20
Internal nitrogen half sat ratio	3.9246125		$K_{qN,ratio}$	Yes	1.05	5
Internal phosphorus half sat ratio	1.3342815		$K_{qP,ratio}$	Yes	1.05	5
Nitrogen uptake water column fraction	0		$N_{UpWCfrac}$	No	0	1
Phosphorus uptake water column fraction	0		$P_{UpWCfrac}$	No	0	1
Detritus (POM):						
Dissolution rate	0	/d	k_{dt}	Yes	0	5
Temp correction	1.07		θ_{dt}	No	1.07	1.07
Settling velocity	0	m/d	v_{dt}	Yes	0	5
Pathogens:						
Decay rate	0	/d	k_{dx}	No	0.8	0.8
Temp correction	1.07		θ_{dx}	No	1.07	1.07
Settling velocity	1	m/d	v_x	No	1	1
alpha constant for light mortality	1	/d per ly/hr	*apath*	No	1	1
pH:						
Partial pressure of carbon dioxide	347	ppm	p_{CO2}			
Hyporheic metabolism						
Model for biofilm oxidation of fast CBOD	Zero-order		*level 1*			
Max biofilm growth rate	5	gO2/m^2/d or /d	"	No	0	20
Temp correction	1.047		"	No	1.047	1.047
Fast CBOD half-saturation	0.5	mgO2/L	"	No	0	2
Oxygen inhib model	Exponential		"			
Oxygen inhib parameter	0.60	L/mgO2	"	No	0.60	0.60
Respiration rate	0.2	/d	*level 2*	No	0.2	0.2
Temp correction	1.07		"	No	1.07	1.07
Death rate	0.05	/d	"	No	0.05	0.05
Temp correction	1.07		"	No	1.07	1.07

QUAL2Kw

Stream Water Quality Model

Cattle (10/17/2006)

Global rate parameters

Fitness:
#DIV/0!

				Auto-calibration inputs		
Parameter	*Value*	*Units*	*Symbol*	*Auto-cal*	*Min value*	*Max value*
External nitrogen half sat constant	15	ugN/L	"	No	15	15
External phosphorus half sat constant	2	ugP/L	"	No	2	2
Ammonia preference	25	ugN/L	"	No	25	25
First-order model carrying capacity	100	gD/m^2	"	No	100	100
Generic constituent						
Decay rate	0.8	/d		No	0.8	0.8
Temp correction	1.07			No	1.07	1.07
Settling velocity	1	m/d		No	1	1
Use generic constituent as COD?	No					
User-defined auto-calibration parameters (optional)						
Point source pH at location 10.2 Km	7.43916				6	7.5

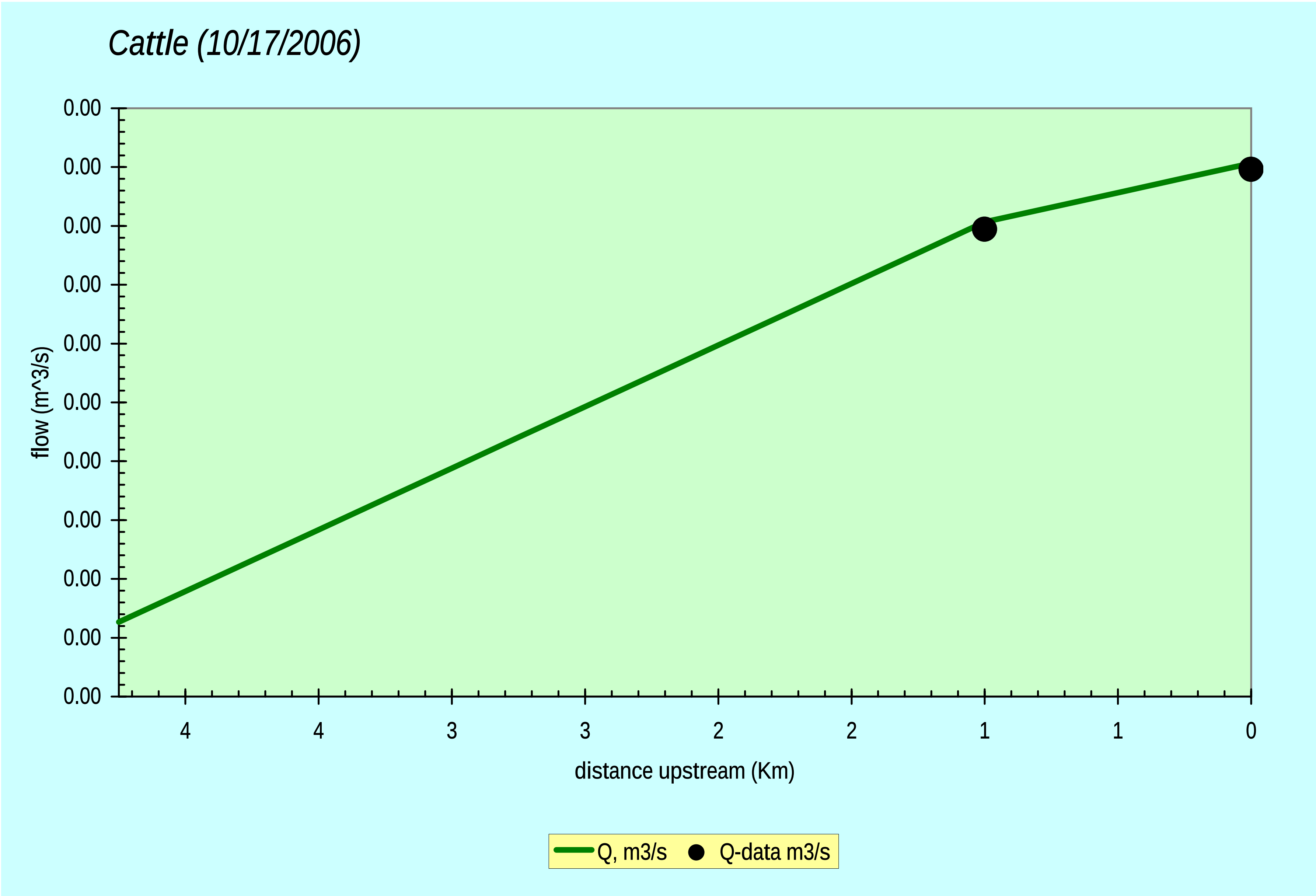
QUAL2Kw

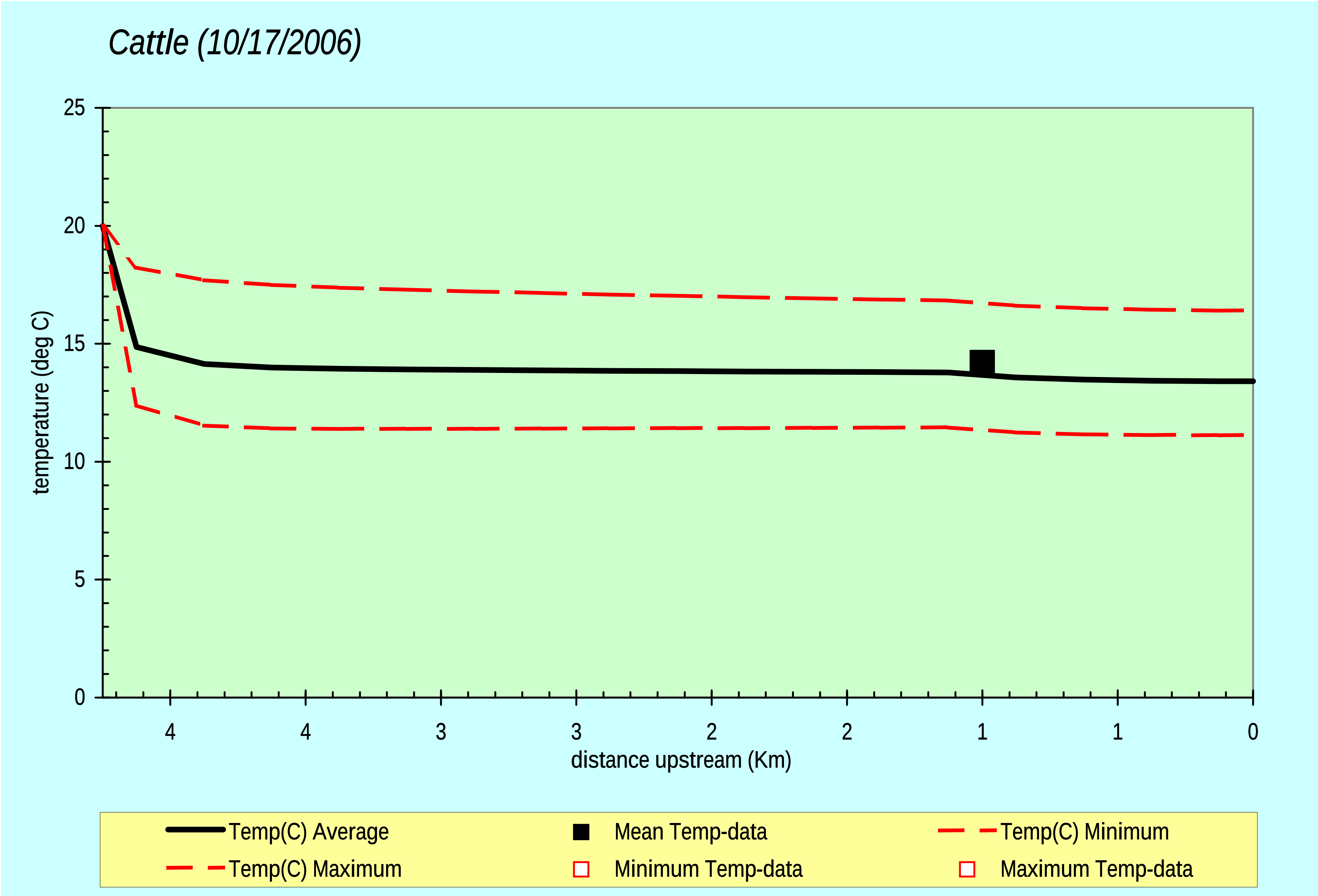
Stream Water Quality Model

Cattle (10/17/2006)

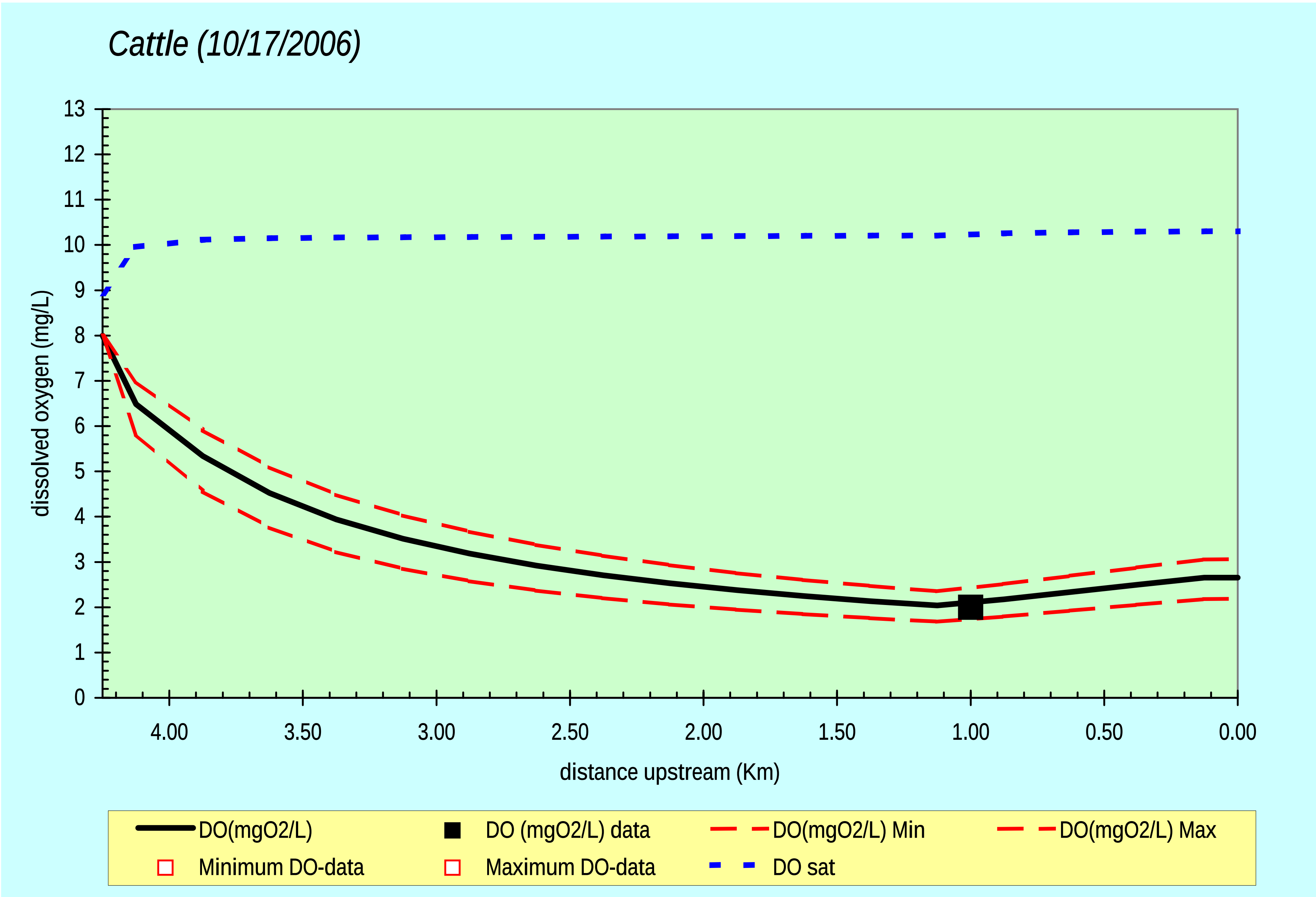
Global rate parameters

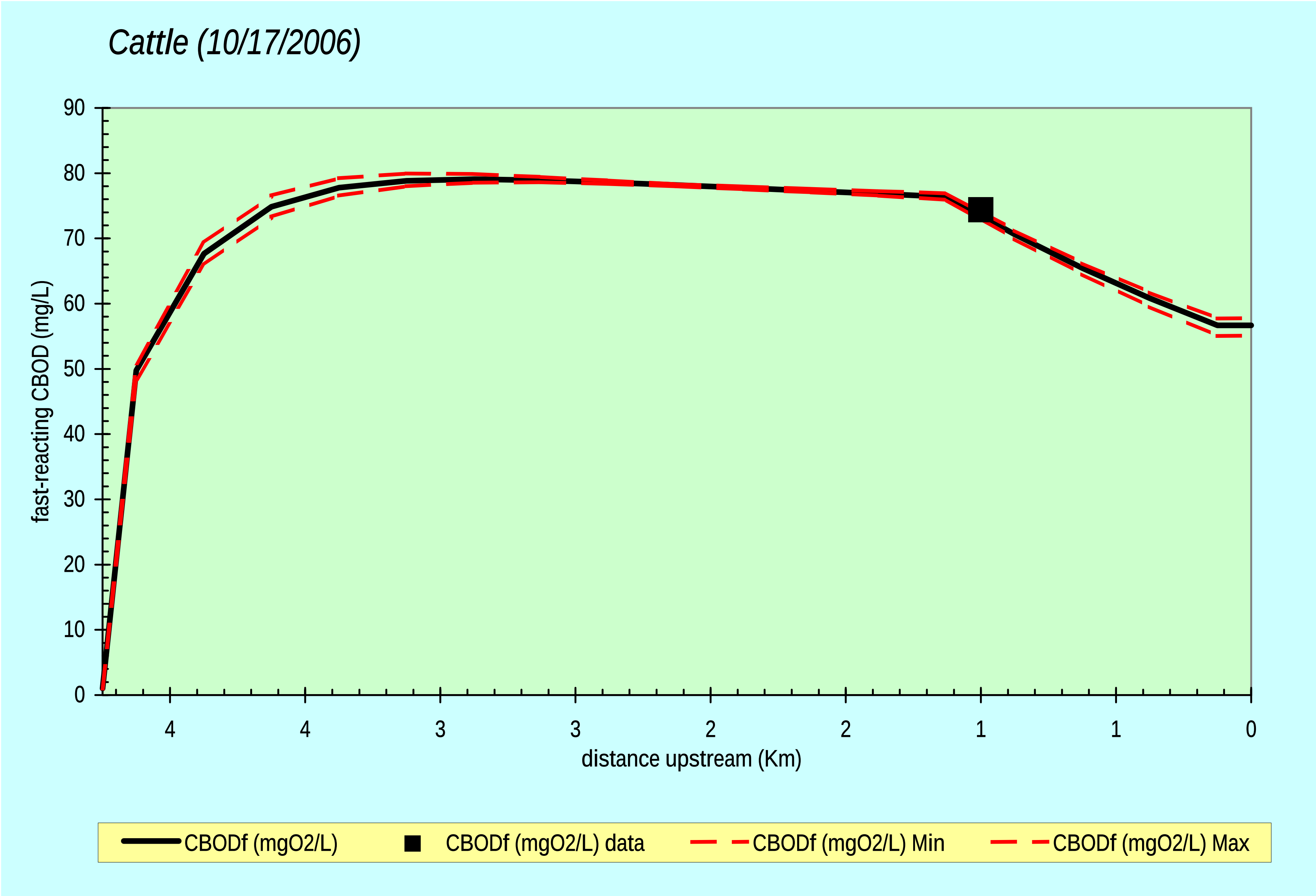
Auto-calibration genetic algorithm control:		
Random number seed	123456	seed
Model runs in a population (<=512)	4	np
Generations in the evolution	2	ngen
Digits to encode genotype (<=6)	5	nd
Crossover mode (1, 2, 3, 4, 5, 6, or 7)	3	icross
Crossover probability (0-1):	0.85	pcross
Mutation mode (1, 2, 3, 4, 5, or 6)	2	imut
Initial mutation rate (0-1):	0.005	pmut
Minimum mutation rate (0-1):	0.0005	pmutmn
Maximum mutation rate (0-1):	0.25	pmutmx
Relative fitness differential (0-1):	1	fdif
Reproduction plan (1, 2, or 3):	1	irep
Elitism (0 or 1):	1	ielite
Restart from previous evolution (0 or 1):	0	irestart


Cattle (10/17/2006)
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
flow (m^3/s)
4
4
3
3
2
2
1
1
0
distance upstream (Km)
Q, m3/s
Q-data m3/s

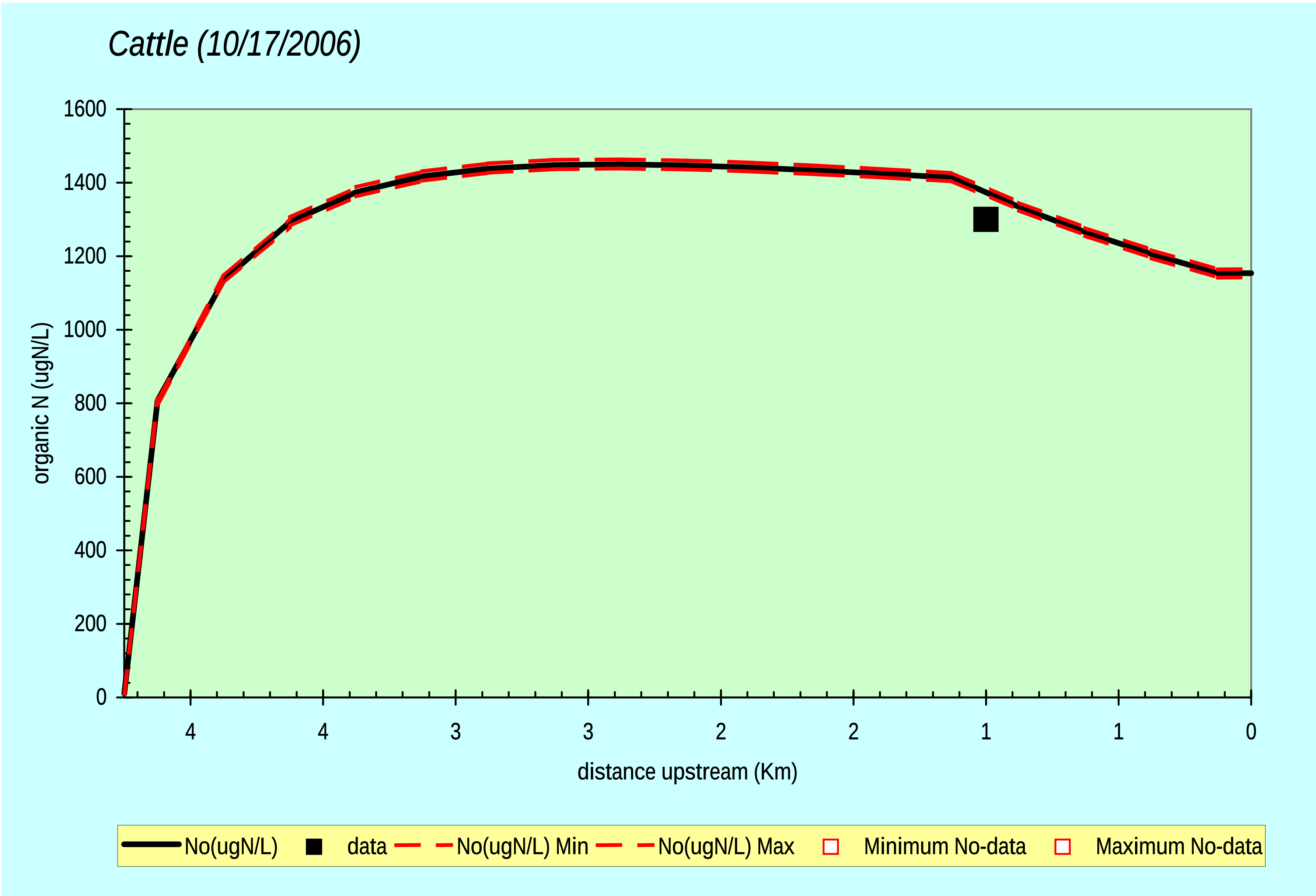


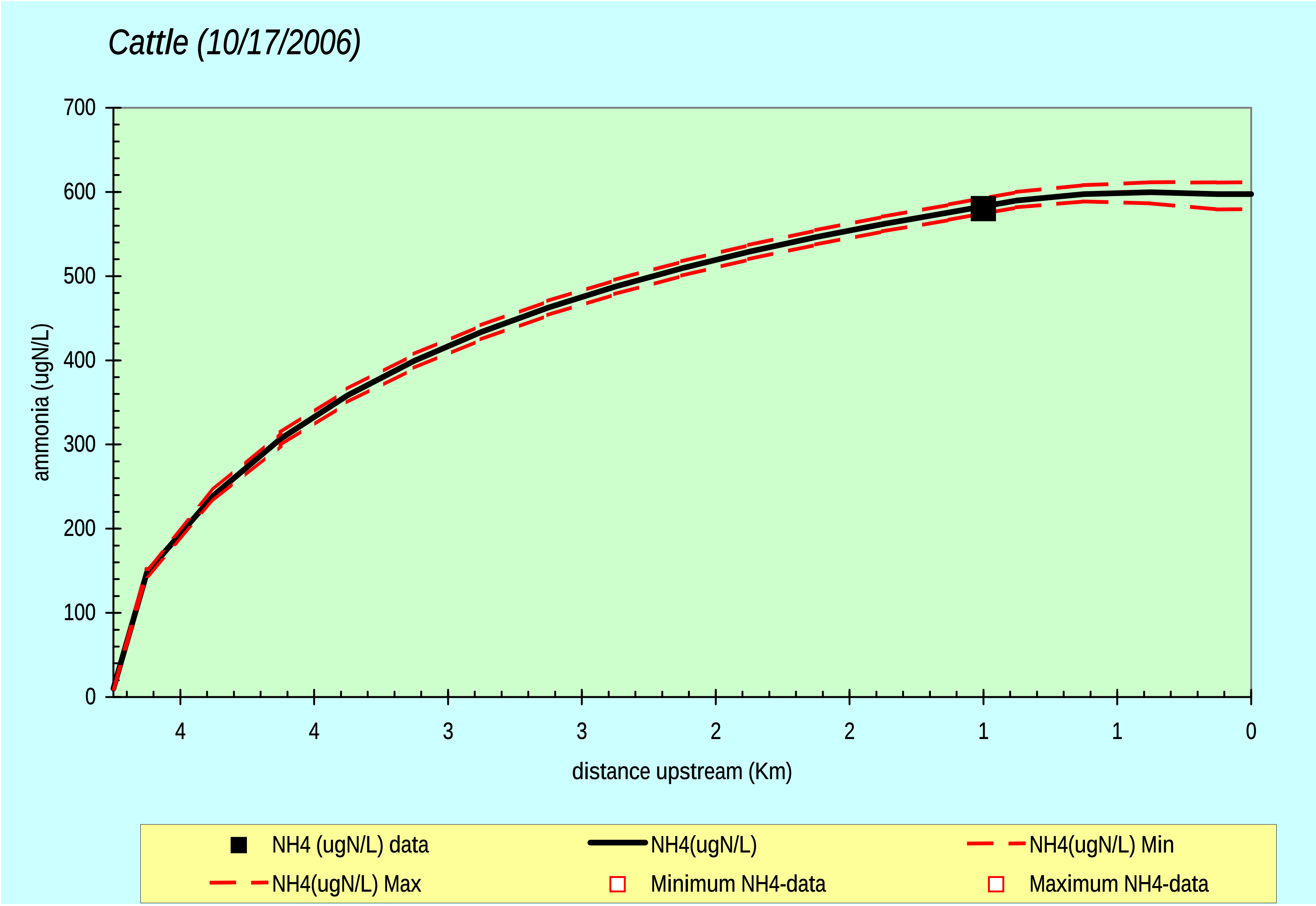
Cattle (10/17/2006)
25
20
15
10
5
0
temperature (deg C)
4
4
3
3
2
2
1
1
0
distance upstream (Km)
Temp(C) Average
Mean Temp-data
Temp(C) Minimum
Temp(C) Maximum
Minimum Temp-data
Maximum Temp-data


Cattle (10/17/2006)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
dissolved oxygen (mg/L)
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
distance upstream (Km)
DO(mgO2/L)
DO (mgO2/L) data
DO(mgO2/L) Min
DO(mgO2/L) Max
Minimum DO-data
Maximum DO-data
DO sat



Cattle (10/17/2006)
90
80
70
60
50
40
30
20
10
0
fast-reacting CBOD (mg/L)
4
4
3
3
2
2
1
1
0
distance upstream (Km)
CBODf (mgO2/L)
CBODf (mgO2/L) data
CBODf (mgO2/L) Min
CBODf (mgO2/L) Max


Cattle (10/17/2006)
1600
1400
1200
1000
800
600
400
200
0
organic N (ugN/L)
4
4
3
3
2
2
1
1
0
distance upstream (Km)
No(ugN/L)
data
No(ugN/L) Min
No(ugN/L) Max
Minimum No-data
Maximum No-data



Cattle (10/17/2006)
700
600
500
400
300
200
100
0
ammonia (ugN/L)
4
4
3
3
2
2
1
1
0
distance upstream (Km)
NH4 (ugN/L) data
NH4(ugN/L)
NH4(ugN/L) Min
NH4(ugN/L) Max
Minimum NH4-data
Maximum NH4-data

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Headwater and Downstream Boundary Data:

Headwater Flow	0.000	m3/s
Prescribed downstream boundary?	No	
Headwater Water Quality	*Units*	*12:00 AM*
Temperature	C	20.00
Conductivity	umhos	0.00
Inorganic Solids	mgD/L	0.00
Dissolved Oxygen	mg/L	7.00
CBODslow	mgO2/L	1.00
CBODfast	mgO2/L	1.00
Organic Nitrogen	ugN/L	10.00
NH4-Nitrogen	ugN/L	10.00
NO3-Nitrogen	ugN/L	0.00
Organic Phosphorus	ugP/L	0.00
Inorganic Phosphorus (SRP)	ugP/L	0.00
Phytoplankton	ugA/L	0.00
Detritus (POM)	mgD/L	0.00
Pathogen	cfu/100 mL	0.00
Generic constituent	user defined	0.00
Alkalinity	mgCaCO3/L	200.00
pH	s.u.	7.33
Downstream Boundary Water Quality (optional)	*Units*	*12:00 AM*

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Reach Data:

Reach for diel plot:	11					
			Reach			*Downstream*
Reach	*Downstream*		*length*	*Downstream*		*location*
Label	*end of reach label*	*Number*	*(km)*	*Latitude*	*Longitude*	*(km)*
	Headwater	0		38.59	89.54	3.300
		1	0.30	38.59	89.54	3.000
		2	0.30	38.59	89.54	2.700
		3	0.30	38.59	89.54	2.400
		4	0.30	38.59	89.54	2.100
		5	0.30	38.59	89.54	1.800
		6	0.30	38.59	89.54	1.500
		7	0.30	38.59	89.54	1.200
		8	0.30	38.59	89.54	0.900
		9	0.30	38.59	89.54	0.600
		10	0.30	38.59	89.54	0.300
		11	0.30	38.59	89.54	0.000

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Reach Data:

	Elevation		Downstream					
	Upstream	Downstream	Latitude			Longitude		
Number	(m)	(m)	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
0		149.000	38.00	35	0	89.00	32	0
1	148.000	146.727	38.00	35	0	89.00	32	0
2	146.727	145.455	38.00	35	0	89.00	32	0
3	145.455	144.182	38.00	35	0	89.00	32	0
4	144.182	142.909	38.00	35	0	89.00	32	0
5	142.909	141.636	38.00	35	0	89.00	32	0
6	141.636	140.364	38.00	35	0	89.00	32	0
7	140.364	139.091	38.00	35	0	89.00	32	0
8	139.091	137.818	38.00	35	0	89.00	32	0
9	137.818	136.545	38.00	35	0	89.00	32	0
10	136.545	135.273	38.00	35	0	89.00	32	0
11	135.273	134.000	38.00	35	0	89.00	32	0

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Reach Data:

	Hyd Hydraulic Model (Weir Overrides Rating Curves; Rating Curves Override Manning Formula					
	Weir		Rating Curves			
	Height	*Width*	*Velocity*		Depth	
Number	*(m)*	*(m)*	*Coefficient*	*Exponent*	*Coefficient*	*Exponent*
0	0.0000	0.0000	0.0000	0.000	0.0000	0.000
1	0.0000	0.0000	0.0000	0.000	0.0000	0.000
2	0.0000	0.0000	0.0000	0.000	0.0000	0.000
3	0.0000	0.0000	0.0000	0.000	0.0000	0.000
4	0.0000	0.0000	0.0000	0.000	0.0000	0.000
5	0.0000	0.0000	0.0000	0.000	0.0000	0.000
6	0.0000	0.0000	0.0000	0.000	0.0000	0.000
7	0.0000	0.0000	0.0000	0.000	0.0000	0.000
8	0.0000	0.0000	0.0000	0.000	0.0000	0.000
9	0.0000	0.0000	0.0000	0.000	0.0000	0.000
10	0.0000	0.0000	0.0000	0.000	0.0000	0.000
11	0.0000	0.0000	0.0000	0.000	0.0000	0.000

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Reach Data:

	a)							
	Manning Formula					*Prescribed*	*Bottom*	*Bottom*
	Channel	*Manning*	*Bot Width*	*Side*	*Side*	*Dispersion*	*Algae*	*SOD*
Number	*Slope*	*n*	*m*	*Slope*	*Slope*	*m2/s*	*Coverage*	*Coverage*
0	0.0001	0.0550	0.45	1.00	1.00	0.00		
1	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
2	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
3	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
4	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
5	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
6	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
7	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
8	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
9	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
10	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%
11	0.0001	0.0550	0.45	1.00	1.00	0.00	0%	100%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Reach Data:

Number	Prescribed SOD gO2/m2/d	Prescribed CH4 flux gO2/m2/d	Prescribed NH4 flux mgN/m2/d	Prescribed Inorg P flux mgP/m2/d	Sediment thermal cond (W/m/degC)	Sediment thermal diff (cm^2/sec)	Sediment/hyporheic zone thickness (cm)	Hyporheic exchange flow fraction of stream flow	Hyporheic sediment porosity (fraction of volume)
0									
1	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
2	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
3	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
4	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
5	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
6	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
7	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
8	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
9	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
10	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
11	5.00	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Air Temperature Data:

				Upstream	*Downstream*	*12:00 AM*	*1:00 AM*	*2:00 AM*	*3:00 AM*	*4:00 AM*
Upstream	*Reach*	*Downstream*	*Reach*	*Distance*	*Distance*	*Hourly air temperature for each reach (degrees C)*				
Label	*Label*	*Label*	*Number*	*km*	*km*	*(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)*				
Headwater			1	3.30	3.00	14.44	12.78	11.67	10.56	11.11
			2	3.00	2.70	14.44	12.78	11.67	10.56	11.11
			3	2.70	2.40	14.44	12.78	11.67	10.56	11.11
			4	2.40	2.10	14.44	12.78	11.67	10.56	11.11
			5	2.10	1.80	14.44	12.78	11.67	10.56	11.11
			6	1.80	1.50	14.44	12.78	11.67	10.56	11.11
			7	1.50	1.20	14.44	12.78	11.67	10.56	11.11
			8	1.20	0.90	14.44	12.78	11.67	10.56	11.11
			9	0.90	0.60	14.44	12.78	11.67	10.56	11.11
			10	0.60	0.30	14.44	12.78	11.67	10.56	11.11
			11	0.30	0.00	14.44	12.78	11.67	10.56	11.11

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Air Temperature Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
2	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
3	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
4	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
5	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
6	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
7	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
8	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
9	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
10	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33
11	11.11	10.00	10.56	11.67	13.89	16.11	18.33	19.44	18.89	18.33

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Air Temperature Data:

Reach Number	*3:00 PM*	*4:00 PM*	*5:00 PM*	*6:00 PM*	*7:00 PM*	*8:00 PM*	*9:00 PM*	*10:00 PM*	*11:00 PM*
1	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
2	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
3	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
4	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
5	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
6	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
7	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
8	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
9	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
10	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56
11	17.22	16.11	13.89	10.56	9.44	8.33	6.11	5.56	5.56

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Dew Point Temperature Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Hourly dewpoint temperature for each reach (degrees C)				
Label	Label	Label	Number	km	km	(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)				
Headwater			1	3.30	3.00	7.22	7.22	7.22	7.22	7.78
			2	3.00	2.70	7.22	7.22	7.22	7.22	7.78
			3	2.70	2.40	7.22	7.22	7.22	7.22	7.78
			4	2.40	2.10	7.22	7.22	7.22	7.22	7.78
			5	2.10	1.80	7.22	7.22	7.22	7.22	7.78
			6	1.80	1.50	7.22	7.22	7.22	7.22	7.78
			7	1.50	1.20	7.22	7.22	7.22	7.22	7.78
			8	1.20	0.90	7.22	7.22	7.22	7.22	7.78
			9	0.90	0.60	7.22	7.22	7.22	7.22	7.78
			10	0.60	0.30	7.22	7.22	7.22	7.22	7.78
			11	0.30	0.00	7.22	7.22	7.22	7.22	7.78

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Dew Point Temperature Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
2	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
3	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
4	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
5	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
6	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
7	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
8	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
9	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
10	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56
11	7.78	6.67	6.11	6.11	5.56	6.11	6.67	7.22	5.56	5.56

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Dew Point Temperature Data:

	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
Reach									
Number									
1	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
2	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
3	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
4	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
5	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
6	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
7	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
8	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
9	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
10	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56
11	5.00	3.33	3.33	1.11	1.11	2.78	4.44	5.56	5.56

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Wind Speed Data:

				Upstream	*Downstream*	*12:00 AM*	*1:00 AM*	*2:00 AM*	*3:00 AM*	*4:00 AM*
Upstream	*Reach*	*Downstream*	*Reach*	*Distance*	*Distance*	*Wind speed for each reach 7m above water surface (m/s)*				
Label	*Label*	*Label*	*Number*	*km*	*km*	*(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)*				
Headwater			1	3.30	3.00	5.66	3.60	3.60	3.09	3.60
			2	3.00	2.70	5.66	3.60	3.60	3.09	3.60
			3	2.70	2.40	5.66	3.60	3.60	3.09	3.60
			4	2.40	2.10	5.66	3.60	3.60	3.09	3.60
			5	2.10	1.80	5.66	3.60	3.60	3.09	3.60
			6	1.80	1.50	5.66	3.60	3.60	3.09	3.60
			7	1.50	1.20	5.66	3.60	3.60	3.09	3.60
			8	1.20	0.90	5.66	3.60	3.60	3.09	3.60
			9	0.90	0.60	5.66	3.60	3.60	3.09	3.60
			10	0.60	0.30	5.66	3.60	3.60	3.09	3.60
			11	0.30	0.00	5.66	3.60	3.60	3.09	3.60

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Wind Speed Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
2	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
3	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
4	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
5	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
6	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
7	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
8	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
9	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
10	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66
11	4.63	4.63	4.12	5.14	5.66	6.17	4.12	5.14	5.14	5.66

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Wind Speed Data:

Reach Number	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
2	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
3	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
4	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
5	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
6	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
7	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
8	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
9	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
10	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17
11	5.14	7.72	7.72	11.32	7.72	8.23	6.69	4.63	6.17

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Cloud Cover Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Hourly cloud cover shade for each reach (Percent)				
Label	Label	Label	Number	km	km	(Percent of sky that is covered by clouds. The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)				
Headwater			1	3.30	3.00	0.0%	0.0%	0.0%	0.0%	0.0%
			2	3.00	2.70	0.0%	0.0%	0.0%	0.0%	0.0%
			3	2.70	2.40	0.0%	0.0%	0.0%	0.0%	0.0%
			4	2.40	2.10	0.0%	0.0%	0.0%	0.0%	0.0%
			5	2.10	1.80	0.0%	0.0%	0.0%	0.0%	0.0%
			6	1.80	1.50	0.0%	0.0%	0.0%	0.0%	0.0%
			7	1.50	1.20	0.0%	0.0%	0.0%	0.0%	0.0%
			8	1.20	0.90	0.0%	0.0%	0.0%	0.0%	0.0%
			9	0.90	0.60	0.0%	0.0%	0.0%	0.0%	0.0%
			10	0.60	0.30	0.0%	0.0%	0.0%	0.0%	0.0%
			11	0.30	0.00	0.0%	0.0%	0.0%	0.0%	0.0%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Cloud Cover Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.0%	7.0%	10.0%	9.0%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Cloud Cover Data:

Reach Number	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
2	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
3	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
4	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
5	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
6	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
7	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
8	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
9	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
10	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%
11	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%	10.0%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Shade Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Integrated hourly effective shade for each reach (Percent)				
Label	Label	Label	Number	km	km	(Percent of solar radiation that is blocked because of shade from topography and vegetation. Hourly values are applied as integrated values for each hour, e.g. the value at 12:00 AM is applied from 12:00 to 1:00 AM)				
Headwater			1	3.30	3.00	0.0%	0.0%	0.0%	0.0%	0.0%
			2	3.00	2.70	0.0%	0.0%	0.0%	0.0%	0.0%
			3	2.70	2.40	0.0%	0.0%	0.0%	0.0%	0.0%
			4	2.40	2.10	0.0%	0.0%	0.0%	0.0%	0.0%
			5	2.10	1.80	0.0%	0.0%	0.0%	0.0%	0.0%
			6	1.80	1.50	0.0%	0.0%	0.0%	0.0%	0.0%
			7	1.50	1.20	0.0%	0.0%	0.0%	0.0%	0.0%
			8	1.20	0.90	0.0%	0.0%	0.0%	0.0%	0.0%
			9	0.90	0.60	0.0%	0.0%	0.0%	0.0%	0.0%
			10	0.60	0.30	0.0%	0.0%	0.0%	0.0%	0.0%
			11	0.30	0.00	0.0%	0.0%	0.0%	0.0%	0.0%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Shade Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Shade Data:

Reach Number	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
7	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
10	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Light Parameters and Surface Heat Transfer Models:

Parameter	*Value*	*Unit*	
Photosynthetically Available Radiation	0.47		
Background light extinction	0.2	*/m*	k_{eb}
Linear chlorophyll light extinction	0.0088	*1/m-(ugA/L)*	α_p
Nonlinear chlorophyll light extinction	0.054	*1/m-(ugA/L)$^{2/3}$*	α_{pn}
ISS light extinction	0.052	*1/m-(mgD/L)*	α_i
Detritus light extinction	0.174	*1/m-(mgD/L)*	α_o
Macrophyte light extinction	0.015	*1/m-(gD/m^3)*	α_{mac}
Solar shortwave radiation model			
Atmospheric attenuation model for solar	Ryan-Stolzenbach		
Bras solar parameter (used if Bras solar model is selected)			
atmospheric turbidity coefficient (2=clear, 5=smoggy, default=2)	2		n_{fac}
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)			
atmospheric transmission coefficient (0.70-0.91, default 0.8)	0.8		a_{tc}
Downwelling atmospheric longwave IR radiation			
atmospheric longwave emissivity model	Brunt		
Evaporation and air convection/conduction			
wind speed function for evaporation and air convection/conduction	Brady-Graves-Geyer		

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Diffuse Source Data:

			Diffuse	Diffuse		Spec	Inorg	Diss	CBOD	CBOD
			Abstraction	Inflow	Temp	Cond	SS	Oxygen	slow	fast
Name	Up (km)	Down (km)	m3/s	m3/s	C	umhos	mgD/L	mg/L	mgO2/L	mgO2/L
1.00	3.3000	0.0000	0.00	0.0045	27.00	0.00	0.00	3.50	25.0	13.0

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Diffuse Source Data:

Organic N ugN/L	Ammon N ugN/L	Nitrate N ugN/L	Organic P ugP/L	Inorganic P ugP/L	Phyto plankton ug/L	Detritus mgD/L	Pathogen cfu/100 mL	Generic constituent user defined	Alk mgCaCO3/L	pH
4450.0	5300.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	7.0

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Global rate parameters

Fitness:
#DIV/0!

				Auto-calibration inputs		
Parameter	*Value*	*Units*	*Symbol*	*Auto-cal*	*Min value*	*Max value*
Stoichiometry:						
Carbon	40	gC	gC	No	30	50
Nitrogen	7.2	gN	gN	No	3	9
Phosphorus	1	gP	gP	No	0.4	2
Dry weight	100	gD	gD	No	100	100
Chlorophyll	1	gA	gA	No	0.4	2
Inorganic suspended solids:						
Settling velocity	0.00236	m/d	v_i	Yes	0	2
Oxygen:						
Reaeration model	O'Connor-Dobbins			f(u h)		
Temp correction	1.024		θ_a			
Reaeration wind effect	None					
O2 for carbon oxidation	2.69	gO_2/gC	r_{oc}			
O2 for NH4 nitrification	4.57	gO_2/gN	r_{on}			
Oxygen inhib model CBOD oxidation	Exponential					
Oxygen inhib parameter CBOD oxidation	0.60	L/mgO2	K_{socf}	No	0.60	0.60
Oxygen inhib model nitrification	Exponential					
Oxygen inhib parameter nitrification	0.60	L/mgO2	K_{sona}	No	0.60	0.60
Oxygen enhance model denitrification	Exponential					
Oxygen enhance parameter denitrification	0.60	L/mgO2	K_{sodn}	No	0.60	0.60
Oxygen inhib model phyto resp	Exponential					
Oxygen inhib parameter phyto resp	0.60	L/mgO2	K_{sop}	No	0.60	0.60
Oxygen enhance model bot alg resp	Exponential					
Oxygen enhance parameter bot alg resp	0.60	L/mgO2	K_{sob}	No	0.60	0.60
Slow CBOD:						
Hydrolysis rate	0.5	/d	k_{hc}	Yes	0	5
Temp correction	1.047		θ_{hc}	No	1	1.07
Oxidation rate	0.1	/d	k_{dcs}	Yes	0	5
Temp correction	1.047		θ_{dcs}	No	1	1.07
Fast CBOD:						
Oxidation rate	3.4	/d	k_{dc}	Yes	0	5
Temp correction	1.047		θ_{dc}	No	1	1.07
Organic N:						
Hydrolysis	0.5	/d	k_{hn}	Yes	0	5
Temp correction	1.07		θ_{hn}	No	1	1.07
Settling velocity	0.05	m/d	v_{on}	Yes	0	2
Ammonium:						
Nitrification	1	/d	k_{na}	Yes	0	10
Temp correction	1.07		θ_{na}	No	1	1.07
Nitrate:						
Denitrification	0.1	/d	k_{dn}	Yes	0	2
Temp correction	1.07		θ_{dn}	No	1	1.07
Sed denitrification transfer coeff	0.01	m/d	v_{di}	Yes	0	1
Temp correction	1.07		θ_{di}	No	1	1.07
Organic P:						
Hydrolysis	0	/d	k_{hp}	Yes	0	5
Temp correction	1.07		θ_{hp}	No	1	1.07
Settling velocity	0.84512	m/d	v_{op}	Yes	0	2
Inorganic P:						
Settling velocity	0	m/d	v_{ip}	Yes	0	2
Sed P oxygen attenuation half sat constant	0.65786	mgO_2/L	k_{spi}	Yes	0	2
Phytoplankton:						
Max Growth rate	0	/d	k_{gp}	No	1.5	3
Temp correction	1.07		θ_{gp}	No	1	1.07
Respiration rate	0	/d	k_{rp}	No	0	1
Temp correction	1.07		θ_{rp}	No	1	1.07
Death rate	0	/d	k_{dp}	No	0	1
Temp correction	1		θ_{dp}	No	1	1.07
Nitrogen half sat constant	15	ugN/L	k_{sPp}	No	0	150
Phosphorus half sat constant	2	ugP/L	k_{sNp}	No	0	50
Inorganic carbon half sat constant	1.30E-05	moles/L	k_{sCp}	No	1.30E-06	1.30E-04
Phytoplankton use HCO3- as substrate	Yes					
Light model	Half saturation					
Light constant	57.6	langleys/d	K_{Lp}	No	28.8	115.2

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Global rate parameters

Fitness:
#DIV/0!

Parameter	Value	Units	Symbol	Auto-calibration inputs		
				Auto-cal	Min value	Max value
Ammonia preference	25	ugN/L	k_{hnxp}	No	25	25
Settling velocity	0.15	m/d	v_a	No	0	5
Bottom Plants:						
Growth model	Zero-order					
Max Growth rate	0	mgA/m^2/d or /d	C_{gb}	Yes	0	500
Temp correction	1.07		θ_{gb}	No	1	1.07
First-order model carrying capacity	1000	mgA/m^2	$a_{b,max}$	No	1000	1000
Respiration rate	0	/d	k_{rb}	Yes	0	0.5
Temp correction	1.07		θ_{rb}	No	1	1.07
Excretion rate	0	/d	k_{eb}	Yes	0	0.5
Temp correction	1.07		θ_{db}	No	1	1.07
Death rate	0	/d	k_{db}	Yes	0	0.5
Temp correction	1.07		θ_{db}	No	1	1.07
External nitrogen half sat constant	0	ugN/L	k_{sPb}	Yes	0	300
External phosphorus half sat constant	0	ugP/L	k_{sNb}	Yes	0	100
Inorganic carbon half sat constant	2.50E-06	moles/L	k_{sCb}	Yes	1.30E-06	1.30E-04
Bottom algae use HCO3- as substrate	Yes					
Light model	Half saturation					
Light constant	3.58588	langleys/d	K_{Lb}	Yes	1	100
Ammonia preference	22.48993	ugN/L	k_{hnxb}	Yes	1	100
Subsistence quota for nitrogen	0.63189468	mgN/mgA	q_{0N}	Yes	0.0072	7.2
Subsistence quota for phosphorus	0.03389707	mgP/mgA	q_{0P}	Yes	0.001	1
Maximum uptake rate for nitrogen	72.64143	mgN/mgA/d	ρ_{mN}	Yes	35	150
Maximum uptake rate for phosphorus	15.03188	mgP/mgA/d	ρ_{mP}	Yes	5	20
Internal nitrogen half sat ratio	3.9246125		$K_{qN,ratio}$	Yes	1.05	5
Internal phosphorus half sat ratio	1.3342815		$K_{qP,ratio}$	Yes	1.05	5
Nitrogen uptake water column fraction	0		$N_{UpWCfrac}$	No	0	1
Phosphorus uptake water column fraction	0		$P_{UpWCfrac}$	No	0	1
Detritus (POM):						
Dissolution rate	0	/d	k_{dt}	Yes	0	5
Temp correction	1.07		θ_{dt}	No	1.07	1.07
Settling velocity	0	m/d	v_{dt}	Yes	0	5
Pathogens:						
Decay rate	0	/d	k_{dx}	No	0.8	0.8
Temp correction	1.07		θ_{dx}	No	1.07	1.07
Settling velocity	1	m/d	v_x	No	1	1
alpha constant for light mortality	1	/d per ly/hr	*apath*	No	1	1
pH:						
Partial pressure of carbon dioxide	347	ppm	p_{CO2}			

QUAL2Kw

Stream Water Quality Model

Chicken (10/18/1991)

Global rate parameters

Fitness:
#DIV/0!

				Auto-calibration inputs		
Parameter	*Value*	*Units*	*Symbol*	*Auto-cal*	*Min value*	*Max value*
Hyporheic metabolism						
Model for biofilm oxidation of fast CBOD	Zero-order		*level 1*			
Max biofilm growth rate	5	gO2/m^2/d or /d	"	No	0	20
Temp correction	1.047		"	No	1.047	1.047
Fast CBOD half-saturation	0.5	mgO2/L	"	No	0	2
Oxygen inhib model	Exponential		"			
Oxygen inhib parameter	0.60	L/mgO2	"	No	0.60	0.60
Respiration rate	0.2	/d	*level 2*	No	0.2	0.2
Temp correction	1.07		"	No	1.07	1.07
Death rate	0.05	/d	"	No	0.05	0.05
Temp correction	1.07		"	No	1.07	1.07
External nitrogen half sat constant	15	ugN/L	"	No	15	15
External phosphorus half sat constant	2	ugP/L	"	No	2	2
Ammonia preference	25	ugN/L	"	No	25	25
First-order model carrying capacity	100	gD/m^2	"	No	100	100
Generic constituent						
Decay rate	0.8	/d		No	0.8	0.8
Temp correction	1.07			No	1.07	1.07
Settling velocity	1	m/d		No	1	1
Use generic constituent as COD?	No					
User-defined auto-calibration parameters (optional)						
Point source pH at location 10.2 Km	7.43916				6	7.5

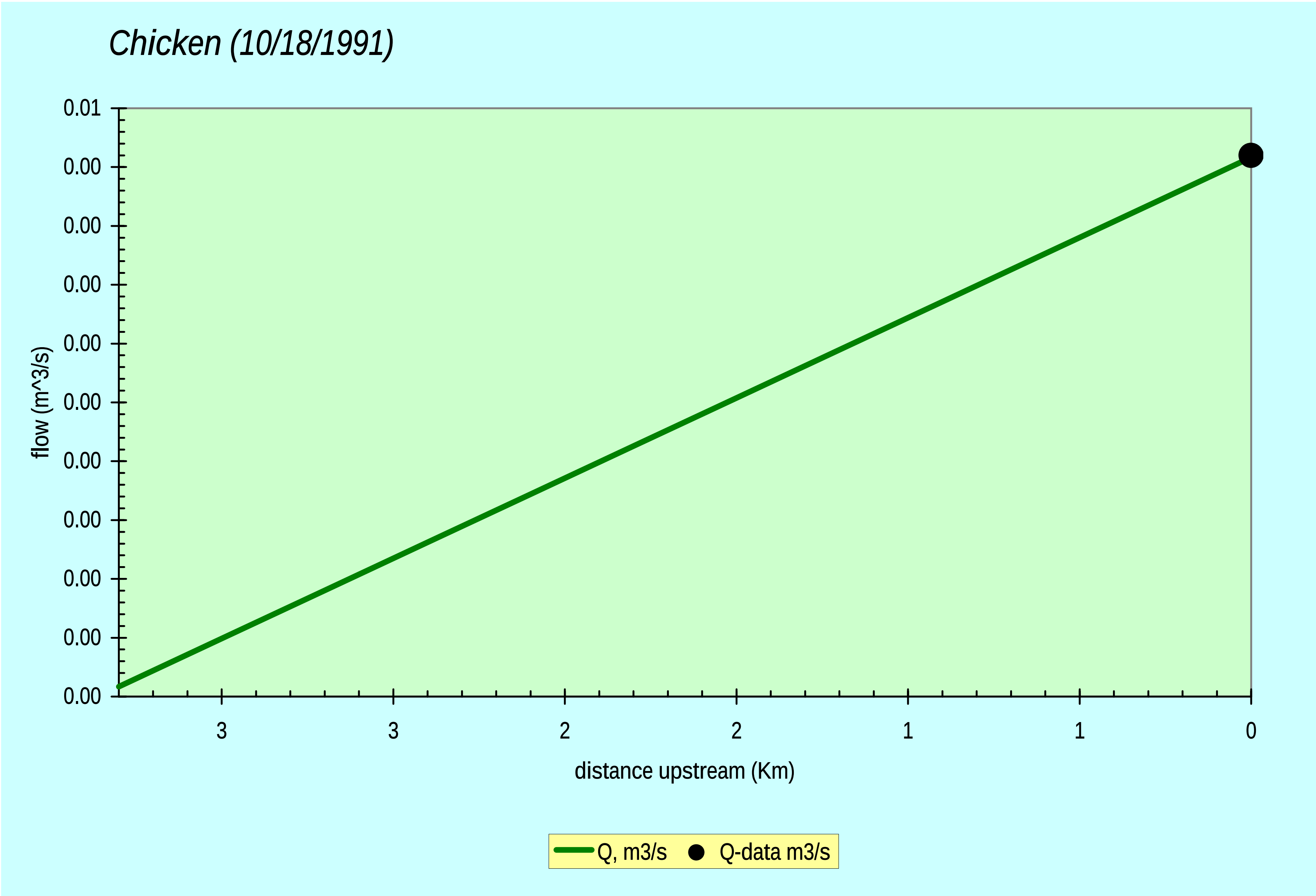
QUAL2Kw

Stream Water Quality Model

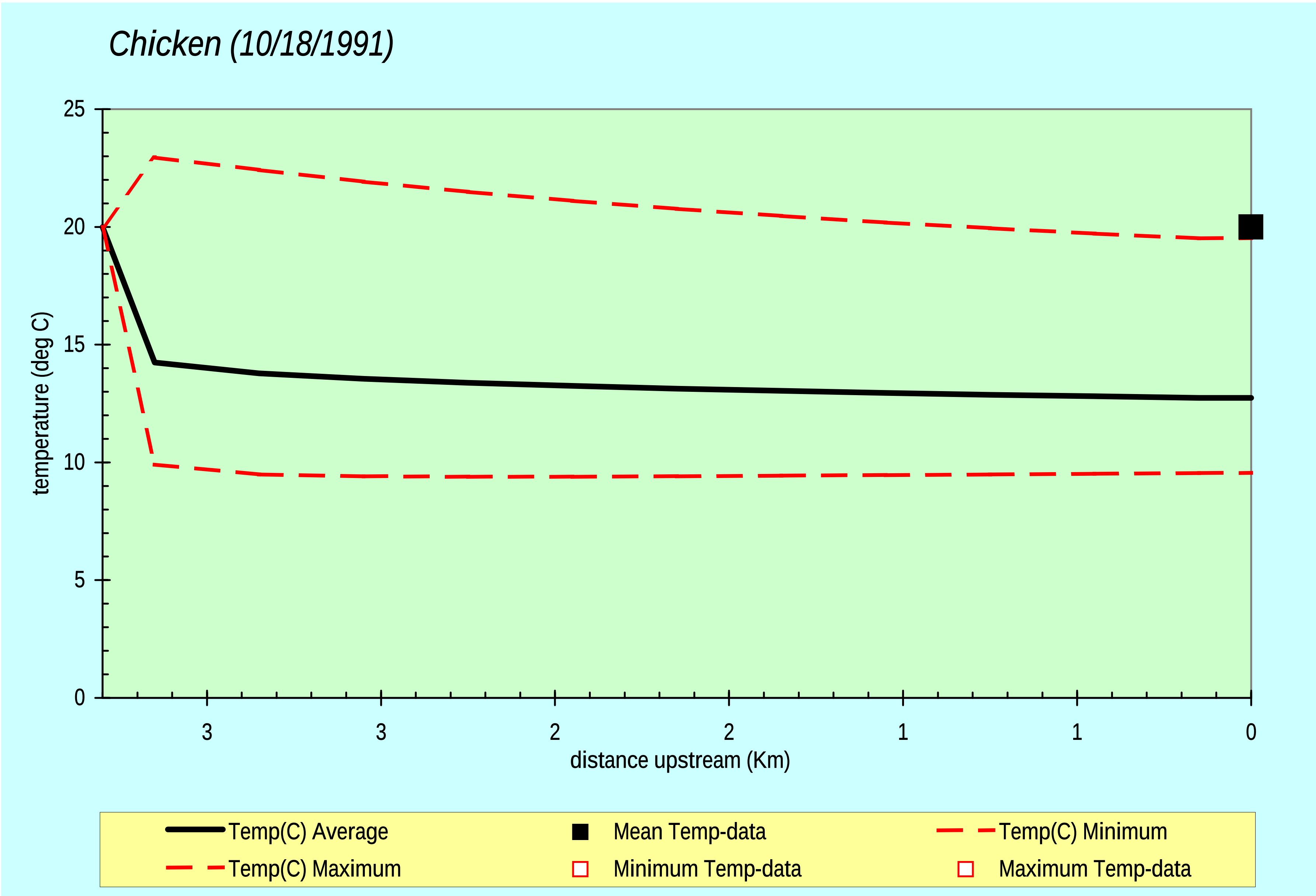
Chicken (10/18/1991)

Global rate parameters

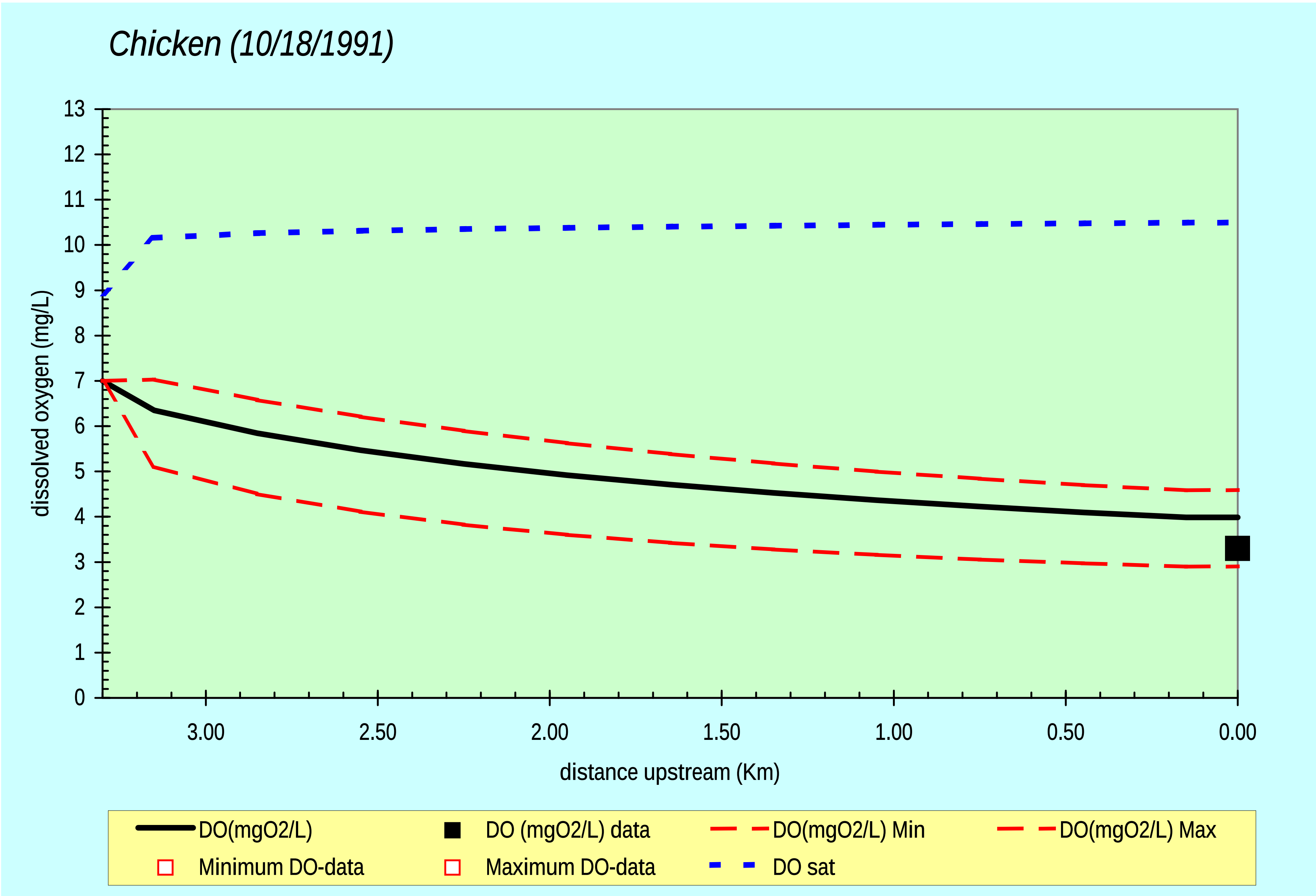
Auto-calibration genetic algorithm control:		
Random number seed	123456	seed
Model runs in a population (<=512)	4	np
Generations in the evolution	2	ngen
Digits to encode genotype (<=6)	5	nd
Crossover mode (1, 2, 3, 4, 5, 6, or 7)	3	icross
Crossover probability (0-1):	0.85	pcross
Mutation mode (1, 2, 3, 4, 5, or 6)	2	imut
Initial mutation rate (0-1):	0.005	pmut
Minimum mutation rate (0-1):	0.0005	pmutmn
Maximum mutation rate (0-1):	0.25	pmutmx
Relative fitness differential (0-1):	1	fdif
Reproduction plan (1, 2, or 3):	1	irep
Elitism (0 or 1):	1	ielite
Restart from previous evolution (0 or 1):	0	irestart



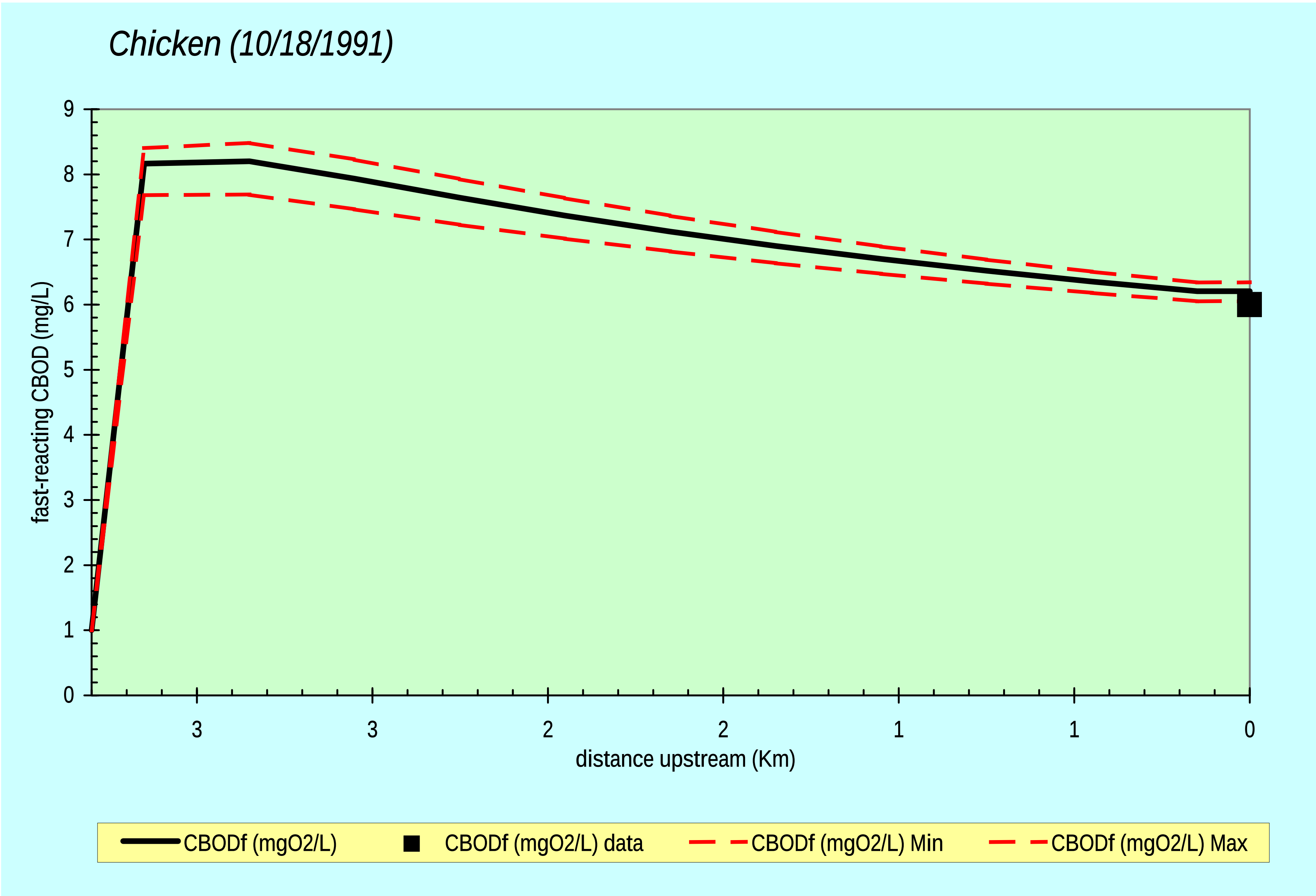
Chicken (10/18/1991)
0.01
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
0.00
flow (m^3/s)
3
3
2
2
1
1
0
distance upstream (Km)
Q, m3/s
Q-data m3/s



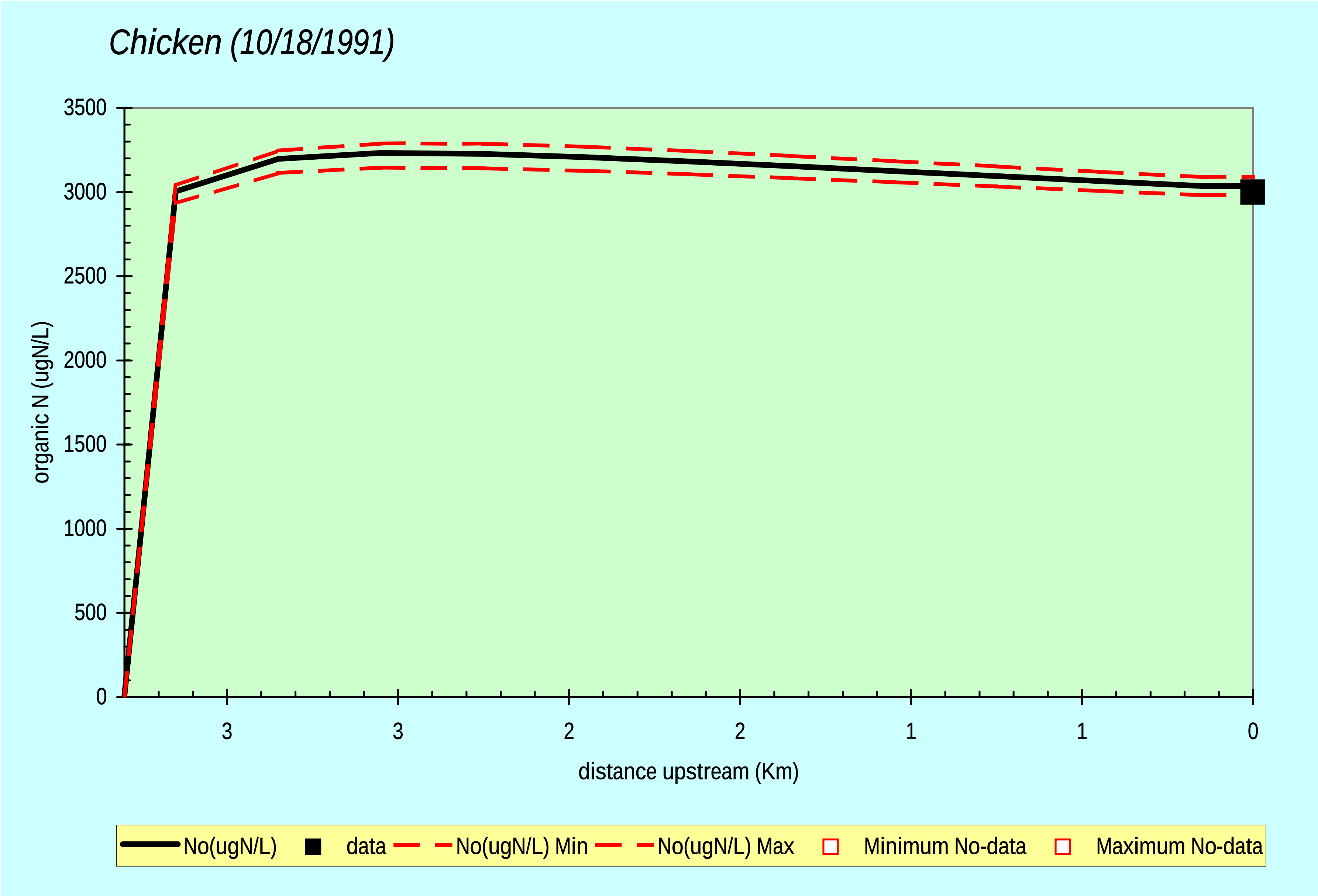
Chicken (10/18/1991)
25
20
15
10
5
0
temperature (deg C)
3
3
2
2
1
1
0
distance upstream (Km)
Temp(C) Average
Mean Temp-data
Temp(C) Minimum
Temp(C) Maximum
Minimum Temp-data
Maximum Temp-data

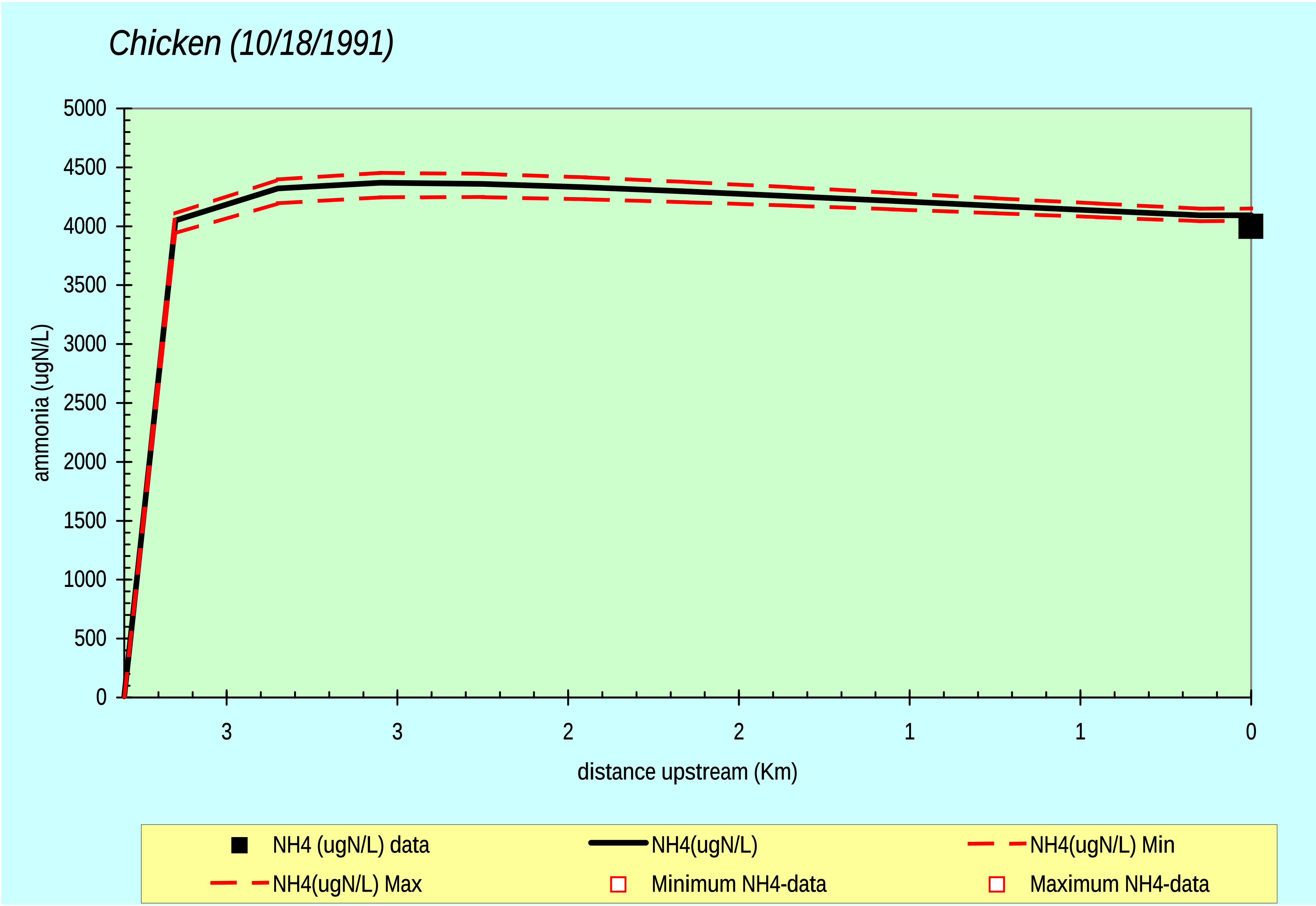


Chicken (10/18/1991)
dissolved oxygen (mg/L)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
3.00
2.50
2.00
1.50
1.00
0.50
0.00
distance upstream (Km)
DO(mgO2/L)
DO (mgO2/L) data
DO(mgO2/L) Min
DO(mgO2/L) Max
Minimum DO-data
Maximum DO-data
DO sat



Chicken (10/18/1991)
9
8
7
6
5
4
3
2
1
0
fast-reacting CBOD (mg/L)
3
3
2
2
1
1
0
distance upstream (Km)
CBODf (mgO2/L)
CBODf (mgO2/L) data
CBODf (mgO2/L) Min
CBODf (mgO2/L) Max


Chicken (10/18/1991)
3500
3000
2500
2000
1500
1000
500
0
organic N (ugN/L)
3
3
2
2
1
1
0
distance upstream (Km)
No(ugN/L)
data
No(ugN/L) Min
No(ugN/L) Max
Minimum No-data
Maximum No-data


Chicken (10/18/1991)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
ammonia (ugN/L)
3
3
2
2
1
1
0
distance upstream (Km)
NH4 (ugN/L) data
NH4(ugN/L)
NH4(ugN/L) Min
NH4(ugN/L) Max
Minimum NH4-data
Maximum NH4-data

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Headwater and Downstream Boundary Data:

Headwater Flow	0.013	m3/s
Prescribed downstream boundary?	No	
Headwater Water Quality	*Units*	*12:00 AM*
Temperature	C	14.00
Conductivity	umhos	0.00
Inorganic Solids	mgD/L	0.00
Dissolved Oxygen	mg/L	6.90
CBODslow	mgO2/L	7.70
CBODfast	mgO2/L	7.70
Organic Nitrogen	ugN/L	1250.00
NH4-Nitrogen	ugN/L	1250.00
NO3-Nitrogen	ugN/L	0.00
Organic Phosphorus	ugP/L	0.00
Inorganic Phosphorus (SRP)	ugP/L	0.00
Phytoplankton	ugA/L	0.00
Detritus (POM)	mgD/L	0.00
Pathogen	cfu/100 mL	0.00
Generic constituent	user defined	0.00
Alkalinity	mgCaCO3/L	200.00
pH	s.u.	7.33

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Reach Data:

Reach for diel plot:	17													
			Reach			Downstream	Elevation		Downstream					
Reach	Downstream		length	Downstream		location	Upstream	Downstream	Latitude			Longitude		
Label	end of reach label	Number	(km)	Latitude	Longitude	(km)	(m)	(m)	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds
	Headwater	0		38.59	89.54	7.250		150.000	38.00	35	0	89.00	32	0
		1	0.25	38.59	89.54	7.000	149.286	148.571	38.00	35	0	89.00	32	0
		2	0.25	38.59	89.54	6.750	148.571	147.857	38.00	35	0	89.00	32	0
		3	0.25	38.59	89.54	6.500	147.857	147.143	38.00	35	0	89.00	32	0
		4	0.25	38.59	89.54	6.250	147.143	146.429	38.00	35	0	89.00	32	0
		5	0.25	38.59	89.54	6.000	146.429	145.714	38.00	35	0	89.00	32	0
		6	0.25	38.59	89.54	5.750	145.714	145.000	38.00	35	0	89.00	32	0
		7	0.25	38.59	89.54	5.500	145.000	144.286	38.00	35	0	89.00	32	0
		8	0.25	38.59	89.54	5.250	144.286	143.571	38.00	35	0	89.00	32	0
		9	0.25	38.59	89.54	5.000	143.571	142.857	38.00	35	0	89.00	32	0
		10	0.25	38.59	89.54	4.750	142.857	142.143	38.00	35	0	89.00	32	0
		11	0.25	38.59	89.54	4.500	142.143	141.429	38.00	35	0	89.00	32	0
		12	0.25	38.59	89.54	4.250	141.429	140.714	38.00	35	0	89.00	32	0
		13	0.25	38.59	89.54	4.000	140.714	140.286	38.00	35	0	89.00	32	0
		14	0.25	38.59	89.54	3.750	140.286	139.857	38.00	35	0	89.00	32	0
		15	0.25	38.59	89.54	3.500	139.857	139.429	38.00	35	0	89.00	32	0
		16	0.25	38.59	89.54	3.250	139.429	139.000	38.00	35	0	89.00	32	0
		17	0.25	38.59	89.54	3.000	139.000	138.571	38.00	35	0	89.00	32	0
		18	0.25	38.59	89.54	2.750	138.571	138.143	38.00	35	0	89.00	32	0
		19	0.25	38.59	89.54	2.500	138.143	137.714	38.00	35	0	89.00	32	0
		20	0.25	38.59	89.54	2.250	137.714	137.286	38.00	35	0	89.00	32	0
		21	0.25	38.59	89.54	2.000	137.286	136.857	38.00	35	0	89.00	32	0
		22	0.25	38.59	89.54	1.750	136.857	136.429	38.00	35	0	89.00	32	0
		23	0.25	38.59	89.54	1.500	136.429	136.000	38.00	35	0	89.00	32	0
		24	0.25	38.59	89.54	1.250	136.000	135.571	38.00	35	0	89.00	32	0
		25	0.25	38.59	89.54	1.000	135.571	135.143	38.00	35	0	89.00	32	0
		26	0.25	38.59	89.54	0.750	135.143	134.714	38.00	35	0	89.00	32	0
		27	0.25	38.59	89.54	0.500	134.714	134.286	38.00	35	0	89.00	32	0
		28	0.25	38.59	89.54	0.250	134.286	134.286	38.00	35	0	89.00	32	0
		29	0.25	38.59	89.54	0.000	134.286	134.286	38.00	35	0	89.00	32	0

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Reach Data:

	Hydraulic Model (Weir Overrides Rating Curves; Rating Curves Override Manning Formula)												
	Weir		Rating Curves				Manning Formula					*Prescribed*	*Bottom*
	Height	*Width*	*Velocity*		Depth		*Channel*	*Manning*	*Bot Width*	*Side*	*Side*	*Dispersion*	*Algae*
Number	*(m)*	*(m)*	*Coefficient*	*Exponent*	*Coefficient*	*Exponent*	*Slope*	*n*	*m*	*Slope*	*Slope*	*m2/s*	*Coverage*
0	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	
1	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
2	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
3	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
4	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
5	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
6	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
7	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
8	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
9	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
10	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
11	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
12	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000029	0.0500	3.03	2.00	2.00	0.00	0%
13	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	0.00	0%
14	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	0.00	0%
15	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	0.00	0%
16	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	0.00	0%
17	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	0.00	0%
18	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	1.00	0%
19	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	2.00	0%
20	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	3.00	0%
21	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	4.00	0%
22	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	5.00	0%
23	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	6.00	0%
24	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	7.00	0%
25	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	8.00	0%
26	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	9.00	0%
27	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000017	0.0500	3.03	2.00	2.00	10.00	0%
28	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000011	0.0500	3.03	2.00	2.00	11.00	0%
29	0.0000	0.0000	0.0000	0.000	0.0000	0.000	0.000011	0.0500	3.03	2.00	2.00	12.00	0%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Reach Data:

Number	Bottom SOD Coverage	Prescribed SOD gO2/m2/d	Prescribed CH4 flux gO2/m2/d	Prescribed NH4 flux mgN/m2/d	Prescribed Inorg P flux mgP/m2/d	Sediment thermal cond (W/m/degC)	Sediment thermal diff (cm^2/sec)	Sediment/hyporheic zone thickness (cm)	Hyporheic exchange flow (fraction of stream flow)	Hyporheic sediment porosity (fraction of volume)
0										
1	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
2	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
3	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
4	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
5	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
6	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
7	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
8	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
9	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
10	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
11	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
12	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
13	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
14	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
15	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
16	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
17	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
18	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
19	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
20	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
21	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
22	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
23	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
24	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
25	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
26	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
27	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
28	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%
29	100%	2.75	0.0000	0.0000	0.0000	1.6	0.0064	10	5%	40%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Air Temperature Data:

				Upstream	*Downstream*	*12:00 AM*	*1:00 AM*	*2:00 AM*	*3:00 AM*	*4:00 AM*
Upstream	*Reach*	*Downstream*	*Reach*	*Distance*	*Distance*	*Hourly air temperature for each reach (degrees C)*				
Label	*Label*	*Label*	*Number*	*km*	*km*	*(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)*				
Headwater			1	7.25	7.00	13.00	14.00	16.00	16.00	14.00
			2	7.00	6.75	13.00	14.00	16.00	16.00	14.00
			3	6.75	6.50	13.00	14.00	16.00	16.00	14.00
			4	6.50	6.25	13.00	14.00	16.00	16.00	14.00
			5	6.25	6.00	13.00	14.00	16.00	16.00	14.00
			6	6.00	5.75	13.00	14.00	16.00	16.00	14.00
			7	5.75	5.50	13.00	14.00	16.00	16.00	14.00
			8	5.50	5.25	13.00	14.00	16.00	16.00	14.00
			9	5.25	5.00	13.00	14.00	16.00	16.00	14.00
			10	5.00	4.75	13.00	14.00	16.00	16.00	14.00
			11	4.75	4.50	13.00	14.00	16.00	16.00	14.00
			12	4.50	4.25	13.00	14.00	16.00	16.00	14.00
			13	4.25	4.00	13.00	14.00	16.00	16.00	14.00
			14	4.00	3.75	13.00	14.00	16.00	16.00	14.00
			15	3.75	3.50	13.00	14.00	16.00	16.00	14.00
			16	3.50	3.25	13.00	14.00	16.00	16.00	14.00
			17	3.25	3.00	13.00	14.00	16.00	16.00	14.00
			18	3.00	2.75	13.00	14.00	16.00	16.00	14.00
			19	2.75	2.50	13.00	14.00	16.00	16.00	14.00
			20	2.50	2.25	13.00	14.00	16.00	16.00	14.00
			21	2.25	2.00	13.00	14.00	16.00	16.00	14.00
			22	2.00	1.75	13.00	14.00	16.00	16.00	14.00
			23	1.75	1.50	13.00	14.00	16.00	16.00	14.00
			24	1.50	1.25	13.00	14.00	16.00	16.00	14.00
			25	1.25	1.00	13.00	14.00	16.00	16.00	14.00
			26	1.00	0.75	13.00	14.00	16.00	16.00	14.00
			27	0.75	0.50	13.00	14.00	16.00	16.00	14.00
			28	0.50	0.25	13.00	14.00	16.00	16.00	14.00
			29	0.25	0.00	13.00	14.00	16.00	16.00	14.00

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Air Temperature Data:

Reach Number	5:00 AM	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM
1	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
2	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
3	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
4	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
5	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
6	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
7	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
8	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
9	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
10	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
11	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
12	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
13	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
14	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
15	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
16	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
17	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
18	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
19	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
20	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
21	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
22	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
23	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
24	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
25	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
26	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
27	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
28	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00
29	13.00	13.00	13.00	13.00	13.00	14.00	14.00	15.00	16.00	16.00

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Air Temperature Data:

Reach Number	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
2	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
3	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
4	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
5	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
6	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
7	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
8	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
9	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
10	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
11	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
12	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
13	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
14	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
15	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
16	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
17	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
18	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
19	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
20	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
21	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
22	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
23	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
24	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
25	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
26	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
27	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
28	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00
29	16.00	16.00	15.00	15.00	15.00	14.00	15.00	14.00	14.00

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Dew Point Temperature Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM	7:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Hourly dewpoint temperature for each reach (degrees C)							
Label	Label	Label	Number	km	km	(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)							
Headwater			1	7.25	7.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			2	7.00	6.75	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			3	6.75	6.50	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			4	6.50	6.25	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			5	6.25	6.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			6	6.00	5.75	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			7	5.75	5.50	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			8	5.50	5.25	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			9	5.25	5.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			10	5.00	4.75	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			11	4.75	4.50	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			12	4.50	4.25	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			13	4.25	4.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			14	4.00	3.75	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			15	3.75	3.50	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			16	3.50	3.25	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			17	3.25	3.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			18	3.00	2.75	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			19	2.75	2.50	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			20	2.50	2.25	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			21	2.25	2.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			22	2.00	1.75	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			23	1.75	1.50	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			24	1.50	1.25	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			25	1.25	1.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			26	1.00	0.75	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			27	0.75	0.50	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			28	0.50	0.25	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00
			29	0.25	0.00	12.00	13.00	15.00	14.00	12.00	11.00	11.00	11.00

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Dew Point Temperature Data:

Reach Number	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
2	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
3	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
4	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
5	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
6	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
7	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
8	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
9	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
10	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
11	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
12	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
13	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
14	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
15	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
16	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
17	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
18	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
19	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
20	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
21	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
22	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
23	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
24	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
25	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
26	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
27	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
28	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
29	11.00	11.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Wind Speed Data:

				Upstream	*Downstream*	*12:00 AM*	*1:00 AM*	*2:00 AM*	*3:00 AM*	*4:00 AM*	*5:00 AM*
Upstream	*Reach*	*Downstream*	*Reach*	*Distance*	*Distance*	*Wind speed for each reach 7m above water surface (m/s)*					
Label	*Label*	*Label*	*Number*	*km*	*km*	*(The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)*					
Headwater			1	7.25	7.00	4.02	4.02	3.58	7.15	8.94	3.58
			2	7.00	6.75	4.02	4.02	3.58	7.15	8.94	3.58
			3	6.75	6.50	4.02	4.02	3.58	7.15	8.94	3.58
			4	6.50	6.25	4.02	4.02	3.58	7.15	8.94	3.58
			5	6.25	6.00	4.02	4.02	3.58	7.15	8.94	3.58
			6	6.00	5.75	4.02	4.02	3.58	7.15	8.94	3.58
			7	5.75	5.50	4.02	4.02	3.58	7.15	8.94	3.58
			8	5.50	5.25	4.02	4.02	3.58	7.15	8.94	3.58
			9	5.25	5.00	4.02	4.02	3.58	7.15	8.94	3.58
			10	5.00	4.75	4.02	4.02	3.58	7.15	8.94	3.58
			11	4.75	4.50	4.02	4.02	3.58	7.15	8.94	3.58
			12	4.50	4.25	4.02	4.02	3.58	7.15	8.94	3.58
			13	4.25	4.00	4.02	4.02	3.58	7.15	8.94	3.58
			14	4.00	3.75	4.02	4.02	3.58	7.15	8.94	3.58
			15	3.75	3.50	4.02	4.02	3.58	7.15	8.94	3.58
			16	3.50	3.25	4.02	4.02	3.58	7.15	8.94	3.58
			17	3.25	3.00	4.02	4.02	3.58	7.15	8.94	3.58
			18	3.00	2.75	4.02	4.02	3.58	7.15	8.94	3.58
			19	2.75	2.50	4.02	4.02	3.58	7.15	8.94	3.58
			20	2.50	2.25	4.02	4.02	3.58	7.15	8.94	3.58
			21	2.25	2.00	4.02	4.02	3.58	7.15	8.94	3.58
			22	2.00	1.75	4.02	4.02	3.58	7.15	8.94	3.58
			23	1.75	1.50	4.02	4.02	3.58	7.15	8.94	3.58
			24	1.50	1.25	4.02	4.02	3.58	7.15	8.94	3.58
			25	1.25	1.00	4.02	4.02	3.58	7.15	8.94	3.58
			26	1.00	0.75	4.02	4.02	3.58	7.15	8.94	3.58
			27	0.75	0.50	4.02	4.02	3.58	7.15	8.94	3.58
			28	0.50	0.25	4.02	4.02	3.58	7.15	8.94	3.58
			29	0.25	0.00	4.02	4.02	3.58	7.15	8.94	3.58

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Wind Speed Data:

Reach Number	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM
1	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
2	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
3	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
4	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
5	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
6	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
7	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
8	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
9	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
10	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
11	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
12	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
13	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
14	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
15	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
16	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
17	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
18	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
19	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
20	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
21	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
22	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
23	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
24	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
25	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
26	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
27	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
28	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13
29	4.47	2.68	4.02	4.02	3.58	3.58	2.68	3.13

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Wind Speed Data:

Reach Number	2:00 PM	3:00 PM	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	1.34	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Cloud Cover Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM	6:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Hourly cloud cover shade for each reach (Percent)						
Label	Label	Label	Number	km	km	(Percent of sky that is covered by clouds. The input values are applied as point estimates at each time. Linear interpolation is used to estimate values between the hourly inputs.)						
Headwater			1	7.25	7.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			2	7.00	6.75	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			3	6.75	6.50	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			4	6.50	6.25	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			5	6.25	6.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			6	6.00	5.75	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			7	5.75	5.50	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			8	5.50	5.25	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			9	5.25	5.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			10	5.00	4.75	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			11	4.75	4.50	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			12	4.50	4.25	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			13	4.25	4.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			14	4.00	3.75	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			15	3.75	3.50	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			16	3.50	3.25	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			17	3.25	3.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			18	3.00	2.75	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			19	2.75	2.50	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			20	2.50	2.25	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			21	2.25	2.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			22	2.00	1.75	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			23	1.75	1.50	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			24	1.50	1.25	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			25	1.25	1.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			26	1.00	0.75	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			27	0.75	0.50	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			28	0.50	0.25	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%
			29	0.25	0.00	95.0%	95.0%	95.0%	95.0%	95.0%	72.5%	95.0%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Cloud Cover Data:

Reach Number	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM
1	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
2	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
3	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
4	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
5	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
6	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
7	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
8	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
9	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
10	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
11	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
12	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
13	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
14	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
15	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
16	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
17	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
18	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
19	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
20	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
21	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
22	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
23	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
24	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
25	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
26	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
27	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
28	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%
29	95.0%	95.0%	95.0%	95.0%	95.0%	91.3%	95.0%	95.0%	95.0%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Cloud Cover Data:

Reach Number	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
2	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
3	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
4	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
5	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
6	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
7	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
8	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
9	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
10	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
11	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
12	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
13	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
14	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
15	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
16	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
17	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
18	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
19	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
20	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
21	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
22	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
23	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
24	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
25	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
26	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
27	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
28	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%
29	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%	95.0%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Shade Data:

				Upstream	Downstream	12:00 AM	1:00 AM	2:00 AM	3:00 AM	4:00 AM	5:00 AM
Upstream	Reach	Downstream	Reach	Distance	Distance	Integrated hourly effective shade for each reach (Percent)					
Label	Label	Label	Number	km	km	(Percent of solar radiation that is blocked because of shade from topography and vegetation. Hourly values are applied as integrated values for each hour, e.g. the value at 12:00 AM is applied from 12:00 to 1:00 AM)					
Headwater			1	7.25	7.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			2	7.00	6.75	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			3	6.75	6.50	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			4	6.50	6.25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			5	6.25	6.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			6	6.00	5.75	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			7	5.75	5.50	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			8	5.50	5.25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			9	5.25	5.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			10	5.00	4.75	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			11	4.75	4.50	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			12	4.50	4.25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			13	4.25	4.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			14	4.00	3.75	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			15	3.75	3.50	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			16	3.50	3.25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			17	3.25	3.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			18	3.00	2.75	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			19	2.75	2.50	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			20	2.50	2.25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			21	2.25	2.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			22	2.00	1.75	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			23	1.75	1.50	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			24	1.50	1.25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			25	1.25	1.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			26	1.00	0.75	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			27	0.75	0.50	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			28	0.50	0.25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
			29	0.25	0.00	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Shade Data:

Reach Number	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM
1	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
2	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
3	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
4	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
5	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
6	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
7	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
8	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
9	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
10	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
11	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
12	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
13	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
14	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
15	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
16	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
17	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
18	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
19	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
20	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
21	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
22	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
23	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
24	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
26	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
27	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
28	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
29	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Shade Data:

Reach Number	4:00 PM	5:00 PM	6:00 PM	7:00 PM	8:00 PM	9:00 PM	10:00 PM	11:00 PM
1	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
2	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
3	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
4	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
5	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
6	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
7	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
8	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
9	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
10	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
11	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
12	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
13	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
14	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
15	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
16	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
17	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
18	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
19	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
20	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
21	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
22	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
23	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
24	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
25	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
26	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
27	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
28	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
29	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Light Parameters and Surface Heat Transfer Models:

Parameter	***Value***	***Unit***	
Photosynthetically Available Radiation	**0.47**		
Background light extinction	**0.2**	***/m***	k_{eb}
Linear chlorophyll light extinction	**0.0088**	***1/m-(ugA/L)***	α_p
Nonlinear chlorophyll light extinction	**0.054**	***1/m-(ugA/L)$^{2/3}$***	α_{pn}
ISS light extinction	**0.052**	***1/m-(mgD/L)***	α_i
Detritus light extinction	**0.174**	***1/m-(mgD/L)***	α_o
Macrophyte light extinction	**0.015**	***1/m-(gD/m^3)***	α_{mac}
Solar shortwave radiation model			
Atmospheric attenuation model for solar	**Bras**		
Bras solar parameter (used if Bras solar model is selected)			
atmospheric turbidity coefficient (2=clear, 5=smoggy, default=2)	**3**		n_{fac}
Ryan-Stolzenbach solar parameter (used if Ryan-Stolzenbach solar model is selected)			
atmospheric transmission coefficient (0.70-0.91, default 0.8)	**0.8**		a_{tc}
Downwelling atmospheric longwave IR radiation			
atmospheric longwave emissivity model	**Brunt**		
Evaporation and air convection/conduction			
wind speed function for evaporation and air convection/conduction	**Brady-Graves-Geyer**		

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Diffuse Source Data:

			Diffuse	Diffuse		Spec	Inorg	Diss	CBOD	CBOD	Organic
			Abstraction	Inflow	Temp	Cond	SS	Oxygen	slow	fast	N
Name	Up (km)	Down (km)	m3/s	m3/s	C	umhos	mgD/L	mg/L	mgO2/L	mgO2/L	ugN/L
1.00	7.2500	3.2900	0.00	0.02	14.00	0.00	0.00	4.00	55.0	27.0	1500.0
1.00	3.2900	0.0000		0.01	14.00	0.00	0.00	4.00	55.0	27.0	1500.0

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Diffuse Source Data:

Ammon	Nitrate	Organic	Inorganic	Phyto			Generic		
N	N	P	P	plankton	Detritus	Pathogen	constituent	Alk	pH
ugN/L	ugN/L	ugP/L	ugP/L	ug/L	mgD/L	cfu/100 mL	user defined	mgCaCO3/L	
1500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	7.0
1500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	7.0

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Global rate parameters

Fitness:
1.85658

Parameter	Value	Units	Symbol	Auto-calibration inputs		
				Auto-cal	Min value	Max value
Stoichiometry:						
Carbon	40	gC	gC	No	30	50
Nitrogen	7.2	gN	gN	No	3	9
Phosphorus	1	gP	gP	No	0.4	2
Dry weight	100	gD	gD	No	100	100
Chlorophyll	1	gA	gA	No	0.4	2
Inorganic suspended solids:						
Settling velocity	0.00236	m/d	v_i	Yes	0	2
Oxygen:						
Reaeration model	O'Connor-Dobbins			f(u h)		
Temp correction	1.024		θ_a			
Reaeration wind effect	None					
O2 for carbon oxidation	2.69	gO_2/gC	r_{oc}			
O2 for NH4 nitrification	4.57	gO_2/gN	r_{on}			
Oxygen inhib model CBOD oxidation	Exponential					
Oxygen inhib parameter CBOD oxidation	0.60	L/mgO2	K_{socf}	No	0.60	0.60
Oxygen inhib model nitrification	Exponential					
Oxygen inhib parameter nitrification	0.60	L/mgO2	K_{sona}	No	0.60	0.60
Oxygen enhance model denitrification	Exponential					
Oxygen enhance parameter denitrification	0.60	L/mgO2	K_{sodn}	No	0.60	0.60
Oxygen inhib model phyto resp	Exponential					
Oxygen inhib parameter phyto resp	0.60	L/mgO2	K_{sop}	No	0.60	0.60
Oxygen enhance model bot alg resp	Exponential					
Oxygen enhance parameter bot alg resp	0.60	L/mgO2	K_{sob}	No	0.60	0.60
Slow CBOD:						
Hydrolysis rate	0.5	/d	k_{hc}	Yes	0	5
Temp correction	1.047		θ_{hc}	No	1	1.07
Oxidation rate	0.1	/d	k_{dcs}	Yes	0	5
Temp correction	1.047		θ_{dcs}	No	1	1.07
Fast CBOD:						
Oxidation rate	3.4	/d	k_{dc}	Yes	0	5
Temp correction	1.047		θ_{dc}	No	1	1.07
Organic N:						
Hydrolysis	0.5	/d	k_{hn}	Yes	0	5
Temp correction	1.07		θ_{hn}	No	1	1.07
Settling velocity	0.1	m/d	v_{on}	Yes	0	2
Ammonium:						

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Global rate parameters

Fitness:
1.85658

Parameter	Value	Units	Symbol	Auto-calibration inputs: Auto-cal	Min value	Max value
Nitrification	1	/d	k_{na}	Yes	0	10
Temp correction	1.07		θ_{na}	No	1	1.07
Nitrate:						
Denitrification	0.01	/d	k_{dn}	Yes	0	2
Temp correction	1.07		θ_{dn}	No	1	1.07
Sed denitrification transfer coeff	0.01	m/d	v_{di}	Yes	0	1
Temp correction	1.07		θ_{di}	No	1	1.07
Organic P:						
Hydrolysis	0	/d	k_{hp}	Yes	0	5
Temp correction	1.07		θ_{hp}	No	1	1.07
Settling velocity	0.84512	m/d	v_{op}	Yes	0	2
Inorganic P:						
Settling velocity	0	m/d	v_{ip}	Yes	0	2
Sed P oxygen attenuation half sat constant	0.65786	mgO_2/L	k_{spi}	Yes	0	2
Phytoplankton:						
Max Growth rate	0	/d	k_{gp}	No	1.5	3
Temp correction	1.07		θ_{gp}	No	1	1.07
Respiration rate	0	/d	k_{rp}	No	0	1
Temp correction	1.07		θ_{rp}	No	1	1.07
Death rate	0	/d	k_{dp}	No	0	1
Temp correction	1		θ_{dp}	No	1	1.07
Nitrogen half sat constant	15	ugN/L	k_{sPp}	No	0	150
Phosphorus half sat constant	2	ugP/L	k_{sNp}	No	0	50
Inorganic carbon half sat constant	1.30E-05	moles/L	k_{sCp}	No	1.30E-06	1.30E-04
Phytoplankton use HCO3- as substrate	Yes					
Light model	Half saturation					
Light constant	57.6	langleys/d	K_{Lp}	No	28.8	115.2
Ammonia preference	25	ugN/L	k_{hnxp}	No	25	25
Settling velocity	0.15	m/d	v_a	No	0	5
Bottom Plants:						
Growth model	Zero-order					
Max Growth rate	0	$mgA/m^2/d$ or /d	C_{gb}	Yes	0	500
Temp correction	1.07		θ_{gb}	No	1	1.07
First-order model carrying capacity	1000	mgA/m^2	$a_{b,max}$	No	1000	1000
Respiration rate	0	/d	k_{rb}	Yes	0	0.5
Temp correction	1.07		θ_{rb}	No	1	1.07

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Global rate parameters

Fitness:
1.85658

				Auto-calibration inputs		
Parameter	*Value*	*Units*	*Symbol*	*Auto-cal*	*Min value*	*Max value*
Excretion rate	0	/d	k_{eb}	Yes	0	0.5
Temp correction	1.07		θ_{db}	No	1	1.07
Death rate	0	/d	k_{db}	Yes	0	0.5
Temp correction	1.07		θ_{db}	No	1	1.07
External nitrogen half sat constant	103.596	ugN/L	k_{sPb}	Yes	0	300
External phosphorus half sat constant	79.313	ugP/L	k_{sNb}	Yes	0	100
Inorganic carbon half sat constant	2.50E-06	moles/L	k_{sCb}	Yes	1.30E-06	1.30E-04
Bottom algae use HCO3- as substrate	Yes					
Light model	Half saturation					
Light constant	3.58588	langleys/d	K_{Lb}	Yes	1	100
Ammonia preference	22.48993	ugN/L	k_{hnxb}	Yes	1	100
Subsistence quota for nitrogen	0.63189468	mgN/mgA	q_{0N}	Yes	0.0072	7.2
Subsistence quota for phosphorus	0.03389707	mgP/mgA	q_{0P}	Yes	0.001	1
Maximum uptake rate for nitrogen	72.64143	mgN/mgA/d	ρ_{mN}	Yes	35	150
Maximum uptake rate for phosphorus	15.03188	mgP/mgA/d	ρ_{mP}	Yes	5	20
Internal nitrogen half sat ratio	3.9246125		$K_{qN,ratio}$	Yes	1.05	5
Internal phosphorus half sat ratio	1.3342815		$K_{qP,ratio}$	Yes	1.05	5
Nitrogen uptake water column fraction	1		$N_{UpWCfrac}$	No	0	1
Phosphorus uptake water column fraction	1		$P_{UpWCfrac}$	No	0	1
Detritus (POM):						
Dissolution rate	0	/d	k_{dt}	Yes	0	5
Temp correction	1.07		θ_{dt}	No	1.07	1.07
Settling velocity	0	m/d	v_{dt}	Yes	0	5
Pathogens:						
Decay rate	0	/d	k_{dx}	No	0.8	0.8
Temp correction	1.07		θ_{dx}	No	1.07	1.07
Settling velocity	1	m/d	v_x	No	1	1
alpha constant for light mortality	1	/d per ly/hr	*apath*	No	1	1
pH:						
Partial pressure of carbon dioxide	347	ppm	p_{CO2}			
Hyporheic metabolism						
Model for biofilm oxidation of fast CBOD	Zero-order		*level 1*			
Max biofilm growth rate	5	gO2/m^2/d or /d	"	No	0	20

QUAL2Kw

Stream Water Quality Model

Locust (10/17/2006)

Global rate parameters

Fitness:
1.85658

				Auto-calibration inputs		
Parameter	*Value*	*Units*	*Symbol*	*Auto-cal*	*Min value*	*Max value*
Temp correction	1.047		"	No	1.047	1.047
Fast CBOD half-saturation	0.5	mgO2/L	"	No	0	2
Oxygen inhib model	Exponential		"			
Oxygen inhib parameter	0.60	L/mgO2	"	No	0.60	0.60
Respiration rate	0.2	/d	*level 2*	No	0.2	0.2
Temp correction	1.07		"	No	1.07	1.07
Death rate	0.05	/d	"	No	0.05	0.05
Temp correction	1.07		"	No	1.07	1.07
External nitrogen half sat constant	15	ugN/L	"	No	15	15
External phosphorus half sat constant	2	ugP/L	"	No	2	2
Ammonia preference	25	ugN/L	"	No	25	25
First-order model carrying capacity	100	gD/m^2	"	No	100	100
Generic constituent						
Decay rate	0.8	/d		No	0.8	0.8
Temp correction	1.07			No	1.07	1.07
Settling velocity	1	m/d		No	1	1
Use generic constituent as COD?	No					
User-defined auto-calibration parameters (optional)						
Point source pH at location 10.2 Km	7.43916				6	7.5

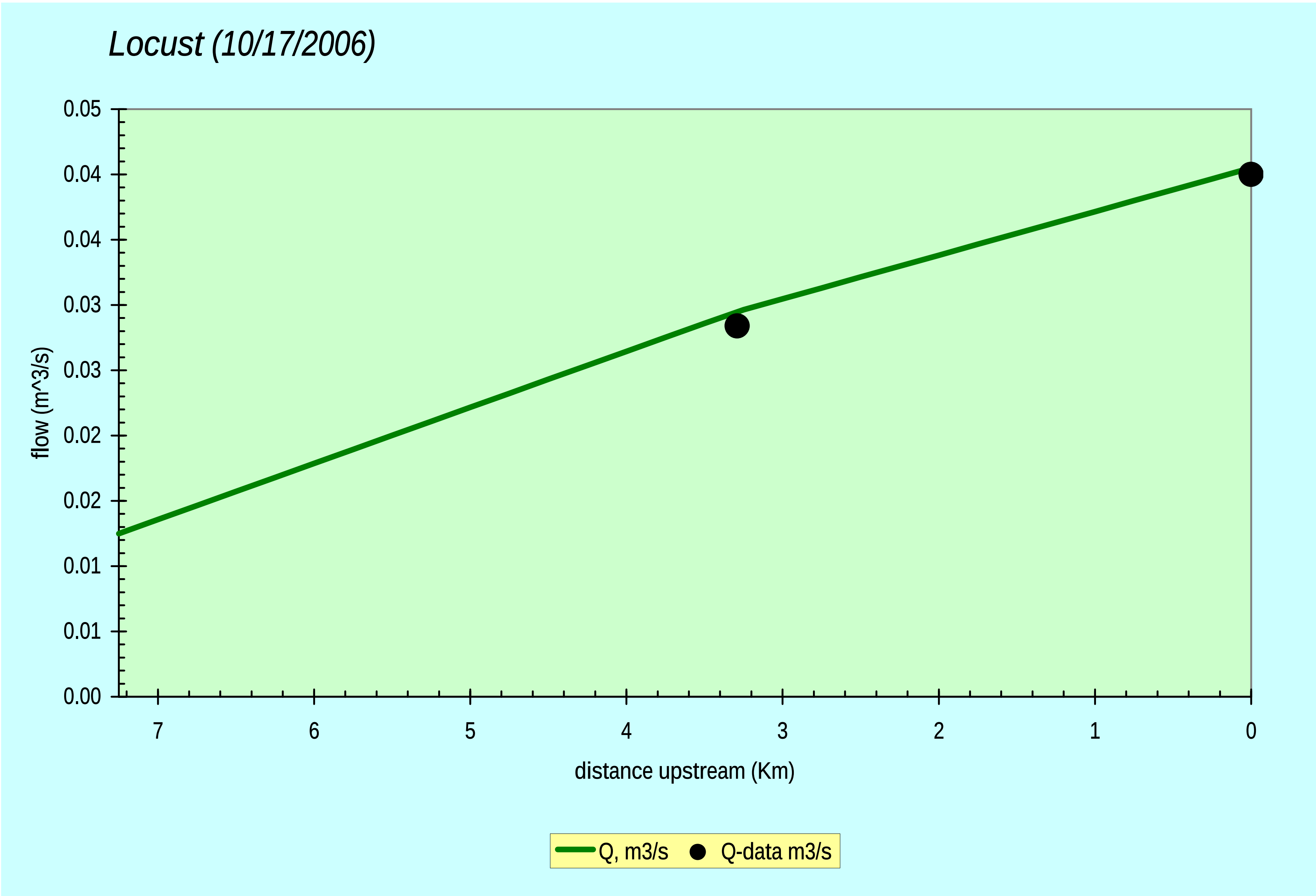
QUAL2Kw

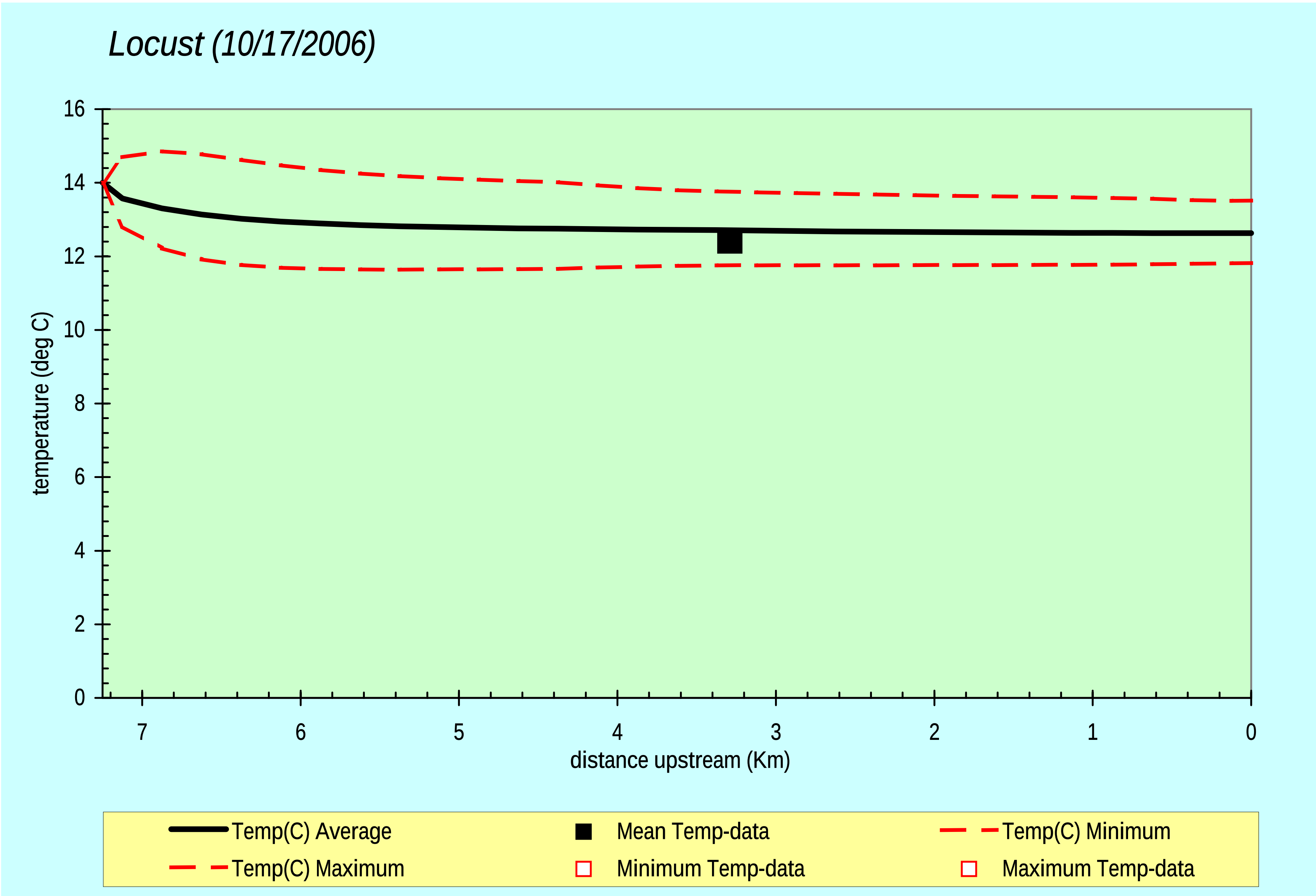
Stream Water Quality Model

Locust (10/17/2006)

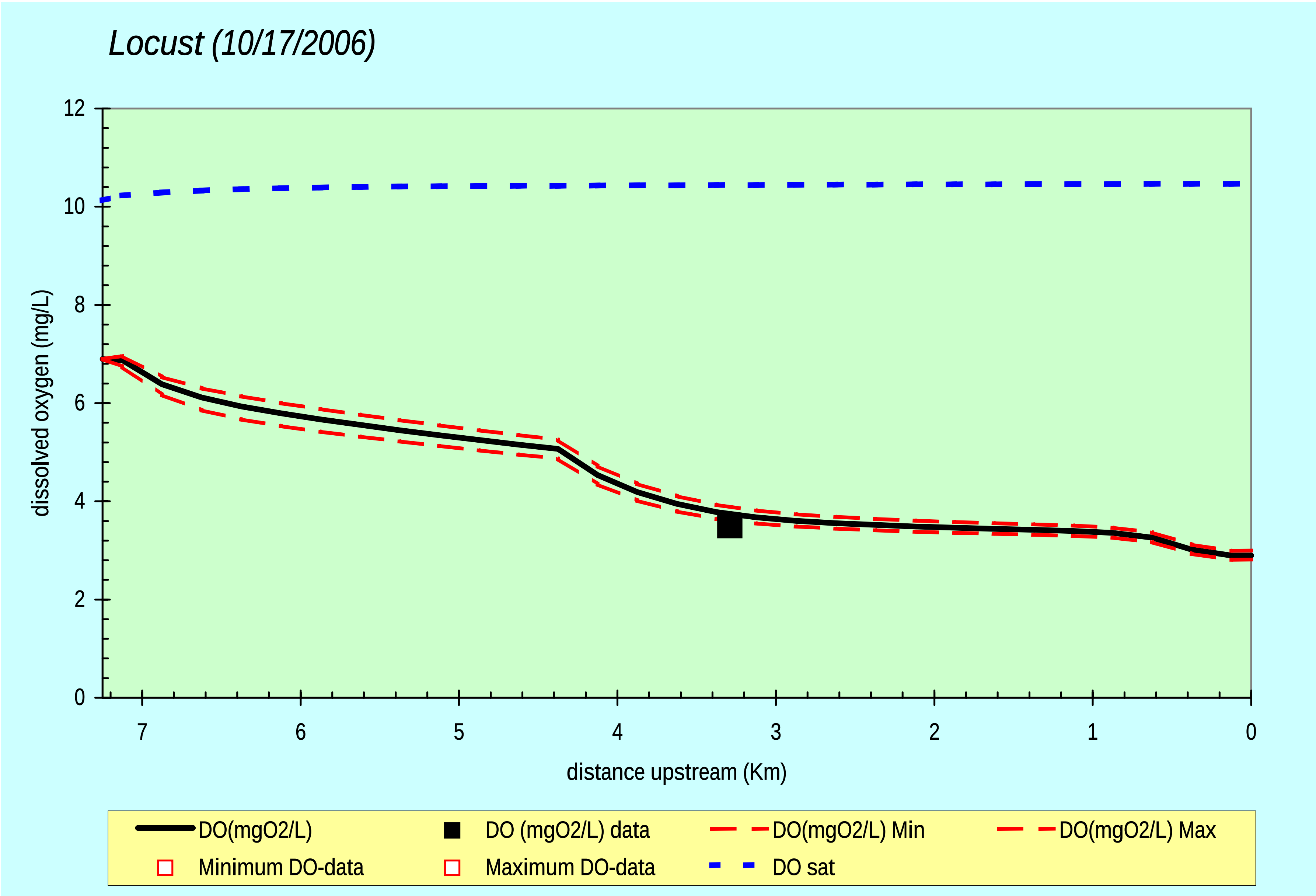
Global rate parameters

Auto-calibration genetic algorithm control:		
Random number seed	123456	seed
Model runs in a population (<=512)	4	np
Generations in the evolution	2	ngen
Digits to encode genotype (<=6)	5	nd
Crossover mode (1, 2, 3, 4, 5, 6, or 7)	3	icross
Crossover probability (0-1):	0.85	pcross
Mutation mode (1, 2, 3, 4, 5, or 6)	2	imut
Initial mutation rate (0-1):	0.005	pmut
Minimum mutation rate (0-1):	0.0005	pmutmn
Maximum mutation rate (0-1):	0.25	pmutmx
Relative fitness differential (0-1):	1	fdif
Reproduction plan (1, 2, or 3):	1	irep
Elitism (0 or 1):	1	ielite
Restart from previous evolution (0 or 1):	0	irestart

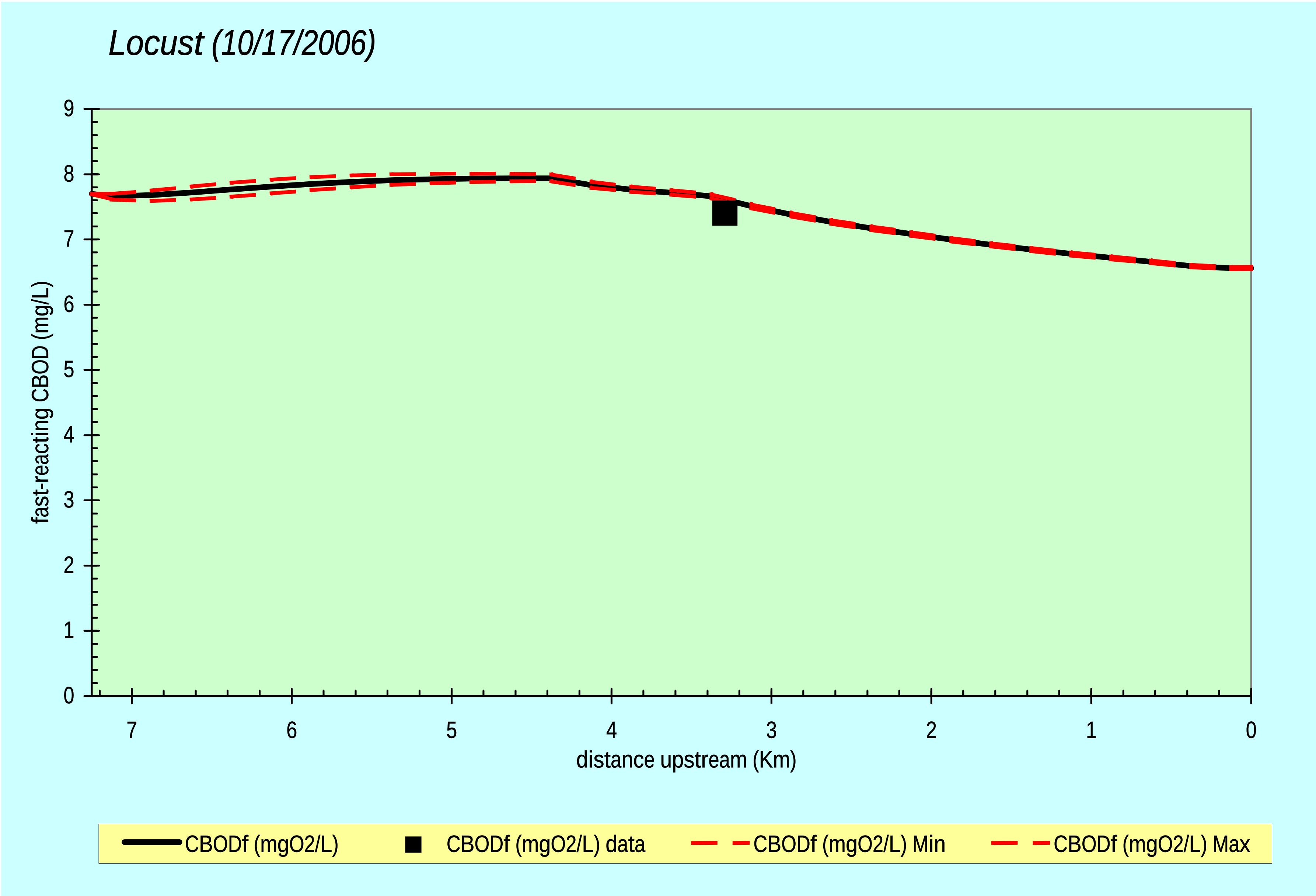

Locust (10/17/2006)
0.05
0.04
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
flow (m^3/s)
7
6
5
4
3
2
1
0
distance upstream (Km)
Q, m3/s
Q-data m3/s



Locust (10/17/2006)
temperature (deg C)
16
14
12
10
8
6
4
2
0
7
6
5
4
3
2
1
0
distance upstream (Km)
Temp(C) Average
Mean Temp-data
Temp(C) Minimum
Temp(C) Maximum
Minimum Temp-data
Maximum Temp-data



Locust (10/17/2006)
12
10
8
6
4
2
0
dissolved oxygen (mg/L)
7
6
5
4
3
2
1
0
distance upstream (Km)
DO(mgO2/L)
DO (mgO2/L) data
DO(mgO2/L) Min
DO(mgO2/L) Max
Minimum DO-data
Maximum DO-data
DO sat



Locust (10/17/2006)
9
8
7
6
5
4
3
2
1
0
fast-reacting CBOD (mg/L)
7
6
5
4
3
2
1
0
distance upstream (Km)
CBODf (mgO2/L)
CBODf (mgO2/L) data
CBODf (mgO2/L) Min
CBODf (mgO2/L) Max

Appendix E : Stage 1 Report

Appendix F : Stage 2 Report

Appendix G : Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from July 31, 2007 through August 17, 2007 postmarked, including those from the August 6, 2007 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. This TMDL is for the Shoal Creek watershed. This report details the watershed characteristics, impairment, sources, load and wasteload allocations, and reductions for each segment. The Illinois EPA implements the TMDL program in accordance with Section 303(d) of the federal Clean Water Act and regulations there under.

Background

The portion of the Shoal Creek watershed addressed in this report has a drainage area of approximately 310 square miles This watershed is part of Bond, Montgomery, Clinton and Madison counties. Land use in the is 72 percent agriculture, 16 percent forest, nine percent urban and two percent urban. Waters impaired in this watershed are Shoal Creek, Locust Fork, Chicken Creek and Cattle Creek. Shoal Creek is listed on the Illinois EPA 2006 Section 303(d) List as being impaired for public water supply use with the potential cause of manganese. It is also impaired for primary contact recreation (swimming) use with the potential cause of fecal coliform. Locust Fork is impaired for aquatic life use with the potential cause of low dissolved oxygen. Chicken Creek is impaired for aquatic life use with the potential causes of low dissolved oxygen and silver. Cattle Creek is impaired for aquatic life use with the potential causes of ammonia, copper, low dissolved oxygen and total dissolved solids. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List.

6.0 PUBLIC MEETINGS

Public meetings were held in Sorento on June 28, 2006, August 6, 2007 and April 10, 2008. The Illinois EPA provided public notices for all meetings by placing display ads in three newspapers in the watershed; the Sorento News, Greenville Advocate and the Breese Journal. These notices gave the date, time, location, and purpose of the meetings. It also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the Sorento Village Hall, Breese City Hall and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The first public meeting on June 28, 2006 started at 6:00 p.m. and was attended by approximately seven people. The second public meeting on August 6, 2007, started at 6:00 p.m. and was attended by nine people. The meeting record remained open until midnight, August 17, 2007. The third public meeting for the implementation plan was held on April 10, 2008 and was attended by nine people.

Questions and Comments

1. Where does fecal coliform come from?

   Response
   Fecal coliform are bacteria in wastes from warm-blooded mammals. It is used as an “indicator organism” because excessive amounts in surface water have been known to indicate increased risk of pathogen-induced illness to humans. Infection due to pathogen-contaminated recreational waters can include gastrointestinal, respiratory, eye, and skin diseases. Fecal coliform sources are humans and animals.

2. Are sewage treatment plants allowed to discharge fecal coliform?

   Response
   Some plants have limits for fecal coliform in their discharge. This limit is given to sewage treatment plants in their NPDES permit and they must monitor to show compliance. Some treatment plants have been given a chlorination exemption in which they do not chlorinate or monitor for fecal coliform. In order to attain this, the plant must prove there is no primary contact (swimming) in the water it is discharging into and submit data to show that at the end of the water reach, the fecal count is lower than 200 cfu/100ml.

3. Does anyone use ozone for disinfection?

   Response
   No facility in Illinois uses ozone. It is very effective, but also expensive. Most treatment plants use chlorine to disinfect and a few use ultraviolet light.

4. What are you going to do about disinfection exemptions in the watershed?

   Response
   Illinois EPA is currently reevaluating the chlorination exemptions. Facilities may be required to demonstrate current compliance or may have their exemption revoked through permitting actions.

5. Is Illinois EPA aware that long-walled mining is going to affect this watershed? Long-wall mining will sink the land and we will not be able to use our land anymore. Do these operations have to have a permit from Illinois EPA? Longwall mining causes stagnant pools to form, in former flowing streams, and destroys tributaries, or streams in pastures that water livestock. What has EPA done, to prohibit the destroying of streams?

   Response
   For underground mining operations, whether they be long-wall or conventional (room-and-pillar), Illinois EPA only permits the surface facilities of such operations. The actual underground mining operation is outside the scope of our authority as granted under 35 Ill. Adm. Code. Subtitle D (mining regulations). The underground mining operations are handled through a mining permit issued by Illinois Department of Natural Resources (IDNR)/Office of Mines and Minerals.

6. I am wondering why the map for Shoal Creek Watershed does not show the source for Shoal Creek, or the three lakes- Lake Lou Yeager, Lake Hillsboro and Glenn Shoals Lake, all of which are formed originally from Shoal Creek. Does a “watershed” include the entire major streams of Shoal Creek?

   Response
   For the purposes of the Illinois Section 2004 and 2006 303(d) List, the prioritization process was done on a watershed basis instead of on individual waterbodies. Illinois EPA watershed boundaries are based on the USGS ten-digit hydrologic units. The three lakes mentioned are in a separate ten-digit waterbody. Because there is a nonimpaired segment of Shoal Creek between the TMDL watershed and Lou Yeager, Illinois EPA chose to do a separate TMDL for the lake. Lake Hillsboro and Glenn Shoals already have TMDLs completed.

Shoal Creek Watershed TMDL Implementation Plan

FINAL REPORT

March 17, 2008

Submitted to:
Illinois Environmental Protection Agency
1021 N. Grand Avenue East
Springfield, IL 62702

Submitted by:
Tetra Tech

TABLE OF CONTENTS

Tables

Figures

KEY FINDINGS

As part of the Section 303(d) listing process, the Illinois Environmental Protection Agency (IEPA) identified four waterbodies in the Shoal Creek watershed as impaired: Cattle Creek, Chicken Creek, Locust Fork, and Shoal Creek (IEPA, 2006). This report addresses the fecal coliform, copper, ammonia, total dissolved solids (TDS), and silver impairments in Cattle Creek, Chicken Creek, and Shoal Creek. Shoal Creek has fecal coliform and manganese concentrations that exceed Illinois' water quality standards. Copper, ammonia, and TDS water quality standards are exceeded in Cattle Creek, and the silver water quality standard is exceeded in Chicken Creek. Details regarding the TMDLs for these water quality impairments can be found in the report titled, "TMDL Development for the Shoal Creek Watershed, Illinois" (also referred to as the "Stage 3" report) (IEPA, 2007).

Pollutant sources in the Shoal Creek watershed are varied. Wastewater treatment plants and septic systems contribute fecal coliforms to Shoal Creek. Septic systems potentially contribute to the ammonia impairment in Cattle Creek as well. The remainder of the impairments (i.e., copper, manganese, silver, and TDS) appear to be due to agricultural sources, natural soil conditions, and associated sediment erosion.

Because of the variety of pollutant sources in the watershed, a number of different best management practices (BMPs) are recommended to reduce pollutant loading. The BMPs most likely to reduce loadings from agricultural operations include: riparian buffers, conservation tillage, cover crops, cattle exclusion from streams, and grazing management. Disinfection of treatment plant effluent is recommended to reduce fecal coliform loads to Shoal Creek. Septic systems should also be inspected and repaired throughout the watershed to reduce fecal coliform and ammonia loadings.

1.0 INTRODUCTION

In 2006, five segments in the Shoal Creek watershed were listed as impaired on Illinois' Section 303(d) list (Table 1-1). The Clean Water Act and U.S. Environmental Protection Agency (USEPA) regulations require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies listed as impaired. At this time, the Illinois Environmental Protection Agency (IEPA) is proceeding with TMDLs for the following waterbody-pollutant combinations:

- Cattle Creek – Ammonia, Copper, and Total Dissolved Solids
- Chicken Creek – Silver
- Shoal Creek (Segments Ol-08 and Ol-09) – Fecal Coliforms and Manganese

TMDLs for these waterbody-pollutant combinations have been completed and are documented in the report titled, "TMDL Development for the Shoal Creek Watershed, Illinois," (also referred to as the "Stage 3" report) (IEPA, 2007).

This report builds on the Stage 3 report by recommending implementation measures to achieve the necessary load reductions. The remainder of this report provides a brief description of the watershed (Section 2.0), summarizes the TMDLs for each waterbody (Section 3.0), presents Best Management Practices (BMPs) to achieve water quality targets (Section 4.0), and discusses BMP priorities (Section 5.0). Sections 6.0 and 7.0 then discuss monitoring recommendations and the available programs to assist in BMP implementation, respectively.

Table 1-1. Illinois' 2006 303(d) List Information for the Shoal Creek Watershed

Waterbody Name	Waterbody Segment	Segment Size (Miles)	Cause of Impairment	Impaired Designated Use
Shoal Creek	OI-08	13.11	**Fecal Coliform**	Primary Contact Recreation
			Manganese	Public Water Supplies
Shoal Creek	OI-09	29.75	**Fecal Coliform**	Primary Contact Recreation
			Manganese	Public Water Supplies
Locust Fork	OIC-02	4.24	Dissolved Oxygen	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Chicken Creek	OIO-09	1.92	Dissolved Oxygen	Aquatic Life
			Silver	Aquatic Life
			Total Nitrogen	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life
Cattle Creek	OIP-10	2.71	**Ammonia**	Aquatic Life
			Copper	Aquatic Life
			Dissolved Oxygen	Aquatic Life
			TDS	Aquatic Life
			Total Phosphorus	Aquatic Life
			Sedimentation/Siltation	Aquatic Life
			Total Suspended Solids	Aquatic Life

Note: Bold font indicates pollutants that are addressed in this report.
Source: IEPA, 2006

2.0 DESCRIPTION OF WATERBODY AND WATERSHED CHARACTERISTICS

The purpose of this section of the report is to provide a basic understanding of the Shoal Creek watershed. More detailed information on the soils, topography, land use/land cover, climate and population of the watershed are available in the Stage One Watershed Characterization Report (IEPA, 2007b).

The Shoal Creek watershed is located in south-central Illinois and has a watershed area of approximately 917 square miles. This report addresses the lower portion of the Shoal Creek watershed encompassing 311 square miles (198,859 acres) in Bond, Clinton, and Montgomery Counties. Figure 2-1 shows the portion of the Shoal Creek watershed addressed in this report.

The Illinois Gap Analysis Project Land Cover Data indicate that approximately 130,122 acres, representing 65 percent of the total watershed area, are devoted to agricultural activities (Table 2-1). The majority of the watershed consists of corn and soybean farming (25 percent and 27 percent, respectively). Upland forests occupy 14 percent of the watershed and wetlands occupy approximately 9 percent. Other land cover categories represent 24 percent of the watershed area.

Hydrologic soil groups B, C and D are found within the watershed. Soil erodibility factors reported for these soils in the STATSGO database range from 0.17 to 0.55, indicating moderate soil erodibility. Soils identified by STATSGO as highly erodible generally have slopes greater than 5 percent and represent only 9 percent of the total watershed area.

Table 2-1. Land Use and Land Cover in the Shoal Creek Watershed.

Land Cover Category	Area (Acres)	Percentage
Soybeans	54,177	27.20%
Corn	50,174	25.20%
Upland	28,618	14.40%
Wetlands[1]	18,320	9.20%
Winter Wheat/Soybeans	14,503	7.30%
Rural Grassland	13,700	6.90%
Winter Wheat	4,757	2.40%
Other Small Grains and Hay	4,630	2.30%
Forested Areas[2]	2,941	1.50%
Low/Medium Density	2,438	1.20%
Other Agriculture	1,881	0.90%
High Density	1,278	0.70%
Urban Open Space	869	0.50%
Surface Water	356	0.20%
Barren and Exposed Land	217	0.10%
Total	198,859	100%

1. Wetlands includes shallow marsh/wet meadow, deep marsh, floodplain forest, swamp, and shallow water.
2. Forested areas include partial canopy/savannah upland and coniferous.

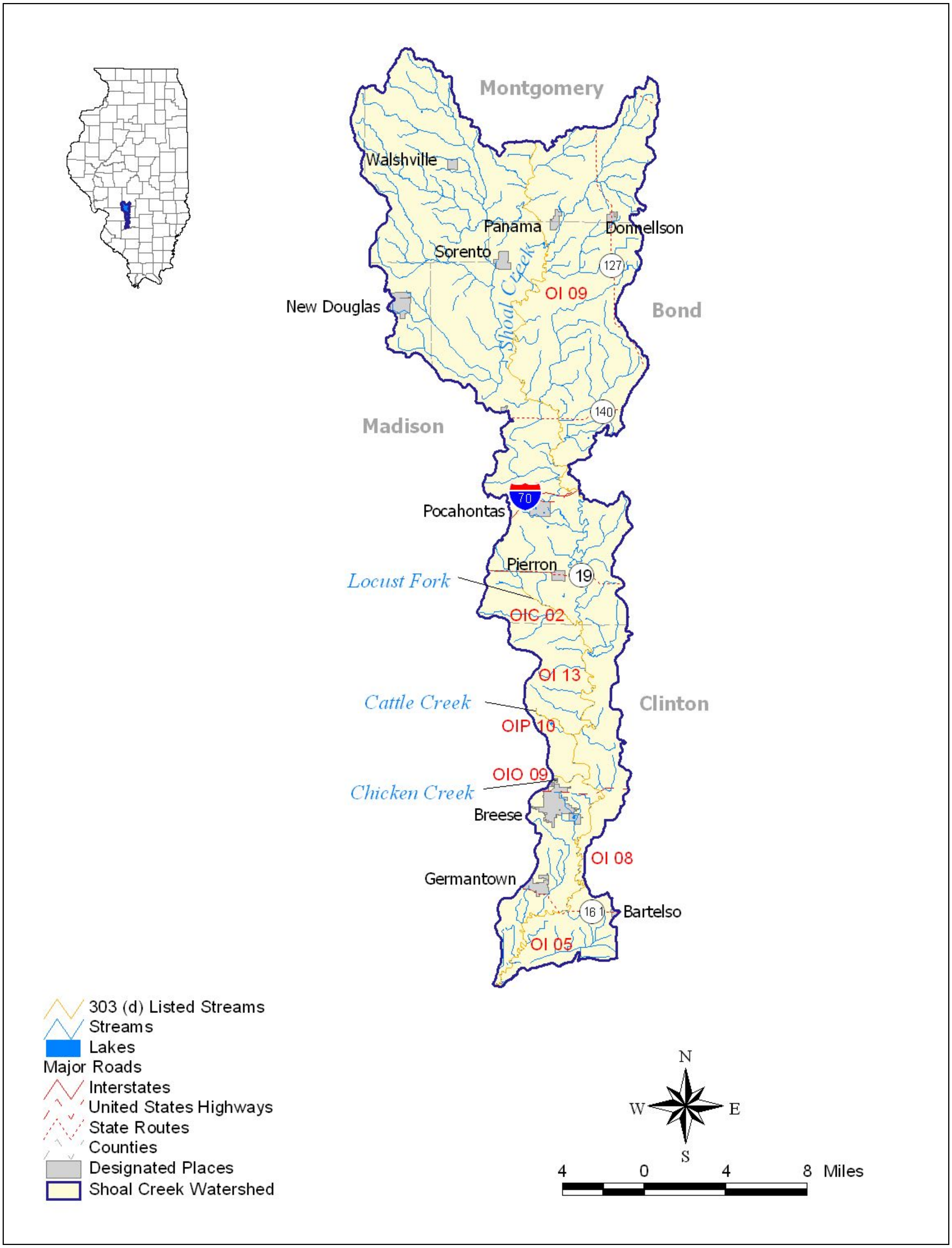


Figure 2-1. Location of the Shoal Creek Watershed

3.0 TMDLS AND SOURCES

TMDLs were completed for three waterbodies (four segments) in the Shoal Creek watershed:

- Cattle Creek – Ammonia, Copper, and Total Dissolved Solids
- Chicken Creek – Silver
- Shoal Creek (Segments Ol-08 and Ol-09) – Fecal Coliforms and Manganese

The following sections summarize the TMDLs and the relevant sources for each waterbody. Source loads and BMP recommendations for each waterbody are presented in Section 5.0. Additional details regarding the TMDLs and sources for each waterbody can be found in the Stage 3 Report (IEPA, 2007).

3.1 Shoal Creek

Fecal coliform concentrations in Shoal Creek (Segments OL-08 and OL-09) exceed Illinois' water quality standard. The TMDL analysis indicates that load reductions are needed during all flow events, ranging from 10 to 94 percent depending on the flow condition. The eight wastewater treatment plants in the watershed are likely the largest sources of fecal coliforms. However, at the time of this report, there were no data from the treatment plants to quantify loads. All eight of the plants have disinfection exemptions. Additional sources of fecal coliforms include animal operations and septic systems.

Manganese concentrations in Shoal Creek also exceed Illinois' water quality standard. The TMDL analysis indicates that load reductions are needed during most flow events, and range from 0 to 69 percent depending on the flow condition. Streambank erosion and crop production (and associated sediment loads) are likely the largest source of anthropogenic manganese loads.

3.2 Cattle Creek

Copper concentrations in Cattle Creek (Segment OLP-10) exceed Illinois' water quality standard. The TMDL analysis indicates that load reductions are needed during low to mid range flow events. Load reductions range from 0 to 99 percent depending on the flow condition. There are no point sources of copper in the watershed, and the potential nonpoint sources are poorly defined. It is suspected that copper containing fertilizers and/or sediment-bound copper are the anthropogenic sources in Cattle Creek.

Ammonia concentrations in Cattle Creek exceed Illinois' water quality standard. The TMDL analysis indicates that load reductions are needed during low flow to dry flow events. Load reductions range from 0 to 66 percent, depending on the flow condition. There are no point sources of ammonia in the watershed. Nonpoint sources of ammonia include feed lots, cattle, fertilizers, and septic systems.

Total dissolved solid (TDS) concentrations in Cattle Creek exceed Illinois' water quality standard. The TMDL analysis indicates that load reductions are needed during low flow to dry flow events. Load reductions range from 0 to 39 percent, depending on the flow condition. There are no point sources of TDS in the watershed. Nonpoint sources of TDS include feed lots, fertilizers, and crop production.

3.3 Chicken Creek

Silver concentrations in Chicken Creek (Segment OLO-09) exceed Illinois' water quality standard. The TMDL analysis indicates that load reductions are needed during mid range flow events (although it should be noted that limited data were available for other flow regimes, and no recent data were available). Load reductions range from 0 to 49 percent depending on the flow condition. There are no point sources of silver in the watershed, and the potential nonpoint sources are poorly defined. It is suspected that sediment-bound silver or other un-identified sources are responsible for the impairment in Chicken Creek.

4.0 BEST MANAGEMENT PRACTICES

Controlling pollutant loading to the impaired reaches of the Shoal Creek watershed will require implementation of various BMPs depending on the pollutant(s) of concern and major sources of loading. This section describes the BMPs that may be used to reduce pollutant loading in the Shoal Creek watershed.

4.1 Disinfection of Primary Effluent from Sewage Treatment Plants

The majority of the sewage treatment plants in the Shoal Creek watershed operate under a disinfection exemption. Reducing the fecal coliform concentrations from a primary outfall of an exempt facility to 200 cfu/100 mL will require a permit change and disinfection of the effluent prior to discharge. Common disinfection techniques include chlorination, ozonation, and ultraviolet (UV) disinfection. In most cases, chlorination is the most cost-effective alternative, although residuals and oxidized compounds are toxic to aquatic life; subsequent dechlorination may be necessary prior to discharge which will increase costs similar to the other two options (USEPA, 1999b). The options most frequently employed are discussed below.

Illinois EPA is reevaluating disinfection exemption status for NPDES facilities. All facilities that are within three miles of a bacteria impaired segment will be reexamined. The facilities in Table 4-1 will have to reapply for the exemption status at the time of their next permit renewal. This will include submission of new discharge data.

Table 4-1. Facilities that need to reapply for exemption status.

Facility	Permit Expiration
Germantown STP	12/31/07*
Breese STP	8/31/2009
Pocahantas STP	12/31/07*
Panama STP	12/31/2012
Sorento STP	12/31/07*

*These permits are going through the renewal process. At the next renewal date they will be required to reapply for exemption status.

4.1.1 Chlorination

Chlorine compounds used for disinfection are usually either chlorine gas or hypochlorite solutions though other liquid and solid forms are available. Oxidation of cellular material destroys pathogenic organisms. The remaining chlorine residuals provide additional disinfection, but may also react with organic material to form harmful byproducts. To reduce the impacts on aquatic life from chlorine residuals and byproducts, a dechlorination step is often included in the treatment process (USEPA, 1999b).

The advantages of chlorine disinfection are

- Generally more cost-effective relative to UV disinfection or ozonation
- Residuals continue to provide disinfection after discharge
- Effective against a wide array of pathogens
- Capable of oxidizing some organic and inorganic compounds
- Provides some odor control
- Allows for flexible dosing

There are several disadvantages as well:

- Chlorine residuals are toxic to aquatic life and may require dechlorination, which may increase costs by 30 to 50 percent
- Highly corrosive and toxic with expensive shipping and handling costs
- Meeting Uniform Fire Code requirements can increase costs by 25 percent
- Oxidation of some organic compounds can produce toxic byproducts
- Effluent has increased concentrations of dissolved solids and chloride

More information about disinfection with chlorine is available online at
http://www.consolidatedtreatment.com/manuals/Fact_sheet_chlorine_disinfection.pdf

4.1.2 Ozonation

Ozone is generated onsite by passing a high voltage current through air or pure oxygen (USEPA, 1999c). The resulting gas (O_3) provides disinfection by destroying the cell wall, damaging DNA, and breaking carbon bonds. The advantages of ozonation include

- Ozone is more effective than chlorine and has no harmful residuals.
- Ozone is generated onsite so there are no hazardous transport issues.
- Short contact time of 10 to 30 minutes.
- Elevates the DO of the effluent.

Disadvantages are

- More complex technology than UV light or chlorine disinfection.
- Highly reactive and corrosive.
- Not economical for wastewater with high concentrations of BOD, TSS, COD, or TOC.
- Initial capital, maintenance, and operating costs are typically higher than for UV light or chlorine disinfection.

More information about ozonation is available online at
http://www.epa.gov/owmitnet/mtb/ozon.pdf

4.1.3 Ultraviolet Disinfection

UV radiation is generated by passing an electrical current through a lamp containing mercury vapor. The radiation attacks the genetic material of the organisms, destroying reproductive capabilities (NSFC, 1998).

The advantages of UV disinfection are

- Highly effective.
- Destruction of pathogens occurs by physical process, so no chemicals must be transported or stored.
- No harmful residuals.
- Easy to operate.
- Short contact time (20 to 30 min).
- Requires less space than chlorination or ozonation.

Disadvantages of UV disinfection are

- Organisms can sometimes regenerate
- Turbidity and TSS can interfere with disinfection at high concentrations

- Not as cost effective compared to chlorination alone, but when fire code regulations and dechlorination are considered, costs are comparable.

More information about disinfection with UV radiation is available online at http://www.nsfc.wvu.edu/nsfc/pdf/eti/UV_Dis_tech.pdf

4.1.4 Effectiveness

The use of disinfection techniques in the sewage treatment plants that operate under a disinfection exemption will help in reducing in-stream fecal coliform concentrations to 200 cfu/100 mL.

4.1.5 Costs

Upgrading the existing wastewater treatment plants to include disinfection prior to discharge can be achieved with chlorination, ozonation, or UV radiation processes. The costs associated with these three techniques include upfront capital costs to construct additional process units, operating and maintenance costs for chemicals, electricity, labor, etc., as well as chemical storage and fire code requirements associated with the chlorination option. USEPA compares the costs of chlorination, ozonation, and UV disinfection in a series of fact sheets available online. This information is summarized below as well as in Table 4-2. Prices in the fact sheets were listed in either 1995 or 1998 dollars. Prices have been converted to year 2004 dollars, assuming a 3 percent per year inflation rate, for comparison with the other BMPs discussed in this plan that must be described in year 2004 dollars.

Chlorine dosage usually ranges from 5 mg/L to 20 mg/L depending on the wastewater characteristics and desired level of disinfection. The cost of adding a chlorination/dechlorination system that meets fire code requirements and treats one million gallons per day (MGD) of wastewater with a chlorine dosage of 10 mg/L costs approximately $1,260,000 in 1995 with annual operation and maintenance costs of $59,200 (USEPA, 1999b). If a 3 percent per year inflation rate is assumed, these costs in 2004 dollars are $1,640,000 and $77,200, respectively.

Costs for ozonation were given by USEPA (1999c) in 1998 dollars. The capital costs in 1998 for treating one MGD of secondary wastewater with BOD and TSS concentrations each less than 30 mg/L was $300,000. The operating and maintenance costs were listed at $18,500 plus the costs of electricity. In 2004 dollars, these costs are $358,200 and $22,000, respectively.

Ultraviolet radiation costs were listed in 1995 dollars by USEPA (1995) relative to the cost per bulb. Based on vendor information available online, approximately 40 bulbs would be required to treat 1 MGD of secondary wastewater. Based on the information presented, the capital costs in 2004 for a 1 MGD facility would be approximately $750,000 and the annual operating and maintenance costs would range from $4,500 to $5,100.

Table 4-2 compares the costs for these three disinfection technologies. Annualized costs are calculated assuming a 20-year system life for each technology before major repairs or replacement would be required.

Table 4-2. Comparison of Disinfection Costs (2004) per 1 MGD of Sewage Treatment Plant Effluent.

Technology	Capital Cost	Annual Operating and Maintenance Cost	Annualized Cost
Chlorination (10 mg/L dosage), dechlorination, fire code regulations	$1,640,000	$77,200	$159,200
Ozonation	$358,200	$22,000	$39,900, plus cost of electricity
UV Disinfection	$750,000	$4,500 to $5,100	$42,000 to $42,600

4.2 Proper Maintenance of Onsite Systems

The most effective BMP for managing loads from septic systems is regular maintenance. Unfortunately, most people do not think about their wastewater systems until a major malfunction occurs (i.e., sewage backs up into the house or onto the lawn). When not maintained properly, septic systems can cause the release of pathogens and excess nutrients into surface water. Good housekeeping measures relating to septic systems are listed below (Goo, 2004):

- Inspect system annually and pump system every 3 to 5 years, depending on the tank size and number of residents per household.
- Refrain from trampling the ground or using heavy equipment above a septic system (to prevent collapse of pipes).
- Prevent septic system overflow by conserving water, not diverting storm drains or basement pumps into septic systems, and not disposing of trash through drains or toilets.

Education is a crucial component of reducing pollution from septic systems. Many owners are not familiar with USEPA recommendations concerning maintenance schedules. Education can occur through public meetings, mass mailings, and radio and television advertisements. The USEPA recommends that septic tanks be pumped every 3 to 5 years depending on the tank size and number of residents in the household (USEPA, 2002b). Annual inspections, in addition to regular maintenance, ensure that systems are functioning properly. An inspection program would help identify those systems that are currently connected to tile drain systems. All tanks discharging to tile drainage systems should be disconnected immediately.

Some communities choose to formally regulate septic systems by creating a database of all the systems in the area. This database usually contains information on the size, age, and type of system. All inspections and maintenance records are maintained in the database through cooperation with licensed maintenance and repair companies. These databases allow the communities to detect problem areas and ensure proper maintenance.

At this time, there is not a formal inspection and maintenance program in Jackson County. The County Health Department does issue permits for new onsite systems and major repairs

4.2.1 Effectiveness

The reductions in pollutant loading resulting from improved operation and maintenance of all systems in the watershed depends on the wastewater characteristics and the level of failure present in the watershed.

4.2.2 Costs

Septic tanks are designed to accumulate sludge in the bottom portion of the tank while allowing water to pass into the drain field. If the tank is not pumped out regularly, the sludge can accumulate and eventually become deep enough to enter the drain field. Pumping the tank every three to five years prolongs the life of the system by protecting the drain field from solid material that may cause clogs and system backups.

The cost to pump a septic tank ranges from $250 to $350 depending on how many gallons are pumped out and the disposal fee for the area. If a system is pumped once every three to five years, this expense averages out to less than $100 per year. Septic systems that are not maintained will likely require replacement which may cost between $2,000 and $10,000.

The cost of developing and maintaining a watershed-wide database of the onsite wastewater treatment systems in the Shoal Creek watershed depends on the number of systems that need to be inspected. After the initial inspection of each system and creation of the database, only systems with no subsequent maintenance records would need to be inspected. A recent inspection program in South Carolina found that inspections cost approximately $160 per system (Hajjar, 2000).

Education of home and business owners that use onsite wastewater treatment systems should occur periodically. Public meetings, mass mailings, and radio, newspaper, and TV announcements can all be used to remind and inform owners of their responsibility to maintain their systems. The costs associated with education and inspection programs will vary depending on the level of effort required to communicate the importance of proper maintenance and the number of systems in the area.

The costs associated with inspecting and maintaining onsite wastewater treatment systems and educating owners of their responsibilities is summarized in Table 4-3.

Table 4-3. Costs Associated with Maintaining and Replacing an Onsite Wastewater Treatment System

Action	Cost per System	Frequency	Annual Cost per System
Pumping	$250 to $350	Once every 3 to 5 years	$70 to $85
Inspection	$160	Initially all systems should be inspected, followed by 5 year inspections for systems not on record as being maintained	Up to $32, assuming all systems have to be inspected once every five years, which is not likely
Replacement	$2,000 to $10,000	With proper maintenance, system life should be 30 years	$67 to $333
Education	$1	Public reminders should occur once per year	$1

4.3 Tillage Practices

Conservation tillage practices and residue management are commonly used to control erosion and surface transport of pollutants from fields used for crop production. The residuals not only provide erosion control, but also provide a nutrient source to growing plants, and continued use of conservation tillage results in a more productive soil with higher organic and nutrient content. Increasing the organic content of soil has the added benefit of reducing the amount of carbon in the atmosphere by storing it in the soil. Researchers estimate that croplands and pasturelands could be managed to trap 5 to 17 percent of the greenhouse gases produced in the United States (Lewandrowski et al., 2004).

Several practices are commonly used to maintain surface residues:

- No-till systems disturb only a small row of soil during planting, and typically use a drill or knife to plant seeds below the soil surface.
- Strip till operations leave the areas between rows undisturbed, but remove residual cover above the seed to allow for proper moisture and temperature conditions for seed germination.
- Ridge till systems leave the soil undisturbed between harvest and planting: cultivation during the growing season is used to form ridges around growing plants. During or prior to the next planting, the top half to two inches of soil, residuals, and weed seeds are removed, leaving a relatively moist seed bed.
- Mulch till systems are any practice that results in at least 30 percent residual surface cover, excluding no-till and ridge till systems.

The NRCS provides additional information on these conservation tillage practices:
no-till and strip till: http://efotg.nrcs.usda.gov/references/public/IL/329a.pdf
ridge till: http://efotg.nrcs.usda.gov/references/public/IL/329b.pdf
mulch till: http://efotg.nrcs.usda.gov/references/public/IL/329c.pdf

Corn residues are more durable and capable of sustaining the required 30 percent cover required for conservation tillage. Soybeans generate less residue, the residue degrades more quickly, and supplemental measures or special care may be necessary to meet the 30 percent cover requirement (UME, 1996). Figure 4-1 shows a comparison of ground cover under conventional and conservation tillage practices.

Figure 4-1. Comparison of conventional (left) and conservation (right) tillage practices.

4.3.1 Effectiveness

Czapar et al. (2006) summarize past and present tillage practices and their impacts on erosion control and nutrient delivery. Historically, the mold board plow was used to prepare the field for planting. This practice disturbed 100 percent of the soil surface and resulted in basically no residual material. Today, conventional tillage typically employs the chisel plow, which is not as disruptive to the soil surface and tends to leave a small amount of residue on the field (0 to 15 percent). Mulch till systems were classified as leaving 30 percent residue; percent cover was not quantified for the no-till systems in this study. The researchers used WEPP modeling to simulate changes in sediment and nutrient loading for these tillage practices. Relative to mold board plowing, chisel plowing reduced phosphorus loads leaving the field by 38 percent, strip tilling reduced loads by 80 percent, and no-till reduced loads by 85 percent. If chisel plowing is now considered conventional, then the strip till and no-till practices are capable of reducing phosphorus loads by 68 percent and 76 percent, respectively (Czapar et al., 2006).

USEPA (2003) reports the findings of several studies regarding the impacts of tillage practices on nutrient, sediment, and manganese loading. The reductions achieved by conservation tillage reported in these studies are summarized below:

- 50 percent reduction in sediment, and likely manganese, silver, copper and TDS, for practices leaving 20 to 30 percent residual cover.
- 90 percent reduction in sediment, and likely manganese, silver, copper and TDS for practices leaving 70 percent residual cover.
- 69 percent reduction in runoff losses for no-till practices.

4.3.2 Costs

Conservation tillage practices generally require fewer trips to the field, saving on labor, fuel, and equipment repair costs, though increased weed production may result in higher pesticide costs relative to conventional till (USDA, 1999). In general, conservation tillage results in increased profits relative to conventional tillage (Olson and Senjem, 2002; Buman et al., 2004; Czapar, 2006). The HRWCI (2005) lists the cost for conservation tillage at $0/ac.

Hydrologic inputs are often the limiting factor for crop yields and farm profits. Conservation practices reduce evaporative losses by covering the soil surface. USDA (1999) reports a 30 percent reduction in evaporative losses when 30 percent ground cover is maintained. Harman et al. (2003) and the Southwest Farm Press (2001) report substantial yield increases during dry years on farms managed with conservation or no-till systems compared to conventional till systems.

Depending on the type of equipment currently used, replacing conventional till equipment with no-till equipment can either result in a net savings or slight cost to the producer. Al-Kaisi et al. (2000) estimated that converting conventional equipment to no-till equipment costs approximately $1.25 to $2.25/ac/yr, but that for new equipment, purchasing no-till equipment is less expensive than conventional equipment. Other researchers report a net gain when conventional equipment is sold to purchase no-till equipment (Harman et al., 2003).

Table 4-4 summarizes the available information for determining average annual cost for this BMP.

Table 4-4. Cost Calculations for Conservation Tillage.

Item	Costs and Frequency	Annualized Cost (Savings)
Conversion of Conventional Equipment to Conservation Equipment	Costs presented in literature were already averaged out to yearly per acre costs: $1.25/ac/yr to $2.25/ac/yr	$1.25/ac/yr to $2.25/ac/yr
Operating Costs of Conservation Tillage Relative to Conventional Costs	$0/ac/yr	$0/ac/yr
Average Annual Costs		**$1.25/ac/yr to $2.25/ac/yr**

4.4 Cover Crops

Grasses and legumes may be used as winter cover crops to reduce soil erosion and improve soil quality (IAH, 2002). These crops may also contribute nitrogen to the following crop. Grasses tend to have low seed costs and establish relatively quickly, but can impede cash crop development by drying out the soil surface or releasing chemicals during decomposition that may inhibit the growth of a following cash crop. Legumes take longer to establish, but are capable of fixing nitrogen from the atmosphere, thus reducing nitrogen fertilization required for the next cash crop. Legumes, however, are more susceptible to harsh winter environments and may not have adequate survival to offer sufficient erosion protection. Planting the cash crop in wet soil that is covered by heavy surface residue from the cover crop may impede emergence by prolonging wet, cool soil conditions. Cover crops should be killed off two or three weeks prior to planting the cash crop either by application of herbicide or mowing and incorporation, depending on the tillage practices used.

(Photo Courtesy of CCSWCD)

Figure 4-2. Use of Cover Crops

The NRCS provides additional information on cover crops at:
http://efotg.nrcs.usda.gov/references/public/IL/340.pdf

4.4.1 Effectiveness

The effectiveness of cover crops in reducing pollutant loading has been reported by several agencies. In addition to these benefits, the reduction in runoff losses will reduce erosion from streambanks, further reducing manganese loads and allowing for the establishment of vegetation and canopy cover. The reported reductions are listed below:

- 50 percent reduction in soil and runoff losses with cover crops alone. When combined with no-till systems, may reduce soil loss by more than 90 percent (IAH, 2002). Manganese, silver, copper, and TDS reductions will likely be similar.
- Useful in conservation tillage systems following low-residue crops such as soybeans (USDA, 1999).

4.4.2 Costs

The National Sustainable Agriculture Information Service recommends planting ryegrass after corn harvest and hairy vetch after soybeans (Sullivan, 2003). Both seeds can be planted at a depth of ¼ to ½ inch at a rate of 20 lb/ac or broadcast at a rate of 25 to 30 lb/ac (Ebelhar and Plumer, 2007; OSUE, 1990).

Researchers at Purdue University estimate the seed cost of ryegrass and hairy vetch at $12 and $30/ac, respectively. Savings in nitrogen fertilizer (assuming nitrogen fertilizer cost of $0.30/lb (Sample, 2007)) are $3.75/ac for ryegrass and $28.50/ac for hairy vetch. Yield increases in the following crop, particularly during droughts, are reported at 10 percent and are expected to offset the cost of this practice (Mannering et al., 1998). Herbicide application is estimated to cost $14.25/ac.

Accounting for the seed cost, herbicide cost, and fertilizer offset results in an average net cost of approximately $19.25/ac assuming that cover crop planting recommendations for a typical 2 year corn/soybean rotation are followed (Mannering et al., 1998). These costs do not account for yield increases which may offset the costs completely. Table 4-5 summarizes the costs and savings associated with ryegrass and hairy vetch.

Table 4-5. Cost Calculations for Cover Crops.

Item	Ryegrass	Hairy Vetch
Seed Costs	$12/ac	$30/ac
Nitrogen Fertilizer Savings	($3.75/ac)	($28.50/ac)
Herbicide Costs	$14.25/ac	$14.25/ac
Annual Costs	$22.50/ac	$15.75/ac
Average Annual Cost Assuming Ryegrass Follows Corn and Hairy Vetch Follows Soybeans: $19.25/ac		

4.5 Filter Strips

Filter strips are used in agricultural and urban areas to intercept and treat runoff before it leaves the site. If topography allows, filter strips may also be used to treat effluent from tile drain outlets. For small dairy operations, filter strips may also be used to treat milk house washings and runoff from the open lot (NRCS, 2003).

Filter strips will require maintenance, including grading and seeding, to ensure distributed flow across the filter and protection from erosion. Periodic removal of vegetation will encourage plant growth and uptake and remove nutrients stored in the plant material. Filter strips are most effective on sites with mild slopes of generally less than 5 percent, and to prevent concentrated flow, the upstream edge of a filter strip should follow one elevation contour (NCDENR, 2005). A grass filter strip is shown in Figure 4-3.

Filter strips also serve to reduce the quantity and velocity of runoff. Filter strip sizing is dependent on site specific features such as climate and topography, but at a minimum, the area of a filter strip should be no less than 2 percent of the drainage area for agricultural land (OSUE, 1994). The minimum filter strip width suggested by NRCS (2002a) is 30 ft. The strips are assumed to function properly with annual maintenance for 30 years before requiring replacement of soil and vegetation.

(Photo Courtesy of NRCS)

Figure 4-3. Grass Filter Strip Protecting Stream from Adjacent Agriculture.

4.5.1 Effectiveness

Filter strips have been found to effectively remove pollutants from agricultural runoff. The following reductions are reported in the literature (USEPA, 2003; Kalita, 2000; Woerner et al., 2006):

- 55 to 87 percent reduction in fecal coliform
- 65 percent reductions for sediment (and likely manganese, silver, copper and TDS)
- Slows runoff velocities and may reduce runoff volumes via infiltration
- 70 percent reduction in total nitrogen (practices that control nitrogen loading are also expected to control total ammonia concentrations, mainly ammonium).

4.5.2 Costs

Filter strips cost approximately $0.30 per sq ft to construct, and the system life is typically assumed to be 20 years (Weiss et al., 2007). Assuming that the required filter strip area is 2 percent of the area drained (OSUE, 1994), 870 square feet of filter strip are required for each acre of agricultural land treated. The construction cost to treat one acre of land is therefore $261/ac. The annualized construction costs are $13/ac/yr. Annual maintenance of filter strips is estimated at $0.01 per sq ft (USEPA, 2002c), for an additional cost of $8.70/ac/yr of agricultural land treated. In addition, the area converted from agricultural production to filter strip will result in a net annual income loss of $3.50. Table 4-6 summarizes the costs assumptions used to estimate the annualized cost to treat one acre of agricultural drainage with a filter strip.

Table 4-6. Cost Calculations for Filter Strips Used in Crop Production.

Item	Costs Required to Treat One Acre of Agricultural Land with Filter Strip
Construction Costs	$0.30
Annual Maintenance Costs	$0.01
Construction Costs	$261
System Life (years)	20
Annualized Construction Costs	$13
Annual Maintenance Costs	$8.70
Annual Income Loss	$3.50
Average Annual Costs	**$25/ac treated**

Filter strips used in animal operations typically treat contaminated runoff from pastures or feedlot areas or washings from the milk houses of small dairy operations (NRCS, 2003). The NRCS (2003) costs for small dairy operations (75 milk cows) assumes that a filter strip area of 12,000 square feet is required. For the pasture operations, it is assumed that a filter strip area of 12,000 square feet (30 ft wide and 400 ft long) would be required to treat runoff from a herd of 50 cattle (NRCS, 2003). The document does not explain why more animals can be treated by the same area of filter strip at the dairy operation compared to the pasture operation.

For animal operations, it is not likely that land used for growing crops would be taken out of production for conversion to a filter strip. Table 4-7 summarizes the capital, maintenance, and annualized costs for filter strips per head of animal.

Table 4-7. Cost Calculations for Filter Strips Used at Animal Operations.

Operation	Capital Costs per Head	Annual Operation and Maintenance Costs per Head	Total Annualized Costs per Head
Small dairy (75 milking cows)	$48 per head of cattle	$1.50 per head of cattle	$4 per head of cattle
Beef or other (50 cattle)	$72 per head of cattle	$2.50 per head of cattle	$6 per head of cattle

4.6 Grassed Waterways

Grassed waterways are stormwater conveyances lined with grass that prevent erosion of the transport channel. In addition, the grassed channel reduces runoff velocities, allows for some infiltration, and filters out some particulate pollutants. Grassed waterways are used in animal operations to divert clean water away from pastures, feedlots, and manure storage areas. A grassed waterway providing surface drainage for a corn field is shown in Figure 4-4.

(Photo Courtesy of CCSWCD)

Figure 4-4. Grassed Waterway.

The NRCS provides additional information on grassed waterways at:
http://efotg.nrcs.usda.gov/references/public/IL/412.pdf

4.6.1 Effectiveness

The effectiveness of grass swales for treating agricultural runoff has not been quantified. The Center for Watershed Protection reports the following reductions in urban settings (Winer, 2000):

- 5 percent reduction in fecal coliform
- 68 percent reduction of total suspended solids (and likely manganese, silver, copper and TDS)

4.6.2 Cost

Grassed waterways cost approximately $0.50 per sq ft to construct (USEPA, 2002c). These stormwater conveyances are best constructed where existing bare ditches transport stormwater, so no income loss from land conversion is expected with this practice. It is assumed that the average area required for a grassed waterway is approximately 0.1 to 0.3 percent of the drainage area, or between 44 and 131 sq ft per acre. The range is based on examples in the Illinois Drainage Guide, information from the NRCS Engineering Field Handbook, and a range of waterway lengths (100 to 300 feet). Waterways are assumed to remove phosphorus effectively for 20 years before soil, vegetation, and drainage material need to be replaced (Weiss et al., 2007). The construction cost spread out over the life of the waterway is thus $2.25/yr for each acre of agriculture draining to a grassed waterway. Annual maintenance of grassed waterways is estimated at $0.02 per sq ft (Rouge River, 2001) for an additional cost of $1.75/ac/yr of agricultural land treated. Table 4-8 summarizes the annual costs assumptions for grassed waterways.

Table 4-8. Cost Calculations for Grassed Waterways in Agricultural Land.

Item	Costs Required to Treat One Acre of Agricultural Land
Cost per Square Foot	
Construction Costs	$0.50
Annual Maintenance Costs	$0.02
Cost to Treat One Acre of Agricultural Land (assuming 44 to 131 sq ft of filter strip)	
Construction Costs	$22 to $65.50
System Life (years)	20
Annualized Construction Costs	$1 to $3.25
Annual Maintenance Costs	$1 to $2.75
Annual Income Loss	$0
Average Annual Cost	**$2 to 6/ac treated**

Grassed waterways are primarily used in animal operations to divert clean water away from pastures, feedlots, and manure storage areas. Table 4-9 summarizes the capital, maintenance, and annualized costs of this practice per head of cattle as summarized by NRCS (2003).

Table 4-9. Cost Calculations for Grassed Waterways Used in Cattle Operations.

Capital Cost per Head	Annual Operation and Maintenance Cost per Head	Total Annualized Cost per Head
$0.50 to $1.50	$0.02 to $0.04	$0.05 to $0.12

4.7 Riparian Buffers

Riparian corridors, including both the stream channel and adjacent land areas, are important components of watershed ecology. The streamside forest slowly releases nutrients as twigs and leaves decompose. These nutrients are valuable to the fungi, bacteria, and invertebrates that form the basis of a stream's food chain. Tree canopies of riparian forests also cool the water in streams which can affect the composition of the fish species in the stream, the rate of biological reactions, and the amount of dissolved oxygen the water can hold. Channelization or widening of streams moves the canopy farther apart, decreasing the amount of shaded water surface, increasing water temperatures, and decreasing dissolved oxygen concentrations.

Preserving the natural vegetation along a stream corridor can mitigate pollutant loading associated with human disturbances. The root structure of the vegetation in a buffer enhances infiltration and subsequent trapping of nonpoint source pollutants. However, the buffers are only effective in this manner when the runoff enters the buffer as a slow moving, shallow "sheet"; concentrated flow in a ditch or gully will quickly pass through the buffer offering minimal opportunity for retention and uptake of pollutants.

Even more important than the filtering capacity of the buffers is the protection they provide to streambanks. The rooting systems of the vegetation serve as reinforcements in streambank soils, which help to hold streambank material in place and minimize erosion. Riparian buffers also prevent cattle access to streams, reducing streambank trampling and defecation in the stream. Due to the increase in stormwater runoff volume and peak rates of runoff associated with agriculture and development, stream channels are subject to greater erosional forces during stormflow events. Thus, preserving natural vegetation along stream channels minimizes the potential for water quality and habitat degradation due to streambank erosion and enhances the pollutant removal of sheet flow runoff from developed areas that pass through the buffer. A riparian buffer protecting the stream corridor from adjacent agricultural areas is shown in Figure 4-5.

Figure 4-5. Riparian Buffer Protecting the Stream from Adjacent Agricultural Fields.

4.7.1 Effectiveness

Riparian buffers should consist of native species and may include grasses, forbs, shrubs, and trees. Minimum buffer widths of 25 feet are required for water quality benefits. Higher removal rates are provided with greater buffer widths. Riparian corridors typically treat a maximum of 300 ft of adjacent land before runoff forms small channels that short circuit treatment. Buffer widths based on slope measurements and recommended plant species should conform to NRCS Field Office Technical Guidelines. The following reductions are reported in the literature:

- 34 to 74 percent reduction of fecal coliform for 30 ft wide buffers (Wenger, 1999).
- 87 percent reduction of fecal coliform for 200 ft wide buffers (Wenger, 1999).
- 70 to 90 percent reduction of sediment (and likely manganese, silver, copper and TDS) (NCSU, 2002).
- 74 percent reduction of total nitrogen for 30 ft wide buffer (Dillaha et al, 1989).
- Increased channel stability will reduce streambank erosion and manganese, silver, copper and TDS loads.

4.7.2 Costs

Restoration of riparian areas costs approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). Maintenance of a riparian buffer should be minimal, but may include items such as period inspection of the buffer, minor grading to prevent short circuiting, and replanting/reseeding dead vegetation following premature death or heavy storms. Assuming a buffer width of 90 ft on either side of the stream channel and an adjacent treated width of 300 ft of agricultural land, one acre of buffer will treat approximately 3.3 acres of adjacent agricultural land. The cost per treated area is thus $30/ac to construct and $142.50/ac to maintain over the life of the buffer. Assuming a system life of 30 years results in an annualized cost of $59.25/yr for each acre of agriculture land treated (Table 4-10).

Table 4-10. Cost Calculations for Riparian Buffers.

Item	Costs Required to Treat One Acre of Agricultural Land
Cost per Acre of Riparian Buffer	
Construction Costs	$100
Maintenance Costs Over System Life	$475
Cost to Treat One Acre of Agricultural Land (assuming 0.3 ac of buffer)	
Construction Costs	$30
Maintenance Costs Over System Life	$142.50
System Life (Years)	30
Annualized Construction Costs	$1
Annualized Maintenance Costs	$4.75
Annual Income Loss	$53.50
Average Annual Cost	**$59.25/ac treated**

Restoration of riparian areas will protect the stream corridor from cattle trampling and reduce the amount of fecal material entering the channel. The cost of this BMP depends more on the length of channel to be protected, not the number of animals having channel access. The cost of restoration is approximately $100/ac to construct and $475/ac to maintain over the life of the buffer (Wossink and Osmond, 2001; NCEEP, 2004). Fecal coliform reductions have been reported for buffers at least 30 ft wide (Wenger, 1999). Large reductions are reported for 200 ft wide buffers. The costs per length of channel for 30 ft and 200 ft wide buffers restored on both sides of a stream channel are listed in Table 4-11. A system life of 30 years is assumed.

Table 4-11. Cost Calculations for Riparian Buffers per Foot of Channel.

Width	Capital Costs per ft	Annual Operation and Maintenance Cost per ft	Total Annualized Cost per ft
30 ft on both sides of channel	$0.14	$0.02	$0.03
60 ft on both sides of channel	$0.28	$0.04	$0.05
90 ft on both sides of channel	$0.42	$0.06	$0.07
200 ft on both sides of channel	$0.93	$0.13	$0.16

4.8 Proper Manure Handling, Collection and Disposal

Animal operations are typically either pasture-based or confined, or sometimes a combination of the two. The operation type dictates the practices needed to manage manure from the facility. A pasture or open lot system with a relatively low density of animals (1 to 2 head of cattle per acre (USEPA, 2002a)) may not produce manure in quantities that require management for the protection of water quality. If excess manure is produced, then the manure will typically be scraped with a tractor to a storage bin constructed on a concrete surface. Stored manure can then be land applied when ground is not frozen and precipitation forecasts are low. Rainfall runoff should be diverted around the storage facility with berms or grassed waterways. Runoff from the feedlot area is considered contaminated and is typically treated in a lagoon.

Confined facilities (typically dairy cattle, swine, and poultry operations) often collect manure in storage pits located under slatted floors. Wash water used to clean the floors and remove manure buildup combines with the solid manure to form a liquid or slurry in the pit. The mixture is usually land applied or transported offsite.

Final disposal of waste usually involves land application on the farm or transportation to another site. Manure is typically applied to the land once or twice per year. To maximize the amount of nutrients and organic material retained in the soil, application should not occur on frozen ground or when precipitation is forecast during the next several days.

An example of a waste storage lagoon is shown in Figure 4-6.

Figure 4-6. Waste Storage Lagoon.

The NRCS provides additional information on waste storage facilities and cover at
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 313 and 367

and on anaerobic lagoons at
http://efotg.nrcs.usda.gov/references/public/IL/IL-365_2004_09.pdf
http://efotg.nrcs.usda.gov/references/public/IL/IL-366_2004_09.pdf

4.8.1 Effectiveness

Though little change in total phosphorus or organic content has been reported, reductions in fecal coliform as a result of manure storage have been documented in two studies:

- 97 percent reduction in fecal coliform concentrations in runoff when manure is stored for at least 30 days prior to land application (Meals and Braun, 2006).
- 90 percent reduction in fecal coliform loading with the use of waste storage structures, ponds, and lagoons (USEPA, 2003).

4.8.2 Costs

Depending on whether or not the production facility is pasture-based or confined, manure is typically deposited in feedlots, around watering facilities, and within confined spaces such as housing units and milking parlors. Except for feedlots serving a low density of animals, each location will require the collection and transport of manure to a storage structure, holding pond, storage pit, or lagoon prior to final disposal.

Manure collected from open lots and watering areas is typically collected by a tractor equipped with a scraper. This manure is in solid form and is typically stored on a concrete pad surrounded by three walls that allow for stacking of contents. Depending on the climate, a roof may be required to protect the manure from frequent rainfall. Clean water from rooftops or up-grade areas should be diverted around waste stockpiles and heavy use areas with berms, grassed channels, or other means of conveyance (USEPA, 2003). Waste storage lagoons, pits, and above ground tanks are good options for large facilities. Methane gas recovered from anaerobic treatment processes can be used to generate electricity.

The NRCS (2003) has developed cost estimates for the various tasks and facilities typically used to transport, store, and dispose of manure. Table 4-12 summarizes the information contained in the NRCS report and lists the capital and operating/maintenance costs reported per head of animal. Annual maintenance costs were assumed 3 percent of capital costs except for gutter downspouts (assumed 10 percent to account for animals trampling the downspouts) and collection and transfer (assumed 15 percent to account for costs associated with additional fuel and labor). The costs presented as a range were given for various sizes of operations. The lower values reflect the costs per head for the larger operations which are able to spread out costs over more animals.

The full NRCS document can be viewed at
http://www.nrcs.usda.gov/Technical/land/pubs/cnmp1.html

The useful life for practices requiring construction is assumed to be 20 years. The total annualized costs were calculated by dividing the capital costs by 20 and adding the annual operation and maintenance costs. Prices are converted to year 2004 dollars.

Table 4-12. Costs Calculation for Manure Handling, Storage, and Treatment per Head.

Item	Application	Capital Cost per Head	Annual Operation and Maintenance Cost per Head	Total Annualized Cost per Head
Collection and Transfer of Solid Manure, Liquid/Slurry Manure, and Contaminated Runoff				
Collection and transfer of manure solids (assuming a tractor must be purchased)	All operations with outside access and solid collection systems for layer houses	$130.50 - dairy cattle $92.50 - beef cattle $0 - layer[1] $37.00 - swine	$19.50 - dairy cattle $13.75 - beef cattle $0.04 - layer $5.50 - swine	$26.00 - dairy cattle $18.25 - beef cattle $0.04 - layer $7.25 - swine
Collection and transfer of liquid/slurry manure	Dairy, swine, and layer operations using a flush system	$160 to $200 - dairy cattle $.50 - layer $5.75 to $4.50 - swine	$12.25 - dairy cattle $0.03 - layer $0.25 - swine	$20.25 to 22.25 - dairy cattle $0.05 - layer $0.50 - swine
Collection and transfer of contaminated runoff using a berm with pipe outlet	Fattened cattle and confined heifers	$4 to $9 - cattle	$0.12 to 0.25 - cattle	$0.25 to $0.75 - cattle
Feedlot Upgrades for Cattle Operations Using Concentrated Feeding Areas				
Grading and installation of a concrete pad	Cattle on feed (fattened cattle and confined heifers)	$35 - cattle	$1 - cattle	$2.75 - cattle
Clean Water Diversions				
Roof runoff management: gutters and downspouts	Dairy and swine operations that allow outside access	$16 - dairy cattle $2.25 - swine	$1.60 - dairy cattle $0.25 - swine	$2.50 - dairy cattle $0.50 - swine
Earthen berm with underground pipe outlet	Fattened cattle and dairy operations	$25.25 to $34.50 - cattle	$0.75 to $1.00 - cattle	$2 to $2.75 - cattle
Earthen berm with surface outlet	Swine operations that allow outside access	$1 - swine	$0.03 - swine	$0.08 - swine
Grassed waterway	Fattened cattle and confined heifer operations: scrape and stack system	$0.50 to $1.50 - cattle	$0.02 to $0.04 - cattle	$0.05 to $0.12 - cattle

[1] Costs presented by NRCS (2003) as operating and maintenance only.

Table 4-12. Cost Calculations for Manure Handling, Storage, and Treatment Per Head (continued).

Item	Application	Capital Cost per Head	Annual Operation and Maintenance Cost per Head	Total Annualized Cost per Head
Storage				
Liquid storage (contaminated runoff and wastewater)	Swine, dairy, and layer operations using flush systems (costs assume manure primarily managed as liquid)	$245 to $267 - dairy cattle $2 - layer $78.50 to $80 - swine	$7.25 - dairy cattle $0.06 - layer $2.50 - swine	$19.50 to $20.50 - dairy cattle $0.16 - layer $6.50 - swine
Slurry storage	Swine and dairy operations storing manure in pits beneath slatted floors (costs assume manure primarily managed as slurry)	$104 to $127 - dairy cattle $15.50 to $19.50 - swine	$3.25 to $3.75 - dairy cattle $0.50 - swine	$8.25 to $10.25 - dairy cattle $1.25 to $1.50 - swine
Runoff storage ponds (contaminated runoff)	All operations with outside access	$125.50 - dairy cattle $140 - beef cattle $23 - swine	$3.75 - dairy cattle $4.25 - beef cattle $0.75 - swine	$10 - dairy cattle $11.25 - beef cattle $2 - swine
Solid storage	All animal operations managing solid wastes (costs assume 100% of manure handled as solid)	$196 - dairy cattle $129 - beef cattle $1 - layer $14.25 - swine	$5.75 - dairy cattle $3.75 - beef cattle $0.03 - layer $0.50 - swine	$15.50 - dairy cattle $10.25 - beef cattle $0.25 - layer $1.25 - swine

Table 4-12. Cost Calculations for Manure Handling, Storage, and Treatment Per Head (continued).

Item	Application	Capital Cost per Head	Annual Operation and Maintenance Cost per Head	Total Annualized Cost per Head
Final Disposal				
Pumping and land application of liquid/slurry	Operations handling manure primarily as liquid or slurry.	Land application costs are listed as capital plus operating for final disposal and are listed as dollars per acre for the application system. The required number of acres per head was calculated for each animal type based on the phosphorus content of manure at the time of application. Pumping costs were added to the land application costs as described in the document.		\$19.50 - dairy cattle \$0.25 - layer \$2.75 - swine
Pumping and land application of contaminated runoff	Operations with outside feedlots and manure handled primarily as solid	Pumping costs and land application costs based on information in NRCS, 2003. Assuming a typical phosphorus concentration in contaminated runoff of 80 mg/L to determine acres of land required for agronomic application (Kizil and Lindley, 2000). Costs for beef cattle listed as range representing variations in number of animals and manure handling systems (NRCS, 2003). Only one type and size of dairy and swine operation were included in the NRCS document.		\$4 - dairy cattle \$3.75 - beef cattle \$4.50 - swine
Land application of solid manure	Operations handling manure primarily as solid	Land application costs are listed as capital plus operating for final disposal and are given as dollars per acre for the application system. The required number of acres per head was calculated for each animal type based on the phosphorus content of manure at the time of application. No pumping costs are required for solid manure.		\$11 - dairy cattle \$0.25 - layer \$1.50 - swine \$10.25 - fattened cattle

4.9 Feeding Strategies

Use of dietary supplements, genetically enhanced feed and specialized diets have been found to reduce ammonia emissions from manure. Excess protein that is not utilized by animals is excreted in manure. Since protein contains nitrogen, controlling the amount of protein fed to animals reduces ammonia gas emission. Zeolites and charcoal have been added to swine feeds in an attempt to bind ammonia, and thereby reduce emissions. Studies done on diet manipulation have shown reducing dietary crude protein to be effective in controlling ammonia emission (USEPA, 2001).

4.9.1 Effectiveness

Diets that are effective in reducing the protein content in manure are successful in inhibiting ammonia gas emission. Ammonia gas reductions achieved through dietary manipulation are presented below:

- 28 percent reduction in ammonia gas from dairy cows that were fed a die containing 9.5 percent crude protein (Lames et al.; 2000).
- 56 percent reduction in ammonia gas from swine manure by supplementing feed with yucca extract.

4.9.2 Costs

Dietary supplements have the potential of reducing feed costs. Reducing intake to dietary requirements established by the USDA may save dairy farmers 25 dollars per year per cow (USEPA, 2002a).

4.10 Composting

Composting is the biological decomposition and stabilization of organic material. The process produces heat that, in turn, produces a final product that is stable, free of pathogens and viable plant seeds, and can be beneficially applied to the land. Like manure storage areas, composting facilities should be located on dry, flat, elevated land at least 100 feet from streams. The landowner should coordinate with local NRCS staff to determine the appropriate design for a composting facility based on the amount of manure generated. Extension agents can also help landowners achieve the ideal nutrient ratios, oxygen levels, and moisture conditions for composting on their site.

Composting can be accomplished by simply constructing a heap of the material, forming composting windrows, or by constructing one or more bins to hold the material. Heaps should be 3 feet wide and 5 feet high with the length depending on the amount of manure being composted. Compost does not have to be turned, but turning will facilitate the composting process (University of Missouri, 1993; PSU, 2005). Machinery required for composting includes a tractor, manure spreader, and front-end loader (Davis and Swinker, 2004). Figure 4-7 shows a poultry litter composting facility.

(Photo courtesy of USDA NRCS.)

Figure 4-7. Poultry Litter Composting Facility.

The NRCS provides additional information on composting facilities at
http://efotg.nrcs.usda.gov/references/public/IL/IL-317rev9-04.pdf
and
ftp://ftp.wcc.nrcs.usda.gov/downloads/wastemgmt/neh637c2.pdf

4.10.1 Effectiveness

Composting stabilizes the organic content of manure and reduces the volume that needs to be disposed of. In addition, the following reductions in loading are reported:

- 99 percent reduction of fecal coliform concentrations as a result of the heat produced during the composting process (Larney et. al., 2003).
- 56 percent reduction in runoff volumes and 68 percent reduction in sediment (and likely manganese, copper, silver, and TDS) as a result of improved soil infiltration following application of composted manure (HRWCI, 2005).

4.10.2 Costs

The costs for developing a composting system include site development costs (storage sheds, concrete pads, runoff diversions, etc.), purchasing windrow turners if that system is chosen, and labor and fuel required to form and turn the piles. Cost estimates for composting systems have not been well documented and show a wide variation even for the same type of system. The NRCS is in the process of developing cost estimates for composting and other alternative manure applications in Part II of the document discussed in Section 4.8.2. Once published, these estimates should provide a good comparison with the costs summarized for the Midwest region in Table 4-12. For now, costs are presented in Table 4-13 based on studies conducted in Wisconsin, Canada, and Indiana.

Researchers in Wisconsin estimated the costs of a windrow composting system using four combinations of machinery and labor (CIAS, 1996). These costs included collection and transfer of excreted material, formation of the windrow pile, turning the pile, and reloading the compost for final disposal. The Wisconsin study was based on a small dairy operation (60 head). Costs for beef cattle, swine, and layer hens were calculated based on animal units and handling weights of solid manure (NRCS, 2003). Equipment life is assumed 20 years. The costs presented in the Wisconsin study are much higher than those presented in Table 4-13 for collection, transfer, and storage of solid manure. However, the Wisconsin study presented a cost comparison of the windrow system to stacking on a remote concrete slab, and these estimates were approximately four and half times higher than the values summarized by NRCS. It is likely that the single data set used for the Wisconsin study is not representative of typical costs.

Two studies have been conducted in Canada regarding the costs of composting. The University of Alberta summarized the per ton costs of windrow composting with a front end load compared to a windrow turner (University of Alberta, 2000). The Alberta Government presented a per ton estimate for a windrow system with turner: this estimate is quite different than the University of Alberta study. These per ton costs were converted to costs per head of dairy cattle, beef cattle, swine, and layer hens based on the manure generation and handling weights presented by NRCS (2003).

In 2001, the USEPA released a draft report titled “Alternative Technologies/Uses for Manure.” This report summarizes results from a Purdue University research farm operating a 400-cow dairy operation. This farm also utilizes a windrow system with turner.

Table 4-13 summarizes the cost estimates presented in each of the studies for the various composting systems. None of these estimates include the final costs of land application, which should be similar to those listed for disposal of solid manure in Table 4-12.

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Table 4-13. Cost Calculations for Manure Composting.

Equipment Used	Capital Cost per Head	Annual Operation and Maintenance Cost per Head	Total Annualized Cost per Head
2004 Cost Estimated from CIAS, 1996 – Wisconsin Study			
Windrow composting with front-end loader	$324.25 - dairy cattle $213.50 - beef cattle $1.75 - layer $23.75 - swine	$179.75 - dairy cattle $118.50 - beef cattle $1 - layer $13.25 - swine	$196 - dairy cattle $129.25 - beef cattle $1 - layer $14.25 - swine
Windrow composting with bulldozer	$266 - dairy cattle $175.25 - beef cattle $1.50 - layer $19.50 - swine	$179.75 - dairy cattle $118.50 - beef cattle $1 - layer $13.25 - swine	$193.25 - dairy cattle $127.25 - beef cattle $1 - layer $14.25 - swine
Windrow composting with custom-hire compost turner	$266 - dairy cattle $175.25 - beef cattle $1.50 - layer $19.50 - swine	$215.25 - dairy cattle $141.75 - beef cattle $1.25 - layer $15.75 - swine	$228.75 - dairy cattle $150.50 - beef cattle $1.25 - layer $16.75 - swine
Windrow composting with purchased compost turner	$617 - dairy cattle $406.25 - beef cattle $3.50 - layer $45.25 - swine	$234.25 - dairy cattle $154.25 - beef cattle $1.25 - layer $17.25 - swine	$265.25 - dairy cattle $174.75 - beef cattle $1.50 - layer $19.50 - swine
2004 Costs Estimated from University of Alberta, 2000			
Windrow composting with front-end loader	Study presented annualized costs per ton of manure composted.		$23.75 to $47.50 - dairy cattle $15.75 to $31.25 - beef cattle $0.13 to $0.25 - layer $1.75 to $3.50 - swine
Windrow composting with compost turner	Study presented annualized costs per ton of manure composted.		$71.25 to $142.50 - dairy cattle $47.00 to $94.00 - beef cattle $0.50 to $0.75 - layer $5.25 to $10.50 - swine
2004 Costs Estimated from Alberta Government, 2004			
Windrow composting with compost turner	Study presented annualized costs per ton of manure composted.		$31.50 - dairy cattle $20.75 - beef cattle $0.25 - layer $2.25 - swine
2004 Costs Estimated from USEPA, 2001 Draft			
Windrow composting with compost turner	Study presented annualized costs per dairy cow.		$15.50 - dairy cattle $10.25 - beef cattle $0.09 - layer $1.25 - swine

4.11 Alternative Watering Systems

Landowners often allow animals direct access to streams for their water supply. This can lead to denuded streambanks and riparian vegetation, and may result in manure that is deposited in or near the stream. Alternative watering systems allow animals to access drinking water away from the stream, thereby minimizing the impacts to the stream and riparian corridor.

Landowners should work with an agricultural extension agent to properly design and locate watering facilities. One option is to collect rainwater from building roofs (with gutters feeding into cisterns) and use this water for the animal watering system to reduce runoff and conserve water use (Tetra Tech, 2006). Whether or not animals are allowed access to streams, the landowner should provide an alternative shady location and water source so that animals are encouraged to stay away from riparian areas.

Figure 4-8 shows a centralized watering tank allowing access from rotated grazing plots and a barn area.

(Photo courtesy of USDA NRCS.)

Figure 4-8. Centralized Watering Tank.

The NRCS provides additional information on these alternative watering components:
Spring development:
http://efotg.nrcs.usda.gov/references/public/IL/IL-574.pdf,
Well development:
http://efotg.nrcs.usda.gov/references/public/IL/IL-642.pdf,
Pipeline:
http://efotg.nrcs.usda.gov/references/public/IL/516.pdf,
Watering facilities (trough, barrel, etc.):
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 614

4.11.1 Effectiveness

The USEPA (2003) reports that the following pollutant load reductions were achieved by supplying cattle with alternative watering locations and excluding cattle from the stream channel by structural or vegetative barrier:

- 29 to 46 percent reductions in fecal coliform loading.

Some researchers have studied the impacts of providing alternative watering sites without structural exclusions and found that cattle spend 90 percent less time in the stream when alternative drinking water is furnished (USEPA, 2003). Prohibiting access to the stream channels will also prevent streambank trampling, decrease bank erosion, protect bank vegetation, and reduce the loading of organic material to the streams. As a result, manganese, copper, silver and TDS loads associated with bank erosion will decrease.

4.11.2 Costs

Alternative drinking water can be supplied by installing a well in the pasture area, pumping water from a nearby stream to a storage tank, developing springs away from the stream corridor, or piping water from an existing water supply. For pasture areas without access to an existing water supply, the most reliable alternative is installation of a well, which ensures continuous flow and water quality for the cattle (NRCS, 2003). Assuming a well depth of 250 ft and a cost of installation of $22.50 per ft, the cost to install a well is approximately $5,625 per well. The well pump would be sized to deliver adequate water supply for the existing herd size. For a herd of 150 cattle, the price per head for installation was estimated at $37.50 per head of cattle.

After installation of the well or extension of the existing water supply, a water storage device is required to provide the cattle access to the water. Storage devices include troughs or tanks. NRCS (2003) lists the costs of storage devices at $23 per head.

Annual operating costs to run the well pump range from $9 to $22 per year for electricity (USEPA, 2003; Marsh, 2001), or up to $0.15 per head. Table 4-14 lists the capital, maintenance, and annualized costs for a well, pump, and storage system assuming a system life of 20 years.

Table 4-14. Cost Calculations for Alternative Watering Facilities.

Item	Capital Cost per Head	Annual Operation and Maintenance Cost per Head	Total Annualized Cost per Head
Installation of well	$37.50	$0	$2
Storage container	$23	$0	$1
Electricity for well pump	$0	$0.15	$0.15
Total system costs	**$60.50**	**$0.15**	**$3.15**

4.12 Cattle Exclusion from Streams

Cattle manure can be a substantial source of fecal coliform loading to streams, particularly where direct access is not restricted and/or where cattle feeding structures are located adjacent to riparian areas. Direct deposition of feces into streams may be a primary mechanism of pollutant loading during baseflow periods. During storm events, overbank and overland flow may entrain manure accumulated in riparian areas resulting in pulsed loads of fecal coliform bacteria into streams. In addition, cattle with unrestrained stream access typically cause severe streambank erosion. The impacts of cattle on stream ecosystems are shown in Figure 4-9 and Figure 4-10.

Figure 4-9. Typical Stream Bank Erosion in Pastures with Cattle Access to Stream.

Figure 4-10. Cattle-Induced Streambank Mass Wasting and Deposition of Manure into Stream.

An example of proper exclusion and the positive impacts it has on the stream channel are shown in Figure 4-11.

(Photo courtesy of USDA NRCS.)

Figure 4-11. Stream Protected from Sheep by Fencing.

The NRCS provides additional information on fencing at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 382

Allowing limited or no animal access to streams will provide the greatest water quality protection. On properties where cattle need to cross streams to have access to pasture, stream crossings should be built so that cattle can travel across streams without degrading streambanks and contaminating streams with manure. Figure 4-12 shows an example of a reinforced cattle access point to minimize time spent in the stream and mass wasting of streambanks.

(Photo courtesy of USDA NRCS.)

Figure 4-12. Restricted Cattle Access Point with Reinforced Banks.

The NRCS provides additional information on use exclusion and controlled access at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 472

4.12.1 Effectiveness

Fencing cattle from streams and riparian areas using vegetative or fencing materials will reduce streambank trampling and direct deposition of fecal material in the streams. As a result, manganese, silver, copper and TDS (associated with eroded sediment) loads will decrease. The USEPA (2003) reports the following reductions in fecal coliform loading as a result of cattle exclusion practices:

- 29 to 46 percent reductions in fecal coliform loading.

4.12.2 Costs

The costs of excluding cattle from streams depends more on the length of channel that needs to be protected than the number of animals on site. Fencing may also be used in a grazing land protection operation to control cattle access to individual plots. The system life of wire fences is reported as 20 years; the high tensile fence materials have a reported system life of 25 years (Iowa State University, 2005). NRCS reports that the average operation needs approximately 35 ft of additional fencing per head to protect grazing lands and streams. Table 4-15 presents the capital, maintenance, and annualized costs for four fencing materials based on the NRCS assumptions.

Table 4-15. Installation and Maintenance Costs of Fencing Material.

Material	Capital Cost per Head	Annual Operation and Maintenance Cost per Head	Total Annualized Cost per Head
Woven Wire	$43.50	$3.50	$5.75
Barbed Wire	$33.50	$2.75	$4.50
High Tensile (non-electric) 8-strand	$30.75	$1.75	$3.00
High Tensile (electric) 5-strand	$23.00	$1.50	$2.50

4.13 Grazing Land Management

While erosion rates from pasture areas are generally lower than those from row-crop areas, a poorly managed pasture can approach or exceed a well-managed row-crop area in terms of erosion rates. Grazing land protection is intended to maximize ground cover on pasture, reduce soil compaction resulting from overuse, reduce runoff concentrations of nutrients and fecal coliform, and protect streambanks and riparian areas from erosion and fecal deposition. Figure 4-13 shows an example of a pasture managed for land protection. Cows graze the left lot while the right lot is allowed a resting period to revegetate.

(Photo courtesy of USDA NRCS.)

Figure 4-13. Example of a Well Managed Grazing System.

The NRCS provides additional information on prescribed grazing at:
http://efotg.nrcs.usda.gov/treemenuFS.aspx
in Section IV B. Conservation Practices Number 528A

And on grazing practices in general at:
http://www.glti.nrcs.usda.gov/technical/publications/nrph.html

4.13.1 Effectiveness

Maintaining sufficient ground cover on pasture lands requires a proper density of grazing animals and/or a rotational feeding pattern among grazing plots. Increased ground cover will also reduce transport of sediment-bound manganese, silver, copper and TDS.

The following reductions in loading are reported in the literature:

- 40 percent reduction in fecal coliform loading as a result of grazing land protection measures (USEPA, 2003)
- 90 percent reduction in fecal coliform loading with rotational grazing (Government of Alberta, 2007).
- 60 percent reduction in total nitrogen loading (USEPA, 2003)

4.13.2 Costs

The costs associated with grazing land protection include acquiring additional land if current animal densities are too high (or reducing the number of animals maintained), fencing and seeding costs, and developing alternative water sources. Establishment of vegetation for pasture areas costs from $39/ac to $69/ac based on data presented in the EPA nonpoint source guidance for agriculture (USEPA, 2003). Annual costs for maintaining vegetative cover will likely range from $6/ac to $11/ac (USEPA, 2003). If cattle are not allowed to graze plots to the point of requiring revegetation, the cost of grazing land protection may be covered by the fencing and alternative watering strategies discussed above.

4.14 Streambank and Shoreline Erosion BMPs

Reducing erosion of streambanks will reduce manganese, silver, copper and TDS loadings. The filter strips and riparian area BMPs discussed in Sections 4.5 and 4.7 and the agricultural BMPs that reduce the quantity and volume of runoff or prevent cattle access will all provide some level of streambank erosion protection.

In addition, the streambanks in the watershed should be inspected for signs of erosion. Banks showing moderate to high erosion rates (indicated by poorly vegetated reaches, exposed tree roots, steep banks, etc.) can be stabilized by engineering controls, vegetative stabilization, and restoration of riparian areas. Peak flows and velocities from runoff areas can be mitigated by infiltration in grassed waterways and passage of runoff through filter strips.

4.14.1 Effectiveness

Because the extent of streambank erosion has not yet been quantified, the effectiveness of erosion control BMPs is difficult to estimate. The benefits of BMPs that offer stream bank protection and runoff control are therefore underestimated in this report.

4.14.2 Costs

Costs associated with the BMPs that offer secondary benefits to streambank erosion are discussed separately for each BMP, as previously described.

4.15 BMP Summary

Table 4-16 summarizes the BMPs that are applicable to the sources in the Shoal Creek watershed.

Table 4-16. Summary of BMPs to reduce fecal coliform, manganese, silver, copper, ammonia, and TDS loadings in the Shoal Creek watershed.

BMP	Fecal Coliform Reduction (percent)	Manganese Reduction (percent)	Silver Reduction (percent)	Copper Reduction (percent)	Ammonia, Total Reduction (percent)		TDS Reduction Percent	Annualized Costs	Additional Benefits for Stream Health
					NH_3	NH_4			
Conservation Tillage	na	50 to 90	50 to 90	50 to 90	na	unknown	50 to 90	$1.25 to $2.25 per ac	Reduces runoff losses by 69 percent, which may reduce rates of streambank erosion.
Cover Crops	na	90	90	90	na	unknown	90	$19.25 per acre	Reduces runoff losses by 50 percent, which may reduce rates of streambank erosion.
Filter Strips	55 to 87	65	65	65	na	unknown	65	$4 to $6 per head of cattle; $25 per acre	Slows rates of runoff and may reduce volume via infiltration. May reduce rates of streambank erosion.
Grassed Waterways	5	68	68	68	na	unknown	68	$0.05 to $0.12 per head of cattle; $2 to $6 per acre	Slows rates of runoff and may reduce volume via infiltration. May reduce rates of streambank erosion.
Riparian Buffers (30 ft wide)	34 to 74	70 to 90	70 to 90	70 to 90	na	unknown	70 to 90	$0.03 per ft of channel; $20 per acre	Slows runoff and may reduce quantity via infiltration. Protects stream channel from erosion and canopy disturbance.
Riparian Buffers (60 to 90 ft wide)	unknown	unknown	unknown	unknown	na	unknown	unknown	$0.05 to $0.07 per ft of channel; $40 to $60 per acre	Slows runoff and may reduce quantity via infiltration. Protects stream channel from erosion and canopy disturbance.

Table 4-16. Summary of BMPs to reduce fecal coliform, manganese, silver, copper, ammonia, and TDS loadings in the Shoal Creek watershed.

BMP	Fecal Coliform Reduction (percent)	Manganese Reduction (percent)	Silver Reduction (percent)	Copper Reduction (percent)	Ammonia, Total Reduction (percent)		TDS Reduction Percent	Annualized Costs	Additional Benefits for Stream Health
					NH_3	NH_4			
Riparian Buffers (200 ft wide)	87	unknown	unknown	unknown	na	unknown	unknown	$0.16 per ft of channel; $130 per acre	Slows runoff and may reduce quantity via infiltration. Protects stream channel from erosion and canopy disturbance.
Constructed Wetlands	92	53 to 81	unknown	53 to 81	unknown	95	53 to 81	$2.50 per head of dairy cattle $4.50 per head of swine	Slows runoff and may reduce quantity via infiltration, evaporation, and transpiration.
Proper Manure Handling, Collection, and Disposal	90 to 97	na	na	na	na	unknown	unknown	Varies by operation and waste handling system	Reduces loads of nutrients and biodegradable organic material entering waterways which may improve dissolved oxygen concentrations.
Feeding Strategies	na	na	na	na	28 to 56	unknown	unknown	Variable	Feeding strategies that reduce nutrient content may decrease eutrophication in streams
Manure Composting	99	na	na	na	na	unknown	na	$1.25 to $10.50 per head of swine; $15.50 to $142.50 per head of dairy cattle; $10.25 to $94 per head of beef or other cattle	Stabilized manure that reaches waterbodies will degrade more slowly and not consume oxygen as quickly as conventional manure.

Table 4-16. Summary of BMPs to reduce fecal coliform, manganese, silver, copper, ammonia, and TDS loadings in the Shoal Creek watershed.

BMP	Fecal Coliform Reduction (percent)	Manganese Reduction (percent)	Silver Reduction (percent)	Copper Reduction (percent)	Ammonia, Total Reduction (percent)		TDS Reduction Percent	Annualized Costs	Additional Benefits for Stream Health
					NH_3	NH_4			
Application of Composted Manure	na	68	68	68	na	unknown	68	$1.25 to $10.50 per head of swine; $15.50 to $142.50 per head of dairy cattle; $10.25 to $94 per head of beef or other cattle	Application of composted manure improves soil infiltration and may reduce runoff volumes by 56 percent, potentially reducing rates of streambank erosion.
Alternative Watering Systems with Cattle Exclusion from Streams	29 to 46	unknown	unknown	unknown	na	unknown	unknown	$5.50 to $9 per head of beef or other pastured cattle	Prevents streambank trampling and therefore decreases loads of manganese, silver, copper and TDS to the stream. Reduces direct deposition of manure into stream channel, which reduces ammonia and fecal coliform.
Grazing Land Management	40 to 90	unknown	unknown	unknown	na	unknown	unknown	Variable – costs may be covered by fencing and alternative watering locations	Reduces soil erosion and associated metals

5.0 BMP PRIORITIZATION

This section discusses the pollutant sources in each of the impaired waterbodies, loads from those sources, and the various BMPs that could be used to reduce pollutant loads.

5.1 Shoal Creek

Fecal coliform and manganese concentrations in Shoal Creek exceed Illinois' water quality standards. The following sections discuss the various pollutant sources and BMPs to achieve the necessary load reductions.

5.1.1 Fecal Coliforms

The Shoal Creek TMDL states that a 10 to 94 percent reduction in fecal coliform loading is needed to achieve water quality standards (depending on the flow condition). Wastewater treatment plants, onsite wastewater systems, and animal operations are likely the major anthropogenic sources of fecal coliforms to Shoal Creek.

Multiple BMPs are likely needed to achieve the fecal coliform water quality standard. Proper manure handling, collection, and disposal practices should be combined with composting manure, grazing land management, and/or alternative watering systems at animal operations located throughout the watershed. The following wastewater management practices are also suggested to meet the water quality standards in Shoal Creek: repairing or replacing failing onsite wastewater systems and disinfection of wastewater treatment plant effluent.

5.1.2 Manganese

The Shoal Creek TMDL states that a 0 to 69 percent reduction in manganese loading is needed to achieve water quality standards (depending on the flow condition). Natural background loading and streambank erosion likely contribute some of this loading, but crop production, which tends to increase rates of erosion over large land areas, is likely the main contributor.

BMPs to reduce sediment loading (and associated manganese concentrations) are recommended for Shoal Creek. These potentially include riparian buffers, conservation tillage, cover crops, alternative watering sources, and grazing land management.

5.2 Cattle Creek

Copper, ammonia, and TDS concentrations in Cattle Creek exceed Illinois' water quality standards. The following sections discuss the various pollutant sources and BMPs to achieve the necessary load reductions.

5.2.1 Copper

The copper TMDL for Cattle Creek stated that a 0 to 99 percent reduction in copper loading is needed to achieve water quality standards (depending on the flow condition). There are no point sources of copper in the watershed, and the potential nonpoint sources are poorly defined. It is suspected that copper containing fertilizers and/or sediment-bound copper are the anthropogenic sources in Cattle Creek. At this time, BMPs to reduce sediment erosion and runoff are recommended to reduce copper loads to Cattle Creek. These potentially include riparian buffers, conservation tillage, cover crops, alternative watering systems, and grazing land management.

5.2.2 Ammonia

The ammonia TMDL for Cattle Creek stated that a 0 to 66 percent reduction in ammonia loading is needed to achieve water quality standards (depending on the flow condition). There are no point sources of ammonia in the watershed. Animal operations and septic systems are believed to be the two largest sources of anthropogenic ammonia in the watershed. BMPs should be implemented to reduce loads from these two sources. Septic systems should be inspected and failing systems upgraded. Other potential BMPs include manure management, grazing land management, alternative watering systems, and riparian buffers.

5.2.3 Total Dissolved Solids

The total dissolved solids (TDS) TMDL for Cattle Creek stated that a 0 to 39 percent reduction in TDS loading is needed to achieve water quality standards (depending on the flow condition). There are no point sources of TDS in the watershed. Potential nonpoint sources of TDS include feed lots, fertilizers, and crop production. Recommended BMPs include conservation tillage, cover crops, and riparian buffers.

5.3 Chicken Creek

The TMDL for Chicken Creek stated that a 0 to 49 percent reduction in silver loading is needed to achieve water quality standards (depending on the flow condition). There are no point sources of silver in the watershed, and the potential nonpoint sources are poorly defined. It is suspected that sediment-bound silver is the major anthropogenic source in Chicken Creek. At this time, BMPs to reduce sediment erosion and runoff are recommended to reduce silver loads. These potentially include riparian buffers, conservation tillage, cover crops, alternative watering systems, and grazing land management.

6.0 MEASURING AND DOCUMENTING PROGRESS

Multiple agricultural BMPs will likely be needed to address the water quality impairments found in the Shoal Creek watershed. Water quality monitoring should be implemented to monitor BMP success, and to determine if additional BMPs are needed to achieve water quality standards. It may also be necessary to begin funding efforts for localized BMPs such as riparian buffer restoration.

7.0 REASONABLE ASSURANCE

USEPA requires reasonable assurance that TMDLs will be achieved and water quality standards will be met. For the Shoal Creek watershed, the primary strategy for attaining water quality standards is to implement agricultural BMPs and wastewater treatment plant effluent disinfection. However, landowner participation may be limited due to resistance to change and upfront costs. Educational efforts and cost sharing programs will likely increase participation to levels needed to protect water quality. The following sections discuss the programs that are available to assist landowners and local entities in implementing BMPs.

7.1 Environmental Quality Incentives Program (EQIP)

Several cost share programs are available to landowners who voluntarily implement resource conservation practices in the Shoal Creek watershed. The most comprehensive is the NRCS Environmental Quality Incentives Program (EQIP) which offers cost sharing and incentives to farmers who utilize approved conservation practices to reduce pollutant loading from agricultural lands.

- The program will pay $10 for one year for each acre of farmland that is managed under a nutrient management plan (up to 400 acres per farm).
- Use of vegetated filter strips will earn the farmer $100/ac/yr for three years (up to 50 acres per farmer).
- The program will also pay 60 percent of the cost to construct grassed waterways, riparian buffers, and windbreaks.
- Use of residue management will earn the farmer $15/ac for three years (up to 400 acres per farm).
- Installation of drainage control structures on tile outlets will earn the farmer $5/ac/yr for three years for the effected drainage area as well as 60 percent of the cost of each structure.
- The program will pay 75 percent of the construction cost for a composting facility.
- Sixty percent of the fencing, controlled access points, spring and well development, pipeline, and watering facility costs are covered by the program.
- Waste storage facilities and covers for those facilities have a 50 percent cost share for construction.
- Prescribed grazing practices will earn the farmer $10/ac/yr for three years (up to 200 acres per farmer).

In order to participate in the EQIP cost share program, all BMPs must be constructed according to the specifications listed for each conservation practice.

The specifications and program information can be found online at:
http://www.il.nrcs.usda.gov/programs/eqip/cspractices.html.

7.2 Conservation Reserve Program (CRP)

The Farm Service Agency of the USDA supports the Conservation Reserve Program (CRP) which rents land that is converted from crop production to grass or forestland for the purposes of reducing erosion and protecting sensitive waters. This program is available to farmers who establish vegetated filter strips or grassed waterways. The program typically provides 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years.

More information about this program is available online at:
http://www.nrcs.usda.gov/programs/crp/

7.3 Conservation 2000

In 1995 the Illinois General Assembly passed the Conservation 2000 bill providing $100 million in funding over a 6-year period for the promotion of conservation efforts. In 1999, legislation was passed to extend the program through 2009. Conservation 2000 currently funds several programs applicable to the Shoal Creek watershed through the Illinois Department of Agriculture.

General information concerning the Conservation 2000 Program can be found online at:
http://www.agr.state.il.us/Environment/conserv/

7.3.1 Conservation Practices Program (CPP)

The Conservation Practices Cost Share Program provides monetary incentives for conservation practices implemented on land eroding at one and one-half times or more the tolerable soil loss rate. Payments of up to 60 percent of initial costs are paid through the local conservation districts. Of the BMPs discussed in this plan, the program will cost share cover crops, filter strips, grassed waterways, no-till systems, and pasture planting. Other sediment control options such as contour farming and installation of stormwater ponds are also covered. Practices funded through this program must be maintained for at least 10 years.

More information concerning the Conservation Practices Program can be found online at:
http://www.agr.state.il.us/Environment/conserv/

7.3.2 Streambank Stabilization Restoration Program

Conservation 2000 also funds a streambank stabilization and restoration program aimed at restoring highly eroding streambanks. Research efforts are also funded to assess the effectiveness of vegetative and bioengineering techniques.

More information about this program is available online at:
http://dnr.state.il.us/orep/c2000/grants/proginfo.asp?id=20

7.3.3 Sustainable Agriculture Grant Program (SARE)

The Sustainable Agricultural Grant Program funds research, education, and outreach efforts for sustainable agricultural practices. Private landowners, organizations, educational, and governmental institutions are all eligible for participation in this program.

More information concerning the Sustainable Agricultural Grant Program can be found online at:
http://www.sare.org/grants/

7.4 Nonpoint Source Management Program (NSMP)

Illinois EPA receives federal funds through Section 319(h) of the Clean Water Act to help implement Illinois' Nonpoint Source (NPS) Pollution Management Program. The purpose of the Program is to work cooperatively with local units of government and other organizations toward the mutual goal of protecting the quality of water in Illinois by controlling NPS pollution. The program emphasizes funding for implementing cost-effective corrective and preventative BMPs on a watershed scale; funding is also available for BMPs on a non-watershed scale and the development of information/education NPS pollution control programs.

The maximum federal funding available is 60 percent, with the remaining 40 percent coming from local match. The program period is two years unless otherwise approved. This is a reimbursement program.

Section 319(h) funds are awarded for the purpose of implementing approved NPS management projects. The funding will be directed toward activities that result in the implementation of appropriate BMPs for the control of NPS pollution or to enhance the public's awareness of NPS pollution. Applications are accepted June 1 through August 1.

More information about this program is available online at:
http://www.epa.state.il.us/water/financial-assistance/non-point.html

7.5 Agricultural Loan Program

The Agricultural Loan Program offered through the Illinois State Treasury office provides low-interest loans to assist farmers who implement soil and water conservation practices. These loans will provide assistance for the construction, equipment, and maintenance costs that are not covered by cost share programs.

More information about this program is available online at:
http://www.state.il.us/TREAS/ProgramsServices.aspx

7.6 Illinois Conservation and Climate Initiative (ICCI)

The Illinois Conservation and Climate Initiative (ICCI) is a joint project of the State of Illinois and the Delta Pollution Prevention and Energy Efficiency (P2/E2) Center that allows farmers and landowners to earn carbon credits when they use conservation practices. These credits are then sold to companies or agencies that are committed to reducing their greenhouse gas emissions. Conservation tillage earns 0.5 metric tons (1.1 US ton) of carbon per acre per year (mt/ac/yr), grass plantings (applicable to filter strips and grassed waterways) earn 0.75 mt/ac/yr, and trees planted at a density of at least 250 stems per acre earn somewhere between 3.5 to 5.4 mt/ac/yr, depending on the species planted and age of the stand.

Carbon credits are currently selling at around $2.50 per mt. Current exchange rates are available online at http://chicagoclimatex.com. Administrative fees of $0.14/mt plus 8 percent are subtracted from the sale price.

Program enrollment occurs through the P2/E2 Center which can be found online at http://p2e2center.org/. The requirements of the program are verified by a third party before credits can be earned.

More information about carbon trading can be found online at:
http://illinoisclimate.org/

7.7 Summary

Tables 7-1 and 7-2 summarize the cost sharing programs available to Illinois landowners.

Table 7-1. Summary of Assistance Programs Available for Farmers in the Shoal Creek Watershed.

Assistance Program	Program Description	Contact Information
NSMP	Provides grant funding for educational programs and implementation of nonpoint source pollution controls.	Illinois Environmental Protection Agency Bureau of Water Watershed Management Section, Nonpoint Source Unit P.O. Box 19276 Springfield, IL 62794-9276 Phone: (217) 782-3362
Agricultural Loan Program	Provides low-interest loans for the construction and implementation of agricultural BMPs. Loans apply to equipment purchase as well.	Office of State Treasurer Agricultural Loan Program 300 West Jefferson Springfield, Illinois 62702 Phone: (217) 782-2072 Fax: (217) 522-1217
NRCS EQIP	Offers cost sharing and rental incentives to farmers statewide who utilize approved conservation practices to reduce pollutant loading from agricultural lands. Applies to nutrient management plans, filter strips, grassed waterways, riparian buffers, and conservation tillage.	Jackson County SWCD 1213 N 14th St Murphysboro, IL 62966-2950 Phone: (618) 684-3471 Fax: (618) 684-3980
FSA CRP	Offsets income losses due to land conversion by rental agreements. Targets highly erodible land or land near sensitive waters. Provides up to 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years for converted land.	
Conservation 2000 CPP	Provides up to 60 percent cost share for several agricultural BMPs: cover crops, filter strips, grassed waterways.	
Conservation 2000 Streambank Stabilization Restoration Program	Provides 75 percent cost share for establishment of riparian corridors along severely eroding stream banks. Also provides technical assistance and educational information for interested parties.	
SARE	Funds educational programs for farmers concerning sustainable agricultural practices.	
Local SWCD	Provides incentives for individual components of nutrient management planning, use of strip tillage, and restoration of riparian buffers.	
ICCI	Allows farmers to earn carbon trading credits for use of conservation tillage, grass, and tree plantings.	

Table 7-2. Assistance Programs Available for Agricultural BMPs.

BMP	Cost Share Programs and Incentives
Education and Outreach	Conservation 2000 Streambank Stabilization Restoration Program SARE NSMP Local SWCD ULWREP
Nutrient Management Plan	EQIP: $10/ac for one year, 400 ac. max. Local SWCD: up to $30/ac for one year ULWREP: contact agency for individual resource allocations
Conservation Tillage	EQIP: $15/ac for three years, 400 ac. max. ICCI: earns 0.5 mt/ac/yr of carbon trading credit ULWREP: contact agency for individual resource allocations
Cover Crops	CPP: cost share of 60 percent ULWREP: contact agency for individual resource allocations
Filter Strips	EQIP: $100/ac for three years, 50 ac. max. CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Grassed Waterways	EQIP: 60 percent of construction costs CPP: 60 percent of construction costs CRP: 50 percent of the upfront cost to establish vegetative cover and $185/ac/yr for up to 15 years ICCI: earns 0.75 mt/ac/yr of carbon trading credit for each acre planted
Land Retirement of Highly Erodible Land or Land Near Sensitive Waters	CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted ULWREP: contact agency for individual resource allocations
Restoration of Riparian Buffers	EQIP: 60 percent of construction of costs CRP: 50 percent of the costs of establishing vegetative cover and cash incentive of $185/ac/yr for 15 years ICCI: earn between 0.75 and 5.4 mt/ac/yr of carbon trading credit depending on species planted ULWREP: contact agency for individual resource allocations

Note: Cumulative cost shares from multiple programs will not exceed 100 percent of the cost of construction.

8.0 IMPLEMENTATION TIMELINE

This implementation plan for the Shoal Creek watershed defines a phased approach for achieving the water quality standards (Figure 8-1). Ideally, implementing control measures on nonpoint sources will be based on voluntary participation which will depend on 1) the effectiveness of the educational programs for farmers, landowners, and owners of onsite wastewater systems, and 2) the level of participation in the programs. In addition, point source dischargers operating under a disinfection exemption are required to comply with the geometric mean fecal coliform water quality standard of 200 cfu/100 mL at the closest point downstream where recreational use occurs in the receiving water or where the water flows into a fecal-impaired segment. Facilities with year-round disinfection exemptions may be required to provide the Agency with updated information to demonstrate compliance with these requirements. Facilities directly discharging into a fecal-impaired segment may have their year-round disinfection exemption revoked through future NPDES permitting actions. This section outlines a schedule for implementing the control measures and determining whether or not they are sufficient to meet the water quality standards.

Phase I of this implementation plan should focus on education of farm owners concerning the benefits of agricultural BMPs on crop yield, soil quality, and water quality as well as cost share programs available in the watershed. It is expected that initial education through public meetings, mass mailings, TV and radio announcements, and newspaper articles could be achieved in less than 6 months. As described in Section 7.0., assistance with educational programs is available through the following agencies: the Illinois Department of Agriculture Conservation 2000 Streambank Stabilization Restoration Program, the Illinois Department of Agriculture Sustainable Agriculture Grant Program (SARE), the Illinois Environmental Protection Agency Nonpoint Source Management Program (NSMP), and the local Soil and Water Conservation Districts. During this phase, the sewage treatment plants may be asked to submit fecal coliform data to IEPA to determine if a disinfection exemption is still appropriate.

Phase II of the implementation schedule will involve voluntary participation of landowners in BMPs such as proper management of manure and fertilizers, grazing land management, and use of filter strips, composting, constructed wetlands, conservation tillage, cattle exclusion from streams, and grassed waterways. The local Natural Resources Conservation Service office will be able to provide technical assistance and cost share information for these BMPs. In addition, initial inspections of all onsite wastewater treatment systems and necessary repairs may begin. Continued monitoring of water quality in the watershed should continue throughout this phase, which will likely take one to three years.

If pollutant concentrations measured during Phase II monitoring remain above the water quality standards, Phase III of the implementation plan will be necessary. The load reduction achieved during Phase II should be estimated by 1) summarizing the areas where BMPs are in use, 2) calculating the reductions in loading from BMPs, and 3) determining the impacts on pollutant concentrations measured before and after Phase II implementation. If BMPs are resulting in decreased concentrations, and additional areas could be incorporated, further efforts to include more stakeholders in the voluntary program will be needed. If the Phase II BMPs are not having the desired impacts on pollutant concentrations, or additional areas of incorporation are not available, supplemental BMPs, such as restoration of riparian areas and stream channels will be needed. In addition, sewage treatment plants may be required to add disinfection processes if fecal coliform standards in receiving and downstream segments are not being met. If required, this phase may last five to ten years.

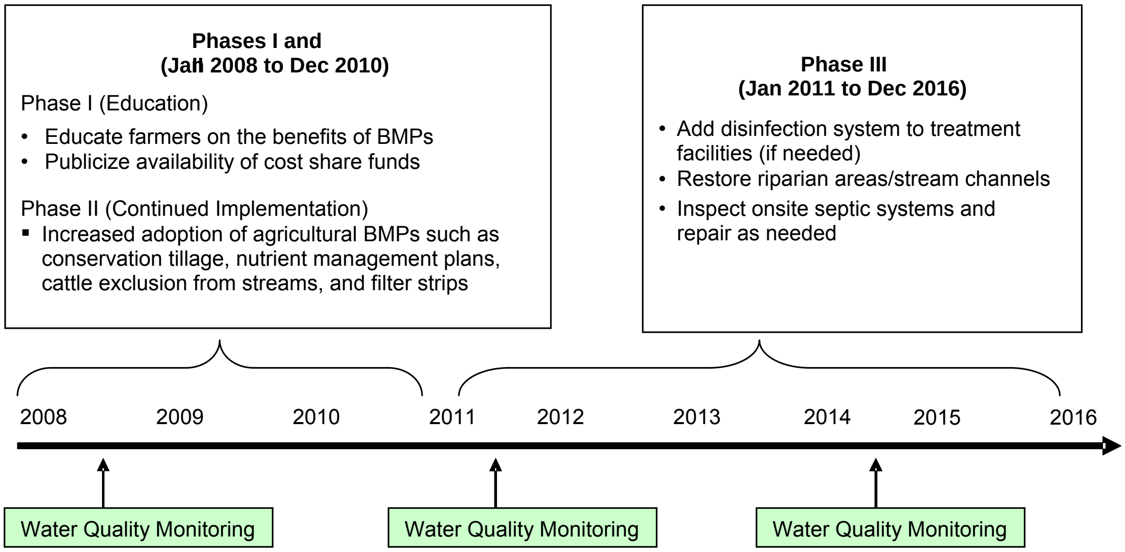

Figure 8-1. Timeline for the Shoal Creek TMDL Implementation Plan.

9.0 CONCLUSIONS

Animal operations, failing onsite sewage treatment systems, and sewage treatment plants that operate under disinfection exemption are considered the most likely sources of fecal coliform in Shoal Creek. Ammonia exceedances in Cattle Creek are likely due to animal operations and septic systems. All of the other water quality exceedances (i.e., manganese in Shoal Creek, silver in Chicken Creek, and total dissolved solids and copper in Cattle Creek) are likely due to sediment erosion and delivery.

The implementation of BMPs in the Shoal Creek watershed should occur in a phased approach. Phase I of this implementation plan should provide education and financial incentives to farmers in the watershed to encourage the use of BMPs. Phase II should occur during and following Phase I and should involve voluntary participation of farmers in the watershed, and submittal of fecal coliform data for the wastewater treatment plants in the watershed. Future water quality monitoring will determine whether or not these BMPs are capable of achieving water quality standards.

Whether or not Phase III will be required depends on the results of future water quality sampling. If the water quality standards are not being met after implementation of the Phase II BMPs, then regional BMPs (such as restoration of stream channels and riparian areas) may be needed. Additional wastewater treatment plant upgrades may also be considered.

As BMPs are implemented, water quality in the watershed should improve accordingly. Measuring the effectiveness of these BMPs will require continued sampling of water quality over the next several years.

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