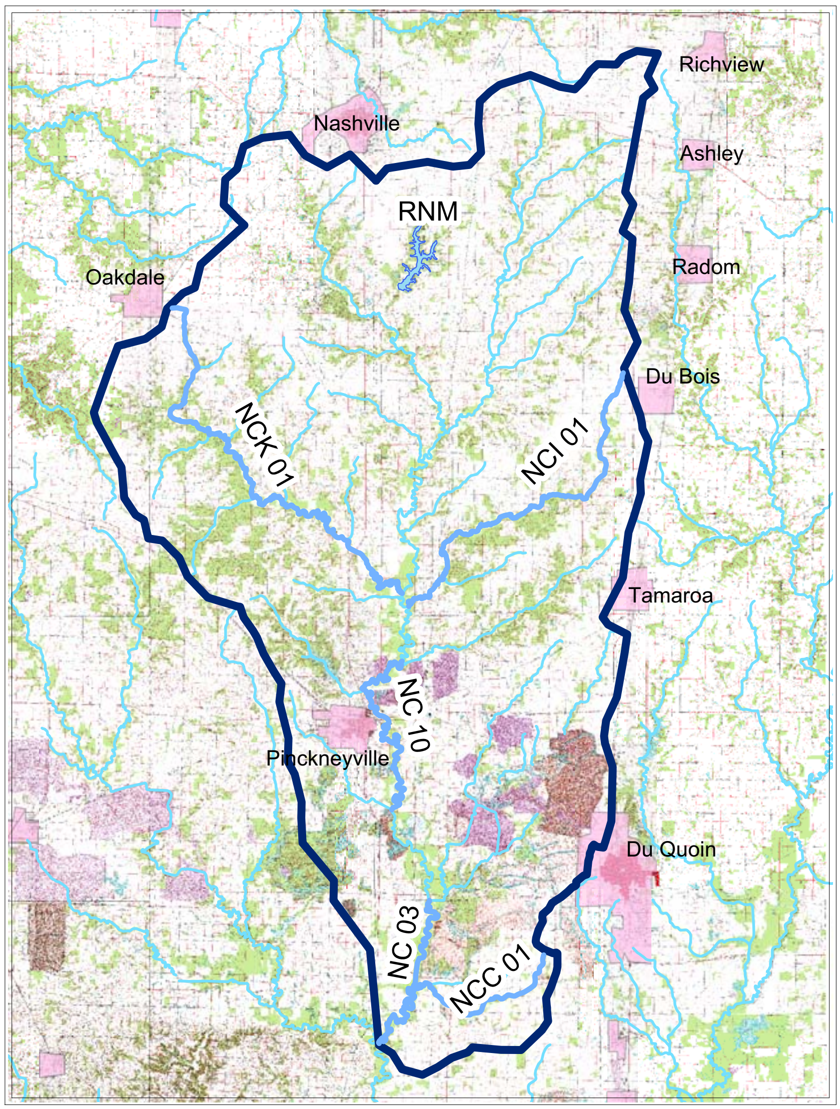
Illinois
Environmental
Protection Agency

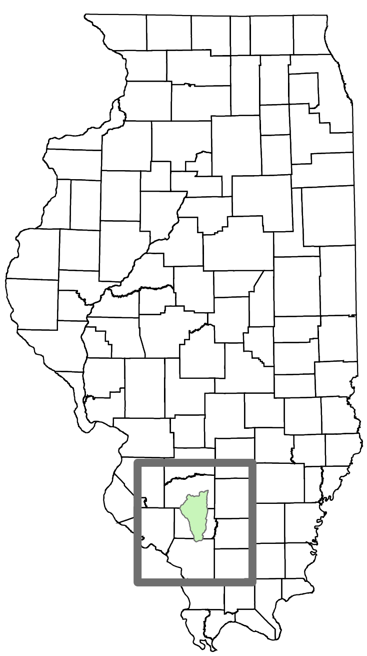
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

June 2004

IEPA/BOW/04-013

BEAUCOUP CREEK TMDL REPORT





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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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REPLY TO THE ATTENTION OF:
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JUN 14 2004

BUREAU OF WATER
BUREAU CHIEF'S OFF

09 JUN 2004

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

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Load (TMDL) submittal for the Beaucoup Creek Watershed, including supporting documentation and follow up information. IEPA's submitted TMDL addresses one lake and five stream segments impaired for General Use. Based on this review, U.S. EPA has determined that Illinois' TMDLs for phosphorus, sulfates, Total Dissolved Solids (TDS), and Manganese meets the requirements of Section 303(d) of the Clean Water Act (CWA) and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves Illinois' 9 TMDLs for the Beaucoup Creek watershed. The statutory and regulatory requirements, and U.S. EPA's review of Illinois' compliance with each requirement, are described in the enclosed decision document.

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

Sincerely yours,

Jo Lynn Traub
Director, Water Division

Enclosure

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Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDLs) for Beaucoup Creek (NC03), Beaucoup Creek (NC10), Little Beaucoup Creek (NCI01), Locust Creek (NCN), Swanwick Creek (NCK01), Walkers Creek (NCC01) and Washington County Lake. In the 1998 Section 303(d) List, these water bodies were listed as impaired for the following parameters:

- Beaucoup Creek (NC03): manganese, sulfates, siltation, total dissolved solids (TDS), other habitat alterations
- Beaucoup Creek (NC10): nitrogen, nitrates, phosphorus, low dissolved oxygen (DO), other habitat alterations, total suspended solids (TSS)
- Little Beaucoup Creek (NCI01): manganese, nitrogen, low DO, other habitat alterations
- Locust Creek (NCN): manganese, DO
- Swanwick Creek (NCK01): manganese, sulfates, nitrogen, siltation, low DO, other habitat alterations
- Walkers Creek (NCC01): manganese, sulfates, TDS, other habitat alterations
- Washington County Lake: Alpha BHC, phosphorus, nitrogen, siltation, low DO, TSS, excessive algal growth, chlorophyll-a

Since then, new data assessed in 2002 for Beaucoup Creek (NC03) showed that it is now impaired for only low DO, sulfates, and TDS. Also, new data assessed in 2002 showed that Locust Creek (NCN) is no longer impaired and is currently supporting all of its designated uses. Therefore, a TMDL will not be developed for Locust Creek (NCN). No new assessments have been made for the other water body segments listed above.

Illinois EPA has since determined that at this time TMDLs will only be developed for those parameters with numeric water quality standards. These numeric water quality standards will serve as the target endpoints for TMDL development and provide a greater degree of clarity and certainty about the TMDL and implementation plans. As a result, this TMDL study will only focus on the parameters listed for the following water body segments:

- Beaucoup Creek (NC03): low DO, sulfates, TDS
- Beaucoup Creek (NC10): low DO
- Little Beaucoup Creek (NCI01): manganese, low DO
- Swanwick Creek (NCK01): manganese, sulfates, low DO

- Walkers Creek (NCC01): Manganese, sulfates, TDS
- Washington County Lake: Phosphorus, low DO

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

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Section 8 Methodology Development for Beaucoup Creek Watershed

Section 9 Total Maximum Daily Load for the Washington County Lake and Beaucoup Creek Watersheds

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Figures

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Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
μg/L	microgram per liter
μmho/cm	microSiemens per centimeter
ALMP	Ambient Lake Monitoring Program
AMLRD	Abandoned Mined Lands Reclamation Division
AWQMN	Ambient Water Quality Monitoring Network
BMP	best management practice
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
$CBOD_5$	5-day carbonaceous biochemical oxygen demand
CCC	Commodity Credit Corporation
cfs	cubic feet per second
CPP	Conservation Practices Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
DEM	Digital Elevation Model
DMR	Discharge Monitoring Reports
DO	dissolved oxygen
EMC	event mean concentration
EQIP	Environmental Quality Incentive Program
FSA	Farm Service Agency
GIS	geographic information system
GWLF	generalized watershed loading function
HUC	Hydrologic Unit Code
IBI	Index of Biotic Integrity
ICLP	Illinois Clean Lakes Program
IDA	Illinois Department of Agriculture
IDNR	Illinois Department of Natural Resources
Illinois EPA	Illinois Environmental Protection Agency
IPCB	Illinois Pollution Control Board
ISWS	Illinois State Water Survey
LA	load allocation
LC	loading capacity

LTA	long-term average
MBI	Macroinvertebrate Biotic Index
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MOS	margin of safety
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NCSU	North Carolina State University
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
PCS	Permit Compliance System
PDEP	Pennsylvania Department of Environmental Protection
ppm	parts per million
PRF	Plugging and Restoration Fund
SOD	sediment oxygen demand
SSRP	Streambank Stabilization and Restoration Practice
STATSGO	State Soil Geographic
STORET	Storage and Retrieval
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
TOC	total organic carbon
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WCLRP	Washington County Lake Resource Plan
WHIP	Wildlife Habitat Incentives Program
WLA	waste load allocation
WMM	watershed management model
WRP	Wetlands Reserve Program
WWTP	wastewater treatment plant

Section 1
Goals and Objectives for Beaucoup Creek Watershed (ILNC05)

1.1 Total Maximum Daily Load (TMDL) Overview

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

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

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 Beaucoup Creek Watershed

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

- Beaucoup Creek (NC10)
- Beaucoup Creek (NC03)
- Little Beaucoup Creek (NCI01)
- Swanwick Creek (NCK01)
- Walkers Creek (NCC01)
- Washington County Lake (RNM)

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

- Loading Capacity (LC) or the maximum amount of pollutant loading a water body can receive without violating water quality standards

- Waste Load Allocation (WLA) or the portion of the TMDL allocated to existing or future point sources

- Load Allocation (LA) or the portion of the TMDL allocated to existing or future nonpoint sources and natural background

- Margin of Safety (MOS) or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality

These elements are combined into the following equation:

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

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

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Beaucoup Creek Watershed Description** provides a description of the impaired water bodies and general watershed characteristics;
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development;
- **Section 4 Beaucoup Creek Watershed Water Quality Standards** defines the water quality standards for the impaired water bodies. Pollution sources will also be discussed in this section;
- **Section 5 Beaucoup Creek Watershed Data Review** provides an overview of available data for the Beaucoup Creek Watershed;
- **Section 6 Methodologies to Complete TMDLs for the Beaucoup Creek Watershed** discusses the models and analyses needed for TMDL development;
- **Section 7 Model Development for Washington County Lake** provides an explanation of model development for Washington County Lake;
- **Section 8 Methodology Development for Beaucoup Creek** describes the analytical procedures used to examine Beaucoup Creek;
- **Section 9 Total Maximum Daily Load for the Beaucoup Creek Watershed** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads;
- **Section 10 Implementation Plan for Beaucoup Creek and Washington County Lake** provides methods to reduce loadings to impaired water bodies;
- **Section 11 References** lists references used in this report.

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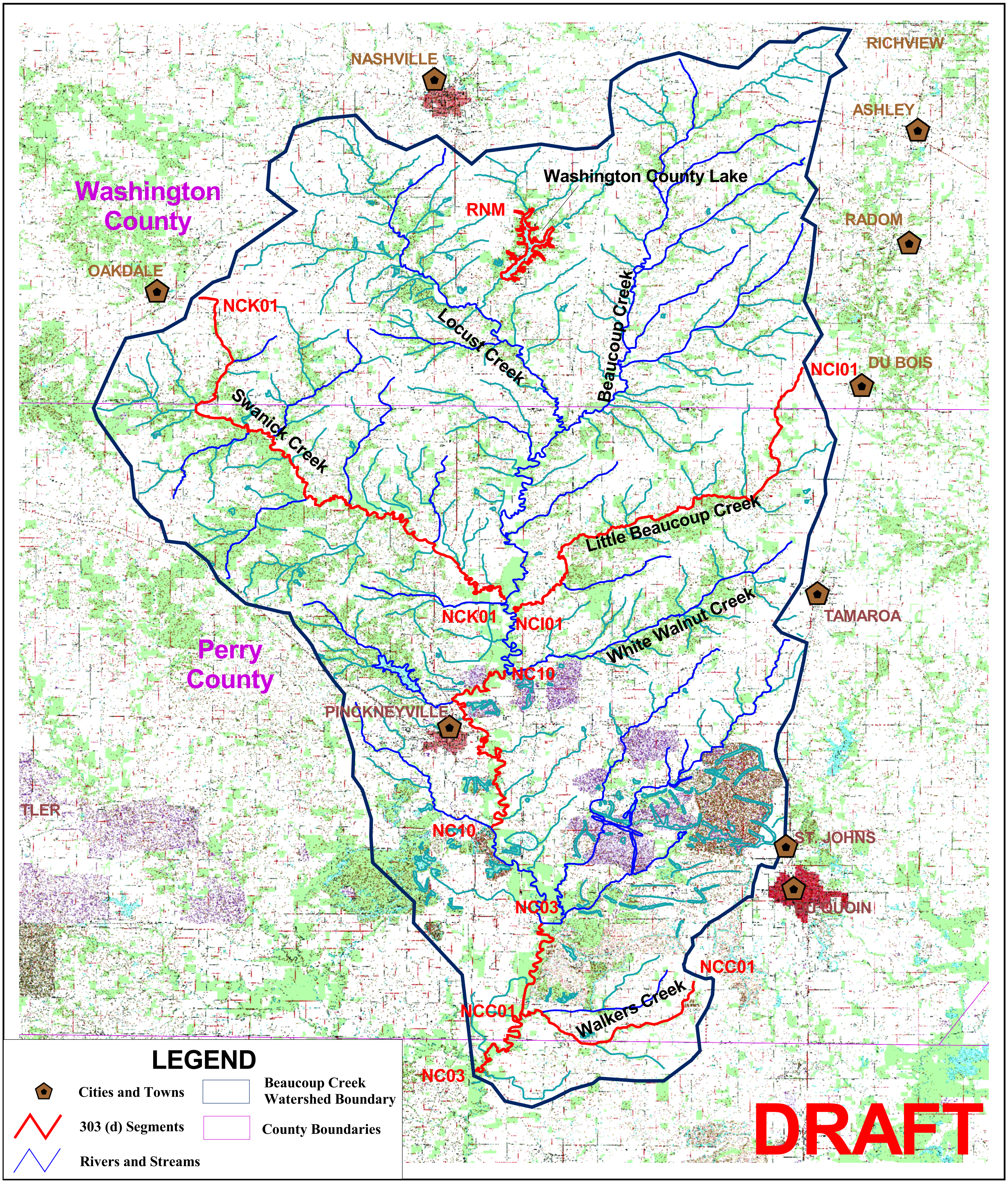

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Figure 1-1
Beaucoup Creek Watershed (ILNC05)
Impaired Water Bodies

CDM

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Section 2
Beaucoup Creek Watershed Description

2.1 Beaucoup Creek Watershed Overview

The Beaucoup Creek Watershed originates in the south central portion of Washington County, Illinois. The watershed is located within the U.S. Geological Survey (USGS) Big Muddy Basin (Hydrologic Unit Code 07140106). The watershed encompasses an area of approximately 320 square miles. Figure 1-1 shows the impaired river and lake segments within the watershed. Impaired segments are shown in red. Table 2-1 lists the water body segments, water body size, and potential causes of impairment for each water body.

Table 2-1 Impaired Water Bodies in Beaucoup Creek Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
NC10	Beaucoup Creek	10.0 miles	Dissolved oxygen (DO)
NC03	Beaucoup Creek	8.5 miles	Sulfates, total dissolved solids (TDS)
NCI01	Little Beaucoup Creek	13.5 miles	Manganese, DO
NCK01	Swanwick Creek	18.8 miles	Manganese, sulfates, DO
NCC01	Walkers Creek	5.9 miles	Manganese, sulfates, TDS
RNM	Washington County Lake	242 acres	Phosphorus, DO

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

Soils within the upper part of the Beaucoup Creek Watershed are primarily silt and loam. The surface layer is about seven inches thick while the subsoil extends to a depth that is more than 60 inches. The lower section of the watershed is primarily comprised of well-drained soils. The surface layer is a yellowish brown gravely silt clay loam and is about three inches thick. The subsurface extends to a depth of more than 60 inches and is a clay loam. Less recently mined areas are characterized by steep slopes and narrow ridges, and the more recently mined areas have gentler slopes and fewer stones (U.S. Department of Agriculture [USDA] 1988).

The climate in the Beaucoup Creek Watershed is cold in the winter and warm in the summer. In the winter, October through March, the average temperature is 43 degrees Fahrenheit (°F) and the average daily minimum temperature is 32°F according to data collected at Du Quoin, Illinois. Summer temperatures are typically 70°F with an average daily maximum of 82 degrees. Annual precipitation for Washington Lake in Washington County is 39 inches of which 22 inches, approximately 56 percent, usually falls in April through September. Annual precipitation for the remainder of Beaucoup Creek Watershed in Perry County is 45 inches of which 25 inches, approximately 55 percent, usually falls in April through September (National Climatic Data Center [NCDC] 2002).

2.2 Stream Segment Site Reconnaissance of Beaucoup Creek Watershed

The project team conducted a site reconnaissance of the Beaucoup Creek Watershed on June 19, 2001. This section briefly describes the stream segments and the site reconnaissance.

Beaucoup Creek riparian zone and surrounding area.

Table 2-1 lists the impaired stream segments in the Beaucoup Creek Watershed. Based on the 1998 303(d) list, Illinois EPA determined that two segments of Beaucoup Creek were impaired; NC10 and NC03. These segments are shown in Figure 1-1. Segment NC10 flows from north to south and is located within Perry County, Illinois. During the site reconnaissance, bridge construction was observed east of Pinckneyville on Illinois Highway 154. The observed portion of segment NC10 has a wooded riparian zone surrounded by agricultural land.

Segment NC03 also flows from north to south and is located within Perry County, Illinois. This segment was observed from the Illinois Routes 12/127 bridge crossing southeast of the Pinckneyville/ Du Quoin airport. A working lumber mill was located to the south of the creek. The waterway has a heavily wooded riparian zone, and the surrounding area was primarily agricultural.

Lumber Mill near segment NC03 of Beaucoup Creek.

Little Beaucoup Creek, buffer zone and streambed.

Little Beaucoup Creek, Segment NCI01, originates in southeast Washington County, Illinois, and northeast Perry County, Illinois. It flows southwest towards Beaucoup Creek as indicated in Figure 1-1. This segment was observed north of Pinckneyville and east of Illinois Route 127 from White Walnut Road. The section of the stream is very narrow, approximately 5 to 8 feet wide, has a narrow vegetative buffer strip, and is surrounded by agricultural lands on both sides.

Figure 1-1 shows that Swanwick Creek, Segment NCK01, flows southeast from its origins in south central Washington County, Illinois, towards its confluence with Beaucoup Creek in Perry County, Illinois. This segment was observed north of Pinckneyville at the crossing of Illinois Route 127. This segment contained turbid or murky water with a slow stream velocity. Algae were observed at the stream edges east of the bridge, and down cutting of the streambank was observed west of the bridge.

Swanwick Creek buffer zone and surrounding area.

Walkers Creek looking northeast from the bridge at Illinois Routes 13/127.

Walkers Creek, Segment NCC01, originates in southeast Perry County, Illinois, and flows north towards Beaucoup Creek as illustrated in Figure 1-1. This stream segment was observed at the crossing of Illinois Routes 13/127. No riparian buffer strip was observed, and the creek showed evidence of previous channelization. Riprap had been placed in several areas presumably to control streambank down cutting and erosion. Agricultural areas were observed to advance up to the edge of the streambank. It was noted that this segment of stream flows from what appeared to be a reclaimed mining area. This mine appears to have been recently closed.

2.3 Lake Segment Site Reconnaissance of Beaucoup Creek Watershed

Illinois EPA has listed one lake segment as impaired based on the 1998 303(d) list in the Beaucoup Creek Watershed. Washington County Lake, Segment RNM, is located on an unnamed tributary to Locust Creek in south central Washington County as shown in Figure 1-1. Washington County Lake Dam was constructed on a tributary to Locust Creek in 1962. The dam is owned by the IDNR. The dam structure is 640 feet in length and 26 feet tall enabling it to store a maximum volume of 4,232 acre-feet, although the normal storage capacity is 1,404 acre-feet. Washington County Lake is primarily used for recreation (U.S. Army Corps of Engineers [USACE] 1999a). Three unnamed tributaries are the primary sources to the lake.

Washington County Lake from the west side looking east.

Washington County Lake was observed from the dam and from the adjoining roadway accessed from Illinois Route 127. The lake showed evidence of eroded banks. The lawns around the lake were well groomed, and the trees all looked recently mulched. Cattails were observed on the west side of the lake.

Section 3
Public Participation and Involvement

3.1 Beaucoup Creek Watershed Public Participation and Involvement

Public knowledge, acceptance, and follow through are necessary to implement a plan to meet recommended TMDLs. It was important to involve the public as early in the process as possible to achieve maximum cooperation and counter concerns as to the purpose of the process and the regulatory authority to implement the recommendations. A public meeting was held to discuss the Beaucoup Creek Watershed at 6:30 p.m. on December 13, 2001 at the Pinckneyville Lions Club in Pinckneyville, Illinois. A total of 56 interested citizens, including public officials and organizations other than Illinois EPA, attended the public meeting. A final public meeting was held to discuss the Beaucoup Creek Watershed TMDL draft final report at 6:00 p.m. on February 25, 2004. A total of 22 interested citizens including public officials and organizations other than the Illinois EPA attended the final public meeting, with the meeting record remaining open until midnight, March 29, 2004.

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Section 4
Beaucoup 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 2000). The only designated uses applicable to the Beaucoup Creek Watershed are General Use.

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

4.3 Illinois Water Quality Standards

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

Table 4-1 Summary of General Use Water Quality Standards for Beaucoup Creek Watershed

Parameter	General Use Water Quality Standard
Phosphorous	0.05 mg/L Lakes/reservoirs >20 acres and streams entering lakes or reservoirs
DO	Greater than 5.0 mg/L Greater than 6.0 mg/L (16 hours of any 24 hour period
Manganese	1.0 mg/L
TDS	TDS = 1,000 mg/L
Sulfates	500 mg/L

4.3.1 Phosphorus

Phosphorous is listed as a cause of impairment for Beaucoup Creek segment NC10 and Washington County Lake. The General Use water quality standard for phosphorus shall not exceed 0.05 milligrams per liter (mg/L) in any lake or reservoir with a surface area of 20 acres or more, or in any stream at the point where it enters any such reservoir or lake. The General Use water quality standard for phosphorous does not apply to streams outside the point where the stream enters a lake or reservoir. At this time, the Illinois EPA has not established phosphorus water quality standards for streams that do not enter lakes or reservoirs. Therefore, the phosphorus impairment for Beaucoup Creek segment NC10 was addressed through reduction of runoff to address DO impairments instead of by calculation of a load allocation.

4.3.2 Dissolved Oxygen (DO)

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

DO is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of Ambient Water Quality Monitoring Network (AWQMN) data, or at least one violation determined from the most recent basin survey or facility survey data. DO is a cause of impairment in lakes and reservoirs if there is at least one General Use water quality violation based on Ambient Lake Monitoring Program (ALMP) or Illinois Clean Lakes Program (ICLP)data, or if there was a known fish kill due to DO depletion.

4.3.3 Manganese

Manganese is listed as a cause of impairment for Beaucoup Creek, Little Beaucoup Creek, Swanwick Creek, and Walkers Creek. The general use water quality standard for manganese is 1.0 mg/L and is based on total manganese.

Manganese is listed as a cause of less than full support use attainment in streams if there is at least one general use water quality violation based on the last three years of AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Manganese is also listed as a cause of less than full support if the manganese concentration in the sediment is 2,800 milligrams per kilogram (mg/kg) or higher (Illinois EPA 2000).

4.3.4 TDS

TDS is listed as a cause of impairment for Beaucoup Creek and Walkers Creek. The general use water quality standard for TDS is 1,000 mg/L. The public and food processing water supplies standards for TDS is 500 mg/L.

TDS is listed as a cause of less than full support use attainment in streams if there is at least one general use water quality violation of TDS in the last three years based on AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Conductivity measurements are used to determine the relative TDS level. If conductivity levels are greater than 1,667 µmho/cm, TDS is estimated to be a cause of impairment.

4.3.5 Sulfates

Sulfates are listed as a cause of impairment for Beaucoup Creek segment NC03, Swanwick Creek, and Walkers Creek. The general use water quality standard for sulfates is 500 mg/L. Sulfates are listed as a cause of a less than full support use attainment in streams if there is at least one general use water quality violation based on the last three years of AWQMN data, or at least one violation from the most recent basin survey or facility survey data.

4.3.6 Parameters without Water Quality Standards

It should be noted that although formal TMDLs will not be developed for parameters without water quality standards in the Beaucoup Creek Watershed, many of the management measures discussed in Section 10 of this report will result in reductions of the parameters listed in the 1998 and 2002 303(d) lists that do not currently have adopted water quality standards. For example, many of the management measures that will be discussed in Section 10 address the other parameters of concern for the watershed. For siltation, excessive algal growth, chlorophyll "a" and habitat alterations management measures that control runoff and erosion, such as filter strips and wetlands, will reduce nutrients and sediment from entering the waterways, thereby reducing excessive algal growth and increased chlorophyll "a" caused by nutrient inputs and siltation and habitat alterations caused by eroding stream banks.

4.4 Pollution Sources

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

Table 4-2 Summary of Potential Sources of Pollutants

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

4.4.1 Municipal Point Sources

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

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

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

Phosphorous and nitrogen can be attributed to municipal point sources and originate from domestic sources. Control of phosphorous entering the stream may reduce the amount of algal growth/chlorophyll "a" in the stream.

There are a total of 186 NPDES permits issued to dischargers in the Big Muddy River basin. There are four WWTPs in the Beaucoup Creek watershed (Muir et al. 1997).

4.4.2 Resource Extraction

Resource extraction consists of both active mining and abandoned mine lands. Runoff and discharges from mines can contain sulfates, TDS, metals, TSS, and can affect the pH of the stream. There are currently 47 permitted coal mines with 169 authorized discharges in the Big Muddy River basin. In addition, 1,177 inactive or abandoned mines have been identified. There are 4 permitted, active coal mines located in the Beaucoup Creek Watershed and 9 permitted, inactive coal mines. Mining is most concentrated in Beaucoup Creek, Galum Creek, Little Muddy River, Pond Creek, Hurricane Creek, and Rend Lake watersheds (Muir et al. 1997).

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

4.4.3 Agriculture

The southern Illinois area is largely agriculture land use. Row crop agriculture is the largest single category land use in the basin. Agricultural land uses can potentially contribute sediment, total suspended solids (TSS), nutrients, and BOD loads to the water resource loading. The amount that is contributed is a function of the soil type, slope, crop management, precipitation, total amount of cropland, and the distance to the water resource (D.B. Muir, R.L. Hite, M.M. King, M.R. Matson 1997).

Erosion of the land and streambanks carries sediment to the streams and lakes, resulting in higher levels of BOD which impacts DO concentrations. This can also be caused by livestock on pastures and feedlots. Wastes from livestock can enter streams, adding to the ammonia nitrogen loading and impact DO.

4.4.4 Contaminated Sediments

Sediments are carried to streams, lakes, and reservoirs during runoff conditions and are generally deposited in streambeds or lake bottoms. Constituents contained in sediment may include nutrients, which can impact BOD loads. Both agricultural lands and urban areas contribute to the nutrient loading in the sediment.

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

Contaminated sediments can slowly leach contaminants to the water column, thereby being a continual source of impact to the waterbody. Phosphorous is commonly released from sediment into the water column especially when anoxic conditions persist.

4.4.5 Urban Runoff/Storm Sewers

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

Section 5
Beaucoup Creek Watershed Data Review

5.1 Existing Data Review

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

- mapping data
- topography data
- flow data
- precipitation data
- temperature data
- evaporation data
- existing water quality data
- land use
- soil data
- cropping practices
- reservoir characteristics
- point sources
- dairy and animal confinement locations
- septic systems

5.1.1 Mapping Data

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

5.1.2 Topography Data

A Digital Elevation Model (DEM) was used to delineate watersheds in a geographic information system (GIS) for Washington County Lake and impaired segments NC03, NC10, NCI01, NCK01, and NCC01. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the BASINS database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic flow and water quality gages for the Beaucoup Creek Watershed and the subwatershed boundaries for each impaired segment in the watershed. The subwatershed boundaries define the area investigated for causes of impairments in each segment. Purple areas in Figure 5-1 represent features of the topographic maps that have been updated through aerial photography, but have not been field verified.

Surface mining activities in the Beaucoup Creek Watershed have significantly altered the natural landscape through changes in topography and the creation of inclined lakes and final cut lakes. Figure 5-2 shows an aerial photograph of the area surrounding the confluence of Beaucoup Creek and Walkers Creek and the GIS-delineated watersheds. The inclined and final cut lakes are visible in Figure 5-2. These lakes were originally strip mined areas and roads dug to the mine floor that were left to become impoundments, once mining activities ceased. From Figure 5-2, it is likely that the GIS watershed delineation is not correct through the mined areas. The possible reasons for the discrepancy are that the DEM resolution is too coarse to capture rapid elevation changes created by strip mines or that the DEM was completed prior to mining activities. An accurate delineation would require elevation data throughout the mined regions, which is not presently available. Without this data or detailed knowledge of flow patterns in the watershed, the GIS-delineated watersheds were used to model the impaired segments. The discrepancy between the GIS-delineated watersheds and the physical landscape will be discussed further in Section 10.

5.1.3 Flow Data

Analyses of the Beaucoup Creek Watershed require an understanding of flow into Washington County Lake and through the Beaucoup Creek Watershed impaired stream segments. No gage for the tributary to Washington County Lake exists, and there is no active stream gage within the impaired segments. Therefore, the drainage area ratio method, represented by the following equation, was used to estimate flows within the watersheds.

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

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

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

USGS gage 05599000 is located in the Beaucoup Creek Watershed; however, the period of record only extends to October 1982 making it inappropriate for modeling recent flows within the watershed. Therefore, USGS gage 05595730 (Rayse Creek near Waltonville, Illinois) was chosen as an appropriate gage from which to compute flow into Washington County Lake and through the impaired segments in the Beaucoup Creek Watershed. Gage 05595730 captures flow from a drainage area of 88 square miles in an upstream section of the Big Muddy River Watershed, which is about 20 miles northeast of the Beaucoup Creek Watershed. Daily streamflow data for the gage were downloaded from the USGS National Water Inventory System (NWIS) for the entire period of record from September 11, 1979 to September 30, 2000 (USGS 2002a).

Figures 5-3 and 5-4, at the end of this section, show the average monthly flows over the period of record into Washington County Lake and through Beaucoup segment NC03, Little Beaucoup segment NCI01, Walkers Creek segment NCC01, and Swanwick Creek segment NCK01 calculated from the drainage area ratio method using gage 05595730. The average monthly flows into Washington County Lake range from 1.9 cubic feet per second (cfs) to 19.5 cfs with a mean annual flow of 11 cfs. For Beaucoup Creek segment NC03, average monthly flows range from 20 to 629 cfs with a mean annual flow of 327 cfs. The average monthly flows through Beaucoup Creek segment NC10 range from 2.2 to 71 cfs and have a mean annual flow of 37 cfs, and the range of average monthly flow through Little Beaucoup Creek segment NCI01 is 1.3 cfs to 47 cfs with a mean annual flow of 21 cfs. For Swanwick Creek segment NCK01, average monthly flows range from 3.4 cfs to 109 cfs with a mean annual flow of 57 cfs. Average monthly flows in Walkers Creek segment NCC01 range from 0.6 cfs to 19.4 cfs with a mean annual flow of 10 cfs. The 7Q10 flow (lowest average seven consecutive day low flow with an average recurrence frequency of once in 10 years) is typically utilized as the critical low flow for NPDES permitting, and is estimated to be zero for segments NC03, NC10, NCI01, NCK01, and NCC01 (Illinois State Water Survey [ISWS] 2002).

5.1.4 Precipitation, Temperature, and Evaporation Data

As discussed in Section 2.1, the Beaucoup Creek Watershed is located within both Washington and Perry Counties. Washington County Lake Watershed is located entirely within Washington County. The remainder of the impaired segments in the Beaucoup Creek Watershed is located primarily in Perry Counties as shown in Figure 5-1. Daily precipitation and temperature data for Washington and Perry County were extracted from the NCDC database for the years of 1985 through 2001. Two months of data were missing from the Perry County gage. Missing data were supplemented with data from a gage in neighboring Franklin County. Table 5-1 lists the station details for the Washington County, Perry County, and Franklin County gages.

Table 5-1 Historical Precipitation Data for the Beaucoup Creek Watershed

NCDC Gage Number	Station Location (Name)	Period of Record
5342	Washington County (Marion 4NNE)	1948 to present
2483	Perry County (Du Quoin)	1901 to present
0608	Franklin County (Benton 2 N)	1948 to present

Table 5-2 Average Monthly Precipitation in Washington and Perry Counties from 1985 to 2001

Month	Washington County Average Precipitation (inches)	Perry County Average Precipitation (inches)
January	2.3	3.2
February	2.3	2.8
March	2.7	3.5
April	3.8	4.3
May	4.3	4.7
June	4.3	5.1
July	4.1	3.8
August	2.4	3.2
September	3.1	3.5
October	2.8	3.1
November	3.9	4.5
December	2.6	3.0
TOTAL	38.6	44.7

Table 5-2 shows the average monthly precipitation of the dataset developed for Washington and Perry Counties for the years 1985 to 2001. The average annual precipitation over the same period is approximately 39 inches for Washington County and approximately 45 inches for Perry County.

Pan evaporation data is available through the ISWS website at nine locations across Illinois (ISWS 2002). The Carlyle station was chosen for its proximity to the 303(d)-listed water bodies and stream segments in southern Illinois and the completeness of the dataset as compared to other stations. The Carlyle station is approximately 35 miles north of the Beaucoup Creek Watershed. The average monthly pan evaporation for the years 1980 to 2001 at the Carlyle station was downloaded from the ISWS website and summed to produce an average annual pan evaporation of 44.2 inches. Actual evaporation is typically less than pan evaporation, so the average annual pan evaporation was multiplied by 0.75 to calculate an average annual evaporation of 33.2 inches (ISWS 2002).

5.1.5 Water Quality Data

Four historic water quality stations exist within the Beaucoup Creek Watershed and are presented in Table 5-3. This table provides the location, station identification number, and the agency that collected the water quality data. Location and station identification number are also shown in Figure 5-1.

Table 5-3 Historic Water Quality Stations for the Beaucoup Creek Watershed

Location (Segment ID)	Station Identification Number	Data Collection Agency
Beaucoup Creek (NC03)	NC03	Illinois EPA Division of Water Pollution Control
Beaucoup Creek (NC10)	NC05	Illinois EPA Division of Water Pollution Control
Little Beaucoup Creek (NCI01)	NCI 01	Illinois EPA Division of Water Pollution Control
Swanwick Creek (NCK01)	NCK 01	Illinois EPA Division of Water Pollution Control
Walkers Creek (NCC01)	NCC 01	Illinois EPA Division of Water Pollution Control
Washington County Lake	RN-A04-M-1	USEPA Region 5
Washington County Lake	RN-A04-M-2	USEPA Region 5
Washington County Lake	RN-A04-M-3	USEPA Region 5

The impaired water body segments in the Beaucoup Creek Watershed were presented in Section 2. For Washington County Lake, segment RNM, there are three historic water quality stations. For Beaucoup Creek segments NC03, NC10, NCI01, NCK01, and NCC01, there is one historic water quality station within each segment. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA Storage and Retrieval (*STORET*) database associated with impairments discussed in Section 2 for the Beaucoup Creek Watershed.

Table 5-4 Water Quality Data for the Beaucoup Creek Watershed

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Beaucoup Creek Segment NC03; Sample Location NC03		
Sulfates	7/24/95-9/19/00	4
TDS	7/24/95-9/19/00	4
DO	7/24/95-9/19/00	4
Beaucoup Creek Segment NC10; Sample location NC05		
DO	9/11/95-3/14/96	2
Little Beaucoup Creek Segment NCI01; Sample Location NCI01		
Manganese	8/4/95-3/5/96	2
DO	8/4/95-3/5/96	2
Swanwick Creek Segment NCK01; Sample Location NCK01		
Manganese	7/24/95-3/5/96	2
Sulfates	7/24/95-3/5/96	2
DO	7/24/95-3/5/96	2
Walkers Creek Segment NCC01; Sample Location NCC01		
Manganese	8/2/95-3/13/96	2
Sulfates	8/2/95-3/13/96	2
TDS	8/2/95-3/13/96	2
Washington County Lake Segment RNM; Sample Locations RNM-1, RNM-2, RNM-3		
RNM-1		
Phosphorus	4/24/90-10/22/01	45
DO	4/24/90-10/22/01	20
RNM-2		
Phosphorus	4/24/90-10/22/01	19
DO	4/24/90-10/22/01	20
RNM-3		
Phosphorus	4/24/90-10/22/01	19
DO	4/24/90-10/22/01	20

5.1.5.1 Washington County Lake Water Quality Data

There are three active water quality stations in Washington County Lake as shown in Figure 5-1 and listed in Table 5-4. The water quality station data for Washington County Lake were downloaded from the *STORET* online database for the years of 1979 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in Washington County Lake, as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

Constituents are sampled at various depths throughout Washington County Lake, and compliance with water quality standards is determined by the sample at a one-foot depth from the lake surface. This section discusses the one-foot depth samples of water quality constituents used in modeling efforts for Washington County Lake. The exception is chlorophyll "a," which was sampled at various depths at each water quality station and will be presented as an average over all sample depths. Modeling of the reservoir required use of phosphorus samples at all depths, which is discussed and presented in Section 7.3.3.2.

5.1.5.1.1 DO

DO measurements were taken at approximately two-foot increments throughout the depth of Washington County Lake. The TMDL endpoint for DO in a lake is a minimum of 6.0 mg/L (16 hours of any 24-hour period) at one-foot depth from the surface of the lake. The average DO values at one-foot depth from the lake surface for each year of available data,, after 1990 at each water quality site in Washington County Lake are summarized in Table 5-5. The lake average represents the average of all data sampled at a one-foot depth over the year.

Table 5-5 Average DO Concentrations (mg/L) in Washington County Lake at One-Foot Depth (Illinois EPA 2002 and USEPA 2002b)

	RNM-1	RNM-2	RNM-3	Lake Average
1990	9.0	10.4	10.1	9.8
1992	14.6			14.6
1995	6.9	8.2	8.1	7.7
1998	7.8	8.8	7.8	8.1
2001	9.6	10.4	10.2	10.1

The annual averages at all three stations and the annual lake averages are all greater than the endpoint, but among values recorded after 1990, individual measurements in 1990, 1995, and 1998 were below the 6.0 mg/L limit. Table 5-6 lists the station, date, and DO value for measurements that violated the DO standard.

DO measurements vary with the diurnal cycle. Typically, DO is lowest in pre-dawn hours when photosynthesis is at a minimum. As the sun rises, photosynthesis and DO increase peaking in the late afternoon. Therefore, the sampling time will have a direct effect on the reported DO.

Table 5-6 Violations of the DO Standard in Washington County Lake (Illinois EPA 2002 and USEPA 2002b)

Station and Date	DO (mg/L)
RNM-1	
10/10/90	5.5
07/05/95	2.8
08/15/95	5.7
10/06/98	4.4
RNM-2	
10/10/90	4.6
07/05/95	5.2
10/06/98	5.5
RNM-3	
10/10/90	5.7
08/15/95	5.9
06/03/98	5.1

DO concentration in lakes is typically a response variable to constituents, such as phosphorus or chlorophyll "a." Chlorophyll "a" indicates presence of excessive algal or aquatic plant growth. Reducing total phosphorus is likely to reduce algal growth thus resulting in attainment of the DO standard. Therefore, the relationship between DO, chlorophyll "a," and total phosphorus in Washington County Lake was investigated. The correlation between DO and chlorophyll "a" is expected to be an inverse relationship, whereas the correlation between chlorophyll "a", and total phosphorus is expected to indicate a direct relationship. These relationships would suggest that controlling phosphorus will decrease chlorophyll "a" concentrations, which will in turn increase DO concentrations. This hypothesis is supported by Wetzel who asserts that eutrophic (nutrient-rich) lakes have rapid rates of oxygen depletion (1983).

5.1.5.1.2 Total Phosphorus

The average total phosphorus concentrations, at a one-foot depth for each year of available data from 1988 to 2001 at each monitoring site in Washington County Lake, are presented in Table 5-7. At station RNM-1, samples were taken at a one-foot depth from the lake surface and at the lake bottom. Samples at stations RNM-2 and RNM-3 were only taken at a one-foot depth from the lake surface. The water quality standard for total phosphorus is less than or equal to 0.05 mg/L at a one-foot depth. The TMDL endpoint for total phosphorus in lakes is 0.05 mg/L. The raw data for all sample depths are contained in Appendix A.

Table 5-7 Average Total Phosphorus Concentrations (mg/L) in Washington County Lake at One-Foot Depth (Illinois EPA 2002 and USEPA 2002b)

Year	RNM-1	RNM-2	RNM-3	Lake Average
1990	0.25	0.17	0.20	0.21
1992	0.20			0.20
1995	0.15	0.15	0.19	0.16
1998	0.16	0.21	0.24	0.20
2001	0.07	0.07	0.11	0.08

The annual averages for total phosphorus at all three stations, and the annual lake averages are all greater than the endpoint of 0.05 mg/L. Appendix A lists the station, date, and total phosphorus value for measurements that violated the phosphorus standard.

Phosphorus exists in water in either a particulate phase or a dissolved phase. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus adsorbed to particulates, and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus. Phosphorus in natural waters is usually found in the form of phosphates ($PO4_3$). Phosphates can be in inorganic or organic form. Inorganic phosphate is phosphate that is not associated with organic material. Types of inorganic phosphate include orthophosphate and polyphosphates. Orthophosphate is sometimes referred to as "reactive phosphorus." Orthophosphate is the most stable kind of phosphate, and is the form used by plants or algae. There are several forms of phosphorus that can be measured. Total phosphorus is a measure of all the forms of phosphorus, dissolved or particulate, that is found in a sample. Soluble reactive phosphorus is a measure of orthophosphate, the filterable (soluble, inorganic) fraction of phosphorus, the form directly taken up by plant cells.

5.1.5.1.3 Chlorophyll "a"

The average chlorophyll "a" concentrations for each year of available data from 1990 to 2001 at each monitoring site in Washington County Lake are presented in Table 5-8. The raw data for all sample depths are contained in Appendix A.

Table 5-8 Average Chlorophyll "a" Concentrations (µg/L) in Washington County Lake (USEPA 2002b)

	RNM-1	RNM-2	RNM-3	Lake Average
1990	61.9	66.4	98.6	75.6
1992	107.0			107.0
1995	50.5	55.2	55.7	53.8
1998	45.9	75.6	76.5	66.0
2001	35.9	36.1	38.2	36.8

5.1.5.1.4 Tributary Data

There is no water quality data available for the tributaries to Washington County Lake. The tributaries to Washington County Lake are unnamed. Tributary water quality data along with flow information would be useful in assessing contributing loads from the watersheds to help differentiate between external loading and internal loading. External loads are those loadings from the watershed, such as nonpoint source runoff and point sources. Internal loads are caused by low DO conditions near lake sediments, which promote re-suspension of phosphorus from the sediments into the water column. External versus internal loads will be discussed further in Section 7.4.

5.1.5.2 Beaucoup Creek Water Quality Data

There is one active water quality station in each impaired stream segment in the Beaucoup Creek Watershed as shown in Figure 5-1. The water quality station data for each segment were downloaded from the *STORET* on-line database for the years of 1990 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in Beaucoup Creek Watershed as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

5.1.5.2.1 Manganese, Sulfates, and TDS

Table 5-9 summarizes historical manganese, sulfates, and TDS data since 1990 from the USEPA *STORET* database, and recent data not yet entered into the *STORET* database for impaired segments in the Beaucoup Creek Watershed. The raw historical water quality data is contained in Appendix A. For impairments on Beaucoup segment NC03, Little Beaucoup segment NCI01, and Walkers Creek segment NCC01, the average of the data sets exceeds the water quality standard for their relative constituents. For impairments on Swanwick Creek segment NCK01, the average of the data exceeds the water quality standards for manganese but only exceeds the water quality standard for sulfates once. The historical water quality samples were also taken during months with historically varying flow conditions.

Table 5-9 Existing Manganese, Sulfates, TDS Water Quality Data, and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Beaucoup Creek Segment NC03; Sample Location NC03					
Sulfates	500	8/16/00-9/19/00; 2	705	1,000	410
TDS	1,000	8/16/00-9/19/00; 2	1,070	1,380	759
Little Beaucoup Creek Segment NCI01; Sample Location NCI01					
Manganese	1.0	8/4/95-3/5/96; 2	1.2	2.1	0.3
Swanwick Creek Segment NCK01; Sample Location NCK01					
Manganese	1.0	7/24/95-3/5/96; 2	2.1	3.8	0.4
Sulfates	500	7/24/95-3/5/96; 2	334	505	162
Walkers Creek Segment NCC01; Sample Location NCC01					
Manganese	1.0	8/2/95-3/13/96; 2	2.0	2.9	1.0
Sulfates	500	8/2/95-3/13/96; 2	1,730	1,890	1,570
TDS	1,000	8/2/95-3/13/96; 2	1,735	1,740	1,730

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events for manganese, sulfates, and TDS are presented in Table 5-10. As discussed in Section 5.1.3, the flow data were calculated from USGS gage 05595730. The flow for each sample date was compared to the monthly average flow shown in Figure 5-4 for the month the sample was taken. Based on this comparison, all samples were taken at below average flow conditions except for the August sampling in Walkers Creek. This suggests that most historical samples were taken under baseflow conditions in Beaucoup Creak, Little Beaucoup Creek, and Swanwick Creek. The flow condition during the August sampling in Walkers Creek was above average suggesting a portion of the constituents can be attributed to runoff.

Table 5-10 Manganese, Sulfates, and TDS Sampling Events and Associated Flow Conditions

Sample Location	Date	Flow (cfs)	Mn (mg/L)	Sulfates (mg/L)	TDS (mg/L)
Beaucoup Creek (NC03)	8/16/2000	11.86	–	410	–
Beaucoup Creek (NC03)	9/19/2000	1.33	–	1,000	–
L. Beaucoup Creek (NCI01)	8/4/1995	0.60	2.1	–	–
L. Beaucoup Creek (NCI01)	3/5/1996	0.33	0.3	–	–
Swanwick Creek (NCK01)	7/24/1995	0.20	3.8	505	–
Swanwick Creek (NCK01)	3/5/1996	0.88	0.4	162	–
Walkers Creek (NCC01)	8/2/1995	1.89	1.0	1,570	1,740
Walkers Creek (NCC01)	3/13/1996	0.49	2.9	1,890	1,730

5.1.5.2.2 DO

Table 5-11 summarizes the available historic DO data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for impaired segments in the Beaucoup Creek Watershed (raw data contained in Appendix A). The average DO concentration for all Beaucoup segments is above the water quality standard of 6.0 mg/L (16 hours of any 24-hour period), but the minimum values observed for all segments are less than the water quality standard of 6.0 mg/L.

Table 5-11 Existing DO Water Quality Data and TMDL Endpoints for Beaucoup Creek Watershed Segments NC03, NC01, NCI01, and NCK01 (USEPA 2002b and Illinois EPA 2002)

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined for Samples and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Beaucoup Creek Segment NC03; Sample Location NC03					
DO	6.0*	7/24/95-9/19/00; 4	6.7	9.9	4.7
Beaucoup Creek Segment NC10; Sample location NC05					
DO	6.0*	9/11/95-3/14/96; 2	7.6	10.4	4.7
Little Beaucoup Creek Segment NCI01; Sample Location NCI01					
DO	6.0*	8/4/95-3/5/96; 2	5.8	10.1	1.5
Swanwick Creek Segment NCK01; Sample Location NCK01					
DO	6.0*	7/24/95-3/5/96; 2	6.6	10.6	2.6

* 16 hours of any 24-hour period.

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events for DO are presented in Table 5-12. Flow data were missing for four months surrounding September 11, 1995 at USGS gage 05595730. Therefore, the last recorded flow before September 11, 1995 was used for evaluation; however this data is considered limited as no actual data was available near the date of the water quality sample. As discussed in Section 5.1.5.2.1, the flow for each sample date was compared to the monthly average flow shown in Figure 5-4 for the month the sample was taken. Based on this comparison, all samples in Table 5-12 with exception of NC10 on September 11, 1995 were taken at below average flow values. This could suggest that the DO impairments are occurring during low flow values for the segments. Low flow values within the stream segment result in stagnant conditions, which could decrease the amount of aeration occurring in the stream. In addition, the days with DO impairment occurred between June and August, which are typically warm weather months. Elevated stream temperatures affect the aquatic environment by limiting the concentration of DO in the water column. For example, the DO concentration for 100 percent air saturated water at sea level is 14.6 mg O_2/L at 0 degrees Celsius (°C) (32°F) and decreases to 8.6 mg O_2/L at 25°C (77°F) (Brown and Brazier 1972).

Table 5-12 DO Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	DO (mg/L)
Beaucoup Creek (NC03)	7/24/1995	0.19	5.0
Beaucoup Creek (NC03)	3/14/1996	2.65	9.9
Beaucoup Creek (NC03)	8/16/2000	1.90	4.7
Beaucoup Creek (NC03)	9/19/2000	0.16	7.0
Beaucoup Creek (NC10)	9/11/1995	48.7	4.7
Beaucoup Creek (NC10)	3/14/1996	1.86	10.4
Little Beaucoup Creek (NCI01)	8/4/1995	0.56	1.5
Little Beaucoup Creek (NCI01)	3/5/1996	0.33	10.1
Swanwick Creek (NCK01)	7/24/1995	0.20	2.6
Swanwick Creek (NCK01)	3/5/1996	0.88	10.6

5.1.6 Land Use

The Illinois Natural Resources Geospatial Clearinghouse distributes the Critical Trends Assessment Land Cover Database of Illinois. This database represents 23 land use classes created by satellite imagery captured between 1991 and 1995. The data were published in 1996 and are distributed by county in grid format for use in GIS.

The GIS-delineated watersheds for Washington County Lake and the Beaucoup Creek impaired segments were used to obtain the land use from the Critical Trends Assessment Land Cover grid. Tables 5-13 and 5-14 list the land uses contributing to the Washington County Lake and the Beaucoup Creek Watershed, as well as each land use area and percent of total area.

Table 5-13 Critical Trends Assessment Land Uses in the Washington County Lake Watershed (IDNR 1996)

Land Use	Acres	Percent of Area
Row Crop (corn, soybeans, and other tilled crops)	2,896	43%
Rural Grassland (pastureland, grassland, waterways, buffer strips, CRP land, etc.)*		
Pasture	539	8%
Hayland	687	10%
Deciduous Forest	1,140	17%
Small Grains (wheat, oats, etc.)	1,099	17%
Open Water	218	3%
Forested Wetlands	54	1%
Shallow Water Wetlands	34	1%
Coniferous Forest	10	0%
Confined Animal Management Facility	8	0%
Shallow Marsh/Wetlands	5	0%
Deep Marsh	3	0%
Dairy	3	0%
Urban (high and medium density)	3	0%
TOTAL	**6,699**	**100%**

*Subclasses of rural grassland were estimated by the Washington County NRCS (2002a)

Table 5-14 Critical Trends Assessment Land Uses in the Beaucoup Creek Watershed

Land Use	Area (acres)	Percent of Total
Row Crop	75,232	37%
Rural Grassland	54,019	27%
Deciduous Forest	32,758	16%
Small Grains	22,979	11%
Forested Wetland	10,315	5%
Open Water	3,415	2%
Shallow Water/Wetlands	1,806	1%
Medium Density	538	1%
Urban Grassland	438	0%
Shallow Marsh/Wetlands	306	0%
Deep Marsh	251	0%
High Density	193	0%
Low Density	84	0%
Barren Lands	70	0%
Coniferous Forest	67	0%
Swamp	29	0%
TOTAL	**202,500**	**100**%

Additional land use data were obtained from the Spatial Analysis Research Center's Cropland Data Layer to supplement the Critical Trends Assessment dataset. The data were requested from the National Agricultural Statistics Service (NASS) website for the years of 1999 and 2000 (NASS 2002). The Cropland Data Layer is also derived from satellite imagery, but the land use classes for crops are more detailed than those presented in the Critical Trends Assessment dataset. The detailing of crops in the Cropland Data Layer land use classes makes it a more accurate dataset for calculation of crop-related parameters. The dataset was also used to verify the land use obtained from the Critical Trends Assessment. Table 5-15 shows the cropland use classes of the Cropland Data Layer and the Critical Trends Assessment classes to which they were applied.

Table 5-15 Comparison of Land Use Classes in the Washington County Lake Watershed

Cropland Data Layer Land Use Class	Critical Trends Assessment Land Use Class
Corn	Row Crop
Sorghum	Small Grains
Soybeans	Row Crop
Winter Wheat	Small Grains
Other Small Grains and Hay	Small Grains
Double-Cropped Winter Wheat/Soybeans	Half to Small Grains Half to Row Crops

5.1.7 Point Sources and Animal Confinement Operations

5.1.7.1 WWTPs

The USEPA BASINS database includes a GIS shapefile of facilities with NPDES permits. These permitted facilities must provide Discharge Monitoring Reports (DMR), which provide effluent discharge samples as part of the Permit Compliance System (PCS) (2002a). Four WWTPs were located in the Beaucoup Creek Watershed as shown in Figure 5-5.

One treatment plant, the Washington County Conservation Area WWTP, is located upstream of Washington County Lake. Effluent water quality data for this plant were available for the months of April through October, from April 1996 to July 2001, from NPDES DMR posted on the PCS database website (USEPA 2002b). Water quality data are not available for the months of November to March because there was no discharge from the plant during these months. Table 5-16 lists the average flow, ammonia concentrations, and 5-day carbonaceous biochemical oxygen demand ($CBOD_5$) concentrations in the effluent over the period of record. The low effluent flow from the plant makes the loadings to Washington County Lake negligible in comparison to loadings from the remainder of the watershed. Therefore, loadings from the plant will not be included in modeling efforts for Washington County Lake.

Table 5-16 Effluent Data from Washington Conservation Area WWTP (USEPA 2002b)

Facility Name Period of Record Permit Number	Constituent	Average Value	Average Loading (lb/d)
Washington County Conservation Area WWTP	Flow (mgd)	0.01	–
04/96 – 07/01	Total Ammonia as N (mg/L)	5.5	1.5
NPDES# IL0048577	$CBOD_5$ (mg/L)	17.4	2.0

The remaining three WWTPs in the watershed discharge to stream segments within the Beaucoup Creek Watershed as shown in Figure 5-5. Two of these facilities discharge to segment NC10. The third drains to a tributary of an unimpaired section of Beaucoup Creek. Effluent water quality data were available for each plant from the PCS database (USEPA 2002b). Table 5-17 lists the period of record for each plant and the average flow, ammonia concentrations, and $CBOD_5$ concentrations over the period of record. Water quality data were not available for multiple months at the Lake Sallateeska plant over the period of record because there was no discharge from the plant during these months. The low effluent flow from each plant makes the loadings to Beaucoup Creek Watershed stream segments negligible in comparison to loadings from the remainder of the watershed. Therefore, loadings from the plants will not be included in modeling efforts.

Table 5-17 Effluent Data from WWTPs Discharging to Beaucoup Creek Stream Segments

Facility Name Period of Record Permit Number	Constituent	Average Value	Average Loading (lb/d)
Pickneyville WWTP #1	Flow (mgd)	0.7	–
04/96 - 06/02	Total Ammonia as N (mg/L)	0.2	1.0
NPDES# IL0021997	$CBOD_5$ (mg/L)	3.0	18.5
Lake Sallateeska Baptist Camp	Flow (mgd)	0.001	–
06/96 - 03/01	Total Ammonia as N (mg/L)	6.8	–
NPDES# IL0045195	$CBOD_5$ (mg/L)	12.4	0.1
Pickneyville East WWTP	Flow (mgd)	0.2	–
01/99 - 06/02	Total Ammonia as N (mg/L)	0.2	0.2
NPDES# IL0050822	$CBOD_5$ (mg/L)	3.0	3.9

5.1.7.2 Coal Mines and Oil and Gas Fields

Acid mine drainage from coal mines could contribute to manganese, sulfates, and TDS concentrations in a watershed. Data from the Illinois Natural Resources Geospatial Data Clearinghouse was reviewed for coal mines, oil fields, and non-coal mines within the Beaucoup Creek Watershed from the following references (full citation provided in Section 11):

- Chenoweth, Cheri, 1998, Areas Mined for Springfield (No. 5) Coal in Illinois
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 1
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 2

- Coal Section, Illinois State Geological Survey, 1991, Point Locations of Active and Abandoned Coal Mines in Illinois
- Illinois Office of Mines and Minerals, 1998, Coal Mine Permits Boundaries in Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois - Points
- Illinois State Geological Survey, not published, Oil and Gas Fields in Illinois

Figure 5-6 presents the findings from these databases for extraction operations in the Beaucoup Creek Watershed. Multiple coal mines were identified within the watershed and labeled on Figure 5-6. The mine names and dates of operation are listed in Appendix B. Figure 5-6 also shows which coal mines are permitted. A comparison of the existing and permitted mine databases suggests that non-permitted mines are likely abandoned or closed. Multiple oil or gas fields were also located in the Beaucoup Creek Watershed. No non-coal mines were located in the watershed; however, the non-coal mine database contains only 20 percent of the non-coal mines in Illinois due to the lack of a legal filing requirement.

Table 5-18 lists water discharge permits for mines in the Beaucoup Creek Watershed, the date the most recent permit was issued, and the permit expiration date. The permits in Table 5-18 may represent multiple pipe outfalls. Figure 5-7 shows the location of each active mine listed in Table 5-18.

Table 5-18 Water Discharge Permits for Mines within Beaucoup Creek Watershed

Permit ID	Facility Name	Receiving Waters	Permit Issued	Permit Expiration
IL0000302	Freeman United Coal - Fidelity	Panther Creek, Tributary to Walkers Creek (NCC01)	11/4/97	09/30/02
IL0000396	GS Metals Corporation - Pickneyville			6/30/01
IL0000493	SCM Corporation - Pit #2			9/25/89
IL0000507	Consolidation Coal Company - NPR			10/1/79
IL0000671	MCA MFG Uni Distributing			1/1/97
IL0026418	Consolidation Coal Company			3/1/91
IL0035840	United Electric Coal Company - Discharge			9/30/79
IL0048160	Consolidation Coal Company - Burning Star	Little Beaucoup Creek (NCI01)	7/11/95	6/1/00
IL0052736	Consolidation Coal Company - Burning Star #2	White Walnut Creek	9/29/98	7/31/03
IL0052744	Consolidation Coal Company - Burning Star #2	Panther Creek (NC03)	12/1/99	6/30/04
IL0052779	Consolidation Coal Company - Burning Star Mine	Beaucoup Creek (NC03)	5/2/96	3/1/01
IL0065102	R&R Resources, Inc			4/1/91
IL0071099	Hoskins, John A Slurry No. 1	Walkers Creek (NCC01)	1/8/99	10/31/03

Sulfate water quality data are available for selected pipe outfalls from the Consolidation Coal Company - Burning Start Mine (IL0052779) and Consolidation Coal Company - Burning Start Mine #2 (IL0052744), which potentially impact Beaucoup Creek segment NC03 and Freeman United Coal – Fidelity Mine (IL0000302), which potentially impacts Walker Creek segment NCC01. Manganese water quality data are available for selected pipe outfalls from Consolidation Coal Company – Burning Start Mine (IL0048160), which potentially impacts Little Beaucoup Creek segment NCI01. These data are summarized in Table 5-19.

Table 5-19 Sulfate, Chloride, and Manganese Pipe Outfall Concentrations

Permit ID and Sample Dates	Pipe Outfall	Flow (cfs)				Sulfate (mg/L)				Chloride (mg/L)				Manganese (mg/L)			
		# of Samples	Minimum	Maximum	Average	# of Samples	Minimum	Maximum	Average	# of Samples	Minimum	Maximum	Average	# of Samples	Minimum	Maximum	Average
IL0052779	002	23	0.011	20.04	1.45	23	45	482	162	na	na	na	na	na	na	na	na
02/00 – 06/03	003A	23	0.002	2.55	0.25	23	64	206	141	na	na	na	na	na	na	na	na
	004	25	0.002	2.00	0.19	25	38	735	150	na	na	na	na	na	na	na	na
	012	34	0.005	60.11	3.60	34	50	306	177	na	na	na	na	na	na	na	na
IL0057244	004	34	0.003	20.07	1.38	34	23	466	171	na	na	na	na	na	na	na	na
01/00 – 06/03	007	34	0.005	20.04	2.11	34	208	540	348	na	na	na	na	na	na	na	na
	008	19	0.062	9.35	2.47	19	247	1262	510	na	na	na	na	na	na	na	na
IL0048160	009	40	0.0186	1.186	0.306	na	na	na	na	na	na	na	na	40	0.026	0.461	0.186
01/00 – 06/03	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
IL0000302	002	42	0.223	2.232	0.928	41	1160	2670	1702	41	7	12	9	na	na	na	na
01/00 – 06/03	006	42	0.335	6.696	2.215	42	618	2100	1304	41	11	24	18	na	na	na	na

na = Not available

Permitted discharges are regulated by Title 35 of the Illinois Administrative Code (IPCB 1999b). The effluent standards for mine discharges are listed in Table 5-20.

Table 5-20 Effluent Standards for Mine Discharges in Illinois (IPCB 1999b)

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

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

All sulfate samples in Table 5-19 are below the effluent standards complying with Title 35; however, sulfate concentrations in over half of the pipe outfalls exceed the water quality standards as evidenced by effluent concentrations greater than 500 mg/L. All manganese samples presented in Table 5-19 fall below the Title 35 effluent standards and water quality standards of 2 mg/L and 1 mg/L, respectively. The IDNR Division of Oil & Gas is the regulatory authority in Illinois for permitting, drilling, operating, and plugging oil and gas production wells. The Division implements the Illinois Oil and Gas Act and enforces standards for the construction and operation of related production equipment and facilities. In addition, the Division of Oil & Gas regulates the injection of fluids into underground injection wells and cleans up abandoned well sites. Oil and gas activities can impact water bodies in several ways. Spills and improper handling of oil and oil field brine can contaminate soils, groundwater, and surface water. Abandoned and leaking injection wells can also cause contamination of groundwater and surface water. Specific pollutants from petroleum activities include chlorides, sodium, sulfates, hydrocarbons, and other organics. Presence of elevated chlorides, sodium, and sulfates can correlate with increases in TDS. Other pollutants of concern associated with petroleum activities are heavy metals such as manganese.

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

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

Table 5-21 shows constituents or "tracers" typically examined when analyzing whether sources of pollutants in a water body are from mining or oil and gas activities. Although only one mine is located in the segment NCK01 subwatershed and no mines are located in the segment NCI01 subwatershed, it is possible that mines do exist in the watersheds and are not represented in the data set. For example, Figure 5-6 shows a permitted mine located in the segment NCK01 subwatershed, but a corresponding post-law mine is not represented. For acid mine drainage, generally elevated concentrations of iron would be observed. For oil and gas contributions, chloride or sodium tracers can be used to assess impacts from brine waste generated in the production of oil and gas. As mentioned previously, the sampling data shown in Table 5-10 was taken under low-flow conditions for all samples except the August 2, 1995 sample in segment NCC01. The absence of exceedences of the water quality standards for manganese or sulfates at higher flows in Table 5-21 supports the conclusion that manganese and sulfates from the remaining segments could have leached into the groundwater from pools within mine sites. Therefore, groundwater could be the source of manganese, sulfates, and TDS for Beaucoup Creek segments NC10 and NC03, Little Beaucoup Creek, and Swanwick Creek. It is possible that surface runoff from mine sites is the source of elevated concentrations in Walkers Creek. This is supported by the analysis, summarized in Section 8, that examines the impacts of sulfate and manganese loads from the permitted active mines on the receiving waters. In addition, no data is available to assess the natural background of manganese, sulfates, and TDS in the watershed. Natural background concentrations typically are attributed to what occurs naturally in groundwater due to mineral conditions of the soils (WERF 1997).

Table 5-21 Historical Water Chemistry in Beaucoup Creek Watershed (USEPA 2002b)

Sample Location	Date	Flow (cfs)	Total Mn (mg/L)	Sulfates (mg/L)	TDS (mg/L)	Total Fe (µg/L)	Total Ca (mg/L)	Total Cl (mg/L)	Total Na (mg/L)	Total K (mg/L)	Total Mg (mg/L)
Beaucoup Creek (NC03)	8/16/2000	11.86	0.27	410	759	990	110	15	49	7.6	48
Beaucoup Creek (NC03)	9/19/2000	1.33	0.29	1,000	1,380	390	240	15	98	7.1	120
L. Beaucoup Creek (NCI01)	8/4/1995	0.60	2.1	31	171	1,500	24	5.9	12	11	10
L. Beaucoup Creek (NCI01)	3/5/1996	0.33	0.29	481	677	530	110	30.4	68	7	53
Swanwick Creek (NCK01)	7/24/1995	0.20	3.8	162	485	1,700	73	30.6	45	9.3	31
Swanwick Creek (NCK01)	3/5/1996	0.88	0.38	505	748	1,100	120	27.8	75	5.4	67
Walkers Creek (NCC01)	8/2/1995	1.89	1	1,570	1,740	1,200	390	15.1	150	6.1	170
Walkers Creek (NCC01)	3/13/1996	0.49	2.9	1,890	1,730	220	380	23.5	170	4.9	170

5.1.7.3 Animal Confinement Operations

The Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Big Muddy River Basin, which contains Washington County Lake and the Beaucoup Creek Watershed. The Illinois EPA assessed the potential impact of each facility on water quality with regard to the size of the facility, the site condition and management, pollutant transport efficiency, and water resources vulnerability. Seventy-six livestock facilities were identified in the Beaucoup Creek Watershed as shown in Figure 5-8. One of the facilities has been designated as potentially having a moderate impact. Of the remaining facilities, 32 were designated as potentially having slight impact, 34 were designated as potentially having no impact, and nine were not assessed.

5.1.8 Soil Data

State Soil Geographic (STATSGO) Database data, created by the USDA – National Resource Conservation Service (NRCS) Soil Survey Division, are aggregated soil surveys for GIS use published for Illinois in 1994. The STATSGO shapefiles were downloaded by Hydrologic Unit Code (HUC) from the USEPA *BASINS* website (USEPA 2002a). STATSGO data are presented as map units of soils in which each map unit has a unique code linking it to attribute tables listing percentages of soil types within a map unit, soil layer depths, hydrologic soil groups, and soil texture among other soil properties.

5.1.9 Cropping Practices

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. Data specific to the Washington County Lake Watershed were not available; however, the Washington County NRCS office recommended percentages of each tillage practice for application to the Washington County Lake Watershed as shown in Table 5-22 (NRCS 2002a).

Table 5-22 Tillage Practices in Washington County (NRCS 2002a)

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0%	0%	0%
Reduced Till	60%	15%	10%
Mulch-Till	10%	30%	60%
No-Till	30%	55%	30%

Crop rotation practices in the Washington County Lake Watershed were obtained from the Washington County NRCS office (2002a). The typical rotations in the watershed are a two-year rotation of corn and soybeans; a three-year rotation of corn, soybeans, and wheat; and a four-year rotation of corn, soybeans, wheat, and meadow.

5.1.10 Reservoir Characteristics

Reservoir characteristics were obtained from GIS analysis, the Illinois EPA, the Washington County Lake Resource Plan, and USEPA water quality data. The resource plan reports the surface area of Washington County Lake as 242 acres (Washington County Lake Resource Plan [WCLRP] 1997). The value from the resource plan was used to validate the surface area of 260 acres obtained from GIS analysis. For modeling analyses, the area obtained through GIS analysis was scaled to equal the area from the resource plan.

The water quality dataset described in Section 5.1.5.1 was used to determine the average depth of Washington County Lake. On each date sampled for water quality constituents, the total depth at the site was measured. Table 5-23 lists the average depth calculated for each water quality site in Washington County Lake for each year of available data after 1990.

Table 5-23 Average Depths for Washington County Lake

	RNM-1	RNM-2	RNM-3	Lake Average
1990	19.9	15.5	7.5	14.3
1995	19.1	13.7	6.5	13.1
2001	18.4	13.8	6.4	12.9

Reservoir characteristics that were unavailable were flows into and out of the reservoir.

5.1.11 Septic Systems

Typically, septic systems near lake waters have greater potential for impacting water quality than systems near streams due to their proximity to the water body of concern. The number of septic systems within the watersheds could not be confirmed from available data sources. There were no residences observed near the lake during the site visit described in Sections 2.2 and 2.3. It is anticipated that failing septic systems are a negligible source of pollutant loads in this watershed.

5.1.12 Aerial Photography

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

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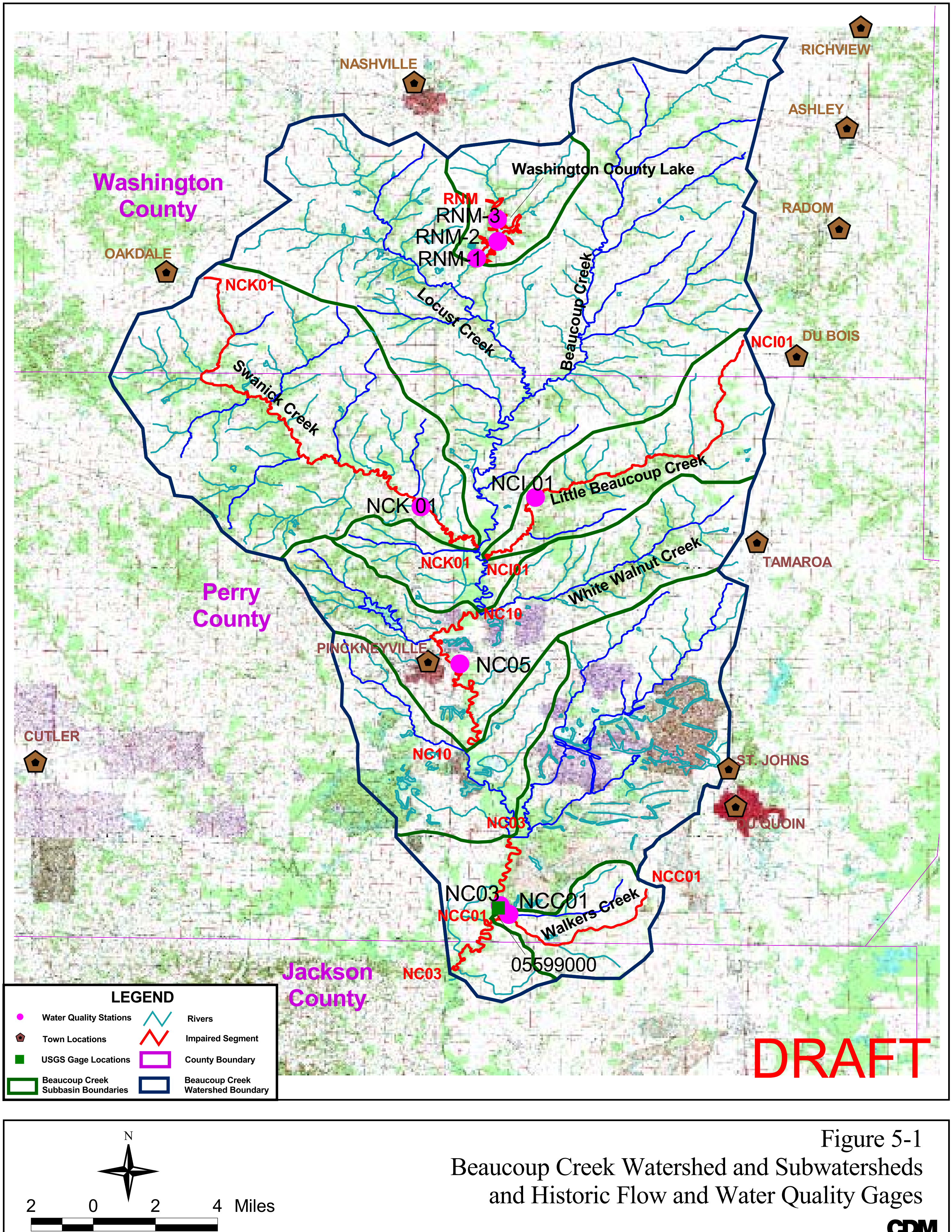

Figure 5-1
Beaucoup Creek Watershed and Subwatersheds
and Historic Flow and Water Quality Gages

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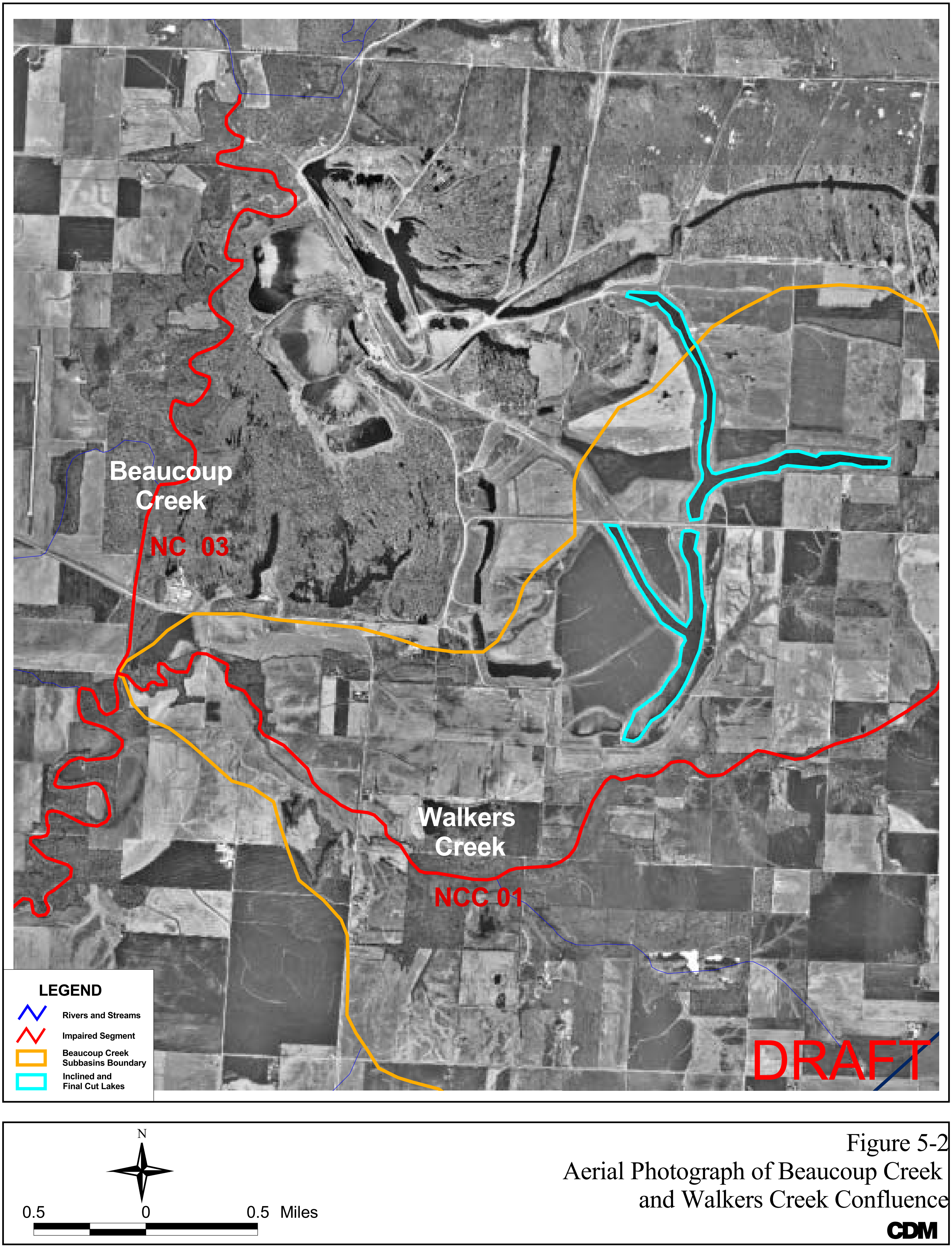

Figure 5-2
Aerial Photograph of Beaucoup Creek
and Walkers Creek Confluence

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Figure 5-3: Estimated Streamflow Upstream of Washington County Lake Calculated from Gage 05595730

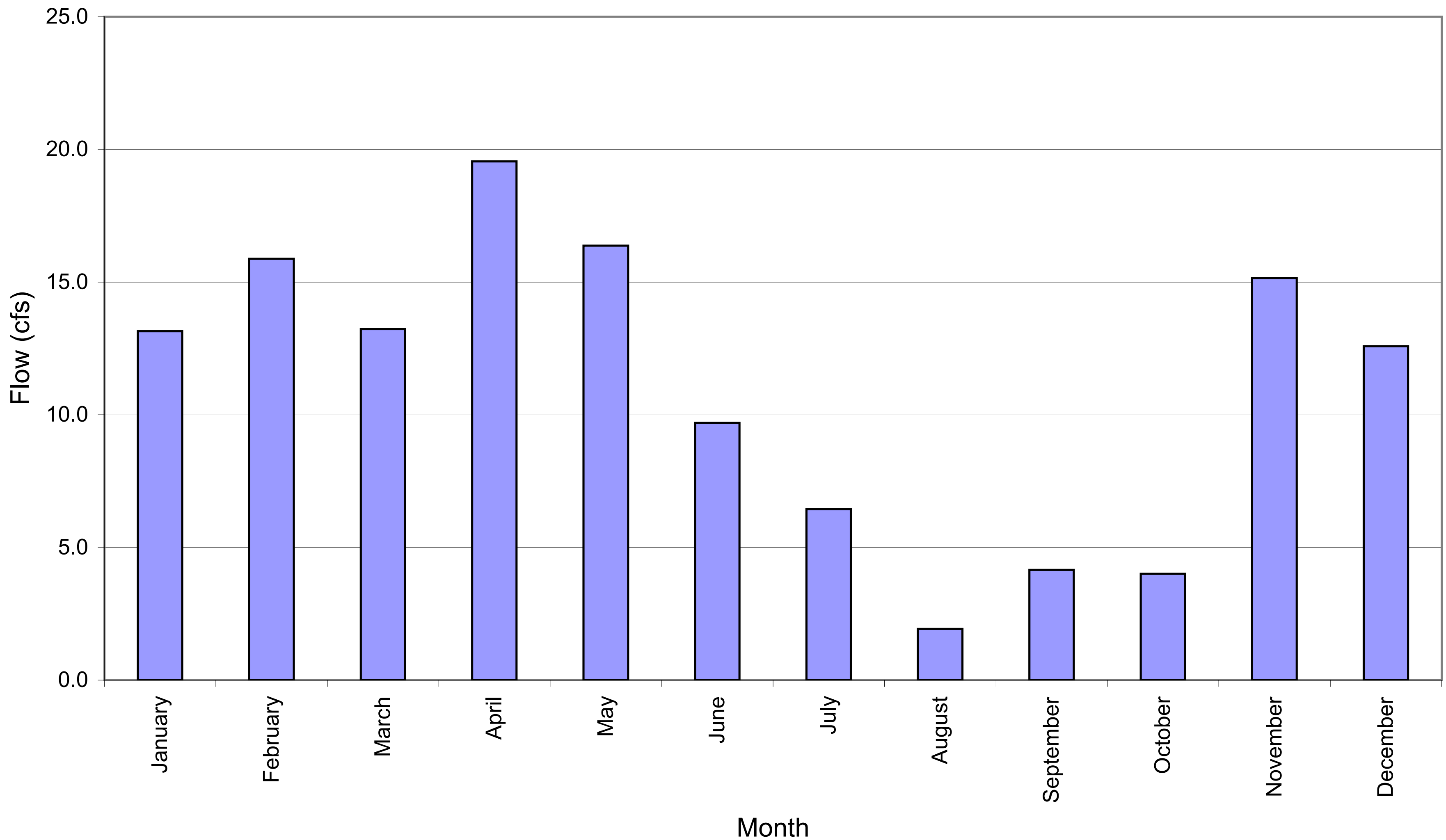

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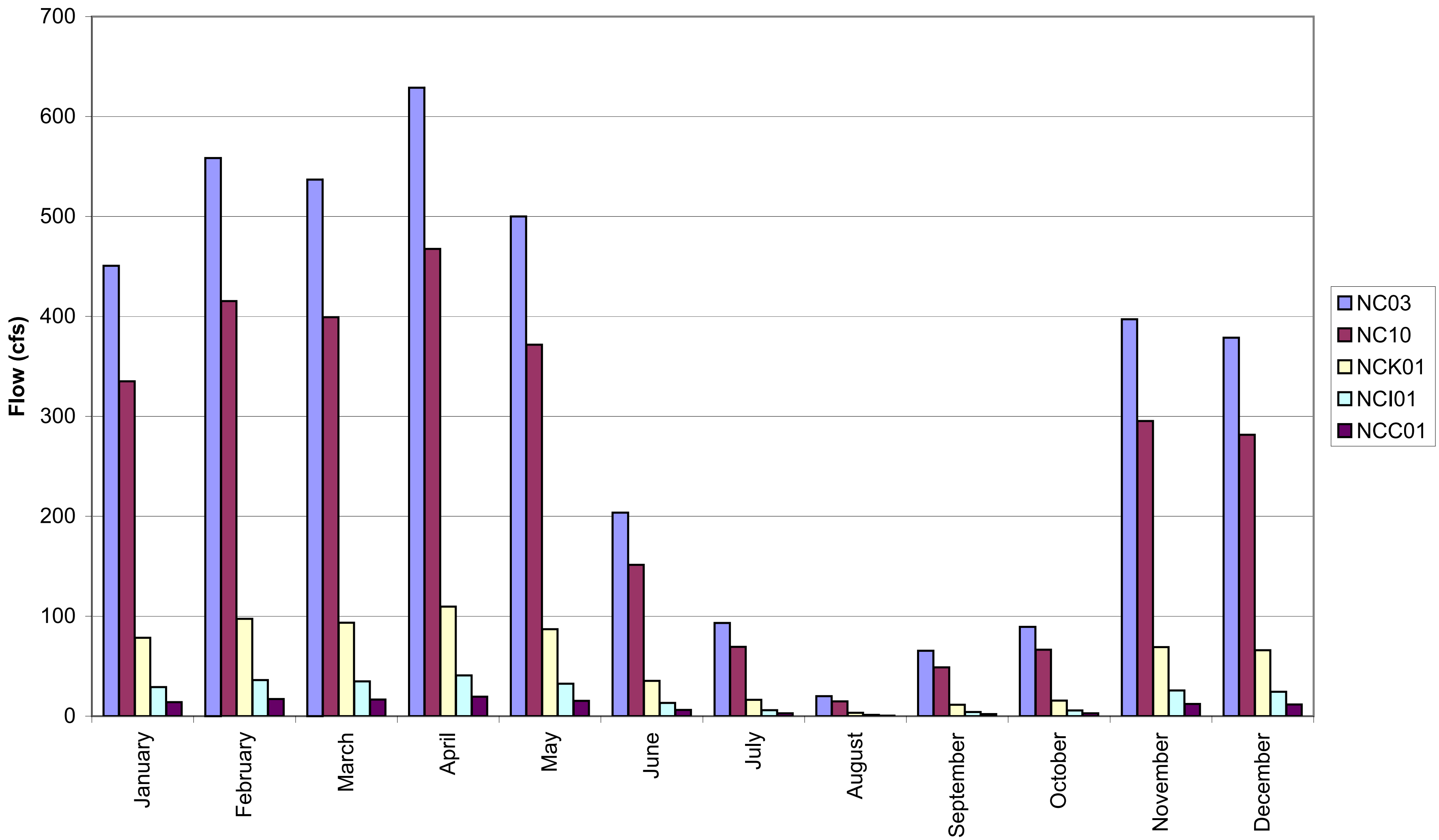
Figure 5-4: Estimated Streamflows in the Beaucoup Creek Watershed Calculated from Gage 05595730



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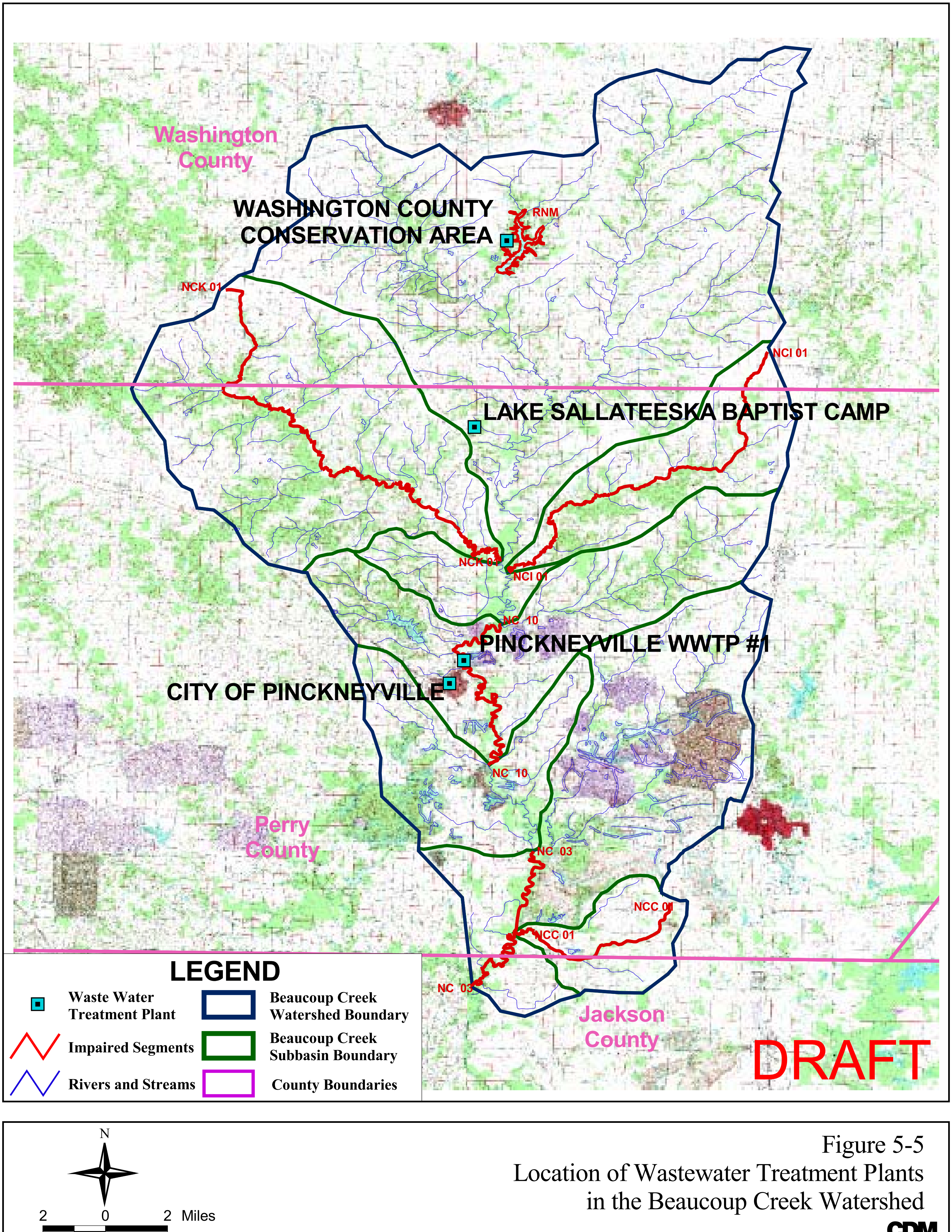

Figure 5-5
Location of Wastewater Treatment Plants in the Beaucoup Creek Watershed

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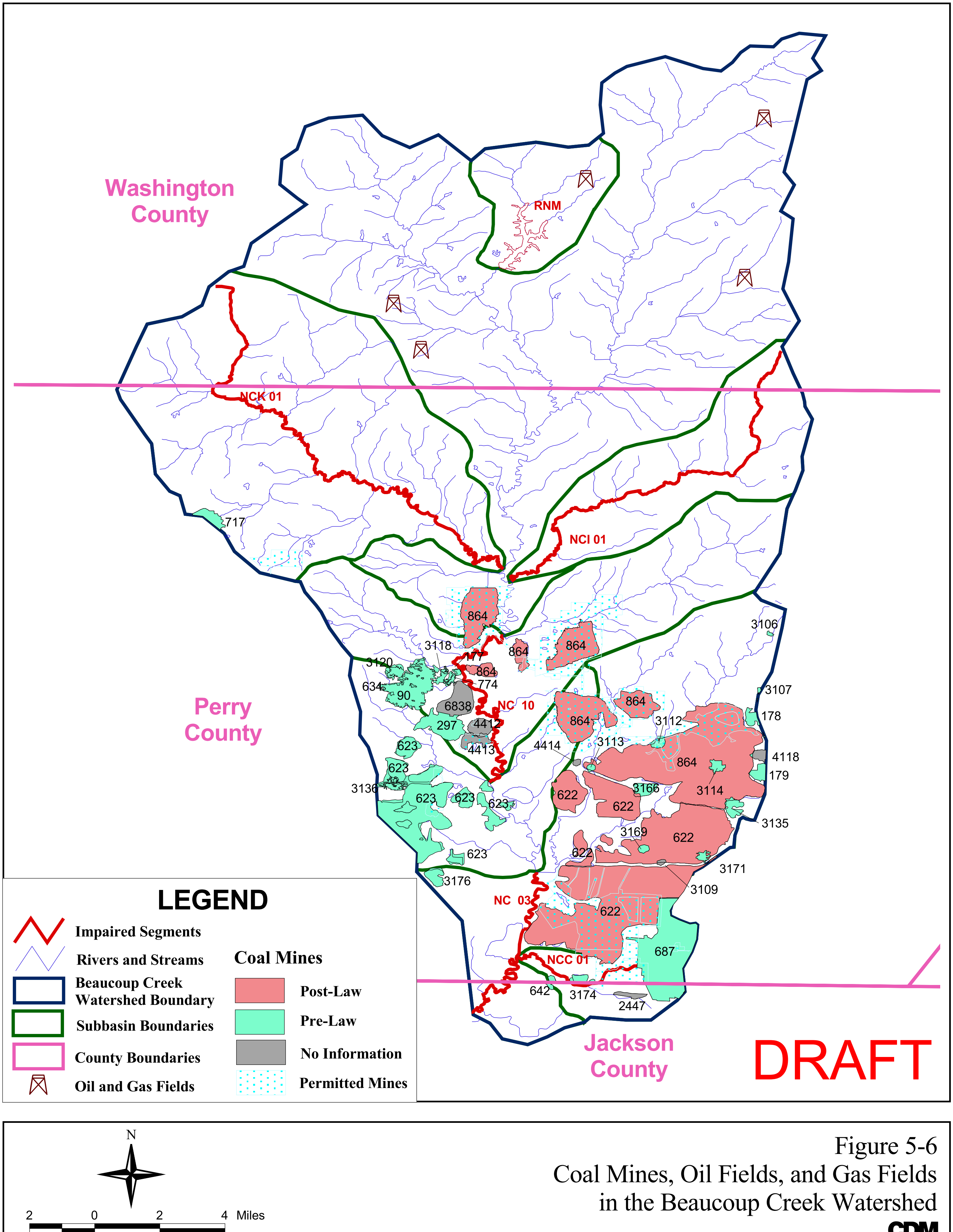

Figure 5-6
Coal Mines, Oil Fields, and Gas Fields
in the Beaucoup Creek Watershed

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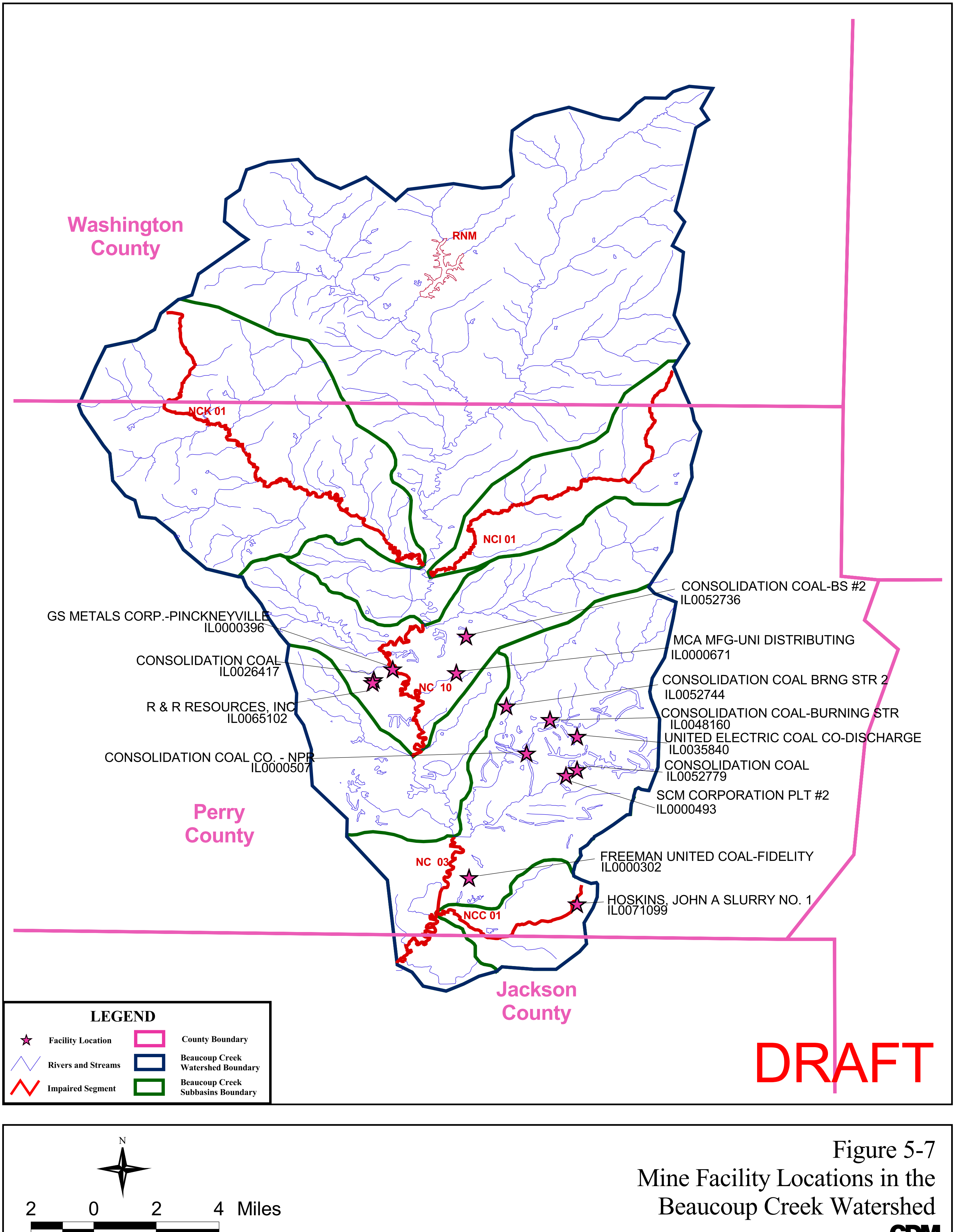

Figure 5-7
Mine Facility Locations in the
Beaucoup Creek Watershed

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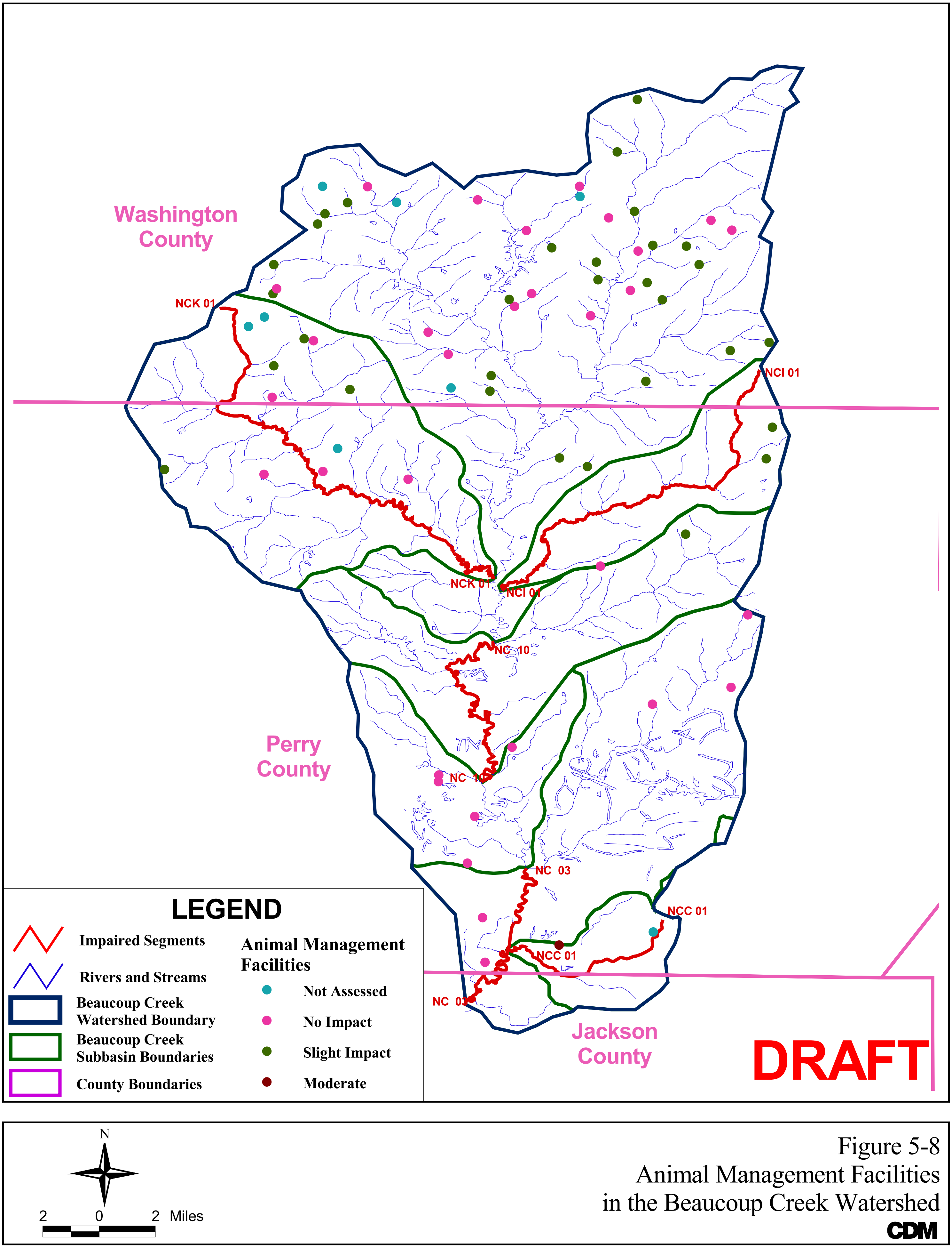

Figure 5-8
Animal Management Facilities in the Beaucoup Creek Watershed

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Section 6
Methodologies and Models to Complete TMDLs for the Beaucoup Creek Watershed

6.1 Set Endpoints for TMDLs

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

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

- stream segments: sulfates, TDS, DO, manganese
- lake segment: phosphorus, DO

6.2 Methodologies and Models to Assess TMDL Endpoints

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

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

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

6.2.1 Watershed Models

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

- simple models
- mid-range models
- detailed models

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

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

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

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

● High ◒ Medium ○ Low – Not Incorporated

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

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

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

● High ◒ Medium ○ Low – Not Incorporated

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

6.2.1.1 Watershed Model Recommendation

The watershed model recommendation for Washington County Lake is the Generalized Watershed Loading Function (GWLF) model. No watershed models will be utilized for stream TMDLs as methodologies will be utilized for stream segments in the Beaucoup Creek Watershed. The GWLF model was chosen for the Washington County Lake TMDL based on the following criteria:

- ease of use and Illinois EPA familiarity
- compatible with pollutants of concern and existing data
- provide adequate level of detail for decision making

The GWLF manual estimates dissolved and total monthly phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and onsite wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion, and sediment yield values (Haith et al. 1996).

6.2.2 Receiving Water Quality Models

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

Table 6-3 General Receiving Water Quality Model Characteristics

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

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

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

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

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

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

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

6.2.2.1 Receiving Water Model Recommendation

The receiving water model recommended for Washington County Lake is BATHTUB, which applies a series of empirical eutrophication models to reservoirs and lakes. The program performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. Eutrophication-related water quality conditions are predicted using empirical relationships (USEPA 1997a).

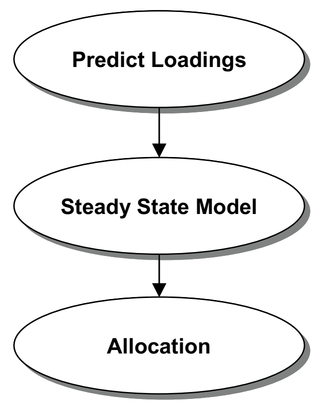
Because of the lack of spatial data sets for the stream segments within the Beaucoup Creek Watershed, methodologies based on the USEPA Screening Methods and Monte Carlo simulations will be utilized for stream TMDL development as discussed in the following section.

6.2.3 Washington County Lake TMDL

For Washington County Lake, a TMDL for the following constituents will be completed using a watershed/receiving water model combination:

- Phosphorus
- DO

The strategy for completing the watershed/receiving water model TMDL for Washington County Lake is shown in the schematic to the right. This strategy applies to constituents whose loads can be predicted using GWLF. This approach allows a linkage between source and endpoint resulting in an allocation to meet water quality standards. After loads are predicted, the BATHTUB model will be used to determine the resulting phosphorus concentrations within Washington County Lake. Model development is discussed further in Section 7.



Schematic 1
Strategy for Lake TMDL Modeling

6.2.4 Stream TMDLs for the Beaucoup Creek Watershed

Because of limited data available for watershed and receiving water model development for the Beaucoup Creek Watershed, TMDLs for the following constituents will be completed using methodologies: sulfates, TDS, DO, and manganese. For DO, a Streeter-Phelps analysis based on the USEPA Screening Procedures was developed. In addition, a screening level Watershed Management Model (WMM) analysis was conducted. These analyses are described in Section 8. For sulfates, TDS, and manganese a Monte Carlo simulation was conducted and the description of this analysis is also contained in Section 8.

6.2.5 Calibration and Validation of Models

The results of loading and receiving water simulations are more meaningful when they are accompanied by some sort of confirmatory analysis. The capability of any model to accurately depict water quality conditions is directly related to the accuracy of input data and the level of expertise required to operate the model. It is also largely dependent on the amount of data available. Calibration involves minimization of deviation between measured field conditions and model output by adjusting parameters of the model. Data required for this step are a set of known input values along with corresponding field observation results. Validation involves the use of a second set of independent information to check the model calibration. The data used for validation should consist of field measurements of the same type as the data output from the model. Specific features such as mean values, variability, extreme values, or all predicted values may be of interest to the modeler and require testing. Models are tested based on the levels of their predictions, whether descriptive or predictive. More accuracy is required of a model designed for absolute versus relative predictions. If the model is calibrated properly, the model predictions will be acceptably close to the field predictions.

The GWLF and BATHTUB models were calibrated based on existing data. As will be outlined in Section 7, the GWLF model was calibrated based on historical flow records. The calibration factors taken into account for the GWLF model were the recession constant and seepage constant. Water quality data on the tributaries to Washington County Lake were not available so the GWLF model could not be calibrated to tributary nutrient loads. Nutrient loads were based on literature values for Southern Illinois. GWLF model validation was not conducted as the hydrology was calibrated based on 16 years of observed flow. Data collection activities needed to calibrate nutrient loads are outlined in Section 10 Implementation Plan. The calibration process for the BATHTUB model is also outlined in Section 7. For Washington County Lake, loads from a normal, wet, and dry precipitation year were taken from GWLF and entered into the BATHTUB model, which predicted average in-lake concentrations that were in turn compared to observed lake concentrations as the basis for calibration.

6.2.6 Seasonal Variation

Consideration of seasonal variation, such that water quality standards for the allocated pollutant will be met during all seasons of the year, is a requirement of a TMDL submittal. TMDLs must maintain or attain water quality standards throughout the year and consider variations in the water body's assimilative capacity caused by seasonal changes in temperature and flow (USEPA 1999). Seasonal variation for the Beaucoup Creek Watershed is discussed in Section 9.

6.2.7 Allocation

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

The MOS can be set explicitly as a portion of the LC or implicitly through applying conservative assumptions in data analysis and modeling approaches. Data analyses and modeling limitations were taken into account when recommending a MOS. The allocation scheme (both LA and WLA) demonstrates that water quality standards will be attained and maintained and that the load reductions are technically achievable. The allocation is the foundation for the implementation and monitoring plan. Further discussion on the allocation is presented in Section 9.

6.2.8 Implementation and Monitoring

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

The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. Reductions from point sources through waste stream management, pretreatment controls, and other structural and nonstructural programs were also identified as applicable. The implementation plan for the Beaucoup Creek Watershed is presented in Section 10.

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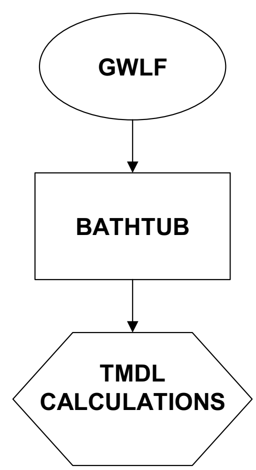
Section 7
Model Development for Washington County Lake

7.1 Basis for DO TMDL

The relationships between DO, chlorophyll "a," and phosphorus were discussed in Section 5.1.5.1.1. Figure 7-1 shows the relationship between chlorophyll "a" and DO for Washington County Lake. As explained in Section 5.1.5.1.1, the figure is expected to show a decrease with DO as chlorophyll "a" increases; however, Figure 7-1 shows a general increase of DO with chlorophyll "a." Reasons for poor correlation between DO and chlorophyll "a" could include diurnal fluctuations of DO and seasonal growth of algae impacting chlorophyll "a" concentrations. Figure 7-2 shows the relationship between chlorophyll "a" and total phosphorus. This figure indicates that as total phosphorus concentrations increase, so do chlorophyll "a" concentrations. The relationship in Figure 7-2 and the expected relationship in Figure 7-1 suggest that controlling total phosphorus will decrease chlorophyll "a" concentrations, which will in turn increase DO concentrations. It is therefore recommended that a TMDL endpoint of 0.05 mg/L for total phosphorus for Washington County Lake be utilized so that the DO standard of 6.0 mg/L (16 hours of any 24-hour period) is achieved.

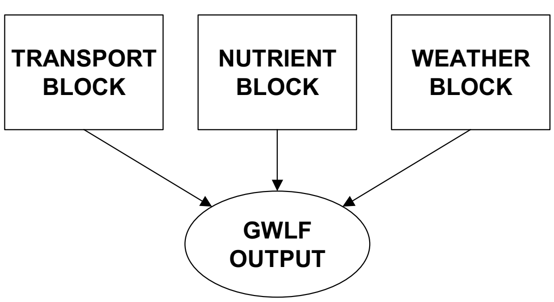
7.2 Model Overview

The models used for the TMDL analysis of Washington County Lake were GWLF and BATHTUB. These models require input from several sources including online databases, GIS-compatible data, and hardcopy data from various agencies. This section describes the existing data reviewed for model development, model inputs, and model calibration and verification.



Schematic 1 Models used for Washington County Lake TMDL calculation.

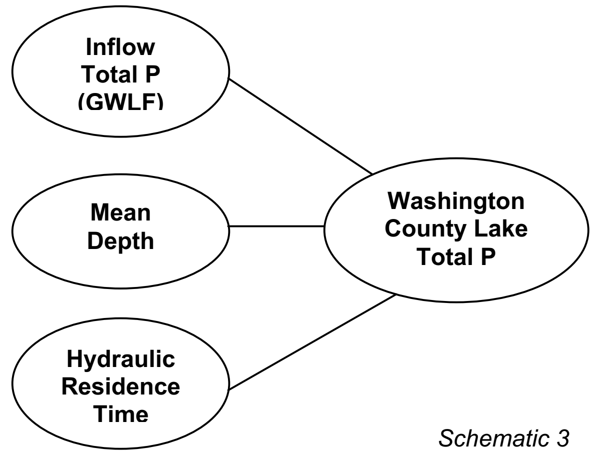
Schematic 1 shows how the GWLF model and BATHTUB model is utilized in calculating the TMDL. The GWLF model predicts phosphorus loads from the watershed. These loads are then inputted in the BATHTUB model to assess resulting phosphorus concentrations. The GWLF model outlined in Schematic 2 shows how GWLF predicts phosphorus loads from the watershed. The transport block of the GWLF model uses the Universal Soil Loss Equation to determine erosion in the watershed. The transport block also calculates runoff based on the SCS Curve Number



Schematic 2 GWLF Model.

equation. The nutrient block allows the model user to input concentrations of phosphorus contained in the soil and in the dissolved phase for runoff. These two blocks, in conjunction with the weather block, predict both solid and dissolved phosphorus loads.

Schematic 3 shows how, by using total phosphorus concentrations predicted from GWLF, the resulting in-lake total phosphorus concentrations can be predicted. The BATHTUB model uses empirical relationships between mean reservoir depth, total phosphorus inputted into the lake, and the hydraulic residence time to determine in-reservoir concentrations.



Schematic 3
BATHTUB Model Schematic.

7.3 Model Development and Inputs

The ability of the GWLF and BATHTUB models to accurately reflect natural processes depends on the quality of the input data. The following sections describe the selection, organization, and use of existing data as input to the GWLF and BATHTUB models and outline assumptions made in the process.

Due to the size of the Washington County Lake Watershed and the multiple tributaries contributing to the lake, the watershed area was divided into six sub-watersheds for accurate representation in the GWLF model. Flows within each of the subbasins were calculated from gage 05595730 with the drainage area ratio method presented in Section 5.1.3. To model Washington County Lake accurately in BATHTUB, the lake was divided in three sections surrounding each of the three monitoring stations.

7.3.1 Watershed Delineation

Prior to developing input parameters for the GWLF or BATHTUB models, a watershed for Washington County Lake was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation indicates that Washington County Lake captures flows from a watershed of approximately 10.3 square miles. The flow through the lake is primarily from northeast to southwest. Figure 7-3 at the end of this section shows the location of each water quality station in Washington County Lake, the boundary of the GIS-delineated watershed contributing to Washington County Lake, the six subbasins used in GWLF modeling, and the division of the lake for BATHTUB modeling purposes.

7.3.2 GWLF Inputs

GWLF requires input in the form of three data files that represent watershed parameters, nutrient contributions, and weather records. Each data file will be discussed in the following sections. The input files and actual values used for each parameter are listed in Appendix C. The GWLF manual is contained in Appendix D.

DEMs of 30-meter resolution were downloaded from the USGS National Elevation Dataset for development of GWLF model parameters discussed in this section (USGS 2002b).

7.3.2.1 Transport Data File

The transport data file provides watershed parameters including land use characteristics, evapotranspiration and erosion coefficients, groundwater and streamflow characteristics, and initial soil conditions. Table 7-1 presents each transport file input parameter and its source. Those requiring further explanation are discussed in the next section.

Table 7-1 Data Needs for GWLF Transport File (Haith et al. 1996)

Input Parameter	Source
Land Use	Critical Trends Assessment Database, GIS
Land Use Area	GIS
Curve Number	STATSGO, GIS, Critical Trends Assessment Database, TR-55 Manual, WMM Manual
KLSCP	STATSGO, GIS, DEM, GWLF Manual pages 34 and 35, NRCS
Evapotranspiration Cover Coefficient	GWLF Manual page 29
Daylight Hours	GWLF Manual page 30
Growing Season	GWLF Manual Recommendation page 54
Erosivity Coefficient	GWLF Manual pages 32 and 37
Sediment Delivery Ratio	GIS, GWLF Manual page 33
5-day Antecedent Rain and Snow	GWLF Manual Recommendation page 37
Initial Unsaturated Storage	GWLF Manual Recommendation page 30
Initial Saturated Storage	GWLF Manual Recommendation page 37
Recession Constant	Calibrated
Seepage Constant	Calibrated
Initial Snow	GWLF Manual Recommendation page 37
Unsaturated Available Water Capacity	GWLF Manual Recommendation page 37

7.3.2.1.1 Land Use

Land use for the Washington County Lake Watershed was extracted from the Critical Trends Assessment Database grid for Washington County in GIS. Within the transport input file, each land use must be identified as urban or rural. The land uses were presented in Table 5-13.

Individually identifying each field of crops or urban community in GWLF would be time intensive, so each land use class was aggregated into one record for GIS and GWLF representation. For example, the area of each row crop field was summed to provide a single area for row crops. Additionally, the parameters for each row crop field were averaged to provide a single parameter for the row crop land use. Details of the parameter calculation are contained in the remainder of this section.

GWLF computes runoff, erosion, and pollutant loads from each land use, but it does not route flow over the watershed. For example, the model does not recognize that runoff may flow from a field of corn over grassland and then into the river. The model assumes all runoff from the field of corn drains directly to the stream. Therefore, the location of each land use is irrelevant to the model allowing each land use class to be aggregated into a single record.

To provide accurate modeling in GWLF, the rural grassland land use class, presented in Table 5-13, was separated into two subclasses of pasture and hayland based on the recommendation of the Washington County NRCS (2002a). The GWLF model requires nutrient runoff concentrations for each land use, and the two subclasses of rural grassland have varying concentrations. The area of each subclass was estimated from the GIS-derived rural grassland area and suggested percentages of each subclass by the Washington County NRCS (2002a).

Due to the detailing of crops, the Cropland Data Layer land use classes, presented in Table 5-16, were used to generate evapotranspiration cover coefficients, cropping management factors, and to verify the land use obtained from the Critical Trends Assessment. Land uses used in GWLF correspond to land uses in the Critical Trends Assessment, so calculations based on the Cropland Data Layer land use classes were typically weighted by area to match the Critical Trends Assessment classes. Details of the calculations are presented in later sections and Appendix E.

7.3.2.1.2 Land Use Area

GIS was used to summarize the area of each aggregated land use in square meters as well as acres and hectares. Area in hectares was input for each land use in the transport data file.

7.3.2.1.3 Curve Number

The curve number, a value between zero and 100, represents the ability of the land surface to infiltrate water, which decreases with increasing curve number. The curve number is assigned with consideration to hydrologic soil group and land use. The hydrologic soil group, represented by the letters A through D, denotes how well a soil drains. A well-drained, sandy soil would be classified as a type A soil, whereas clay would be classified as a type D soil. This property is identified in the STATSGO attribute table for each soil type.

Assigning curve numbers to a large area with multiple soil types and land uses was streamlined using the GIS *ArcView* project, CRWR-PrePro (Olivera 1998), developed at the University of Texas at Austin. This process was used to develop a curve number grid. Scripts in the project intersect shapefiles of land use and soil with the STATSGO attribute table to create a grid in which each cell contains a curve number based on the combination.

The transport data file requires that a single curve number be associated with each land use. To accomplish this, the curve number in each grid cell was averaged over each aggregated land use area. Details of the GIS process are provided in Appendix E.

7.3.2.1.4 KLSCP

GWLF uses the Universal Soil Loss Equation, represented by the following equation (Novotny and Olem 1994), to calculate soil erosion.

$$A = (R)(K)(LS)(C)(P)$$

where A = calculated soil loss in tons/ha for a given storm or period
R = rainfall energy factor
K = soil erodibility factor
LS = slope-length factor
C = cropping management factor
P = supporting practice factor

The combined coefficient, KLSCP, is required as input to GWLF for each rural land use. The development of each factor will be discussed in the next sections. GWLF calculates the rainfall energy factor (R) with precipitation and a rainfall erosivity coefficient that will be discussed in Section 7.3.2.1.5.

Soil Erodibility Factor (K). The soil erodibility factor, K, represents potential soil erodibility. The STATSGO soils representation in GIS is by map unit, which incorporates multiple soil types (and K-values) in each unit, but the STATSGO attribute table lists the K factor for each soil type. Using this column, a weighted K factor was developed for each GIS map unit. Details of this process are provided in Appendix E.

Topographic Factor (LS). The topographic, or LS, factor represents the contribution to erosion from varying topography. This factor is independent of soil type, but dependent on land use and land surface elevations, requiring use of the DEM. Multiple equations and methodologies are used to calculate the LS factor, and for this application, we used methodology outlined in the *TMDL USLE* software package (USEPA 2001). The LS factor was calculated with a series of equations that compute intermediate values of slope steepness, runoff length, and rill to interill erosion before combining them into the LS factor. This process was also performed with GIS analyses to automate computational tasks. Details of the GIS computation are provided in Appendix E.

Cropping Management Factor (C). The cropping management factor, C, represents the influence of ground cover, soil condition, and management practices on erosion. The Washington County NRCS office provided a table of C factors for various crops and tillage practices (NRCS 2002a). The table is included as Appendix F. The NRCS office also estimated the percentage of each tillage practice for corn, soybeans, and small grains in the Washington County Lake Watershed. Although the percentage of each tillage practice is known, the specific locations in the watershed to which these practices are applied were unknown, so a weighted C-factor was created for these crops. In Table 7-2, the weighted C factor for corn, soybeans, and small grains, and the C factor for other land uses, are listed by the Cropland Data Layer land uses and areas in the Washington County Lake Watershed.

Table 7-2 Cropland Data Layer Land Uses and C Factors

Land Use	Area (acres)	C factor
Corn	977	0.12
Sorghum	6	0.12
Soybeans	1534	0.08
Winter Wheat	248	0.11
Other Small Grains & Hay	169	0.11
Double-Cropped WW/SB	975	0.12
Idle Cropland/CRP	11	0.004
Fallow/Idle Cropland	265	0.004
Pasture/Grassland/Non-ag	877	0.004
Woods	1160	0.003
Clouds	9	–
Urban	20	–
Water	206	–
Buildings/Homes/Subdivisions	61	–
Wetlands	62	–

The identification of crops is more detailed in the Cropland Data Layer file than the Critical Trends Land Assessment file, but the latter is used for GWLF input. Therefore, the C factor associated with the Cropland Data Layer land uses was weighted by area to create a C factor for the Critical Trends Land Assessment land uses shown in Table 7-3 at the end of this section. A more detailed description of the weighting procedure is provided in Appendix E.

Supporting Practice Factor (P). The supporting practice factor, P, represents erosion control provided by various land practices such as contouring or terracing. None of these land practices are utilized in the Washington County Lake Watershed, so a P factor of one was assigned to each land use.

7.3.2.1.5 Erosivity Coefficient

The erosivity coefficient varies spatially across the United States. Figure B-1 on page 32 of the GWLF manual places Washington County Lake in Zone 19, which corresponds to a cool season rainfall erosivity coefficient of 0.14 and a warm season coefficient of 0.27.

7.3.2.1.6 Evapotranspiration (ET) Cover Coefficient

An ET cover coefficient for each month is required as an input parameter to GWLF representing the effects of ground cover on evapotranspiration. Ground cover changes with land use and growing season, so the computation of a single cover coefficient for each month required a series of calculations. ET cover coefficients for corn, winter wheat, sorghum, and soybeans at 10 percent increments of the growing season were obtained from GWLF Manual, page 29. These coefficients were weighted by the area of each crop in the Cropland Data Layer land use file to compute a single crop ET cover coefficient for each 10 percent increment of the growing season. The crop coefficients for each portion of the growing season were averaged to obtain a single crop coefficient for each calendar month. Monthly ET cover coefficients for pasture, woods, and urban areas were also obtained from pages 29 and 30 of the GWLF

Manual. A monthly cover coefficient for water and wetlands was assumed to be 0.75. Weighting the coefficient for each land use by the Cropland Data Layer land use area created a single ET cover coefficient for each month. Details of the ET cover coefficient calculation are provided in Appendix E.

7.3.2.1.7 Recession Constant

The recession coefficient controls the falling limb of the hydrograph in GWLF. This coefficient was calibrated to USGS streamflow and is discussed in Section 7.4.1.

7.3.2.1.8 Seepage Constant

The seepage constant controls the amount of water lost from the GWLF system by deep seepage. This value was also determined by calibration and is detailed in Section 7.4.1.

7.3.2.1.9 Sediment Delivery Ratio

The sediment delivery ratio is based on watershed area. The watershed area determined by GIS was used to obtain the corresponding sediment delivery ratio from the chart on page 33 of the GWLF manual. The sediment delivery ratios, representing the annual sediment yield per annual erosion for each subbasin contributing to Washington County Lake, are presented in Table 7-4.

Table 7-4 Sediment Delivery Ratios in the Washington County Lake Watershed

Subbasin	Area (ac)	Sediment Delivery Ratio
1	1431	0.25
2	1535	0.25
3	1130	0.28
4	823	0.30
5	1093	0.28
6	577	0.33

7.3.2.2 Nutrient Data File

The nutrient input file contains information about dissolved phosphorus and nitrogen from each rural land use, solid-phase phosphorus and nitrogen from urban runoff, solid-phase nutrient concentrations in the soil and groundwater, and any point source inputs of phosphorus or nitrogen.

All solid-phase nutrient concentrations from runoff for Washington County Lake were obtained from the GWLF manual. Figure B-4 (page 39 of Appendix D) was utilized for determining solid-phase phosphorus concentrations in the soil. A mid-range value of 0.15 percent phosphate was selected and then converted to 1,500 parts per million (ppm) using the relationship 0.1 percent = 1,000 ppm. Phosphate is composed of 44 percent phosphorus, so the 1,500-ppm phosphate was multiplied by 0.44 to obtain a value of 660-ppm phosphorus in the sediment. This solid-phase phosphorus concentration was multiplied by the recommended enrichment ratio of 2.0 and therefore a total solid-phase concentration of 1,320 ppm was utilized for modeling purposes. The enrichment ratio represents the ratio of phosphorus in the eroded soil to that in the non-eroded soil. Specific soil phosphorus data is not available, so the GWLF manual recommended enrichment ratio of 2.0 was used. Dissolved phosphorus concentrations in the runoff from each agricultural land use were obtained from page 41 of the GWLF manual, with the exception of hayland under the rural grassland land use and concentrations from animal management facilities. The hayland dissolved phosphorus concentration was estimated from the dissolved phosphorus concentration for pasture. Hayland is assured to have less animals, and therefore animal waste, than pasture land, so the concentration was reduced for hayland. The selection of dissolved phosphorus concentrations will be confirmed in Section 7.4.1. The concentration from the dairy was obtained from USEPA, which provides a range of 5 to 500 mg/L for dairy barnyards (2000). The runoff phosphorus concentration from the feedlots and animal management areas were obtained from Novotny and Olem with a range of 4 to 15 mg/L (1994). The concentrations used to model the dairies and animal management areas were dependent on the potential impact each facility had on the receiving waters, as recorded in the GIS file discussed in Section 5.1.7.3. One dairy was identified in the Washington County Lake Watershed as potentially having a slight impact on water quality in the receiving stream, and one animal management facility was not assessed. The remaining three facilities in the watershed were designated as potentially having no impact on water quality. The suggested range of dissolved phosphorus concentrations for dairies was categorized by the assessed impacts on water quality. Table 7-5 lists the range of concentrations in mg/L assigned to each assessment category. The dairy in the Washington County Lake Watershed was assigned a dissolved phosphorus concentration of 125 mg/L because it is the middle of the "slight impact" range. The non-assessed animal management facility was assigned a dissolved phosphorus concentration of 9.5 mg/L, which is the midpoint of the suggested range of 4 to 15 mg/L.

Table 7-5 Dissolved Phosphorus Concentrations for Dairies Based on Assessment

Range (mg/L)	Impact Assessment
5 – 50	No Impact
50 – 200	Slight
200 – 350	Moderate
350 – 500	High

Table 7-6 lists the land uses in the Washington County Lake Watershed and associated runoff phosphorus concentrations used in the GWLF model. It should be noted that although the majority of dissolved phosphorus concentrations in Table 7-6 exceed the endpoint of 0.05 mg/L of total phosphorus, once the surface runoff reaches Washington County Lake or its tributaries, it mixes with water already in the stream or lake and the concentration decreases. Therefore, it cannot be concluded, without analysis, that constituents with dissolved concentrations above the endpoint for total phosphorus are responsible for water quality impairments.

Table 7-6 Dissolved Phosphorus Concentrations in Runoff from the Washington County Lake Watershed

Land Use	Dissolved Phosphorus (mg/L)
Row Crop	0.26
Small Grains	0.30
Rural Grasslands	
Pasture	0.25
Hayland	0.15
Deciduous Forest	0.009
Coniferous Forest	0.009
Dairy	125
Animal Management	9.5
Urban-High Density	0.01

The GWLF manual suggests nutrient concentrations in groundwater based on the percentage of agricultural versus forestlands. These percentages were calculated from the land use areas in the watershed, and the appropriate groundwater concentrations were selected from the GWLF manual, page 41. The percentage of agricultural lands in each subbasin and their corresponding groundwater dissolved phosphorus concentrations are provided in Table 7-7.

Table 7-7 Percentage of Agricultural and Forest Lands and Groundwater Phosphorus Concentrations in the Washington County Lake Watershed (Haith et al. 1996)

Subbasin	Agriculture	Forest	Dissolved Phosphorus (mg/L)
1	89%	9%	0.085
2	92%	7%	0.085
3	87%	12%	0.085
4	66%	27%	0.067
5	57%	33%	0.055
6	58%	30%	0.055

7.3.2.3 Weather Data File

The weather data file is a text file of daily precipitation and temperature and was compiled from weather data presented in Section 5.1.4. An excerpt of the weather data file is recorded in Appendix C. The precipitation data are used in GWLF to determine runoff, erosion, and evapotranspiration, and temperature data are used to compute potential evaporation and snowmelt.

7.3.3 BATHTUB Inputs

BATHTUB has three primary input interfaces: global, reservoir segment(s), and watershed inputs. The individual inputs for each of these interfaces are described in the following sections, and the data input screens are provided in Appendix C.

Table 7-8 Annual Precipitation in Washington County

Model Year	Precipitation (inches)
1986	44
1987	35
1988	39
1989	36
1990	40
1991	39
1992	32
1993	48
1994	35
1995	47
1996	41
1997	35
1998	41
1999	36
2000	43
2001	31
Average	39

Multiple simulations of the BATHTUB model were run to investigate variations in total phosphorus concentrations in a wet, normal, and dry year of precipitation to bracket conditions for calibration. The first step in choosing the wet, normal, and dry years was to calculate average annual precipitation. BATHTUB models lake concentrations based on a water year (October to September), so the precipitation data presented in Section 5.1.4 were averaged to coincide with the water year. Table 7-8 shows these annual and average annual precipitation values in Washington County. Each water year was then classified as wet, dry, or normal based on a comparison to the average water year precipitation of 39 inches. Another consideration in selecting the years for simulation was determining which years coincided with the collection dates of in-lake total phosphorus concentrations at the water quality stations within recent years. With these criteria, the normal, wet, and dry years were chosen as 1990, 1995, and 2001, respectively, for Washington County Lake. Based on Table 7-8, 1990 is designated as the normal year, 1995 is designated as the wet year, and 2001 is designated as a dry year.

7.3.3.1 Global Inputs

Global inputs represent atmospheric contributions of precipitation, evaporation, and atmospheric phosphorus. Precipitation was discussed in the previous section and is shown in Table 7-8 for the model years 1990, 1995, and 2001. An average annual evaporation was determined from pan evaporation data as discussed in Section 5.1.4. The default atmospheric phosphorus deposition rate suggested in the BATHTUB model was used in absence of site-specific data, which is a value of 30 kg/km^2-yr (USACE 1999).

7.3.3.2 Reservoir Segment Inputs

The data included as segment inputs represents reservoir characteristics in BATHTUB. These data were used in BATHTUB simulations and for calibration targets. The calibration targets are observed water quality data summarized in Section 5.1.5.1.

Washington County Lake was modeled as three segments in BATHTUB to represent the lake characteristics around each water quality station, so an average annual value of total phosphorus was calculated for each site for input of observed data. The lake segments are shown in Figure 7-3 at the end of this section. The averages of total phosphorus sampled at one-foot depth were presented in Table 5-7; however, the BATHTUB model calculates an average lake concentration. Therefore, total phosphorus samples at all depths were averaged to provide targets for the BATHTUB model. Table 7-9 shows the average annual total phosphorus concentrations for all sample depths at each station in Washington County Lake. As mentioned in Section 5.1.5.1.2, station RNM-1 had samples taken at one-foot depth from the surface and at the lake bottom, whereas stations RNM-2 and RNM-3 were only sampled at one-foot depth. The raw data for all sample depths are contained in Appendix A.

Table 7-9 Average Total Phosphorus Concentrations in Washington County Lake (mg/L) over all Depths

Year	RNM-1	RNM-2	RNM-3	Lake Average
1990	0.22	0.17	0.20	0.20
1995	0.27	0.15	0.19	0.20
2001	0.09	0.07	0.11	0.09

Other segment inputs include lake depth, lake length, and depth to the metalimnion. The lake depth was represented by the averaged data from the water quality stations shown in Table 5-23. The lake length was determined in GIS, and the depth to the metalimnion was estimated from a chart of temperature versus depth. The charts are presented in Appendix G.

7.3.3.3 Tributary Inputs

Tributary inputs to BATHTUB are drainage area, flow, and total phosphorus (dissolved and solid-phase) loading. The drainage area of each tributary is equivalent to the basin or subbasin it represents, which was determined with GIS analyses. For the Washington County Lake Watershed, the six subbasins modeled in GWLF represent tributary inputs. Loadings were calculated with the monthly flow and total phosphorus concentrations obtained from GWLF output. The monthly values were summed over the water year for input to BATHTUB. To obtain flow in units of volume per time, the depth of flow was multiplied by the drainage area and divided by one year. To obtain phosphorus concentrations, the nutrient mass was divided by the volume of flow.

7.4 Model Calibration and Verification

The GWLF model was calibrated prior to BATHTUB calibration. The GWLF model for the Washington County Lake Watershed was calibrated to flow data, as tributary phosphorus concentrations were not available. Nutrient concentrations entered into the GWLF model were calibrated based on response occurring in the BATHTUB model. Therefore, the nutrient block of the GWLF model and the BATHTUB model were calibrated together to reach agreement with observed data in Washington County Lake.

7.4.1 GWLF Calibration

The GWLF model must run from April to March to coincide with the soil erosion cycle. GWLF does not retain erodible sediment between model years, so the model year must begin after the previous year's sediment has been washed off. The model assumes that the soil erosion cycle begins with spring runoff events in April and that erodible soil for the year has been washed off, by the end of winter, for the cycle to begin again the following April. GWLF generates monthly outputs including precipitation, flow, runoff and nutrient mass per watershed, and annual outputs including precipitation, flow, runoff, and nutrient mass per land use. These outputs are part of the input for the BATHTUB model.

Instream nutrient data was not available for model calibration, so GWLF was only calibrated to flow. The monthly average flow output from GWLF was compared to the monthly average streamflow calculated from USGS gage 05595730 with the drainage area ratio method presented in Section 5.1.3. The model flow was calibrated visually through the recession constant and seepage constant. Visual calibration is a subjective approach to model calibration in which the modeler varies inputs to determine the parameter combination that looks like the best fit to the observed data (Chapra 1997). According to the GWLF manual, an acceptable range for the recession constant is 0.01 to 0.2. No range suggestions are provided for the seepage constant. Figure 7-4 (at the end of this section) shows the comparison between the two flows for subbasin 1 of Washington County Lake. The GWLF model for Washington County Lake was visually calibrated with a resulting recession constant of 0.1 and a seepage constant of 0.05 in each subbasin. Once calibrated, the model output data could properly be included as BATHTUB inputs. The GWLF model was not validated as flow was calibrated by visually comparing 16 years of observed flow. The summary output from GWLF for each subbasin is included in Appendix C.

Although instream nutrient concentrations are not available for the tributaries to Washington County Lake, Clean Lakes Studies have been conducted by the Illinois EPA on various Illinois lake watersheds, which do provide instream nutrient data for lake tributaries including dissolved and total phosphorus. The dissolved and total phosphorus concentrations, predicted by GWLF for tributaries to the Washington County Lake subbasins, were compared to the measured dissolved and total phosphorus concentrations from tributaries to lakes observed in the Clean Lakes studies as shown in Figure 7-5. The concentrations within the Washington County Lake Watershed are within the ranges of those in the other lake watersheds shown in Figure 7-5.

Table 7-10 shows the comparison between dissolved and total phosphorus in watersheds from Clean Lakes Studies and in the Washington County Lake Watershed.

Table 7-10 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Washington County Lake Watershed

Watershed	Site	Mean Dissolved Phosphorus (mg/L)	Mean Total Phosphorus (mg/L)	Dissolved/Total Phosphorus
Nashville City	ROO 02	0.68	0.89	0.76
Paradise	RCG 02	0.06	0.07	0.87
Raccoon	RA 02	0.30	0.46	0.66
	RA 03	0.21	0.29	0.71
	RA 04	0.46	0.63	0.73
	RA 05	0.07	0.22	0.30
Lake Lou Yeager	A	0.06	0.13	0.46
	B	0.15	0.16	0.92
	C	0.05	0.25	0.20
	D	0.13	0.17	0.78
	E	0.06	0.12	0.46
	F	0.17	0.20	0.87
	G	0.33	0.41	0.79
	H	0.33	0.35	0.93
	I	0.13	0.14	0.96
Washington County	1	0.08	0.22	0.35
	2	0.08	0.34	0.24
	3	0.15	0.35	0.41
	4	0.04	0.17	0.24
	5	0.03	0.13	0.24
	6	0.02	0.14	0.17

The ratio of dissolved to total phosphorus in the Washington County Lake subbasins is within the range of ratios represented by the Clean Lakes Studies, except for Subbasin 6, which is slightly below the low end of the range.

7.4.2 BATHTUB Comparison with Observed Data

The BATHTUB model's response to changes in the GWLF nutrient block was compared to known in-lake concentrations of total phosphorus and chlorophyll "a" for each year of simulation. These known concentrations were presented in Tables 5-7 and 5-8. The BATHTUB manual defines the limits of total phosphorus calibration factors as 0.5 and 2.0. The calibration factor accounts for sedimentation rates, and the limits were determined by error analysis calculations performed on test data sets (USACE 1999). The calibration limits for chlorophyll "a" are not defined in the BATHTUB manual.

The GWLF model was set at a total phosphorus soil concentration of 1,320 ppm based on comparison with observed data in the BATHTUB model. As part of the comparison process, the watershed was also modeled with a total phosphorus soil concentration of 1,672 ppm to perform a sensitivity analysis on soil phosphorus. Increasing the total soil phosphorus concentration shows little impact on the estimated in-lake concentrations (Table 7-11). The calibration factor range for total phosphorus modeling in BATHTUB is 0.5 to 2, and use of the 1,320 ppm total phosphorus in the soil falls within this accepted range except for 1990. This calibration set (1,320 ppm total soil phosphorus) was still utilized as the other two recent years fell within the calibration range, and no recent soil phosphorus test data was available to confirm use of a higher soil phosphorus. Table 7-11 also shows what calibration factors for chlorophyll "a" would be required so that estimated concentrations would match observed concentrations. The columns labeled *target* in Table 7-11 represent the average observed in-lake concentrations. The results of the modeling sensitivity analyses are contained in Appendix H.

Table 7-11 Washington County Lake Calibration Sensitivity Analysis

Year	In-Lake Target Total Phosphorus (mg/L)	In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Target Chlorophyll "a" (μg/L)	In-Lake Estimated Chlorophyll "a" (μg/L)	Chlorophyll "a" Calibration Factor
Soil Total Phosphorus 1,320 ppm							
1990	0.19	0.07	85%	2.6	73.0	38.2	1.9
1995	0.18	0.11	73%	1.8	54.2	48.3	1.1
2001	0.08	0.07	39%	1.2	36.5	33.2	1.1
Soil Total Phosphorus 1,672 ppm							
1988	0.19	0.08	84%	2.5	73.0	39.1	1.9
1994	0.18	0.11	70%	1.6	54.2	50.3	1.1
2001	0.08	0.08	31%	1.0	36.5	37.1	1.0

A robust calibration and validation of Washington County Lake could not be completed because the following information was not available: observed nutrient concentrations in tributaries to the lake, site-specific data on internal cycling rates, reservoir outflow rates, and nutrient concentrations in reservoir releases. The analysis presented in Table 7-11 is therefore considered a preliminary calibration. However, BATHTUB modeling results indicate a fair estimate between predicted and observed values, for the years modeled based on error statistics calculated by the BATHTUB model, and should be sufficient for estimating load reductions required in the watershed and from internal cycling within the reservoir. BATHTUB calculates three measures of error on each output concentration. If the absolute value of the error statistic is less than 2.0, the modeled output concentration is within the 95 percent confidence interval for that constituent (USACE 1999). A robust calibration and validation of Washington

County Lake will be possible if data collection activities outlined in the future monitoring in Section 10 Implementation are implemented.

Based on modeling results, it appears that internal cycling is occurring in all pools of Washington County Lake in 1990 and near the dam pool in 1995 and 2001. The BATHTUB manual notes that internal cycling can be significant in shallow prairie reservoirs and provides Lake Ashtabula (approximately 42 feet deep) as an example (USACE 1999 and 2003). Table 5-23 notes a depth of approximately 14 feet for Washington County Lake, which places it in the category of shallow reservoir. Literature sources suggest that internal loading for deeper, more stratified lakes could be in the range of 10 to 30 percent of total loadings and that values for shallower reservoirs could be much higher (Wetzel 1983). Estimates of internal cycling are also included in Table 7-11.

Because the modeling of Washington County Lake changes based on annual loadings and climatic conditions, a validation of the model could not be completed. The model was calibrated for three climatic conditions, which will be the basis for the TMDL analysis presented in Section 9. The preliminary calibrated model was used to estimate the amount of load reductions needed from the watershed and internal loads to meet water quality standards.

Figure 7-1: Relationship between DO at One-foot Depth and Chlorophyll "a" in Washington County Lake

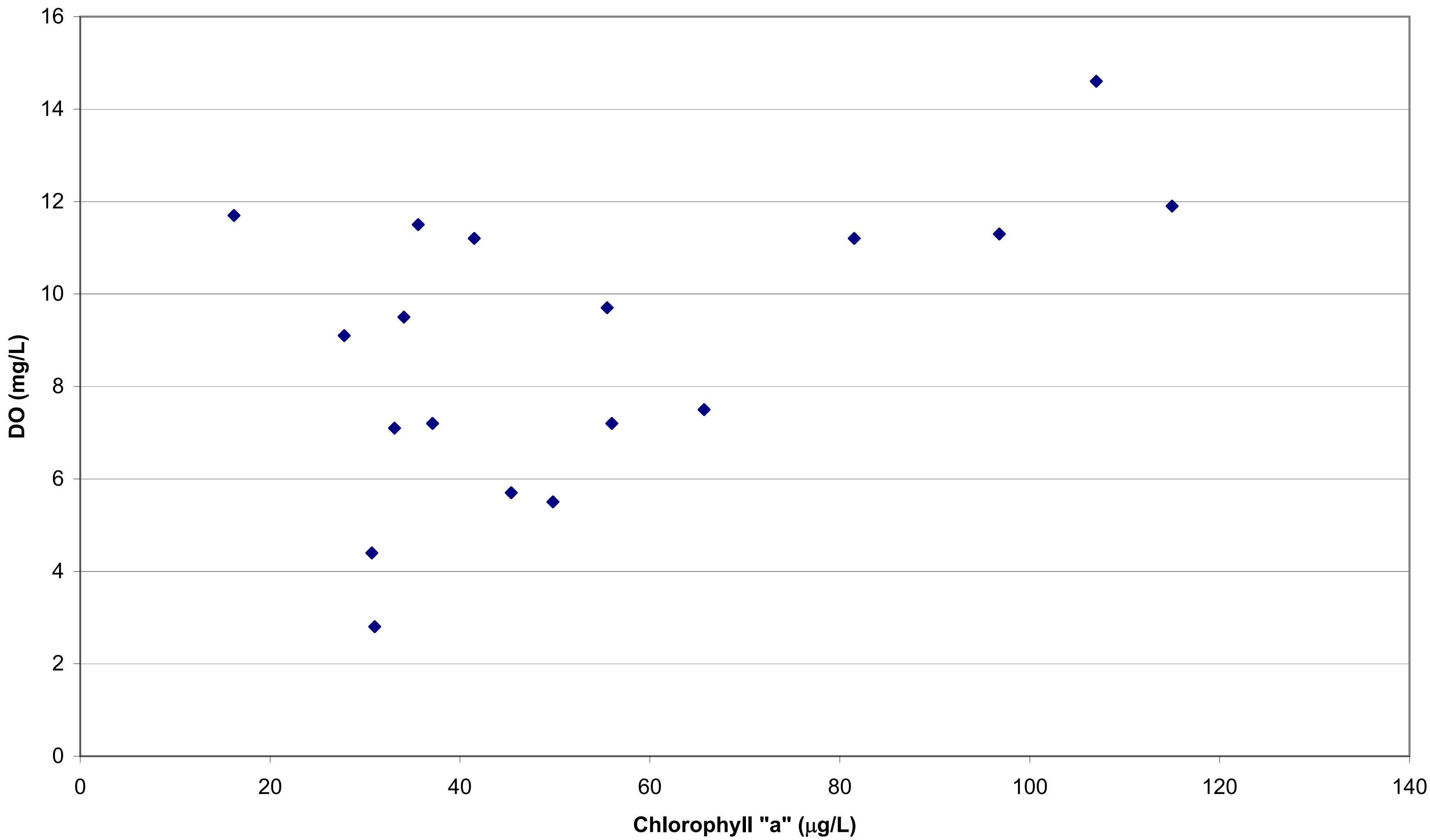


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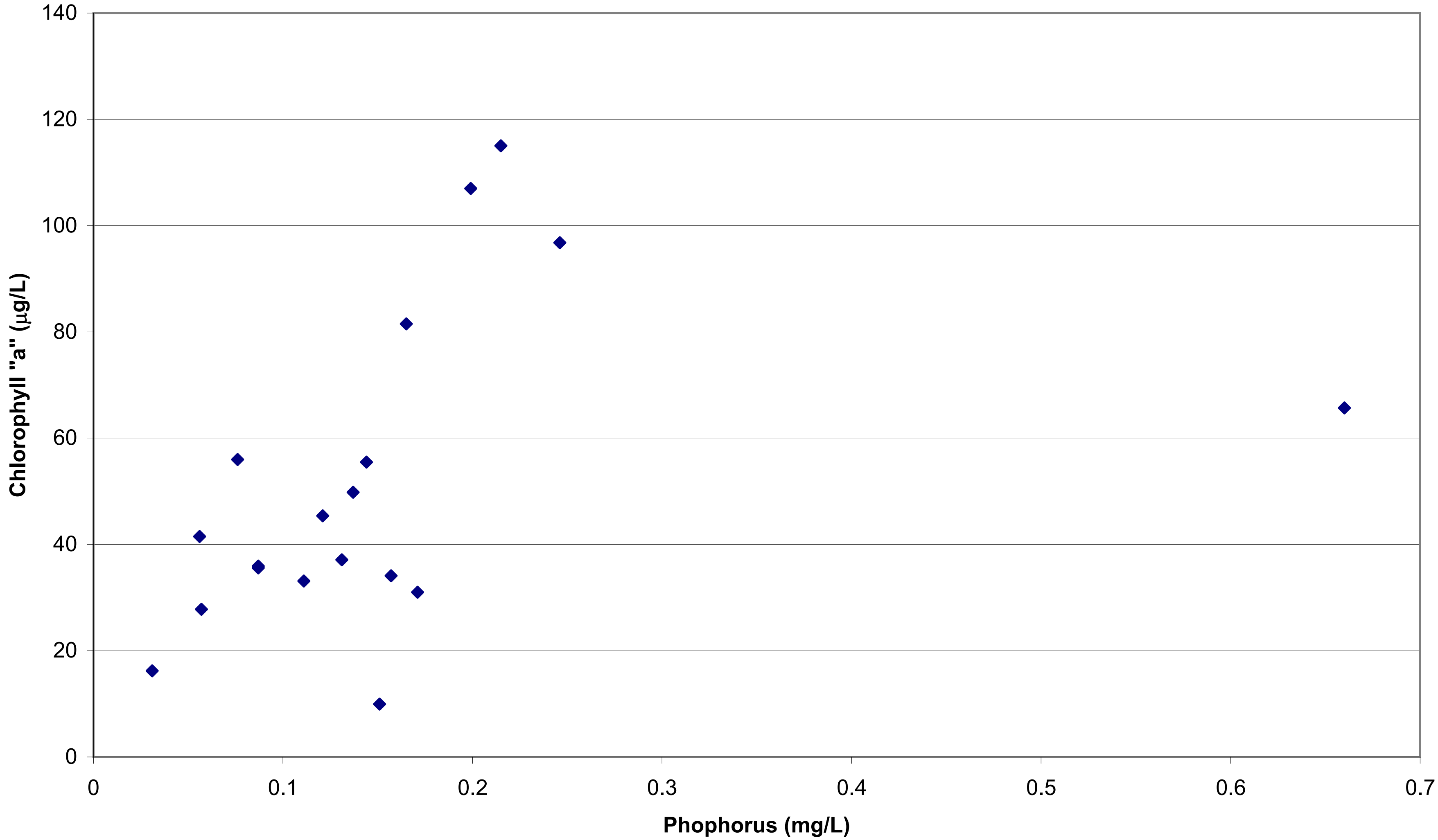
Figure 7-2: Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" in Washington County Lake



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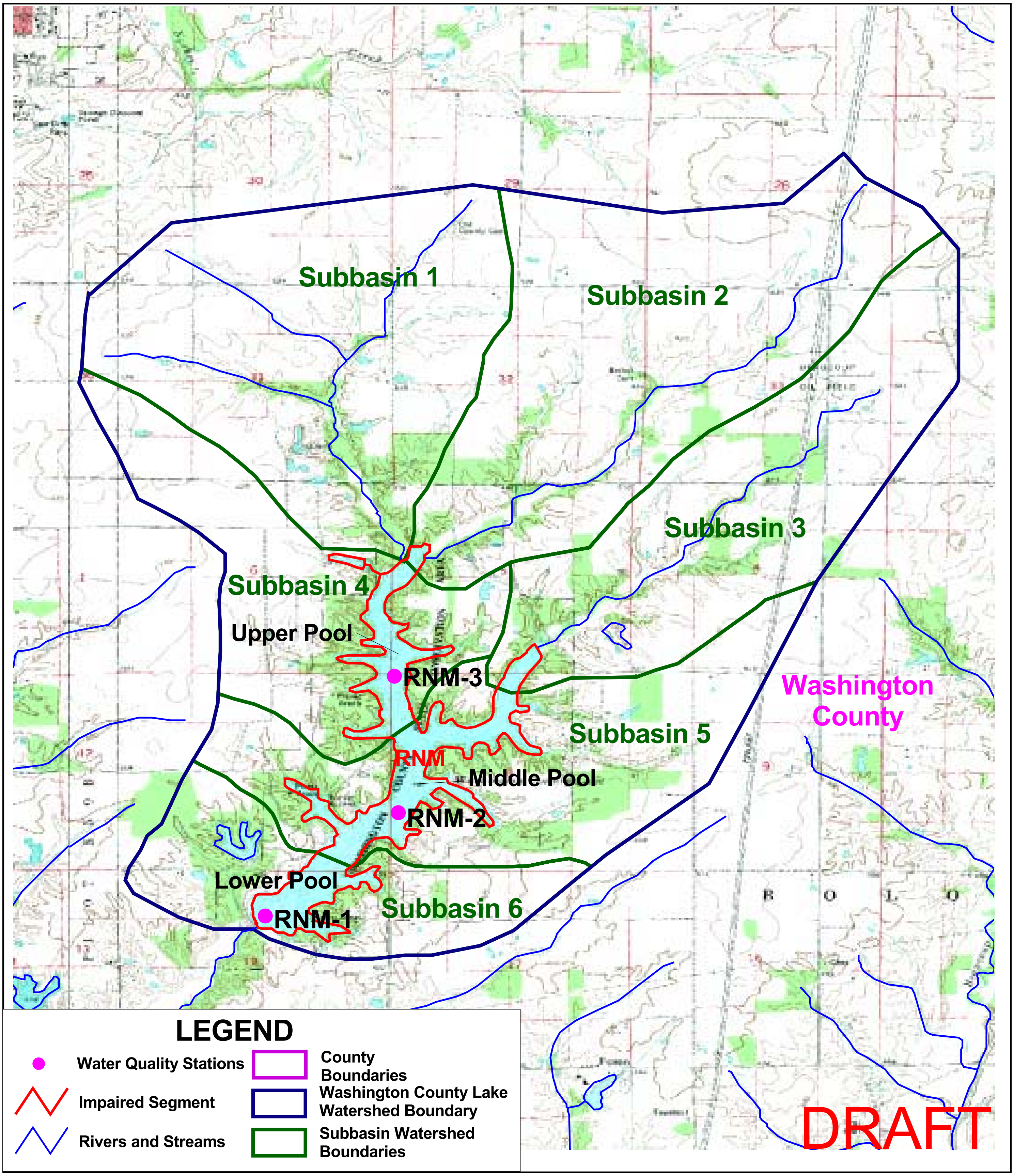

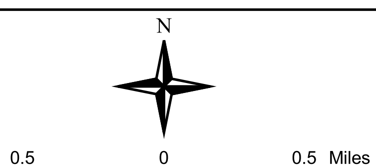

Figure 7-3
Washington County Lake Watershed, Historic Sampling Locations, and Modeling Divisions

CDM

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Figure 7-4: Washington County Lake Inflows
Subbasin 1 Monthly Flow Comparison

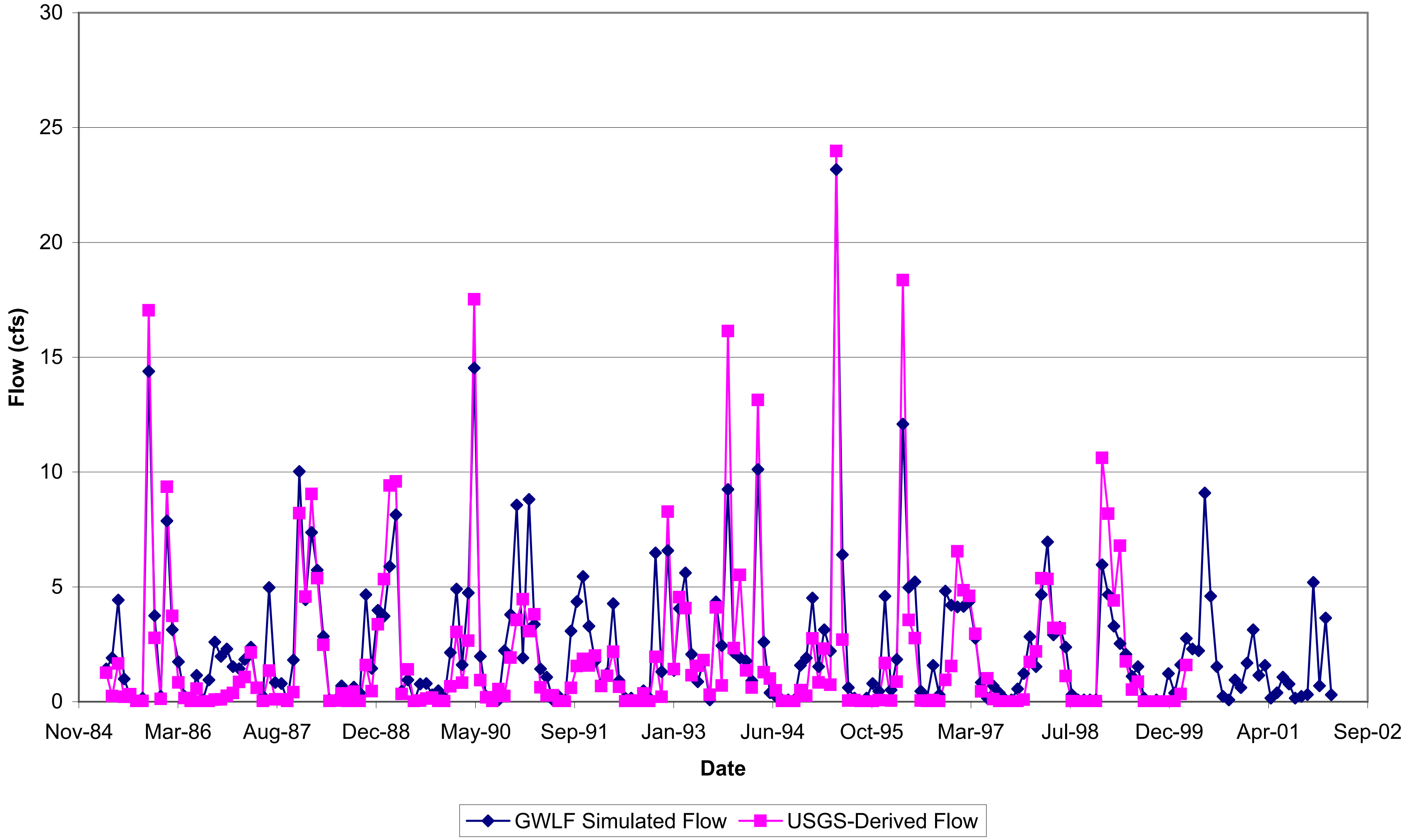

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Figure 7-5: Dissolved and Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Washington County Lake

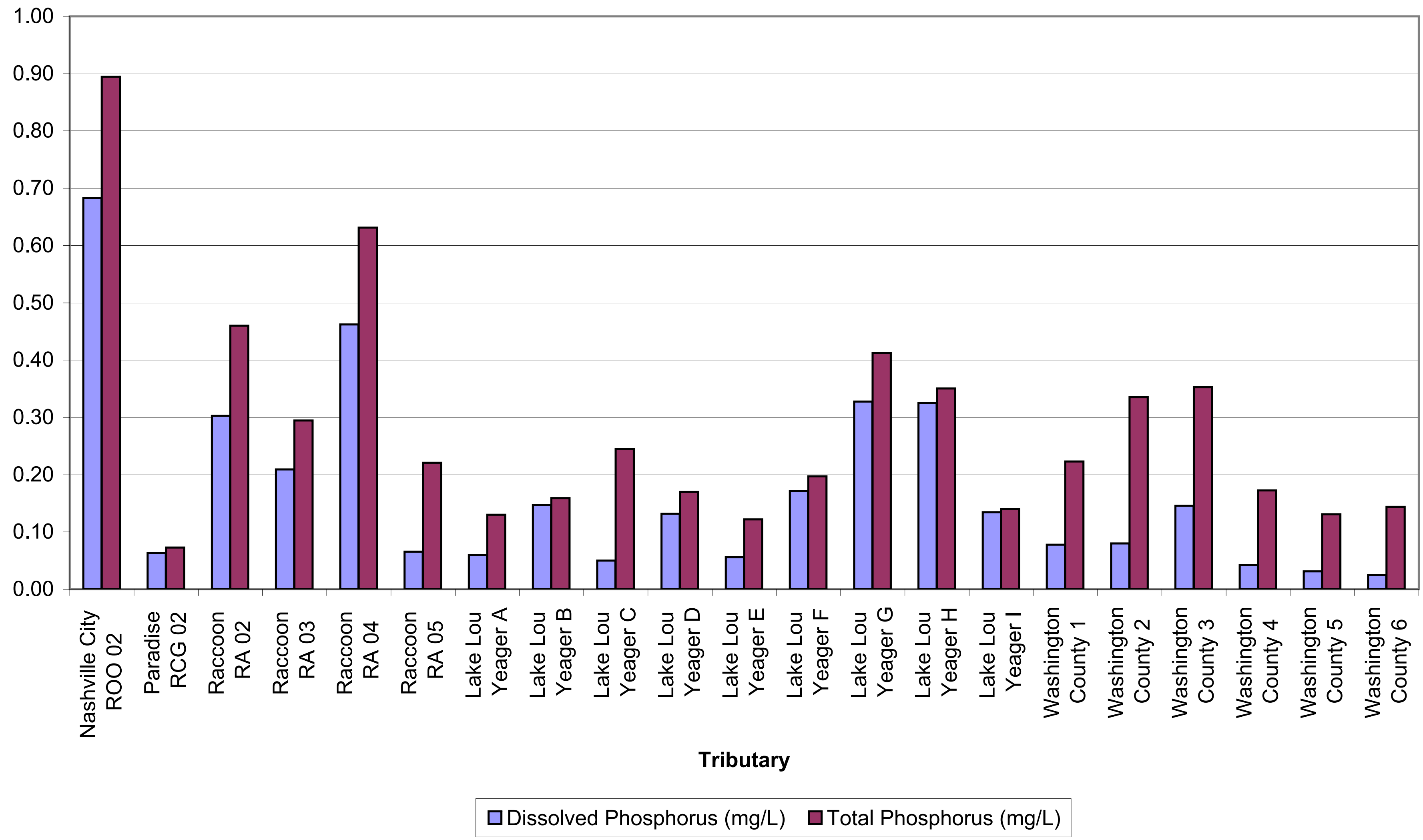

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Table 7-3 Critical Trends Land Assessment Land Uses and C Factors

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4		Subbasin 5		Subbasin 6	
Landuse	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**	**Area (ac)**	**C-factor**
High Density	0	---	2	---	1	---	0	---	0	---	0	---
Row Crop	658	0.101	1025	0.098	568	0.120	174	0.095	236	0.100	158	0.111
Small Grains	287	0.118	154	0.116	196	0.113	267	0.115	130	0.116	64	0.113
Rural Grassland	300	0.004	221	0.004	205	0.004	104	0.004	259	0.004	112	0.004
Deciduous	132	0.003	101	0.003	132	0.003	221	0.003	356	0.003	162	0.003
Deciduous	0	---	0	---	0	---	0	---	0	---	0	---
Coniferous	0	---	0	---	0	---	0	---	0	---	10	0.003
Open Water	0	---	0	---	5	---	47	---	109	---	57	---
Wetland	0	---	0.2	---	0	---	5	---	0	---	0	---
Deep Marsh	0	---	0	---	1	---	2	---	0	---	0	---
Forested Wetland	17	---	15	---	5	---	0	---	0	---	1	---
Shallow Water Wetland	9	---	0	---	5	---	5	---	2	---	12	---
Barren Land	0	---	0	---	0	---	0	---	0	---	0	---

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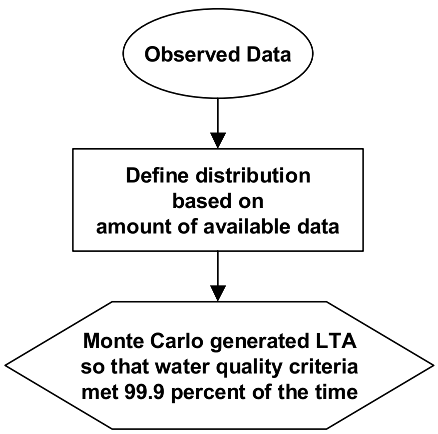
Section 8
Methodology Development for Beaucoup Creek Watershed

8.1 Methodology Overview

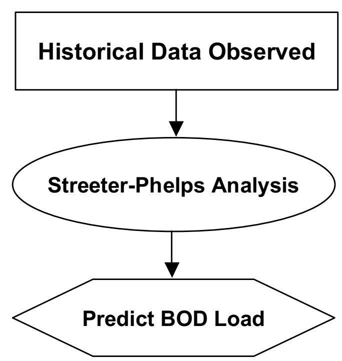
Methodologies were utilized in the TMDL analysis of Beaucoup Creek segments NC03 and NC10, Little Beaucoup Creek (NCI01), Swanwick Creek (NCK01), and Walkers Creek (NCC01) in the Beaucoup Creek Watershed. For manganese, sulfates, and TDS, a Monte Carlo simulation was utilized to estimate a long-term average instream concentration needed to meet water quality standards. Investigation of DO required a Streeter-Phelps analysis.



Schematic 1

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

The Streeter-Phelps analysis was conducted as illustrated in the schematic to the right. Observed data were utilized to set up a Streeter-Phelps analysis to predict stream coefficients that would be required to result in observed DO concentrations. This Streeter-Phelps analysis was based on USEPA's Screening Procedures (Mills et al. 1985). The 5-day biochemical oxygen demand (BOD_5) load and reaeration coefficient (k_a) utilized in the Streeter-Phelps analysis were examined in the TMDL for DO for segments NC03, NC10, NCI01, and NCK01.



Schematic 2

8.2 Watershed Delineation

Watersheds for Beaucoup Creek segments NC03, NC10, NCI01, NCK01, and NCC01 were delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation suggests that the Beaucoup Creek segment NC03 (the most downstream segment) captures flows from a watershed of approximately

316 square miles. Figure 8-1 at the end of this section shows the location of the water quality stations in Beaucoup Creek and the boundary of the GIS-delineated watershed contributing to the impaired segments in Beaucoup Creek.

8.3 Methodology Development and Results

This section discusses the methodologies utilized to examine manganese, sulfates, TDS, and DO levels in the Beaucoup Creek Watershed.

8.3.1 Monte Carlo Analysis Development and Results

For each constituent exceeding water quality standards, the available data was analyzed and an appropriate distribution was chosen to represent the data. A triangle distribution was chosen to analyze segments NC03, NCI01, NCK01, and NCC01 since data for these sites was extremely limited.

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

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

where PR = required percent reduction for the current iteration
Cc = water quality criterion in mg/L
Cd = randomly generated pollutant source concentration in mg/L based on the triangular distribution with the observed data's minimum, mode, and maximum values

A triangular distribution assumes that the values of a given dataset are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. In the case where available water quality data is limited, a triangular distribution was used to describe the observed data. Since the available observed data is not sufficient to truly predict the mode, the mode was assumed to be the mean as shown in Table 5-10.

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

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

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

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

8.3.1.1 Monte Carlo Results for Beaucoup Creek Segment NC03

Segment NC03 is the lower section of Beaucoup Creek, extending from the Walker Creek confluence downstream to Galum Creek. Sample data for this section was very limited. Sulfates and TDS values ranged from 410 to 1,000 mg/L and 759 to 1,380 mg/L, respectively, as shown in Table 5-10. As discussed previously, a triangular distribution was chosen for the reason that only four samples each were available for sulfates and for TDS.

Two of the output model concentrations are significant to the TMDL analysis of segment NC03. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 8-1 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Beaucoup Creek segment NC03. Calculation details are presented in Appendix I.

Table 8-1 LTA Sulfates and TDS Concentrations Required to Meet Water Quality Standards in Beaucoup Creek Segment NC03

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Sulfates	705	355
TDS	1,069	784

Table 8-1 shows that the concentration required to meet water quality reductions, the LTA, is lower than the observed average concentration for sulfates and TDS; therefore, the TMDL for Beaucoup Creek segment NC03 requires that a load reduction be made for both sulfates and TDS based upon the available data. The TMDL will be discussed in Section 9.

8.3.1.2 Monte Carlo Results for Little Beaucoup Creek Segment NCI01

Segment NCI01 is the Little Beaucoup Creek and is located in the middle portion of the Beaucoup Creek Watershed. Sample data for this section were very limited; manganese values ranged from 0.3 to 2.1 mg/L as shown in Table 5-10. A triangular distribution was chosen for the reason that only two samples were available for manganese.

Two of the output model concentrations are significant to the TMDL analysis of segment NCI01. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 8-2 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Beaucoup Creek segment NCI01. Calculation details are presented in Appendix I.

Table 8-2 LTA Manganese Concentrations Required to Meet Water Quality Standards in Little Beaucoup Creek Segment NCI01

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	1.2	0.6

Table 8-2 shows that the concentration required to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese; therefore, the TMDL for Beaucoup Creek segment NCI01 requires that a load reduction be made for manganese based upon the available data. The TMDL will be discussed in Section 9.

8.3.1.3 Monte Carlo Results for Swanwick Creek Segment NCK01

Segment NCK01 is the Swanwick Creek and is located in the middle portion of the Beaucoup Creek Watershed. Sample data for this section was very limited; manganese and sulfates values ranged from 0.4 to 3.8 mg/L and 162 to 505 mg/L, respectively, as shown in Table 5-10. As discussed previously, a triangular distribution was chosen for the reason that only two samples were available for manganese and sulfates.

Two of the output model concentrations are significant to the TMDL analysis of segment NCK01. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 8-3 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Swanwick Creek segment NCK01. Calculation details are presented in Appendix I.

Table 8-3 LTA Manganese and Sulfates Concentrations Required to Meet Water Quality Standards in Swanwick Creek Segment NCK01

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	2.1	0.6
Sulfates	332	332

Table 8-3 shows that the concentration required to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese; therefore, the TMDL for Swanwick Creek segment NCK01 requires that a load reduction be made for manganese based upon the available data. The observed concentration and the LTA for sulfates are equal, meaning that over the long term, sulfate concentration in segment NCK01 should not exceed the water quality standard according to the requirement of a less than one in three year exceedence; however, due to the limited dataset, a load allocation was developed for sulfates in segment NCK01. The TMDL will be discussed in Section 9.

8.3.1.4 Monte Carlo Results for Walkers Creek Segment NCC01

Segment NCC01 is Walkers Creek and is located in the lower portion of the Beaucoup Creek Watershed. Sample data for this section was very limited; manganese, sulfates, and TDS values ranged from 1.0 to 2.9 mg/L, 1,570 to 1,890 mg/L, and 1,730 to 1,740 mg/L, respectively, as shown in Table 5-10. As discussed previously, a triangular distribution was chosen for the reason that only two samples were available for manganese, sulfates, and TDS.

Two of the output model concentrations are significant to the TMDL analysis of segment NCC01. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 8-4 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Walkers Creek segment NCC01. Calculation details are presented in Appendix I.

Table 8-4 LTA Manganese, Sulfates, and TDS Concentrations Required to Meet Water Quality Standards in Walkers Creek Segment NCC01

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	1.9	0.7
Sulfates	1,730	460
TDS	1,734	997

Table 8-4 shows that the concentration required to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese, sulfates, and TDS; therefore, the TMDL for Walkers Creek segment NCC01 requires that a load reduction be made for manganese, sulfates, and TDS based upon the available data. The TMDL will be discussed in Section 9.

8.3.1.5 Loading Analysis from Permitted Mines

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

To assess the relative loading from the mines in relation to loading in the stream the average loading in stream versus loading from the mine was estimated. Results for the sulfate loading analysis for Beaucoup Creek segment NC03, which is listed for sulfates and TDS, and Walkers Creek, which is listed for manganese, sulfates, and TDS, are shown in Table 8-5. The discharge monitoring data for each of the mines discharging to this segment report sulfates, but not TDS. None of the data reported by the DMRs provided an acceptable surrogate for TDS; therefore, the analysis only estimated the target effluent concentration for sulfate and similar results are assumed to apply to TDS. Table 8-5 shows that the percent of sulfate loading from the mines into segment NC03 and NCC01 is likely insignificant in comparison to nonpoint sources or background loads of sulfate.

Table 8-5 Comparison of Loadings for Stream vs. Permitted Mine for Sulfates

Mine	Average River Flow (cfs)	Average River Concentration (mg/L)	Average River Sulfate Load (lb/day)	Average Mine Flow (cfs)	Average Mine Sulfate Concentration (mg/L)	Average Mine Sulfate Load (lb/day)	Percent of Sulfate Load from Mine (%)
IL0052779 (NC03)	52	705	197,600	1.6	155	1299	1
IL0052744 (NC03)	52	705	197,600	1.8	321	3167	2
IL0000302 (NCC01)	10	1730	93265	1.6	1491	12651	14

Results of the manganese analysis for Little Beaucoup Creek segment NCI01and Walkers Creek segment NCC01 are shown in Table 8-6. Manganese data was not reported on the DMRs available for IL0000302, which discharges to segment NCC01; therefore, iron was used as a surrogate for manganese for IL0000302. Similar to Beaucoup Creek segment NC03, the mine effluent comprises a small portion of the total load. Therefore, it is not recommended that IL0052779 and IL0052744 reduce their concentrations of sulfates and TDS in discharges to Beaucoup Creek segment NC03. Similarly, there is not a need for IL0000302 to reduce its discharge of manganese, sulfates, and TDS to Walkers Creek segment NCC01. Also, it is not necessary for IL0048160 to reduce discharges of manganese to Little Beaucoup Creek segment NCI01.

Table 8-6 Comparison of Loadings for Stream vs. Permitted Mine for Manganese

Mine	Average River Flow (cfs)	Average River Concentration (mg/L)	Average River Manganese Load (lb/day)	Average Mine Flow (cfs)	Average Mine Manganese Concentration (mg/L)	Average Mine Manganese Load (lb/day)	Percent of Manganese Load from Mine (%)
IL0048160 (NCI01)	21	1.2	135	0.33	0.19	0.33	0.2
IL0000302 (NCC01)	10	1.95	105	1.57	0.52	4.38	0.4

8.3.2 DO Analysis Development and Results

A Streeter-Phelps analysis was utilized for investigation of DO in the Beaucoup Creek Watershed. Data availability useful for analyzing DO for this watershed is described in Table 8-7. The historic water quality data were investigated from 1990 to 2000.

Table 8-7 Data Availability from 1990 to 2000

Model Parameter	Historic Data Available (Yes/No)
Flow	Yes
Stream temperature	Yes
DO	Yes
Carbonaceous biochemical oxygen demand (5-day)	No
Organic nitrogen	Yes
Ammonia	Yes
Nitrate + Nitrite	Yes
pH	Yes
Carbonaceous biochemical oxygen demand (20-day)	No
Daily minimum and maximum DO	No
Chlorophyll "a"	No
Stream depth	Yes

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

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

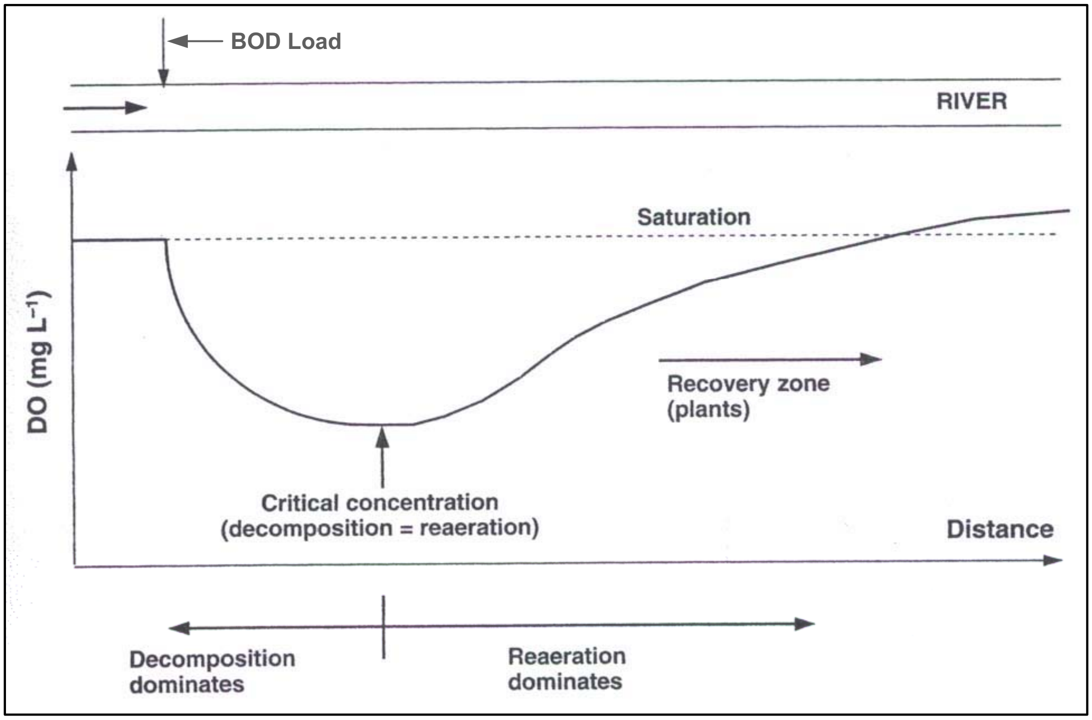
- respiration by algae and aquatic vascular plants that use oxygen during night and early morning hours to sustain their living processes

Major oxygen sources are:

- atmospheric reaeration, where oxygen is transported from the air into the water through turbulence at the air-water interface
- photosynthesis, where chlorophyll-containing organisms (producers such as algae and aquatic plants) convert carbon dioxide to organic matter with a consequent production of oxygen

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

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



Water quality models have built upon the Streeter-Phelps equation to evaluate the DO balance in streams. The analysis for Beaucoup Creek segments NC03 and NC10, Little Beaucoup Creek segment NCI01, and Swanwick Creek segment NCK01 is based on BOD_5 and reaeration only. There is not enough coincident nutrient and algal historical data from these sites to assess impacts of nutrient loads on algal growth that also impact DO levels. Free floating and attached algae as well as aquatic plants are of concern. The extent to which algae impact the DO resources of a river is dependent on many factors, such as turbidity, which can decrease light transmittance through the water column. Additionally, the photosynthetic rate constantly changes in response to variations in sunlight intensity and is not constant. This results in diurnal fluctuations in DO levels (Mills et al. 1985). In addition, there is not enough data available to estimate the impacts of SOD at these sites.

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

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

where:
- DO_o = Calculated DO concentration (mg/L)
- D_S = DO at saturation (mg/L)
- D_o = Initial DO deficit (mg/L)
- k_a = Reaeration rate (1/day)
- k_d = BOD_5 decay rate (1/day)
- x = Distance downstream of discharge (ft)
- v = Stream velocity (ft/day)
- L_0 = Initial BOD_5 (mg/L) at x = 0

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

Literature provides equations to calculate both the BOD_5 decay rate coefficient (k_d) and reaeration rate coefficient (k_a). The decay rate coefficient is dependent on stream depth, and the reaeration coefficient is dependent on depth and velocity. Due to the limits of the data set shown in Table 5-10, the decay rate coefficient was calculated from either known depths or rating curves allowing the reaeration coefficient to be calculated from the Streeter-Phelps equation presented above as the only unknown variable. The rating curves used to determine depths are available in Appendix J.

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

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

$$= 0.3 \text{ for } H > 8$$

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

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

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

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

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

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

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

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

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

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

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

Four WWTPs were located in the Beaucoup Creek Watershed as shown in Figure 5-5. The low effluent flow from each plant makes the loadings to Beaucoup Creek Watershed stream segments negligible in comparison to loadings from the remainder of the watershed. Since point sources were identified as a negligible contributor to either segment, it was assumed that the BOD_5 load from all nonpoint sources is evenly distributed throughout each segment as shown in the following figure:

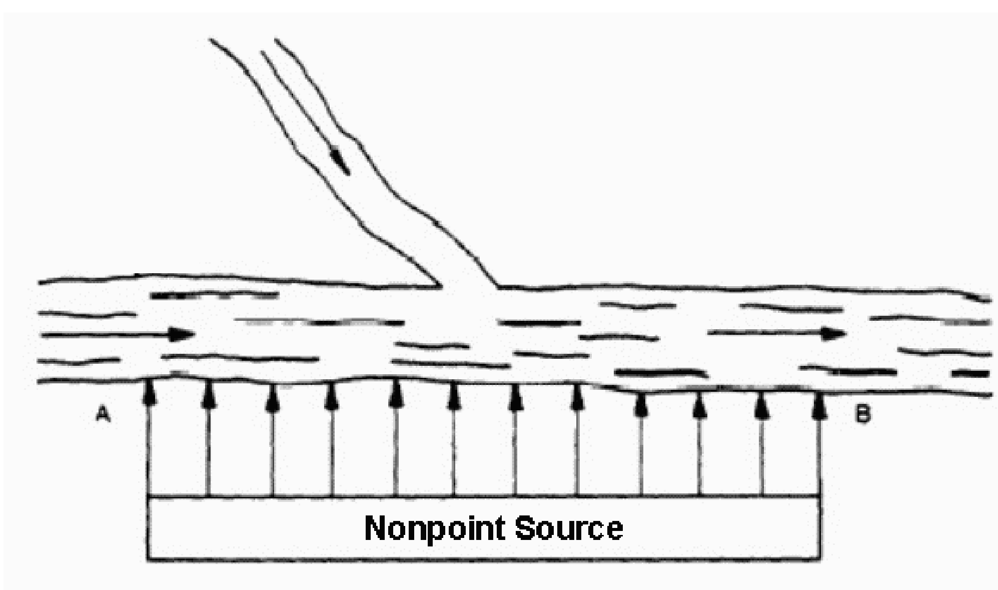


Table 8-8 shows the observed TOC data and the BOD_5 concentrations (L_0) calculated from observed TOC data. It also shows the k_a and k_d coefficients calculated with the above equations. In addition, the estimated BOD_5 load was calculated based on the calculated BOD_5 concentration and average daily flow on the day the sample was taken. Revised k_a and k_d values are also shown in Table 8-8. These values were utilized in the Streeter-Phelps equation described above and the resulting calculated DO was compared to observed DO readings. If there was not a match between the calculated DO and observed DO, k_a and k_d were revised within their accepted ranges so that calculated DO more closely matched observed DO. If possible, only k_a was revised as it was calculated based on estimated depth and flow while k_d was based on estimated depth. Table 8-8 also includes precipitation values near or on the sampling date, so that estimates of pollutant loads from runoff can be compared to loads estimated based on the BOD_5/TOC ratio. A DO sample of 5.0 mg/L was measured in segment NC03 on July 24, 1995; however, a corresponding TOC sample was not available, so the sample date was not analyzed. Analysis details are contained in Appendix K.

Table 8-8 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations

Sample Location and Date	NC03 3/14/96	NC03 8/16/00	NC03 9/19/00	NC10 9/11/95	NC10 3/14/96	NCI01 8/4/95	NCI01 3/5/96	NCK01 7/24/95	NCK01 3/5/96
Measured DO (mg/L)	9.9	4.7	7	4.7	10.4	1.5	10.1	2.6	10.6
Measured TOC (mg/L)	8.5	6.8	4.7	6.4	9.1	9.8	7.5	10.3	5.4
Calculated BOD_5 Concentration (mg/L)	11.1	8.8	6.1	8.3	11.8	12.7	9.8	13.4	7.0
Calculated BOD_5 Load (lb/day)	985	357	44	1	784	38	17	14	33
Calculated k_a (1/day)	9.6	1.9	42.0	5.6	10.8	72.6	65.1	5.0	41.1
Revised k_a (1/day)	16.3	5.8	7.6	0.8	18.0	0.1	10.9	0.8	20.1
Calculated k_d (1/day)	0.45	0.64	1.10	0.69	0.45	1.61	0.85	0.89	0.76
Revised k_d (1/day)	0.45	0.64	1.10	0.69	0.45	2.08	0.85	0.89	0.76
Precipitation (in)	0.14	0.32	0.55	0.03	0.14	0.18	0.51	0.93	0.51
Dates Precipitation Occurred	8 days before sample	8 days before sample	7 days before sample	4 days before sample	8 days before sample	On sample date	On sample date	On sample date	On sample date
Flow (cfs)	16.5	7.5	1.3	0.0	12.3	0.6	0.3	0.2	0.9
Water Temperature (°C)	9.1	29.5	19.2	19.5	8.1	24.4	8.6	28.3	9.7

The sample date that measured the lowest DO concentration in the Beaucoup Creek Watershed, August 4, 1995 at NCI01, required that both k_a and k_d be revised to obtain a match between the calculated and observed DO. In this case, k_a was reduced to the minimum of the literature range, 0.1/day, and k_d was revised to match the calculated and observed DO for the sample date. The need to reduce the aeration coefficient, k_a, to its minimum suggests that lack of aeration is a primary contributor to DO impairments. An error analysis was run on the literature ranges of values for k_a and k_d for each sample date to validate their use for the Streeter-Phelps analysis. This analysis is contained in Appendix L.

As discussed in Section 6.2.4, the WMM model was run as a screening tool to assess the BOD_5 loads that are typically generated annually for the watershed. The major inputs to the model are land use, precipitation, and event mean concentration (EMC). Land use for the watershed was presented in Table 5-14. The average monthly and annual precipitation for Perry County was presented in Table 5-2. The EMCs used for each land use type are shown in Table 8-9.

Table 8-9 BOD_5 EMCs by Land Use Type for the Beaucoup Creek Watershed

Land Use	Area (acres)	Percent of Total	BOD_5 EMC (mg/L)	Source
Row Crop	75,232	37%	8.0	2
Rural Grassland	54,019	27%	2.0	1
Deciduous Forest	32,758	16%	2.0	1
Small Grains	22,979	11%	8.0	2
Forested Wetland	10,315	5%	0.0	1
Open Water	3,415	2%	0.0	1
Shallow Water/Wetlands	1,806	1%	0.0	1
Medium Density	538	1%	14.1	1
Urban Grassland	438	0%	2.0	1
Shallow Marsh/Wetlands	306	0%	0.0	1
Deep Marsh	251	0%	0.0	1
High Density	193	0%	14.1	1
Low Density	84	0%	14.1	1
Barren Land	*70*	*0%*	0.0	1
Coniferous Forest	67	0%	2.0	1
Swamp	29	0%	0.0	1

Source:
1 Smullen et al. 1999
2 Denison and Tilton 1998

Results of the WMM screening are shown in Table 8-10. The results are for the entire watershed contributing to segment NC03, which receives flow from the entire watershed. Results shown are an estimate of annual loads and loads from the precipitation events provided in Table 8-8. The loads estimated from WMM generated based on precipitation events near the sampling events are all greater than those shown in Table 8-8. The WMM model files are contained in Appendix M. This analysis indicates that loading from runoff events is not the sole source of DO impairments. Other factors that could contribute to low DO levels include stagnant flow conditions occurring during low flows, elevated stream temperatures during summer months, and nutrient loads from nonpoint sources in the watershed. The implementation plan in Section 10 will address other factors that could also cause decreased DO levels in the Beaucoup Creek Watershed.

Table 8-10 Results of WMM Screening Analysis for the Beaucoup Creek Watershed

Event	Total BOD_5 Load (lb/event)	Precipitation (in)
Annual	1,538,740	44.7
07/24/1995	51,636	1.0
08/04/1995	6,196	0.18
09/11/1995	1,033	0.03
03/05/1996	17,556	0.51
03/14/1996	4,819	0.14
08/16/2000	11,016	0.32
09/19/2000	18,933	0.55

The estimated BOD_5 loads in Table 8-8 are low in comparison to the WMM loads predicted suggesting that they represent loadings occurring during ambient conditions. Therefore, it is likely that further reductions in BOD concentrations could be achieved. The WMM results represent loadings from precipitation events shown in Table 8-8 that, in some cases, occurred before the sample date. On two of the four impaired dates shown in Table 8-8, the precipitation occurred between four and eight days prior to the sampling date, and it is likely that the loads from the event passed through the stream system before the sample was taken. The other two impaired dates had precipitation occurring on the sample date and had higher TOC measurements than the other impaired dates. This suggests that a portion of the BOD_5 loading may be from runoff events. As discussed in Section 5.1.5.2.2, all DO samples were taken at below average flow values suggesting that low flows may be the cause of DO impairments. At low flows, conditions in a stream can become stagnant (lack of aeration) where water pools in slow-moving sections of the stream. Therefore, the TMDL described in Section 9 and the implementation plan outlined in Section 10 will focus on increases in reaeration needed to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period). The implementation plan in Section 10 will also address methods to reduce the BOD_5 loading to the stream and other factors that could also cause decreased DO levels in the Beaucoup Creek Watershed, such as elevated stream temperatures during summer months and nutrient loads from nonpoint sources in the watershed.

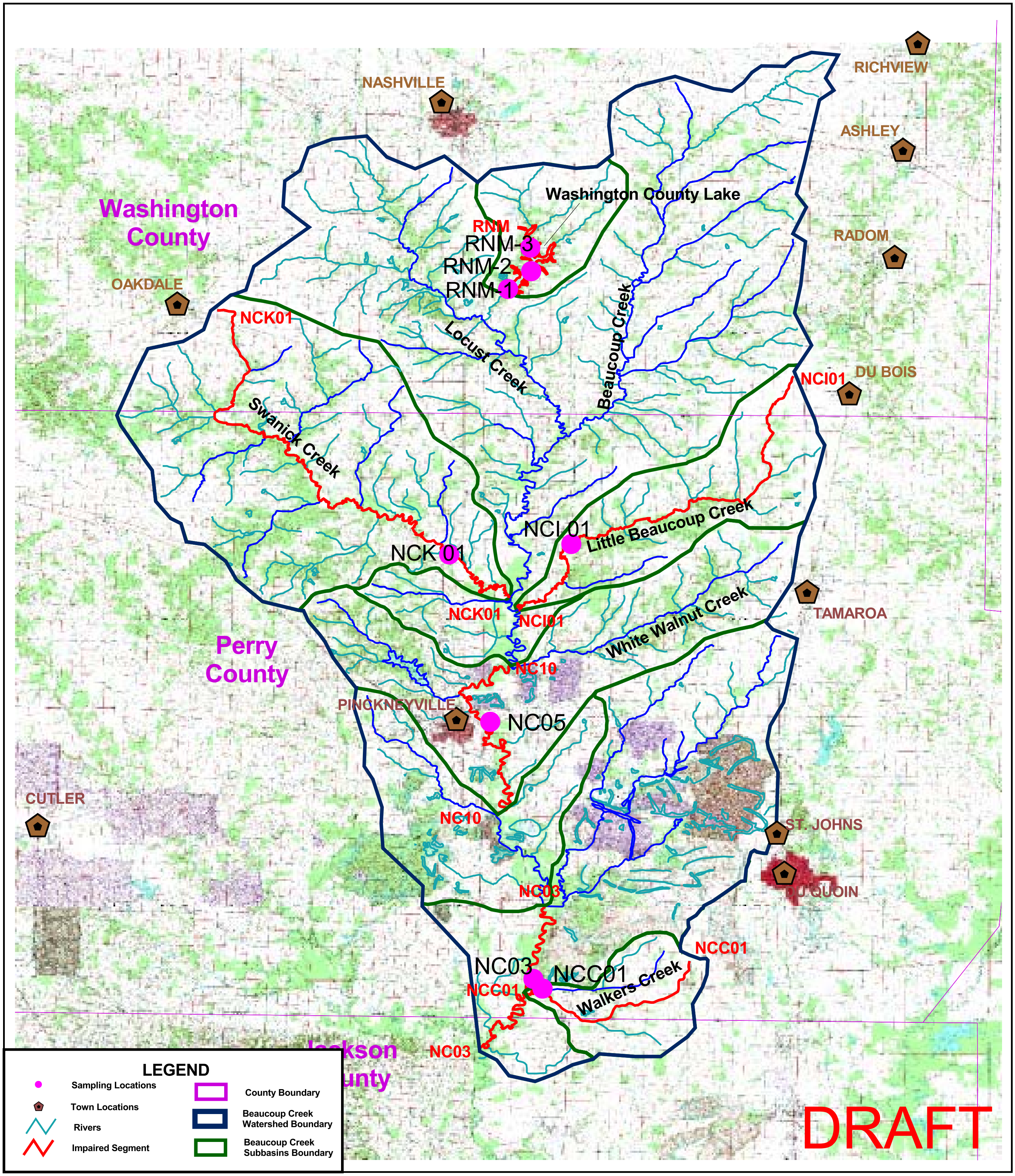


Figure 8-1
Beaucoup Creek Watershed
and Historic Sampling Locations

CDM

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Section 9
Total Maximum Daily Load for the Washington County Lake and Beaucoup Creek Watersheds

9.1 TMDL Endpoints for Washington County Lake

The desired in-lake water quality concentration for DO is above 6.0 mg/L for 16 hours of any 24-hour period and less than or equal to 0.05 mg/L for total phosphorus. Tables 5-5 and 5-7 in Section 5 summarized the average DO and total phosphorus concentrations sampled in the Washington County Lake Watershed. As noted in Section 5.1.5.1.1, all observed in-lake DO averages meet this target, but individual samples are below 6.0 mg/L, violating the endpoint. As discussed in Section 5.1.5.1.2, all observed in-lake total phosphorus averages have exceeded the target. The DO and total phosphorus targets are set to prevent eutrophic conditions in Washington County Lake and maintain aquatic life. Phosphorus is a concern as nuisance plant growth and algal concentrations in many freshwater lakes are enhanced by the availability of phosphorus.

9.1.1 Pollutant Sources and Linkages

The TMDL for DO in Washington County Lake is dependent on a relationship between DO, chlorophyll "a," and phosphorus as explained in Section 5.1.5.1.1 and Section 7.1. A general relationship between phosphorus and chlorophyll "a" was determined, but the relationship between chlorophyll "a" and DO for this analysis is poor.

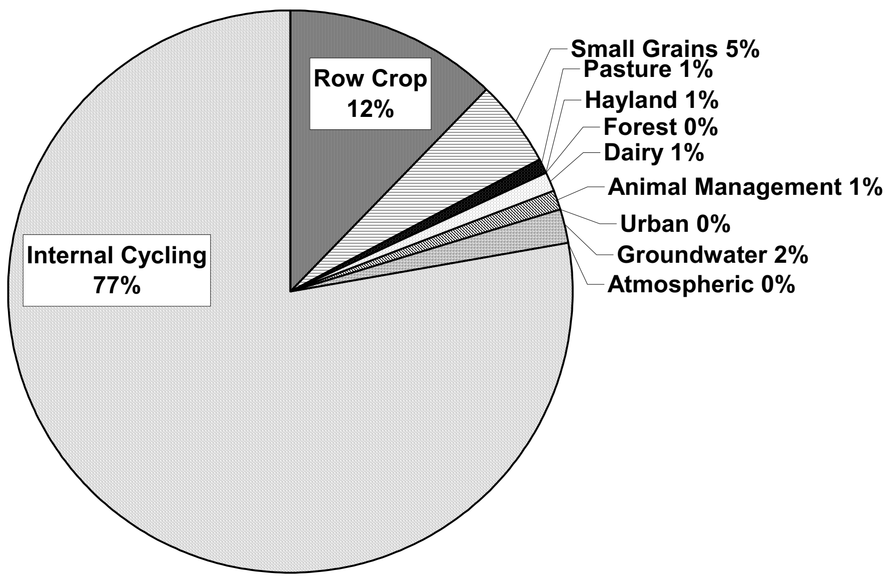
This TMDL is based on the assumption that trends in Washington County Lake will follow those observed in literature where the control of phosphorus results in increased DO concentrations. The remainder of this section focuses on reductions in phosphorus to control DO.

Pollutant sources and their linkages to Washington County Lake were established through the GWLF and BATHTUB modeling techniques described in Section 7. The likely source of oxygen demanding constituents is nonpoint source loads in the watershed, plus other factors occurring during low flow conditions, such as stagnant flows and increased water temperatures promoting algal growth.

Pollutant sources of phosphorus include nonpoint source runoff from agriculture. Atmospheric deposition and internal cycling are also potential sources of loads. The predicted phosphorus loads from GWLF modeling and their sources are presented in Table 9-1. The mean loads presented in Table 9-1 will be used in the overall TMDL calculation for the amount of reductions that need to occur in the Washington County Lake watershed.

Table 9-1 Modeled Total Phosphorus Loads by Source

	1990 (normal)		1995 (wet)		2001 (dry)		Mean	
Land Use	**lb/yr**	**Percent**	**lb/yr**	**Percent**	**lb/yr**	**Percent**	**lb/yr**	**Percent**
Row Crop	2,346	7%	5,602	14%	1,127	34%	3,025	12%
Small Grains	1,007	3%	2,480	6%	515	15%	1,334	5%
Pasture	137	1%	288	1%	0	0%	142	1%
Hayland	114	0%	244	1%	0	0%	119	1%
Forest	69	0%	177	0%	37	1%	94	0%
Dairies	343	1%	686	2%	25	1%	351	1%
Feedlots	126	1%	244	1%	25	1%	131	1%
Urban	0	0%	0	0%	0	0%	0	0%
Groundwater	709	2%	864	2%	257	8%	610	2%
Atmospheric	65	0%	65	0%	65	2%	65	0%
Internal Cycling	27,467	85%	29,382	73%	1,285	38%	19,378	77%
TOTAL	32,383	100%	40,032	100%	3,336	100%	25,249	100%



The majority of the predicted phosphorus load is from internal cycling and agricultural nonpoint sources as shown in the pie chart to the right. The loads represented in Table 9-1 and the pie chart were entered into the BATHTUB model, as explained in Section 7, to determine resulting in-lake total phosphorus concentration in mg/L. As explained in Section 7, these loads result in in-lake concentrations that exceed the total phosphorus target of 0.05 mg/L. The TMDL explained throughout the remainder of this section will examine how much both the external and internal loads need to be reduced in order to meet the total phosphorus water quality standard of 0.05 mg/L in Washington County Lake.

9.1.2 Allocation

As explained in Section 1, the TMDL for Washington County Lake will address the following equation:

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

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

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

9.1.2.1 Loading Capacity

The loading capacity of Washington County Lake is the pounds per year of total phosphorus that can be allowed as input to the lake and still meet the water quality standard of 0.05 mg/L total phosphorus. The allowable phosphorus loads that can be generated in the watershed and still maintain water quality standards was determined with the models that were set up and calibrated as discussed in Section 7. To accomplish this, the loads presented in Table 9-1 were reduced by a percentage and entered into the BATHTUB model until the water quality standard of 0.05 mg/L total phosphorus was met in Washington County Lake. Table 9-2 shows the allowable phosphorus loading determined for 1990, 1995, and 2001 by reducing modeled inputs to Washington County Lake through GWLF and BATHTUB. Although model year 2001 was impaired for phosphorus, it was not impaired for DO on any sample dates; however, the average total phosphorus at each station in 2001 was lower than all other sample years, validating the assumption that decreasing phosphorus to water quality standards will result in acceptable DO levels. The output files to BATHTUB showing the results of the load reductions for 1990, 1995, and 2001 are contained in Appendix N.

Table 9-2 Allowable Total Phosphorus Load by Model Year for Washington County Lake

Model Year	Total Phosphorus (lb/yr)
1990	3,383
1995	4,449
2001	1,261
Mean	3,031

The allowable pounds per year resulting from the modeling show the effects of varying climatic conditions observed during these years. Therefore, an average value of these years was set as the target loading to meet the in-lake water quality standards of 0.05 mg/L.

9.1.2.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold, as well as wet or dry. Seasonal variation is represented in the Washington County Lake TMDL as conditions were modeled on an annual basis and by taking 15 years of daily precipitation data when calculating run-off through the GWLF model. This takes into account the seasonal effects the reservoir will undergo during a given year. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., atmospheric deposition year round, spring run-off loads), the loadings for this TMDL will focus on average annual loadings rather than specifying different loadings by season. In addition, three data sets (wet, dry, average) were examined to assess the effects of varying precipitation on loading to the reservoir and resulting in-lake concentrations.

9.1.2.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. The MOS for the Washington County Lake TMDL should be based on a combination of both. Model inputs were selected from the GWLF manual when site-specific data were unavailable. These default input values are assumed to be conservative, which implicitly includes a MOS in the modeling effort. Because the default input values are not site-specific, they are assumed more conservative and therefore a MOS can be implicitly assumed. Default input values include:

- sediment delivery ratio – using literature value is assumed conservative as cropping practices have changed within Illinois since ratio was developed in 1975.
- soil phosphorus concentration – phosphorus concentrations in the soil were not available; therefore literature values were assumed conservative as the mid-point of the range of suggested literature range was used as a starting point for analyses.

In addition, averaging of a normal and dry year is assumed to be conservative and part of the implicit MOS.

Due to uncertainty with nutrient model inputs as explained in Section 7.4, an explicit MOS of 5 percent is also recommended. Due to unknowns regarding estimated versus actual measurements of loadings to the lake, an explicit MOS is included. The 5 percent MOS is appropriate based upon the generally good agreement between the GWLF loading model and observed flows, and in the BATHTUB water quality model and observed values in Washington County Lake (Section 7.4). Since these models reasonably reflect the conditions in the watershed, a 5 percent MOS is considered to be adequate to address the uncertainty in the TMDL, based upon the data available. The MOS can be reviewed in the future as new data is developed.

9.1.2.4 Waste Load Allocation

The WWTP in the Washington County Lake Watershed contributes minimal loadings to Washington County Lake as discussed in Section 5.1.7.1; therefore, no WLA is recommended at this time.

9.1.2.5 Load Allocation and TMDL Summary

Table 9-3 shows a summary of the TMDL for Washington County Lake. On average, a total reduction of 89 percent of total phosphorus loads to Washington County Lake would result in compliance with the water quality standard of 6.0 mg/L DO (16 hours of any 24-hour period) based on modeling efforts.

Table 9-3 TMDL Summary for Total Phosphorus in Washington County Lake

LC (lb/yr)	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	Reduction Needed (lb/yr)	Reduction Needed (percent)
3,031	0	2,880	152	22,370	89%

Table 9-4 shows the respective reductions needed from internal cycling, atmospheric loads, and nonpoint sources in the watershed to meet the TMDL. The reduction of atmospheric loads is zero because atmospheric contributions cannot be controlled by watershed management measures. The percent reduction from internal cycling is estimated as 90 percent based on attainable reductions from management measures that will be discussed in Section 10. An approximate 85 percent reduction of nonpoint sources from the watershed, in addition to the reduction of internal cycling, would be necessary to meet the load allocation presented in Table 9-3. Methods to meet these targets will be outlined in Section 10.

Table 9-4 Sources for Total Phosphorus Reductions

Source	Current Load (lb/yr)	Load Reduction (lb/yr)	Percent Reduction
Internal Cycling	19,378	17,440	90%
Atmospheric	65	0	0%
Nonpoint Sources	5,807	4,930	85%

9.2 TMDL Endpoints for Beaucoup Creek

The TMDL endpoints for manganese, sulfates, TDS, and DO in a stream segment are summarized in Table 9-5. For manganese, sulfates, and TDS, the concentrations must be below the TMDL endpoint. For DO, concentrations must be greater than 6.0 mg/L for 16 hours of any 24-hour period. These endpoints are based on protection of aquatic life in Beaucoup Creek and its tributaries. Some of the average concentrations, which are based on a limited data set, meet the desired endpoints. However, the data set has maximum or minimum values, presented in Section 5.1.5.2.1, that do not meet the desired endpoints, and this was the basis for TMDL analysis. Further monitoring as outlined in the monitoring plan presented in Section 10, will help further define when impairments are occurring in the watershed and support the TMDL allocations outlined in the remainder of this section.

Table 9-5 TMDL Endpoints and Average Observed Concentrations for Impaired Constituents in the Beaucoup Creek Watershed

Constituent	TMDL Endpoint (mg/L)	Average Observed Concentrations				
		NC03 (mg/L)	NC10 (mg/L)	NCI01 (mg/L)	NCK01 (mg/L)	NCC01 (mg/L)
Manganese	1.0	–	–	1.2	2.1	2.0
Sulfates	500	705	–	–	334	1,730
TDS	1,000	1,070	–	–	–	1,735
DO	6.0 (16 hours of any 24-hour period)	6.7	7.6	5.8	6.6	–

9.2.1 Pollutant Source and Linkages

Pollutant sources for Beaucoup Creek were identified through the existing data review described in Section 5. Based on the data review, the source of manganese, sulfates, and TDS in the Beaucoup Creek Watershed is groundwater potentially contaminated by oil and gas activities and coal mines. One of the samples in Walkers Creek showing impairments was taken at above average flow conditions suggesting that sources may include surface runoff from mining activity. The likely source of oxygen demanding constituents is primarily factors occurring during low flow conditions, such as stagnant flows and increased water temperatures promoting algal growth. Nonpoint source loads in the watershed, such as runoff from agriculture and crop land, may also contribute to low DO in the stream.

9.2.2 Allocation

As explained in Section 1, the TMDL for impaired segments in the Beaucoup Creek Watershed will address the following equation:

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

where LC = maximum amount of pollutant loading a water body can receive without violating water quality standards

WLA = the portion of the TMDL allocated to existing or future point sources

LA = portion of the TMDL allocated to existing or future nonpoint sources and natural background

MOS = an accounting of uncertainty about the relationship between pollutant loads and receiving water quality

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

9.2.2.1 Manganese, Sulfates, and TDS TMDL

9.2.2.1.1 Loading Capacity

The loading capacity for manganese, sulfates, and TDS for impaired segments in the Beaucoup Creek Watershed were based on the Monte Carlo analysis described in Section 8. The LTA, determined by analysis to meet water quality standards generated from the Monte Carlo analysis, is the basis for loading capacity for the impaired segments. This LTA was multiplied by average flow in each segment to determine an average load. These average loads are shown in Table 9-6.

Table 9-6 Average Loads Based on LTA for Manganese, Sulfates, and TDS

Segment and Constituent	LTA (mg/L)	Allowable Load (lb/day)
NC03 - Sulfates	355	620,204
NC03 - TDS	784	1,369,690
NCI01 - Manganese	0.6	66
NCK01 - Manganese	0.6	179
NCK01 - Sulfates	332	100,998
NCC01 - Manganese	0.7	37
NCC01 - Sulfates	460	24,811
NCC01 - TDS	997	53,776

9.2.2.1.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold, as well as wet or dry. Seasonal variation is represented in the Beaucoup Creek TMDL, as conditions were investigated during all seasons of the year. Section 5.1.3 discusses the flow data available for the Beaucoup Creek watershed and Section 5.1.5 and Appendix A contain the water quality data available for manganese, sulfates, and TDS. A review of the flow data (Figures 5-3 and 5-4) shows seasonal variations. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., spring run-off loads), the loadings for this TMDL will focus on a LTA loading rather than specifying different loadings by season. As more data is gathered, further refinement of the seasonal variation may be possible.

9.2.2.1.3 Margin of Safety

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

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

9.2.2.1.4 Waste Load Allocation

Mine effluent from two permitted mines (IL052779, IL0052744) is discharged into Beaucoup Creek segment NC03, from one permitted mine (IL0048160) into Little Beaucoup Creek segment NCI01, and from one permitted mine (IL0000302) into Walkers Creek segment NCC01. However, the sulfate and manganese loads from the mines into segments NC03, NCC01, and NCI01 are negligible in comparison to loading in the river from nonpoint sources or background loads. Hence, no WLA is recommended at this time for those segments.

Additionally, the three WWTPs that discharge to river segments were found to have minimal loadings and thus negligible impacts on the receiving waters. Therefore, no WLA is recommended at this time.

9.2.2.1.5 Load Allocation and Summary TMDLs

Table 9-7 shows a summary of the TMDL for manganese, sulfates, and TDS in the Beaucoup Creek Watershed. The calculated allowable loads (LC) necessary to maintain the water quality standard are reduced by the MOS, representing the uncertainty in the data analysis, to determine the allowable loading from the watershed, the LA. The LC was calculated from the LTA presented in Section 8.3.1. Reductions between 10 and 76 percent were estimated as the required decreases in loadings so that water quality standards will be met in the stream segments. Although the average observed concentration and the LTA for sulfates in segment NCK01 were equivalent as discussed in Section 8.3.1.3, the limited dataset and uncertainty in the analysis necessitate application of a reduction equal to the MOS.

Table 9-7 TMDL Summary for Manganese, Sulfates, and TDS

Segment and Constituent	LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Reduction Needed (lb/day)	Reduction Needed (percent)
NC03 - Sulfates	620,204	0	558,183	62,020	673,489	55%
NC03 - TDS	1,369,690	0	1,232,721	136,969	634,879	34%
NCI01 - Manganese	66	0	59	7	77	57%
NCK01 - Manganese	179	0	162	18	477	75%
NCK01 - Sulfates	100,998	0	90,898	10,100	10,100	10%
NCC01 - Manganese	37	0	33	4	72	68%
NCC01 - Sulfates	24,811	0	22,330	2,481	70,982	76%
NCC01 - TDS	53,776	0	48,399	5,378	45,130	48%

The required LTAs presented in Section 8 and in Table 9-6 were reduced because of the applied MOS and are presented in Table 9-8. The recalculated LTA represents the LA in Table 9-7. Methods to meet these LTAs will be outlined in Section 10.

Table 9-8 LTAs Required Based on TMDL MOS

Segment and Constituent	Monte Carlo LTA (mg/L)	Recalculated LTA (mg/L)
NC03 - Sulfates	355	320
NC03 - TDS	784	706
NCI01 - Manganese	0.6	0.5
NCK01 - Manganese	0.6	0.5
NCK01 - Sulfates	332	299
NCC01 - Manganese	0.7	0.6
NCC01 - Sulfates	460	414
NCC01 - TDS	997	897

9.2.2.2 DO TMDL

As discussed in Section 8.3.2, the BOD_5 loads in segments NC03, NC10, NCI01, and NCK01 likely represent background loadings, which suggests that the principle cause of DO impairments in these segments is a lack of aeration caused by low flows and stagnant pools. Table 9-9 shows the aeration coefficient calculated from the observed DO in Section 8.3 for sample dates that did not meet the TMDL endpoint and the coefficient that would be required to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period) for sampling events that had DO measurements less than 6.0 mg/L. Increasing aeration in the stream is not a parameter for which a TMDL can be developed. Therefore, no TMDL will be developed at this time. Methods to achieve elevated reaeration coefficients will be outlined in Section 10.

Table 9-9 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Beaucoup Creek Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Modeled k_a (1/day)	Required k_a (1/day)
NC03	08/16/00	4.7	5.8	14.0
NC10	09/11/95	4.7	0.8	2.6
NCI01	08/04/95	1.5	0.1	11.9
NCK01	07/24/95	2.6	0.8	9.9

Based on the data analysis, increases of aeration would be required in summer months but not during winter conditions. Monitoring data to make the analysis more robust will be discussed in Section 10, as well as management measures to increase aeration and reduce nonpoint source loads contributing to non-attainment of the DO water quality standard.

To confirm that reductions in BOD_5 loads to meet the water quality standard are not an appropriate measure for controlling DO in this watershed, the Streeter-Phelps equations presented in Section 8.3.2 were used to estimate the BOD_5 loading required to meet the water quality standard on each sample date impaired for DO. Table 9-10 shows the BOD_5 loads estimated from TOC, as discussed in Section 8.3.2, and the BOD_5 loading that would be necessary to meet water quality standards.

Table 9-10 Calculated BOD_5 Loads and Required BOD Loads in the Beaucoup Creek Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Calculated BOD_5 (lb/d)	Required BOD_5 (lb/d)
NC03	08/16/00	4.7	357	0
NC10	09/11/95	4.7	1	0
NCI01	08/04/95	1.5	38	0
NCK01	07/24/95	2.6	14	0

Table 9-10 shows that the reductions in BOD_5 loads necessary for compliance with the DO loads are not a feasible option for increasing DO in the Beaucoup Creek Watershed

Section 10
Implementation Plan for Beaucoup Creek and Washington County Lake Watersheds

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

An adaptive management or phased approach is recommended for the manganese, sulfates, and TDS TMDL for this watershed because of the limited amount of data available for the TMDL analysis of Beaucoup Creek Watershed. Adaptive management is a systematic process for continually improving management policies and practices through learning from the outcomes of operational programs. Some of the differentiating characteristics of adaptive management are:

1. acknowledgement of uncertainty about what policy or practice is "best" for the particular management issue;

2. thoughtful selection of the policies or practices to be applied (the assessment and design stages of the cycle);

3. careful implementation of a plan of action designed to reveal the critical knowledge that is currently lacking;

4. monitoring of key response indicators;

5. analysis of the management outcomes in consideration of the original objectives, and incorporation of the results into future decisions (British Columbia Ministry of Forests 2000).

Based on existing data review, presented in Section 5, the likely sources of manganese, sulfates, and TDS in the Beaucoup Creek Watershed are from groundwater potentially contaminated by oil and gas activities and active and abandoned coal mines. Further source identification is required as outlined in the next section.

10.1.1 Source Identification for Manganese, Sulfates, and TDS

It is recommended that further source identification activities take place within the watershed because the current data regarding sources of manganese, sulfate, and TDS in Beaucoup Creek Watershed is limited. The GIS data and mapping provided in Section 5 (Figure 5-6) should be the basis for the start of the source investigation. Collection of data during various flow conditions may also be beneficial in determining the source of these constituents. Available GIS data do not show any abandoned coal mines in the segment NCI01 subwatershed. Therefore, any improperly functioning injection wells, abandoned injection wells, or leaking brine storage tanks should be identified. For the Beaucoup Creek Watershed, the location of the potential discharge from abandoned coal mines should be identified, in addition to other mining activity, which could increase manganese, sulfate, and TDS concentrations in the receiving waters. Once potential sources are identified and located, sampling stations should be placed in appropriate locations to assess water quality downstream of these sources. The potential source identification and station sampling placement should be the result of field investigations.

The difficulty of using GIS to delineate watersheds through areas with surface mining was discussed in Section 5.1.2. Although the watershed delineation through mined areas may not be exact, the implementation actions and management measures remain applicable to the entire Beaucoup Creek Watershed.

10.1.2 Manganese, Sulfates, and TDS Management Measures

If the sources of manganese, sulfates, and TDS in the Beaucoup Creek Watershed are confirmed to be from oil and gas activities, sources could be improperly functioning injection wells, abandoned injection wells, or leaking brine storage tanks. The IDNR Division of Oil & Gas Plugging and Restoration Fund Program (PRF) provide treatment of abandoned injection wells. The IDNR Division of Oil & Gas also regulates brine storage and permitted injection wells. If these operations are found to be the source of manganese and TDS, the Division of Oil & Gas will be able to regulate these activities within its permit program. Because the exceedences of water quality standards occurred during low conditions, it is likely that contaminated groundwater by oil and gas activities could cause impairments in the Beaucoup Creek Watershed.

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

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

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

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

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

Following are examples of the passive treatment technologies:

- aerobic wetland
- compost or anaerobic wetland
- open limestone channels
- diversion wells
- anoxic limestone drains
- vertical flow reactors
- pyroclastic process

The remainder of this section discusses these technologies.

10.1.2.1 Aerobic Wetland

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

10.1.2.2 Compost or Anaerobic Wetland

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

10.1.2.3 Open Limestone Channels

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

10.1.2.4 Diversion Wells

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

10.1.2.5 Anoxic Limestone Drains

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

10.1.2.6 Vertical Flow Reactors

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

10.1.2.7 Pyrolusite Process

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

10.2 Implementation Actions and Management Measures for DO and Phosphorus

DO impairments are addressed by focusing on organic loads that consume oxygen through decomposition and nutrient loads that can cause algal growth, which can also deplete DO. The correlation between low DO and elevated phosphorus concentrations in Washington County Lake was established in Section 7, so management measures for Washington County Lake focus on phosphorus reduction. Analysis provided in Section 8 established a relationship between reaeration, BOD_5, and DO concentrations in Beaucoup Creek segments NC10, NC03, NCI01, and NCK01, so management measures for the Beaucoup Creek Watershed will focus on increasing reaeration and decreasing BOD_5 loads to increase DO concentrations. Although it was shown that based on current data, BOD_5 loads do not need to be reduced, it is likely that during storm events, high BOD_5 loads are transported to the stream, and therefore reducing these loads will also help increase DO concentrations.

Phosphorus loads in Washington County Lake originate from external and internal sources. From modeling estimates, internal phosphorus cycling from sediments accounts for approximately 77 percent of the loading to Washington County Lake. External loads from nonpoint source runoff from agricultural crops and a dairy farm account for an additional 21 percent of the loading. The remaining two percent of the loading is attributed to groundwater. To achieve the 89 percent phosphorus reduction for the load allocations established in Section 9 for Washington County Lake (Table 9-3), management measures must address nonpoint source loading through sediment and surface runoff controls and internal nutrient cycling through in-lake management. Phosphorus sorbs readily to soil particles and controlling sediment load into the reservoir helps control phosphorus loadings.

DO impairments in Beaucoup Creek Watershed segments NC10, NC03, NCI01, and NCK01 are mostly attributed to low flow or stagnant conditions within the creek. Runoff from nonpoint sources may also contribute a BOD_5 load in Beaucoup Creek segments NC10, NC03, NCI01, and NCK01. An additional contributor to low DO is increased water temperatures. Therefore, management measures for segments NC10, NC03, NCI01, and NCK01 will focus on reducing nonpoint source loading through sediment and surface runoff controls, reducing stream temperatures, and reducing stagnant conditions through reaeration.

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

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

Implementation actions and management measures are described for each nonpoint source in the watershed. Nonpoint sources include cropland and rural grassland. The final source is internal phosphorus cycled from lake sediments.

10.2.1 Nonpoint Source Phosphorus and DO Concentration Management

The sources of nonpoint source pollution in the Beaucoup Creek and Washington County Lake TMDL are divided between agricultural cropland and animal management facilities. BMPs evaluated that could be utilized to treat these nonpoint sources are:

- filter strips,
- wetlands,
- conservation tillage practices,
- nutrient management,
- reaeration.

Organic and nutrient loads originating from cropland is most efficiently treated with a combination of riparian buffer or grass filter strips and wetlands. No-till or conservation tillage practices provide further reductions to sediment and phosphorus in runoff from croplands. Nutrient management focuses on source control of nonpoint source contributions to Washington County Lake.

Instream management measures for DO focus on reaeration techniques. The Streeter-Phelps equations presented in Section 8 utilizes a reaeration coefficient. Increasing the reaeration coefficient by physical means will increase DO in Beaucoup Creek segments NC10, NC03, NCI01, and NCK01.

WCLRP suggests structural BMPs, such as dry dams and wetlands, and shoreline protection to control sedimentation to Washington County Lake. The plan provides potential alternatives and cost summaries that could be considered for implementation.

10.2.1.1 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to both Washington County Lake and Beaucoup Creek Watershed. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff, help reduce stream water temperatures thereby increasing the water body DO saturation level, and provide bank stabilization decreasing erosion and deposition. Additionally, filter strips mitigate nutrient loads to lakes. The following paragraphs focus on the implementation of filter strips in the Washington County Lake and Beaucoup Creek Watershed, separately. Finally, design criteria and size selection of filter strips are detailed.

Grass and riparian buffer strips filter out nutrients and organic matter associated with sediment loads to a water body. Reduction of nutrient concentrations, specifically phosphorus, in Washington County Lake, will reduce the amount of algal growth in the lake system, which can cause depletion of DO when algae expire and cause more significant diurnal fluctuations from photosynthesis. Filter strips reduce nutrient and sediment loads to lakes by establishing ground depressions and roughness that settles sediment out of runoff and providing vegetation to filter nutrients out of overland flow. As much as 75 percent of sediment and 45 percent of total phosphorus can be removed from runoff by a grass filter strip (North Carolina State University [NCSU] 2000). Currently, approximately 53 percent of the fields in the Washington Lake Watershed use filter strips (NRCS 2002a). It should be noted that filter strips are only likely to be this effective if sheet flow is maintained over the filter strip. In addition, filter strips should be harvested periodically, so that removal rate efficiencies over extended periods of time remain high (USEPA 1993).

Organic debris in topsoil contributes to the BOD_5 load to water bodies (USEPA 1997b). Increasing the length of stream bordered by grass and riparian buffer strips will decrease the amount of BOD_5 and nutrient load associated with sediment loads to Beaucoup Creek segments NC03 and NC10, Swanwick Creek segment NCK01, and Little Beaucoup Creek segment NCI01. Nutrient criteria, currently being developed and expected to be adopted around 2007 by the Illinois EPA, will assess the instream nutrient concentrations required for the watershed. As stated previously, excess nutrients in streams can cause excessive algal growth, which can deplete DO in streams. Adoption of nutrient criteria will affect this DO TMDL and may require reassessment of the DO model for Beaucoup Creek segments NC03 and NC10, Swanwick Creek segment NCK01, and Little Beaucoup Creek segment NCI01 upon adoption.

Filter strips will help control BOD_5 levels by removing organic loads associated with sediment from runoff; however, no studies were identified as providing an estimate of removal efficiency. Grass filter strips can remove as much as 75 percent of sediment and 45 percent of total phosphorus from runoff, so it is assumed that the removal of BOD_5 falls within this range (NCSU 2000). Riparian buffer strips also help reduce water temperatures increasing the water body DO saturation level as explained in Section 8.

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

Filter strip widths for the Beaucoup Creek and Washington County Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 10-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on slope estimates near tributaries within the watershed, filter strips widths of 72 to 180 feet could be incorporated in locations throughout the watershed. The total acreage examined was 2,800 acres.

Table 10-1 Filter Strip Flow Lengths Based on Land Slope

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

The acreages provided above are used to calculate an approximation of BMP cost in Section 10.3 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips according to the NRCS guidance presented in Table 10-1. Programs available to fund the construction of these buffer strips are discussed in Section 10.3.

10.2.1.2 Wetlands

The use of wetlands as a structural control are most applicable to nutrient reduction in Washington County Lake, and therefore this section only focuses on the Washington County Lake Watershed. To treat loads from agricultural runoff, a wetland or multiple wetlands could be constructed in locations that will maximize the capture of surface runoff prior to entering the lake. Wetlands are assumed to be an effective BMP because they:

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

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

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

Guidelines for wetland design suggest a wetland to watershed ratio of 0.6 percent for nutrient and sediment removal from agricultural runoff. Table 10-2 outlines estimated wetland areas for each subbasin in the Washington County Lake Watershed based on these recommendations. A wetland system to treat agricultural runoff from the six subbasins comprising the 6,600-acre (10.3-square mile) Washington County Lake Watershed would range between three to nine acres (Denison and Tilton 1993).

Table 10-2 Acres of Wetland Required

Subbasin	Area (acres)	Wetland (acres)
1	1,434	9
2	1,536	9
3	1,133	7
4	826	5
5	1,094	7
6	576	3

There are 76 animal management facilities located in the Beaucoup Creek Watershed. Thirty-four of the animal management facilities in the watershed have been designated as potentially having no impact on receiving waters, 32 have been designated as potentially having a slight impact on receiving waters, one has been designated as potentially having a moderate impact on receiving waters, and the remaining nine have not been assessed. Wetlands were not analyzed as part of a treatment for this TMDL due to the data indicating a lack of impact on the system. However, it is recommended that facilities that impose a moderate and slight impact on receiving waters or in the event that the eight non-assessed facilities are found to have a negative impact on water quality, a constructed wetland could be used to treat loads from the animal management operations between the operation and the creek.

10.2.1.3 Conservation Tillage Practices

For the Washington County Lake Watershed, conservation tillage practices could help reduce nutrient loads in the lake. Nonpoint source runoff from 3,937 acres of row crops and small grain agriculture in the Washington County Lake Watershed, subject to all types of tillage practices, were estimated to contribute 17 percent of the total phosphorus load to Washington County Lake. Total phosphorus loading from cropland is controlled through management BMPs, such as conservation tillage. Conservation tillage maintains at least 30 percent of the soil surface covered by residue after planting. Crop residuals or living vegetation cover on the soil surface protect against soil detachment from water and wind erosion. Conservation tillage practices can remove 45 percent of the dissolved and total phosphorus from runoff and 75 percent of the sediment (NCSU 2000). Additionally, studies have found 93 percent less erosion occurred from no-till acreage compared to acreage subject to moldboard plowing (NCSU 2000). Current tillage practices for the Washington County Lake Watershed are provided in Table 10-3. To achieve the reductions needed, erosion control through conservation tillage could reduce phosphorus loads. The watershed's modeled erosion rate from row crop and small grains averages one ton/acre/year. To achieve a 30 percent reduction in phosphorus load, the erosion rate for the watershed would need to be reduced to 0.7 tons/acre/year. Similarly, the C-factors for corn, soybeans, and small grains would need to be reduced from 0.12, 0.08, and 0.11 to 0.08, 0.05, and 0.08, respectively.

Table 10-3 Current Tillage Practices in the Washington County Lake Watershed

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0%	0%	0%
Reduced Till	60%	15%	10%
Mulch-Till	10%	30%	60%
No-Till	30%	55%	30%

The tillage practices on an additional 94,274 acres of cropland in the remainder of the Beaucoup Creek Watershed should be assessed, and conservation practices should be continued and improved upon where needed to further reduce nutrient and sediment loading to streams in the Beaucoup Creek Watershed.

10.2.1.4 Nutrient Management

Nutrient management could result in reduced phosphorus and nitrogen loads to Washington County Lake. Crop management of nitrogen and phosphorus can be accomplished through Nutrient Management Plans, which focus on increasing the efficiency with which applied nutrients are used by crops, thereby reducing the amount available to be transported to both surface and groundwater. In the past, nutrient management focused on application rates designed to meet crop nitrogen requirements but avoid groundwater quality problems created by excess nitrogen leaching. This results in buildup of soil phosphorus above amounts sufficient for optimal crop yields.

Illinois, along with most Midwestern states, demonstrates high soil test phosphorus in greater than 50 percent of soil samples analyzed (Sharpley et al. 1999).

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

- plan summary,
- manure summary, including annual manure generation, use, and export,
- nutrient application rates by field and crop,
- summary of excess manure utilization procedures,
- implementation schedule,
- manure management and stormwater BMPs.

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

10.2.1.5 Reaeration

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

10.2.2 In-Lake Phosphorus

Internal cycling of phosphorus contributes approximately 77 percent of the phosphorus load to Washington County Lake Watershed. Reduction of phosphorus from in-lake cycling through management strategies is necessary for attainment of the TMDL load allocation. Internal phosphorus loading occurs when the water above the sediments become anoxic causing the reduction of iron phosphate, which releases phosphate from the sediment in a form that is available for plant uptake. The addition of bioavailable phosphorus in the water column stimulates more plant growth and die-off, which perpetuates the anoxic conditions and enhances the reduction of iron and the subsequent phosphate release from ferric phosphate into the water.

Control of internal phosphorus cycling must limit release of phosphorus from the sediments either through lake oxygen concentration or sediment management. If the water column never becomes anaerobic, the ferric phosphate will not be reduced to bioavailable phosphorus. Aeration, which simulates lake mixing and keeps oxygen conditions from being depleted in the epilimnon, can be very effective at preventing re-release of bound phosphorus. Reduction of internal phosphorus cycling from this measure is typically determined based on site-specific studies.

Phosphorus release from the sediment is greatest from recently deposited layers. Dredging about one meter of recently deposited phosphorus-rich sediment can remove approximately 80 to 90 percent of the internally loaded phosphorus without the addition of potentially toxic compounds to the reservoir, although it is more costly than other management options (NRC 1992).

10.2.3 Implementation Actions and Management Measures Summary

10.2.3.1 Washington County Lake Watershed

To meet the reductions outlined in Section 9 for Washington County Lake, 90 percent of the phosphorus from internal loading and 85 percent of phosphorus loaded from nonpoint source pollution would need to be reduced to meet the TMDL target of a DO concentration greater than 6.0 mg/L. The GWLF model was used to model the following practices to estimate achievable reductions in total phosphorus:

- filter strips,
- conservation tillage,
- nutrient management (reduction of total phosphorus in sediment by 20 percent).

The modeling effort showed that filter strips do not provide much total phosphorus reduction, most likely due to routing constraints of the GWLF model as discussed in Section 7.3.2.1.1 and the small magnitude of area available for filter strip development. Reductions of external loads by conservation tillage, nutrient management, filter strips, and wetlands are summarized in Table 10-4. Wetlands were not modeled with GWLF because wetland performance is a result of placement in the watershed, and GWLF does not recognize spatial data due to routing constraints of the model. Therefore, 50 percent of the literature value for phosphorus reduction by wetlands was utilized in Table 10-4 to estimate load reductions.

Table 10-4 Summary of Total Phosphorus Load Reductions

Management Measure	Potential Percent Reduction
Nutrient Management	10%
Conservation Tillage Practices	11%
Filter Strips*	22%
Wetland*	5%

* 50% of literature value utilized for estimation

A combination of implementing these external load reduction practices coupled with the available treatments for internal loads, would allow the Washington County Lake Watershed to meet its total goal of reducing phosphorus loads by a combined 89 percent. Section 10.3 outlines planning level costs and programs available to help with cost-sharing so that this goal can be achieved.

10.2.3.2 Beaucoup Creek Watershed

Mitigations to DO impairments in the Beaucoup Creek Watershed should focus on reducing nonpoint source loads and stream temperature. Evaluation of land near streams and lakes and creation of grass or hardwood filter strips, according to the NRCS guidance presented in Table 10-1, will help reduce stream temperatures and may potentially reduce the organic loads thereby reducing the BOD_5 loading. Additionally, methods for increasing reaeration, such as bank stabilization, will increase DO. Adaptive management principles will be utilized to assess further management measures in the future.

10.3 Reasonable Assurance

Reasonable assurance means that a demonstration is given that the pollutant reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Sections 10.1 and 10.2 provided a means for obtaining the reductions necessary. The remainder of this section discusses the programs available to assist with funding and an estimate of costs to the watershed for implementing these practices.

10.3.1 Available Programs for TDS and Manganese TMDL

As mentioned previously, the Illinois EPA is responsible for regulating permitted coal mines in Illinois. As outlined in Section 10.1, the Illinois EPA has the authority to revise permit limits to protect water quality standards. It is recommended that additional data on abandoned mine sites and their contribution to impairments be examined prior to revision of permit limits in Beaucoup Creek Watershed.

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

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

10.3.2 Available Programs for DO and Phosphorus TMDL

Approximately 75 percent of the Beaucoup Creek and Washington County Lake Watershed is classified as rural grassland (pasture land, CRP, waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill, which encourage landowners to implement resource-conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following sections.

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

The Illinois Department of Agriculture (IDA) and Illinois EPA are presently co-sponsoring a cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 98,211 acres of cropland have been targeted in the Beaucoup Creek Watershed. This voluntary project will supply incentive payments to producers to have Nutrient Management Plans developed and implemented. Additionally, if sediments or phosphorus has been identified as a cause for impairment in the watershed, then traditional erosion control practices will be eligible for cost-share assistance through the Nutrient Management Plan project as well.

10.3.2.2 Clean Water Act Section 319 Grants

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

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

10.3.2.3 Streambank Stabilization and Restoration Practice

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

10.3.2.4 Conservation Reserve Program

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

Eligible land must be one of the following:

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

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

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

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

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

10.3.2.5 Wetlands Reserve Program

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

The 2002 Farm Bill reauthorized the program through 2007. Increasing the acreage enrollment cap to 2,275,000 acres with an annual enrollment of 250,000 acres per calendar year. The program is limited by the acreage cap and not by program funding. The program offers three enrollment options: permanent easements, 30-year conservation easements, and 10-year restoration cost-share agreements. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs, and the average project size is 177 acres. The costs for each enrollment option follows in Table 10-5 (USDA 1996).

Table 10-5 Costs for Enrollment Options of WRP Program

Option	Permanent Easement	30-year Easement	Restoration Agreement
Payment for Easement	100% Agricultural Value	75% Agricultural Value	NA
Payment Options	Lump Sum	Lump Sum	NA
Restoration Payments	100% Restoration Cost Reimbursement	75% Restoration Cost Reimbursement	75% Restoration Cost Reimbursement

10.3.2.6 Environmental Quality Incentive Program

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

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

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

10.3.2.7 Conservation Practices Program

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

10.3.2.8 Wildlife Habitat Incentives Program

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

- the landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness.

NRCS agrees to provide technical assistance and pay up to 75 percent of the cost of installing the wildlife habitat practices. Additional financial or technical assistance may be available through cooperating partners (NRCS 2002b).

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Washington County are listed in Table 10-6 below.

Table 10-6 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
Robert Spencer	424 East Holzhauer Drive, Nashville, IL 62263	618-327-8862 x3
Local FSA Office		
Nashville Service Center	424 East Holzhauer Drive, Nashville, IL 62263	618-327-8862

10.3.3 Cost Estimates for BMPs

Cost estimates for different BMPs and individual practice prices, such as filter strip installation, are detailed in the following sections. Table 10-7 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Beaucoup Creek and Washington County Lake Watershed are presented in Section 10.3.3.8 and Table 10-8.

10.3.3.1 Streambank Stabilization

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

10.3.3.2 Wetland

Washington County has no acreage enrolled in the WRP at this time; therefore, cost estimate information was derived from adjacent counties. The price to establish a wetland is site specific. In general, the cost to construct a wetland includes creation of wetland hydrology, site preparation for planting, shrub or tree planting, and labor costs. The average project cost to establish a wetland in Washington County is $1,250/acre. It should be noted that the larger the wetland acreage to be established, the more cost-effective the project.

10.3.3.3 Filter Strips and Riparian Buffers

Perry County estimates an average cost per acre to install a grass filter strip with a 15-year life span at $260/acre. A riparian buffer strip established with bare root stock has a life span of 15 years and an installation cost of $280/acre. Although parts of the Beaucoup Creek Watershed are in Washington County, the majority of the watershed is contained in Perry County. Therefore, costs from Perry County were used to develop the costs in Tables 10-8 and 10-9 for filter strips and riparian buffers in the Beaucoup Creek Watershed.

10.3.3.4 Nutrient Management Plan - NRCS

A significant portion of the agricultural land in the Beaucoup Creek Watershed is comprised of cropland. Estimates of Nutrient Management Plans across Illinois suggest the average plan costs $5 to $15/acre.

10.3.3.5 Nutrient Management Plan - IDA and Illinois EPA

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

10.3.3.6 Conservation Tillage

Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted. The installation cost for conservation tillage is $17/acre, and the average annual cost for maintaining conservation tillage is $17.35/acre/year (NCSU 2000).

10.3.3.7 Internal Cycling

Controls of internal phosphorus cycling in lakes are costly. Dredging is typically the most expensive management practice averaging $8,000/acre; however, the practice is 80 to 90 percent effective at nutrient removal and will last for at least 50 years. An aeration system, consisting of an air compressor, pump, weighted tubing, and diffuser stations costs approximately $69,000 for material and installation. Operating costs to run the pump are estimated as $36/day for approximately 180 days/year, which totals about $6,000/year in operating costs (Cortell 2002; Geney 2002).

10.3.3.8 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 10-7. The column labeled *Program* lists the financial assistance program available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 10-7 Cost Estimate of Various BMP Measures in Washington County

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	WRP	Wetland	10	$1,250	$125.00
	CRP	Grass Filter Strips	15	$260	$26.00
	CRP	Riparian Buffer	10	$280	$18.67
	319 or SSRP	Streambank Stabilization*	10	$40	$4.00
	CRP	Grassed Waterways	10	$1,870	$187.00
	NRCS	Nutrient Management Plan		$10	
		Nutrient Management Plan		$7	
	CRP	Conservation Tillage	1	$17	$17.35
Internal Cycling		Dredging	50	$8,000	$160.00
		Aeration	20	$583	$29.15

* Streambank Stabilization cost calculated on linear foot basis.

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $16,526,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 10-8 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 10-8 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs, calculated as 10 percent of the capital costs. These do not represent the total costs of operating the measure over its life cycle.

Table 10-8 Cost Estimate of Implementation Measures in the Beaucoup Creek Watershed

		Capital Costs		Maintenance Costs	
BMP	Treated Acres	Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Wetland	40	$1,250	$50,000	$125.00	$5,000
Grass Filter Strips	2,800	$260	$728,000	$26.00	$73,000
Nutrient Management Plan (IDA and Illinois EPA)	98,211	$7	$690,000		
Conservation Tillage	98,211	$17	$1,670,000	$17.35	$1,700,000
Streambank Stabilization*	299,376	$40	$11,975,000	$4.00	$1,197,500
Aeration	242	$583	$141,000	$29.15	$7,000
Total			**$15,254,000**		**$2,982,500**

*Streambank Stabilization cost calculated on linear foot basis.

10.4 Monitoring Plan

The purpose of the monitoring plan for the Beaucoup Creek Watershed is to assess the overall implementation of management actions outlined in this section. This can be accomplished by conducting the following monitoring programs:

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

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

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

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

Illinois EPA monitors Washington County Lake from April through October approximately every three years. Segments within the Beaucoup Creek Watershed are monitored approximately every five years as part of the Big Muddy River Basin Intensive Survey. Continuation of this monitoring will assess instream water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the watershed are being attained. To further support DO modeling and to plan for future nutrient criteria in the watershed, the following parameters should be added to the monitoring list:

- $BOD_{5,}$
- $BOD_{20,}$
- Chlorophyll 'a' or algae monitoring in impaired creeks.

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

10.5 Implementation Time Line

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

Section 11
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Appendix A
Historic Water Quality Data

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Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RNM-1	4/24/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.056	1
RNM-1	4/24/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.071	Lake Bottom
RNM-1	6/12/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.144	1
RNM-1	6/12/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.227	Lake Bottom
RNM-1	7/11/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.66	1
RNM-1	7/11/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.182	Lake Bottom
RNM-1	8/15/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.246	1
RNM-1	8/15/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.334	Lake Bottom
RNM-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.137	1
RNM-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.161	Lake Bottom
RNM-1	8/3/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.199	1
RNM-1	8/3/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.189	Lake Bottom
RNM-1	4/18/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.111	1
RNM-1	4/18/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.089	Lake Bottom
RNM-1	6/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.215	1
RNM-1	6/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.364	Lake Bottom
RNM-1	7/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.171	1
RNM-1	7/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.61	Lake Bottom
RNM-1	8/14/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.121	1
RNM-1	8/14/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.908	Lake Bottom
RNM-1	10/3/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.057	1
RNM-1	10/3/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.05	Lake Bottom
RNM-1	4/14/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.131	1
RNM-1	4/14/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.117	Lake Bottom
RNM-1	6/3/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.157	1
RNM-1	6/3/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.512	Lake Bottom
RNM-1	7/2/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.165	1
RNM-1	7/2/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.305	Lake Bottom
RNM-1	8/4/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.168	1
RNM-1	8/4/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.3	Lake Bottom
RNM-1	4/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.087	1
RNM-1	4/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.063	10
RNM-1	4/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.071	17
RNM-1	6/8/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	1
RNM-1	6/8/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.045	10
RNM-1	6/8/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	17
RNM-1	7/16/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.071	1
RNM-1	7/16/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.069	10
RNM-1	7/16/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.377	17
RNM-1	8/22/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.076	1
RNM-1	8/22/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.085	9
RNM-1	8/22/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.112	16
RNM-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.065	1
RNM-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.066	9
RNM-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.07	15
RNM-2	4/24/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.08	1
RNM-2	6/12/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.139	1
RNM-2	7/11/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.186	1
RNM-2	8/15/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.23	1
RNM-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.215	1
RNM-2	4/18/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.117	1

RNM-2	6/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.205	1
RNM-2	7/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.152	1
RNM-2	8/14/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.151	1
RNM-2	10/3/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.108	1
RNM-2	4/14/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.236	1
RNM-2	6/3/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.162	1
RNM-2	7/2/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.204	1
RNM-2	8/4/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.218	1
RNM-2	4/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.081	1
RNM-2	6/8/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.044	1
RNM-2	7/16/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	1
RNM-2	8/22/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.085	1
RNM-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.085	1
RNM-3	4/24/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.127	1
RNM-3	6/12/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.168	1
RNM-3	7/11/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.212	1
RNM-3	8/15/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.234	1
RNM-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.252	1
RNM-3	4/18/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.118	1
RNM-3	6/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.213	1
RNM-3	7/5/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.171	1
RNM-3	8/14/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.238	1
RNM-3	10/3/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.186	1
RNM-3	4/14/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.186	1
RNM-3	6/3/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.239	1
RNM-3	7/2/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.295	1
RNM-3	8/4/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.248	1
RNM-3	4/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.124	1
RNM-3	6/8/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.05	1
RNM-3	7/16/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.105	1
RNM-3	8/22/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.143	1
RNM-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.106	1

Station	Start Date	Parameter Long Name		Result Value	Sample Depth (ft)
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.3	0
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.2	1
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.9	3
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.1	5
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.2	7
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.2	9
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4	11
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.5	13
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.6	15
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.8	17
RNM-1	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.1	19
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10	0
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.7	1
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	3
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.2	5
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.2	7
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.5	9
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	11
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	13
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	15
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	17
RNM-1	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	19
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.7	0
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	1
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.7	3
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6	5
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5	7
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.8	9
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2	11
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	13
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	15
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	17
RNM-1	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	19
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.3	0
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.3	1
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	3
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.8	5
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.8	7
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.4	9
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	11
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	13
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	15
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	17
RNM-1	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	19
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	0
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	1
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	3
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	5
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	7
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	9
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	11
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	13
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	15
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	17
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	19
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	14.6	0

RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	14.6	1
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	14.6	3
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.9	5
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.3	7
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7	9
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6	11
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.8	13
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	15
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5	17
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.9	19
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.8	21
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.5	23
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.4	25
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.5	27
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.3	29
RNM-1	8/3/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	31
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	0
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	1
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	3
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	5
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.8	7
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	9
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.7	11
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.2	13
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.6	15
RNM-1	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.7	17
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.9	0
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.9	1
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.2	3
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.8	5
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.3	7
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	9
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	11
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	15
RNM-1	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	17
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.8	0
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.8	1
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.6	3
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.8	5
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.9	7
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1	9
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.4	11
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	15
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	17
RNM-1	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	19
RNM-1	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.4	0
RNM-1	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.7	1
RNM-1	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.6	3
RNM-1	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4	5
RNM-1	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.2	7
RNM-1	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	9
RNM-1	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	11
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9	0
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.1	1
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.9	3

RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.8	5
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.8	7
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.8	9
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	11
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.9	13
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	15
RNM-1	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.4	17
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.2	0
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.2	1
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.7	3
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.5	5
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.3	7
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.1	9
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.7	11
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	13
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.1	15
RNM-1	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.9	17
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.5	0
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.5	1
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.5	3
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.5	5
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.6	7
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.5	9
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8	11
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	13
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	15
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	17
RNM-1	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	19
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.3	0
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.2	1
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.7	3
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.5	5
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.5	7
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	9
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	11
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	15
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	17
RNM-1	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	19
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	0
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.8	1
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.2	3
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.9	5
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6	7
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.6	9
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.3	11
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	15
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	17
RNM-1	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	19
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.7	0
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.4	1
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.3	3
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.7	5
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.5	7
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.4	9
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.4	11

RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.9	13
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.2	15
RNM-1	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.5	17
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.6	0
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.5	1
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.5	3
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.4	5
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10	7
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.6	9
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.8	11
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	13
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.6	15
RNM-1	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.6	17
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.8	0
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.7	1
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.9	3
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.8	5
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.6	7
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	9
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.2	11
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	13
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.3	15
RNM-1	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.3	17
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.8	0
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.5	1
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.3	3
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.9	5
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.6	7
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.4	9
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.4	11
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	13
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	15
RNM-1	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	17
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.3	0
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.2	1
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	3
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.5	5
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.4	7
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3	9
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.3	11
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.3	13
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.3	15
RNM-1	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	17
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.4	0
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.2	1
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.8	3
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.5	5
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.4	7
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.3	9
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.9	11
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.7	13
RNM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.1	15
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.8	0
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.7	1
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.6	3
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.5	5
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.5	7

RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	9
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.7	11
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.3	13
RNM-2	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.7	15
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.1	0
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13	1
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.9	3
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.4	5
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.8	7
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.3	9
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.5	11
RNM-2	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	13
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8	0
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.9	1
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.4	3
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	5
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.1	7
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.6	9
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	11
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	13
RNM-2	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	15
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.8	0
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.8	1
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.7	3
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.5	5
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.8	7
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.2	9
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.9	11
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.2	13
RNM-2	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0	15
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	0
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	1
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	3
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	5
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	7
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	9
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	11
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.6	13
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.7	0
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.7	1
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	3
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	5
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	7
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	9
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	11
RNM-2	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	13
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.8	0
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.2	1
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.7	3
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.7	5
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.4	7
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.6	9
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	11
RNM-2	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	0
RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.2	1
RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.1	3

RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5	5
RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5	7
RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.9	9
RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.8	11
RNM-2	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.7	13
RNM-2	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.2	0
RNM-2	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	1
RNM-2	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.8	3
RNM-2	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.1	5
RNM-2	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.7	0
RNM-2	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	1
RNM-2	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.4	3
RNM-2	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.4	5
RNM-2	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.8	7
RNM-2	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.7	9
RNM-2	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.7	11
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.5	0
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.5	1
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.3	3
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.1	5
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.9	7
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	9
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7	11
RNM-2	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.2	13
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	0
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.2	1
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	3
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.9	5
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7	7
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.9	9
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	11
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-2	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	15
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11	0
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.4	1
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.4	3
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.1	5
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	7
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	9
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	11
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-2	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	15
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.3	0
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.3	1
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.2	3
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.9	5
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.1	7
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.9	9
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.4	11
RNM-2	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.1	13
RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.7	0
RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	1
RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	3
RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.2	5
RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5	7
RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5	9
RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.9	11

RNM-2	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.9	13
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.9	0
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.8	1
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.4	3
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.5	5
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10	7
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.6	9
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.2	11
RNM-2	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7	13
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.7	0
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.4	1
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.2	3
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.2	5
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.1	7
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.3	9
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.5	11
RNM-2	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.1	13
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.7	0
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.2	1
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.9	3
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.7	5
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.9	7
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.1	9
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.6	11
RNM-2	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	0.3	13
RNM-2	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.1	0
RNM-2	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.9	1
RNM-2	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	3
RNM-2	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8	5
RNM-2	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7	7
RNM-2	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.4	9
RNM-2	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.9	11
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.7	13
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.6	0
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.3	1
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.7	3
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.7	5
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.3	7
RNM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.5	9
RNM-3	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.7	0
RNM-3	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.6	1
RNM-3	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13.3	3
RNM-3	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.7	5
RNM-3	4/24/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.4	7
RNM-3	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	13	0
RNM-3	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.9	1
RNM-3	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.7	3
RNM-3	6/12/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.3	5
RNM-3	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	0
RNM-3	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	1
RNM-3	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6	3
RNM-3	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.8	5
RNM-3	7/11/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.9	7
RNM-3	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.7	0
RNM-3	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.6	1
RNM-3	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.3	3
RNM-3	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.3	5

RNM-3	8/15/1990	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.2	7
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.7	0
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.7	1
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.6	3
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	5
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.2	7
RNM-3	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.2	0
RNM-3	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.2	1
RNM-3	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.2	3
RNM-3	4/18/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.2	5
RNM-3	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.4	0
RNM-3	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.3	1
RNM-3	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.8	3
RNM-3	6/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.1	5
RNM-3	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.2	0
RNM-3	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	1
RNM-3	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.1	3
RNM-3	7/5/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7	5
RNM-3	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.5	0
RNM-3	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.9	1
RNM-3	8/15/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.5	3
RNM-3	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.4	0
RNM-3	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.2	1
RNM-3	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.6	3
RNM-3	10/3/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.9	5
RNM-3	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.5	0
RNM-3	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	12.6	1
RNM-3	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.9	3
RNM-3	4/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.4	5
RNM-3	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.3	0
RNM-3	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.1	1
RNM-3	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.5	3
RNM-3	6/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.6	5
RNM-3	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.5	0
RNM-3	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.4	1
RNM-3	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.5	3
RNM-3	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.6	5
RNM-3	7/2/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.5	7
RNM-3	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.4	0
RNM-3	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.4	1
RNM-3	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.3	3
RNM-3	8/4/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.1	5
RNM-3	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.6	0
RNM-3	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.4	1
RNM-3	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.3	3
RNM-3	10/6/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	6.3	5
RNM-3	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.8	0
RNM-3	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.1	1
RNM-3	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.1	3
RNM-3	6/8/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	5.6	5
RNM-3	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.7	0
RNM-3	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.5	1
RNM-3	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.4	3
RNM-3	4/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.2	5
RNM-3	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	9.1	0
RNM-3	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.8	1
RNM-3	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	8.6	3

RNM-3	7/16/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7.6	5
RNM-3	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.8	0
RNM-3	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.5	1
RNM-3	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.2	3
RNM-3	8/22/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10	5
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.2	0
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.9	1
RNM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.6	3

Sample Location	Date	Parameter	Result (mg/L)
NC 03	8/16/2000	SULFATE, TOTAL (MG/L AS SO4)	410
NC 03	9/19/2000	SULFATE, TOTAL (MG/L AS SO4)	1000
NC 03	8/16/2000	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	759
NC 03	9/19/2000	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	1380
NC 03	7/24/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5
NC 03	3/14/1996	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.9
NC 03	8/16/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.7
NC 03	9/19/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7

Sample Location	Date	Parameter		Result (mg/L)
NC 05	9/11/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.7
NC 05	3/14/1996	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.4

Sample Location	Date	Parameter		Result (mg/L)
NCI 01	8/4/1995	MANGANESE, TOTAL (UG/L AS MN)		2.1
NCI 01	3/5/1996	MANGANESE, TOTAL (UG/L AS MN)		0.29
NCI 01	8/4/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	1.5
NCI 01	3/5/1996	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.1

Primary Station ID	Start Date	Parameter Long Name		Result Value
NCK 01	7/24/1995	MANGANESE, TOTAL (UG/L AS MN)		3800
NCK 01	3/5/1996	MANGANESE, TOTAL (UG/L AS MN)		380
NCK 01	3/5/1996	SULFATE, TOTAL (MG/L AS SO4)		505
NCK 01	7/24/1995	SULFATE, TOTAL (MG/L AS SO4)		162
NCK 01	7/24/1995	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	2.6
NCK 01	3/5/1996	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.6

Sample Location	Date	Parameter	Result (mg/L)
NCC 01	8/2/1995	MANGANESE, TOTAL (UG/L AS MN)	1
NCC 01	3/13/1996	MANGANESE, TOTAL (UG/L AS MN)	2.9
NCC 01	8/2/1995	SULFATE, TOTAL (MG/L AS SO4)	1570
NCC 01	3/13/1996	SULFATE, TOTAL (MG/L AS SO4)	1890
NCC 01	8/2/1995	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	1740
NCC 01	3/13/1996	SOLIDS, RESIDUE ON EVAPORATION AT 180 DEG C, DISSOLVED (MG/L)	1730

Appendix B
Directory of Coal Mines
for Perry County, Illinois
May 4, 2002

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APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR PERRY COUNTY, ILLINOIS (IDNR 2000)
MAY 4, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
90	RITCHEY C C	RICHEY	1	SHAFT	MRP	1910-20	HERRIN	PERRY	5S	3W	23
90	SOUTHERN GEM C C	SOUTH GEM	5	SHAFT		1921-27	HERRIN	PERRY	5S	3W	23
90	BREWERTON C C	BREWERTON	45	SHAFT		1927-34	HERRIN	PERRY	5S	3W	23
90	BRIAR HILL COAL MNG C	BRIAR HILL	45	SHAFT		1934-37	HERRIN	PERRY	5S	3W	23
90	PINCKNEYVILLE MNG CO	PICKNEYVILLE	5	SHAFT		1937-52	HERRIN	PERRY	5S	3W	23
177	SCHNEIDER C C	SCHNEIDER		SHAFT	MRP	1913-22	HERRIN	PERRY	5S	3W	13
177	ILLINOIS 6TH VEIN C C	ILL 6		SHAFT		1918-22	HERRIN	PERRY	5S	3W	13
178	SUN OIL & COKE CO	SUN		SHAFT	MRP	1884-42	HERRIN	PERRY	5S	1W	30
178	EATEN FUEL CO	BLACK DIAMOND		SHAFT		1902-05	HERRIN	PERRY	5S	1W	29
178	DIAMOND FUEL CO	DIAMOND		SHAFT		1906-10	HERRIN	PERRY	5S	1W	30
178	DIAMOND FUEL CO	BLACK DIAMOND	3	SHAFT		1906-11	HERRIN	PERRY	5S	1W	29
178	BAILEY BROS C C	DIAMOND	1	SHAFT		1911-42	HERRIN	PERRY	5S	1W	30
179	WEAVER COAL & COKE	JUPITER	2	SHAFT	RPB	1903-04	HERRIN	PERRY	5S	1W	32
179	MANUFACTURERS FUEL CO	JUPITER	2	SHAFT		1904-06	HERRIN	PERRY	5S	1W	32
179	IMPERIAL C C	IMPERIAL	2	SHAFT		1906-12	HERRIN	PERRY	5S	1W	32
179	MORRIS, JOSEPH	IMPERIAL	2	SHAFT		1912-13	HERRIN	PERRY	5S	1W	32
179	GREENWOOD DAVIS C C	GREENWOOD	2	SHAFT		1913-18	HERRIN	PERRY	5S	1W	32
179	KANAWHA FUEL CO	OLD ABE	2	SHAFT		1918-22	HERRIN	PERRY	5S	1W	32
183	UNION COLLIERY CO	KATHLEEN		SHAFT	RP	1918-47	HERRIN	JACKSON	7S	1W	5
297	WHITE WALNUT C C	WHITE WALNUT		SHAFT	RPB	1901-08	HERRIN	PERRY	5S	3W	25
297	BESSEMER WASHED C C	WHITE WALNUT		SHAFT		1908-13	HERRIN	PERRY	5S	3W	25
622	UNITED ELECTRIC C C	FIDELITY	11	STRIP		1929-74	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
622	FREEMAN UNITED COAL MNG CO	FIDELITY	11	STRIP		1975-	HERRIN	PERRY	6S	2W	21
623	PYRAMID C C	PYRAMID		STRIP		1926-52	HERRIN	PERRY	6S	3W	10
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	5S	3W	35
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	5S	3W	26
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	3S	1
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	2W	6
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	2W	6
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	2W	7
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	5S	3W	35
623	PYRAMID C C	PYRAMID STRIP		STRIP		1926-52	HERRIN	PERRY	6S	3W	13
623	BINKLEY C C	PYRAMID PIT		STRIP		1934-34	HERRIN	PERRY	6S	3W	10
623	TRUAX TRAER C C	PYRAMID		STRIP		1952-60	HERRIN	PERRY	5S	3W	35
634	SOUTHERN GEM C C	SOUTH GEM	6	SHAFT	MRP	1923-33	HERRIN	PERRY	5S	3W	23
634	BEAUCOUP C C	BEAUCOUP		SHAFT		1933-51	HERRIN	PERRY	5S	3W	23

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR PERRY COUNTY, ILLINOIS (IDNR 2000)
MAY 4, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION TWP	RGE	SEC
634	SERVICE C C	SERVICE	6	SHAFT		1951-55	HERRIN	PERRY	5S	3W	23
642	WILLS C C	WILLS		STRIP		1936-42	HERRIN	JACKSON	7S	2W	4
687	UNION COLLIERY CO	NEW KATHLEEN		SLOPE	MRP	1946-58	HERRIN	PERRY	6S	2W	36
687	TRUAX TRAER C C	NEW KATHLEEN		SLOPE		1958-58	HERRIN	PERRY	6S	2W	36
717	AVERY C & MNG CO	BALD EAGLE		SHAFT	RPB	1906-10	DANVILLE	PERRY	4S	4W	25
717	AVERY COAL & MNG CO	BALD EAGLE		SHAFT		1906-10	HERRIN	PERRY	4S	4W	25
717	BALD EAGLE MNG CO	BALD EAGLE		SHAFT		1910-14	DANVILLE	PERRY	4S	4W	25
717	BALD EAGLE MNG CO	BALD EAGLE		SHAFT		1910-14	HERRIN	PERRY	4S	4W	25
717	CHIME COAL CO	BALD EAGLE		SHAFT		1914-15	DANVILLE	PERRY	4S	4W	25
717	CHIME COAL CO	BALD EAGLE		SHAFT		1914-15	HERRIN	PERRY	4S	4W	25
717	GRANGER C C	BALD EAGLE		SHAFT		1915-17	HERRIN	PERRY	4S	4W	25
717	CROWN C C	BALD EAGLE		SHAFT		1917-20	HERRIN	PERRY	4S	4W	25
717	COLUMBIA COLLIERY	BALD EAGLE		SHAFT		1920-28	DANVILLE	PERRY	4S	4W	25
717	COLUMBIA COLLIERY CO	BALD EAGLE		SHAFT		1920-28	HERRIN	PERRY	4S	4W	25
717	DELCO MNG CO	BALD EAGLE		SHAFT		1928-30	DANVILLE	PERRY	4S	4W	25
717	DELCO COAL MNG CO	BALD EAGLE		SHAFT		1928-30	HERRIN	PERRY	4S	4W	25
717	EGYPTIAN C C	EGYPTIAN		SHAFT		1930-32	DANVILLE	PERRY	4S	4W	25
717	EGYPTIAN COAL CO	BALD EAGLE		SHAFT		1930-32	HERRIN	PERRY	4S	4W	25
717	WINKLE COAL CO	WINKLE		SHAFT		1932-36	DANVILLE	PERRY	4S	4W	25
717	WINKLE COAL CO	BALD EAGLE		SHAFT		1932-36	HERRIN	PERRY	4S	4W	25
774	STRAIT C C	STRAIT		SHAFT	RPB	1903-14	HERRIN	PERRY	5S	3W	13
774	HAGGARD,SHERMAN	HAGGARD		SHAFT		1914-15	HERRIN	PERRY	5S	3W	13
774	MONTGOMERY BROS & LANGWITH	MONTGOMERY		SHAFT		1915-16	HERRIN	PERRY	5S	3W	13
774	MONTGOMERY C C	MONTGOMERY		SHAFT		1916-19	HERRIN	PERRY	5S	3W	13
774	mine idle	MONTGOMERY		SHAFT		1919-27	HERRIN	PERRY	5S	3W	13
774	NORTH SIDE C C	NORTH SIDE		SHAFT		1928-29	HERRIN	PERRY	5S	3W	13
864	TRUAX TRAER C C	BURNING STAR	2	STRIP		1951-71	HERRIN	PERRY	5S	2W	26
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	26
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	6
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	9
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	8
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	18
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	22
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	28
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	36
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	STRIP		1971-95	HERRIN	PERRY	5S	2W	27
864	CONSOLIDATION CC,MIDWEST DIV	BURNING STAR	2	AUGER		1995-95	HERRIN	PERRY	5S	2W	22
3106	LEMMONS,WELDON	LEMMONS		SHAFT	RPB	1934-44	HERRIN	PERRY	5S	1W	8
3106	PARADISE C C	PARADISE		SHAFT		1934-44	HERRIN	PERRY	5S	1W	8
3106	SQUARE DEAL C C	SQUARE DEAL		SHAFT		1934-44	HERRIN	PERRY	5S	1W	8
3106	CLARK,RICHARD & LEMMON,TOM	CLARK & LEMMON		SHAFT		1941-42	HERRIN	PERRY	5S	1W	8

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR PERRY COUNTY, ILLINOIS (IDNR 2000)
MAY 4, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
3107	SUN COAL & COKE CO	SUN	3	SHAFT	RPB	1885-90	HERRIN	PERRY	5S	1W	20
3107	SUN MNG CO	SUN	3	SHAFT		1885-90	HERRIN	PERRY	5S	1W	20
3107	SUNFIELD COAL & COKE CO	SUN	3	SHAFT		1890-00	HERRIN	PERRY	5S	1W	20
3107	BAILEY BROS C C	SUN	3	SHAFT		1901-14	HERRIN	PERRY	5S	1W	20
3108	SUN MNG CO (ALSO E8)	SUN	2	SHAFT	RPB	1882-83	HERRIN	PERRY	5S	1W	20
3108	SUN COAL & COKE CO (ALSO E8)	SUN	2	SHAFT		1884-84	HERRIN	PERRY	5S	1W	29
3109	KELLERMAN & STANHOUSE			UG	RP			PERRY	6S	2W	14
3112	SHAKERAG C C	SHAKERAG	2	SHAFT		1927-28	HERRIN	PERRY	5S	2W	26
3113	PANTHER CREEK C C	PANTHER CREEK				1925-26	HERRIN	PERRY	5S	2W	33
3114	MANUFACTURERS FUEL CO	JUPITER	5	SHAFT		1904-06	HERRIN	PERRY	5S	2W	36
3114	ORION C C	JUPITER	5	SHAFT		1909-13	HERRIN	PERRY	5S	2W	36
3114	VICTORY C C	VICTORY	2	SHAFT		1921-26	HERRIN	PERRY	5S	2W	36
3118	CITY C C,	CITY		SHAFT	MRP	1935-38	HERRIN	PERRY	5S	3W	13
3118	BOLINSKI C C	BOLINSKI		SHAFT		1938-42	HERRIN	PERRY	5S	3W	13
3118	CITY COAL CO	CITY		SHAFT		1943-46		PERRY	5S	3W	13
3118	MILLAR,GIACOMA & RIGDON C C	CITY		SHAFT		1946-48	HERRIN	PERRY	5S	3W	13
3118	GEM C C	GEM		SHAFT		1948-57	HERRIN	PERRY	5S	3W	13
3120	DONK & CO,ANTE 1883	BEAUCOUP		SHAFT	RPB	1883-85	HERRIN	PERRY	5S	3W	14
3121	BROWN,G W	BROWN		SHAFT	RPB	1890-03	HERRIN	PERRY	5S	3W	24
3121	WEAVER COAL & COKE	WEAVER	4	SHAFT		1903-04	HERRIN	PERRY	5S	3W	24
3121	MANUFACTURERS FUEL CO	JUPITER	4	SHAFT		1904-05	HERRIN	PERRY	5S	3W	24
3121	BIBY C C	BIBY		DRIFT		1923-34	HERRIN	PERRY	5S	3W	24
3135	SUPERIOR C C	LAKE		SHAFT	RP	1889-99	HERRIN	PERRY	6S	1W	6
3135	PORTER,JOHN C	LAKE		SHAFT		1899-00	HERRIN	PERRY	6S	1W	6
3135	SUPERIOR C C	LAKE		SHAFT		1900-03	HERRIN	PERRY	6S	1W	6
3135	WEAVER COAL & COKE	WEAVER	3	SHAFT		1903-04	HERRIN	PERRY	6S	1W	6
3135	MANUFACTURERS FUEL CO	JUPITER	3	SHAFT		1904-06	HERRIN	PERRY	6S	1W	6
3135	DUQUOIN C C	SUPERIOR		SHAFT		1906-08	HERRIN	PERRY	6S	1W	6
3135	DUQUOIN C C	DUQUOIN	3	SHAFT		1906-12	HERRIN	PERRY	6S	1W	6
3135	MILLER-HORN C C	MILLER-HORN		SHAFT		1908-09	HERRIN	PERRY	6S	1W	6
3135	DUQOIN C C	SUPERIOR		SHAFT		1909-12	HERRIN	PERRY	6S	1W	6
3136	PYRAMID C. C.	PYRAMID		SLOPE	MRP	1944-44	HERRIN	PERRY	6S	3W	2
3166	POPE MNG CO	POPE		SHAFT	RP	1895-02	HERRIN	PERRY	6S	2W	2
3166	SUPERIOR C C	POPE		SHAFT		1902-03	HERRIN	PERRY	6S	2W	2
3166	LAKE SUPERIOR C C	MIFFLIN		SHAFT		1903-06	HERRIN	PERRY	6S	2W	2
3166	DUQUOIN FUEL CO	MIFFLIN		SHAFT		1906-07	HERRIN	PERRY	6S	2W	2
3166	GREAT CENTRAL MNG CO	GREAT CENTRAL		SHAFT		1907-08	HERRIN	PERRY	6S	2W	2
3169	CEDAR HILL C C	CEDAR HILL		SHAFT		1934-37	HERRIN	PERRY	6S	2W	11
3171	JEWEL C C	JEWEL	2	SHAFT		1921-26	HERRIN	PERRY	6S	2W	13
3174	C & M,INC	JOLIANA		STRIP		1948-49	HERRIN	PERRY	6S	2W	33
3174	R.P.M. INC	JOLIANA		STRIP		1949-52	HERRIN	PERRY	6S	2W	33

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR PERRY COUNTY, ILLINOIS (IDNR 2000)
MAY 4, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
3176	COAL STRIPPING CO	COAL STRIP	1	STRIP		1931-35	HERRIN	PERRY	6S	3W	14
3176	PYRAMID C C	PYRAMID	1	STRIP		1935-36	HERRIN	PERRY	6S	3W	14
4118	POLINSKI C C	POLINSKI		STRIP		1948-50	HERRIN	WILLIAMSON	9S	4E	29
4406	JACOB'S MINE	JACOB						PERRY	6S	1W	7
4412	OWEN'S MINE	OWENS						PERRY	5S	3W	25
4413	L & M C C	L & M						PERRY	5S	2W	30
4414	DENNY MINE	DENNY						PERRY	5S	2W	32
4418				UG	RP			PERRY	5S	1W	31
6838	general mined out area	unknown .. ref Brown mine				HERRIN	PERRY	5S	3W	24	

Appendix C
GWLF and BATHTUB
Input and Output Files

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GWLF Data Input File Template

Transprt.dat

number of rural landuses, number of urban landuses
recession coefficient, seepage constant, initial unsaturated storage, initial saturated storage, initial snow, sediment delivery ratio, unsaturated available capacity
1-day antecedent precipitation
2-day antecedent precipitation
3-day antecedent precipitation
4-day antecedent precipitation
5-day antecedent precipitation
month1, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month2, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month3, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month4, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month5, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month6, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month7, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month8, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month9, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month10, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month11, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
month12, ET cover coefficient, mean daylight hours, growing season, rainfall erosivity coefficient
rural_landuse_1, hectares, curve number, KLSCP coefficient
rural_landuse_2, hectares, curve number, KLSCP coefficient
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rural_landuse_n, hectares, curve number, KLSCP coefficient
urban_landuse_1, hectares, curve number, KLSCP coefficient
urban_landuse_2, hectares, curve number, KLSCP coefficient
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urban_landuse_n, hectares, curve number, KLSCP coefficient

Nutrient.dat
nitrogen in sediment, phosphorus in sediment, nitrogen in groundwater, phosphorus in groundwater
number of land uses over which manure is spread, first month of manure spread, last month of manure spread
rural_landuse_1 dissolved nitrogen, rural_landuse_1 dissolved phosphorus
rural_landuse_2 dissolved nitrogen, rural_landuse_2 dissolved phorphorus
.
.
.
rural_landuse_n dissolved nitrogen, rural_landuse_n dissolved phosphorus
urban_landuse_1 total nitrogen buildup, urban_landuse_1 total phosphorus buildup
urban_landuse_2 total nitrogen buildup, urban_landuse_2 total phosphorus buildup
.
.
.
urban_landuse_n total nitrogen buildup, urban_landuse_n total phosphorus buildup
manure nitrogen concentration, manure phosphorus concentration (if applicable)
point_source_1 nitrogen, point_source_1 phosphorus (if applicable)
point_source_2 nitrogen, point_source_2 phosphorus (if applicable)
.
.
.
point_source_n nitrogen, point_source_n phosphorus (if applicable)
model septic systems (0 = no, 1 = yes)
# of septic systems month1, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month2, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month3, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month4, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month5, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month6, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month7, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month8, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month9, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month10, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month11, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
# of septic systems month12, # of normal systems, # of ponded systems, # of short-circuited systems, # of direct discharge systems (if applicable)
per capita septic nitrogen effluent, per capita septic phorphorus effluent, plant nitrogen uptake, plant phosphorus uptake (if applicable)

Weather.dat

# of days in month1
average temperature in Centigrade, total precipitation (cm) on day 1
average temperature in Centigrade, total precipitation (cm) on day 2
average temperature in Centigrade, total precipitation (cm) on day 3
average temperature in Centigrade, total precipitation (cm) on day 4
.
.
.
average temperature in Centigrade, total precipitation (cm) on day n
# of days in month 2
average temperature in Centigrade, total precipitation (cm) on day 1
average temperature in Centigrade, total precipitation (cm) on day 2
average temperature in Centigrade, total precipitation (cm) on day 3
average temperature in Centigrade, total precipitation (cm) on day 4
.
.
.
average temperature in Centigrade, total precipitation (cm) on day n

GWLF Input Data Files

Subbasin 1

Transprt.dat

```
6,2
0.1,0.05,10,0,0,0.25,10
0
0
0
0
0
"APR",0.53,13,0,0.27
"MAY",0.71,14,1,0.27
"JUNE",0.99,14.5,1,0.27
"JULY",0.96,14.3,1,0.27
"AUG",0.90,13.4,1,0.27
"SEPT",0.79,12.2,1,0.27
"OCT",0.59,11,1,0.14
"NOV",0.50,10,0,0.14
"DEC",0.48,9.4,0,0.14
"JAN",0.54,9.7,0,0.14
"FEB",0.55,10.6,0,0.14
"MAR",0.55,11.8,0,0.14
"Row-Crop",266.2,86.8,0.0050
"Small-Grains",116.1,84.8,0.0077
"Pasture",53.8,76.6,0.0003
"Hayland",67.3,76.6,0.0003
"Deciduous",53.4,71.3,0.0006
"Animal-mgt",0.4,76.8,0.0003
"Forest-Wetl",7.1,100.0,0.0000
"Shall-Water",3.6,100.0,0.0000
```

Nutrient.dat

```
3000,1320,0.77,0.085
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
29.5,9.5
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subbasin 2

Transprt.dat

```
6,3
0.1,0.05,10,0,0,0.25,10
0
0
0
0
0
"APR",0.52,13,0,0.27
"MAY",0.67,14,1,0.27
"JUNE",0.95,14.5,1,0.27
"JULY",0.93,14.3,1,0.27
"AUG",0.87,13.4,1,0.27
"SEPT",0.78,12.2,1,0.27
"OCT",0.57,11,1,0.14
"NOV",0.48,10,0,0.14
"DEC",0.45,9.4,0,0.14
"JAN",0.54,9.7,0,0.14
"FEB",0.55,10.6,0,0.14
"MAR",0.54,11.8,0,0.14
"Row-Crop",412.3,87.23,0.0057
"Small-Grains",62.1,84.90,0.0071
"Pasture",39.8,76.83,0.0004
"Hayland",49.8,76.83,0.0004
"Deciduous",41.1,72.63,0.0005
"Animal-Mgt",2.7,87.29,0.0004
"Shall-Marsh/We",0.1,100.00,0.0000
"Forest-Wetl",6.0,99.61,0.0000
"High-Density",1.0,91.32,0.0000
```

Nutrient.dat

```
3000,1320,0.77,0.085
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
29.5,9.5
0,0
0,0
0.076,0.010
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subbasin 3

Transprt.dat

```
6,5
0.1,0.05,10,0,0,0.28,10
0
0
0
0
0
"APR",0.62,13,0,0.27
"MAY",0.78,14,1,0.27
"JUNE",0.95,14.5,1,0.27
"JULY",1.01,14.3,1,0.27
"AUG",0.97,13.4,1,0.27
"SEPT",0.88,12.2,1,0.27
"OCT",0.68,11,1,0.14
"NOV",0.55,10,0,0.14
"DEC",0.52,9.4,0,0.14
"JAN",0.63,9.7,0,0.14
"FEB",0.65,10.6,0,0.14
"MAR",0.64,11.8,0,0.14
"Row-Crop",230.0,87.4,0.0070
"Small-Grains",79.2,85.0,0.0075
"Pasture",36.3,76.3,0.0004
"Hayland",45.4,76.3,0.0004
"Deciduous",53.6,72.4,0.0005
"Dairy",1.2,75.0,0.0004
"Open-Water",1.9,100.0,0.0000
"Deep-Marsh",0.3,100.0,0.0000
"Forest-Wetl",2.2,100.0,0.0000
"Shall-Water",1.9,100.0,0.0000
"High-Density",0.4,90.3,0.0000
```

Nutrient.dat

```
3000,1320,0.77,0.085
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
29.3,125
0,0
0,0
0,0
0,0
0.076,0.01
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
```

Subbasin 4

Transprt.dat

```
5,4
0.1,0.05,10,0,0,0.3,10
0
0
0
0
0
"APR",0.56,13,0,0.27
"MAY",0.81,14,1,0.27
"JUNE",1.02,14.5,1,0.27
"JULY",0.99,14.3,1,0.27
"AUG",0.91,13.4,1,0.27
"SEPT",0.79,12.2,1,0.27
"OCT",0.69,11,1,0.14
"NOV",0.52,10,0,0.14
"DEC",0.51,9.4,0,0.14
"JAN",0.57,9.7,0,0.14
"FEB",0.58,10.6,0,0.14
"MAR",0.57,11.8,0,0.14
"Row-Crop",70.2,86.5,0.0044
"Small-Grains",108.0,84.5,0.0052
"Pasture",18.7,75.4,0.0004
"Hayland",23.4,75.4,0.0004
"Deciduous",89.3,71.3,0.0008
"Open-Water",18.8,100.0,0.0000
"Shall-Marsh",1.9,100.0,0.0000
"Deep-Marsh",0.8,100.0,0.0000
"Shall-Water",2.1,100.0,0.0000
```

Nutrient.dat

```
3000,1320,0.8,0.067
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subbasin 5

Transprt.dat

```
5,2
0.1,0.05,10,0,0,0.28,10
0
0
0
0
0
“APR”,0.57,13,0,0.27
“MAY”,0.81,14,1,0.27
“JUNE”,0.95,14.5,1,0.27
“JULY”,0.94,14.3,1,0.27
“AUG”,0.90,13.4,1,0.27
“SEPT”,0.84,12.2,1,0.27
“OCT”,0.73,11,1,0.14
“NOV”,0.53,10,0,0.14
“DEC”,0.50,9.4,0,0.14
“JAN”,0.58,9.7,0,0.14
“FEB”,0.60,10.6,0,0.14
“MAR”,0.59,11.8,0,0.14
“Row-Crop”,95.5,86.8,0.0041
“Small-Grains”,52.5,84.7,0.0063
“Pasture”,46.6,76.2,0.0004
“Hayland”,58.3,76.2,0.0004
“Deciduous”,144.2,71.8,0.0006
“Open-Water”,44.3,99.8,0.0000
“Shall-Water”,0.9,100.0,0.0000
```

Nutrient.dat

```
3000,1320,0.8,0.055
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subbasin 6

Transprt.dat

```
6,3
0.1,0.05,10,0,0,0.33,10
0
0
0
0
0
“APR”,0.67,13,0,0.27
“MAY”,0.87,14,1,0.27
“JUNE”,0.94,14.5,1,0.27
“JULY”,0.94,14.3,1,0.27
“AUG”,0.92,13.4,1,0.27
“SEPT”,0.88,12.2,1,0.27
“OCT”,0.78,11,1,0.14
“NOV”,0.61,10,0,0.14
“DEC”,0.58,9.4,0,0.14
“JAN”,0.68,9.7,0,0.14
“FEB”,0.70,10.6,0,0.14
“MAR”,0.69,11.8,0,0.14
“Row-Crop”,64.0,85.7,0.0065
“Small-Grains”,25.8,83.6,0.0064
“Pasture”,20.2,75.0,0.0005
“Hayland”,25.3,75.0,0.0005
“Deciduous”,65.4,71.2,0.0006
“Coniferous”,4.2,74.0,0.0007
“Open-Water”,23.2,100.0,0.0000
“Forest-Wetl”,0.5,100.0,0.0000
“Shall-Water”,5.0,100.0,0.0000
```

Nutrient.dat

```
3000,1320,0.8,0.055
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Weather.dat (excerpt)

```
30.00
6.67,0.00
12.50,0.00
16.67,0.00
12.78,0.00
8.33,0.53
7.50,0.91
5.00,0.13
3.89,0.13
5.00,0.00
14.17,0.00
16.39,0.91
17.78,0.00
16.94,0.00
13.33,0.43
17.50,1.09
16.67,0.00
20.56,0.00
20.28,0.00
20.83,0.00
21.94,0.00
22.22,0.00
21.11,0.00
17.22,0.00
17.50,0.13
20.00,0.00
20.56,0.00
19.72,0.00
16.94,0.00
19.44,0.00
20.00,0.00
31.00
15.00,1.93
13.89,3.71
16.67,0.00
18.33,0.00
19.72,0.00
18.61,0.00
17.78,0.00
20.00,0.00
19.72,0.00
19.72,0.00
24.72,0.00
21.11,0.00
23.33,0.00
18.89,1.32
18.06,0.46
13.89,0.00
15.00,0.03
18.61,0.00
20.56,0.00
21.39,0.00
17.22,0.00
15.83,0.48
18.89,1.52
21.39,0.00
```

23.33,0.00
24.17,0.00
20.56,0.00
20.56,0.23
23.89,0.00
27.22,0.00
22.78,0.00
30.00
23.89,0.00
21.67,0.41
21.39,1.78
21.39,0.36
18.89,0.58
20.56,1.37
23.33,3.84
25.00,0.03
23.61,0.00
21.67,2.44
14.72,1.68
16.11,0.76
17.78,0.00
21.94,0.00
24.72,0.51
24.72,0.69
20.28,1.37
18.61,0.66
20.83,0.00
23.61,0.00
22.78,0.00
25.83,0.36
26.67,0.00
25.83,0.10
27.50,0.08
26.94,0.00
20.28,0.00
21.11,0.71
23.06,0.00
21.39,0.13

GLWF Output Files

Subbasin 1

rnm1 17 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	3.7	3.3	2.1	5.4
MAY	10.8	6.9	2.5	2.2	4.7
JUNE	10.8	11.9	0.9	1.7	2.6
JULY	10.3	10.5	0.3	1.3	1.7
AUG	6.1	6.4	0.1	0.3	0.4
SEPT	7.8	4.2	0.0	1.0	1.0
OCT	7.0	2.6	0.3	0.7	1.1
NOV	9.8	1.2	1.9	2.4	4.3
DEC	6.5	0.6	2.5	1.2	3.7
JAN	5.8	0.6	2.3	1.5	3.8
FEB	5.8	0.9	2.8	1.3	4.1
MAR	6.9	1.8	2.6	1.2	3.8
ANNUAL	97.2	51.2	19.6	16.9	36.5

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.1	0.0	0.4	0.5	0.0	0.1
MAY	0.1	0.0	0.4	0.4	0.0	0.1
JUNE	0.1	0.0	0.3	0.3	0.0	0.1
JULY	0.1	0.0	0.2	0.2	0.0	0.0
AUG	0.1	0.0	0.0	0.0	0.0	0.0
SEPT	0.1	0.0	0.1	0.2	0.0	0.0
OCT	0.0	0.0	0.1	0.1	0.0	0.0
NOV	0.1	0.0	0.4	0.5	0.0	0.1
DEC	0.0	0.0	0.3	0.3	0.0	0.1
JAN	0.0	0.0	0.3	0.4	0.0	0.1
FEB	0.0	0.0	0.3	0.3	0.0	0.1
MAR	0.0	0.0	0.3	0.3	0.0	0.1
ANNUAL	0.9	0.2	3.0	3.7	0.3	0.6

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	266.	19.40	1.85	1.50	1.87	0.13	0.30
Small-Grains	116.	16.54	2.86	0.35	0.59	0.06	0.17
Pasture	54.	9.09	0.11	0.15	0.15	0.01	0.01
Hayland	67.	9.09	0.11	0.18	0.19	0.01	0.01
Deciduous	53.	6.32	0.22	0.00	0.01	0.00	0.00
Animal-mgt	0.	9.22	0.11	0.01	0.01	0.00	0.00
Forest-Wetl	7.	97.48	0.00	0.00	0.00	0.00	0.00
Shall-Water	4.	97.48	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.86	0.86	0.09	0.09
POINT SOURCE				0.00	0.00	0.00	0.00
TOTAL				3.05	3.68	0.31	0.59

Subbasin 2

rnm2 17 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	3.6	3.3	2.2	5.5
MAY	10.8	6.5	2.5	2.2	4.8
JUNE	10.8	11.7	1.0	1.8	2.8
JULY	10.3	10.5	0.4	1.5	1.8
AUG	6.1	6.4	0.1	0.3	0.4
SEPT	7.8	4.2	0.0	1.0	1.1
OCT	7.0	2.5	0.3	0.8	1.1
NOV	9.8	1.1	1.9	2.5	4.4
DEC	6.5	0.5	2.5	1.3	3.7
JAN	5.8	0.6	2.2	1.7	3.9
FEB	5.8	0.9	2.7	1.4	4.1
MAR	6.9	1.7	2.6	1.3	3.8
ANNUAL	97.2	50.3	19.5	18.0	37.4

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.1	0.0	0.5	0.6	0.1	0.1
MAY	0.2	0.0	0.5	0.6	0.1	0.1
JUNE	0.2	0.0	0.3	0.4	0.0	0.1
JULY	0.2	0.0	0.3	0.3	0.0	0.1
AUG	0.1	0.0	0.1	0.1	0.0	0.0
SEPT	0.1	0.0	0.2	0.2	0.0	0.0
OCT	0.0	0.0	0.1	0.2	0.0	0.0
NOV	0.1	0.0	0.5	0.6	0.1	0.1
DEC	0.0	0.0	0.3	0.4	0.0	0.1
JAN	0.0	0.0	0.4	0.5	0.0	0.1
FEB	0.0	0.0	0.4	0.4	0.0	0.1
MAR	0.0	0.0	0.3	0.4	0.0	0.1
ANNUAL	1.1	0.3	3.9	4.7	0.4	0.8

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
Row-Crop	412.	20.10	2.11	2.40	3.06	0.22	0.50
Small-Grains	62.	16.67	2.63	0.19	0.31	0.03	0.09
Pasture	40.	9.24	0.15	0.11	0.11	0.01	0.01
Hayland	50.	9.24	0.15	0.14	0.14	0.01	0.01
Deciduous	41.	6.92	0.19	0.00	0.01	0.00	0.00
Animal-Mgt	3.	20.20	0.15	0.16	0.16	0.05	0.05
Shall-Marsh/We	0.	97.48	0.00	0.00	0.00	0.00	0.00
Forest-Wetl	6.	87.16	0.00	0.00	0.00	0.00	0.00
High-Density	1.	28.89	0.00	0.00	0.01	0.00	0.00
GROUNDWATER				0.92	0.92	0.10	0.10
POINT SOURCE				0.00	0.00	0.00	0.00
TOTAL				3.92	4.72	0.42	0.77

Subbasin 3

rnm3 17 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	4.2	3.1	2.1	5.2
MAY	10.8	7.5	2.2	2.2	4.4
JUNE	10.8	11.4	0.8	1.7	2.5
JULY	10.3	10.9	0.3	1.4	1.7
AUG	6.1	6.4	0.1	0.3	0.4
SEPT	7.8	4.5	0.0	1.0	1.0
OCT	7.0	3.0	0.2	0.7	1.0
NOV	9.8	1.2	1.6	2.4	4.0
DEC	6.5	0.6	2.3	1.2	3.5
JAN	5.8	0.7	2.1	1.6	3.7
FEB	5.8	1.0	2.7	1.3	4.0
MAR	6.9	2.1	2.4	1.2	3.6
ANNUAL	97.2	53.5	17.9	17.1	35.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.1	0.0	0.3	0.4	0.1	0.1
MAY	0.1	0.0	0.3	0.4	0.1	0.1
JUNE	0.1	0.0	0.2	0.3	0.0	0.1
JULY	0.1	0.0	0.2	0.2	0.0	0.0
AUG	0.1	0.0	0.0	0.0	0.0	0.0
SEPT	0.1	0.0	0.1	0.2	0.0	0.0
OCT	0.0	0.0	0.1	0.1	0.0	0.0
NOV	0.1	0.0	0.3	0.4	0.1	0.1
DEC	0.0	0.0	0.2	0.3	0.0	0.1
JAN	0.0	0.0	0.2	0.3	0.0	0.1
FEB	0.0	0.0	0.2	0.3	0.0	0.1
MAR	0.0	0.0	0.2	0.3	0.0	0.1
ANNUAL	0.8	0.2	2.5	3.2	0.4	0.7

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	230.	20.39	2.60	1.36	1.86	0.12	0.34
Small-Grains	79.	16.80	2.78	0.24	0.42	0.04	0.12
Pasture	36.	8.90	0.15	0.10	0.10	0.01	0.01
Hayland	45.	8.90	0.15	0.12	0.13	0.01	0.01
Deciduous	54.	6.81	0.19	0.00	0.01	0.00	0.00
Dairy	1.	8.14	0.15	0.03	0.03	0.12	0.12
Open-Water	2.	97.48	0.00	0.00	0.00	0.00	0.00
Deep-Marsh	0.	97.48	0.00	0.00	0.00	0.00	0.00
Forest-Wetl	2.	97.48	0.00	0.00	0.00	0.00	0.00
Shall-Water	2.	97.48	0.00	0.00	0.00	0.00	0.00
High-Density	0.	26.25	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.62	0.62	0.07	0.07
POINT SOURCE				0.00	0.00	0.00	0.00
TOTAL				2.47	3.18	0.37	0.68

Subbasin 4

rnm4 17 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	3.9	3.2	2.2	5.4
MAY	10.8	7.8	2.2	2.4	4.6
JUNE	10.8	11.8	0.6	1.9	2.6
JULY	10.3	10.3	0.2	1.6	1.8
AUG	6.1	6.0	0.1	0.6	0.7
SEPT	7.8	4.1	0.0	1.2	1.2
OCT	7.0	3.0	0.2	1.0	1.2
NOV	9.8	1.2	1.6	2.5	4.1
DEC	6.5	0.6	2.3	1.3	3.5
JAN	5.8	0.6	2.1	1.5	3.7
FEB	5.8	0.9	2.7	1.3	4.1
MAR	6.9	1.8	2.5	1.3	3.8
ANNUAL	97.2	51.9	17.8	18.9	36.7

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.0	0.0	0.2	0.2	0.0	0.0
MAY	0.1	0.0	0.2	0.2	0.0	0.0
JUNE	0.1	0.0	0.1	0.1	0.0	0.0
JULY	0.1	0.0	0.1	0.1	0.0	0.0
AUG	0.0	0.0	0.0	0.0	0.0	0.0
SEPT	0.0	0.0	0.0	0.1	0.0	0.0
OCT	0.0	0.0	0.0	0.1	0.0	0.0
NOV	0.0	0.0	0.2	0.2	0.0	0.0
DEC	0.0	0.0	0.1	0.1	0.0	0.0
JAN	0.0	0.0	0.1	0.2	0.0	0.0
FEB	0.0	0.0	0.1	0.2	0.0	0.0
MAR	0.0	0.0	0.1	0.2	0.0	0.0
ANNUAL	0.4	0.1	1.3	1.6	0.1	0.3

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	70.	18.93	1.63	0.39	0.49	0.03	0.08
Small-Grains	108.	16.16	1.93	0.31	0.50	0.05	0.13
Pasture	19.	8.37	0.15	0.05	0.05	0.00	0.01
Hayland	23.	8.37	0.15	0.06	0.06	0.00	0.00
Deciduous	89.	6.32	0.30	0.00	0.03	0.00	0.01
Open-Water	19.	97.48	0.00	0.00	0.00	0.00	0.00
Shall-Marsh	2.	97.48	0.00	0.00	0.00	0.00	0.00
Deep-Marsh	1.	97.48	0.00	0.00	0.00	0.00	0.00
Shall-Water	2.	97.48	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.47	0.47	0.04	0.04
POINT SOURCE				0.00	0.00	0.00	0.00
TOTAL				1.28	1.60	0.13	0.27

Subbasin 5

rnm5   17 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	3.9	3.1	2.3	5.4
MAY	10.8	7.8	2.1	2.5	4.7
JUNE	10.8	11.1	0.7	2.0	2.7
JULY	10.3	10.2	0.3	1.7	2.0
AUG	6.1	6.1	0.1	0.7	0.8
SEPT	7.8	4.3	0.0	1.3	1.3
OCT	7.0	3.2	0.2	1.1	1.2
NOV	9.8	1.2	1.4	2.5	4.0
DEC	6.5	0.6	2.2	1.3	3.5
JAN	5.8	0.6	2.1	1.6	3.6
FEB	5.8	0.9	2.7	1.4	4.1
MAR	6.9	1.9	2.4	1.4	3.8
ANNUAL	97.2	51.9	17.3	19.7	37.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.0	0.0	0.2	0.2	0.0	0.0
MAY	0.1	0.0	0.2	0.2	0.0	0.0
JUNE	0.1	0.0	0.1	0.1	0.0	0.0
JULY	0.0	0.0	0.1	0.1	0.0	0.0
AUG	0.0	0.0	0.0	0.0	0.0	0.0
SEPT	0.0	0.0	0.1	0.1	0.0	0.0
OCT	0.0	0.0	0.0	0.1	0.0	0.0
NOV	0.0	0.0	0.2	0.2	0.0	0.0
DEC	0.0	0.0	0.1	0.2	0.0	0.0
JAN	0.0	0.0	0.2	0.2	0.0	0.0
FEB	0.0	0.0	0.2	0.2	0.0	0.0
MAR	0.0	0.0	0.2	0.2	0.0	0.0
ANNUAL	0.3	0.1	1.6	1.9	0.1	0.3

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	96.	19.40	1.52	0.54	0.66	0.05	0.10
Small-Grains	53.	16.41	2.34	0.16	0.26	0.03	0.07
Pasture	47.	8.84	0.15	0.12	0.13	0.01	0.01
Hayland	58.	8.84	0.15	0.15	0.16	0.01	0.01
Deciduous	144.	6.54	0.22	0.01	0.03	0.00	0.01
Open-Water	44.	91.45	0.00	0.00	0.00	0.00	0.00
Shall-Water	1.	97.48	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.61	0.61	0.04	0.04
POINT SOURCE				0.00	0.00	0.00	0.00
TOTAL				1.59	1.85	0.13	0.25

Subbasin 6

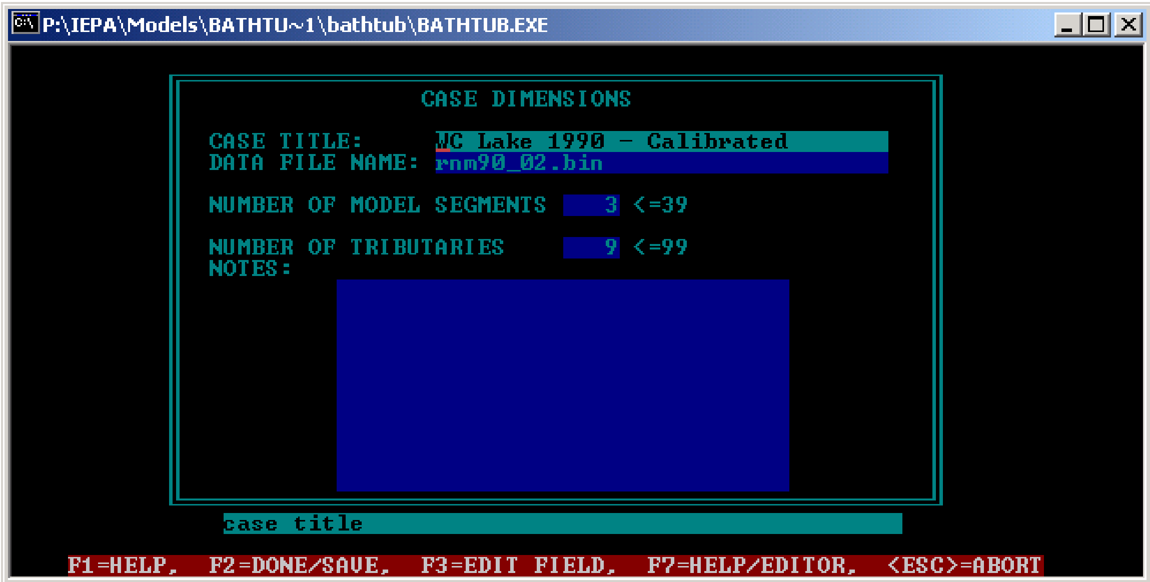
rnm6 17 -year means

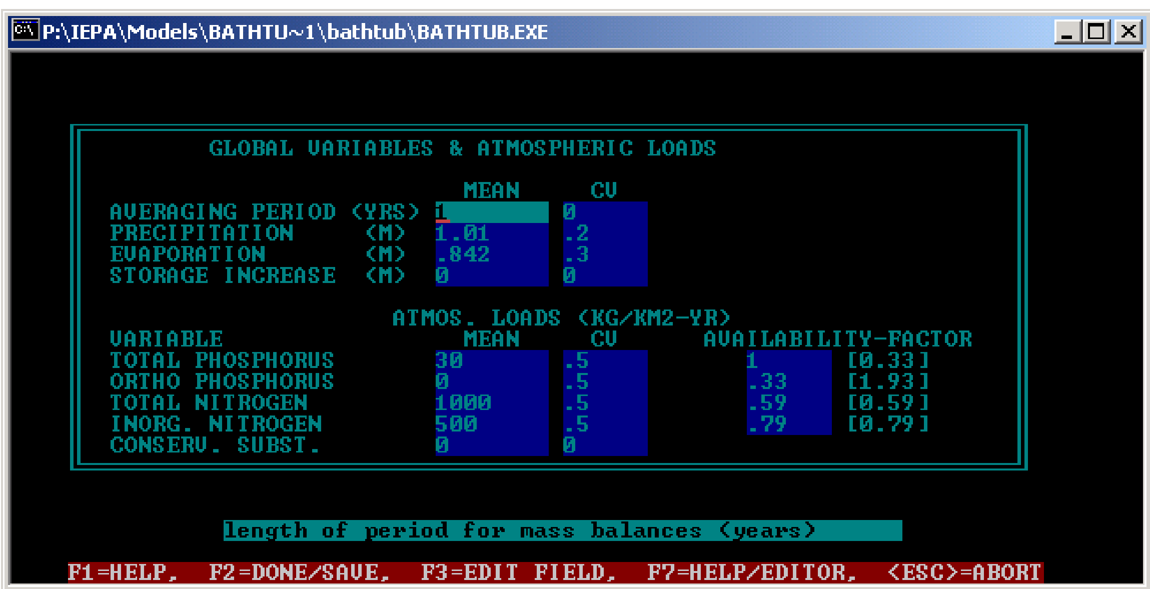
	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	4.5	2.7	2.5	5.2
MAY	10.8	8.4	1.8	2.8	4.6
JUNE	10.8	10.7	0.5	2.3	2.8
JULY	10.3	9.9	0.2	2.0	2.2
AUG	6.1	5.9	0.1	0.9	0.9
SEPT	7.8	4.4	0.0	1.5	1.5
OCT	7.0	3.3	0.1	1.2	1.4
NOV	9.8	1.4	1.2	2.7	3.9
DEC	6.5	0.7	1.9	1.4	3.3
JAN	5.8	0.7	1.8	1.7	3.5
FEB	5.8	1.1	2.5	1.5	4.0
MAR	6.9	2.2	2.1	1.5	3.7
ANNUAL	97.2	53.2	14.9	22.0	36.9

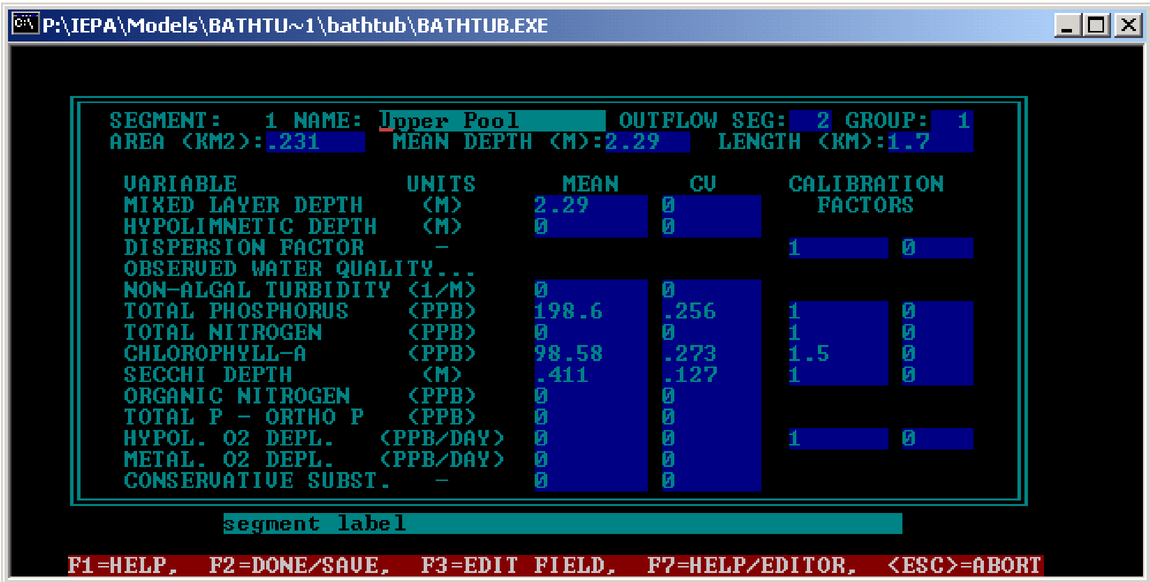
	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.0	0.0	0.1	0.1	0.0	0.0
MAY	0.0	0.0	0.1	0.1	0.0	0.0
JUNE	0.0	0.0	0.1	0.1	0.0	0.0
JULY	0.0	0.0	0.0	0.1	0.0	0.0
AUG	0.0	0.0	0.0	0.0	0.0	0.0
SEPT	0.0	0.0	0.0	0.0	0.0	0.0
OCT	0.0	0.0	0.0	0.0	0.0	0.0
NOV	0.0	0.0	0.1	0.1	0.0	0.0
DEC	0.0	0.0	0.1	0.1	0.0	0.0
JAN	0.0	0.0	0.1	0.1	0.0	0.0
FEB	0.0	0.0	0.1	0.1	0.0	0.0
MAR	0.0	0.0	0.1	0.1	0.0	0.0
ANNUAL	0.2	0.1	0.8	1.0	0.1	0.2

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
Row-Crop	64.	17.75	2.41	0.33	0.48	0.03	0.10
Small-Grains	26.	15.08	2.37	0.07	0.13	0.01	0.04
Pasture	20.	8.14	0.19	0.05	0.05	0.00	0.01
Hayland	25.	8.14	0.19	0.06	0.07	0.00	0.01
Deciduous	65.	6.28	0.22	0.00	0.02	0.00	0.01
Coniferous	4.	7.60	0.26	0.00	0.00	0.00	0.00
Open-Water	23.	97.48	0.00	0.00	0.00	0.00	0.00
Forest-Wetl	1.	97.48	0.00	0.00	0.00	0.00	0.00
Shall-Water	5.	97.48	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.28	0.28	0.02	0.02
POINT SOURCE				0.00	0.00	0.00	0.00
TOTAL				0.79	1.03	0.07	0.17

BATHTUB Input Screens for 1990 Model Simulation



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AREA (KM2):.231 MEAN DEPTH (M):2.29 LENGTH (KM):1.7
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.29 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 198.6 .256 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 98.58 .273 1.5 0
SECCHI DEPTH (M) .411 .127 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
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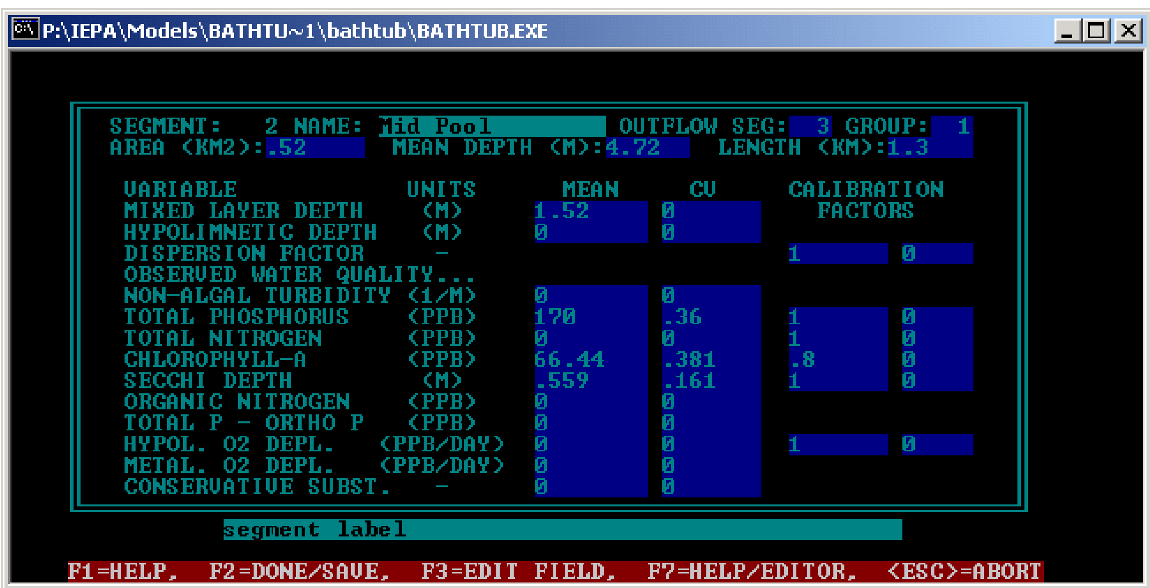
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SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2):.52 MEAN DEPTH (M):4.72 LENGTH (KM):1.3
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 1.52 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 170 .36 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 66.44 .381 .8 0
SECCHI DEPTH (M) .559 .161 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
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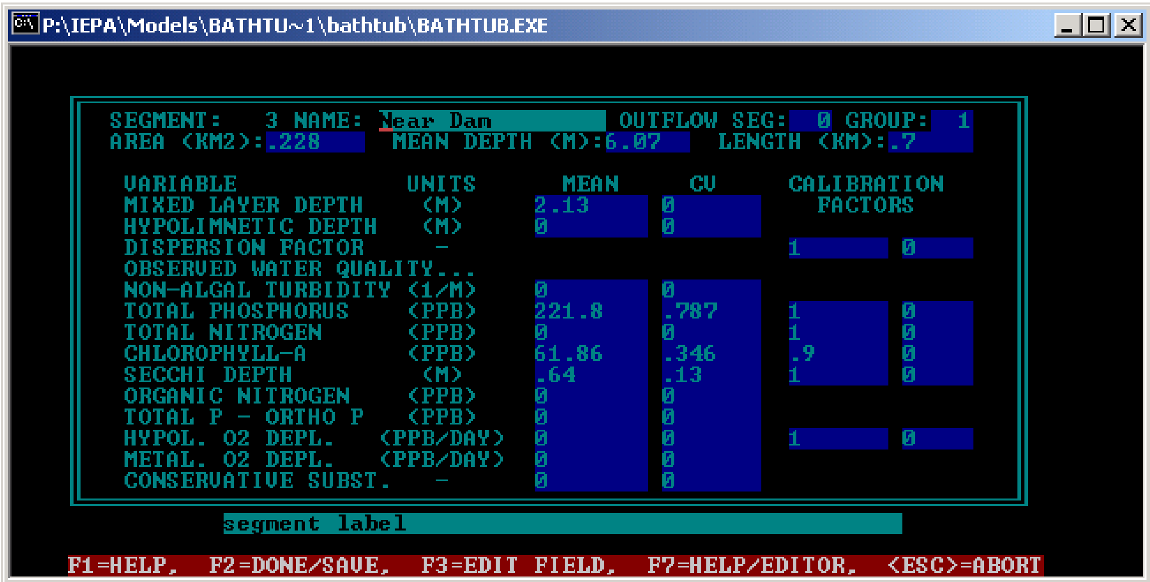
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SEGMENT: 3 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .228 MEAN DEPTH (M): 6.07 LENGTH (KM): .7
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.13 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 221.8 .787 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 61.86 .346 .9 0
SECCHI DEPTH (M) .64 .13 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
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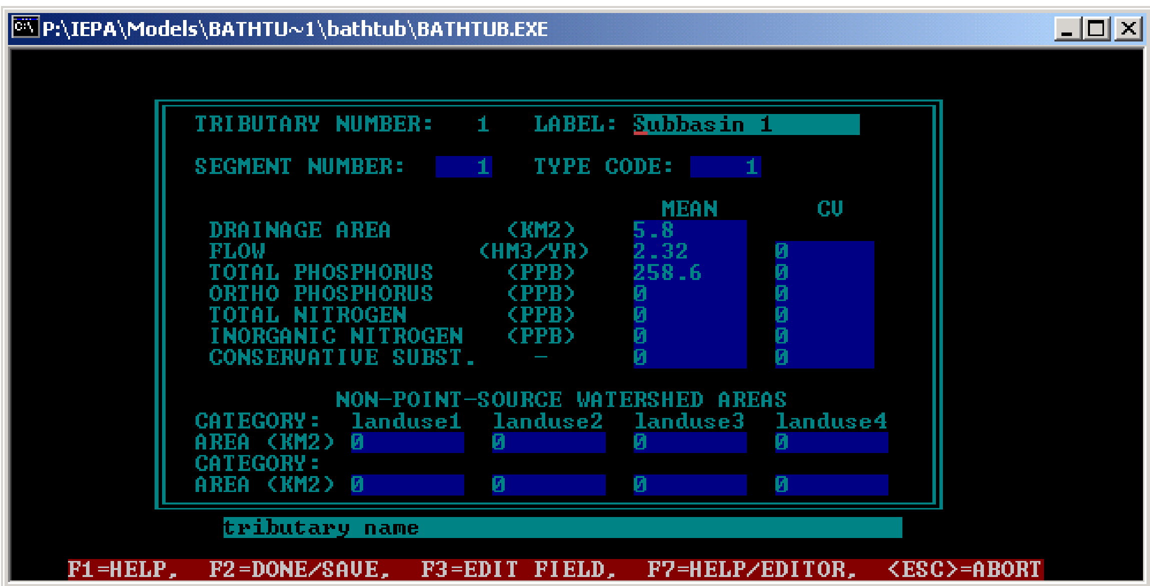
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SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 5.8
FLOW (HM3/YR) 2.32 0
TOTAL PHOSPHORUS (PPB) 258.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
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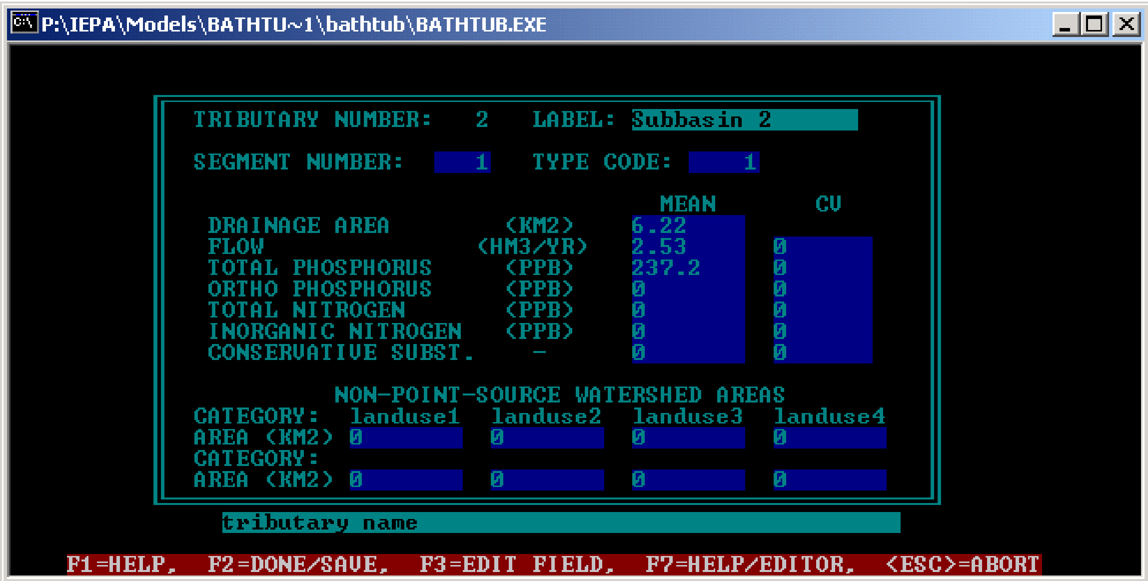
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SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 6.22
FLOW (HM3/YR) 2.53 0
TOTAL PHOSPHORUS (PPB) 237.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
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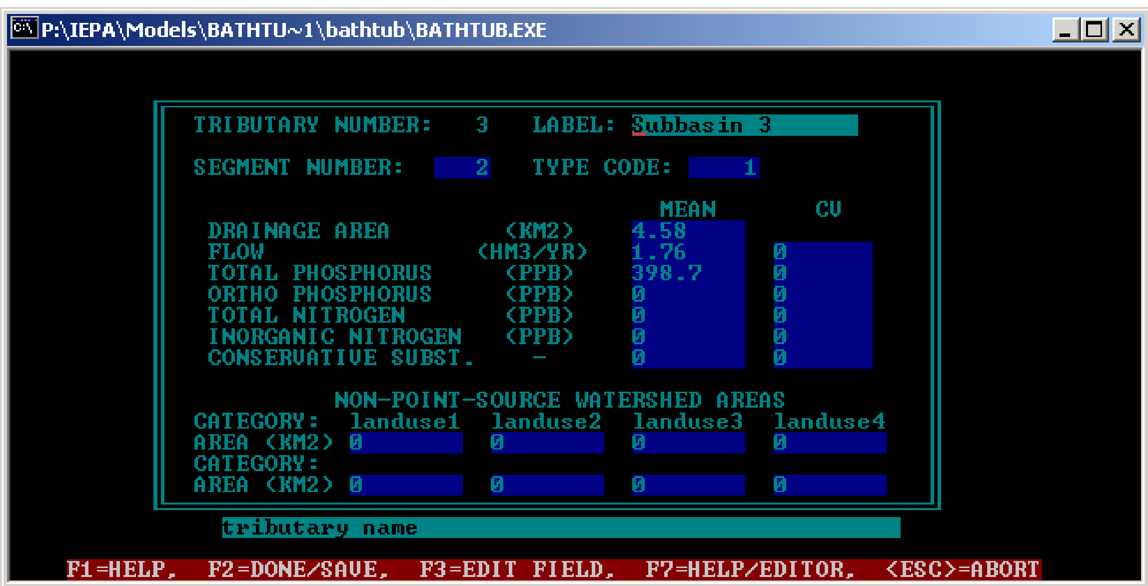
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SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 4.58
FLOW (HM3/YR) 1.76 0
TOTAL PHOSPHORUS (PPB) 398.7 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
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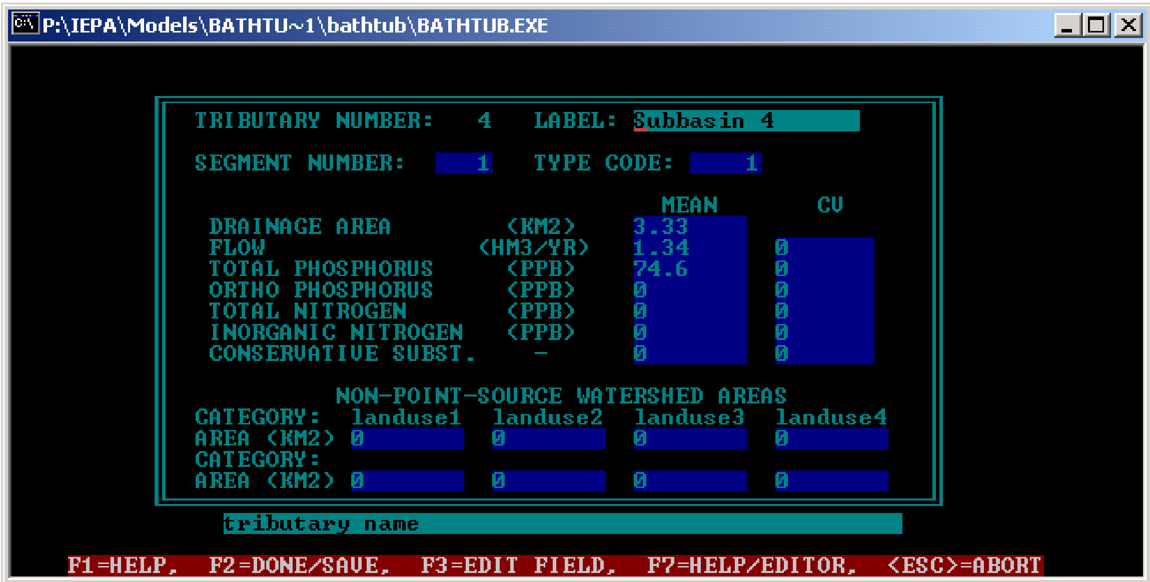
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SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 3.33
FLOW (HM3/YR) 1.34 0
TOTAL PHOSPHORUS (PPB) 74.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
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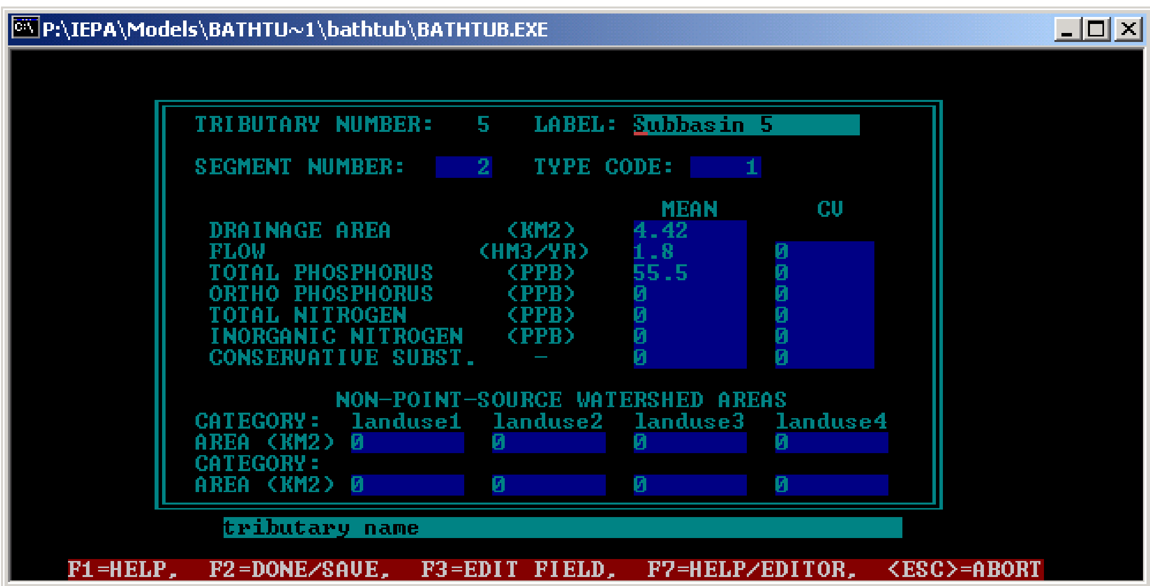
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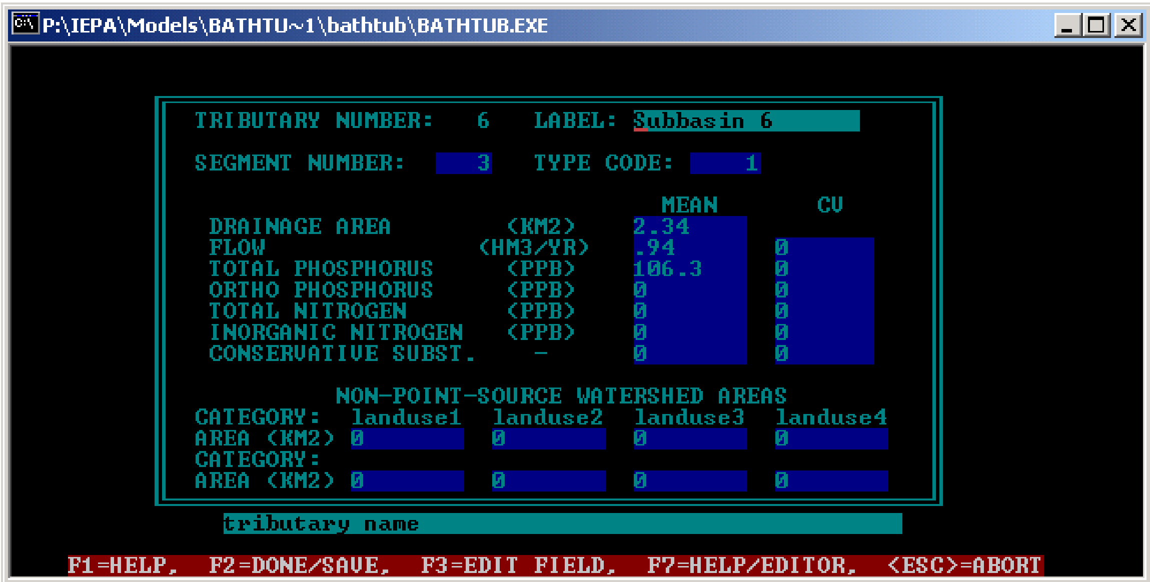
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 4.42
FLOW (HM3/YR) 1.8 0
TOTAL PHOSPHORUS (PPB) 55.5 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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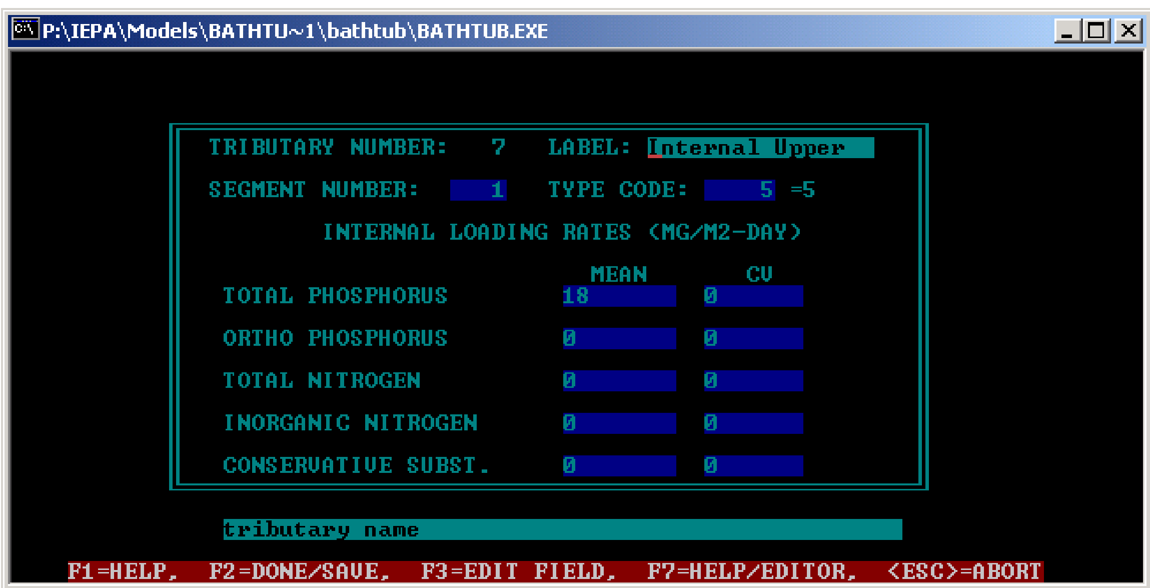
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.34
FLOW (HM3/YR) .94 0
TOTAL PHOSPHORUS (PPB) 106.3 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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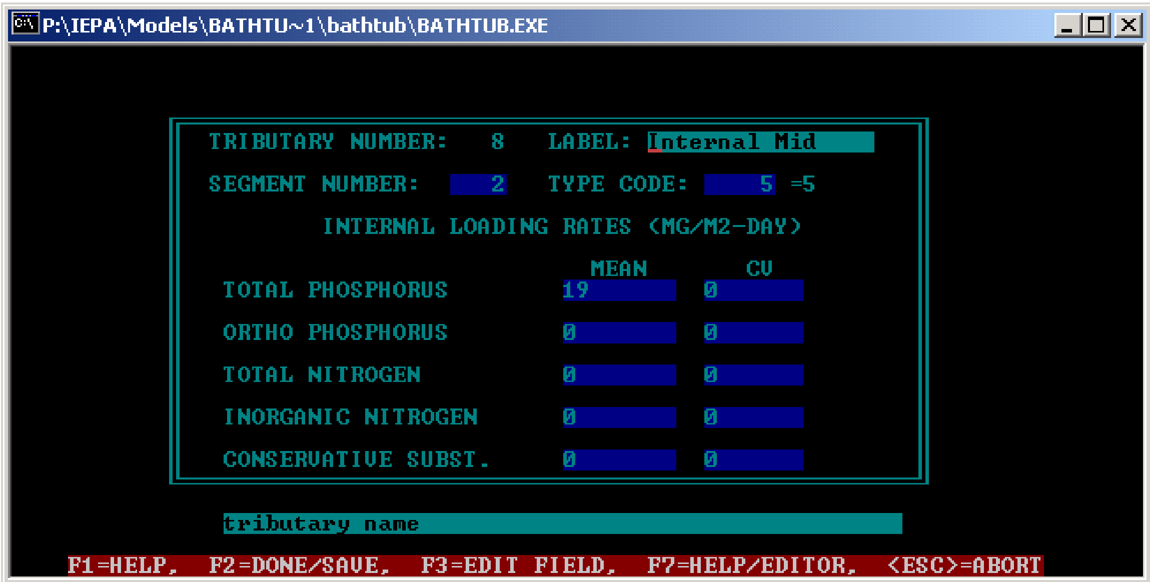
TRIBUTARY NUMBER: 7 LABEL: Internal Upper
SEGMENT NUMBER: 1 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 18 0
ORTHO PHOSPHORUS 0 0
TOTAL NITROGEN 0 0
INORGANIC NITROGEN 0 0
CONSERVATIVE SUBST. 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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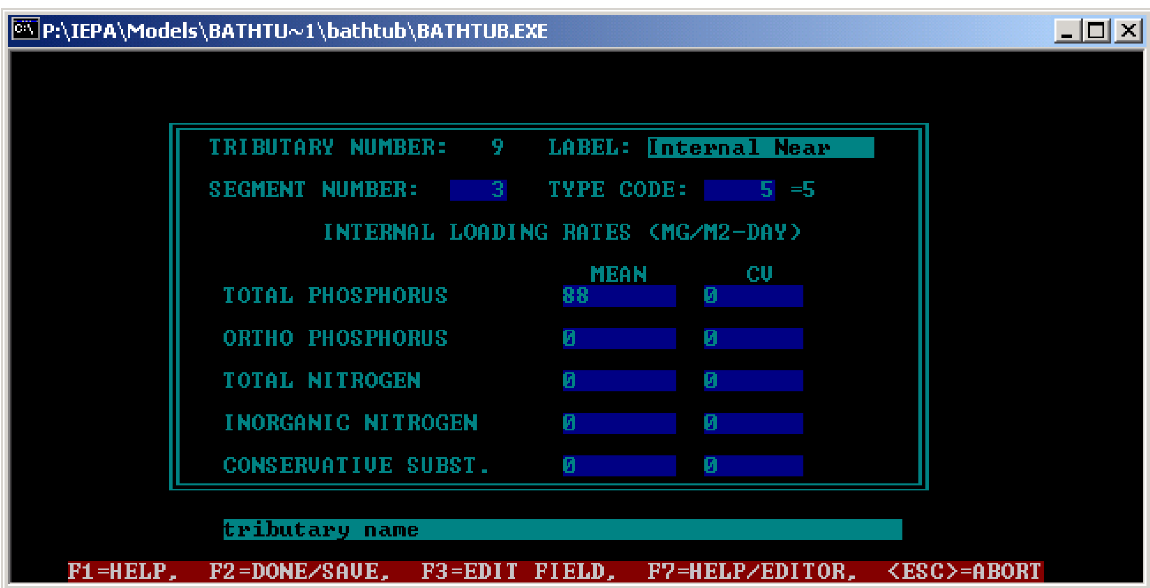
TRIBUTARY NUMBER: 8 LABEL: Internal Mid
SEGMENT NUMBER: 2 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 19 0
ORTHO PHOSPHORUS 0 0
TOTAL NITROGEN 0 0
INORGANIC NITROGEN 0 0
CONSERVATIVE SUBST. 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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TRIBUTARY NUMBER: 9 LABEL: Internal Near
SEGMENT NUMBER: 3 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 88 0
ORTHO PHOSPHORUS 0 0
TOTAL NITROGEN 0 0
INORGANIC NITROGEN 0 0
CONSERVATIVE SUBST. 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Output for 1990 Simulation

CASE: WC Lake 1990 - Calibrated

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	198.6	.26	197.2	.45	1.01	.03	.03	.01
CHL-A	MG/M3	98.6	.27	96.6	.44	1.02	.07	.06	.04
SECCHI	M	.4	.13	.4	.30	1.03	.20	.09	.08
ORGANIC N	MG/M3	.0	.00	2365.6	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	169.7	.41	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	170.0	.36	169.5	.45	1.00	.01	.01	.01
CHL-A	MG/M3	66.4	.38	64.6	.40	1.03	.08	.08	.05
SECCHI	M	.6	.16	.6	.39	.97	-.17	-.10	-.06
ORGANIC N	MG/M3	.0	.00	1638.5	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	113.8	.38	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	221.8	.79	221.5	.45	1.00	.00	.01	.00
CHL-A	MG/M3	61.9	.35	63.7	.38	.97	-.08	-.08	-.06
SECCHI	M	.6	.13	.6	.31	1.07	.52	.24	.20
ORGANIC N	MG/M3	.0	.00	1615.5	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	111.2	.35	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	188.8	.45	188.1	.45	1.00	.01	.01	.01
CHL-A	MG/M3	73.0	.34	71.9	.35	1.01	.04	.04	.03
SECCHI	M	.5	.15	.5	.33	1.01	.05	.03	.02
ORGANIC N	MG/M3	.0	.00	1804.7	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	126.4	.36	.00	.00	.00	.00

CASE: WC Lake 1990 - Calibrated

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	2.320	.000E+00	.000	.400
2	1	Subbasin 2	6.220	2.530	.000E+00	.000	.407
3	1	Subbasin 3	4.580	1.760	.000E+00	.000	.384
4	1	Subbasin 4	3.330	1.340	.000E+00	.000	.402
5	1	Subbasin 5	4.420	1.800	.000E+00	.000	.407
6	1	Subbasin 6	2.340	.940	.000E+00	.000	.402
PRECIPITATION			.979	.989	.391E-01	.200	1.010
TRIBUTARY INFLOW			26.690	10.690	.000E+00	.000	.401
***TOTAL INFLOW			27.669	11.679	.391E-01	.017	.422
ADVECTIVE OUTFLOW			27.669	10.854	.100E+00	.029	.392
***TOTAL OUTFLOW			27.669	10.854	.100E+00	.029	.392
***EVAPORATION			.000	.824	.612E-01	.300	.000

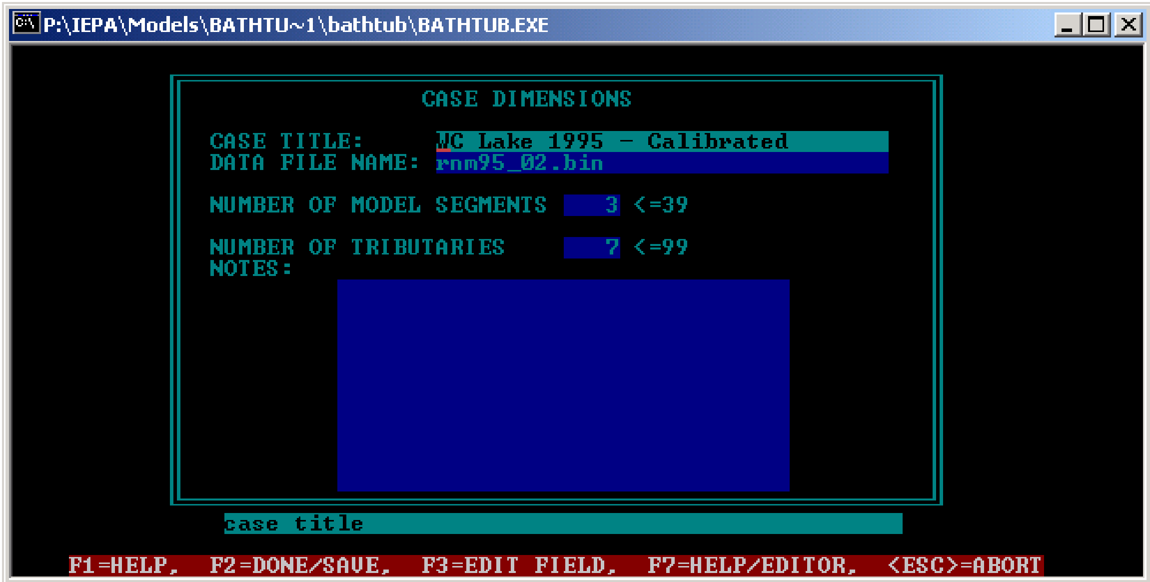
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

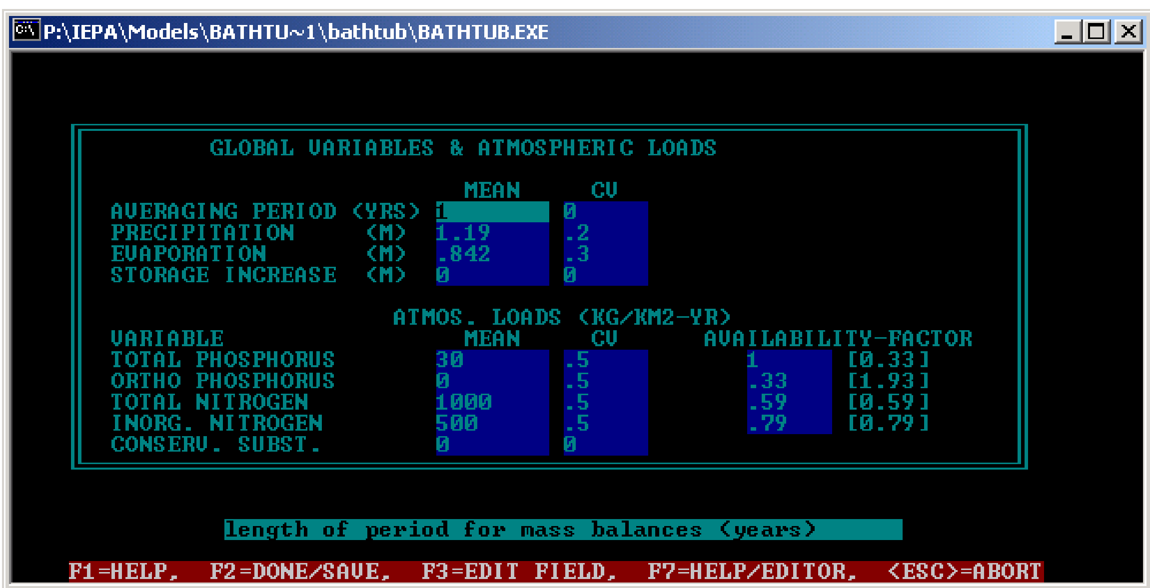
COMPONENT: TOTAL P

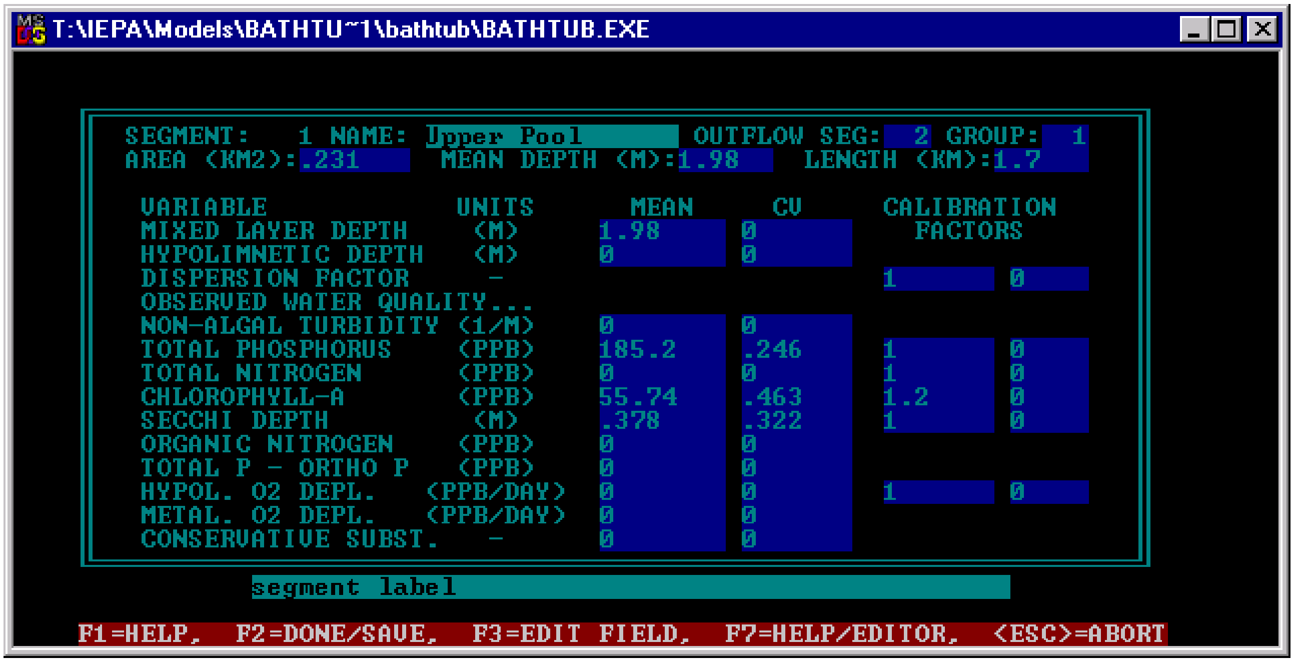
ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	600.0	4.1	.000E+00	.0	.000	258.6	103.4
2	1	Subbasin 2	600.1	4.1	.000E+00	.0	.000	237.2	96.5
3	1	Subbasin 3	701.7	4.8	.000E+00	.0	.000	398.7	153.2
4	1	Subbasin 4	100.0	.7	.000E+00	.0	.000	74.6	30.0
5	1	Subbasin 5	99.9	.7	.000E+00	.0	.000	55.5	22.6
6	1	Subbasin 6	99.9	.7	.000E+00	.0	.000	106.3	42.7
PRECIPITATION			29.4	.2	.216E+03	100.1	.500	29.7	30.0
INTERNAL LOAD			12455.8	84.8	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			2201.6	15.0	.000E+00	.0	.000	205.9	82.5
***TOTAL INFLOW			14686.7	100.0	.216E+03	100.0	.001	1257.6	530.8
ADVECTIVE OUTFLOW			2403.7	16.4	.118E+07	*******	.452	221.5	86.9
***TOTAL OUTFLOW			2403.7	16.4	.118E+07	*******	.452	221.5	86.9
***RETENTION			12283.0	83.6	.118E+07	*******	.089	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
11.09	.4024	188.8	.0561	17.8105	.8363

BATHTUB Input Screens for 1995 Model Simulation



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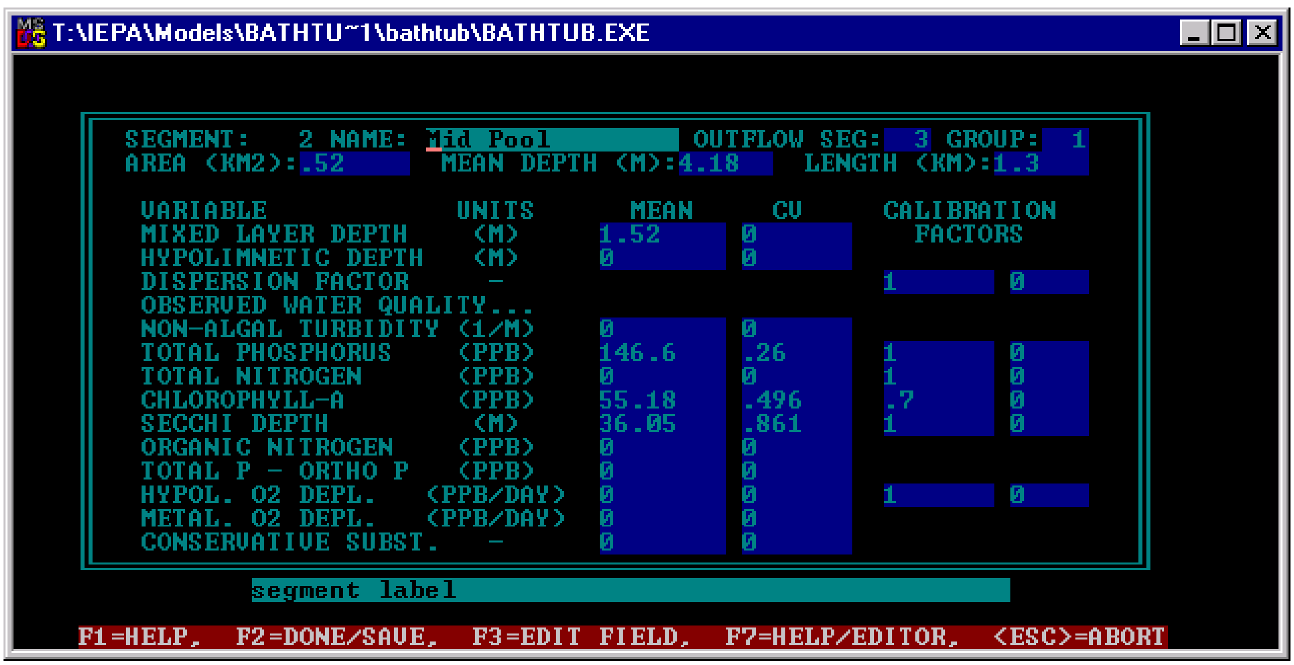
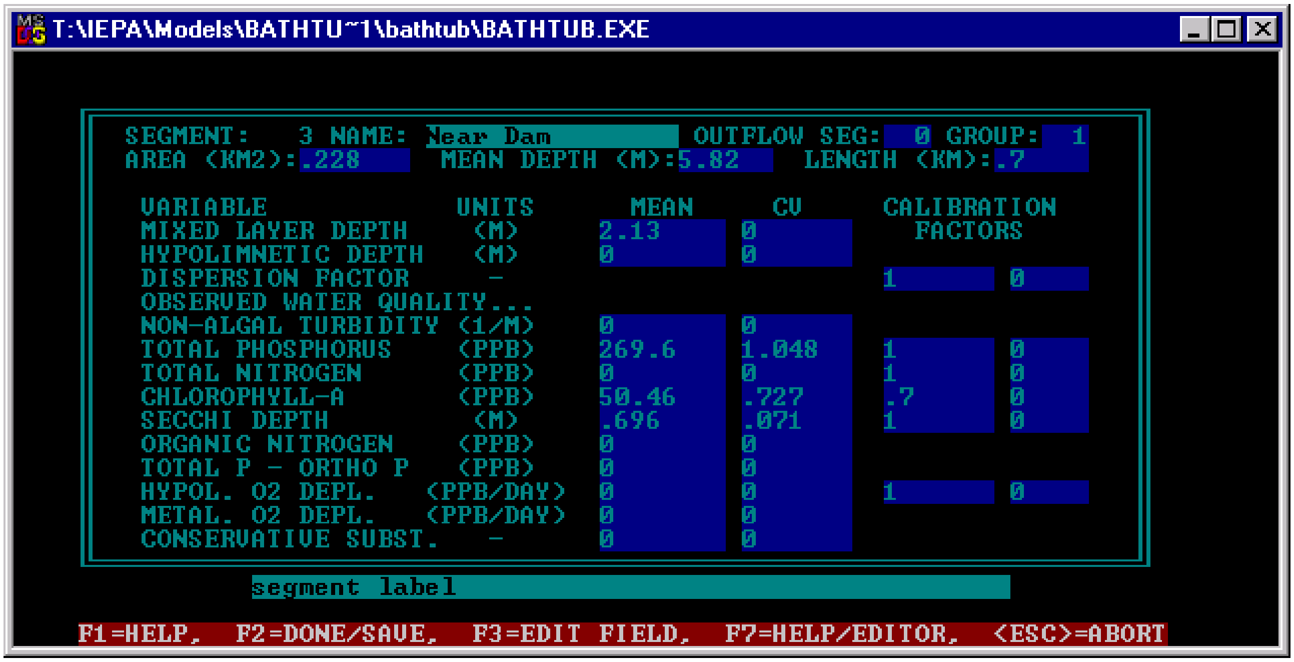
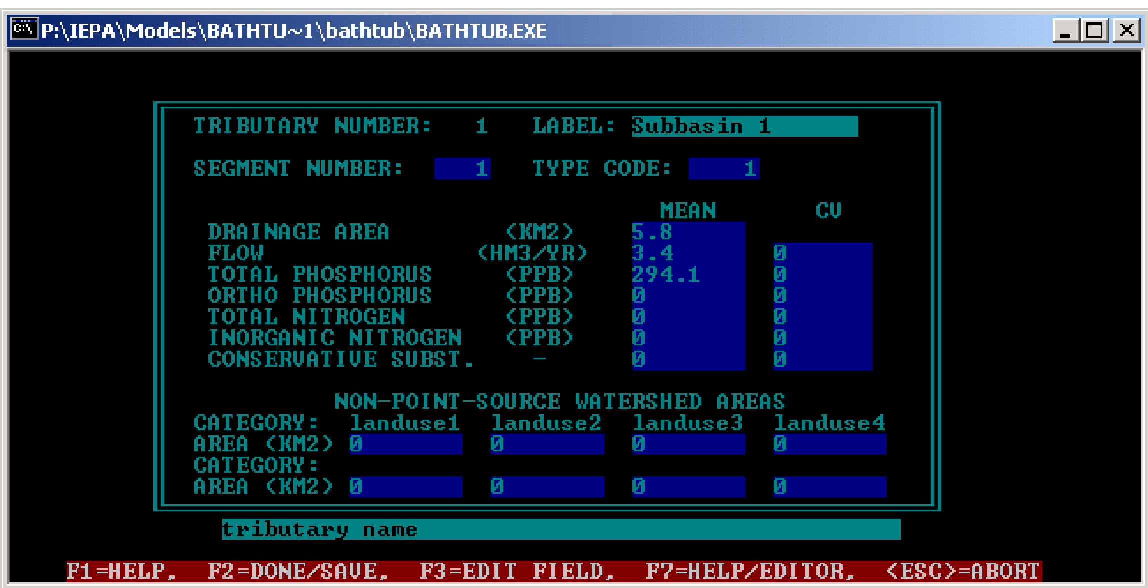
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2): .231 MEAN DEPTH (M): 1.98 LENGTH (KM): 1.7
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 1.98 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 185.2 .246 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 55.74 .463 1.2 0
SECCHI DEPTH (M) .378 .322 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2): .52 MEAN DEPTH (M): 4.18 LENGTH (KM): 1.3
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 1.52 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 146.6 .26 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 55.18 .496 .7 0
SECCHI DEPTH (M) 36.05 .861 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .228 MEAN DEPTH (M): 5.82 LENGTH (KM): .7
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.13 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 269.6 1.048 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 50.46 .727 .7 0
SECCHI DEPTH (M) .696 .071 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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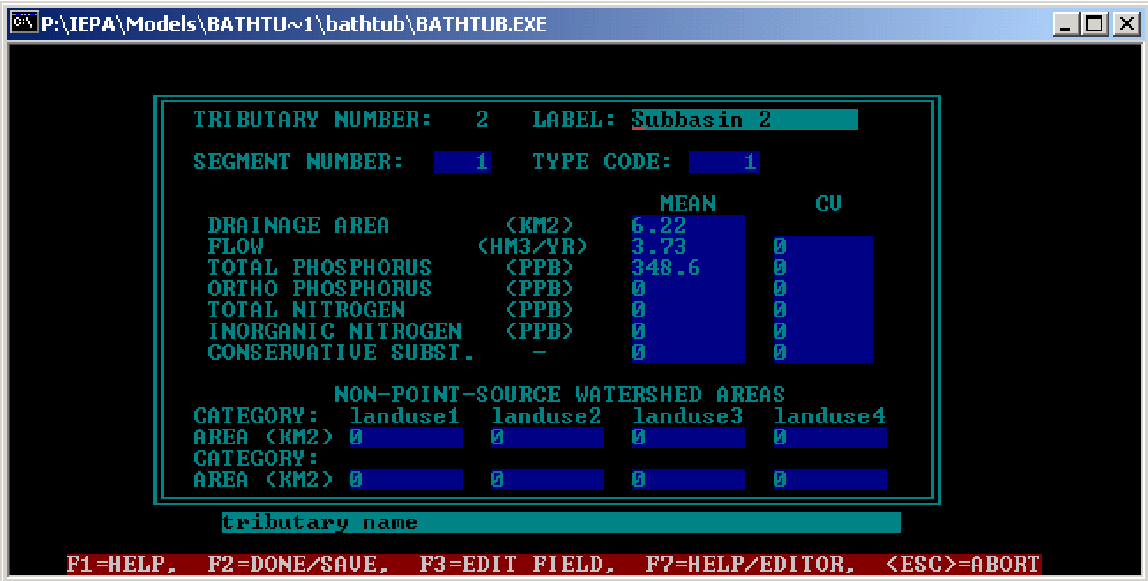
TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 5.8
FLOW (HM3/YR) 3.4 0
TOTAL PHOSPHORUS (PPB) 294.1 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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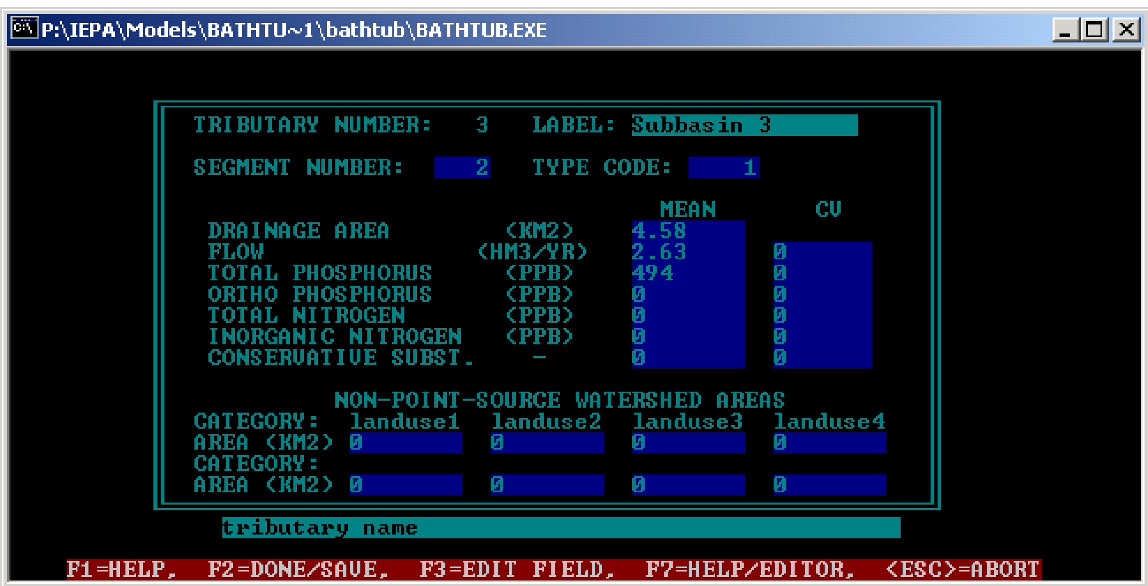
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 6.22
FLOW (HM3/YR) 3.73 0
TOTAL PHOSPHORUS (PPB) 348.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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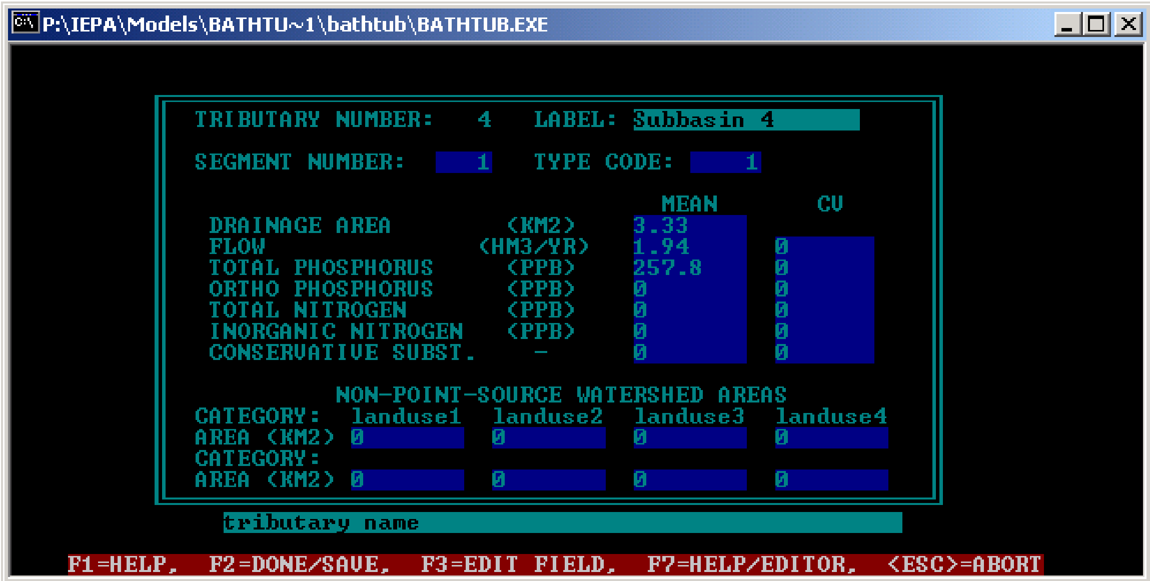
TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 4.58
FLOW (HM3/YR) 2.63 0
TOTAL PHOSPHORUS (PPB) 494 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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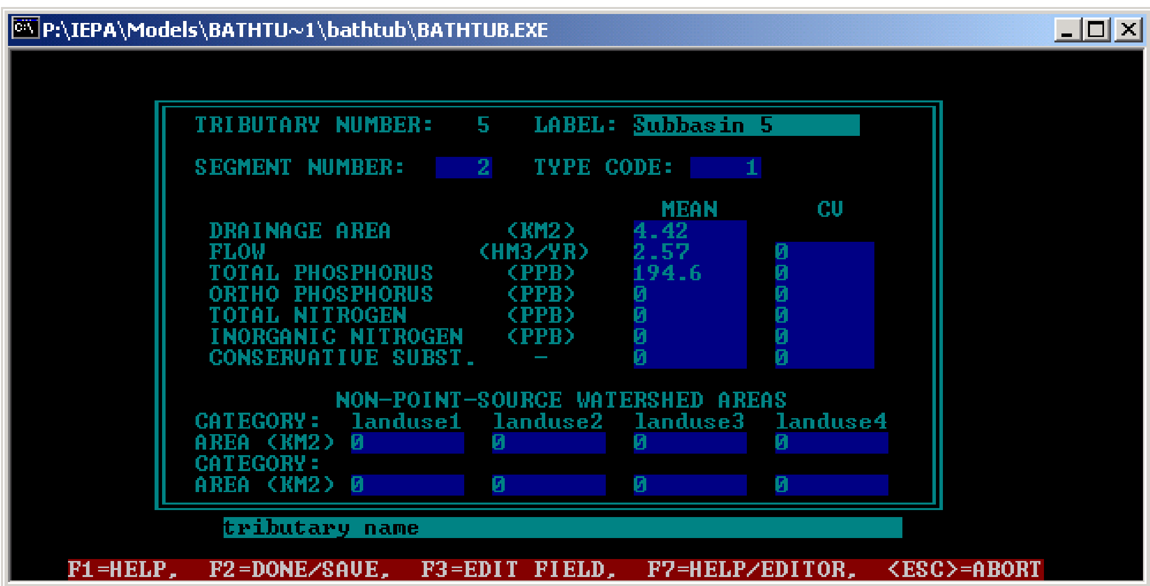
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 3.33
FLOW (HM3/YR) 1.94 0
TOTAL PHOSPHORUS (PPB) 257.8 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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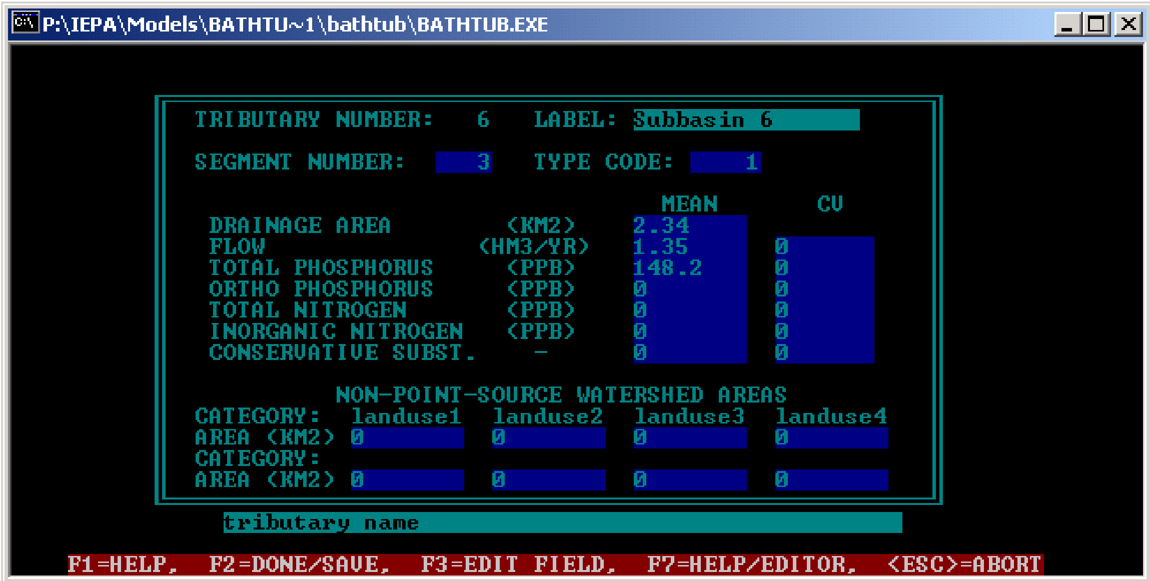
TRIBUTARY NUMBER: 5 LABEL: Subbasin 5
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 4.42
FLOW (HM3/YR) 2.57 0
TOTAL PHOSPHORUS (PPB) 194.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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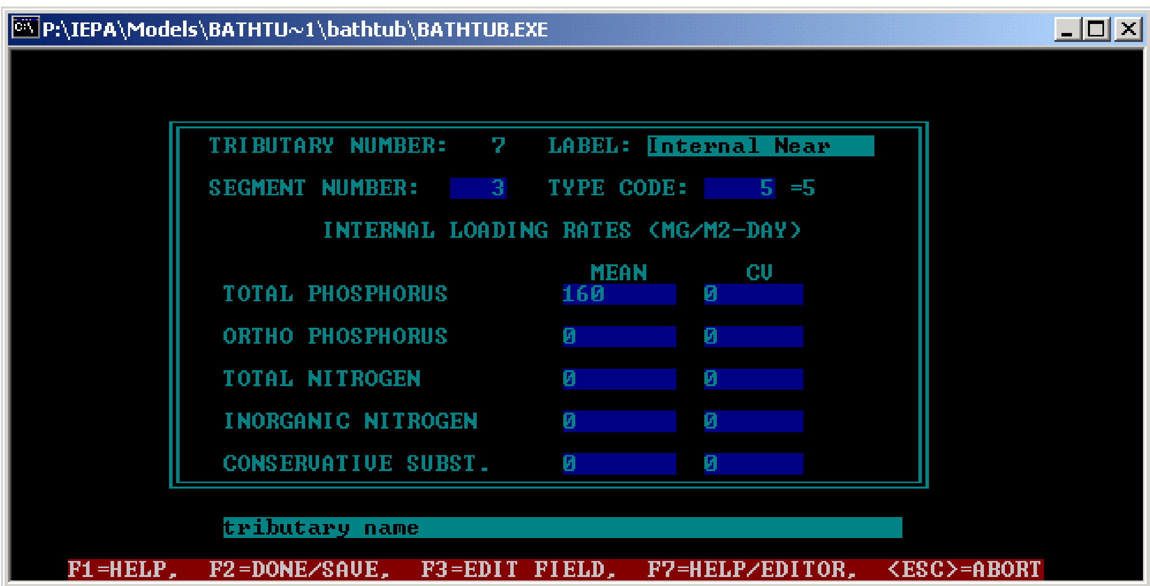
TRIBUTARY NUMBER: 6 LABEL: Subbasin 6
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.34
FLOW (HM3/YR) 1.35 0
TOTAL PHOSPHORUS (PPB) 148.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 7 LABEL: Internal Near
SEGMENT NUMBER: 3 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 160 0
ORTHO PHOSPHORUS 0 0
TOTAL NITROGEN 0 0
INORGANIC NITROGEN 0 0
CONSERVATIVE SUBST. 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Output 1995 Simulation

```
CASE: WC Lake 1995 - Calibrated

 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR

 SEGMENT:  1 Upper Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN     CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3   185.2   .25   170.2    .45    1.09     .34     .31     .17
 CHL-A      MG/M3    55.7   .46    54.6    .43    1.02     .05     .06     .03
 SECCHI         M      .4   .32      .4    .32     .99    -.03    -.04    -.02
 ORGANIC N  MG/M3      .0   .00  1495.8    .34     .00     .00     .00     .00
 TP-ORTHO-P MG/M3      .0   .00   122.7    .29     .00     .00     .00     .00
 --------------------------------------------------------------------------

 SEGMENT:  2 Mid Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN     CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3   146.6   .26   160.0    .47     .92    -.34    -.33    -.16
 CHL-A      MG/M3    55.2   .50    54.5    .41    1.01     .02     .04     .02
 SECCHI         M    36.0   .86      .7    .44   52.01    4.59   14.11    4.09
 ORGANIC N  MG/M3      .0   .00  1405.8    .36     .00     .00     .00     .00
 TP-ORTHO-P MG/M3      .0   .00    94.8    .39     .00     .00     .00     .00
 --------------------------------------------------------------------------

 SEGMENT:  3 Near Dam
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN     CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3   269.6  1.05   249.3    .46    1.08     .07     .29     .07
 CHL-A      MG/M3    50.5   .73    47.9    .47    1.05     .07     .15     .06
 SECCHI         M      .7   .07      .7    .43     .96    -.64    -.16    -.10
 ORGANIC N  MG/M3      .0   .00  1262.8    .38     .00     .00     .00     .00
 TP-ORTHO-P MG/M3      .0   .00    85.4    .34     .00     .00     .00     .00
 --------------------------------------------------------------------------

 SEGMENT:  4 AREA-WTD MEAN
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN     CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3   184.4   .53   183.2    .45    1.01     .01     .02     .01
 CHL-A      MG/M3    54.2   .54    53.0    .36    1.02     .04     .07     .04
 SECCHI         M    19.4   .85      .6    .35   30.89    4.03   12.25    3.73
 ORGANIC N  MG/M3      .0   .00  1393.8    .32     .00     .00     .00     .00
 TP-ORTHO-P MG/M3      .0   .00    99.2    .34     .00     .00     .00     .00
 --------------------------------------------------------------------------
 CASE: WC Lake 1995 - Calibrated
 GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
```

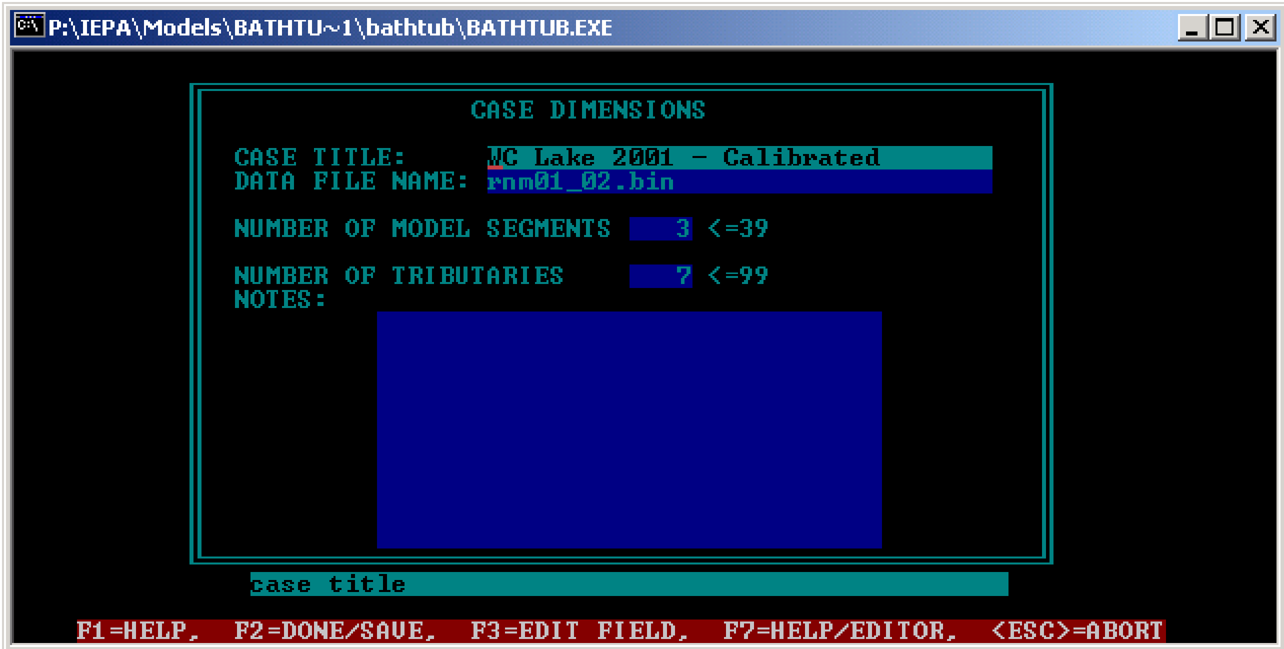
ID	T	LOCATION	KM2	MEAN	VARIANCE	CV	M/YR
1	1	Subbasin 1	5.800	3.400	.000E+00	.000	.586
2	1	Subbasin 2	6.220	3.730	.000E+00	.000	.600
3	1	Subbasin 3	4.580	2.630	.000E+00	.000	.574
4	1	Subbasin 4	3.330	1.940	.000E+00	.000	.583
5	1	Subbasin 5	4.420	2.570	.000E+00	.000	.581
6	1	Subbasin 6	2.340	1.350	.000E+00	.000	.577
PRECIPITATION			.979	1.165	.543E-01	.200	1.190
TRIBUTARY INFLOW			26.690	15.620	.000E+00	.000	.585
***TOTAL INFLOW			27.669	16.785	.543E-01	.014	.607
ADVECTIVE OUTFLOW			27.669	15.961	.115E+00	.021	.577
***TOTAL OUTFLOW			27.669	15.961	.115E+00	.021	.577
***EVAPORATION			.000	.824	.612E-01	.300	.000

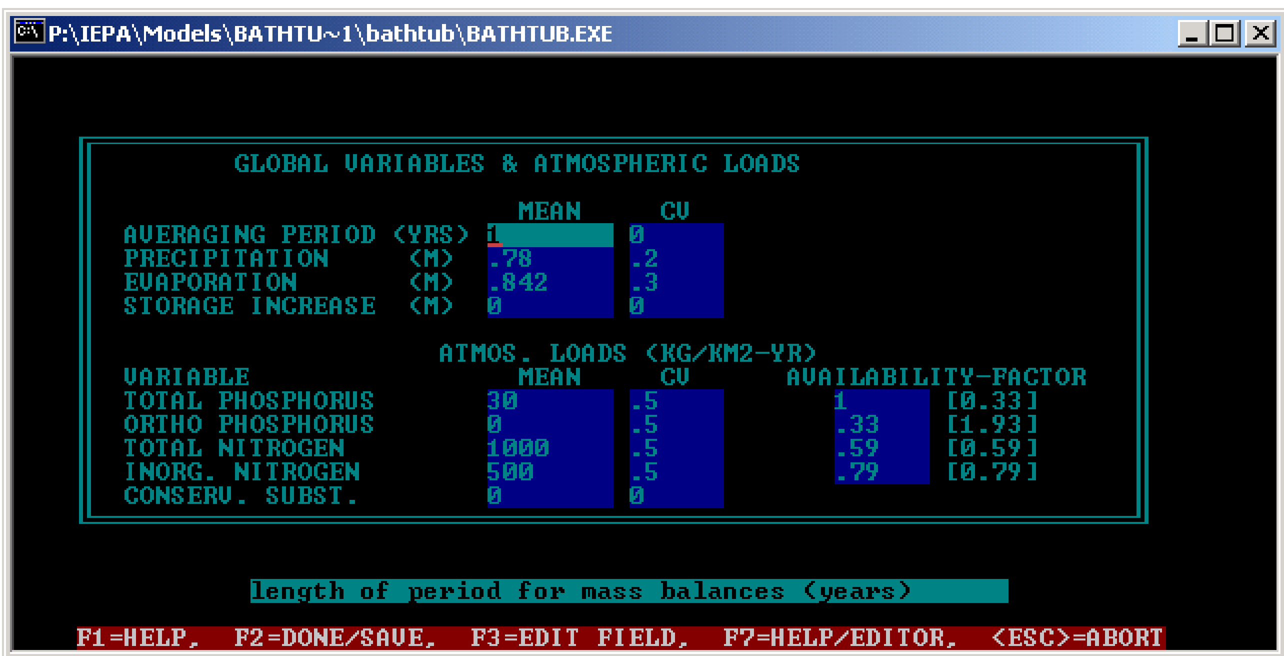
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

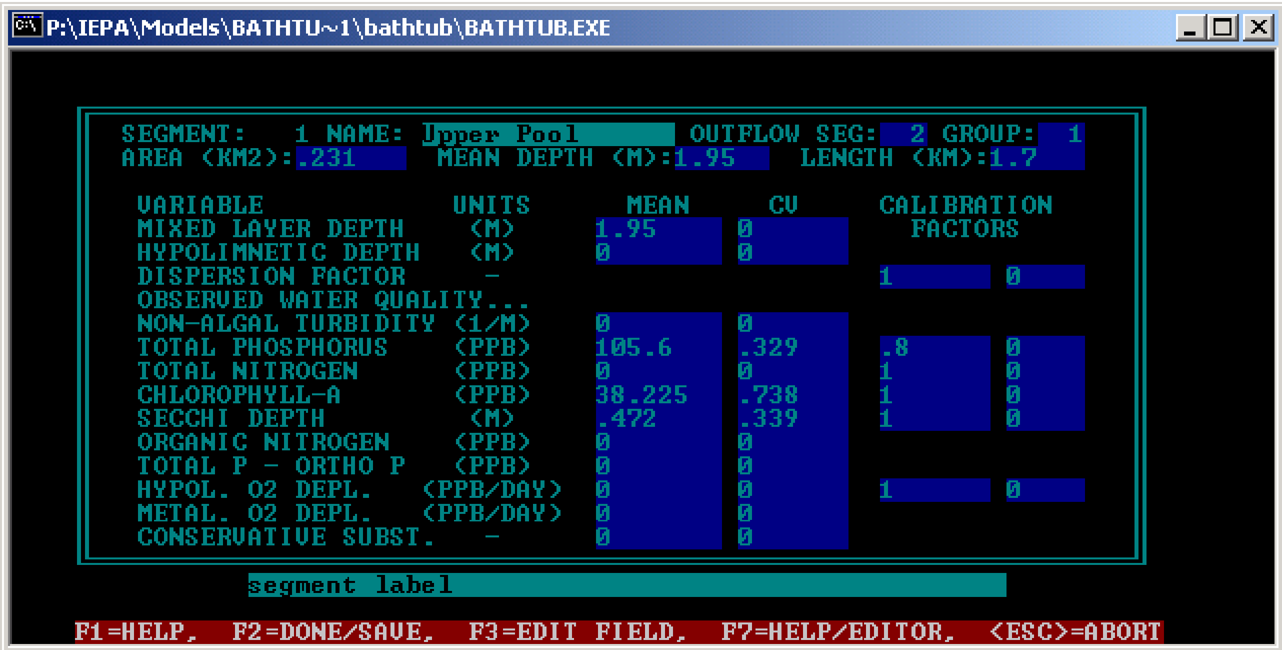
			LOADING		VARIANCE			CONC	EXPORT
ID	T	LOCATION	KG/YR	%(I)	KG/YR**2	%(I)	CV	MG/M3	KG/KM2
1	1	Subbasin 1	999.9	5.5	.000E+00	.0	.000	294.1	172.4
2	1	Subbasin 2	1300.3	7.2	.000E+00	.0	.000	348.6	209.0
3	1	Subbasin 3	1299.2	7.2	.000E+00	.0	.000	494.0	283.7
4	1	Subbasin 4	500.1	2.8	.000E+00	.0	.000	257.8	150.2
5	1	Subbasin 5	500.1	2.8	.000E+00	.0	.000	194.6	113.1
6	1	Subbasin 6	200.1	1.1	.000E+00	.0	.000	148.2	85.5
PRECIPITATION			29.4	.2	.216E+03	99.6	.500	25.2	30.0
INTERNAL LOAD			13324.3	73.4	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			4799.8	26.4	.000E+00	.0	.000	307.3	179.8
***TOTAL INFLOW			18153.5	100.0	.216E+03	100.0	.001	1081.5	656.1
ADVECTIVE OUTFLOW			3979.4	21.9	.328E+07	*******	.455	249.3	143.8
***TOTAL OUTFLOW			3979.4	21.9	.328E+07	*******	.455	249.3	143.8
***RETENTION			14174.0	78.1	.328E+07	*******	.128	.0	.0

	HYDRAULIC	TOTAL P			
OVERFLOW RATE M/YR	RESIDENCE TIME YRS	POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
16.30	.2480	184.4	.0402	24.8793	.7808

BATHTUB Input Screens for 2001 Simulation



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SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2): .231 MEAN DEPTH (M): 1.95 LENGTH (KM): 1.7
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 1.95 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 105.6 .329 .8 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 38.225 .738 1 0
SECCHI DEPTH (M) .472 .339 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
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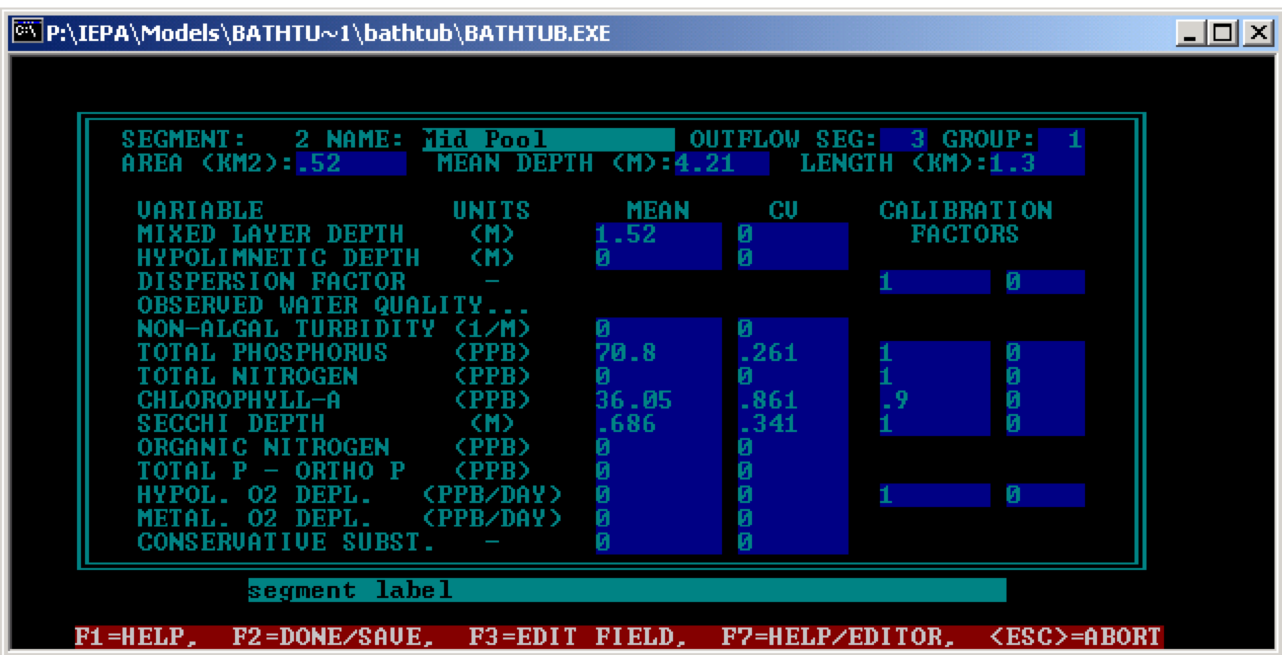
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AREA (KM2): .52 MEAN DEPTH (M): 4.21 LENGTH (KM): 1.3
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 1.52 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 70.8 .261 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 36.05 .861 .9 0
SECCHI DEPTH (M) .686 .341 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
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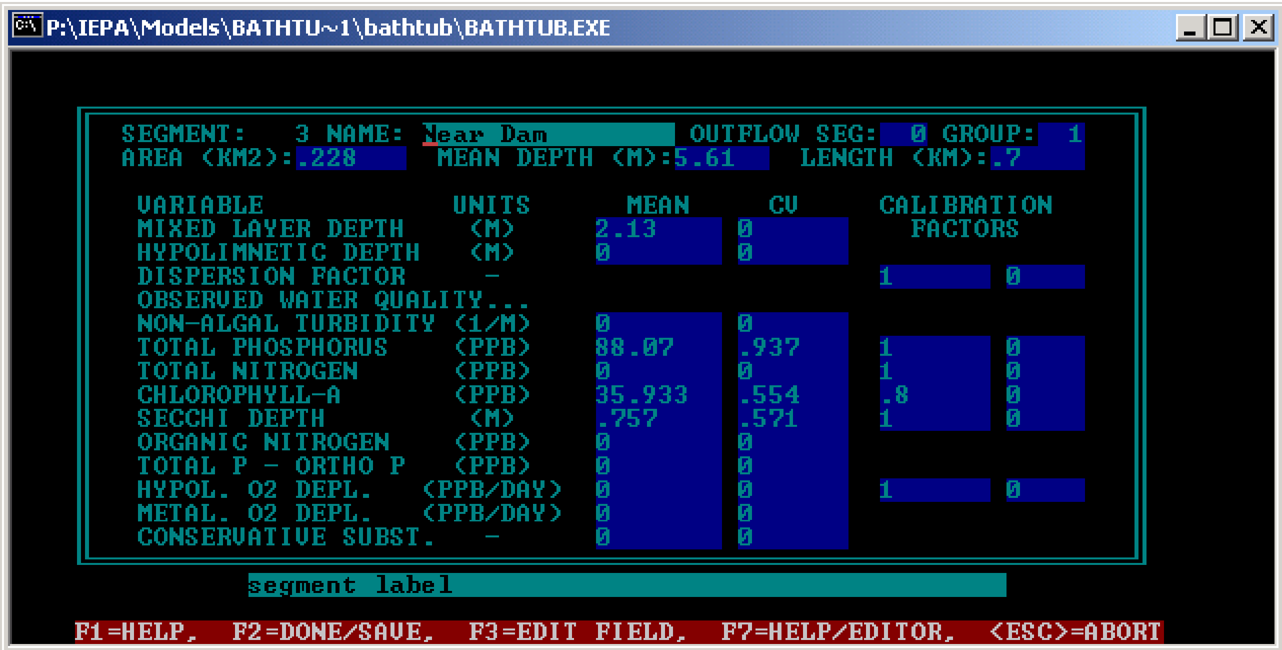
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SEGMENT: 3 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .228 MEAN DEPTH (M): 5.61 LENGTH (KM): .7
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.13 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 88.07 .937 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 35.933 .554 .8 0
SECCHI DEPTH (M) .757 .571 1 0
ORGANIC NITROGEN (PPB) 0 0
TOTAL P - ORTHO P (PPB) 0 0
HYPOL. O2 DEPL. (PPB/DAY) 0 0 1 0
METAL. O2 DEPL. (PPB/DAY) 0 0
CONSERVATIVE SUBST. - 0 0
segment label
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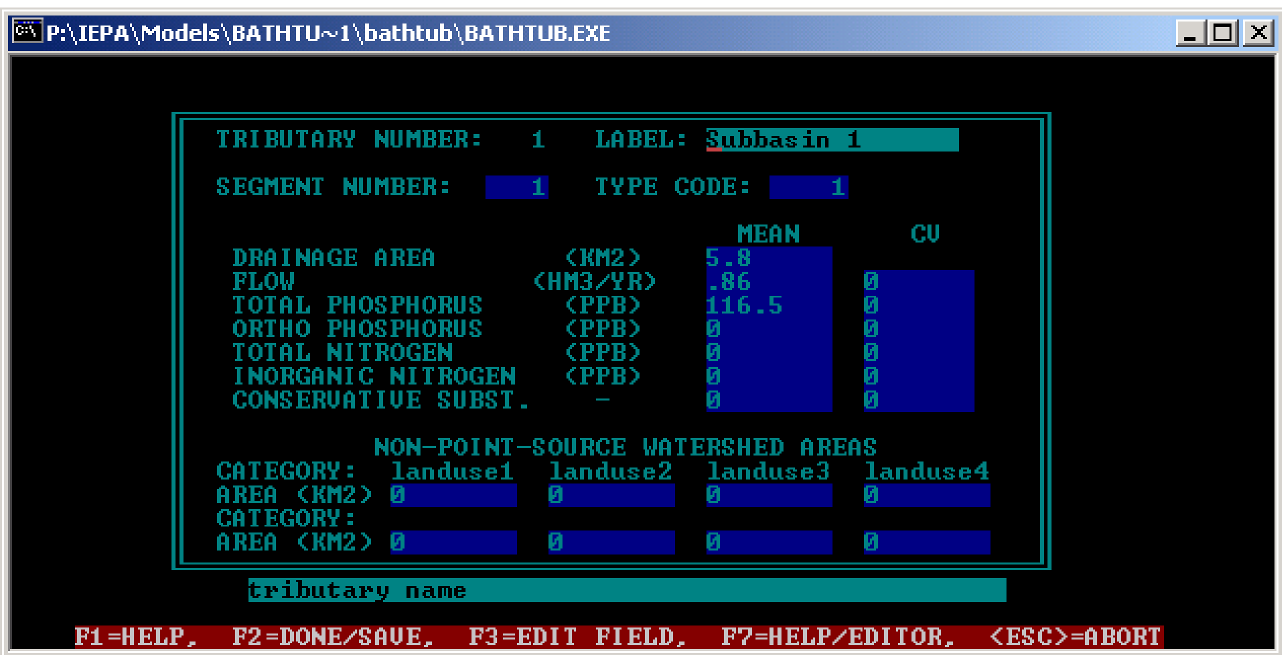
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TRIBUTARY NUMBER: 1 LABEL: Subbasin 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 5.8
FLOW (HM3/YR) .86 0
TOTAL PHOSPHORUS (PPB) 116.5 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
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tributary name
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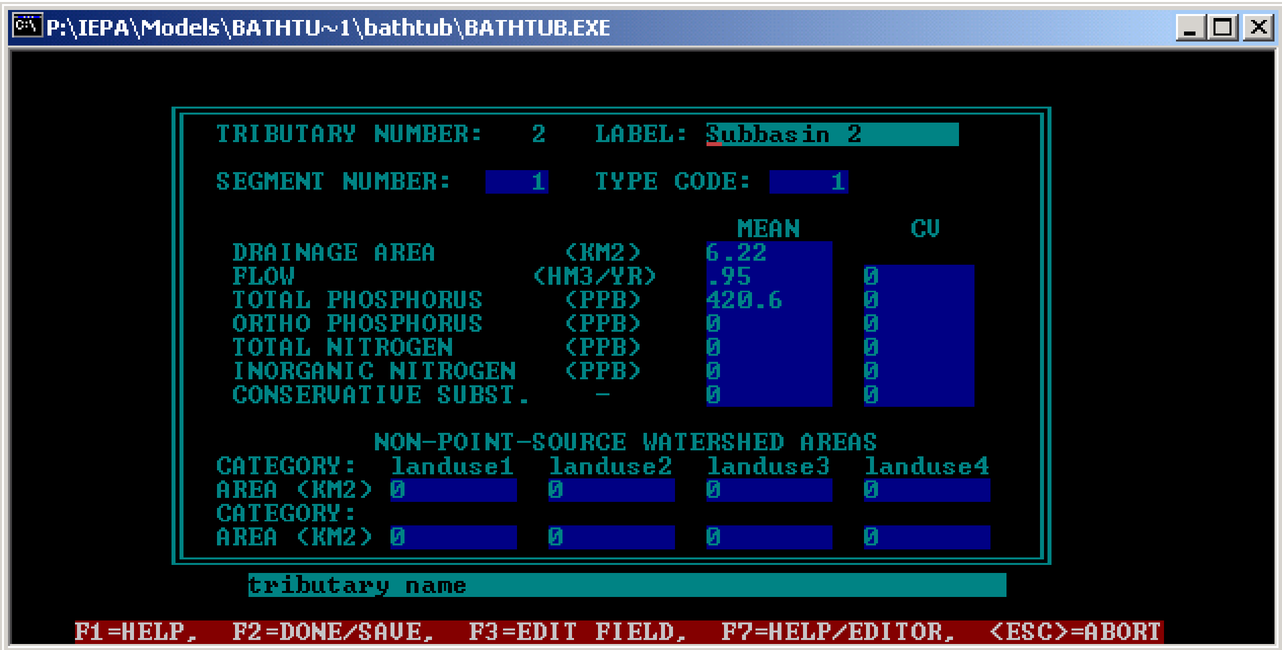
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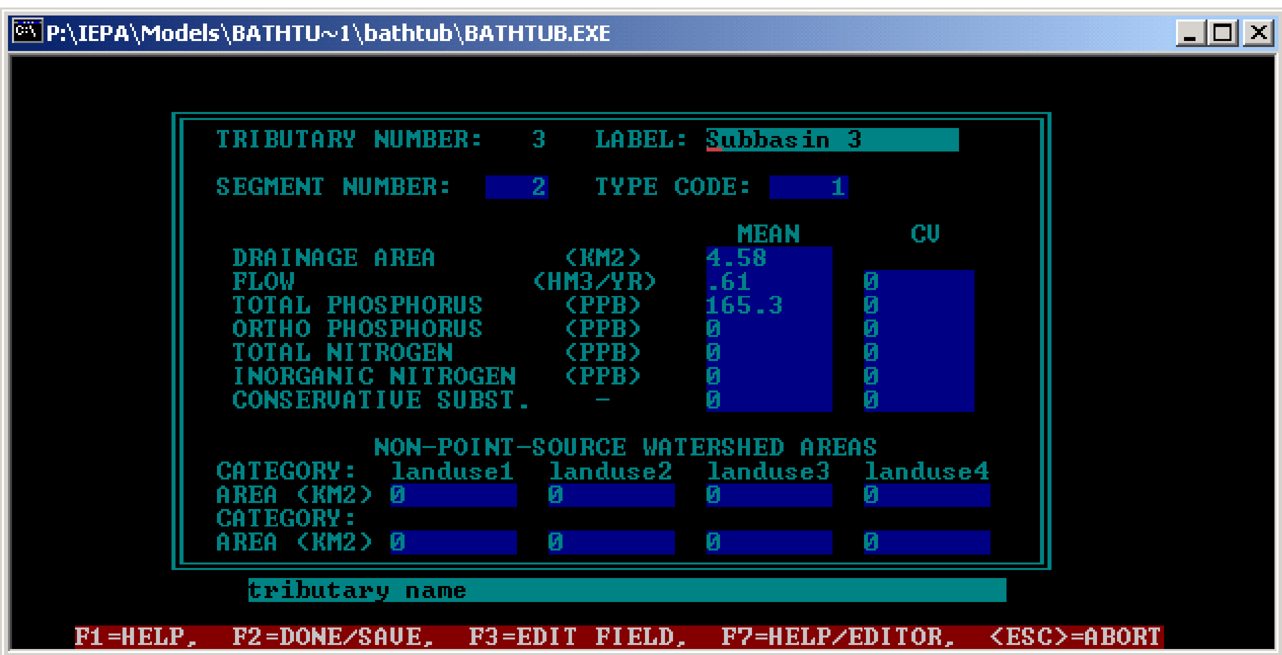
TRIBUTARY NUMBER: 2 LABEL: Subbasin 2
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 6.22
FLOW (HM3/YR) .95 0
TOTAL PHOSPHORUS (PPB) 420.6 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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TRIBUTARY NUMBER: 3 LABEL: Subbasin 3
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 4.58
FLOW (HM3/YR) .61 0
TOTAL PHOSPHORUS (PPB) 165.3 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
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tributary name
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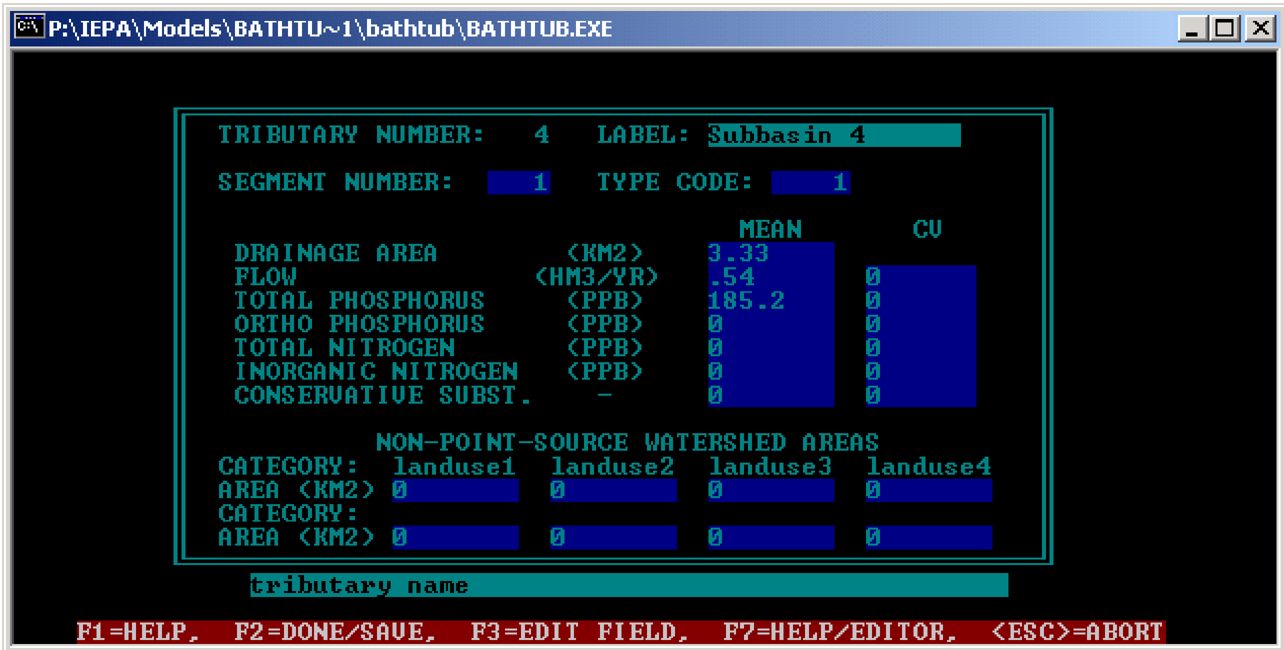
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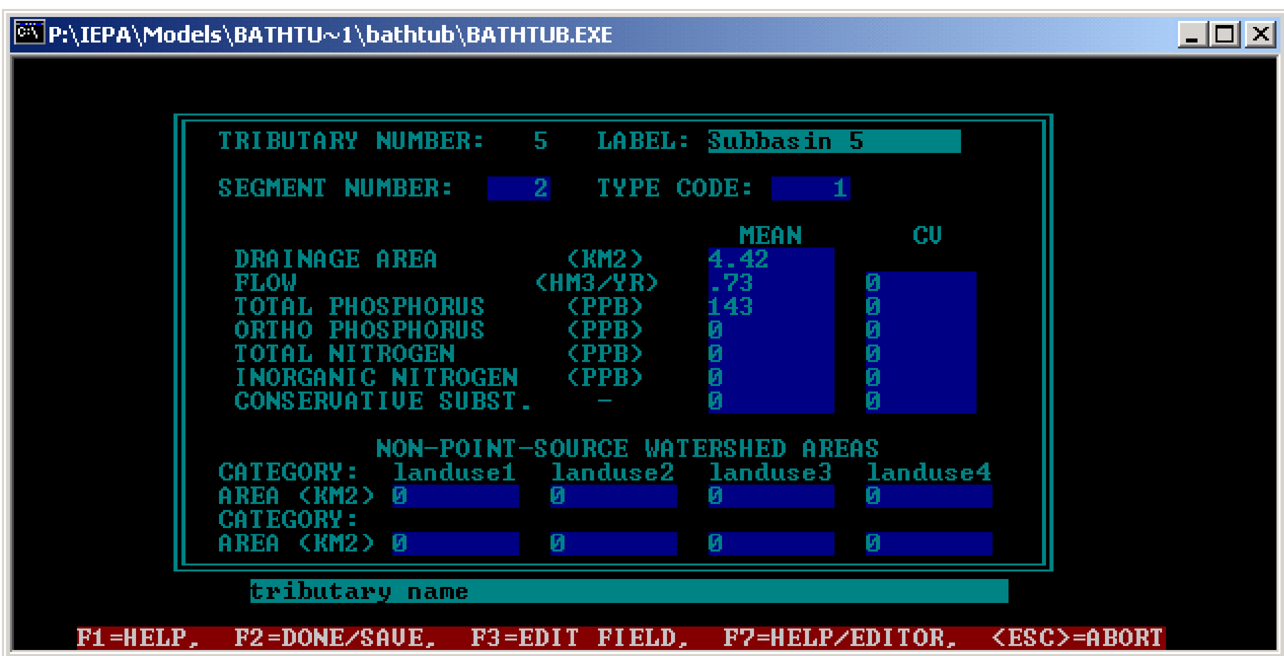
TRIBUTARY NUMBER: 4 LABEL: Subbasin 4
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 3.33
FLOW (HM3/YR) .54 0
TOTAL PHOSPHORUS (PPB) 185.2 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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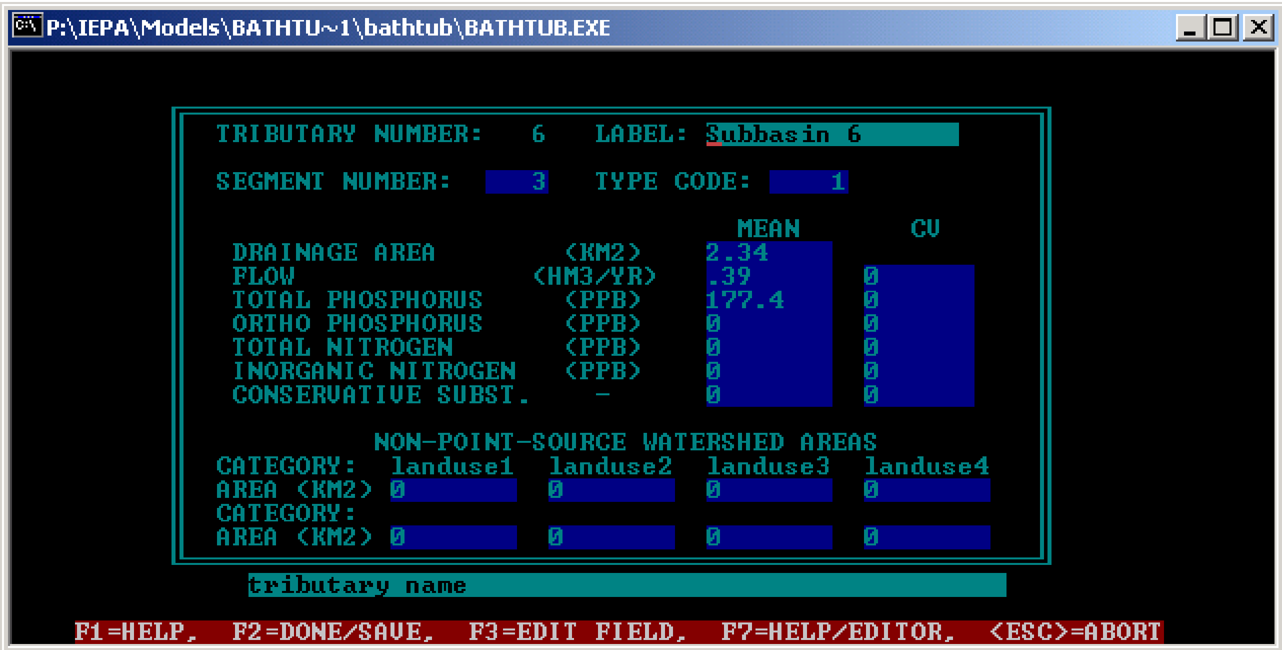
TRIBUTARY NUMBER: 5 LABEL: Subbasin 5
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 4.42
FLOW (HM3/YR) .73 0
TOTAL PHOSPHORUS (PPB) 143 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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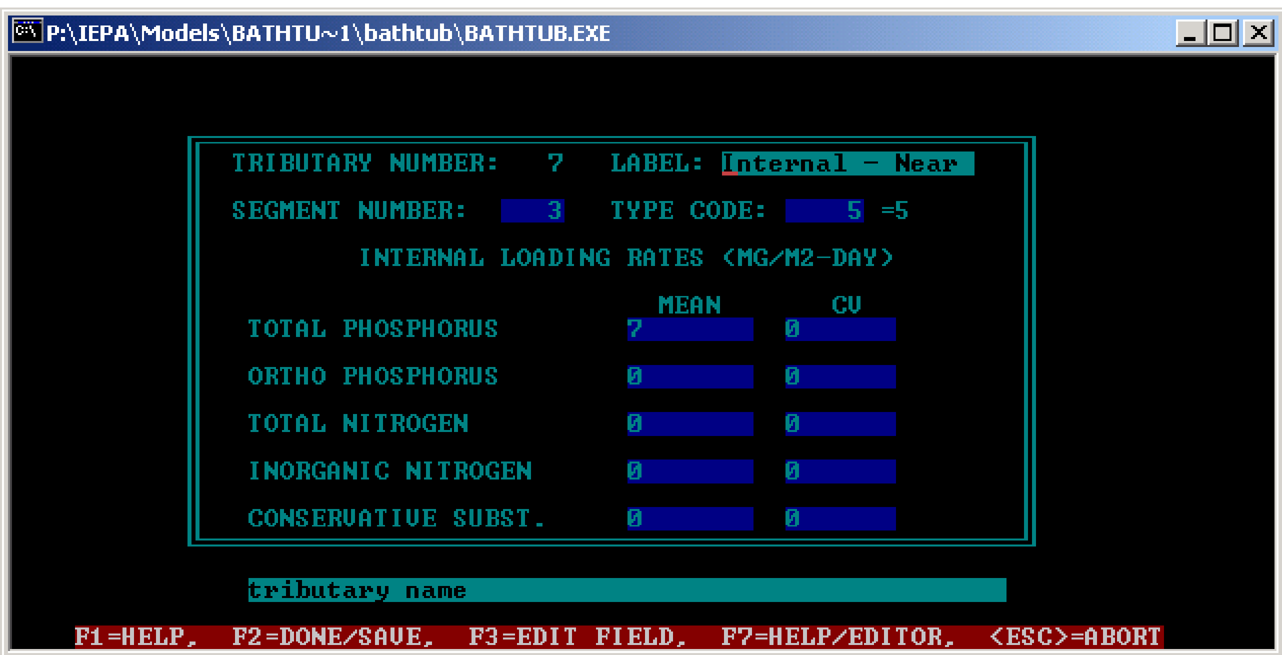
TRIBUTARY NUMBER: 6 LABEL: Subbasin 6
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.34
FLOW (HM3/YR) .39 0
TOTAL PHOSPHORUS (PPB) 177.4 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: landuse1 landuse2 landuse3 landuse4
AREA (KM2) 0 0 0 0
CATEGORY:
AREA (KM2) 0 0 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT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TRIBUTARY NUMBER: 7 LABEL: Internal - Near
SEGMENT NUMBER: 3 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 7 0
ORTHO PHOSPHORUS 0 0
TOTAL NITROGEN 0 0
INORGANIC NITROGEN 0 0
CONSERVATIVE SUBST. 0 0
tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

BATHTUB Output for 2001 Simulation

CASE: WC Lake 2001 - Calibrated

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	105.6	.33	102.0	.45	1.04	.11	.13	.06
CHL-A	MG/M3	38.2	.74	38.3	.47	1.00	.00	-.01	.00
SECCHI	M	.5	.34	.5	.41	1.00	.00	.00	.00
ORGANIC N	MG/M3	.0	.00	1118.0	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	91.7	.33	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	70.8	.26	71.8	.46	.99	-.05	-.05	-.03
CHL-A	MG/M3	36.0	.86	36.2	.54	1.00	.00	-.01	.00
SECCHI	M	.7	.34	.7	.57	1.00	.01	.01	.00
ORGANIC N	MG/M3	.0	.00	1023.4	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	73.5	.46	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	88.1	.94	87.2	.45	1.01	.01	.04	.01
CHL-A	MG/M3	35.9	.55	32.3	.51	1.11	.19	.30	.14
SECCHI	M	.8	.57	.8	.59	.93	-.12	-.25	-.09
ORGANIC N	MG/M3	.0	.00	926.2	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	63.5	.40	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	83.0	.45	82.5	.45	1.01	.01	.02	.01
CHL-A	MG/M3	36.5	.76	35.8	.47	1.02	.03	.06	.02
SECCHI	M	.7	.40	.7	.42	.98	-.05	-.07	-.03
ORGANIC N	MG/M3	.0	.00	1023.1	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	75.4	.40	.00	.00	.00	.00

CASE: WC Lake 2001 - Calibrated

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	.860	.000E+00	.000	.148
2	1	Subbasin 2	6.220	.950	.000E+00	.000	.153
3	1	Subbasin 3	4.580	.610	.000E+00	.000	.133
4	1	Subbasin 4	3.330	.540	.000E+00	.000	.162
5	1	Subbasin 5	4.420	.730	.000E+00	.000	.165
6	1	Subbasin 6	2.340	.390	.000E+00	.000	.167
PRECIPITATION			.979	.764	.233E-01	.200	.780
TRIBUTARY INFLOW			26.690	4.080	.000E+00	.000	.153
***TOTAL INFLOW			27.669	4.844	.233E-01	.032	.175
ADVECTIVE OUTFLOW			27.669	4.019	.845E-01	.072	.145
***TOTAL OUTFLOW			27.669	4.019	.845E-01	.072	.145
***EVAPORATION			.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	100.2	6.7	.000E+00	.0	.000	116.5	17.3
2	1	Subbasin 2	399.6	26.9	.000E+00	.0	.000	420.6	64.2
3	1	Subbasin 3	100.8	6.8	.000E+00	.0	.000	165.3	22.0
4	1	Subbasin 4	100.0	6.7	.000E+00	.0	.000	185.2	30.0
5	1	Subbasin 5	104.4	7.0	.000E+00	.0	.000	143.0	23.6
6	1	Subbasin 6	69.2	4.7	.000E+00	.0	.000	177.4	29.6
PRECIPITATION			29.4	2.0	.216E+03	100.0	.500	38.5	30.0
INTERNAL LOAD			582.9	39.2	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			874.2	58.8	.000E+00	.0	.000	214.3	32.8
***TOTAL INFLOW			1486.5	100.0	.216E+03	100.0	.010	306.9	53.7
ADVECTIVE OUTFLOW			350.7	23.6	.252E+05	11667.4	.452	87.2	12.7
***TOTAL OUTFLOW			350.7	23.6	.252E+05	11667.4	.452	87.2	12.7
***RETENTION			1135.8	76.4	.253E+05	11742.3	.140	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	-------------- TOTAL P -------------- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
4.11	.9750	83.0	.2189	4.5684	.7641

Appendix D
GWLF Manual

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G W L F

GENERALIZED WATERSHED LOADING FUNCTIONS

VERSION 2.0

USER'S MANUAL

December, 1992
(Corrected & reprinted: January, 1996)

Douglas A. Haith, Ross Mandel & Ray Shyan Wu

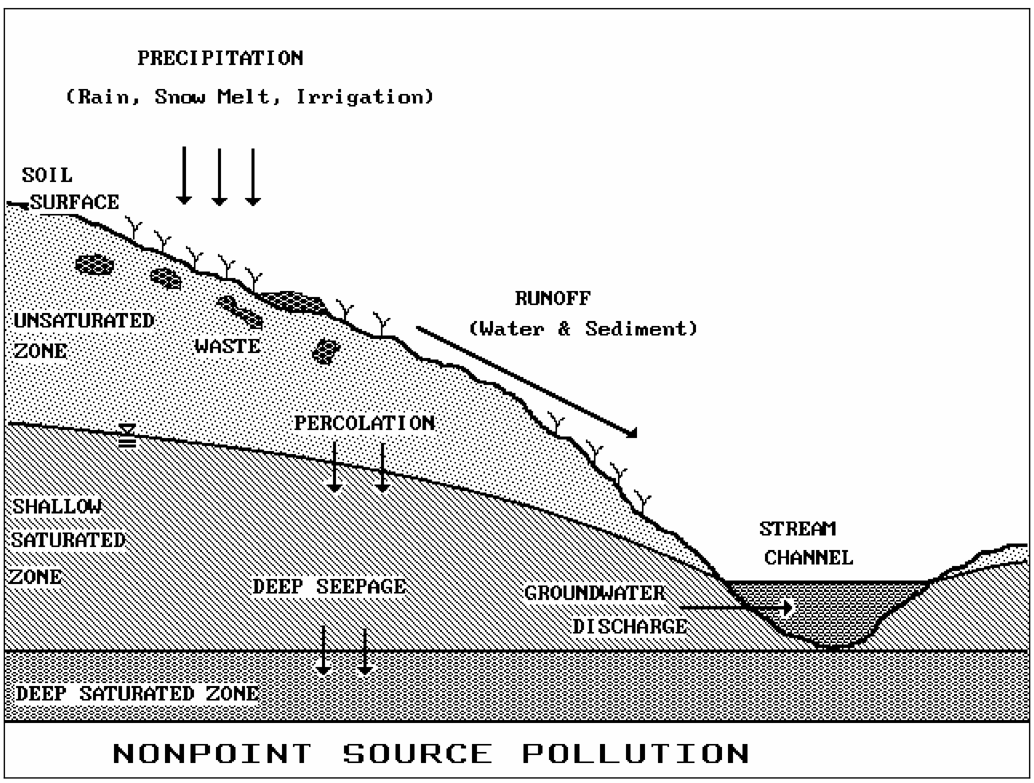

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TABLE OF CONTENTS

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<u>INTRODUCTION</u>

Mathematical models for estimating nonpoint sources of nitrogen and phosphorus in streamflow include export coefficients, loading functions and chemical simulation models. Export coefficients are average annual unit area nutrient loads associated with watershed land uses. Coefficients provide gross estimates of nutrient loads, but are of limited value for determining seasonal loads or evaluating water pollution control measures. Chemical simulation models are mechanistic (mass balance) descriptions of nutrient availability, wash off, transport and losses. Chemical simulation models provide the most complete descriptions of nutrient loads, but they are too data intensive for use in many water quality studies.

Loading functions are engineering compromises between the empiricism of export coefficients and the complexity of chemical simulation models. Mechanistic modeling is limited to water and/or sediment movement. Chemical behavior of nutrients is either ignored or described by simple empirical relationships. Loading functions provide useful means of estimating nutrient loads when chemical simulation models are impractical.

The Generalized Watershed Loading Functions (GWLF) model described in this manual estimates dissolved and total monthly nitrogen and phosphorus loads in streamflow from complex watersheds. Both surface runoff and groundwater sources are included, as well as nutrient loads from point sources and on-site wastewater disposal (septic) systems. In addition, the model provides monthly streamflow, soil erosion and sediment yield values. The model does not require water quality data for calibration, and has been validated for an 85,000 ha watershed in upstate New York.

The model described in this manual is a based on the original GWLF model as described by Haith & Shoemaker (1987). However, the current version (Version 2.0) contains several enhancements. Nutrient loads from septic systems are now included and the urban runoff model has been modified to more closely approximate procedures used in the Soil Conservation Service's Technical Release 55 (Soil Conservation Service, 1986) and models such as SWMM (Huber & Dickinson, 1988) and STORM (Hydrologic Engineering Center, 1977). The groundwater model has been given a somewhat stronger conceptual basis by limiting the unsaturated zone moisture storage capacity. The graphics outputs have been converted to VGA and color has been used more extensively.

The most significant changes in the manual are an expanded mathematical description of the model (Appendix A) and much more detailed guidance on parameter estimation (Appendix B). Both changes are in response to suggestions by many users. The extra mathematical details are for the benefit of researchers who wish to modify (and improve) GWLF for their own purposes. The new sections on parameter estimation (and the many new tables) are for users who may not be familiar with curve numbers, erosivity coefficients, etc., or who do not have access to some of the primary sources. The general intent has been to make the manual self-contained.

This manual describes the computer software package which can be used to implement GWLF. The associated programs are written in QuickBASIC 4.5 for personal computers using the MS-DOS operating system and VGA graphics. The manual and associated programs (on floppy disk) are available without charge from the senior author. The programs are distributed in both executable (.EXE) and source code form (.BAS). Associated example data files and outputs for Example 1 and a 30-yr weather set for Walton NY used in Example 3 are also included on the disk.

The main body of this manual describes the program structures and input and output files and options. Three examples are also presented. Four appendices present the mathematical structure of GWLF, methods for estimation of model parameters, results of a validation study, and sample listings of input and output files.

In this manual, the program name, options in the menu page, and input by the user are written in **bold**, <u>underline</u> and *italic*, respectively.

MODEL DESCRIPTION

Model Structure

The GWLF model includes dissolved and solid-phase nitrogen and phosphorus in streamflow from the sources shown in Figure 1. Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Runoff is computed by using the Soil Conservation Service Curve Number Equation. Solid-phase rural nutrient loads are given by the product of monthly sediment yield and average sediment nutrient concentrations. Erosion is computed using the Universal Soil Loss Equation and the sediment yield is the product of erosion and sediment delivery ratio. The yield in any month is proportional to the total transport capacity of daily runoff during the month. Urban nutrient loads, assumed to be entirely solid-phase, are modeled by exponential accumulation and washoff functions. Septic systems are classified according to four types: normal systems, ponding systems, short-circuiting systems, and direct discharge systems. Nutrient loads from septic systems are calculated by estimating the per capita daily load from each type of system and the number of people in the watershed served by each type. Daily evapotranspiration is given by the product of a cover factor and potential evapotranspiration. The latter is estimated as a function of daylight hours, saturated water vapor pressure and daily temperature.

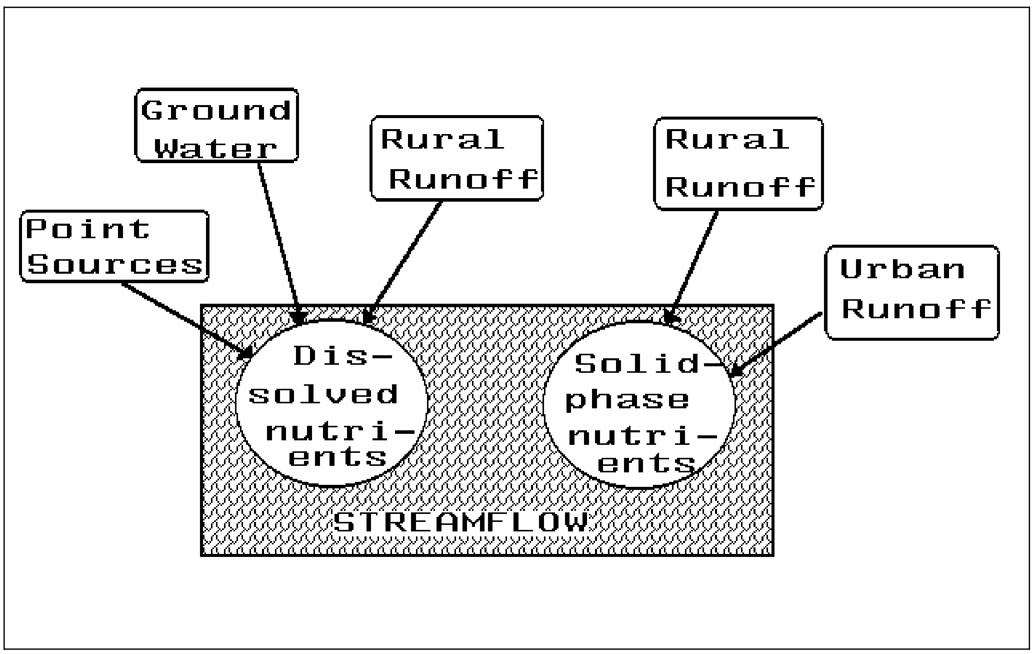

Figure 1. Nutrient Sources in GWLF.

Streamflow consists of runoff and discharge from groundwater. The latter is obtained from a lumped parameter watershed water balance. Daily water balances are calculated for unsaturated and shallow saturated zones. Infiltration to the unsaturated and shallow saturated zones equals the excess, if any, of rainfall and snowmelt less runoff and evapotranspiration. Percolation occurs when unsaturated zone water exceeds field capacity. The shallow saturated zone is modeled as a linear groundwater reservoir.

Model structure, including mathematics, is discussed in more detail in Appendix A.

Input Data

The GWLF model requires daily precipitation and temperature data, runoff sources and transport and chemical parameters. Transport parameters include areas, runoff curve numbers for antecedent moisture condition II and the erosion product ḲḶṢÇP for each runoff source. Required watershed transport parameters are groundwater recession and seepage coefficients, the available water capacity of the unsaturated zone, the sediment delivery ratio and monthly values for evapotranspiration cover factors, average daylight hours, growing season indicators and rainfall erosivity coefficients. Initial values must also be specified for unsaturated and shallow saturated zones, snow cover and 5-day antecedent rain fall plus snowmelt.

Input nutrient data for rural source areas are dissolved nitrogen and phosphorus concentrations in runoff and solid-phase nutrient concentrations in sediment. If manure is spread during winter months on any rural area, dissolved concentrations in runoff are also specified for each manured area. Daily nutrient accumulation rates are required for each urban land use. Septic systems need estimates of the per capita nutrient load in septic system effluent and per capita nutrient losses due to plant uptake, as well as the number of people served by each type of system. Point sources of nitrogen and phosphorus are assumed to be in dissolved form and must be specified for each month. The remaining nutrient data are dissolved nitrogen and phosphorus concentrations in groundwater.

Procedures for estimating transport and nutrient parameters are described in Appendix B. Examples are given in Appendix C and in subsequent sections of this manual.

Model Output

The GWLF program provides its simulation results in tables as well as in graphs. The following principal variables are given:

Monthly Streamflow
Monthly Watershed Erosion and Sediment Yield
Monthly Total Nitrogen and Phosphorus Loads in Streamflow
Annual Erosion from Each Land Use
Annual Nitrogen and Phosphorus Loads from Each Land Use

The program also provides

Monthly Precipitation and Evapotranspiration
Monthly Ground Water Discharge to Streamflow
Monthly Watershed Runoff
Monthly Dissolved Nitrogen and Phosphorus Loads in Streamflow
Annual Dissolved Nitrogen and Phosphorus Loads from Each Land Use
Annual Dissolved Nitrogen and Phosphorus Loads from Septic Systems

GWLF PROGRAM

Required Files

Simulations by GWLF require four program modules and three data files on the default drive. The three necessary data files are **WEATHER.DAT**, **TRANSPRT.DAT** and **NUTRIENT.DAT**. The four compiled modules, **GWLF20.EXE**, **TRAN20.EXE**, **NUTR20.EXE**, and **OUTP20.EXE** are run by typing *GWLF20*.

Two daily weather files for Walton, NY are included on the disks. **WALT478.382** is the four year (4/78-3/92) record used for model validation and in Examples 1 and 2. **WALT462.392** is the 30 year (4/62- 3/92) record used in Example 3. Prior to running the programs, the appropriate weather record should be copied to **WEATHER.DAT**.

The final two data files on the disks (**RESULTS.DAT**, and **SUMMARY.DAT**) are output files from Example 1. **GWLF20.BAS**, **TRAN20.BAS**, **NUTR20.BAS**, and **OUTP20.BAS** are the uncompiled, Quick-BASIC files for the modules, and can be used to modify the existing program.

Program Structure

The structure of GWLF is illustrated in Figure 2. Once the program has been activated, the main control page appears on the screen, as shown in DISPLAY 1.This page is the main menu page that leads to the four major options of the program. The selection of a program option provides access to another set of menu pages within the chosen option. After completing an option, the program returns the user to the main menu page for further actions.

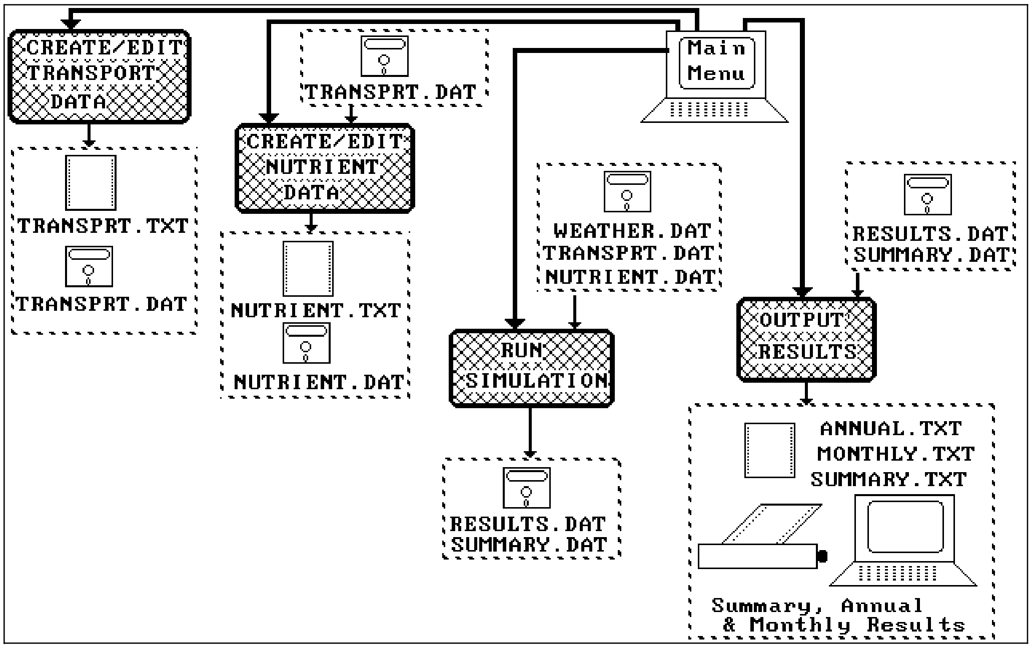

Figure 2. Structure of the GWLF Program.

The selection of the menu options is done by typing the number indicating a choice and then *Enter*. For example, selection of Run simulation is done by typing *3* and *Enter*.

```
Select one of the following :
      1      Create or print TRANSPRT.DAT (Transport parameters)
      2      Create or print NUTRIENT.DAT (nutrient parameters)
               (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3      Run simulation
      4      Obtain output
      5      Stop (End)
?
```

DISPLAY 1. The Main Menu Page of the GWLF Program.

Transport Data Manipulation

The first step in using the program is to define transport parameters either by creating a new transport data file or modifying an existing one. Options are shown in DISPLAY 2. If the user wishes to create a new transport data file, selection of Create new TRANSPRT.DAT file leads to the input mode. On the other hand, if the user wishes to modify an existing transport data file, selection of Modify existing TRANSPRT.DAT file leads to the modification mode. After input/modification, the user can obtain a hard copy of the transport data by selecting Print TRANSPORT data.

```
Select :
      1      Create new TRANSPRT.DAT file
      2      Modify existing TRANSPRT.DAT file
      3      Print TRANSPORT data
  otherwise  Return
?
```

DISPLAY 2. The Menu Page for Manipulation of Transport Parameters.

Create a New TRANSPRT.DAT File. New values of transport parameters are input one by one in this mode. Values are separated by *Enter* keys. After the number of land uses are input, a table is displayed in the screen to help the user to input data. The line in the bottom of the screen provides on-line help which indicates the expected input data type.

In cases when a serious error has been made, the user can always restart this process by hitting *F1*, then *Enter*. Alternatively, the user may save current input and modify the data in the modification mode.

After all input is complete, the user is asked whether to save or abort the changes. An input of *Y* will overwrite the existing, if any, transport data file.

Modify an Existing TRANSPRT.DAT File. An existing transport data file can be modified in this mode. This is convenient when only minor modification of transport data is needed, e.g., in the case of studying impacts of changes of land use on a watershed.

In this mode, the user is expected to hit *Enter* if no change would be made and *Space bar* if a new value would be issued. The two lines at the bottom of screen provide on-line help.

Print TRANSPORT Data. The user can choose one or more of the three types of print out of transport parameters, namely, to display to screen, print a hard copy, or create a ASCII text file named **TRANSPRT.TXT**. The text file can later be imported to a word processor to generate reports.

Nutrient Data Manipulation

0When nutrient loads are of concern, the nutrient data file (**NUTRIENT.DAT**) must be available before a simulation can be run. This is done by either creating a new nutrient data file or modifying an existing one. Options are shown in DISPLAY 3. Procedures for creating, modifying or printing nutrient data are similar to those described for the transport data. The ASCII text file is **NUTRIENT.TXT**.

```
Select :
      1      Create new NUTRIENT.DAT file
      2      Modify existing NUTRIENT.DAT file
      3      Print NUTRIENT data
      4      Return
?
```

DISPLAY 3. The Menu Page for Manipulation of Nutrient Parameters.

Simulation

Four categories of simulation can be performed, as shown in DISPLAY 4. To simulate streamflow or sediment yield, two data files, **WEATHER.DAT** and **TRANSPRT.DAT** must be in the default directory. An additional data file, **NUTRIENT.DAT**, is required when nutrient loads are simulated.

```
Select program options:
      1     Streamflow simulation only
      2     Streamflow and sediment yield only
      3     Streamflow, sediment yield, and nutrient loads
      4     Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise  Return
?
```

DISPLAY 4. The Menu Page for Simulation Options.

After choosing the type of simulation, the user inputs the title of this specific simulation. This title can be a word, a sentence, or a group of words. The user then decides the length, in years, of the simulation run (not to exceed the number of years of weather data in **WEATHER.DAT**).

Results Output

Simulation output can be reported in three categories, namely, overall means, annual values, and monthly values. Either tables or graphs can be generated, as shown in DISPLAY 5. In producing tables, i.e., when one of the first three options is selected, the user can choose to display it on screen, print it on a printer, or save it as an ASCII text file. When one of the graph options is selected, the user is able to see the graph on the screen. If the computer has suitable printer driver, a hard copy of the graph can be obtained by pressing *Shift-PrtSc* keys together.

```
Select :
      1      Print summary
      2      Print annual results
      3      Print monthly results
      4      Graph summary (average)
      5      Graph annual results
      6      Graph monthly results
             (PrtSc for hard copy, carriage return to continue)
  otherwise  Return
?
```

DISPLAY 5. The Menu Page for Output Generation.

EXAMPLE 1: 4-YEAR STUDY IN WEST BRANCH DELAWARE BASIN

This example is designed to allow the user to become familiar with the operation of the program and the way results are presented. The data set and results are those described in Appendix C for the GWLF validation for the West Branch Delaware River Watershed in New York.

The programs **GWLF20.EXE, TRAN20.EXE, NUTR20.EXE,** and **OUTP20.EXE**, and the data files **WEATHER.DAT, TRANSPRT.DAT,** and **NUTRIENT.DAT** must be on the default drive. The weather file can be obtained by copying **WALT478.382** to **WEATHER.DAT**.

Simulation

To start the program, type *GWLF20* then *Enter*. The first screen is the main menu (see DISPLAY 1). To select Run simulation, type *3* and *Enter*. This will lead to the simulation option menu (see DISPLAY 4). Since nutrient fluxes and septic system loads are of interest, type *4* and *Enter*. This will start the simulation.

The user is then asked to input the title of this simulation. Type *Example 1* and *Enter*. Finally the user is expected to specify the length of the simulation. Type *4*, then *Enter*. This concludes the information required for a simulation run. The input section described above is shown in DISPLAY 6.

```
Select one of the following :
      1      Create or print TRANSPRT.DAT (Transport parameters)
      2      Create or print NUTRIENT.DAT (nutrient parameters)
               (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3      Run simulation
      4      Obtain output
      5      Stop (End)
? 3

Select program options:
      1      Streamflow simulation only
      2      Streamflow and sediment yield only
      3      Streamflow, sediment yield, and nutrient loads
      4      Streamflow, sediment yield, nutrient loads, and septic systems
  otherwise Return
? 3

TITLE OF SIMULATION? Example 1
LENGTH OF RUN IN YEARS? 4
```

DISPLAY 6. Input Section in Example 1. User Input is Indicated by Italics.

The screen is now switched to graphic mode. During the computation, part of the result will be displayed. This is to provide a sample of the result and to monitor the progress of the simulation. As shown in Figure 3, the line on the top of the screen reports the length of simulation and the current simulated month/year.

The main menu is displayed at the end of the simulation. From here, the user can generate several types of results.

Results Generation

Type *4*, then *Enter* to generate results. For printing out monthly streamflows, sediment yields, and nutrient loads, type *3*, then *Enter*. The user is asked whether to specify the range of the period to be reported. Type *N*, then *Enter* to select the default full period.

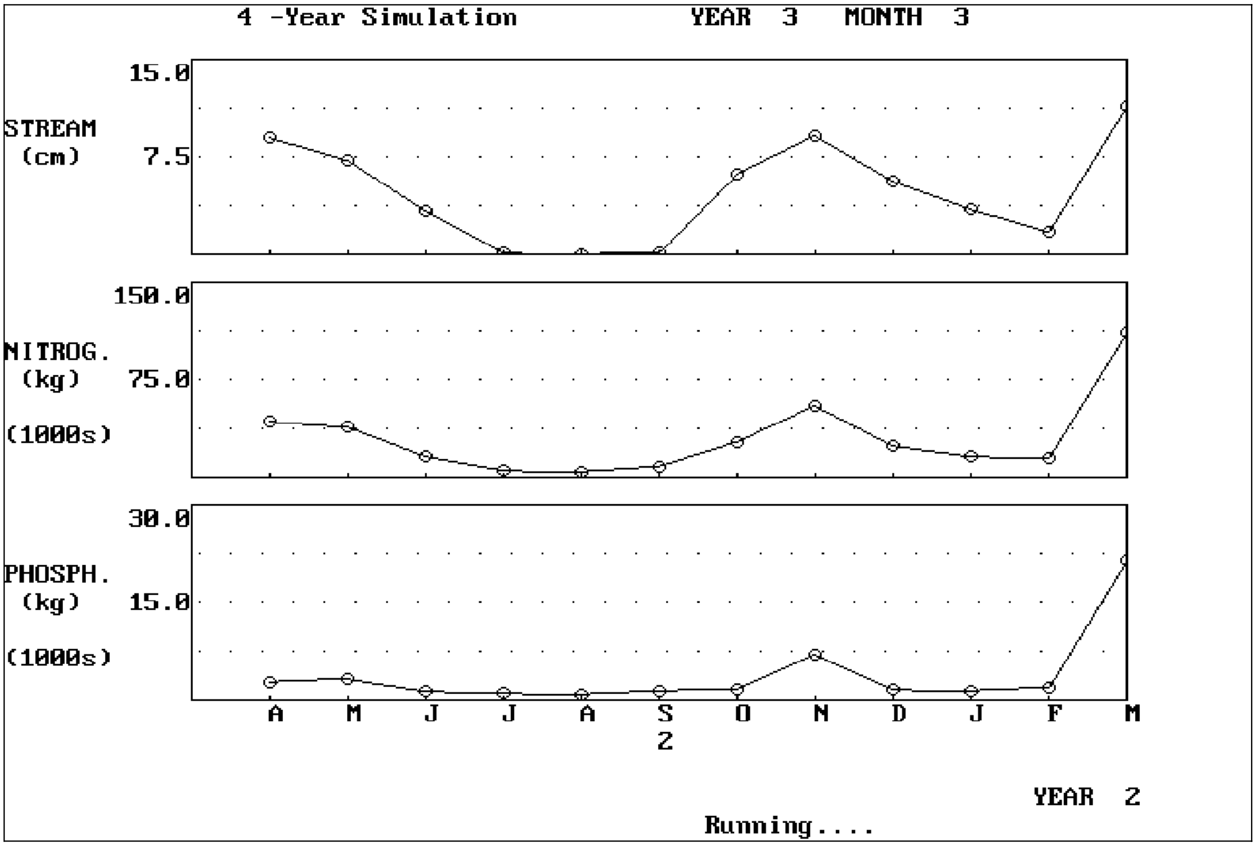

Figure 3. Screen Display during Simulation.

The user decides on the type of output. Type *1*, then *Enter* to print to the screen. The result is displayed in nine screens. After reading a screen, press *Enter* to bring up the next screen. To generate a hard copy, turn on the printer, type *2* and *Enter*. Alternatively, the user can save the result in a text file, **MONTHLY.TXT**. The user can go back to the previous page menu to select another option of results generation by pressing *Enter*. Part of the process described above is shown in DISPLAY 7. To generate graphs of the monthly results, type *6* and *Enter*. This produces graphs such as Figure 4 and Figure 5. The user can call up the main menu again by pressing *Enter* keys. The data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** for this example are listed in Appendix E with the various **.TXT** files that may be generated.

EXAMPLE 2: EFFECTS OF ELIMINATION OF WINTER MANURE SPREADING

In this example, nutrient parameters are modified to investigate effects of winter manure applications. The example involves manipulation of the data file **NUTRIENT.DAT**. If the user wishes to save the original file, it should first be copied to a new file, say **NUTRIENT.EX1**.

Nutrient Parameters Modification

From the main menu, type *2*, *Enter*. This leads to the nutrient data manipulation option. Type *2*, *Enter* to modify **NUTRIENT.DAT** (see DISPLAY 8).

Type *Enter* to accept the original dissolved nutrient concentrations. Repeat this procedure until the cursor is in the line, Number of Land Uses on Which Manure is Spread (see DISPLAY 9), hit *Space-bar*, type *0*, and hit *Enter*.

Accept all the rest of original data by hitting *Enter* key until the end of the file. Type *Y* to save the changes. This concludes the modification of **NUTRIENT.DAT**.

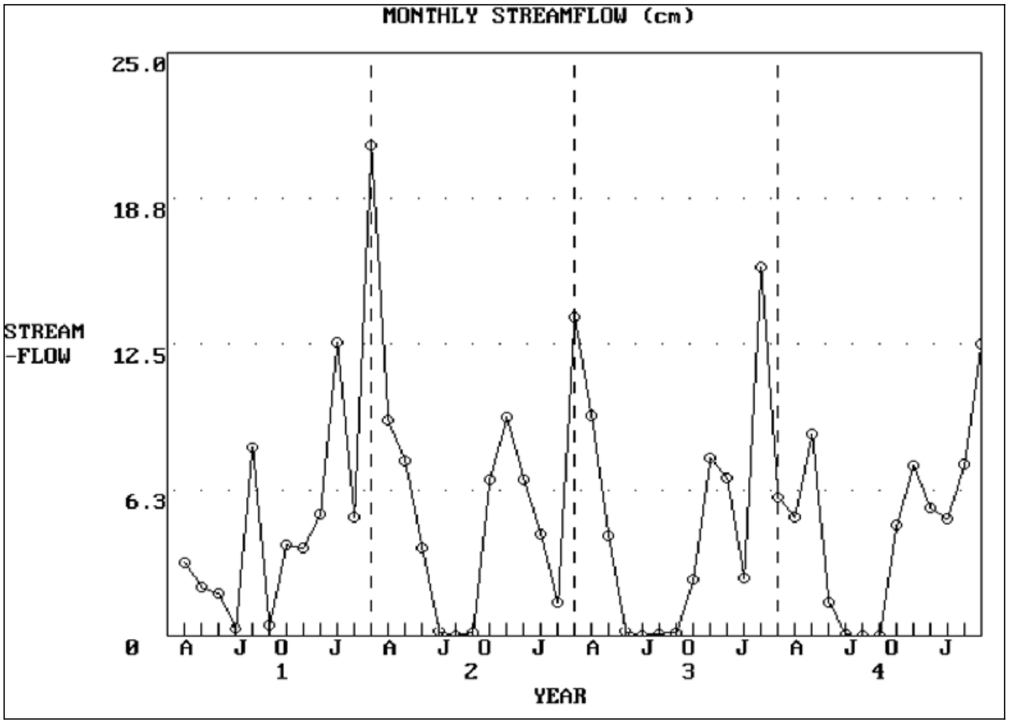

Figure 4. Monthly Streamflows for Example 1.

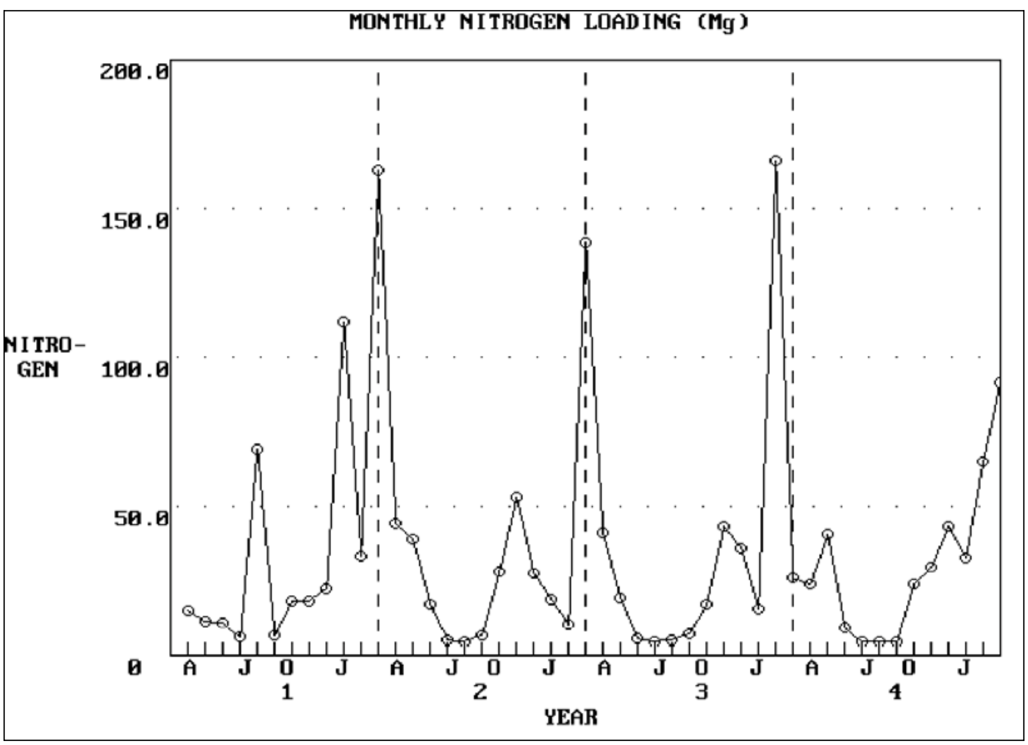

Figure 5. Monthly Nitrogen Loads for Example 1.

The user may print out nutrient data to make sure these changes have been made. To do so, the user selects Print NUTRIENT data in the nutrient data manipulation page (see DISPLAY 3). Then select Print to screen to display the current nutrient parameters.

```
Select one of the following :
       1      Create or print TRANSPRT.DAT (Transport parameters)
       2      Create or print NUTRIENT.DAT (nutrient parameters)
                (TRANSPRT.DAT must be created before NUTRIENT.DAT)
       3      Run simulation
       4      Obtain output
       5      Stop (End)
? 4

Select :
       1      Print summary
       2      Print annual results
       3      Print monthly results
       4      Graph summary (average)
       5      Graph annual results
       6      Graph monthly results
              (PrtSc for hard copy, carriage return to continue)
  otherwise   Return
? 3
      Want to specify the range of years in output?   ( Type  Y  or  N )
? N

Select : (For printing MONTHLY data)
       1      Print to screen (carriage return to continue)
       2      Print a hard copy (turn on printer first)
       3      Print to a file named MONTHLY.TXT
  otherwise   Return
? 1
```

DISPLAY 7. Result Generating Menu in Example 1.

```
Select one of the following :
       1      Create or print TRANSPRT.DAT (Transport parameters)
       2      Create or print NUTRIENT.DAT (nutrient parameters)
                (TRANSPRT.DAT must be created before NUTRIENT.DAT)
       3      Run simulation
       4      Obtain output
       5      Stop (End)
? 2

Select :
       1      Create new NUTRIENT.DAT file
       2      Modify existing NUTRIENT.DAT file
       3      Print NUTRIENT data
  otherwise   Return
? 2
```

DISPLAY 8. Modification of Nutrient Parameters.

Simulation and Results Generation

Following the procedures described in Example 1, the results of a 3-year simulation are shown in Figure 6.

Number of Land Uses on Which Manure is Spread: -1

To redo from start, Hit <F1> then <ENTER> key
Hint: Press Space-Bar to Input Value or Enter-Key to Accept Current Value

DISPLAY 9. The First Screen for Modifying Nutrient Parameters. The Original Number is 1. Hit the *Space Bar*, Type *0*, and then Hit *Enter* Key to Change this Number to 0.

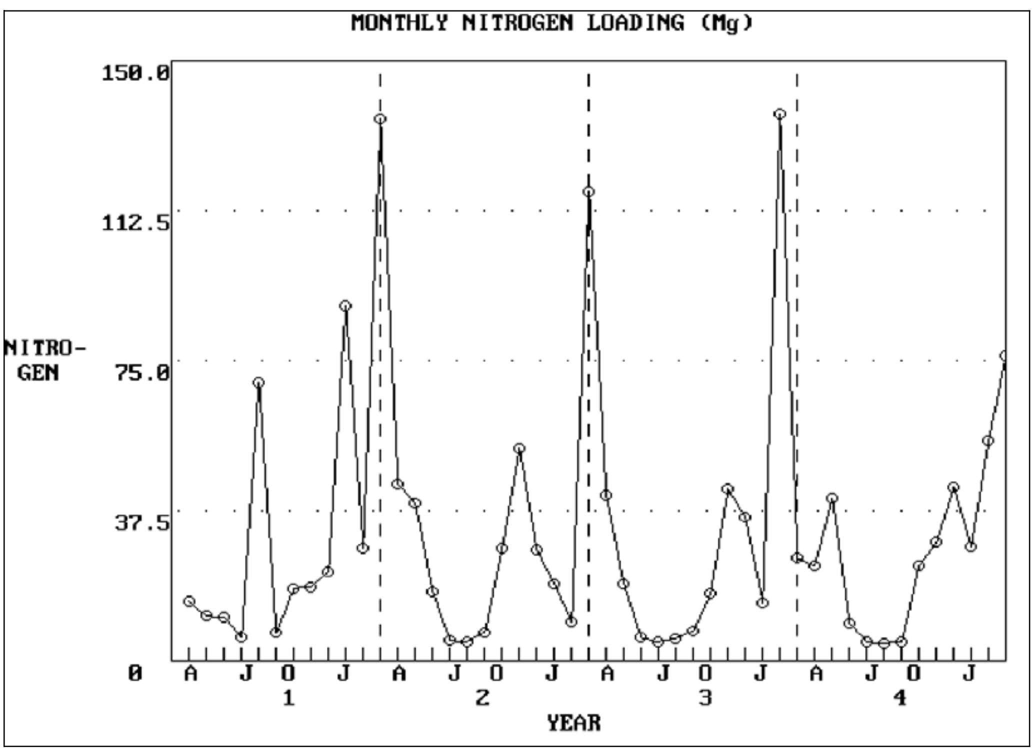

Figure 6. Monthly Nitrogen Loads with no Manure Spreading .

EXAMPLE 3: A 30-YEAR SIMULATION STUDY

In Example 3, a simulation of the West Branch Delaware River Basin is based on a 30-yr (4/62-3/92) weather record given in the file **WALT462.392**.

Simulation and Results Generation

The simulation is run by following procedures as in Example 1 (see DISPLAY 6). Answer LENGTH OF RUN IN YEARS by typing *30* and then *Enter*.

At the end of the computation, the main menu is displayed. From here, the user can generate several types of results by typing *4*, then *Enter*. For a summary of the results, type *1* and *Enter*. To display the summary in screen, type *1* and *Enter*. The summary is displayed in three screens. After reading a screen, press *Enter* to bring up next screen. To generate a hard copy from the printer, turn on the printer, select Print a hard copy. Hit *Enter* to obtain the output option menu.

From the output generation menu (see DISPLAY 5), to obtain a graphical description of the summary, type *4* and then *Enter*. This brings up a screen of options (see DISPLAY 10). Eighteen types of graphs can be generated. For example, to investigate the relative magnitudes of average monthly streamflow, type *5* and *Enter*. This produces the bar chart shown in Figure 7. Similarly, to investigate the nitrogen loads from each source, type *15* and then *Enter*. This generates another bar chart as shown in Figure 8.

```
Select :
    1     Mean Monthly Precipitation
    2     Mean Monthly Evapotranspiration
    3     Mean Monthly Groundwater Flow
    4     Mean Monthly Runoff
    5     Mean Monthly Streamflow
    6     Mean Monthly Erosion
    7     Mean Monthly Sediment
    8     Mean Monthly Dissolved Nitrogen
    9     Mean Monthly Total Nitrogen
   10     Mean Monthly Dissolved Phosphorus
   11     Mean Monthly Total Phosphorus
   12     Mean Annual Runoff from Sources
   13     Mean Annual Erosion from Sources
   14     Mean Annual Dissolved Nitrogen Loads from Sources
   15     Mean Annual Total Nitrogen Loads from Sources
   16     Mean Annual Dissolved Phosphorus Loads from Sources
   17     Mean Annual Total Phosphorus Loads from Sources
   18     Areas of Sources
otherwise Return
?
```

DISPLAY 10. The Options for Plotting Summary

For plotting annual streamflows, sediment yields and nutrient loads, type *5*, then *Enter*. The graphs will be displayed on several screens. For example, Figure 9 shows the predicted annual streamflows.

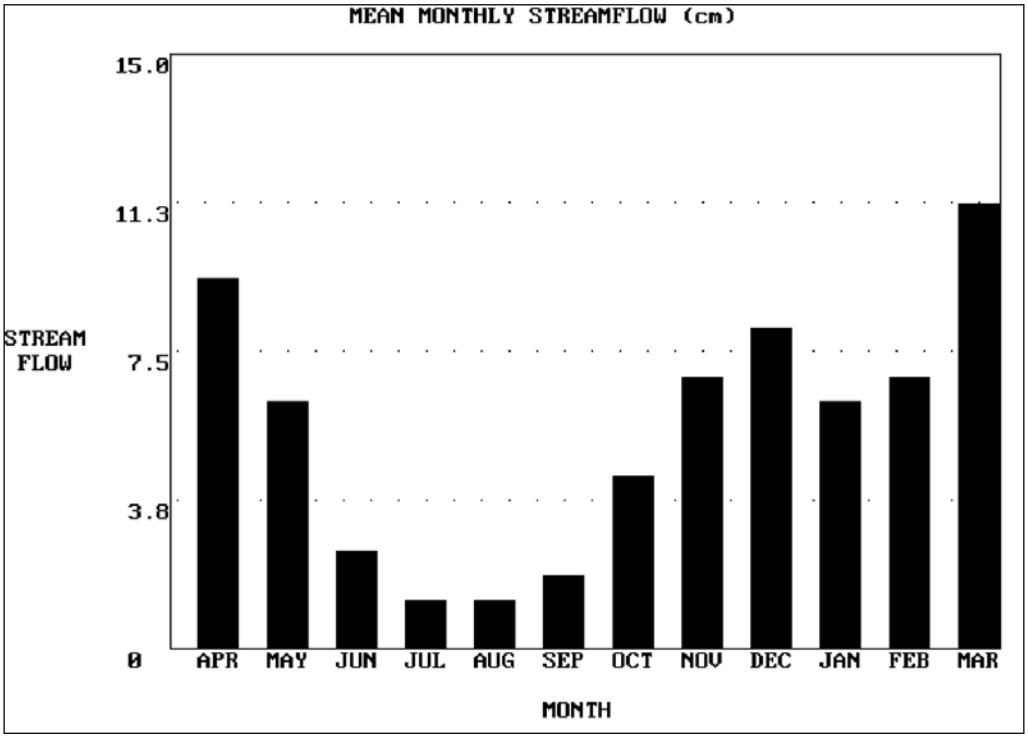

Figure 7. Mean Monthly Streamflows for 30-yr Simulation.

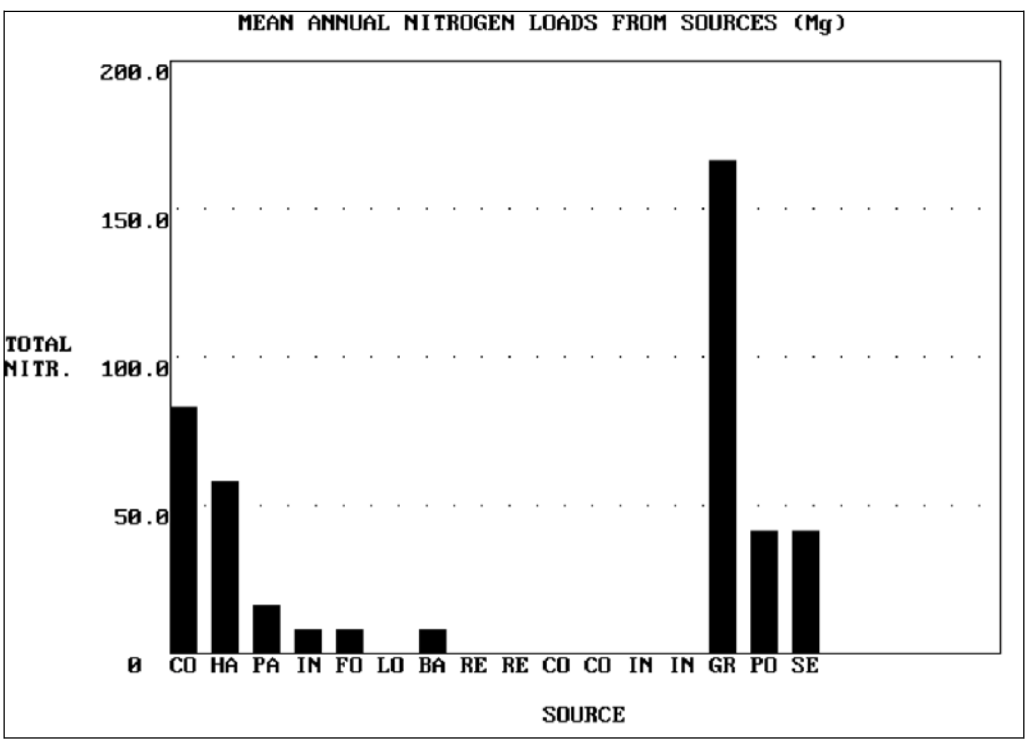

Figure 8. Mean Annual Nitrogen Load from Sources for 30-yr Simulation.

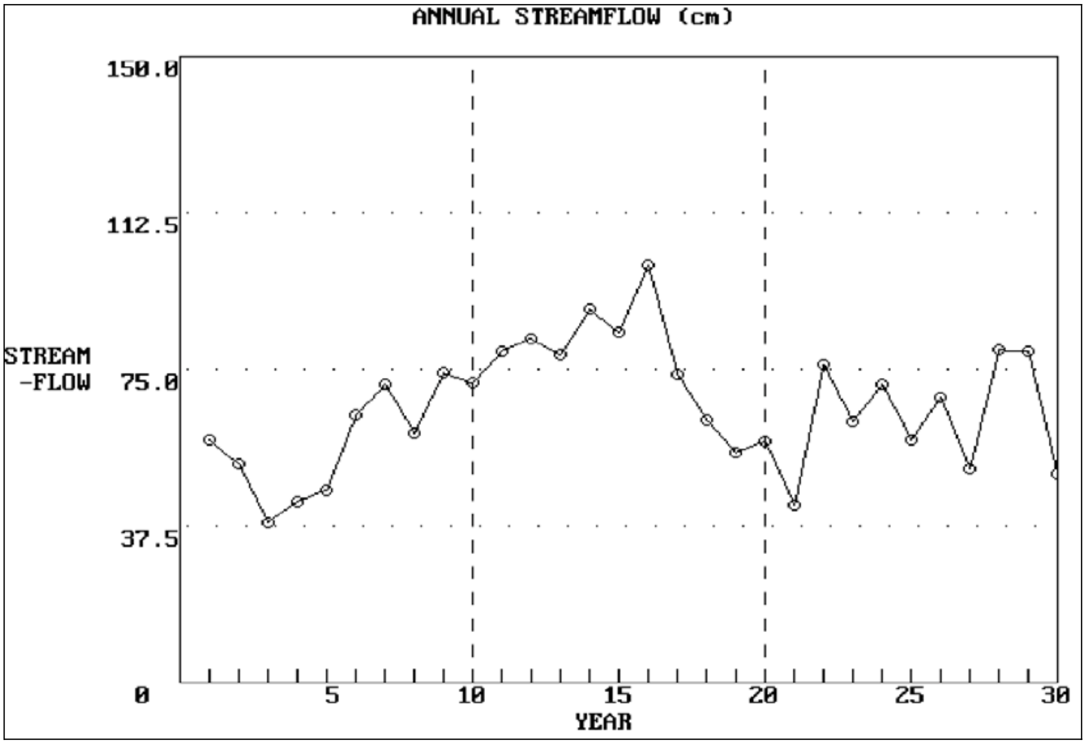

Figure 9. Annual Streamflows for 30-yr Simulation.

APPENDIX A: MATHEMATICAL DESCRIPTION OF GWLF

General Structure

Streamflow nutrient flux contains dissolved and solid phases. Dissolved nutrients are associated with runoff, point sources and groundwater discharges to the stream. Solid-phase nutrients are due to point sources, rural soil erosion or wash off of material from urban surfaces. The GWLF model describes nonpoint sources with a distributed model for runoff, erosion and urban wash off, and a lumped parameter linear reservoir groundwater model. Point sources are added as constant mass loads which are assumed known. Water balances are computed from daily weather data but flow routing is not considered. Hence, daily values are summed to provide monthly estimates of streamflow, sediment and nutrient fluxes (It is assumed that streamflow travel times are much less than one month).

Monthly loads of nitrogen or phosphorus in streamflow in any year are

$$LD_m = DP_m + DR_m + DG_m + DS_m \qquad \text{(A-1)}$$

$$LS_m = SP_m + SR_m + SU_m \qquad \text{(A-2)}$$

In these equations, LD_m is dissolved nutrient load, LS_m is solid-phase nutrient load, DP_m, DR_m, DG_m and DS_m are point source, rural runoff, groundwater and septic system dissolved nutrient loads, respectively, and SP_m, SR_m and SU_m and are solid-phase point source, rural runoff and urban runoff nutrient loads (kg), respectively, in month m (m = 1,2,...12). Note that the equations assume (i) point source, groundwater and septic system loads are entirely dissolved; and (ii) urban nutrient loads are entirely solid.

Rural Runoff Loads

Rural nutrient loads are transported in runoff water and eroded soil from numerous source areas, each of which is considered uniform with respect to soil and cover.

Dissolved Loads. Dissolved loads from each source area are obtained by multiplying runoff by dissolved concentrations. Monthly loads for the watershed are obtained by summing daily loads over all source areas:

$$LD_m = 0.1 \sum_k \sum_{t=1}^{d_m} Cd_k \, Q_{kt} \, AR_k \qquad \text{(A-3)}$$

where Cd_k = nutrient concentration in runoff from source area k (mg/*l*), Q_{kt} = runoff from source area k on day t (cm) and AR_k = area of source area k (ha) and d_m = number of days in month m.

Runoff is computed from daily weather data by the U.S. Soil Conservation Service's Curve Number Equation (Ogrosky & Mockus, 1964):

$$Q_{kt} = \frac{(R_t + M_t - 0.2\, DS_{kt})^2}{R_t + M_t + 0.8\, DS_{kt}} \qquad \text{(A-4)}$$

Rainfall R_t (cm) and snowmelt M_t (cm of water) on day t are estimated from daily precipitation and temperature data. Precipitation is assumed to be rain when daily mean air temperature T_t (°C) is above 0 and snow fall otherwise. Snowmelt water is computed by a degree-day equation (Haith, 1985):

$$M_t = 0.45\, T_t, \text{ for } T_t > 0 \qquad \text{(A-5)}$$

The detention parameter DS_{kt} (cm) is determined from a curve number CN_{kt} as

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4 \tag{A-6}$$

Curve numbers are selected as functions of antecedent moisture as described in Haith (1985), and shown in Figure A-1. Curve numbers for antecedent moisture conditions 1 (driest), 2 (average) and 3 (wettest) are $CN1_k$, $CN2_k$ and $CN3_k$ respectively. The actual curve number for day t, CN_{kt}, is selected as a linear function of A_t, 5-day antecedent precipitation (cm):

$$A_t = \sum_{n=t-5}^{t-1} (R_n + M_n) \tag{A-7}$$

Recommended values (Ogrosky & Mockus, 1964) for the break points in Figure A-1 are AM1 = 1.3, 3.6 cm, and AM2 = 2.8, 5.3 cm, for dormant and growing seasons, respectively. For snowmelt conditions, it is assumed that the wettest antecedent moisture conditions prevail and hence regardless of A_t, $CN_{kt} = CN3_k$ when $M_t > 0$.

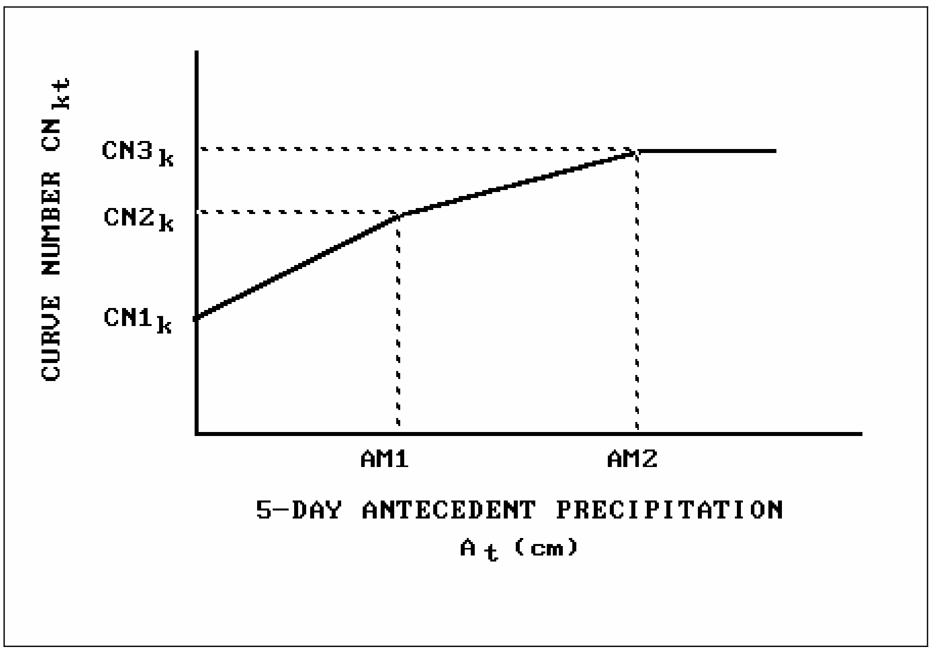

Figure A-1. Curve Number as Function of Antecedent Moisture.

The model requires specification of $CN2_k$. Values for $CN1_k$ and $CN3_k$ are computed from Hawkins (1978) approximations:

$$CN1_k = \frac{CN2_k}{2.334 - 0.01334\ CN2_k} \tag{A-8}$$

$$CN3_k = \frac{CN2_k}{\quad} \tag{A-9}$$

$$0.4036 + 0.0059\ CN2_k$$

Solid-Phase Loads. Solid-phase rural nutrient loads (SR_m) are given by the product of monthly watershed sediment yields (Y_m, Mg) and average sediment nutrient concentrations (c_s, mg/kg):

$$SR_m = 0.001\ c_s\ Y_m \qquad \text{(A-10)}$$

Monthly sediment yields are determined from the model developed by Haith (1985). The model is based on three principal assumptions: (i) sediment originates from sheet and rill erosion (gully and stream bank erosion are neglected); (ii) sediment transport capacity is proportional to runoff to the 5/3 power (Meyer & Wischmeier, 1969); and (iii) sediment yields are produced from soil which erodes in the current year (no carryover of sediment supply from one year to the next).

Erosion from source area k on day t (Mg) is given by

$$X_{kt} = 0.132\ RE_t\ K_k\ (LS)_k\ C_k\ P_k\ AR_k \qquad \text{(A-11)}$$

in which K_k, $(LS)_k$, C_k and P_k are the standard values for soil erodibility, topographic, cover and management and supporting practice factors as specified for the Universal Soil Loss Equation (Wischmeier & Smith, 1978). RE_t is the rainfall erosivity on day t (MJ-mm/ha-h). The constant 0.132 is a dimensional conversion factor associated with the SI units of rainfall erosivity. Erosivity can be estimated by the deterministic portion of the empirical equation developed by Richardson et al. (1983) and subsequently tested by Haith & Merrill (1987):

$$RE_t = 64.6\ a_t\ R_t^{1.81} \qquad \text{(A-12)}$$

where the coefficient a_t varies with season and geographical location.

The total watershed sediment supply generated in month j (Mg) is

$$SX_j = DR \sum_k \sum_{t=1}^{d_j} X_{kt} \qquad \text{(A-13)}$$

where DR is the watershed sediment delivery ratio. The transport of this sediment from the watershed is based on the transport capacity of runoff during that month. A transport factor TR_j is defined as

$$TR_j = \sum_{t=1}^{d_j} Q_t^{5/3} \qquad \text{(A-14)}$$

The sediment supply SX_j is allocated to months j, j + 1, ... , 12 in proportion to the transport capacity for each month. The total transport capacity for months j, j + 1, ... , 12 is proportional to B_j, where

$$B_j = \sum_{h=j}^{12} TR_h \qquad \text{(A-15)}$$

For each month m, the fraction of available sediment X_j which contributes to Y_m, the monthly sediment yield (Mg), is TR_m/B_j. The total monthly yield is the sum of all contributions from preceding months:

$$Y_m = TR_m \sum_{j=1}^{m} (X_j/B_j) \qquad \text{(A-16)}$$

Urban Runoff

The urban runoff model is based on general accumulation and wash off relationships proposed by Amy et al. (1974) and Sartor & Boyd (1972). The exponential accumulation function was subsequently used in SWMM (Huber & Dickinson, 1988) and the wash off function is used in both SWMM and STORM (Hydrologic Engineering Center, 1977). The mathematical development here follows that of Overton and Meadows (1976).

Nutrients accumulate on urban surfaces over time and are washed off by runoff events. Runoff volumes are computed by equations A-4 through A-7.

If $N_k(t)$ is the accumulated nutrient load on source area (land use) k on day t (kg/ha), then the rate of accumulation during dry periods is

$$\frac{dN_k}{dt} = n_k - \beta N_k \qquad \text{(A-17)}$$

where n_k is a constant accumulation rate (kg/ha-day) and β is a depletion rate constant (day^{-1}). Solving equation A-17, we obtain

$$N_k(t) = N_{k0} e^{-\beta t} + (n_k/\beta)(1 - e^{-\beta t}) \qquad \text{(A-18)}$$

in which $N_{k0} = N_k(t)$ at time t = 0.

Equation A-18 approaches an asymptotic value $N_{k,max}$:

$$N_{k,max} = \lim_{t \to \infty} N_k(t) = n_k/\beta \qquad \text{(A-19)}$$

Data given in Sartor & Boyd (1972) and shown in Figure A-2 indicates that $N_k(t)$ approaches its maximum value in approximately 12 days. If we conservatively assume that $N_k(t)$ reaches 90% of $N_{k,max}$ in 20 days, then for $N_{k0} = 0$,

$$0.90\,(n_k/\beta) = (n_k/\beta)(1 - e^{-20\beta}), \text{ or } \beta = 0.12$$

Equation A-18 can also be written for a time interval $\Delta t = t_2 - t_1$ as

$$N_k(t_2) = N_k(t_1) e^{-0.12\Delta t} + (n_k/0.12)(1 - e^{-0.12\Delta t}) \qquad \text{(A-20)}$$

or, for a time interval of one day,

$$N_{k,t+1} = N_{kt} e^{-0.12} + (n_k/0.12)(1 - e^{-0.12}) \qquad \text{(A-21)}$$

where N_{kt} is the nutrient accumulation at the beginning of day t (kg/ha).

Equation A-21 can be modified to include the effects of wash off:

$$N_{k,t+1} = N_{kt} e^{-0.12} + (n_k/0.12)(1 - e^{-0.12}) - W_{kt} \qquad \text{(A-22)}$$

in which W_{kt} = runoff nutrient load from land use k on day t(kg/ha).

The runoff load is

$$W_{kt} = w_{kt}\,[N_{kt} e^{-0.12} + (n_k/0.12)(1 - e^{-0.12})] \qquad \text{(A-23)}$$

where w_{kt} is the first-order wash off function suggested by Amy et al. (1974):

$$w_{kt} = 1 - e^{-1.81 Q_{kt}} \qquad \text{(A-24)}$$

Equation A-24 is based on the assumption that 1.27 cm (0.5 in) of runoff will wash off 90% of accumulated pollutants. Monthly runoff loads of urban nutrients are thus given by

$$SU_m = \sum_k \sum_{t=1}^{d_m} W_{kt} AR_k \qquad \text{(A-25)}$$

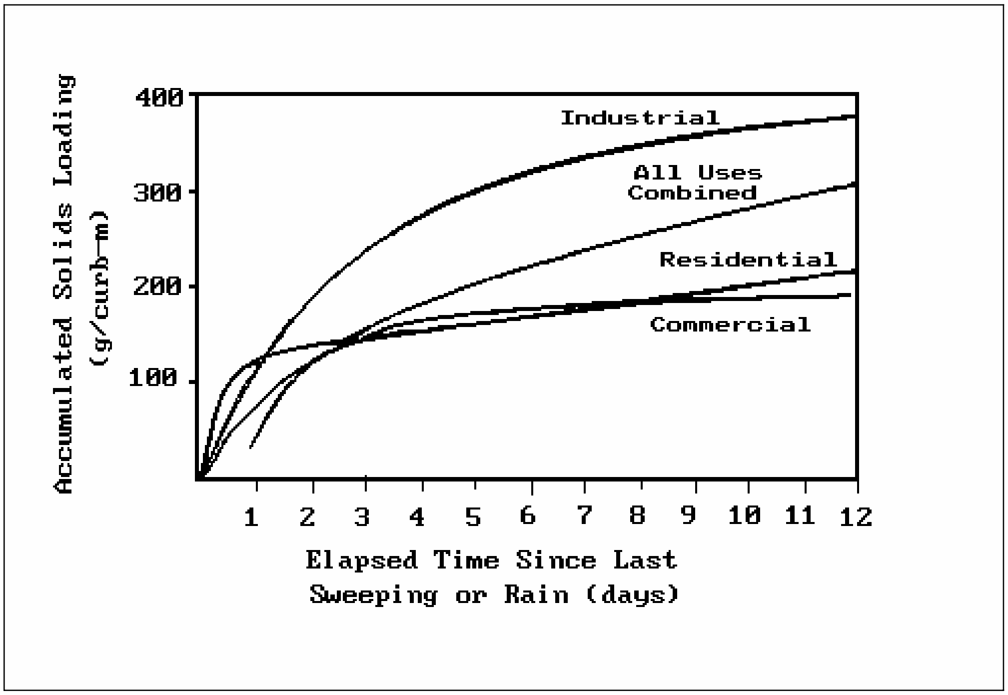

Figure A-2. Accumulation of Pollutants on Urban Surfaces (Sartor & Boyd, 1972; redrawn in Novotny & Chesters, 1981).

Groundwater Sources

The monthly groundwater nutrient load to the stream is

$$DG_m = 0.1\, C_g\, AT \sum_{t=1}^{d_m} G_t \qquad \text{(A-26)}$$

in which C_g = nutrient concentration in groundwater (mg/*l*), AT = watershed area (ha), and G_t = groundwater discharge to the stream on day t (cm).

Groundwater discharge is described by the lumped parameter model shown in Figure A-3. Streamflow consists of total watershed runoff from all source areas plus groundwater discharge from a shallow saturated zone. The division of soil moisture into unsaturated, shallow saturated and deep saturated zones is similar to that used by Haan (1972).

Daily water balances for the unsaturated and shallow saturated zones are

$$U_{t+1} = U_t + R_t + M_t - Q_t - E_t - PC_t \quad \text{(A-27)}$$

$$S_{t+1} = S_t + PC_t - G_t - D_t \quad \text{(A-28)}$$

In these equations, U_t and S_t are the unsaturated and shallow saturated zone soil moistures at the beginning of day t and Q_t, E_t, PC_t, G_t and D_t are watershed runoff, evapotranspiration, percolation into the shallow saturated zone, groundwater discharge to the stream and seepage flow to the deep saturated zone, respectively, on day t (cm).

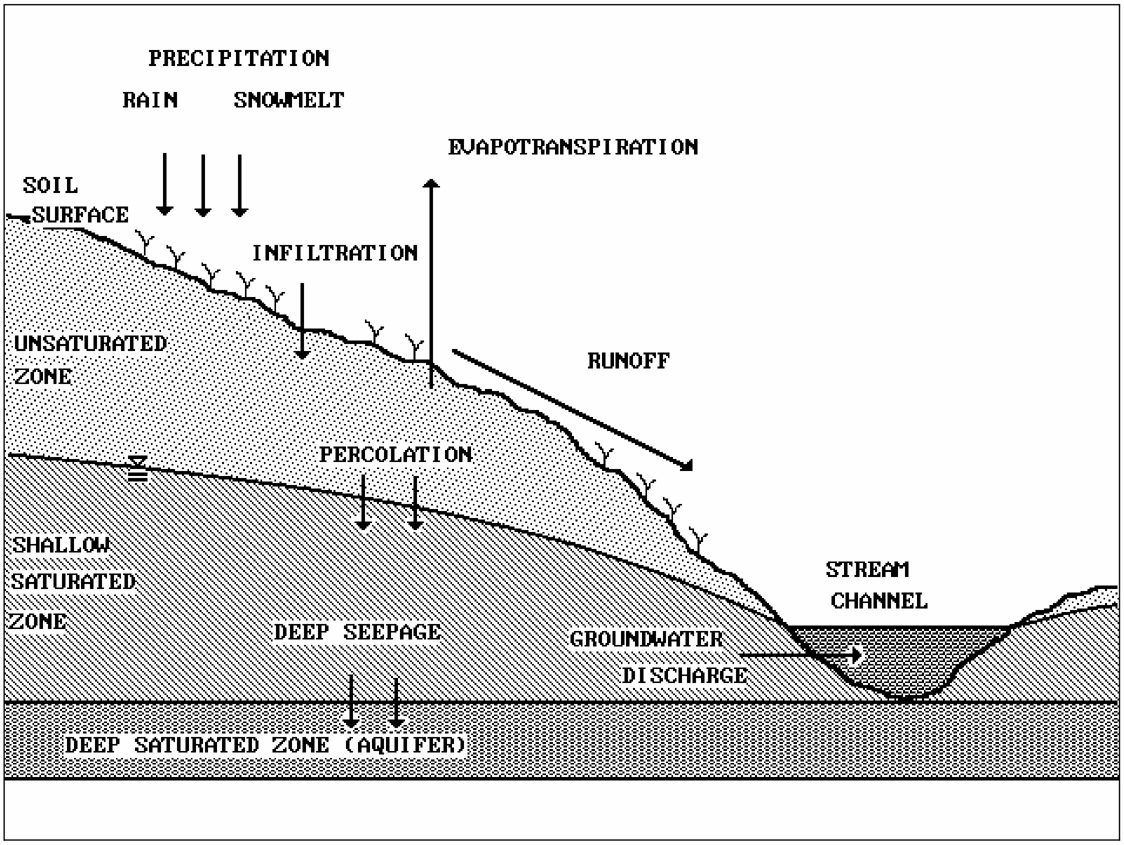

Figure A-3. Lumped Parameter Model for Groundwater Discharge.

Percolation occurs when unsaturated zone water exceeds available soil water capacity U^* (cm):

$$PC_t = \text{Max}\ (0; U_t + R_t + M_t - Q_t - E_t - U^*) \quad \text{(A-29)}$$

Evapotranspiration is limited by available moisture in the unsaturated zone:

$$E_t = \text{Min}\ (CV_t\ PE_t; U_t + R_t + M_t - Q_t) \quad \text{(A-30)}$$

for which CV_t is a cover coefficient and PE_t is potential evapotranspiration (cm) as given by Hamon (1961):

$$PE_t = \frac{0.021\ H_t^2\ e_t)}{T_t + 273} \quad \text{(A-31)}$$

In this equation, H_t is the number of daylight hours per day during the month containing day t, e_t is the saturated water vapor pressure in millibars on day t and T_t is the temperature on day t (°C). When $T_t \leq 0$, PE_t is set to zero. Saturated vapor pressure can be approximated as in (Bosen, 1960):

$$e_t = 33.8639\ [\ (0.00738\ T_t + 0.8072)^8 - 0.000019\ (1.8\ T_t + 48) + 0.001316\ ]\ ,\ \ T_t \geq 0 \qquad \text{(A-32)}$$

As in Haan (1972), the shallow unsaturated zone is modeled as a simple linear reservoir. Groundwater discharge and deep seepage are

$$G_t = r\ S_t \qquad \text{(A-33)}$$

and

$$D_t = s\ S_t \qquad \text{(A-34)}$$

where r and s are groundwater recession and seepage constants, respectively (day^{-1}).

Septic (On-site Wastewater Disposal) Systems

The septic system component of GWLF is based on the model developed by Mandel (1993). For purposes of assessing watershed water quality impacts, septic systems loads can be divided into four types:

$$DS_m = DS_{1m} + DS_{2m} + DS_{3m} + DS_{4m} \qquad \text{(A-35)}$$

where DS_{1m}, DS_{2m}, DS_{3m} and DS_{4m} are the dissolved nutrient load to streamflow from normal, short-circuited, ponded and direct discharge systems, respectively in month m (kg). These loads are computed from per capita daily effluent loads and monthly populations served a_{jm} for each system (j =1,2,3,4).

Normal Systems. A normal septic system is a system whose construction and operation conforms to recommended procedures such as those suggested by the EPA design manual for on-site wastewater disposal systems (U. S. Environmental Protection Agency, 1980). Effluents from such systems infiltrate into the soil and enter the shallow saturated zone. Effluent nitrogen is converted to nitrate, and except for removal by plant uptake, the nitrogen is transported to the stream by groundwater discharge. Conversely, phosphates in the effluent are adsorbed and retained by the soil and hence normal systems provide no phosphorus loads to streamflow. The nitrogen load to groundwater from normal systems in month m (kg) is

$$SL_{1m} = 0.001\ a_{1m}\ d_m\ (e - u_m) \qquad \text{(A-36)}$$

in which e = per capita daily nutrient load in septic tank effluent (g/day) and u_m = per capita daily nutrient uptake by plants in month m (g/day).

Normal systems are generally some distance from streams and their effluent mixes with other groundwater. Monthly nutrient loads are thus proportional to groundwater discharge to the stream. The portion of the annual load delivered in month m is equivalent to the portion of annual groundwater discharge which occurs in that month. Thus the load in month m of any year is

$$DS_{1m} = \frac{GR_m \sum_{m=1}^{12} SL_{1m}}{\sum_{m=1}^{12} GR_m} \qquad \text{(A-37)}$$

where GR_m = total groundwater discharge to streamflow in month m (cm), obtained by summing the daily values G_t for the month. Equation A-37 applies only for nitrogen. In the case of phosphorus, DS_{1m} = 0.

Short-Circuited Systems. These systems are located close enough to surface waters (< 15 m) so that negligible adsorption of phosphorus takes place. The only nutrient removal mechanism is plant uptake, and the watershed load for both nitrogen and phosphorus is

$$DS_{2m} = 0.001\, a_{2m}\, d_m\, (e - u_m) \qquad \text{(A-38)}$$

Ponded Systems. These systems exhibit hydraulic failure of the tank's absorption field and resulting surfacing of the effluent. Unless the surfaced effluent freezes, ponding systems deliver their nutrient loads to surface waters in the same month that they are generated through overland flow. If the temperature is below freezing, the surfacing effluent is assumed to freeze in a thin layer at the ground surface. The accumulated frozen effluent melts when the snowpack disappears and the temperature is above freezing. The monthly nutrient load is

$$DS_{3m} = 0.001 \sum_{t=1}^{d_m} PN_t \qquad \text{(A-39)}$$

where PN_t = watershed nutrient load in runoff from ponded systems on day t (g). Nutrient accumulation under freezing conditions is

$$FN_{t+1} = \begin{cases} FN_t + a_{3m}\, e\,, & SN_t > 0 \text{ or } T_t \leq 0 \\ 0\,, & \text{otherwise} \end{cases} \qquad \text{(A-40)}$$

where FN_t = frozen nutrient accumulation in ponded systems at the beginning of day t (g). The runoff load is thus

$$PN_t = \begin{cases} a_{3m}\, e + FN_t - u_m\,, & SN_t = 0 \text{ and } T_t > 0 \\ 0\,, & \text{otherwise} \end{cases} \qquad \text{(A-41)}$$

Direct Discharge Systems. These illegal systems discharge septic tank effluent directly into surface waters. Thus,

$$DS_{4m} = 0.001\, a_{4m}\, d_m\, e \qquad \text{(A-42)}$$

APPENDIX B: DATA SOURCES & PARAMETER ESTIMATION

Four types of information must be assembled for GWLF model runs. Land use data consists of the areas of the various rural and urban runoff sources. Required weather data are daily temperature (°C) and precipitation (cm) records for the simulation period. Transport parameters are the necessary hydrologic, erosion and sediment data and nutrient parameters are the various nitrogen and phosphorus data required for loading calculations. This appendix discusses general procedures for estimation of these parameters. Examples of parameter estimation are provided in Appendix C.

Land Use Data

Runoff source areas are identified from land use maps, soil surveys and aerial or satellite photography (Haith & Tubbs, 1981; Delwiche & Haith, 1983). In principle, each combination of soil, surface cover and management must be designated. For example, each corn field in the watershed can be considered a source area, and its area determined and estimates made for runoff curve number and soil erodibility and topographic, cover and supporting practice factors. In practice, these fields can often be aggregated, as in Appendix C into one "corn" source area with area-weighted parameters. Each urban land use is broken down into impervious and pervious areas. The former are solid surfaces such as streets, driveways, parking lots and roofs.

Weather Data

Daily precipitation and temperature data are obtained from meteorological records and assembled in the data file **WEATHER.DAT**. An example of this file is given in Appendix D. Weather data must be organized in "weather years" which are consistent with model assumptions. Both the groundwater and sediment portions of GWLF require that simulated years begin at a time when soil moisture conditions are known and runoff events have "flushed" the watershed of the previous year's accumulated sediment. In the eastern U.S. this generally corresponds to early spring and hence in such locations an April - March weather year is appropriate.

Transport Parameters

A sample set of hydrologic, erosion and sediment parameters required for the data file **TRANSPRT.DAT** is given in Appendix D.

Runoff Curve Numbers. Runoff curve numbers for rural and urban land uses have been assembled in the U.S. Soil Conservation Service's Technical Release No. 55, 2nd edition (Soil Conservation Service, 1986). These curve numbers are based on the soil hydrologic groups given in Table B-1. Curve numbers for average antecedent moisture conditions ($CN2_k$) are listed in Tables B-2 through B-5. Barnyard curve numbers are given by Overcash & Phillips (1978) as $CN2_k$ = 90, 98 and 100 for earthen areas, concrete pads and roof areas draining into the barnyard, respectively.

Evapotranspiration Cover Coefficients. Estimation of evapotranspiration cover coefficients for watershed studies is problematic. Cover coefficients may be determined from published seasonal values such as those given in Tables B-6 and B-7. However, their use often requires estimates of crop development (planting dates, time to maturity, etc.) which may not be available. Moreover, a single set of consistent values is seldom available for all of a watershed's land uses.

Soil Hydrologic Group	Description
A	Low runoff potential and high infiltration rates even when thoroughly wetted. Chiefly deep, well to excessively drained sands or gravels. High rate of water transmission (> 0.75 cm/hr).
B	Moderate infiltration rates when thoroughly wetted. Chiefly moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. Moderate rate of water transmission (0.40-0.75 cm/hr).
C	Low infiltration rates when thoroughly wetted. Chiefly soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. Low rate of water transmission (0.15-0.40 cm/hr).
D	High runoff potential. Very low infiltration rates when thoroughly wetted. Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, or shallow soils over nearly impervious material. Very low rate of water transmission (0-0.15 cm/hr).
Disturbed Soils (Major altering of soil profile by construction, development):	
A	Sand, loamy sand, sandy loam.
B	Silt loam, loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay, clay.

Table B-1. Descriptions of Soil Hydrologic Groups (Soil Conservation Service, 1986)

A simplified procedure can be developed, however, based on a few general observations:

1. Cover coefficients should in principle vary between 0 and 1.

2. Cover coefficients will approach their maximum value when plants have developed full foliage.

3. Because evapotranspiration measures both transpiration and evaporation of soil water, the lower limit for cover coefficients will be greater than zero. This lower limit essentially represents a situation without any plant cover.

4. The protection of soil by impervious surfaces prevents evapotranspiration.

The cover coefficients given for annual crops in Table B-6 fall to approximately 0.3 before planting and after harvest. Similarly, cover coefficients for forests reach minimum values of 0.2 to 0.3 when leaf area indices approach zero. This suggests that monthly cover coefficients for can be given the value 0.3 when foliage is absent and 1.0 otherwise. Perennial crops, such as grass, hay, meadow, and pasture, crops grown in flooded soil, such as rice, and conifers can be given a cover coefficient of 1.0 year round.

Land Use/Cover		Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Fallow	Bare Soil	-	77	86	91	94
Crop residue cover (CR)		Poor[a]	76	85	90	93
		Good	74	83	88	90
Row Crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small Grains	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[a] Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good $ 20%), and (e) degree of surface roughness.

Table B-2. Runoff Curve Numbers (Antecedent Moisture Condition II) for Cultivated Agricultural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Pasture, grassland or range - continuous forage for grazing	Poor[a/]	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - continuous grass, protected from grazing, generally mowed for hay	-	30	58	71	78
Brush - brush/weeds/grass mixture with brush the major element	Poor[b/]	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods/grass combination (orchard or tree farm)[c/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor[/d]	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads - buildings, lanes, driveways and surrounding lots	-	59	74	82	86

[a/] Poor: < 50% ground cover or heavily grazed with no mulch; Fair: 50 to 75% ground cover and not heavily grazed; Good: > 75% ground cover and lightly or only occasionally grazed.

[b/] Poor: < 50% ground cover; Fair: 50 to 75% ground cover; Good: > 75% ground cover.

[c/] Estimated as 50% woods, 50% pasture.

[d/] Poor: forest litter, small trees and brush are destroyed by heavy grazing or regular burning; Fair: woods are grazed but not burned and some forest litter covers the soil; Good: Woods are protected from grazing and litter and brush adequately cover the soil.

Table B-3. Runoff Curve Numbers (Antecedent Moisture Condition II) for other Rural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Herbaceous - grass, weeds & low-growing brush; brush the minor component	Poor[a/]	-	80	87	93
	Fair	-	71	81	89
	Good	-	62	74	85
Oak/aspen - oak brush, aspen, mountain mahogany, bitter brush, maple and other brush	Poor	-	66	74	79
	Fair	-	48	57	63
	Good	-	30	41	48
Pinyon/juniper - pinyon, juniper or both; grass understory	Poor	-	75	85	89
	Fair	-	58	73	80
	Good	-	41	61	71
Sagebrush with grass understory	Poor	-	67	80	85
	Fair	-	51	63	70
	Good	-	35	47	55
Desert scrub - saltbush, greasewood, creosotebrush, blackbrush, bursage, palo verde, mesquite and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[a/] Poor: < 30% ground cover (litter, grass and brush overstory); Fair: 30 to 70% ground cover; Good: > 70% ground cover.

Table B-4. Runoff Curve Numbers (Antecedent Moisture Condition II) for Arid and Semiarid Rangelands (Soil Conservation Service, 1986).

Land Use	Soil Hydrologic Group A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50-75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.)	98	98	98	98
Streets and roads:				
Paved with curbs & storm sewers	98	98	98	98
Paved with open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Western desert urban areas:				
Natural desert landscaping (pervious areas, only)	63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1-2 in sand or gravel mulch and basin borders)	96	96	96	96

Table B-5. Runoff Curve Numbers (Antecedent Moisture Condition II) for Urban Areas (Soil Conservation Service, 1986).

	% of Growing Season										
Crop	0	10	20	30	40	50	60	70	80	90	100

Field corn	0.45	0.51	0.58	0.66	0.75	0.85	0.96	1.08	1.20	1.08	0.70
Grain sorghum	0.30	0.40	0.65	0.90	1.10	1.20	1.10	0.95	0.80	0.65	0.50
Winter wheat	1.08	1.19	1.29	1.35	1.40	1.38	1.36	1.23	1.10	0.75	0.40
Cotton	0.40	0.45	0.56	0.76	1.00	1.14	1.19	1.11	0.83	0.58	0.40
Sugar beets	0.30	0.35	0.41	0.56	0.73	0.90	1.08	1.26	1.44	1.30	1.10
Cantaloupe	0.30	0.30	0.32	0.35	0.46	0.70	1.05	1.22	1.13	0.82	0.44
Potatoes	0.30	0.40	0.62	0.87	1.06	1.24	1.40	1.50	1.50	1.40	1.26
Papago peas	0.30	0.40	0.66	0.89	1.04	1.16	1.26	1.25	0.63	0.28	0.16
Beans	0.30	0.35	0.58	1.05	1.07	0.94	0.80	0.66	0.53	0.43	0.36
Rice	1.00	1.06	1.13	1.24	1.38	1.55	1.58	1.57	1.47	1.27	1.00

Table B-6. Evapotranspiration Cover Coefficients for Annual Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

	Alfalfa	Pasture	Grapes	Citrus Orchards	Deciduous Orchards	Sugarcane
Jan	0.83	1.16	-	0.58	-	0.65
Feb	0.90	1.23	-	0.53	-	0.50
Mar	0.96	1.19	0.15	0.65	-	0.80
Apr	1.02	1.09	0.50	0.74	0.60	1.17
May	1.08	0.95	0.80	0.73	0.80	1.21
June	1.14	0.83	0.70	0.70	0.90	1.22
July	1.20	0.79	0.45	0.81	0.90	1.23
Aug	1.25	0.80	-	0.96	0.80	1.24
Sept	1.22	0.91	-	1.08	0.50	1.26
Oct	1.18	0.91	-	1.03	0.20	1.27
Nov	1.12	0.83	-	0.82	0.20	1.28
Dec	0.86	0.69	-	0.65	-	0.80

Table B-7. Evapotranspiration Cover Coefficients for Perennial Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

In urban areas, ground cover is a mixture of trees and grass. It follows that cover factors for pervious areas are weighted averages of the perennial crop, hardwood, and softwood cover factors. It may be difficult to determine the relative fractions of urban areas with these covers. Since these covers would have different values only during dormant seasons, it is reasonable to assume a constant month value of 1.0 for urban pervious surfaces and zero for impervious surfaces.

These approximate cover coefficients are given in Table B-8. Table B-9 list mean monthly values of daylight hours (H_t) for use in Equation A-31.

Cover	Dormant Season	Growing Season
Annual crops (foliage only in growing season)	0.3	1.0
Perennial crops (year-round foliage: grass, pasture, meadow, etc.)	1.0	1.0

Saturated crops (rice)	1.0	1.0
Hardwood (deciduous) forests & orchards	0.3	1.0
Softwood (conifer) forests & orchards	1.0	1.0
Disturbed areas & bare soil (barn yards, fallow, logging trails, construction and mining)	0.3	0.3
Urban areas (I = impervious fraction)	1 - I	1 - I

Table B-8. Approximate Values for Evapotranspiration Cover Coefficients.

	Latitude North (E)						
	48	46	44	42	40	38	36
	(---------------------------- hr/day ----------------------------)						
Jan	8.7	8.9	9.2	9.3	9.5	9.7	9.9
Feb	10.0	10.2	10.3	10.4	10.5	10.6	10.7
Mar	11.7	11.7	11.7	11.7	11.8	11.8	11.8
Apr	13.4	13.3	13.2	13.1	13.0	13.0	12.9
May	14.9	14.7	14.5	14.3	14.1	14.0	13.8
Jun	15.7	15.4	15.2	15.0	14.7	14.5	14.3
Jul	15.3	15.0	14.8	14.6	14.4	14.3	14.1
Aug	14.0	13.8	13.7	13.6	13.6	13.4	13.3
Sep	12.3	12.3	12.3	12.3	12.2	12.2	12.2
Oct	10.6	10.7	10.8	10.9	11.0	11.0	11.1
Nov	9.1	9.3	9.5	9.7	9.8	10.0	10.1
Dec	8.3	8.5	8.8	9.0	9.2	9.4	9.6

	34	32	30	28	26	24
Jan	10.0	10.2	10.3	10.5	10.6	10.7
Feb	10.8	10.9	11.0	11.1	11.1	11.2
Mar	11.8	11.8	11.8	11.8	11.8	11.9
Apr	12.8	12.8	12.7	12.7	12.6	12.6
May	13.7	13.6	13.5	13.4	13.2	13.1
Jun	14.2	14.0	13.9	13.7	13.6	13.4
Jul	14.0	13.8	13.7	13.5	13.4	13.3
Aug	13.2	13.3	13.0	13.0	12.9	12.8
Sep	12.2	12.2	12.2	12.1	12.1	12.1
Oct	11.2	11.2	11.3	11.3	11.4	11.4
Nov	10.2	10.4	10.5	10.6	10.7	10.9
Dec	9.8	10.0	10.1	10.3	10.4	10.6

Table B-9. Mean Daylight Hours (Mills et al., 1985).

Groundwater. The groundwater portion of GWLF requires estimates of available unsaturated zone available soil moisture capacity U^* , recession constant r and seepage constant s.

In principle, U^* is equivalent to a mean watershed maximum rooting depth multiplied by a mean volumetric soil available water capacity. The latter also requires determination of a mean unsaturated zone depth, and this is probably impractical for most watershed studies. A default value of 10 cm can be assumed for pervious areas, corresponding to a 100 cm rooting depth and a 0.1 cm/cm volumetric available water capacity. These values appear typical for a wide range of plants (Jensen et al., 1989; U.S. Forest Service, 1980) and soils (Rawls et al., 1982).

Estimates of the recession constant r can be estimated from streamflow records by standard hydrograph separation techniques (Chow, 1964). During a period of hydrograph recession, the rate of change in shallow saturated zone water S(t) (cm) is given by the linear reservoir relationship

$$\frac{dS}{dt} = -r\,S \qquad \text{(B-1)}$$

or,

$$S(t) = S(0)\,e^{-rt} \qquad \text{(B-2)}$$

where S(0) is the shallow saturated zone moisture at t = 0. Groundwater discharge to the stream G(t) (cm) at time t is

$$G(t) = r\,S(t) = r\,S(0)\,e^{-rt} \qquad \text{(B-3)}$$

During periods of streamflow recession, it is assumed that runoff is negligible, and hence streamflow F(t) (cm) consists of groundwater discharge given by Equation B-3; i.e., F(t) = G(t). A recession constant can be estimated from two streamflows $F(t_1)$, $F(t_2)$ measured on days t_1 and t_2 ($t_2 > t_1$) during the hydrograph recession. The ratio $F(t_1)/F(t_2)$ is

$$\frac{F(t_1)}{F(t_2)} = \frac{r\,S(0)\,e^{-rt_1}}{r\,S(0)\,e^{-rt_2}} = e^{r(t_2 - t_1)} \qquad \text{(B-4)}$$

The recession constant is thus given by

$$r = \frac{\ln\,[F(t_1)/F(t_2)]}{t_2 - t_1} \qquad \text{(B-5)}$$

Recession constants are measured for a number of hydrographs and an average value is used for the simulations. Typical values range from 0.01 to 0.2

No standard techniques are available for estimating the rate constant for deep seepage loss (s). The most conservative approach is to assume that s = 0 (all precipitation exits the watershed in evapotranspiration or streamflow). Otherwise the constant must be determined by calibration.

Erosion and Sediment. The factors K_k, $(LS)_k$, C_k and P_k for the Universal Soil Loss Equation must be specified as the product $K_k\,(LS)_k\,C_k\,P_k$ for each rural runoff source area. Values K_k, C_k and P_k are given for a range of soils and conditions in Tables B-10 - B-13. More complete sets of values are provided in Mills et al. (1985) and Wischmeier & Smith (1978). The $(LS)_k$ factor is calculated for each source area k as in Wischmeier & Smith (1978):

$$LS = (0.045x_k)^b\,(65.41 \sin^2\theta_k + 4.56 \sin\theta_k + 0.065) \qquad \text{(B-6)}$$

$$\theta_k = \tan^{-1}(ps_k/100) \qquad \text{(B-7)}$$

in which x_k = slope length (m) and ps_k = per cent slope. The exponent in Equation B-6 is given by b = 0.5 for ps_k $ 5, b = 0.4 for 5 < ps_k < 3, b = 0.3 for 3 ≤ ps_k ≤ 1, and b = 0.2 for ps_k < 1 (Wischmeier & Smith, 1978).

The rainfall erosivity coefficient a_t for Equation A-12 can be estimated using methods developed by Selker et al. (1990). General values for the rainfall erosivity zones shown in Figure B-1 are given in Table B-14. Watershed sediment delivery ratios are most commonly obtained from the area-based relationship shown in

Figure B-2.

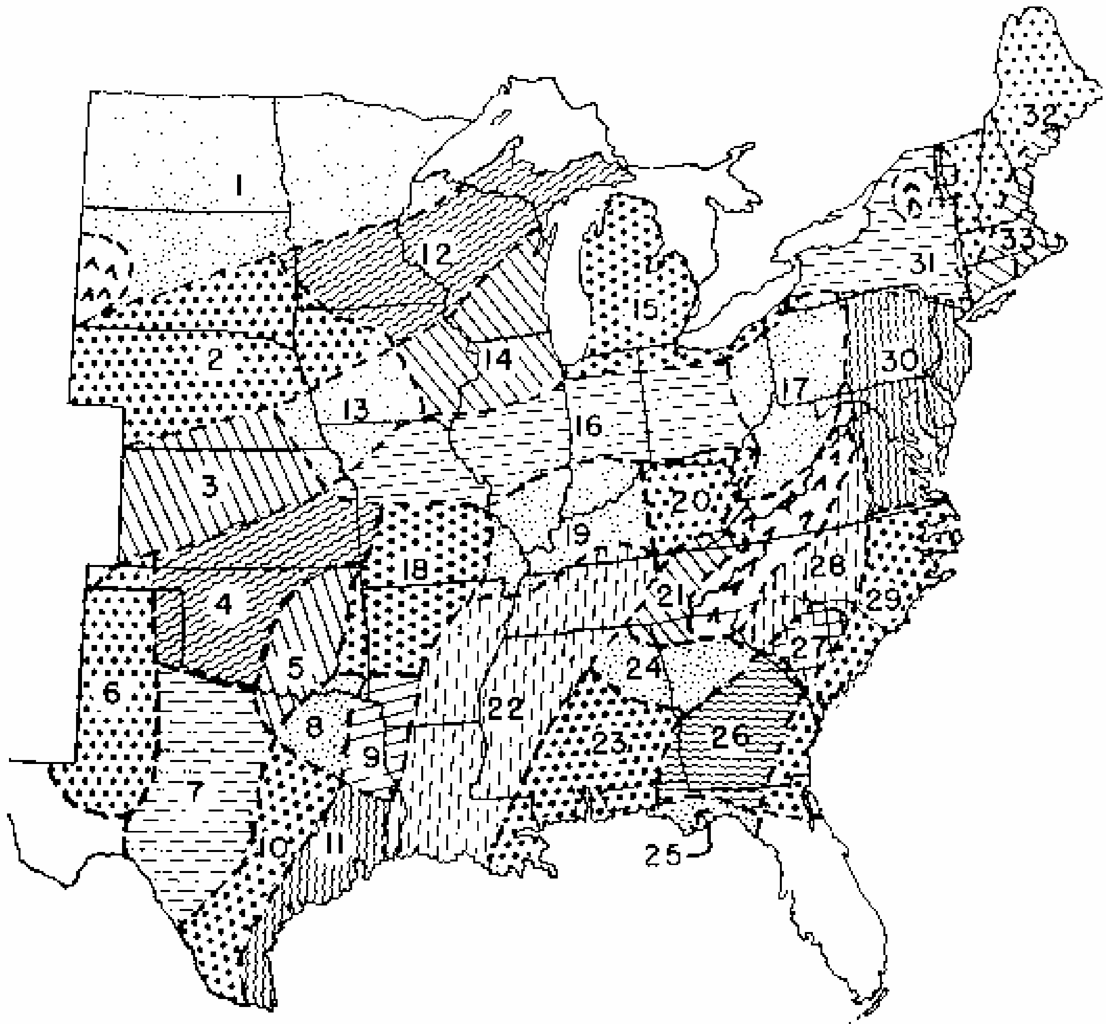

Figure B-1. Rainfall Erosivity Zones in Eastern U.S. (Wischmeier & Smith, 1978).

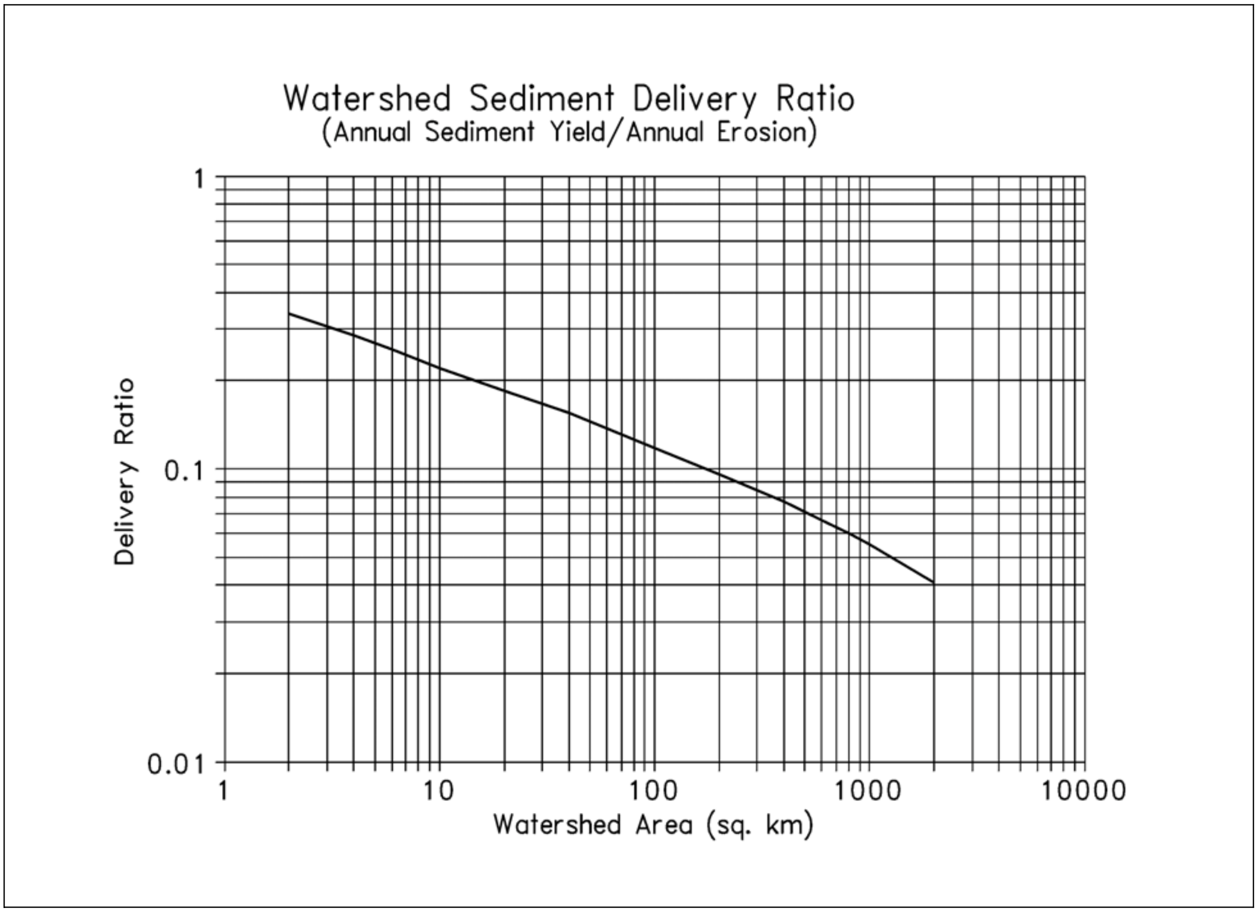

Figure B-2. Watershed Sediment Delivery Ratios (Vanoni, 1975).

	Organic Matter Content (%)		
Texture	<0.5	2	4
Sand	0.05	0.03	0.02
Fine sand	0.16	0.14	0.10
Very fine sand	0.42	0.36	0.28
Loamy sand	0.12	0.10	0.08
Loamy fine sand	0.24	0.20	0.16
Loamy very fine sand	0.44	0.38	0.30
Sandy loam	0.27	0.24	0.19
Fine sandy loam	0.35	0.30	0.24
Very fine sandy loam	0.47	0.41	0.33
Loam	0.38	0.34	0.29
Silt loam	0.48	0.42	0.33
Silt	0.60	0.52	0.42
Sandy clay loam	0.27	0.25	0.21
Clay loam	0.28	0.25	0.21
Silty clay loam	0.37	0.32	0.26
Sandy clay	0.14	0.13	0.12
Silty clay	0.25	0.23	0.19
Clay	-	0.13-0.29	-

Table B-10. Values of Soil Erodibility Factor (K) (Stewart et al., 1975).

Crop, rotation & management[b/]	Productivity[a/] High	Moderate
Continuous fallow, tilled up and down slope	1.00	1.00
CORN		
1 C, RdR, fall TP, conv (1)	0.54	0.62
2 C, RdR, spring TP, conv (1)	0.50	0.59
3 C, RdL, fall TP, conv (1)	0.42	0.52
4 C, RdR, wc seeding, spring TP, conv (1)	0.40	0.49
5 C, RdL, standing, spring TP, conv (1)	0.38	0.48
6 C, fall shred stalks, spring TP, conv (1)	0.35	0.44
7 C(silage)-W(RdL,fall TP) (2)	0.31	0.35
8 C, RdL, fall chisel, spring disk, 40-30% re (1)	0.24	0.30
9 C(silage), W wc seeding, no-till pl in c-k W (1)	0.20	0.24
10 C(RdL)-W(RdL,spring TP) (2)	0.20	0.28
11 C, fall shred stalks, chisel pl, 40-30% re (1)	0.19	0.26
12 C-C-C-W-M, RdL, TP for C, disk for W (5)	0.17	0.23
13 C, RdL, strip till row zones, 55-40% re (1)	0.16	0.24
14 C-C-C-W-M-M, RdL, TP for C, disk for W (6)	0.14	0.20
15 C-C-W-M, RdL, TP for C, disk for W (4)	0.12	0.17
16 C, fall shred, no-till pl, 70-50% re (1)	0.11	0.18
17 C-C-W-M-M, RdL, TP for C, disk for W (5)	0.087	0.14
18 C-C-C-W-M, RdL, no-till pl 2nd & 3rd C (5)	0.076	0.13
19 C-C-W-M, RdL, no-till pl 2d C (4)	0.068	0.11
20 C, no-till pl in c-k wheat, 90-70% re (1)	0.062	0.14
21 C-C-C-W-M-M, no-till pl 2d & 3rd C (6)	0.061	0.11
22 C-W-M, RdL, TP for C, disk for W (3)	0.055	0.095
23 C-C-W-M-M, RdL, no-till pl 2d C (5)	0.051	0.094
24 C-W-M-M, RdL, TP for C, disk for W (4)	0.039	0.074
25 C-W-M-M-M, RdL, TP for C, disk for W (5)	0.032	0.061
26 C, no-till pl in c-k sod, 95-80% re (1)	0.017	0.053
COTTON[/c]		
27 Cot, conv (western plains) (1)	0.42	0.49
28 Cot, conv (south) (1)	0.34	0.40
MEADOW (HAY)		
29 Grass & legume mix	0.004	0.01
30 Alfalfa, lespedeza or sericia	0.020	-
31 Sweet clover	0.025	-
SORGHUM, GRAIN (western plains)		
32 RdL, spring TP, conv (1)	0.43	0.53
33 No-till pl in shredded 70-50% re	0.11	0.18
SOYBEANS[/c]		
34 B, RdL, spring TP, conv (1)	0.48	0.54
35 C-B, TP annually, conv (2)	0.43	0.51
36 B, no-till pl	0.22	0.28
37 C-B, no-till pl, fall shred C stalks (2)	0.18	0.22

Table B-11. CONTINUED

Crop, rotation & management[b/]	Productivity[a/] High	Moderate
WHEAT		
38 W-F, fall TP after W (2)	0.38	-
39 W-F, stubble mulch, 500 lb re (2)	0.32	-
40 W-F, stubble mulch, 1000 Lb re (2)	0.21	-
41 Spring W, RdL, Sept TP, conv (ND,SD) (1)	0.23	-
42 Winter W, RdL, Aug TP, conv (KS) (1)	0.19	-
43 Spring W, stubble mulch, 750 lb re (1)	0.15	-
44 Spring W, stubble mulch, 1250 lb re (1)	0.12	-
45 Winter W, stubble mulch, 750 lb re (1)	0.11	-
46 Winter W, stubble mulch, 1250 lb re (1)	0.10	-
47 W-M, conv (2)	0.054	-
48 W-M-M, conv (3)	0.026	-
49 W-M-M-M, conv (4)	0.021	-

[a/] High level exemplified by long-term yield averages greater than 75 bu/ac corn or 3 ton/ac hay or cotton management that regularly provides good stands and growth.

[b/] Numbers in parentheses indicate numbers of years in the rotation cycle. (1) indicates a continuous one-crop system.

[c/] Grain sorghum, soybeans or cotton may be substituted for corn in lines 12, 14, 15, 17-19, 21-25 to estimate values for sod-based rotations.

Abbreviations:

B	soybeans	F	fallow
C	corn	M	grass & legume hay
c-k	chemically killed	pl	plant
conv	conventional	W	wheat
cot	cotton	wc	winter cover

lb re	pounds of residue per acre remaining on surface after new crop seeding
% re	percentage of soil surface covered by residue mulch after new crop seeding
xx-yy% re	xx% cover for high productivity, yy% for moderate
RdR	residues (corn stover, straw, etc.) removed or burned
RdL	residues left on field (on surface or incorporated)
TP	turn plowed (upper 5 or more inches of soil inverted, covering residues

Table B-11. Generalized Values of Cover and Management Factor (C) for Field Crops East of the Rocky Mountains (Stewart et al., 1975).

Cover	Value
Permanent pasture, idle land, unmanaged woodland	
95-100% ground cover	
as grass	0.003
as weeds	0.01
80% ground cover	
as grass	0.01
as weeds	0.04
60% ground cover	
as grass	0.04
as weeds	0.09
Managed woodland	
75-100% tree canopy	0.001
40-75% tree canopy	0.002-0.004
20-40% tree canopy	0.003-0.01

Table B-12. Values of Cover and Management Factor (C) for Pasture and Woodland (Novotny & Chesters, 1981).

Practice Slope(%):	1.1-2	2.1-7	7.1-12	12.1-18	18.1-24
No support practice	1.00	1.00	1.00	1.00	1.00
Contouring	0.60	0.50	0.60	0.80	0.90
Contour strip cropping					
R-R-M-M[a/]	0.30	0.25	0.30	0.40	0.45
R-W-M-M	0.30	0.25	0.30	0.40	0.45
R-R-W-M	0.45	0.38	0.45	0.60	0.68
R-W	0.52	0.44	0.52	0.70	0.90
R-O	0.60	0.50	0.60	0.80	0.90
Contour listing or ridge planting	0.30	0.25	0.30	0.40	0.45
Contour terracing[b/]	0.6/%n	0.5/%n	0.6/%n	0.8/%n	0.9/%n

[a/] R = row crop, W = fall-seeded grain, M = meadow. The crops are grown in rotation and so arranged on the field that row crop strips are always separated by a meadow or winter-grain strip.

[b/] These factors estimate the amount of soil eroded to the terrace channels. To obtain off-field values, multiply by 0.2. n = number of approximately equal length intervals into which the field slope is divided by the terraces. Tillage operations must be parallel to the terraces.

Table B-13. Values of Supporting Practice Factor (P) (Stewart et al., 1975).

Zone[a/]	Location	Season[b/] Cool	Warm
1	Fargo ND	0.08	0.30
2	Sioux City IA	0.13	0.35
3	Goodland KS	0.07	0.15
4	Wichita KS	0.20	0.30
5	Tulsa OK	0.21	0.27
6	Amarillo TX	0.30	0.34
7	Abilene TX	0.26	0.34
8	Dallas TX	0.28	0.37
9	Shreveport LA	0.22	0.32
10	Austin TX	0.27	0.41
11	Houston TX	0.29	0.42
12	St. Paul MN	0.10	0.26
13	Lincoln NE	0.26	0.24
14	Dubuque IA	0.14	0.26
15	Grand Rapids MI	0.08	0.23
16	Indianapolis IN	0.12	0.30
17	Parkersburg WV	0.08	0.26
18	Springfield MO	0.17	0.23
19	Evansville IN	0.14	0.27
20	Lexington KY	0.11	0.28
21	Knoxville TN	0.10	0.28
22	Memphis TN	0.11	0.20
23	Mobile AL	0.15	0.19
24	Atlanta GA	0.15	0.34
25	Apalachacola FL	0.22	0.31
26	Macon GA	0.15	0.40
27	Columbia SC	0.08	0.25
28	Charlotte NC	0.12	0.33
29	Wilmington NC	0.16	0.28
30	Baltimore MD	0.12	0.30
31	Albany NY	0.06	0.25
32	Caribou ME	0.07	0.13
33	Hartford CN	0.11	0.22

[a/] Zones given in Figure B-1.

[b/] Cool season: Oct - Mar; Warm season: Apr - Sept.

Table B-14. Rainfall Erosivity Coefficients (a) for Erosivity Zones in Eastern U.S. (Selker et al., 1990).

Initial Conditions. Several initial conditions must be provided in the **TRANSPRT.DAT** file: initial unsaturated and shallow saturated zone soil moistures (U_1 and S_1), snowmelt water (SN_1) and antecedent rain + snowmelt for the five previous days. It is likely that these values will be uncertain in many applications. However, they will not affect model results for more than the first month or two of the simulation period. It is generally most practical to assign arbitrary initial values (U^* for U_1 and zero for the remaining variables) and to discard the first year of the simulation results.

Nutrient Parameters

A sample set of nutrient parameters required for the data file **NUTRIENT.DAT** is given in Appendix D.

Although the GWLF model will be most accurate when nutrient data are calibrated to local conditions, a set of default parameters has been developed to facilitate uncalibrated applications. Obviously these parameters, which are average values obtained from published water pollution monitoring studies, are only approximations of conditions in any watershed.

Rural and Groundwater Sources. Solid-phase nutrients in sediment from rural sources can be estimated as the average soil nutrient content multiplied by an enrichment ratio. Soil nutrient levels can be determined from soil samples, soil surveys or general maps such as those given in Figures B-3 and B-4. A value of 2.0 for the enrichment ratio falls within the mid-range of reported ratios and can be used in absence of more specific data (McElroy et al., 1976; Mills et al., 1985).

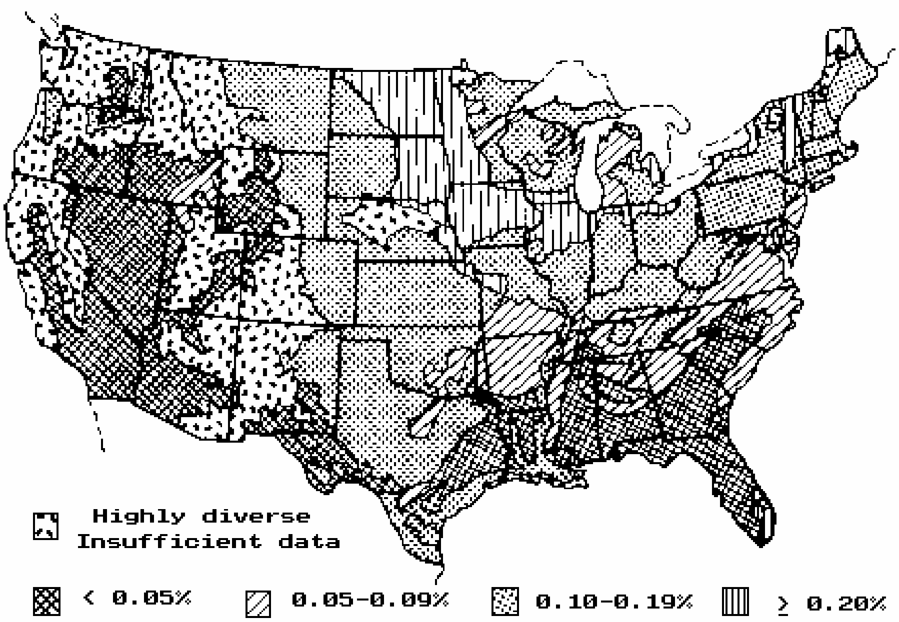

Figure B-3. Nitrogen in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

Default flow-weighted mean concentrations of dissolved nitrogen and phosphorus in agricultural runoff are given in Table B-15. The cropland and barnyard data are from multi-year storm runoff sampling studies in South Dakota (Dornbush et al., 1974) and Ohio (Edwards et al., 1972). The concentrations for snowmelt runoff from fields with manure on the soil surface are taken from a manual prepared by U. S. Department of Agriculture scientists (Gilbertson et al., 1979).

Default values for nutrient concentrations in groundwater discharge can be inferred from the U.S. Eutrophication Survey results (Omernik, 1977) given in Table B-16. These data are mean concentrations computed from 12 monthly streamflow samples in watersheds free of point sources. Since such limited sampling is unlikely to capture nutrient fluxes from storm runoff, the streamflow concentrations can be assumed to represent groundwater discharges to streams.

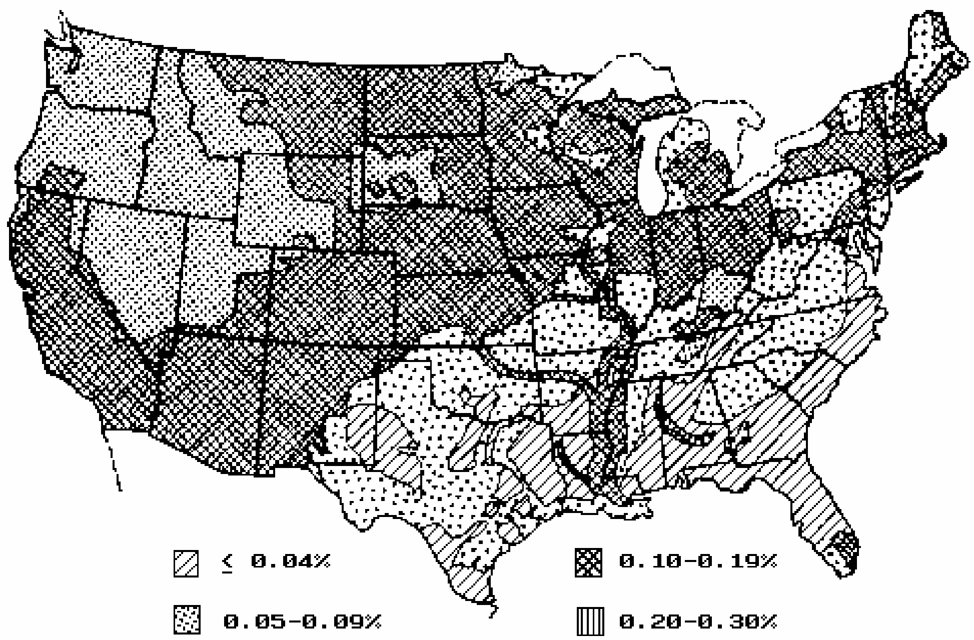

Figure B-4. P_2O_5 (44% phosphorus) in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

Dissolved nutrient data for forest runoff are essentially nonexistent. Runoff is a small component of streamflow from forest areas and studies of forest nutrient flux are based on streamflow rather than runoff sampling. Hence the only possible default option is the use of the streamflow concentrations from the "$ 90% Forest" category in Table B-16 as estimates of runoff concentrations.

Default values for urban nutrient accumulation rates are provided in Table B-17. These values were developed for Northern Virginia conditions and are probably suitable for smaller and relatively new urban areas. They would likely underestimate accumulations in older large cities.

Septic Systems. Representative values for septic system nutrient parameters are given in Table B-18. Per capita nutrient loads in septic tank effluent were estimated from typical flows and concentrations. The EPA Design Manual (U.S. Environmental Protection Agency, 1980) indicates 170 *l*/day as a representative wastewater flow from on-site wastewater disposal systems. Alhajjar et al. (1989) measured mean nitrogen and phosphorus concentrations in septic tank effluents of 73 and 14 mg/*l*, respectively. The latter concentration is based on use of phosphate detergents. When non-phosphate detergents are used, the concentration dropped to 7.9 mg/*l*. These concentrations were combined with the 170 *l*/day flow to produce the effluent nutrient loads given in Table B-18.

Nutrient uptake by plants (generally grasses) growing over the septic system adsorption field are frankly speculative. Brown & Thomas (1978) suggest that if the grass clippings are harvested, nutrients from a septic system effluent can support at least twice the normal yield of grass over the absorption field. Petrovic & Cornman (1982) suggest that retention of turf grass clippings can reduce required fertilizer applications by 25%, thus implying nutrient losses of 75% of uptakes. It appears that a conservative estimate of nutrient losses from plant cover would be 75% of the nutrient uptake of from a normal annual yield of grass. Reed et al. (1988) reported that Kentucky bluegrass annually utilizes 200-270 kg/ha nitrogen and 45 kg/ha phosphorus. Using the 200 kg/ha nitrogen value, and assuming a six month growing season and a 20 m^2 per capita absorption area, an estimated 1.6 g/day nitrogen and 0.4 g/day phosphorus are lost by plant uptake on a per capita basis during the growing season. The 20 m^2 adsorption area was based on per bedroom adsorption area recommendations by the U.S. Public Health Service for a soil with average percolation rate (.12 min/cm) (U.S. Public Health Service, 1967).

The remaining information needed are the numbers of people served by the four different types of septic systems (normal, short-circuited, ponded and direct discharge). A starting point for this data will generally be estimates of the unsewered population in the watershed. Local public health officials may be able to estimate the fractions of systems within the area which are of each type. However, the most direct way of generating the information is through a septic systems survey.

Land Use	Nitrogen	Phosphorus
	(-----------------(mg/l)	---------------)
Fallow[a/]	2.6	0.10
Corn[a/]	2.9	0.26
Small grains[a/]	1.8	0.30
Hay[a/]	2.8	0.15
Pasture[a/]	3.0	0.25
Barn yards[b/]	29.3	5.10
Snowmelt runoff from manured land[c/]:		
Corn	12.2	1.90
Small grains	25.0	5.00
Hay	36.0	8.70

[a/]Dornbush et al. (1974)

[b/]Edwards et al. (1972)

[c/]Gilbertson et al. (1979); manure left on soil surface.

Table B-15. Dissolved Nutrients in Agricultural Runoff.

Watershed Type	Concentrations (mg/l) Eastern U.S.	Central U.S.	Western U.S.
Nitrogen[a/]:			
$ 90% Forest	0.19	0.06	0.07
$ 75% Forest	0.23	0.10	0.07
$ 50% Forest	0.34	0.25	0.18
$ 50% Agriculture	1.08	0.65	0.83
$ 75% Agriculture	1.82	0.80	1.70
$ 90% Agriculture	5.04	0.77	0.71
Phosphorus[b/]:			
$ 90% Forest	0.006	0.009	0.012
$ 75% Forest	0.007	0.012	0.015
$ 50% Forest	0.013	0.015	0.015
$ 50% Agriculture	0.029	0.055	0.083
$ 75% Agriculture	0.052	0.067	0.069
$ 90% Agriculture	0.067	0.085	0.104

[a/]Measured as total inorganic nitrogen.

[b/]Measured as total orthophosphorus

Table B-16. Mean Dissolved Nutrients Measured in Streamflow by the National Eutrophication Survey (Omernik, 1977).

Land Use	Sus-pended Solids	BOD	Total Nitrogen	Total Phosphorus
	(------------------------------	kg/ha-day	----------------------------	)
Impervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	2.5	0.15	0.045	0.0045
Medium density (units/ha ≥ 1.2)	6.2	0.22	0.090	0.0112
Townhouses & apartments	6.2	0.22	0.090	0.0112
High rise residential	3.9	0.71	0.056	0.0067
Institutional	2.8	0.39	0.056	0.0067
Industrial	2.8	0.71	0.101	0.0112
Suburban shopping center	2.8	0.71	0.056	0.0067
Central business district	2.8	0.85	0.101	0.0112
Pervious Surfaces				
Single family residential				
Low density (units/ha < 1.2)	1.3	0.08	0.012	0.0016
Medium density (units/ha ≥ 1.2)	1.1	0.15	0.022	0.0039
Townhouses & apartments	2.2	0.29	0.045	0.0078
High rise residential	0.8	0.08	0.012	0.0019
Institutional	0.8	0.08	0.012	0.0019
Industrial	0.8	0.08	0.012	0.0019
Suburban shopping center	0.8	0.08	0.012	0.0019
Central business district	0.8	0.08	0.012	0.0019

Table B-17. Contaminant Accumulation Rates for Northern Virginia Urban Areas (Kuo, et al., 1988).

Parameter		Value
e, per capita daily nutrient load in septic tank effluent (g/day)		
Nitrogen		12.0
Phosphorus		
Phosphate detergents use		2.5
Non-phosphate detergents use		1.5
u_m, per capita daily nutrient uptake by plants during month m (g/day)		
Nitrogen:	Growing season	1.6
	Non-growing season	0.0
Phosphorus:	Growing season	0.4
	Non-growing season	0.0

Table B-18. Default Parameter Values for Septic Systems.

APPENDIX C: VALIDATION STUDY

The GWLF model was tested by comparing model predictions with measured streamflow, sediment and nutrient loads from the West Branch Delaware River Basin during a three-year period (April, 1979 - March, 1982). The model was run using the four-year period April, 1978 - March, 1982 and first year results were ignored to eliminate effects of arbitrary initial conditions.

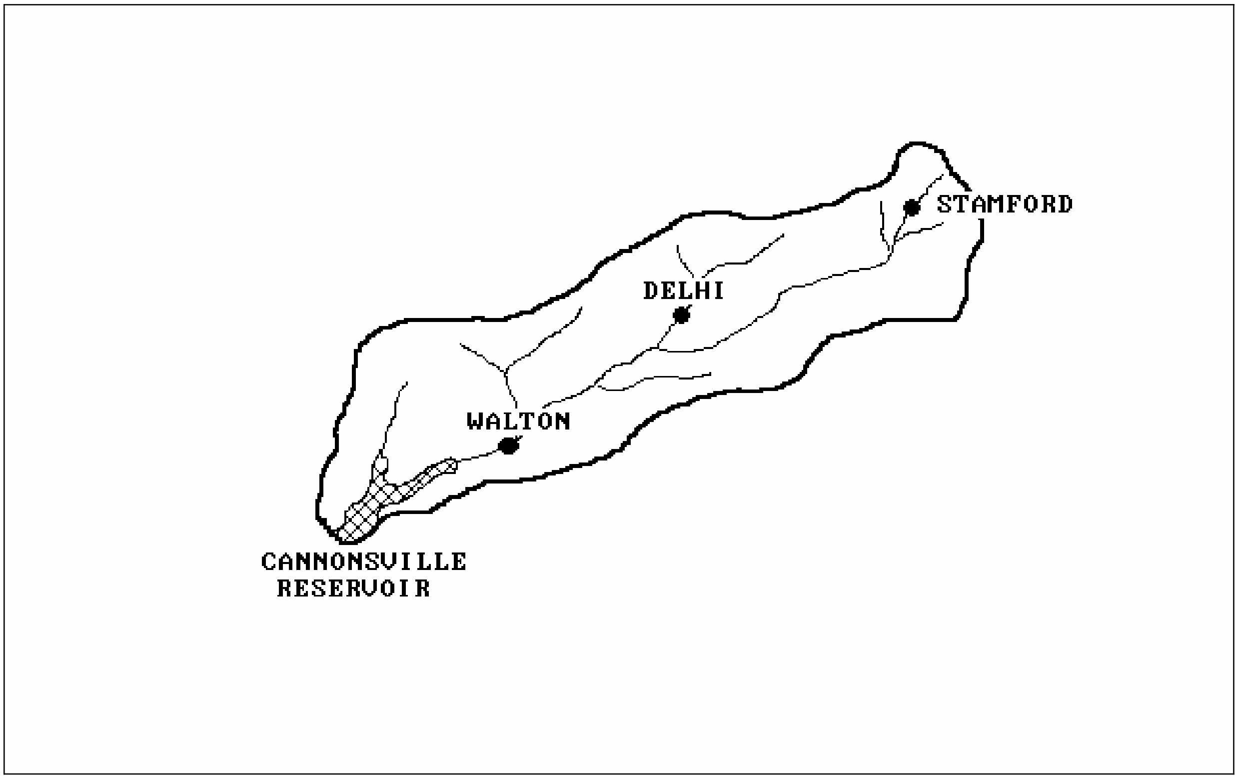

Figure C-1. West Branch Delaware River Watershed.

The 850 km^2 watershed, which is shown in Figure C-1, is in a dairy farming area in southeast New York which consists of 30% agricultural, 67% forested and 2% urban land uses. The river empties into Cannonsville Reservoir, which is a water supply source for the City of New York.

The model was run for the four-year period using daily precipitation and temperature records from the U.S. Environmental Data and Information service weather station at Walton, NY. To test the usefulness of the default parameters presented previously, no attempt was made to calibrate the model. No water quality data from the watershed were used to estimate parameters. All transport and chemical parameters were obtained by the general procedures described in the Appendix B.

Water Quality Observations

Continuous streamflow records were available from a U.S. Geological Survey gauging station at Walton, NY. Nutrient and sediment data were collected, analyzed and summarized by the N.Y. State Department of Environmental Conservation (Brown et al., 1985). During base flow conditions, samples were collected at approximately one-week intervals. During storm events, samples were collected at 2-4 hour intervals during hydrograph rise and at 6-8 hour intervals in the 2-3 days following flow peak. More frequent sampling was carried out during major snowmelt events. Total and dissolved phosphorus and sediment (suspended solids) data were collected from March, 1980 through March, 1982. The sampling periods for dissolved and total nitrogen were less extensive: March, 1980 - September, 1981 and January, 1981 - September, 1981, respectively.

Mass fluxes were computed by multiplying sediment or nutrient concentrations in a sample by "a volume of water determined by numerically integrating flow over the period of time from half of the preceding sampling time interval through half of the following sampling time interval" (Brown et al., 1985).

Watershed Data

Land Uses. The parameters needed for the agricultural and forest source areas were estimated from a land use sampling procedure similar to that described by Haith & Tubbs (1981). U.S. Geological Survey 1:24,000 topographic maps of the watershed were overlain by land use maps derived from 1971-1974 aerial photography. The maps were then overlain by a grid with 1-ha cells which was the basis of the sampling procedure. The land uses were divided into two general categories: forest and agriculture. Forest areas were subdivided into forest brushland and mature forest, and agricultural areas were subdivided into cropland, pasture and inactive agriculture. A random sample of 500 cells was taken, stratified over the two major land uses to provide more intense sampling of agricultural areas (390 samples vs. 110 for forest).

For each agricultural sample, the following were recorded: land use (cropland, pasture or inactive), soil type and length and gradient of the slope of the field in which the 1-ha sample was located. Crops were separated into two categories, corn or hay, since these two crops make up 99% of the county cropland.

Barnyard areas were identified from examination of conservation plans for 30 watershed dairy farm barnyards. Average earthen and roof drainage areas were 0.1306 ha and 0.0369 ha, respectively. These values were assumed representative of the watershed's 245 barnyards, producing total earth and roof drainage areas of 32 and 9 ha, respectively.

Urban land uses (low-density residential, commercial and industrial) were calculated from Delaware County tax maps. The impervious portions of these areas were 16%, 54% and 34% for residential, commercial and industrial land uses, respectively.

Runoff Curve Numbers. In forest areas, curve numbers were selected by soil type, assuming "good" hydrologic condition. Agricultural curve numbers were selected based on soil type, crop, management practice (e.g., strip cropping) and hydrologic condition. All pasture, hay and corn-hay rotations were assumed to be in good condition. Inactive agricultural areas were assumed to be the same as pasture. Corn grown in continuous rotation was considered in poor condition. Cropland breakdown into hay, continuous corn and rotated corn was determined from county data assembled by Soil Conservation Service (1976) and confirmed from Bureau of the Census (1980).

Rural source areas and curve numbers are listed in Table C-1. These areas were subsequently aggregated for the GWLF input files into the large areas given in Table C-2. Urban and barnyard areas are also given in Table C-2. Curve numbers are area-weighted averages for each source area.

Erosion and Sediment Parameters. Data required for estimation of soil loss parameters for logging sites were obtained from a forestry survey (Slavicek, 1980). Logging areas were located from a 1979 aerial survey. Transects of the logging roads at these sites were measured for soil loss parameters K_k, $(LS)_k$, C_k and P_k, and from this information an average $K_k\ (LS)_k\ C_k\ P_k$ value was calculated.

Soil erodibility factors (K_k) for agricultural land were obtained from the Soil Conservation Service. Cover factors (C) were selected Table B-10 based on several assumptions. For corn, the assumptions were that all residues are removed from the fields (91% of the corn in the county is used for silage (Bureau of the Census, 1980)), and all fields are spring turn-plowed and in the high productivity class (Knoblauch, 1976). A moderate productivity was assumed for hay (Knoblauch, 1976). Supporting practice factors of P = 1 were used for all source areas except strip crop corn. Area-weighted $K_k\ (LS)_k\ C_k\ P_k$ values are given in Table C-2. Coefficients for daily rainfall erosivity were selected from Table B-13 for Zone 31 (Figure B-1) . A watershed sediment delivery ratio of 0.065 was determined from Figure B-2.

Source Area	Soil Hydrologic Group	Area(ha)	Curve Number[a]
Continuous corn	B	414	81
	C	878	88
Rotated corn	B	620	78
	C	1316	85
Strip crop corn	C	202	82
Hay	B	2319	72
	C	10690	81
	D	76	85
Pasture	B	378	61
	C	4639	74
	D	76	80
Inactive agriculture	B	328	61
	C	3227	74
	D	126	80
Forest brushland	B	3118	48
	C	24693	65
	D	510	73
Mature forest	B	510	55
	C	27851	70

[a/] Antecedent moisture condition 2 ($CN2_k$)

Table C-1. Areas and Curve Numbers for Agricultural and Forest Runoff Sources for West Branch Delaware River Basin.

Land Use	Area(ha)	Curve Number[a/]	Erosion Product[b/]
Corn	3430	83.8	0.214
Hay	13085	79.4	0.012
Pasture	5093	73.1	0.016
Inactive Agriculture	3681	73.1	0.017
Barnyards	41	92.2	--
Forest	56682	66.5	--
Logging Trails	20	--	0.217
Residential (Low Density)			
Impervious	104	98.0	--
Pervious	546	74.0	--
Commercial			
Impervious	49	98.0	--
Pervious	41	74.0	--
Industrial			
Impervious	34	98.0	--
Pervious	67	74.0	--

[a/]Antecedent moisture condition 2 ($CN2_k$).

[b/]K_k $(LS)_k$ C_k P_k

Table C-2. Aggregated Runoff Source Areas in West Branch Delaware River Basin.

Land Use	Area(ha)	Cover Coefficient May-Oct	Cover Coefficient Nov-Apr
Corn	3430	1.0	0.3
Hay	13085	1.0	1.0
Pasture	5093	1.0	1.0
Inactive Agriculture	3681	1.0	1.0
Forest	56682	1.0	0.3
Logging	20	0.3	0.3
Barn Yards	41	0.3	0.3
Residential	650	0.84	0.84
Commercial	90	0.46	0.46
Industrial	101	0.66	0.66
Watershed Weighted Mean	82873	1.00	0.49

Table C-3. Evapotranspiration Cover Coefficients for West Branch Delaware River Basin.

Other Transport Parameters. For purpose of curve number and evapotranspiration cover coefficient selection, the growing season was assumed to correspond to months during which mean air temperature is at least 10EC (May-October). Cover coefficients were selected from Table B-8 and are listed in Table C-3 along with the area-weighted watershed values. An average groundwater recession constant of r = 0.1 was determined from analysis of 30 hydrograph recessions from the period 1971 - 1978. The seepage constant (s) was assumed to be zero, and the default value of 10 cm was used for unsaturated zone available soil moisture capacity U^*.

Nutrient Concentrations and Accumulation Rates. Using the soil nutrient values given in Figures B-3 and B-4 and the previously suggested enrichment ratio of 2.0 produced sediment nutrient concentrations of 3000 mg/kg nitrogen and 1300 mg/kg phosphorus. Rural dissolved nutrient concentrations were selected from Tables B-15 and B-16. Manure is spread on corn land in the watershed and hence the manured land concentrations were used for corn land runoff in snowmelt months (January - March). Inactive agricultural land was assumed to have nutrient concentrations midway between pasture and forest values. Urban nutrient accumulation rates from Table B-17 were used, with "Central business district" values used for commercial land.

Septic System Parameters. The default values for nutrient loads and plant uptake given in Table B-18 were used to model septic systems. The population served by each type of septic system was estimated by determining the percentage of the total number of systems falling within each class and multiplying by the year-round and seasonal (June - August) unsewered populations in the watershed. Table C-4 summarizes the population data for septic systems.

System Type	Percent of Total Population	Population Served Year-round	Seasonal[a/]
Normal	86	7572	1835
Short-circuited	1	88	21
Ponded	10	881	213
Direct discharge	3	264	64

[a/] June - August

Table C-4. Estimated Populations Served by Different Septic System Types in West Branch Delaware River Basin.

The year-round unsewered population estimate for the watershed was based on 1980 Census data. These data were also used to determine the average number of people per household and the number of housing units used on a part-time basis. The seasonal population was then calculated by assuming the number of people per household was the same for seasonal and year-round residents.

A range of values for the current (1991) percentage of each type of system was supplied by the New York City Department of Environmental Protection (Personal Communication, J. Kane, New York City Department of Environmental Protection). A estimate of the percentages for the study period was determined by comparing the range of current values with the percentages from a survey of a neighboring area of Delaware County with construction practices and code enforcement similar to the West Branch Delaware River Watershed at the time of the study (Personal Communication, A. Lemley, Cornell University).

Point Sources. Point sources of nutrients are dissolved loads from five municipal and two industrial wastewater treatment plants. These inputs are 3800 kg/mo nitrogen and 825 kg/mo phosphorus (Brown & Rafferty, 1980; Dickerhoff, 1981).

Complete data inputs for the validation simulation run are given in Appendix D.

Validation Results

The GWLF streamflow predictions are compared with observations in Figure C-2. It is apparent that although the model mirrors the timing of observed streamflow, predictions for any particular month may have substantial errors. Accuracy is poorest for low flows, when predicted streamflows are essentially zero due to the very simple lumped parameter groundwater model.

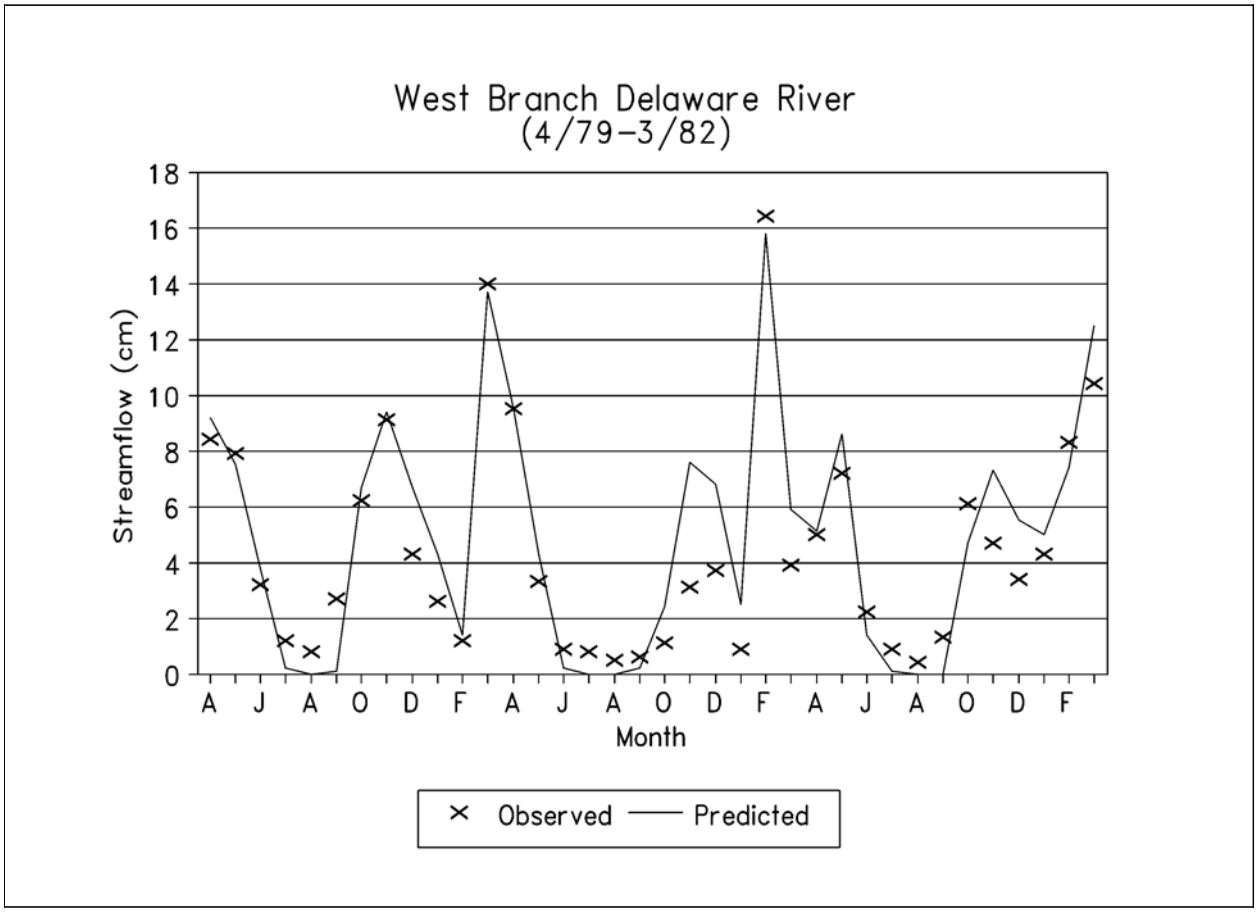

Figure C-2. Observed and Predicted Monthly Streamflow.

Model predictions and observations for total phosphorus and nitrogen are compared in Figures C-3 and C-4. Both sets of predictions match the variations in observations but under-predict the February, 1981 peak values by 35% and 26% for phosphorus and nitrogen, respectively. A quantitative summary of the comparisons of predictions with observations is given in Table C-5. Monthly mean predictions are within 10% of observation means for five of the six model outputs. The predicted mean total nitrogen flux is 73% of the observed mean. No coefficient of determination (R^2) is less than 0.88, indicating that the model explains at least 88% of the observed monthly variation in streamflow, sediment yield and nutrient fluxes.

Mean annual nutrient loads from each source for the four-year simulation period are provided in Table C-6. It is apparent that cropland runoff is a major source of streamflow nitrogen and phosphorus. Groundwater discharge is the largest source of nitrogen, accounting for 41% of dissolved and 36% of total nitrogen loads. Point sources constitute 11% of total nitrogen and 20% of total phosphorus. Septic tank drainage provides nearly as much nitrogen as point sources, but is a minor phosphorus source.

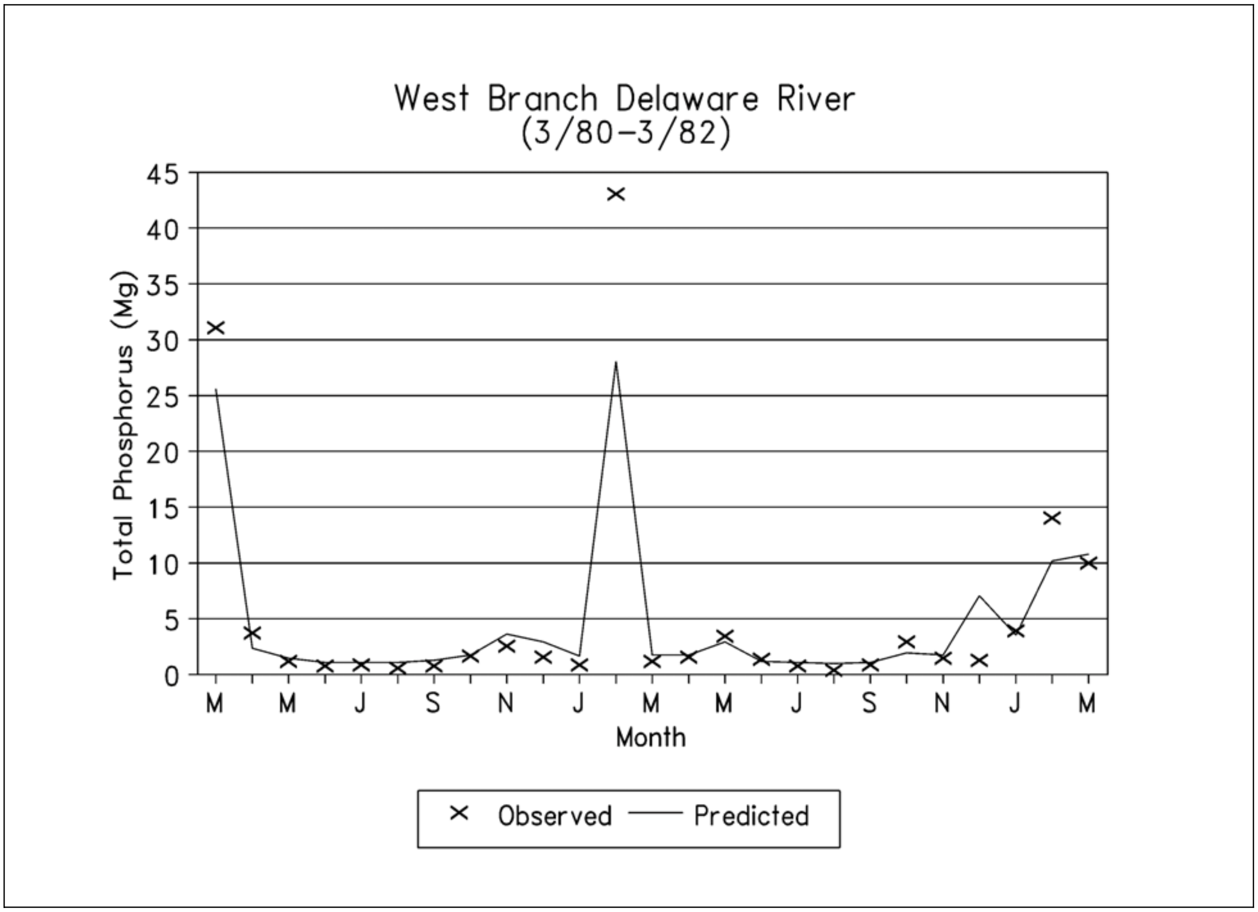

Figure C-3. Observed and Predicted Total Phosphorus in Streamflow.

Constituent	Validation Period	Monthly Means Predicted	Observed	Coefficient of Determination (R^2)
Streamflow (cm)	4/79-3/82	4.9	4.5	0.88
Sediment (1000 Mg)	3/80-3/82	1.6	1.7	0.95
Nitrogen (Mg)				
Dissolved	3/80-9/81	27.8	27.8	0.94
Total	1/81-9/81	32.9	44.8	0.99
Phosphorus (Mg)				
Dissolved	3/80-3/82	2.6	2.4	0.95
Total	3/80-3/82	4.7	5.2	0.95

Table C-5. Comparison of GWLF Predictions and Observations for the West Branch Delaware River Watershed.

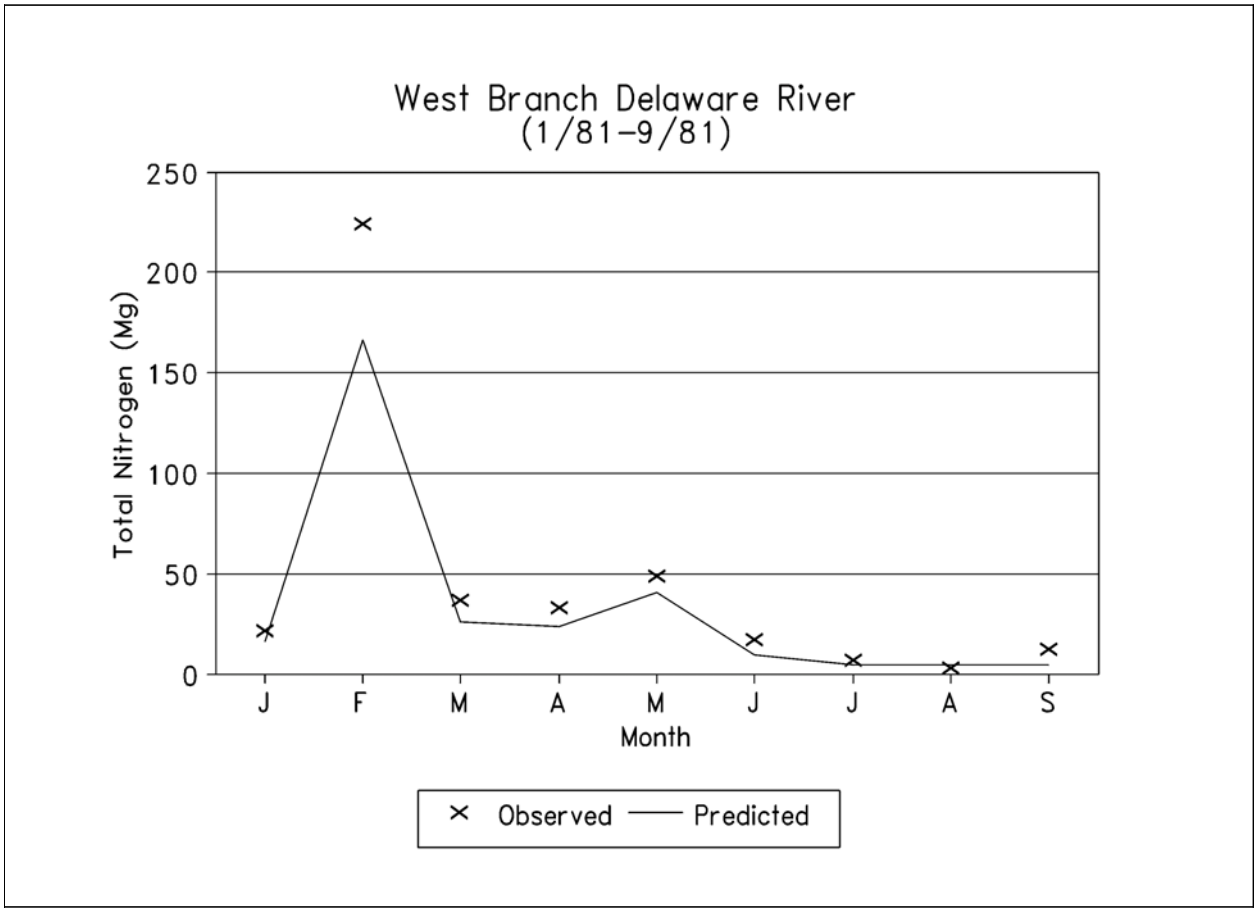

Figure C-4. Observed and Predicted Total Nitrogen in Streamflow.

Conclusions

The watershed loading functions model GWLF is based on simple runoff, sediment and groundwater relationships combined with empirical chemical parameters. The model is unique in its ability to estimate monthly nutrient fluxes in streamflow without calibration. Validation studies in a large New York watershed indicated that the model possesses a high degree of predictive accuracy. Although better results could perhaps be obtained by more detailed chemical simulation models, such models have substantially greater data and computational requirements and must be calibrated from water quality sampling data.

The GWLF model has several limitations. Peak monthly nutrient fluxes were underestimated by as much as 35%. Since nutrient chemistry is not modeled explicitly, the model cannot be used to estimate the effects of fertilizer management or urban storm water storage and treatment. The model has only been validated for a largely rural watershed in which agricultural runoff and groundwater discharge provided most of the nutrient load. Although the urban runoff component is based on well-known relationships which have been used previously in such models as STORM and SWMM, GWLF performance in more urban watersheds is uncertain.

Source	Nitrogen (Mg) Dissolved	Total	Phosphorus (Mg) Dissolved	Total
Runoff				
Corn	52.9	84.6	7.8	21.5
Hay	48.6	55.4	2.6	5.5
Pasture	13.2	16.7	1.1	2.6
Inactive Agriculture	5.1	7.8	0.4	1.6
Forest & logging	5.9	6.1	0.2	0.3
Barn yards	4.3	4.3	0.8	0.8
Urban	--	2.8	--	0.3
Groundwater, Point Sources, & Septic Systems				
Groundwater Discharge	149.6	149.6	5.7	5.7
Point sources	45.6	45.6	9.9	9.9
Septic systems	38.1	38.1	1.1	1.1
Watershed Total	363.4	411.1	29.6	48.3

Table C-6. Mean Annual Nutrient Loads Estimated from GWLF for the West Branch Delaware River Watershed: 4/78 - 3/82.

APPENDIX D: DATA AND OUTPUT LISTINGS FOR VALIDATION STUDY (EXAMPLE 1)

The first listing in this appendix is the set of sequential data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** used in the validation study and Example 1. The first two files are constructed by selecting the appropriate option from GWLF menus. The weather file is arranged by months (April - March, in this application) with the first entry for each month being the number of days in the month, and subsequent entries being temperature (EC) and precipitation (cm) for each day. Only a partial listing of **WEATHER.DAT** is given. The next listings are the text files for the transport and nutrient data (**TRANSPRT.TXT** and **NUTRIENT.TXT**). The remaining listings are text files of the several program outputs (**SUMMARY.TXT** and **MONTHLY.TXT**).

TRANSPRT.DAT

```
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.1,0,10,0,0,.065,10
0
0
0
0
0
"APR",.49,13.1,0,.25
"MAY",1,14.3,1,.25
"JUNE",1,15,1,.25
"JULY",1,14.6,1,.25
"AUG",1,13.6,1,.25
"SEPT",1,12.3,1,.25
"OCT",1,10.9,1,.06
"NOV",.49,9.7,0,.06
"DEC",.49,9,0,.06
"JAN",.49,9.3,0,.06
"FEB",.49,10.4,0,.06
"MAR",.49,11.7,0,.06
"CORN",3430,83.8,.214
"HAY",13085,79.4,.012
"PASTURE",5093,73.1,.016
"INACTIVE",3681,73.1,.017
"FOREST",56682,66.5,0
"LOGGING",20,0,.217
"BARN YARDS",41,92.2,0
"RES-imperv",104,98,0
"RES-perv",546,74,0
"COMM-imperv",49,98,0
"COMM-perv",41,74,0
"INDUS-imperv",34,98,0
"INDUS-perv",67,74,0
```

NUTRIENT.DAT

```
3000,1300,.34,.013
1,10,12
2.9,.26
2.8,.15
3,.25
1.6,.13
.19,.006
0,0
29.3,5.1
0.045,0.0045
0.012,0.0016
0.101,0.0112
0.012,0.0019
0.101,0.0112
0.012,0.0019
12.2,1.9
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
3800,825
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9407,1094,109,328
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WEATHER.DAT

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15,.8
10,.2
15,0
13,0
16,0
14,0
12,.5
11,.4
11,.8
14,.4
17,.2
!
!
!
```

TRANSPRT.TXT

TRANSPRT DATA

LAND USE	AREA(ha)	CURVE NO	KLSCP
CORN	3430.	83.8	0.21400
HAY	13085.	79.4	0.01200
PASTURE	5093.	73.1	0.01600
INACTIVE	3681.	73.1	0.01700
FOREST	56682.	66.5	0.00000
LOGGING	20.	0.0	0.21700
BARN YARDS	41.	92.2	0.00000
RES-imperv	104.	98.0	0.00000
RES-perv	546.	74.0	0.00000
COMM-imperv	49.	98.0	0.00000
COMM-perv	41.	74.0	0.00000
INDUS-imperv	34.	98.0	0.00000
INDUS-perv	67.	74.0	0.00000

MONTH	ET CV()	DAY HRS	GROW. SEASON	EROS. COEF
APR	0.490	13.1	0	.25
MAY	1.000	14.3	1	.25
JUNE	1.000	15	1	.25
JULY	1.000	14.6	1	.25
AUG	1.000	13.6	1	.25
SEPT	1.000	12.3	1	.25
OCT	1.000	10.9	1	.06
NOV	0.490	9.7	0	.06
DEC	0.490	9	0	.06
JAN	0.490	9.3	0	.06
FEB	0.490	10.4	0	.06
MAR	0.490	11.7	0	.06

ANTECEDENT RAIN+MELT FOR DAY -1 TO DAY -5
0 0 0 0 0
INITIAL UNSATURATED STORAGE (cm) = 10
INITIAL SATURATED STORAGE (cm) = 0
RECESSION COEFFICIENT (1/day) = .1
SEEPAGE COEFFICIENT (1/day) = 0
INITIAL SNOW (cm water) = 0
SEDIMENT DELIVERY RATIO = 0.065
UNSAT AVAIL WATER CAPACITY (cm) = 10

NUTRIENT.TXT

NUTRIENT DATA

RURAL LAND USE	DIS.NITR IN RUNOFF(mg/l)	DIS.PHOS IN RUNOFF(mg/l)
CORN	2.9	.26
HAY	2.8	.15
PASTURE	3	.25
INACTIVE	1.6	.13
FOREST	.19	.006
LOGGING	0	0
BARN YARDS	29.3	5.1

NUTRIENT CONCENTRATIONS IN RUNOFF FROM MANURED AREAS

LAND USE	NITROGEN(mg/l)	PHOSPHORUS(mg/l)
CORN	12.2	1.9

URBAN LAND USE	NITR.BUILD-UP(kg/ha-day)	PHOS.BUILD-UP(kg/ha-day)
RES-imperv	.045	.0045
RES-perv	.012	.0016
COMM-imperv	.101	.0112
COMM-perv	.012	.0019
INDUS-imperv	.101	.0112
INDUS-perv	.012	.0019

MONTH	POINT SOURCE NITR.(kg)	POINT SOURCE PHOS.(kg)
APR	3800	825
MAY	3800	825
JUNE	3800	825
JULY	3800	825
AUG	3800	825
SEPT	3800	825
OCT	3800	825
NOV	3800	825
DEC	3800	825
JAN	3800	825
FEB	3800	825
MAR	3800	825

NITROGEN IN GROUNDWATER (mg/l): 0.340
PHOSPHORUS IN GROUNDWATER (mg/l): 0.013
NITROGEN IN SEDIMENT (mg/kg): 3000
PHOSPHORUS IN SEDIMENT (mg/kg): 1300

MANURE SPREADING JAN THRU MAR

SEPTIC SYSTEMS

	POPULATION SERVED			
MONTH	NORMAL SYSTEMS	PONDING SYSTEMS	SHORT-CIRCUIT SYSTEMS	DISCHARGE SYSTEMS
APR	7572	881	88	264
MAY	7572	881	88	264
JUNE	9407	1094	109	328
JULY	9407	1094	109	328
AUG	9407	1094	109	328
SEPT	7572	881	88	264
OCT	7572	881	88	264
NOV	7572	881	88	264
DEC	7572	881	88	264
JAN	7572	881	88	264
FEB	7572	881	88	264
MAR	7572	881	88	264

PER CAPITA TANK EFFLUENT NITROGEN (g/day) = 12
PER CAPITA TANK EFFLUENT PHOSPHORUS (g/day) = 2.5
PER CAPITA GROWING SEASON NITROGEN UPTAKE (g/day) = 1.6
PER CAPITA GROWING SEASON PHOSPHORUS UPTAKE (g/day) = .4

SUMMARY.TXT

W. Branch Delaware River 4/78-3/82   4 -year means

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	9.6	1.9	6.5	0.3	6.7
MAY	9.8	7.5	5.3	0.3	5.6
JUNE	8.3	9.7	1.8	0.0	1.8
JULY	8.6	11.3	0.1	0.0	0.2
AUG	10.4	9.2	1.2	0.9	2.0
SEPT	11.6	5.8	0.1	0.1	0.2
OCT	11.5	3.1	4.3	0.1	4.4
NOV	8.2	0.7	6.6	0.4	7.0
DEC	8.0	0.2	5.6	0.4	6.0
JAN	8.1	0.1	5.0	1.1	6.1
FEB	8.5	0.2	5.7	1.8	7.4
MAR	9.8	0.8	10.9	2.4	13.3
ANNUAL	112.3	50.7	53.1	7.8	60.8

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	29.2	0.0	30.7	31.1	1.9	2.0
MAY	35.7	0.2	26.9	27.7	1.8	2.1
JUNE	23.5	0.0	10.7	10.9	1.1	1.2
JULY	28.1	0.0	4.9	5.2	1.0	1.0
AUG	45.8	1.2	17.2	21.0	1.7	3.2
SEPT	45.0	0.0	6.2	6.6	1.1	1.1
OCT	11.2	0.1	21.3	21.8	1.6	1.7
NOV	6.3	0.9	33.3	36.1	2.1	3.2
DEC	0.8	1.1	28.9	32.3	1.9	3.3
JAN	0.4	1.1	41.4	45.0	3.6	5.1
FEB	0.5	4.4	55.4	68.8	4.9	10.6
MAR	3.7	6.0	86.6	104.8	7.0	14.8
ANNUAL	230.4	15.0	363.4	411.0	29.6	49.3

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
CORN	3430.	18.03	47.43	52.92	84.64	7.78	21.52
HAY	13085.	13.27	2.66	48.60	55.39	2.60	5.54
PASTURE	5093.	8.65	3.55	13.22	16.74	1.10	2.63
INACTIVE	3681.	8.65	3.77	5.10	7.80	0.41	1.59
FOREST	56682.	5.47	0.00	5.89	5.89	0.19	0.19
LOGGING	20.	0.00	48.10	0.00	0.19	0.00	0.08
BARN YARDS	41.	36.11	0.00	4.34	4.34	0.76	0.76
RES-imperv	104.	74.11	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	9.20	0.00	0.00	0.29	0.00	0.04
COMM-imperv	49.	74.11	0.00	0.00	0.91	0.00	0.10
COMM-perv	41.	9.20	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.11	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	9.20	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				149.58	149.58	5.72	5.72
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.13	38.13	1.11	1.11
TOTAL				363.37	411.05	29.57	49.34

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W. Branch Delaware River 4/78-3/82 YEAR 1

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	5.2	1.7	3.1	0.0	3.1
MAY	7.9	7.4	2.1	0.0	2.1
JUNE	10.5	9.7	1.8	0.0	1.8
JULY	10.8	10.9	0.3	0.0	0.4
AUG	17.0	10.4	4.6	3.4	8.1
SEPT	7.6	5.5	0.4	0.1	0.4
OCT	11.6	3.1	3.9	0.0	3.9
NOV	4.7	0.7	3.7	0.1	3.8
DEC	12.6	0.2	5.2	0.0	5.2
JAN	19.1	0.2	8.7	3.8	12.6
FEB	4.0	0.1	4.6	0.5	5.1
MAR	10.9	1.1	16.5	4.6	21.0
YEAR	121.9	50.9	54.9	12.6	67.4

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	8.3	0.0	14.9	15.0	1.3	1.3
MAY	13.3	0.0	11.3	11.5	1.1	1.2
JUNE	29.3	0.0	10.8	11.0	1.2	1.2
JULY	39.4	0.0	5.8	6.1	1.0	1.0
AUG	109.6	4.7	54.9	69.5	3.8	10.0
SEPT	35.4	0.0	6.8	6.9	1.1	1.1
OCT	10.3	0.0	17.8	18.1	1.4	1.4
NOV	1.4	0.0	18.2	18.4	1.4	1.4
DEC	1.8	0.0	22.1	22.3	1.5	1.5
JAN	0.0	3.8	100.4	112.2	8.9	13.9
FEB	0.0	0.2	32.7	33.5	2.8	3.1
MAR	5.0	7.7	139.6	163.2	11.2	21.3
YEAR	253.8	16.5	435.3	487.5	36.6	58.3

SOURCE	AREA	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(Mg)			
CORN	3430.	24.70	52.26	81.18	116.13	12.18	27.33
HAY	13085.	19.27	2.93	70.59	78.06	3.78	7.02
PASTURE	5093.	13.86	3.91	21.18	25.06	1.76	3.45
INACTIVE	3681.	13.86	4.15	8.16	11.14	0.66	1.95
FOREST	56682.	9.81	0.00	10.57	10.57	0.33	0.33
LOGGING	20.	0.00	52.99	0.00	0.21	0.00	0.09
BARN YARDS	41.	44.22	0.00	5.31	5.31	0.92	0.92
RES-imperv	104.	82.95	0.00	0.00	0.86	0.00	0.09
RES-perv	546.	14.52	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	82.95	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	14.52	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	82.95	0.00	0.00	0.63	0.00	0.07
INDUS-perv	67.	14.52	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				154.61	154.61	5.91	5.91
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				435.30	487.55	36.58	58.33

W. Branch Delaware River 4/78-3/82 YEAR 2

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.0	1.8	8.5	0.7	9.2
MAY	15.3	7.6	6.8	0.6	7.5
JUNE	4.2	9.6	3.8	0.0	3.8
JULY	7.2	11.5	0.2	0.0	0.2
AUG	9.2	7.6	0.0	0.0	0.0
SEPT	14.3	6.0	0.0	0.1	0.1
OCT	11.2	3.4	6.7	0.1	6.7
NOV	13.5	0.9	8.6	0.8	9.4
DEC	5.0	0.4	6.7	0.0	6.7
JAN	3.7	0.2	4.3	0.0	4.3
FEB	4.0	0.1	1.4	0.0	1.4
MAR	14.8	0.7	10.7	3.0	13.7
YEAR	113.4	49.8	57.6	5.4	63.0

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	35.1	0.2	43.4	44.2	2.6	2.8
MAY	66.9	0.5	37.6	39.3	2.4	3.1
JUNE	11.2	0.0	17.2	17.3	1.3	1.4
JULY	15.4	0.0	4.9	5.1	0.9	1.0
AUG	19.1	0.0	4.4	4.6	0.9	1.0
SEPT	64.7	0.1	6.5	7.0	1.1	1.2
OCT	8.2	0.0	27.9	28.2	1.7	1.8
NOV	21.0	2.6	45.2	53.3	2.7	6.1
DEC	0.7	0.0	27.6	27.9	1.7	1.7
JAN	1.7	0.0	18.9	19.0	1.4	1.4
FEB	0.0	0.0	10.2	10.3	1.2	1.2
MAR	8.6	13.0	99.0	138.5	8.5	25.5
YEAR	252.7	16.4	342.6	394.6	26.4	48.1

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
CORN	3430.	15.22	52.02	37.28	72.08	5.26	20.34
HAY	13085.	10.54	2.92	38.60	46.05	2.07	5.29
PASTURE	5093.	6.11	3.89	9.33	13.19	0.78	2.45
INACTIVE	3681.	6.11	4.13	3.60	6.56	0.29	1.58
FOREST	56682.	3.26	0.00	3.51	3.51	0.11	0.11
LOGGING	20.	0.00	52.75	0.00	0.21	0.00	0.09
BARN YARDS	41.	33.71	0.00	4.05	4.05	0.70	0.70
RES-imperv	104.	74.86	0.00	0.00	0.88	0.00	0.09
RES-perv	546.	6.62	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	74.86	0.00	0.00	0.93	0.00	0.10
COMM-perv	41.	6.62	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	74.86	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.62	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				162.40	162.40	6.21	6.21
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.21	38.21	1.12	1.12
TOTAL				342.59	394.64	26.44	48.10

W. Branch Delaware River 4/78-3/82 YEAR 3

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	11.9	2.1	9.3	0.2	9.5
MAY	3.2	7.6	4.3	0.0	4.3
JUNE	10.4	9.1	0.2	0.0	0.2
JULY	9.5	11.5	0.0	0.0	0.0
AUG	9.9	10.3	0.0	0.0	0.0
SEPT	10.7	6.3	0.0	0.2	0.2
OCT	10.0	3.0	2.2	0.2	2.4
NOV	8.8	0.5	6.7	0.9	7.6
DEC	6.3	0.1	6.2	0.6	6.8
JAN	2.8	0.0	2.4	0.1	2.5
FEB	16.8	0.6	10.7	5.1	15.8
MAR	4.3	0.8	5.9	0.0	5.9
YEAR	104.6	52.0	47.8	7.4	55.2

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	45.5	0.0	40.9	41.2	2.2	2.3
MAY	6.7	0.0	19.2	19.3	1.4	1.4
JUNE	38.2	0.0	5.4	5.7	1.0	1.0
JULY	37.6	0.0	4.5	4.7	1.0	1.0
AUG	41.7	0.0	5.2	5.4	1.0	1.0
SEPT	36.6	0.1	7.1	7.5	1.1	1.2
OCT	15.9	0.1	16.3	17.0	1.5	1.7
NOV	0.5	0.8	40.3	43.1	2.5	3.6
DEC	0.2	0.6	33.9	35.8	2.1	2.9
JAN	0.0	0.0	15.6	15.8	1.5	1.6
FEB	2.1	13.0	126.8	166.2	11.1	28.0
MAR	0.7	0.0	25.7	26.0	1.7	1.7
YEAR	225.7	14.7	340.9	387.6	28.1	47.5

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
CORN	3430.	17.55	46.48	48.63	79.72	7.06	20.53
HAY	13085.	12.74	2.61	46.69	53.34	2.50	5.38
PASTURE	5093.	8.17	3.47	12.48	15.93	1.04	2.54
INACTIVE	3681.	8.17	3.69	4.81	7.46	0.39	1.54
FOREST	56682.	5.14	0.00	5.54	5.54	0.17	0.17
LOGGING	20.	0.00	47.13	0.00	0.18	0.00	0.08
BARN YARDS	41.	35.45	0.00	4.26	4.26	0.74	0.74
RES-imperv	104.	70.37	0.00	0.00	0.85	0.00	0.08
RES-perv	546.	8.69	0.00	0.00	0.28	0.00	0.04
COMM-imperv	49.	70.37	0.00	0.00	0.90	0.00	0.10
COMM-perv	41.	8.69	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	70.37	0.00	0.00	0.62	0.00	0.07
INDUS-perv	67.	8.69	0.00	0.00	0.03	0.00	0.01
GROUNDWATER				134.79	134.79	5.15	5.15
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				340.89	387.61	28.08	47.45

W. Branch Delaware River 4/78-3/82 YEAR 4

	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	10.3	2.1	5.0	0.1	5.1
MAY	13.0	7.4	8.1	0.5	8.6
JUNE	8.1	10.4	1.4	0.0	1.4
JULY	7.0	11.4	0.1	0.0	0.1
AUG	5.4	8.7	0.0	0.0	0.0
SEPT	13.7	5.4	0.0	0.0	0.0
OCT	13.1	2.9	4.6	0.2	4.7
NOV	5.9	0.7	7.3	0.0	7.3
DEC	8.2	0.1	4.3	1.1	5.5
JAN	6.6	0.1	4.6	0.4	5.0
FEB	9.1	0.1	5.9	1.5	7.4
MAR	9.0	0.7	10.7	1.8	12.5
YEAR	109.4	50.0	52.0	5.7	57.7

	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	28.0	0.0	23.5	23.9	1.6	1.7
MAY	55.8	0.4	39.3	40.8	2.3	2.9
JUNE	15.4	0.0	9.3	9.4	1.1	1.1
JULY	20.1	0.0	4.6	4.8	0.9	1.0
AUG	12.7	0.0	4.3	4.5	0.9	0.9
SEPT	43.2	0.0	4.6	4.9	1.0	1.0
OCT	10.5	0.2	23.0	23.8	1.6	1.9
NOV	2.4	0.0	29.5	29.7	1.7	1.7
DEC	0.5	3.6	32.0	43.2	2.2	7.0
JAN	0.0	0.7	30.6	32.9	2.6	3.5
FEB	0.0	4.3	51.9	65.1	4.5	10.1
MAR	0.7	3.1	82.0	91.6	6.7	10.7
YEAR	189.3	12.3	334.7	374.4	27.2	43.5

SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
CORN	3430.	14.66	38.98	44.57	70.64	6.60	17.89
HAY	13085.	10.52	2.19	38.54	44.12	2.06	4.48
PASTURE	5093.	6.48	2.91	9.90	12.79	0.82	2.08
INACTIVE	3681.	6.48	3.10	3.81	6.04	0.31	1.27
FOREST	56682.	3.67	0.00	3.95	3.95	0.12	0.12
LOGGING	20.	0.00	39.52	0.00	0.15	0.00	0.07
BARN YARDS	41.	31.05	0.00	3.73	3.73	0.65	0.65
RES-imperv	104.	68.27	0.00	0.00	0.87	0.00	0.09
RES-perv	546.	6.96	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	68.27	0.00	0.00	0.92	0.00	0.10
COMM-perv	41.	6.96	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	68.27	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.96	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				146.50	146.50	5.60	5.60
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				334.70	374.40	27.18	43.49

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Appendix E
Calculation Details

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This appendix provides details for the computation of GWLF input parameters requiring multiple steps.

Curve Number

The curve number must be developed within an ArcView project named *iepa_prepro.apr*, which contains all of the necessary extensions except Spatial Analyst. The Spatial Analyst extension of ArcView must be available for this calculation.

1. Add the landuse and STATSGO shapefiles and the landuse grid to the View. Open the attribute table for the STATSGO shapefile.
2. Add the attribute tables lookup.dbf and statsgoc.dbf to the project. The lookup table is common to any soil/landuse combination, but the STATSGO table must reflect the area for which the curve number is being calculated. In the statsgoc.dbf table, the field *comppct* identifies the percentage of each soil type in a map unit. This field is a string field and must be converted to a number field.
3. To convert the string field to a number field: add a new number field to the statsgoc.dbf attribute table named *comppct2*, and fill it with the values of the field *comppct* (to fill a number field with values from a string field, the calculation should read "*comppct.AsNumber*"). Delete the field *comppct*. Create a new number field, *comppct*, and fill it with the values of *comppct2*. Delete the field *commct2*. The *comppct* field now exists as a number field.
4. From the CRWR-PrePro menu, select "Soil Group Percentages". When prompted, input statsgo.dbf for the map unit table and statsgoc.dbf for the component table. The script will automatically create an output table, muidjoin.dbf, listing the percentage of each hydrologic soil group in each map unit.
5. From the CRWR-PrePro menu, select "Curve Number Grid". When prompted, select the STATSGO shapefile as the soils theme, the landuse shapefile as the landuse theme, lookup.dbf as the lookup table, muidjoin.dbf as the table with the soil group percentages, and set the analysis extent and the cell size to the landuse grid. The curve number grid can take between 2 and 15 minutes to compute depending on the computer speed and size of the basin.
6. Save the temporary curve number grid as a permanent grid named *CN_grid*.
7. To average the curve number grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-1 presents the resulting curve numbers associated with each landuse and used in the GWLF program.

Table E-1 Curve Numbers in the Washington County Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6
Row Crop	86.8	87.2	87.4	86.5	86.8	85.7
Small Grains	84.8	84.9	85.0	84.5	84.7	83.6
Rural Grassland	76.6	76.8	76.3	75.4	76.2	75.0
Deciduous	71.3	72.6	72.4	71.3	71.8	71.2
Coniferous	---	---	---	---	---	74.0
Animal Management	76.8	87.3	---	---	---	---
Dairy	---	---	75.0	---	---	---
Open Water	---	---	100.0	100.0	99.8	100.0
Shallow Marsh/ Wetland	---	100.0	---	100.0	---	---
Deep Marsh	---	---	100.0	100.0	---	---
Forested Wetland	100.0	99.6	100.0	---	---	100.0
Shallow Water Wetland	100.0	---	100.0	100.0	100.0	100.0
High Density	---	91.3	90.3	---	---	---

Soil Erodibility Factor (K)

The K factor is developed in ArcView and Excel.

1. In ArcView, add the attribute tables statsgoc.dbf and statsgol.dbf to the Table list. Join the statsgoc.dbf table to the statsgol.dbf table by field *muidsegnum*. This appends the percentage of each soil type to the soils in each layer. Export the joined table as a .dbf named statsgo_kf.dbf.

1. Open the table statsgo_kf.dbf in Excel. Remove all fields except *muid, layernum, kffact, kfact,* and *comppct*.
2. Sort the entire table by *layernum* then by *muid*. This promotes all soils in layer 1 to the top of the spreadsheet.
3. Remove all records for soils below layer 1.
4. Ensure the sum of the *comppct* field for each muid is equal to 100.
5. In a new column labeled *product*, multiply *kffact* by *comppct* and divide by 100 for each record. If the value in the *kffact* field is zero, use the value in the *kfact* field
6. In a new column labeled *kffact_r* (revised), sum *product* over each muid to obtain the revised K factor for each muid.
7. Copy the *kffact_r* column and use the "Paste Special/Values" option to paste the column into the *layernum* column. This is done so that the *kffact_r* values will be retained when the statsgo_kf.dbf table is saved and used again in ArcView.
8. Delete all columns except for *muid* and *kffact_r.* Delete any rows without a value in the *kffact_r* field.
9. Save the table.
10. In ArcView, add the table statsgo_kf.dbf, the STATSGO shapefile in UTM 16 projection, and the landuse grid. Join the statsgo_kf.dbf table to the statsgo.dbf table by *muid*. This attaches the average K factor to each muid in statsgo.dbf.
11. Set the analysis extent and cell size to the landuse grid.
12. Convert the SATSGO shapefile to a grid using the *kffact_r* field as the grid value.
13. To average the K factor grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-2 presents the resulting K-factors associated with each landuse and used in the GWLF program.

Table E-2 Weighted K factors for the Washington Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6
Row Crop	0.37	0.38	0.38	0.38	0.39	0.42
Small Grains	0.36	0.39	0.39	0.37	0.39	0.42
Rural Grassland	0.37	0.39	0.40	0.40	0.40	0.42
Deciduous	0.42	0.40	0.40	0.42	0.41	0.42
Coniferous	---	---	---	---	---	0.42

Topographic Factor (LS)
Computation of the LS factor is done in the ArcView project *iepa_prepro.apr*.

1. In ArcView, add the Digital Elevation Model (DEM) to the View
2. Set the analysis extent and cell size to the DEM.
3. Select "Fill Sinks" from the CRWR-PrePro menu to fill sinks in the DEM. Save the temporary grid as a permanent grid named *Fill_grid*.
4. Open the script "New_Slope" from the project window, and press the "Run" button to compute percent slopes from the filled DEM. Save the temporary grid as a permanent grid named *Slope_grid*.
5. Select "Flow Direction" from the CRWR-PrePro menu to derive the direction of flow through each grid cell. Save the temporary grid as a permanent grid named *Fdr_grid*.
6. Compute the theta grid (in radians) with the map calculator.
   - Map Calc. Statement: (([slope_grid] / 100)).Atan
   - Save Map Calc 1 as a permanent grid named *Theta_grid*.
7. Compute the S grid with the map calculator and a succession of calculations
   - Map Calc. 1: ([slope_grid] <= 9)
     - Output: 1 in cells where slope is less or equal to 9; zero elsewhere
   - Map Calc. 2: ((([theta_grid].Sin) * 10.8) + 0.03)
     - Output: S-value computed for slopes <= 9 in all cells
   - Map Calc. 3: ([Map Calculation 2 * [Map Calculation 1])
     - Output: Correct S-value in cells with slope <= 9; zero elsewhere
   - Map Calc. 4: ([slope_grid] > 9)
     - Output: 1 in cells where slope > 9, zero elsewhere
   - Map Calc. 5: ((([theta_grid].Sin) * 16.8) – 0.5)
     - Output: S-value computed for slopes > 9 in all cells
   - Map Calc. 6: ([Map Calculation 5] * [Map Calculation 4])
     - Output: Correct S-value in cells with slope > 9; zero elsewhere
   - Map Calc. 7: ([Map Calculation 3] + [Map Calculation 6])
     - Output: Correct S-value in each cell
   - Save Map Calculation 7 as a permanent grid named *S_grid*.

8. Compute the Beta grid with the map calculator.
   Map Calc. 1: ((([theta_grid].Sin) / 0.0896) /
   ((([theta_grid].Sin).Pow(0.8)) * 3.0 + 0.56)
   Save Map Calculation 1 as a permanent grid named *Beta_grid*.
9. Compute the M grid with the map calculator.
   Map Calc. 1: ([beta_grid] / ([beta_grid] + 1))
   Save Map Calculation 1 as permanent grid named *M_grid*.
10. Compute the flow length (Lambda) grid with the map calculator and a succession of calculations
   Map Calc. 1: ([fdr] = 1 OR [fdr] = 4 OR [fdr] = 16 OF [fdr] = 64)
      Output: 1 in cells flowing in cardinal direction and 0 in other cells
   Map Calc. 2: ([Map Calculation 1] * 30.8875)
      {30.885 = cell length}
      Output: 30.885 in cells flowing in cardinal direction and 0 in others.
   Map Calc. 3: ([Map Calculation 2] = 0)
      Output: 0 in cells flowing in cardinal direction and 1 in others
   Map Calc. 4: ([Map Calculation 3] * 43.682)
      {43.682= length across cell diagonal}
      Output: 43.682 in cells flowing in non-cardinal direction, 0 in others.
   Map Calc. 5: ([Map Calculation 4] + [Map Calculation 2])
      Output: correct flow lengths in each cell – 30.885 in cardinal, 43.682 in others
   Map Calc. 6: ([Map Calculation 5] * 100 / 2.54 / 12
      Output: flow length grid in feet
   Save Map Calculation 6 as a permanent grid named *Lambda_grid*
11. Compute the L with the map calculator.
   Map Calc. Statement: ([lambda_grid] / 72.6).Pow([m_grid])
   Save Map Calculation 1 as a permanent grid named *L_grid*.
12. Compute the LS grid with the map calculator.
   Map Calc. Statement: ([L-grid] * [S_grid])
   Save Map Calculation 1 as a permanent grid named *LS_grid*.
13. To average the LS grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table E-3 presents the resulting LS factors for each landuse used in GWLF.

Table E-3 Weighted LS factors for the Washington Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6
Row Crop	0.133	0.154	0.156	0.124	0.106	0.140
Small Grains	0.181	0.157	0.172	0.121	0.139	0.135
Rural Grassland	0.218	0.252	0.248	0.242	0.234	0.279
Deciduous	0.501	0.410	0.394	0.659	0.488	0.476
Coniferous	---	---	---	---	---	0.572

In the following discussions, fields in bold type represent calculations in Excel. Fields in non-bold type are input fields.

Cropping Management Factor (C factor)
The C factor is calculated in Excel. C factors were selected for each crop by tillage practice and crop rotation from the table provided by the Washington County NRCS office included as Appendix F. The Washington County NRCS office also provided an estimate of the percentage of each crop rotation across the Washington County Lake Watershed. The spreadsheet used to calculate a weighted c-factor for corn, soybeans, and small grains is shown at the end of this appendix. The values in Table 1 of the spreadsheet are a weighted average of values from columns C, F and I. This weighted average allows the influence of crop rotations to be included in the c-factors for the Washington County Lake Watershed. The values in the Table 1 are then weighted by the percentage of each tillage practice in Table 2 to determine a single c-factor for corn, soybeans, and small grains.

The weighted C factor for each crop is then appended to the table of Cropland Data Layer landuses and areas in the Washington County Lake Watershed. Table E-4 shows the Cropland Data Layer landuse areas, and C factors. C factors for landuses other than corn, soybean, and small grains were obtained from the table included as Appendix F.

Table E-4 Cropland Data Layer C factors for Washington County Lake Watershed

Landuse	C-factor
Corn	0.12
Sorghum	0.12
Soybeans	0.08
Winter Wheat	0.11
Other Small Grains & Hay	0.11
Double-Cropped WW/SB	0.12
Idle Cropland/CRP	0.004
Fallow/Idle Cropland	0.004
Pasture/Grassland/ Nonagriculture	0.004
Woods	0.003

The landuse classes in GWLF are represented by the Critical Trends Land Assessment classes rather than the Cropland Data Layer classes, so an area-weighted average was used to calculate the C factor coefficients for “Row Crop” and “Small Grains” in the Critical Trends Land Assessment landuse file. Table E-5 shows the Critical Trends Land Assessment landuse classes and the calculated C factor coefficients. The coefficient for “Row Crop” was calculated with an area-weighed average of the C factors for corn, soybeans, and half of the double-cropped WW/SB area in the Cropland Data Layer. The coefficient for “Small Grains” was calculated with an area-weighted average of the C factors for winter wheat, other small grains and hay, and half of double-cropped WW/SB area from the Cropland Data Layer.

Table E-5 C Factors by Critical Trends Assessment Landuse Classes in the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6
Row Crop	0.10	0.10	0.12	0.10	0.10	0.11
Small Grains	0.12	0.12	0.11	0.12	0.12	0.11
Rural Grassland	0.004	0.004	0.004	0.004	0.004	0.004
Deciduous	0.003	0.003	0.003	0.003	0.003	0.003
Coniferous	---	---	---	---	---	0.003

Evapotranspiration (ET) Cover Coefficient

The ET cover coefficient was calculated in an Excel spreadsheet. The cover coefficients for crops available in the GWLF Manual and the crops listed in the Cropland Data Layer landuse file differ. Therefore, crops in the Cropland Data Layer file were summed into classes matching the available crop cover coefficients. Table E-6 (at the end of this section) shows the original and adjusted areas for Washington County Lake. The adjusted sorghum area is the sum of sorghum and other small grains and hay, and the adjusted soybean area represents soybeans plus half of the double-cropped WW/SB area. Adjusted area from winter wheat represents winter wheat plus half the double-cropped WW/SB area.

Table E-7 shows the calculation of a single crop coefficient for each 10% of the growing season and for each calendar month. The ET cover coefficients for each crop were obtained from page 29 of the GWLF Manual. To create the coefficient for each 10% of the growing season, each crop coefficient in columns B-E was weighted by its corresponding area in Table E-8. An average monthly ET coefficient (column G) was calculated from the coefficients in Column F, and then each growing season was assigned to a calendar month (Column H).

Table E-7 Calculation of the Monthly Crop Evapotranspiration Cover Coefficients for Subbasin 1 of the Washington County Lake Watershed

A	B	C	D	E	**F**	**G**	H
% of Growing Season	Field Corn	Grain Sorghum	Winter Wheat	Soybeans	**Weighted Average ET Coefficient**	**Average Monthly ET Coefficient**	Month
0	0.45	0.3	1.08	0.3	**0.48**	**0.48**	Nov - Apr
10	0.51	0.4	1.19	0.35	**0.54**		
20	0.58	0.65	1.29	0.58	**0.70**	**0.62**	May
30	0.66	0.9	1.35	1.05	**0.99**		
40	0.75	1.1	1.4	1.07	**1.04**	**1.02**	June
50	0.85	1.2	1.38	0.94	**1.00**	**1.00**	July
60	0.96	1.1	1.36	0.8	**0.95**		
70	1.08	0.95	1.23	0.66	**0.88**	**0.91**	Aug
80	1.2	0.8	1.1	0.53	**0.82**		
90	1.08	0.65	0.75	0.43	**0.67**	**0.74**	Sep
100	0.7	0.5	0.4	0.36	**0.46**		
					0.48	**0.47**	Oct

Table E-8 shows the calculation of a single area-weighted crop coefficient for each month. First, the crop coefficients from Table E-7 were entered into Column B of Table E-8. The monthly ET values in Columns C, D, E, and F were obtained from the GWLF

Manual, pages 29 and 30. A monthly cover coefficient for water and wetlands was assumed to be 0.75. Finally, a single area-weighted crop coefficient for each month was calculated (Column G) from the adjusted areas in Table E-6 and the monthly ET cover coefficients in Table E-8.

Table E-8 Calculation of a Monthly ET Cover Coefficient in Subbasin 1 of the Washington County Lake Watershed

A	B	C	D	E	F	G
	Crop	Pasture	Forest	Urban	Water/ Wetland	**Weighted Average ET**
April	0.48	1.09	0.3	0.32	0.75	**0.53**
May	0.62	0.95	1	0.32	0.75	**0.71**
June	1.02	0.83	1	0.32	0.75	**0.99**
July	1.00	0.79	1	0.32	0.75	**0.96**
August	0.91	0.8	1	0.32	0.75	**0.90**
September	0.74	0.91	1	0.32	0.75	**0.79**
October	0.47	0.91	1	0.32	0.75	**0.59**
November	0.48	0.83	0.3	0.32	0.75	**0.50**
December	0.48	0.69	0.3	0.32	0.75	**0.48**
January	0.48	1.16	0.3	0.32	0.75	**0.54**
February	0.48	1.23	0.3	0.32	0.75	**0.55**
March	0.48	1.19	0.3	0.32	0.75	**0.54**

Table E-9 shows the calculated ET cover coefficients for each subbasin in the Washington County Lake Watershed.

Table E-9 ET Cover Coefficients in the Washington County Lake Watershed

Month	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4	Subbasin 5	Subbasin 6
April	0.53	0.52	0.62	0.56	0.57	0.67
May	0.71	0.67	0.78	0.81	0.81	0.87
June	0.99	0.95	0.95	1.02	0.95	0.94
July	0.96	0.93	1.01	0.99	0.94	0.94
August	0.90	0.87	0.97	0.91	0.90	0.92
September	0.79	0.78	0.88	0.79	0.84	0.88
October	0.59	0.57	0.68	0.69	0.73	0.78
November	0.50	0.48	0.55	0.52	0.53	0.61
December	0.48	0.45	0.52	0.51	0.50	0.58
January	0.54	0.54	0.63	0.57	0.58	0.68
February	0.55	0.55	0.65	0.58	0.60	0.70
March	0.54	0.54	0.64	0.57	0.59	0.69

A B C D E F G H I J K L M N

Corn-Soybean Rotation
15% of watershed

Conventional Till (Spring Plow)	
Corn after Soybean	0.30
Soybean after Corn[1,7]	0.30
Reduced-Till (20% Cover)	
Corn after Soybean[2]	0.25
Soybean after Corn[1,7]	0.14
Mulch-Till (30% cover)	
Corn after Soybean[2]	0.22
Soybean after Corn[1,7]	0.13
No-Till (90% Cover)	
Corn after Soybean[3]	0.12
Soybean after Corn[1]	0.03

Corn-Soybean-Wheat Rotation
75% of watershed

Conventional Till (Spring Plow)	
Corn after Wheat[4]	0.25
Soybean after Corn[1,7]	0.30
Wheat after Soybean[5,6]	0.17
Reduced-Till (20% Cover)	
Corn after Wheat[2,4]	0.147
Soybean after Corn[1,7]	0.145
Wheat after Soybean[5]	0.13
Mulch-Till (30% cover)	
Corn after Wheat[2,4]	0.126
Soybean after Corn[1,7]	0.13
Wheat after Soybean[5]	0.12
No-Till (90% Cover)	
Corn after Wheat[4]	0.03
Soybean after Corn[1]	0.03
Wheat after Soybean[3,5]	0.08

Corn-Soybean-Wheat-Meadow Rotation
10% of watershed

Conventional Till (Spring Plow)	
Corn after Meadow	0.11
Soybean after Corn[1,7]	0.30
Wheat after Soybean[5]	0.17
Meadow after Wheat	0.004
Reduced-Till (20% Cover)	
Corn after Meadow[2]	0.08
Soybean after Corn[1,7]	0.14
Wheat after Soybean[5]	0.13
Meadow after Wheat	0.004
Mulch-Till (30% cover)	
Corn after Meadow[2]	0.06
Soybean after Corn[1,7]	0.13
Wheat after Soybean[5]	0.12
Meadow after Wheat	0.004
No-Till (90% Cover)	
Corn after Meadow	0.01
Soybean after Corn[1]	0.03
Wheat after Soybean[3,5]	0.08
Meadow after Wheat	0.004

Table 1 C-factors Weighted by Percent of Crop Rotation in the Watershed

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0.24	0.30	0.17
Reduced Till	0.15	0.14	0.13
Mulch-Till	0.13	0.13	0.12
No-Till	0.04	0.03	0.08

Table 2 Percent of Each Tillage Practice

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0%	0%	0%
Reduced Till	60%	15%	10%
Mulch-Till	10%	30%	60%
No-Till	30%	55%	30%

C-factors Weighted by Percent of Each Tillage Practice

Corn	Soybeans	Small Grains	Grassland
0.12	0.08	0.11	0.004

[1]Assumed Drilled
[2]Tilled in the Spring, so c-factor is multiplied by 0.7
[3]Used 40% Cover
[4]Used Corn after Small Grain
[5]Used Small Grain after Soybean
[6]Used Fall Plow Value
[7]Used an average value of Spring and Fall tillage numbers

Table E-6 Cropland Data Layer Landuses, Areas and Adjusted Areas

Landuse	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4		Subbasin 5		Subbasin 6	
	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)
Corn	1,175,400	1,175,400	1,239,300	1,239,300	733,500	733,500	145,800	145,800	461,700	461,700	213,300	213,300
Sorghum	21,600	56,700	900	284,400	926,100	1,132,200		80,100		38,700		42,300
Soybeans	1,665,900	2,291,850	2,077,200	2,495,700		269,550	724,500	1,035,450	713,700	953,100	102,600	220,050
Winter Wheat	117,000	742,950	6,300	424,800	297,000	566,550	193,500	504,450	154,800	394,200	233,100	350,550
Other Small Grains & Hay	35,100		283,500		206,100		80,100		38,700		42,300	
Double-Cropped WW/SB	1,251,900		837,000		539,100		621,900		478,800		234,900	
Idle Cropland/CRP	2,700	2,700	20,700	20,700	10,800	10,800	2,700	2,700	5,400	5,400	1,800	1,800
Fallow/Idle Cropland	151,200	151,200	329,400	329,400	338,400	338,400	36,900	36,900	98,100	98,100	118,800	118,800
Pasture/Grassland/Nonag	551,700	551,700	739,800	739,800	759,600	759,600	410,400	410,400	667,800	667,800	408,600	408,600
Woods	721,800	721,800	559,800	559,800	634,500	634,500	878,400	878,400	1,280,700	1,280,700	617,400	617,400
Clouds	13,500	13,500	11,700	11,700	6,300	6,300	1,800	1,800	3,600	3,600		0
Urban	10,800	10,800	17,100	17,100	21,600	21,600	1,800	1,800	7,200	7,200	22,500	22,500
Water	21,600	21,600	11,700	11,700	22,500	22,500	165,600	165,600	382,500	382,500	230,400	230,400
Buildings/Homes/Subdivisions	24,300	24,300	63,000	63,000	49,500	49,500	20,700	20,700	44,100	44,100	46,800	46,800
Wetlands	18,000	18,000	21,600	21,600	18,900	18,900	40,500	40,500	78,300	78,300	72,900	72,900
Total	5,782,500	5,782,500	6,219,000	6,219,000	4,563,900	4,563,900	3,324,600	3,324,600	4,415,400	4,415,400	2,345,400	2,345,400

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Appendix F
Crop Management "C" Factor Values
for Rainfall E.I. Distribution Curve #19

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TABLE 3 - CROP MANAGEMENT "C" FACTOR VALUES FOR RAINFALL "E.I." DISTRIBUTION CURVE # 19 1/

CROP SEQUENCE		FALL PLOW	SPRING PLOW	CHISEL - DISK - RIDGE 2/ % Cover After Plant				No-Till % Cover After Plant			
				20%	30%	40%	50%	60%	70%	80%	90%
CORN after Soybeans		.43	.30	.35	.32	.27	---	20% .20	30% .16	40% .12	3/
CORN after Corn		.38	.25	.20	.18	.15	.13	.07	.05	.04	.03
CORN after Small Grain		.39	.25	.21	.18	.16	.14	.07	.05	.04	.03
CORN after Meadow 4/		.17	.11	.11	.09	.08	.07	.03	.02	.01	.01
CORN 2nd yr. after Meadow 4/		.33	.21	.18	.16	.14	.12	.06	.05	.04	.03
SOYBEANS after Soybeans 5/	Wide Row	.48	.37	.37	.36	---	---	20% .22	30% .17	40% .13	3/
	Drill	.42	.29	.34	.33	---	---	.19	.14	.10	
SOYBEANS after Corn 5/	Wide Row	.40	.31	.19	.16	.14	.12	.08	.06	.04	.03
	Drill	.34	.25	.17	.15	.13	.11	.07	.06	.04	.03
SOYBEANS after Sm. Grain 5/	Wide Row	.45	.27	.22	.19	.17	.15	.08	.07	.04	.03
	Drill	.38	.22	.18	.16	.14	.12	.08	.07	.04	.03
SOYBEANS after Meadow 4, 5/	Wide Row	.19	.14	.09	.07	.06	.05	.03	.02	.01	.01
	Drill	.16	.11	.08	.07	.06	.05	.03	.02	.01	.01
SOYBEANS after Corn 2nd year after meadow 5/	Wide Row	.35	.26	.16	.14	.12	.11	.08	.06	.04	.03
	Drill	.30	.21	.15	.13	.11	.10	.07	.06	.04	.03
SMALL GRAIN after Corn (Grain) 6/		.15	.14	.11	.10	.09	.08	.06	.05	.04	.03
SMALL GRAIN after Corn (Silage) 7/		.22	---	.22	---	---	---	.16	---	---	---
SMALL GRAIN after Soybeans 6/		.17	.15	.13	.12	---	---	20% .10	30% .09	40% .08	3/

WHEAT/SOYBEANS (Double Crop)

		Tillage for Soybeans Plow	Disk	No-Till
Tillage	Plow	.32	.20	.16
for	Disk	.24	.12	.08
Wheat	No-Till	.20	.08	.04

Meadow (Full year-Established)

Grass-Legume	.004
Legume only	.02

USDA-SCS-Illinois
February, 1982 *

Footnotes for "C" Factor Tables

1. Values in this table are based on high level management with yields equal to or exceeding the following: corn - 100 bu/ac; soybeans - 40 bu/ac; wheat - 45 bu/ac; oats - 60 bu/ac; meadow - 3 tons/ac. For medium level management multiply factors by 1.2.

2. Values for chisel and disk systems are for fall primary tillage and two secondary tillage operations prior to planting. For primary tillage in the spring and ridge planting up and down hill multiply values by the appropriate factor: E.I. Curve 14-.9; E.I. Curve 16-.8; E.I. Curve 19-.7. For ridge planting on the contour, multiply values by the appropriate factor: E.I. Curve 14-.7; E.I. Curve 16-.6; E.I. Curve 19-.5. (These factors are in addition to the appropriate "P" factor.) Ridge planting is applicable only for row crops following row crops.

3. Percentages apply only to crops following soybeans.

4. Values are based on sod or a grass-legume mixture consisting of at least 50% grass and has been established at least one full growing season. If meadow stand is primarily legume, multiply factor by 1.2.

5. Use wide row factors for row widths greater than 20 inches and drill factors for 20 inches and less.

6. The same factors are applicable for both small grain with and without meadow seedings.

7. Factors for Disk and No-till are for the tillage system with no residue on surface after planting.

RLD:tm:6/7

Appendix G
Metalimnion Charts

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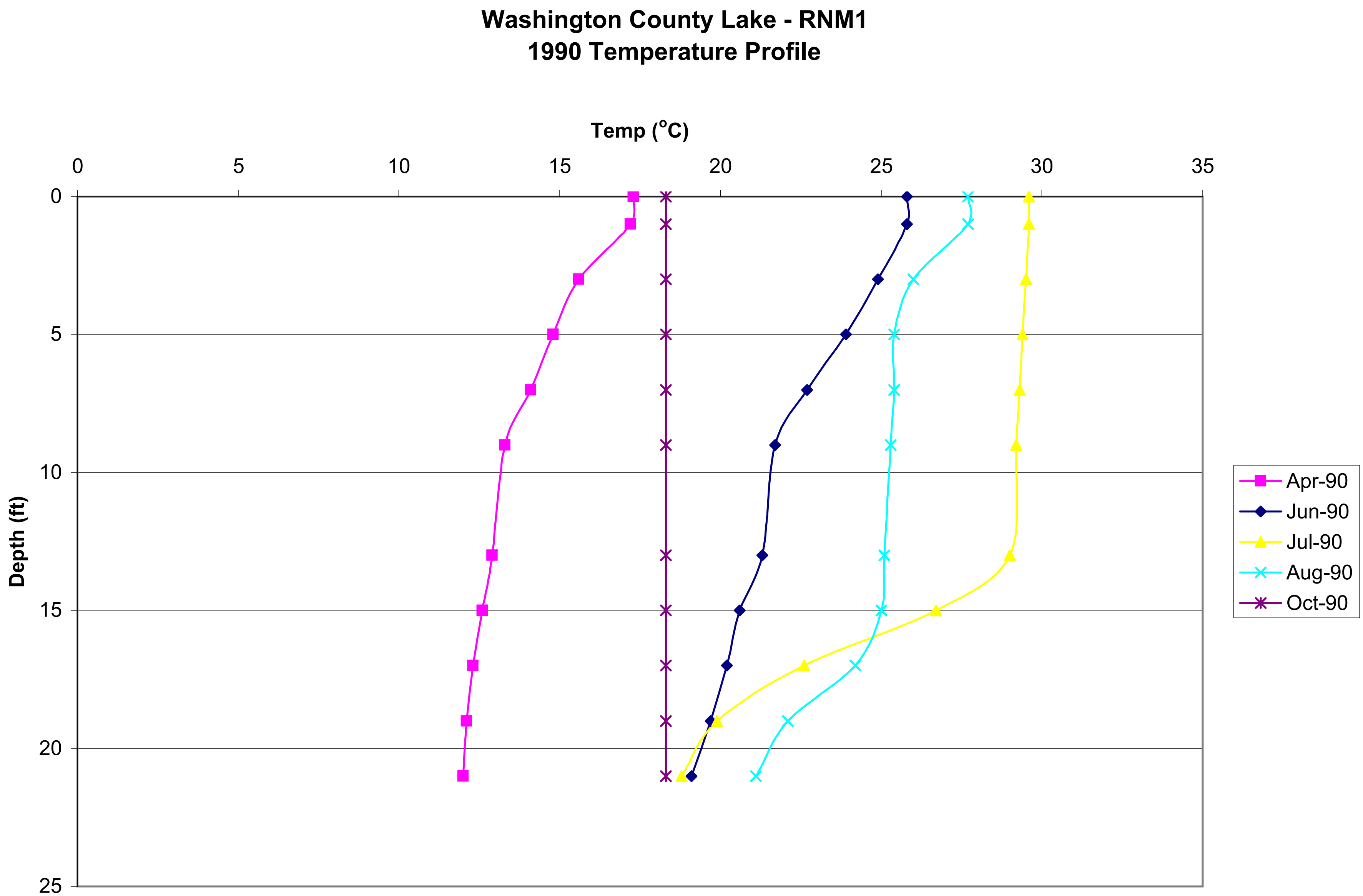
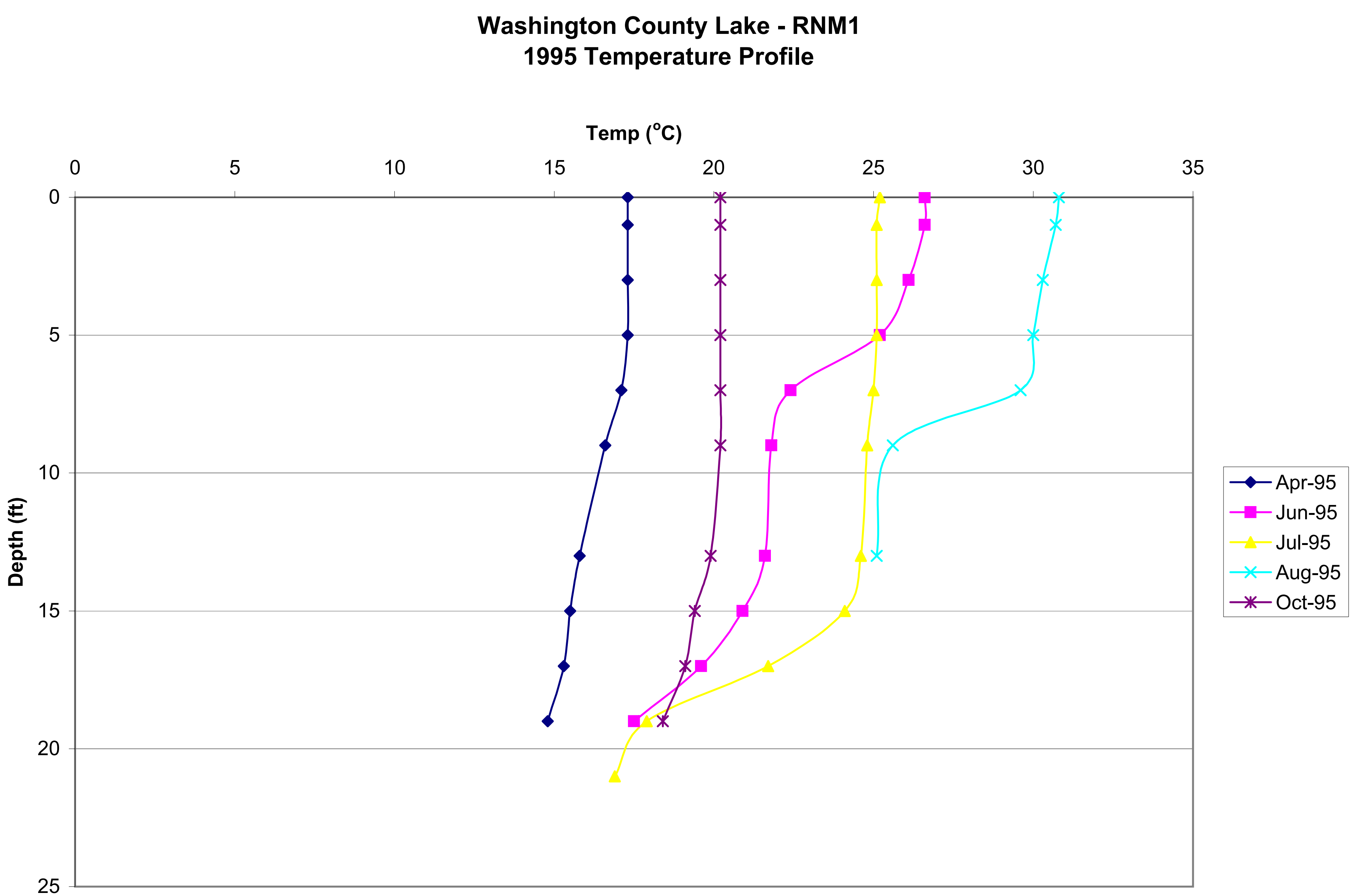
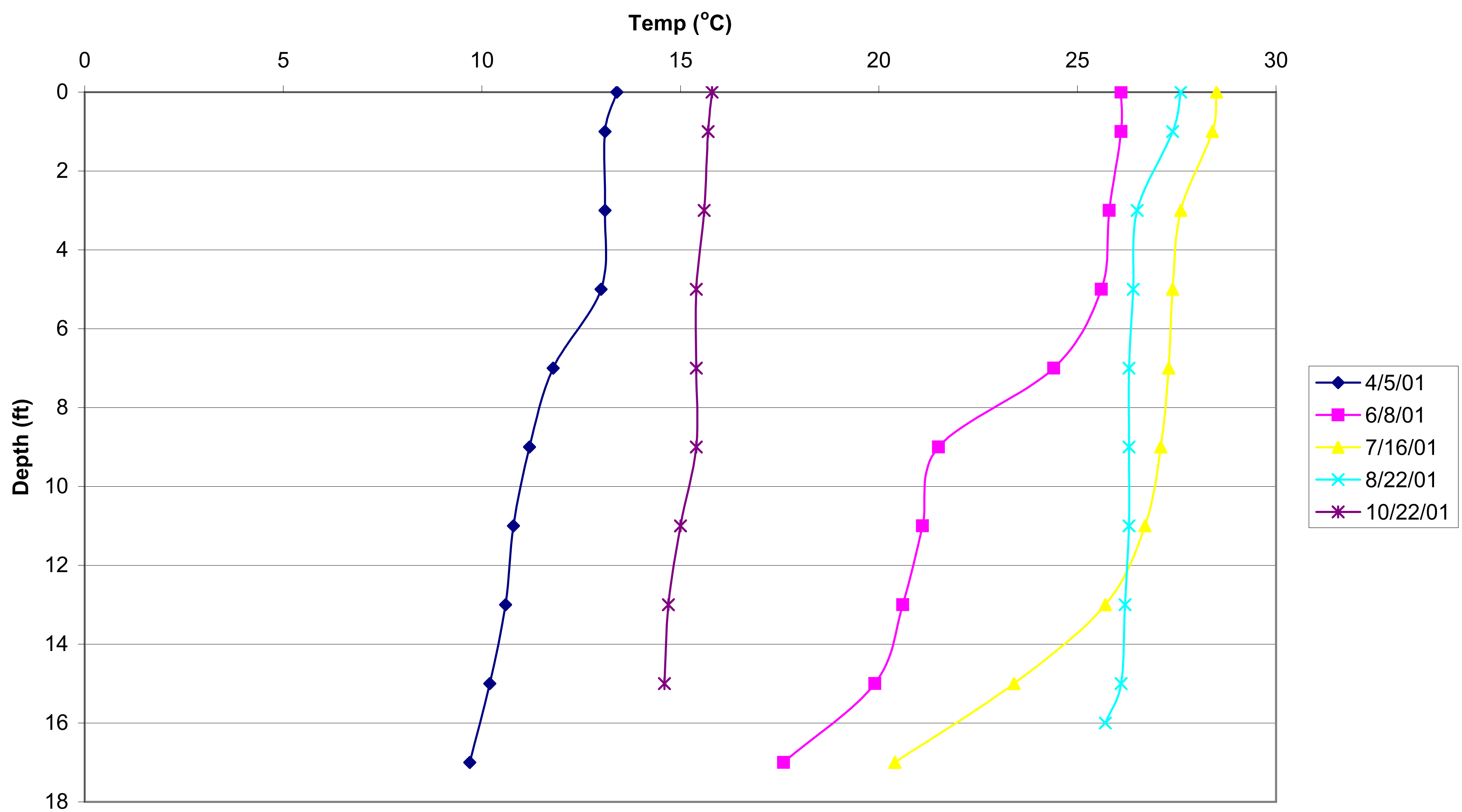
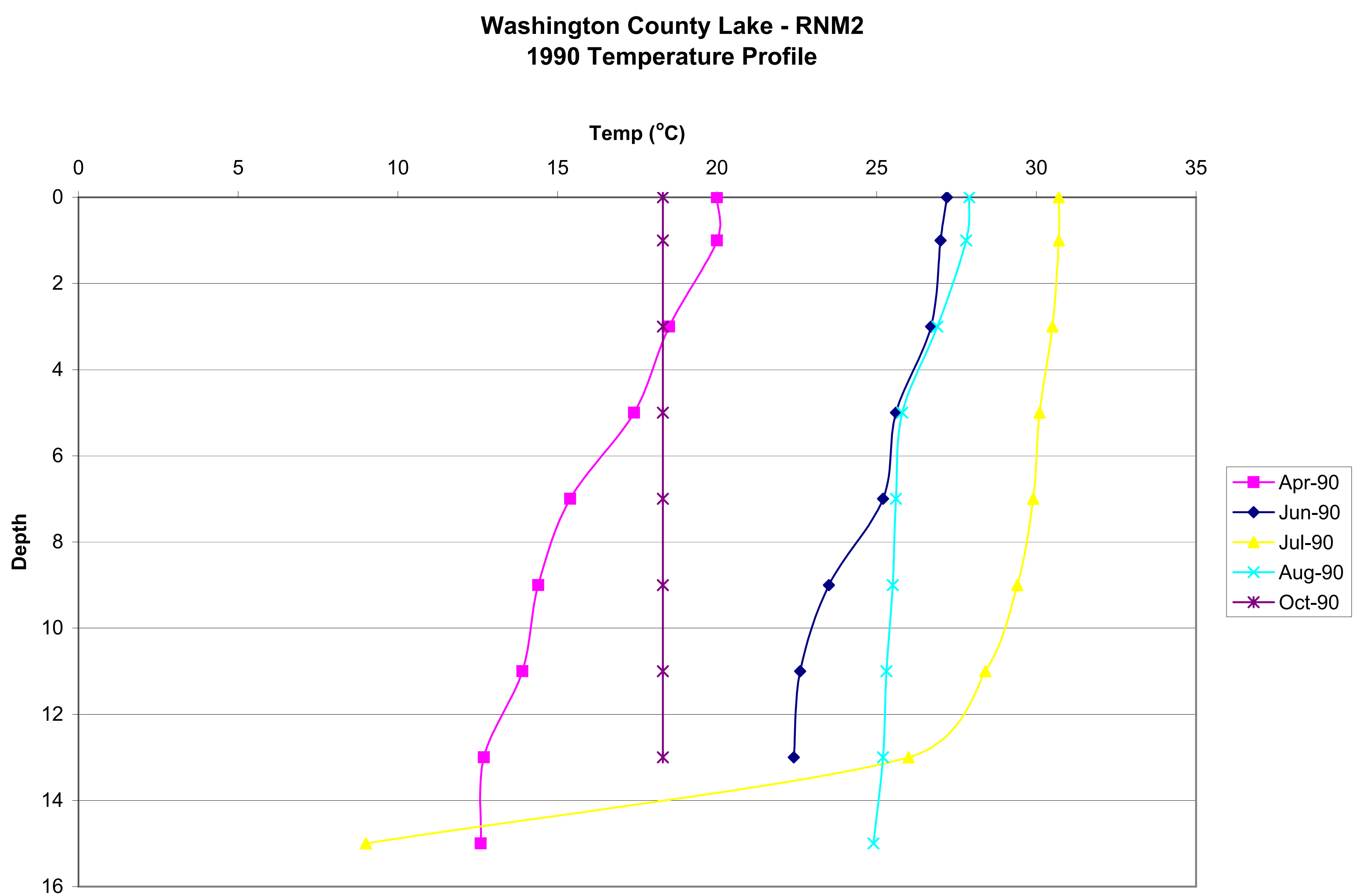

Washington County Lake - RNM1
1990 Temperature Profile
Temp (°C)
0
5
10
15
20
25
30
35
Depth (ft)
0
5
10
15
20
25
Apr-90
Jun-90
Jul-90
Aug-90
Oct-90

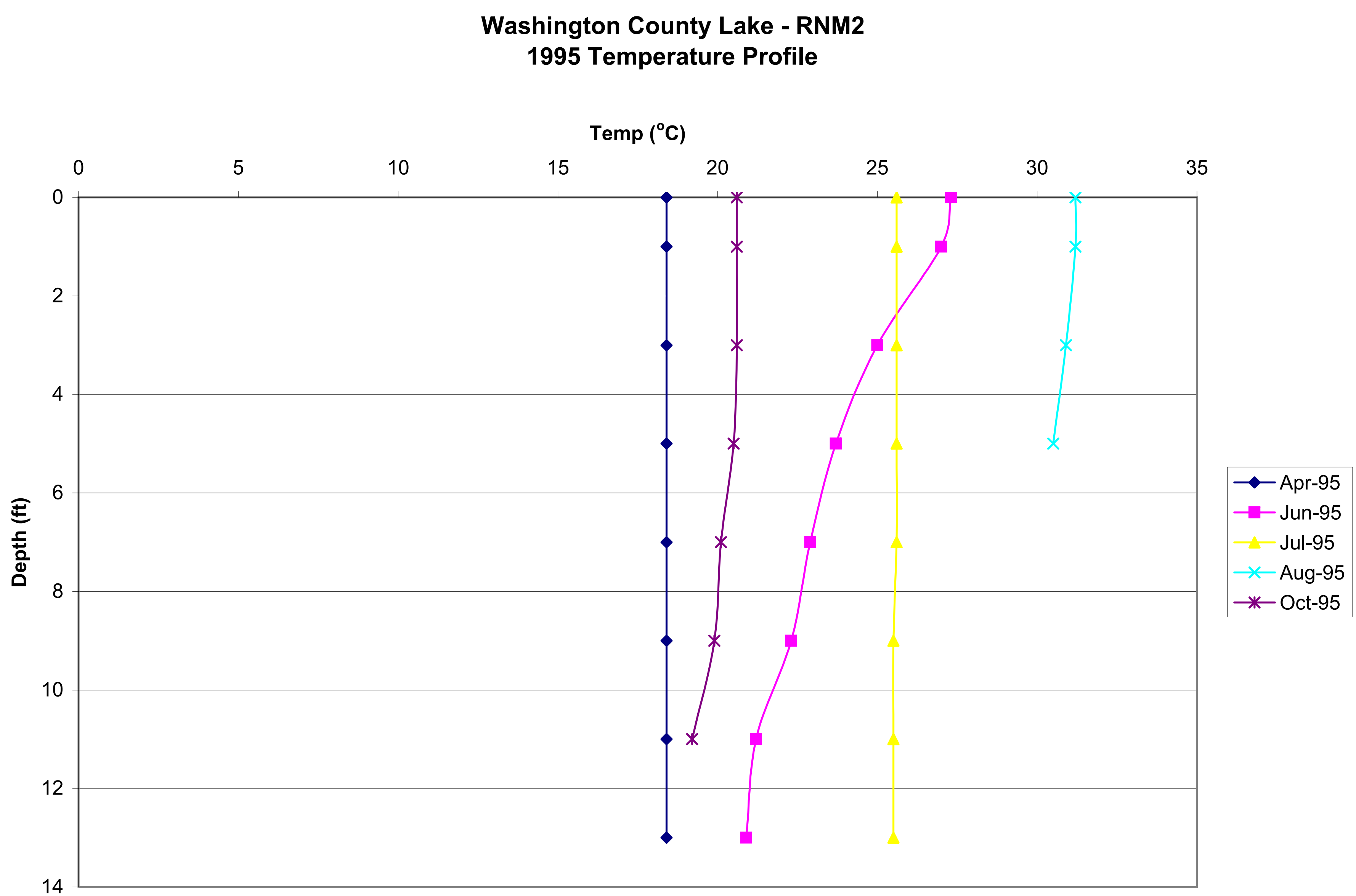

Washington County Lake - RNM1
1995 Temperature Profile
Temp (°C)
0
5
10
15
20
25
30
35
Depth (ft)
0
5
10
15
20
25
Apr-95
Jun-95
Jul-95
Aug-95
Oct-95

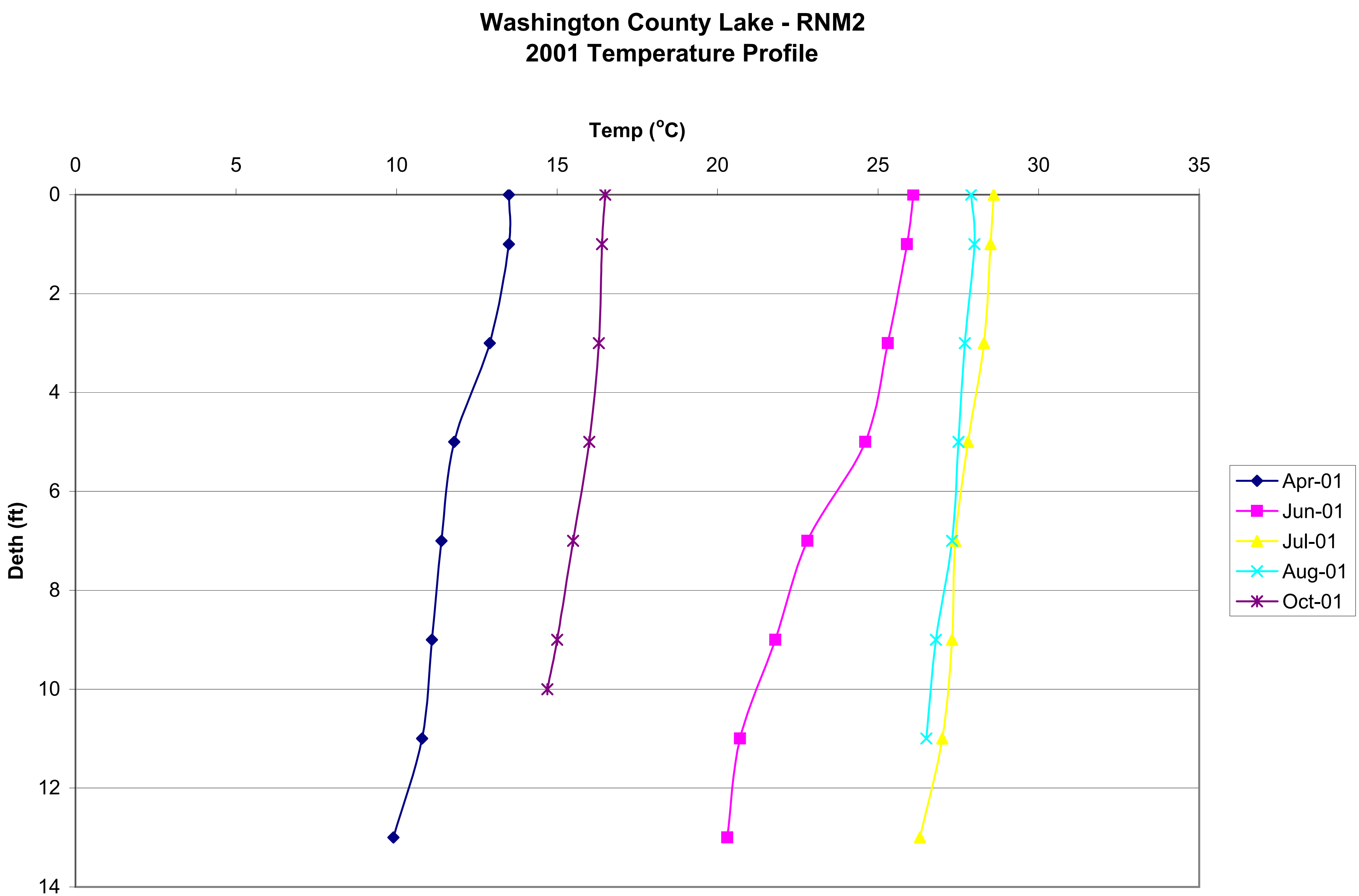
Washington County Lake - RNM1
2001 Temperature Profile



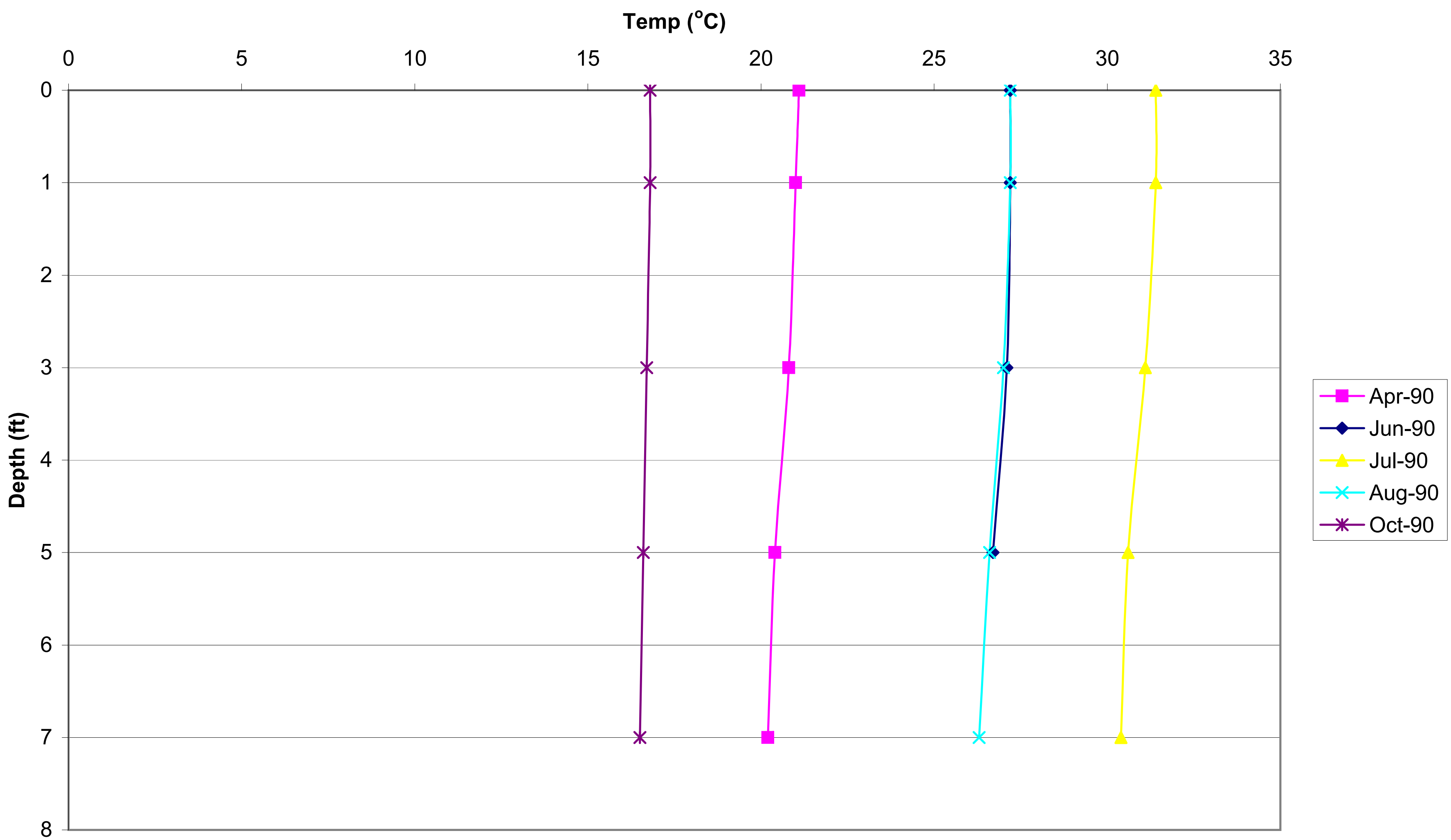


Washington County Lake - RNM2
1990 Temperature Profile
Temp (°C)
0
5
10
15
20
25
30
35
Depth
0
2
4
6
8
10
12
14
16
Apr-90
Jun-90
Jul-90
Aug-90
Oct-90

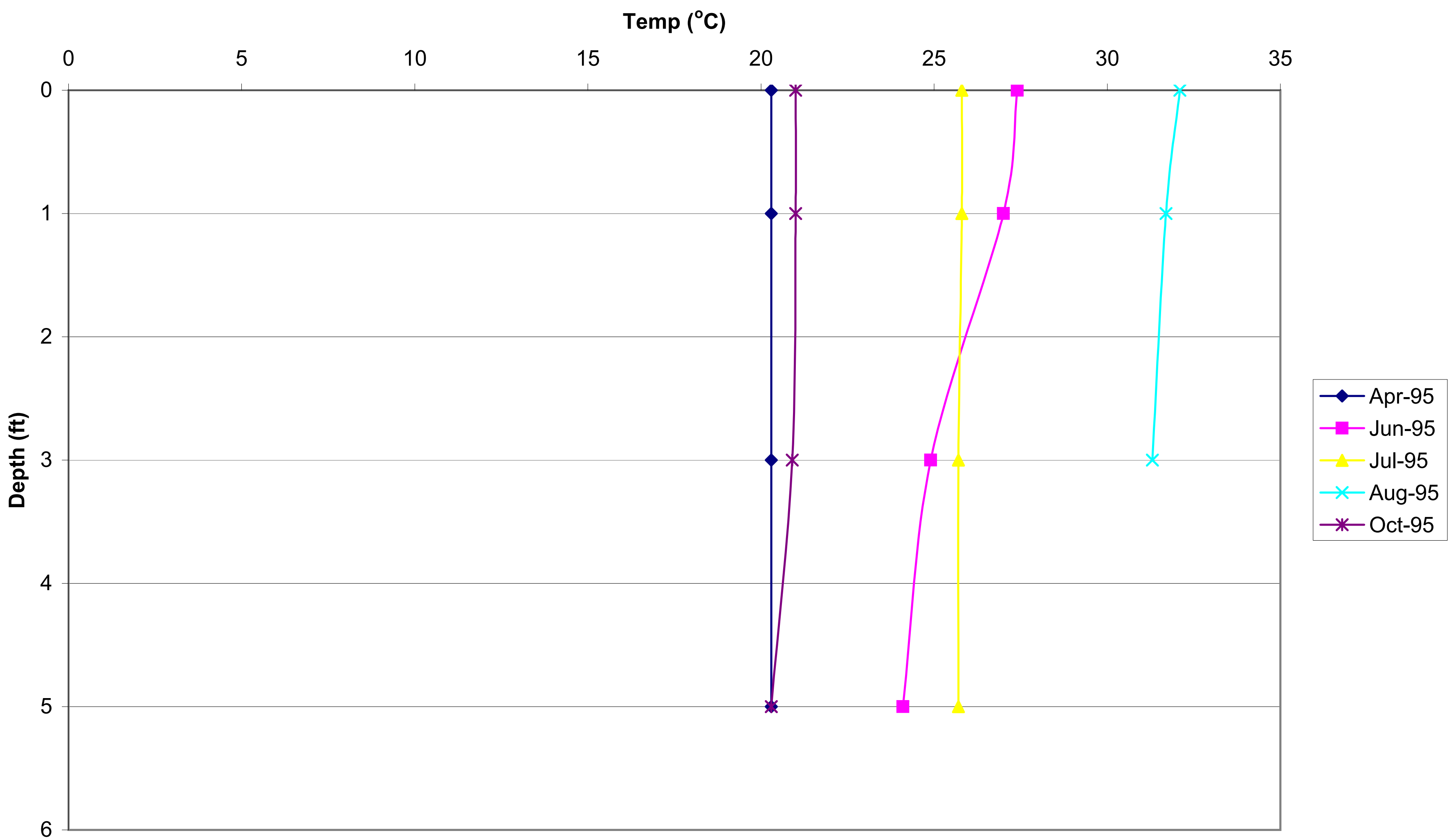

Washington County Lake - RNM2
1995 Temperature Profile
Temp (°C)
0
5
10
15
20
25
30
35
Depth (ft)
0
2
4
6
8
10
12
14
Apr-95
Jun-95
Jul-95
Aug-95
Oct-95

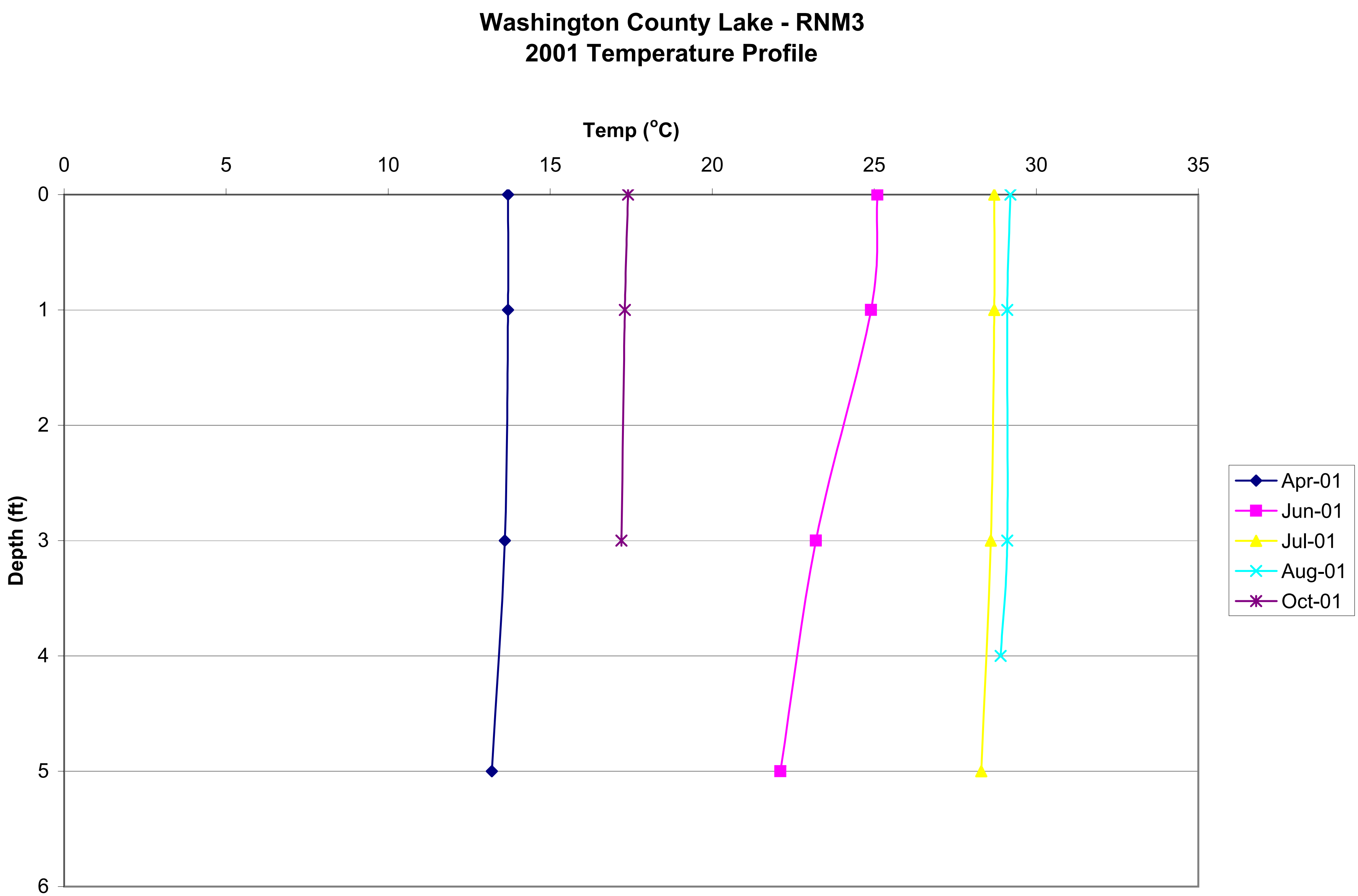

Washington County Lake - RNM2
2001 Temperature Profile
Temp (°C)
0
5
10
15
20
25
30
35
Deth (ft)
0
2
4
6
8
10
12
14
Apr-01
Jun-01
Jul-01
Aug-01
Oct-01

Washington County Lake - RNM3
1990 Temperature Profile



Washington County Lake - RNM3
1995 Temperature Profile




Washington County Lake - RNM3
2001 Temperature Profile
Temp (°C)
0
5
10
15
20
25
30
35
Depth (ft)
0
1
2
3
4
5
6
Apr-01
Jun-01
Jul-01
Aug-01
Oct-01

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Appendix H
Sensitivity Analysis - BATHTUB Output Files

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H.1 BATHTUB Sensitivity

This appendix provides the BATHTUB output files for the soil phosphorus sensitivity analysis. For each modeled year, the BATHTUB model was run with soil phosphorus values of 1,320 ppm and 1,672 ppm. The output concentrations from BATHTUB were not calibrated so that the raw model results could be compared.

BATHTUB Output for 1990 Sensitivity Analysis
Constant Sediment Phosphorus Concentration of 1,320 mg/kg

CASE: WC Lake 1990 - No Calibration (Sed 1320)

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	198.6	.26	117.3	.46	1.69	2.06	1.96	1.01
CHL-A	MG/M3	98.6	.27	51.8	.48	1.90	2.36	1.86	1.17
SECCHI	M	.4	.13	.7	.41	.57	-4.49	-2.04	-1.33
ORGANIC N	MG/M3	.0	.00	1344.6	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	90.0	.41	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	170.0	.36	62.5	.45	2.72	2.78	3.72	1.74
CHL-A	MG/M3	66.4	.38	35.8	.73	1.86	1.63	1.79	.75
SECCHI	M	.6	.16	1.0	.94	.57	-3.48	-2.00	-.59
ORGANIC N	MG/M3	.0	.00	981.9	.62	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	62.6	.81	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	221.8	.79	55.3	.45	4.01	1.77	5.16	1.53
CHL-A	MG/M3	61.9	.35	30.1	1.27	2.05	2.08	2.08	.55
SECCHI	M	.6	.13	1.2	1.73	.53	-4.84	-2.25	-.36
ORGANIC N	MG/M3	.0	.00	849.4	1.08	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	51.4	1.55	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	188.8	.45	73.8	.45	2.56	2.08	3.49	1.47
CHL-A	MG/M3	73.0	.34	38.2	.65	1.91	1.90	1.87	.88
SECCHI	M	.5	.15	1.0	.84	.56	-3.97	-2.08	-.68
ORGANIC N	MG/M3	.0	.00	1036.6	.56	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	66.5	.70	.00	.00	.00	.00

CASE: WC Lake 1990 - No Calibration (Sed 1320)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	2.320	.000E+00	.000	.400
2	1	Subbasin 2	6.220	2.530	.000E+00	.000	.407
3	1	Subbasin 3	4.580	1.760	.000E+00	.000	.384
4	1	Subbasin 4	3.330	1.340	.000E+00	.000	.402
5	1	Subbasin 5	4.420	1.800	.000E+00	.000	.407
6	1	Subbasin 6	2.340	.940	.000E+00	.000	.402
PRECIPITATION			.979	.989	.391E-01	.200	1.010
TRIBUTARY INFLOW			26.690	10.690	.000E+00	.000	.401
***TOTAL INFLOW			27.669	11.679	.391E-01	.017	.422
ADVECTIVE OUTFLOW			27.669	10.854	.100E+00	.029	.392
***TOTAL OUTFLOW			27.669	10.854	.100E+00	.029	.392
***EVAPORATION			.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	600.0	26.9	.000E+00	.0	.000	258.6	103.4
2	1	Subbasin 2	600.1	26.9	.000E+00	.0	.000	237.2	96.5
3	1	Subbasin 3	701.7	31.5	.000E+00	.0	.000	398.7	153.2
4	1	Subbasin 4	100.0	4.5	.000E+00	.0	.000	74.6	30.0
5	1	Subbasin 5	99.9	4.5	.000E+00	.0	.000	55.5	22.6
6	1	Subbasin 6	99.9	4.5	.000E+00	.0	.000	106.3	42.7
PRECIPITATION			29.4	1.3	.216E+03	100.0	.500	29.7	30.0
TRIBUTARY INFLOW			2201.6	98.7	.000E+00	.0	.000	205.9	82.5
***TOTAL INFLOW			2230.9	100.0	.216E+03	100.0	.007	191.0	80.6
ADVECTIVE OUTFLOW			600.2	26.9	.743E+05	34469.7	.454	55.3	21.7
***TOTAL OUTFLOW			600.2	26.9	.743E+05	34469.7	.454	55.3	21.7
***RETENTION			1630.8	73.1	.745E+05	34529.7	.167	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
11.09	.4024	188.8	.3696	2.7054	.7310

1990 – *Constant Sediment Phosphorus Concentration of 1,672 mg/kg*

CASE: WC Lake 1990- No Calib (sed1672)

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	198.6	.26	123.4	.46	1.61	1.86	1.77	.91
CHL-A	MG/M3	98.6	.27	53.2	.47	1.85	2.26	1.78	1.13
SECCHI	M	.4	.13	.7	.40	.58	-4.30	-1.95	-1.31
ORGANIC N	MG/M3	.0	.00	1375.9	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	92.5	.41	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	170.0	.36	63.5	.45	2.68	2.74	3.66	1.71
CHL-A	MG/M3	66.4	.38	36.5	.73	1.82	1.57	1.73	.73
SECCHI	M	.6	.16	1.0	.93	.58	-3.37	-1.94	-.57
ORGANIC N	MG/M3	.0	.00	998.9	.62	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	63.9	.81	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	221.8	.79	56.0	.45	3.96	1.75	5.12	1.51
CHL-A	MG/M3	61.9	.35	30.7	.72	2.01	2.02	2.02	.88
SECCHI	M	.6	.13	1.2	.92	.54	-4.70	-2.18	-.65
ORGANIC N	MG/M3	.0	.00	864.1	.59	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	52.5	.80	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	188.8	.45	75.9	.45	2.49	2.02	3.39	1.43
CHL-A	MG/M3	73.0	.34	39.1	.61	1.87	1.84	1.80	.90
SECCHI	M	.5	.15	1.0	.71	.57	-3.84	-2.01	-.77
ORGANIC N	MG/M3	.0	.00	1056.5	.53	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	68.0	.65	.00	.00	.00	.00

CASE: WC Lake 1990- No Calib (sed1672)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	2.320	.000E+00	.000	.400
2	1	Subbasin 2	6.220	2.530	.000E+00	.000	.407
3	1	Subbasin 3	4.580	1.760	.000E+00	.000	.384
4	1	Subbasin 4	3.330	1.340	.000E+00	.000	.402
5	1	Subbasin 5	4.420	1.800	.000E+00	.000	.407
6	1	Subbasin 6	2.340	.940	.000E+00	.000	.402
PRECIPITATION			.979	.989	.391E-01	.200	1.010
TRIBUTARY INFLOW			26.690	10.690	.000E+00	.000	.401
***TOTAL INFLOW			27.669	11.679	.391E-01	.017	.422
ADVECTIVE OUTFLOW			27.669	10.854	.100E+00	.029	.392
***TOTAL OUTFLOW			27.669	10.854	.100E+00	.029	.392
***EVAPORATION			.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	600.0	25.7	.000E+00	.0	.000	258.6	103.4
2	1	Subbasin 2	700.1	30.0	.000E+00	.0	.000	276.7	112.5
3	1	Subbasin 3	701.7	30.1	.000E+00	.0	.000	398.7	153.2
4	1	Subbasin 4	100.0	4.3	.000E+00	.0	.000	74.6	30.0
5	1	Subbasin 5	99.9	4.3	.000E+00	.0	.000	55.5	22.6
6	1	Subbasin 6	99.9	4.3	.000E+00	.0	.000	106.3	42.7
PRECIPITATION			29.4	1.3	.216E+03	100.0	.500	29.7	30.0
TRIBUTARY INFLOW			2301.5	98.7	.000E+00	.0	.000	215.3	86.2
***TOTAL INFLOW			2330.9	100.0	.216E+03	100.0	.006	199.6	84.2
ADVECTIVE OUTFLOW			608.0	26.1	.764E+05	35438.8	.455	56.0	22.0
***TOTAL OUTFLOW			608.0	26.1	.764E+05	35438.8	.455	56.0	22.0
***RETENTION			1722.9	73.9	.766E+05	35499.4	.161	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
11.09	.4024	188.8	.3538	2.8266	.7392

BATHTUB Output for 1995 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 1,320 mg/kg

CASE: WC Lake 1995 - No Calibration (Sed 1320)

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	185.2	.25	167.2	.46	1.11	.42	.38	.20
CHL-A	MG/M3	55.7	.46	45.2	.43	1.23	.45	.61	.33
SECCHI	M	.4	.32	.4	.36	.90	-.33	-.38	-.22
ORGANIC N	MG/M3	.0	.00	1281.0	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	106.0	.29	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	146.6	.26	89.2	.45	1.64	1.91	1.85	.96
CHL-A	MG/M3	55.2	.50	53.5	.48	1.03	.06	.09	.05
SECCHI	M	36.0	.86	.7	.50	51.07	4.57	14.05	3.95
ORGANIC N	MG/M3	.0	.00	1382.0	.43	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	93.0	.47	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	269.6	1.05	78.3	.45	3.44	1.18	4.60	1.08
CHL-A	MG/M3	50.5	.73	39.6	.56	1.27	.33	.70	.26
SECCHI	M	.7	.07	.9	.59	.81	-2.95	-.75	-.35
ORGANIC N	MG/M3	.0	.00	1073.4	.45	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	70.6	.45	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	184.4	.53	105.1	.45	1.75	1.07	2.09	.81
CHL-A	MG/M3	54.2	.54	48.3	.43	1.12	.22	.33	.17
SECCHI	M	19.4	.85	.7	.42	28.79	3.94	12.00	3.54
ORGANIC N	MG/M3	.0	.00	1286.3	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	90.8	.41	.00	.00	.00	.00

```
CASE: WC Lake 1995 - No Calibration (Sed 1320)
 GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
 ID  T LOCATION                 KM2          MEAN  VARIANCE    CV       M/YR
 ----------------------------------------------------------------------------
  1  1 Subbasin 1             5.800         3.400  .000E+00  .000       .586
  2  1 Subbasin 2             6.220         3.730  .000E+00  .000       .600
  3  1 Subbasin 3             4.580         2.630  .000E+00  .000       .574
  4  1 Subbasin 4             3.330         1.940  .000E+00  .000       .583
  5  1 Subbasin 5             4.420         2.570  .000E+00  .000       .581
  6  1 Subbasin 6             2.340         1.350  .000E+00  .000       .577
 ----------------------------------------------------------------------------
 PRECIPITATION                 .979         1.165  .543E-01  .200      1.190
 TRIBUTARY INFLOW            26.690        15.620  .000E+00  .000       .585
 ***TOTAL INFLOW             27.669        16.785  .543E-01  .014       .607
 ADVECTIVE OUTFLOW           27.669        15.961  .115E+00  .021       .577
 ***TOTAL OUTFLOW            27.669        15.961  .115E+00  .021       .577
 ***EVAPORATION                .000          .824  .612E-01  .300       .000
 ----------------------------------------------------------------------------

 GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
 COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---         CONC  EXPORT
 ID T LOCATION              KG/YR   %(I)  KG/YR**2   %(I)     CV  MG/M3  KG/KM2
 -------------------------------------------------------------------------------
  1 1 Subbasin 1            999.9   20.7  .000E+00     .0   .000  294.1   172.4
  2 1 Subbasin 2           1300.3   26.9  .000E+00     .0   .000  348.6   209.0
  3 1 Subbasin 3           1299.2   26.9  .000E+00     .0   .000  494.0   283.7
  4 1 Subbasin 4            500.1   10.4  .000E+00     .0   .000  257.8   150.2
  5 1 Subbasin 5            500.1   10.4  .000E+00     .0   .000  194.6   113.1
  6 1 Subbasin 6            200.1    4.1  .000E+00     .0   .000  148.2    85.5
 -------------------------------------------------------------------------------
 PRECIPITATION               29.4     .6  .216E+03  100.1   .500   25.2    30.0
 TRIBUTARY INFLOW          4799.8   99.4  .000E+00     .0   .000  307.3   179.8
 ***TOTAL INFLOW           4829.1  100.0  .216E+03  100.0   .003  287.7   174.5
 ADVECTIVE OUTFLOW         1249.8   25.9  .323E+06*******   .455   78.3    45.2
 ***TOTAL OUTFLOW          1249.8   25.9  .323E+06*******   .455   78.3    45.2
 ***RETENTION              3579.3   74.1  .323E+06*******   .159     .0      .0
 -------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P --------------
  OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
      RATE      TIME      CONC      TIME     RATIO      COEF
      M/YR       YRS     MG/M3       YRS         -         -
     16.30     .2480     184.4     .1511    6.6183     .7412
```

1995 - *Constant Sediment Phosphorus Concentration of 1,672mg/kg*

CASE: WC Lake 1995 -No Calib (Sed1672)

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	185.2	.25	183.3	.46	1.01	.04	.04	.02
CHL-A	MG/M3	55.7	.46	46.8	.42	1.19	.38	.50	.28
SECCHI	M	.4	.32	.4	.35	.92	-.27	-.31	-.19
ORGANIC N	MG/M3	.0	.00	1318.9	.33	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	108.9	.28	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	146.6	.26	94.2	.45	1.56	1.70	1.65	.85
CHL-A	MG/M3	55.2	.50	55.7	.47	.99	-.02	-.03	-.01
SECCHI	M	36.0	.86	.7	.48	53.10	4.61	14.19	4.02
ORGANIC N	MG/M3	.0	.00	1433.3	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	97.0	.46	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	269.6	1.05	83.2	.45	3.24	1.12	4.37	1.03
CHL-A	MG/M3	50.5	.73	41.3	.55	1.22	.27	.58	.22
SECCHI	M	.7	.07	.8	.57	.84	-2.43	-.62	-.30
ORGANIC N	MG/M3	.0	.00	1112.9	.45	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	73.6	.44	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	184.4	.53	112.6	.45	1.64	.94	1.83	.71
CHL-A	MG/M3	54.2	.54	50.3	.42	1.08	.14	.22	.11
SECCHI	M	19.4	.85	.7	.41	29.81	3.99	12.13	3.60
ORGANIC N	MG/M3	.0	.00	1331.7	.37	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	94.4	.40	.00	.00	.00	.00

CASE: WC Lake 1995 -No Calib (Sed1672)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	3.400	.000E+00	.000	.586
2	1	Subbasin 2	6.220	3.730	.000E+00	.000	.600
3	1	Subbasin 3	4.580	2.630	.000E+00	.000	.574
4	1	Subbasin 4	3.330	1.940	.000E+00	.000	.583
5	1	Subbasin 5	4.420	2.570	.000E+00	.000	.581
6	1	Subbasin 6	2.340	1.350	.000E+00	.000	.577
PRECIPITATION			.979	1.165	.543E-01	.200	1.190
TRIBUTARY INFLOW			26.690	15.620	.000E+00	.000	.585
***TOTAL INFLOW			27.669	16.785	.543E-01	.014	.607
ADVECTIVE OUTFLOW			27.669	15.961	.115E+00	.021	.577
***TOTAL OUTFLOW			27.669	15.961	.115E+00	.021	.577
***EVAPORATION			.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	1200.2	22.1	.000E+00	.0	.000	353.0	206.9
2	1	Subbasin 2	1500.2	27.6	.000E+00	.0	.000	402.2	241.2
3	1	Subbasin 3	1399.2	25.8	.000E+00	.0	.000	532.0	305.5
4	1	Subbasin 4	500.1	9.2	.000E+00	.0	.000	257.8	150.2
5	1	Subbasin 5	500.1	9.2	.000E+00	.0	.000	194.6	113.1
6	1	Subbasin 6	300.1	5.5	.000E+00	.0	.000	222.3	128.3
PRECIPITATION			29.4	.5	.216E+03	100.1	.500	25.2	30.0
TRIBUTARY INFLOW			5399.9	99.5	.000E+00	.0	.000	345.7	202.3
***TOTAL INFLOW			5429.3	100.0	.216E+03	100.0	.003	323.5	196.2
ADVECTIVE OUTFLOW			1327.3	24.4	.364E+06	*******	.455	83.2	48.0
***TOTAL OUTFLOW			1327.3	24.4	.364E+06	*******	.455	83.2	48.0
***RETENTION			4102.0	75.6	.364E+06	*******	.147	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P: POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
16.30	.2480	184.4	.1344	7.4409	.7555

BATHTUB Output for 2001 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 1,320 mg/kg

CASE: WC Lake 2001 - No Calibration (sed 1320)

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	105.6	.33	126.8	.46	.83	-.56	-.68	-.33
CHL-A	MG/M3	38.2	.74	43.7	.45	.87	-.18	-.39	-.16
SECCHI	M	.5	.34	.4	.37	1.06	.18	.22	.12
ORGANIC N	MG/M3	.0	.00	1240.9	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	101.2	.32	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	70.8	.26	56.0	.45	1.27	.90	.87	.45
CHL-A	MG/M3	36.0	.86	31.7	.57	1.14	.15	.37	.12
SECCHI	M	.7	.34	.7	.63	.93	-.22	-.27	-.11
ORGANIC N	MG/M3	.0	.00	922.8	.44	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	65.6	.49	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	88.1	.94	51.0	.46	1.73	.58	2.03	.53
CHL-A	MG/M3	35.9	.55	26.0	.59	1.38	.58	.93	.40
SECCHI	M	.8	.57	.9	.72	.81	-.36	-.74	-.23
ORGANIC N	MG/M3	.0	.00	782.1	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	52.2	.48	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	83.0	.45	71.5	.45	1.16	.33	.55	.23
CHL-A	MG/M3	36.5	.76	33.2	.49	1.10	.12	.27	.11
SECCHI	M	.7	.40	.7	.47	.91	-.23	-.33	-.15
ORGANIC N	MG/M3	.0	.00	965.1	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	70.9	.42	.00	.00	.00	.00

CASE: WC Lake 2001 - No Calibration (sed 1320)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	.860	.000E+00	.000	.148
2	1	Subbasin 2	6.220	.950	.000E+00	.000	.153
3	1	Subbasin 3	4.580	.610	.000E+00	.000	.133
4	1	Subbasin 4	3.330	.540	.000E+00	.000	.162
5	1	Subbasin 5	4.420	.730	.000E+00	.000	.165
6	1	Subbasin 6	2.340	.390	.000E+00	.000	.167
PRECIPITATION			.979	.764	.233E-01	.200	.780
TRIBUTARY INFLOW			26.690	4.080	.000E+00	.000	.153
***TOTAL INFLOW			27.669	4.844	.233E-01	.032	.175
ADVECTIVE OUTFLOW			27.669	4.019	.845E-01	.072	.145
***TOTAL OUTFLOW			27.669	4.019	.845E-01	.072	.145
***EVAPORATION			.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	100.2	11.1	.000E+00	.0	.000	116.5	17.3
2	1	Subbasin 2	399.6	44.2	.000E+00	.0	.000	420.6	64.2
3	1	Subbasin 3	100.8	11.2	.000E+00	.0	.000	165.3	22.0
4	1	Subbasin 4	100.0	11.1	.000E+00	.0	.000	185.2	30.0
5	1	Subbasin 5	104.4	11.6	.000E+00	.0	.000	143.0	23.6
6	1	Subbasin 6	69.2	7.7	.000E+00	.0	.000	177.4	29.6
PRECIPITATION			29.4	3.3	.216E+03	100.0	.500	38.5	30.0
TRIBUTARY INFLOW			874.2	96.7	.000E+00	.0	.000	214.3	32.8
***TOTAL INFLOW			903.5	100.0	.216E+03	100.0	.016	186.5	32.7
ADVECTIVE OUTFLOW			204.8	22.7	.873E+04	4050.2	.456	51.0	7.4
***TOTAL OUTFLOW			204.8	22.7	.873E+04	4050.2	.456	51.0	7.4
***RETENTION			698.7	77.3	.887E+04	4115.0	.135	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
4.11	.9750	83.0	.3601	2.7769	.7733

2001 - *Constant Sediment Phosphorus Concentration of 1,672mg/kg*

CASE: WC Lake 2001 -No Calib (Sed1672)

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	105.6	.33	141.9	.46	.74	-.90	-1.10	-.53
CHL-A	MG/M3	38.2	.74	46.4	.43	.82	-.26	-.56	-.23
SECCHI	M	.5	.34	.4	.36	1.10	.27	.33	.19
ORGANIC N	MG/M3	.0	.00	1301.8	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	106.0	.31	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	70.8	.26	64.6	.45	1.10	.35	.34	.18
CHL-A	MG/M3	36.0	.86	36.5	.55	.99	-.01	-.03	-.01
SECCHI	M	.7	.34	.7	.58	1.01	.02	.03	.01
ORGANIC N	MG/M3	.0	.00	1030.6	.43	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	74.0	.47	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	88.1	.94	57.9	.46	1.52	.45	1.56	.40
CHL-A	MG/M3	35.9	.55	29.2	.57	1.23	.37	.60	.26
SECCHI	M	.8	.57	.9	.66	.87	-.24	-.49	-.16
ORGANIC N	MG/M3	.0	.00	854.8	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	57.9	.46	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	83.0	.45	81.3	.45	1.02	.05	.08	.03
CHL-A	MG/M3	36.5	.76	37.1	.47	.98	-.02	-.05	-.02
SECCHI	M	.7	.40	.7	.43	.98	-.05	-.07	-.03
ORGANIC N	MG/M3	.0	.00	1053.6	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	77.8	.41	.00	.00	.00	.00

CASE: WC Lake 2001 -No Calib (Sed1672)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	.860	.000E+00	.000	.148
2	1	Subbasin 2	6.220	.950	.000E+00	.000	.153
3	1	Subbasin 3	4.580	.610	.000E+00	.000	.133
4	1	Subbasin 4	3.330	.540	.000E+00	.000	.162
5	1	Subbasin 5	4.420	.730	.000E+00	.000	.165
6	1	Subbasin 6	2.340	.390	.000E+00	.000	.167
PRECIPITATION			.979	.764	.233E-01	.200	.780
TRIBUTARY INFLOW			26.690	4.080	.000E+00	.000	.153
***TOTAL INFLOW			27.669	4.844	.233E-01	.032	.175
ADVECTIVE OUTFLOW			27.669	4.019	.845E-01	.072	.145
***TOTAL OUTFLOW			27.669	4.019	.845E-01	.072	.145
***EVAPORATION			.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	200.3	17.7	.000E+00	.0	.000	232.9	34.5
2	1	Subbasin 2	399.6	35.2	.000E+00	.0	.000	420.6	64.2
3	1	Subbasin 3	201.6	17.8	.000E+00	.0	.000	330.5	44.0
4	1	Subbasin 4	110.1	9.7	.000E+00	.0	.000	203.8	33.0
5	1	Subbasin 5	109.4	9.6	.000E+00	.0	.000	149.8	24.7
6	1	Subbasin 6	84.0	7.4	.000E+00	.0	.000	215.4	35.9
PRECIPITATION			29.4	2.6	.216E+03	100.0	.500	38.5	30.0
TRIBUTARY INFLOW			1104.9	97.4	.000E+00	.0	.000	270.8	41.4
***TOTAL INFLOW			1134.3	100.0	.216E+03	100.0	.013	234.2	41.0
ADVECTIVE OUTFLOW			232.5	20.5	.113E+05	5222.5	.456	57.9	8.4
***TOTAL OUTFLOW			232.5	20.5	.113E+05	5222.5	.456	57.9	8.4
***RETENTION			901.7	79.5	.114E+05	5291.2	.118	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
4.11	.9750	83.0	.2869	3.4859	.7950

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Appendix I
Monte Carlo Analyses

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I.1 Monte Carlo Analyses

This appendix contains results of the Monte Carlo analyses for manganese, sulfates, and TDS in the Beaucoup Creek Watershed. Each analysis generates 10,000 random numbers which can be obtained electronically.

IEPA
Watershed Load Reductions
7/11/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : NC03

Sulfate

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

Percent Reduction

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

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 0.477564 percent

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

mean 704.7133 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 368.1675 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 0.495859 percent

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

mean 704.7133 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 355.275 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NC03

TSS

Cc (TSS)	1000	mg/L	- Water quality criterion
Cd (TSS)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

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

PR (TSS) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (TSS) 0.249357 percent

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

mean 1069.505 mg/L

LTA = mean * (1 - PR99)

LTA (TSS) 802.8162 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (TSS) 0.266212 percent

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

mean 1069.505 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 784.7901 mg/L

Simulation Results for IEPA_Monte_Carlo_NC03b.xls

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 2
Sampling Type= Monte Carlo
Runtime= 00:00:20
Run on 11/5/2002, 1:04:36 PM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B94	PR (TSS)	0	7.88E-02	0.274216
B56	PR (Sulfate)	0	0.271258	0.498674
B12	(Input) Cd (Mn)	1.016869	1.953331	2.891618
B50	(Input) Cd (Sulfate)	412.035	704.7133	997.3557
B88	(Input) Cd (TSS)	763.1844	1069.505	1377.82

@RISK Simulation of	Run on 11/	Simulations=	Iterations=		
Name	PR (TSS)	PR (Sulfate)	Cd (Mn)	Cd (Sulfate)	Cd (TSS)
Description	Output	Output	Triang(1,1.	Triang(410,70	Triang(759,1070,1380)
Cell	B94	B56	B12	B50	B88
Minimum =	0	0	1.016869	412.035	763.1844
Maximum =	0.274216	0.4986744	2.891618	997.3557	1377.82
Mean =	7.88E-02	0.2712575	1.953331	704.7133	1069.505
Std Deviation =	7.64E-02	0.1258585	0.384571	120.3263	126.3757
Variance =	5.83E-03	1.58E-02	0.147895	14478.43	15970.82
Skewness =	0.570666	-0.5191457	-2.41E-02	4.03E-03	1.72E-02
Kurtosis =	2.096777	2.476938	2.387359	2.393913	2.364731
Errors Calculated =	0	0	0	0	0
Mode =	0	0	1.795766	607.8176	808.4481
5% Perc =	0	5.65E-03	1.311483	502.8429	858.5411
10% Perc =	0	7.67E-02	1.425089	541.5126	899.3358
15% Perc =	0	0.124567	1.524185	571.1459	927.5585
20% Perc =	0	0.1621911	1.60236	596.7948	955.082
25% Perc =	0	0.1906739	1.675239	617.798	978.2984
30% Perc =	0	0.215043	1.739994	636.9776	998.1353
35% Perc =	1.78E-02	0.237001	1.802663	655.3089	1018.104
40% Perc =	3.37E-02	0.2578088	1.858599	673.6809	1034.88
45% Perc =	5.04E-02	0.2748005	1.909863	689.4654	1053.096
50% Perc =	6.48E-02	0.290475	1.9601	704.6968	1069.329
55% Perc =	0.07929	0.3056419	2.009025	720.0896	1086.118
60% Perc =	9.25E-02	0.3208533	2.057383	736.218	1101.876
65% Perc =	0.107023	0.3354867	2.110272	752.4304	1119.85
70% Perc =	0.121976	0.351583	2.169625	771.1087	1138.921
75% Perc =	0.138084	0.3677431	2.22737	790.8177	1160.206
80% Perc =	0.155562	0.3848507	2.296591	812.8108	1184.22
85% Perc =	0.173901	0.4028007	2.378514	837.2415	1210.509
90% Perc =	0.194134	0.4243198	2.47003	868.5378	1240.902
95% Perc =	0.220796	0.4470604	2.594018	904.2579	1283.362
Filter Minimum =					
Filter Maximum =					
Type (1 or 2) =					
# Values Filtered =	0	0	0	0	0
Scenario #1 =	>75%	>75%			
Scenario #2 =	<25%	<25%			
Scenario #3 =	>90%	>90%			
Target #1 (Value)=	0.249357	0.47756419	2.76047	957.055359	1332.192
Target #1 (Perc%)=	99%	99%	99%	99%	99%
Target #2 (Value)=	0.266212	0.49585888	2.852862	991.785767	1362.791
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (TSS) in Cell B94

(From @RISK Simulation of IEPA_Monte_Carlo_NC03b.xls- Run on 11/5/2002, 1:04:36 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity	Rank Correlation Coefficient
#1	B88	Cd (TSS)	0.953669	0.985895
#2	B12	Cd (Mn)	0	3.65E-03
#3	B50	Cd (Sulfate)	0	5.47E-03

Simulation Sensitivities for PR (Sulfate) in Cell B56

(From @RISK Simulation of IEPA_Monte_Carlo_NC03b.xls- Run on 11/5/2002, 1:04:36 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity	Rank Correlation Coefficient
#1	B50	Cd (Sulfate)	0.985784	0.999949
#2	B12	Cd (Mn)	0	6.25E-03
#3	B88	Cd (TSS)	0	5.50E-03

Simulation Variables for IEPA_Monte_Carlo_NC03b.xls
(From @RISK Simulation of IEPA_Monte_Carlo_NC03b.xls- Run on 11/5/2002, 1:04:36 PM, Simulations= 1, Iterations= 1(
Outputs:

Cell	Name	Current
B94	PR (TSS)	0.065129
B56	PR (Sulfate)	0.29078

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(1,1.95,2.9)	[IEPA_Monte_Carlo_NC03	'=RiskTriang(1,1.95,2.9)
! B50	Cd (Sulfate	Triang(410,705,1000)	[IEPA_Monte_Carlo_NC03	'=RiskTriang(410,705,1000)
! B88	Cd (TSS)	Triang(759,1070,1380)	[IEPA_Monte_Carlo_NC03	'=RiskTriang(759,1070,1380)

0000

Monte Carlo Simulations using @RISK 3.5

Watershed : NCI 01

Manganese

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

Percent Reduction

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

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 0.494107 percent

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

mean 1.195503 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.604796 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 0.516179 percent

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

mean 1.195503 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.578409 mg/L

Simulation Results for IEPA_Monte_Carlo_NCI01.xls

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 1
Sampling Type= Monte Carlo
Runtime= 00:00:18
Run on 7/12/2002, 7:57:56 AM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B18	PR (Mn)	0.00E+00	0.177123	0.521106
B12	(Input) Cd (Mn)	0.291382	1.195503	2.088143
B50	(Input) Cd (Sulfate)	1570.836	1729.982	1888.521
B88	(Input) Cd (TSS)	1730.071	1735.006	1739.929

@RISK Simulation of	Run on 7/1	Simulations= 1	Iterations= 10000	
Name	PR (Mn)	Cd (Mn)	Cd (Sulfate)	Cd (TSS)
Description	Output	Triang(0.29,1.2,	Triang(1570,173(	Triang(1730,1735,1740)
Cell	B18	B12	B50	B88
Minimum =	0.00E+00	0.2913817	1570.836	1730.071
Maximum =	0.521106	2.088143	1888.521	1739.929
Mean =	0.177123	1.195503	1729.982	1735.006
Std Deviation =	0.16107	3.71E-01	6.51E+01	2.017419
Variance =	2.59E-02	1.38E-01	4.23E+03	4.06998
Skewness =	0.332234	-0.002763596	1.33E-03	0.017623
Kurtosis =	1.74006	2.402694	2.43008	2.425458
Errors Calculated =	0	0	0	0
Mode =	0	1.051174	1624.065	1736.376
5% Perc =	0	0.5713763	1620.606	1731.621
10% Perc =	0	0.6901209	1641.667	1732.3
15% Perc =	0	0.7839316	1658.987	1732.799
20% Perc =	0	0.8605831	1672.456	1733.187
25% Perc =	0	0.9295187	1684.012	1733.567
30% Perc =	0	0.9923881	1694.574	1733.894
35% Perc =	0.044777	1.046876	1704.352	1734.189
40% Perc =	0.091494	1.100708	1713.628	1734.485
45% Perc =	0.131766	1.151763	1721.786	1734.742
50% Perc =	0.164248	1.196527	1729.71	1734.98
55% Perc =	0.193366	1.239719	1737.464	1735.244
60% Perc =	0.223924	1.288533	1745.857	1735.506
65% Perc =	0.255135	1.342526	1755.05	1735.794
70% Perc =	0.285739	1.400049	1765.372	1736.112
75% Perc =	0.314863	1.459562	1776.501	1736.424
80% Perc =	0.344996	1.526708	1788.712	1736.831
85% Perc =	0.37878	1.609736	1802.025	1737.271
90% Perc =	0.411709	1.699838	1818.421	1737.748
95% Perc =	0.449172	1.815448	1839.748	1738.386
Filter Minimum =				
Filter Maximum =				
Type (1 or 2) =				
# Values Filtered =	0	0	0	0
Scenario #1 =	>75%			
Scenario #2 =	<25%			
Scenario #3 =	>90%			
Target #1 (Value)=	0.494107	1.97670424	1868.106567	1739.323
Target #1 (Perc%)=	99%	99%	99%	99%
Target #2 (Value)=	0.516179	2.066880703	1881.680176	1739.779
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Mn) in Cell B18
(From @RISK Simulation of IEPA_Monte_Carlo_NCI01.xls- Run on 7/12/2002, 7:57:56 AM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity	Rank Correlation Coefficient
#1	B12	Cd (Mn)	0.954911	0.985326
#2	B50	Cd (Sulfate	0	8.00E-03
#3	B88	Cd (TSS)	0	1.20E-02

Simulation Variables for IEPA_Monte_Carlo_NCI01.xls
(From @RISK Simulation of IEPA_Monte_Carlo_NCI01.xls- Run on 7/12/2002, 7:57:56 AM, Simulations= 1, Iterations= 10000)
Outputs:

Cell	Name	Current
B18	PR (Mn)	0.164345404

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(0.29,1.2,2.1)	[IEPA_Monte_Carlo_NCI01.xls]NCC01	'=RiskTriang(0.29,1.2,2.1)
! B50	Cd (Sulfate)	Triang(1570,1730,1890)	[IEPA_Monte_Carlo_NCI01.xls]NCC01	'=RiskTriang(1570,1730,1890)
! B88	Cd (TSS)	Triang(1730,1735,1740)	[IEPA_Monte_Carlo_NCI01.xls]NCC01	'=RiskTriang(1730,1735,1740)

Monte Carlo Simulations using @RISK 3.5

Watershed : NCK 01

Manganese

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

Percent Reduction

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

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 0.719108 percent

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

mean 2.099869 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.589836 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 0.73237 percent

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

mean 2.099869 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.561988 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NCK 01

Sulfate

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

Percent Reduction

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

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 0 percent

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

mean 331.8241 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 331.8241 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 0 percent

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

mean 331.8241 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 331.8241 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NCK 01

TSS

Cc (TSS)	1000	mg/L	- Water quality criterion
Cd (TSS)	#NAME?	mg/L	- Randomly generated pollutant source concentration base on the observed data

Percent Reduction

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

PR (TSS) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (TSS) 0.711339 percent

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

mean 1734.985 mg/L

LTA = mean * (1 - PR99)

LTA (TSS) 500.8217 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (TSS) 0.712617 percent

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

mean 1734.985 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 498.6058 mg/L

Simulation Results for IEPA_Monte_Carlo_NCK01.xls

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 2
Sampling Type= Monte Carlo
Runtime= 00:00:20
Run on 7/11/2002, 3:49:13 PM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B18	PR (Mn)	0.00E+00	0.466944	0.735817
B56	PR (Sulfate)	0	0	0
B12	(Input) Cd (Mn)	0.409221	2.099869	3.785252
B50	(Input) Cd (Sulfate)	164.5308	331.8241	499.0022
B88	(Input) Cd (TSS)	1730.032	1734.992	1739.95

@RISK Simulation of	Run on 7/1	Simulations= 1	Iterations= 10000		
Name	PR (Mn)	PR (Sulfate)	Cd (Mn)	Cd (Sulfate	Cd (TSS)
Description	Output	Output	Triang(0.38,2.09,:	Triang(162	Triang(1730,1735,1740)
Cell	B18	B56	B12	B50	B88
Minimum =	0.00E+00	0	0.4092208	164.5308	1730.032
Maximum =	0.735817	0	3.785252	499.0022	1739.95
Mean =	0.466944	0	2.099869	331.8241	1734.992
Std Deviation =	0.199055	0.00E+00	7.03E-01	69.55619	2.034053
Variance =	3.96E-02	0.00E+00	4.94E-01	4838.063	4.137373
Skewness =	-1.025704	0	-1.06E-03	0.027672	-1.04E-02
Kurtosis =	3.140375	0	2.382064	2.402126	2.403854
Errors Calculated =	0	0	0	0	0
Mode =	0	0	1.78762	227.3991	1734.834
5% Perc =	0	0	0.9194467	216.4267	1731.587
10% Perc =	0.126275	0	1.144525	239.2462	1732.23
15% Perc =	0.242965	0	1.320942	254.8647	1732.729
20% Perc =	0.317387	0	1.464959	269.0074	1733.167
25% Perc =	0.373916	0	1.59723	281.0259	1733.54
30% Perc =	0.415403	0	1.710579	293.192	1733.873
35% Perc =	0.450227	0	1.818933	303.6594	1734.175
40% Perc =	0.478675	0	1.91819	313.3507	1734.439
45% Perc =	0.502897	0	2.011654	323.3403	1734.72
50% Perc =	0.524039	0	2.101014	331.5218	1735
55% Perc =	0.543413	0	2.190161	339.7952	1735.271
60% Perc =	0.560867	0	2.277212	348.9675	1735.542
65% Perc =	0.578794	0	2.374133	358.7955	1735.825
70% Perc =	0.597588	0	2.485018	369.7514	1736.133
75% Perc =	0.615829	0	2.603005	381.6765	1736.457
80% Perc =	0.634345	0	2.734814	394.2063	1736.832
85% Perc =	0.65367	0	2.887418	409.1065	1737.229
90% Perc =	0.672924	0	3.057397	426.3518	1737.693
95% Perc =	0.694839	0	3.276954	449.0117	1738.4
Filter Minimum =					
Filter Maximum =					
Type (1 or 2) =					
# Values Filtered =	0	0	0	0	0
Scenario #1 =	>75%	>75%			
Scenario #2 =	<25%	<25%			
Scenario #3 =	>90%	>90%			
Target #1 (Value)=	0.719108	0	3.560088634	478.2444	1739.282
Target #1 (Perc%)=	99%	99%	99%	99%	99%
Target #2 (Value)=	0.73237	0	3.736499071	495.3033	1739.762
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Mn) in Cell B18

(From @RISK Simulation of IEPA_Monte_Carlo_NCK01.xls- Run on 7/11/2002, 3:49:13 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity	Rank Correlation Coefficient
#1	B12	Cd (Mn)	0.947314	0.999858
#2	B50	Cd (Sulfate	0.006278	-5.93E-03
#3	B88	Cd (TSS)	-0.005871	5.75E-03

Simulation Sensitivities for PR (Sulfate) in Cell B56

(From @RISK Simulation of IEPA_Monte_Carlo_NCK01.xls- Run on 7/11/2002, 3:49:13 PM, Simulations= 1, Iterations= 10000)

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

Simulation Variables for IEPA_Monte_Carlo_NCK01.xls
(From @RISK Simulation of IEPA_Monte_Carlo_NCK01.xls- Run on 7/11/2002, 3:49:13 PM, Simulations= 1, Iterations= 10000)
Outputs:

Cell	Name	Current
B18	PR (Mn)	0.539403651
B56	PR (Sulfate)	0

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(0.38,2.09,3.8)	[IEPA_Monte_Carlo_NCK01.xls]NCK01	'=RiskTriang(0.38,2.09,3.8)
! B50	Cd (Sulfate)	Triang(162,333.5,505)	[IEPA_Monte_Carlo_NCK01.xls]NCK01	'=RiskTriang(162,333.5,505)
! B88	Cd (TSS)	Triang(1730,1735,1740)	[IEPA_Monte_Carlo_NCK01.xls]NCK01	'=RiskTriang(1730,1735,1740)

Monte Carlo Simulations using @RISK 3.5

Watershed : NCC 01

Manganese

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

Percent Reduction

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

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 0.637122 percent

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

mean 1.94321 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.705148 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 0.649162 percent

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

mean 1.94321 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.681751 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NCC 01

Sulfate

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

Percent Reduction

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

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 0.732378 percent

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

mean 1729.94 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 462.9705 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 0.734438 percent

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

mean 1729.94 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 459.4057 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : NCC 01

TDS

Cc (TDS)	1000	mg/L	- Water quality criterion
Cd (TDS)	#NAME?	mg/L	- Randomly generated pollutant source concentration based on the observed data

Percent Reduction

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

PR (TDS) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (TDS) 0.425052 percent

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

mean 1734.984 mg/L

LTA = mean * (1 - PR99)

LTA (TDS) 997.5253 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (TDS) 0.42521 percent

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

mean 1734.984 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 997.2514 mg/L

Simulation Results for Book2

Iterations= 10000
Simulations= 1
# Input Variables= 3
# Output Variables= 3
Sampling Type= Monte Carlo
Runtime= 00:00:20
Run on 7/11/2002, 3:35:34 PM

Summary Statistics

Cell	Name	Minimum	Mean	Maximum
B18	PR (Mn)	1.84E-02	0.463036	0.652654
B56	PR (Sulfate)	0.681878	0.710559	0.73514
B94	PR (TSS)	0.42199	0.423625	0.425261
B12	(Input) Cd (Mn)	1.018786	1.94321	2.878974
B50	(Input) Cd (Sulfate)	1571.723	1729.94	1887.792
B88	(Input) Cd (TSS)	1730.073	1734.984	1739.92

@RISK Simulation of	Run on 7/1	Simulations= 1	Iterations= 10000			
Name	PR (Mn)	PR (Sulfate)	PR (TSS)	Cd (Mn)	Cd (Sulfate	Cd (TSS)
Description	Output	Output	Output	Triang(1,1.	Triang(157	Triang(1730,1735,1740)
Cell	B18	B56	B94	B12	B50	B88
Minimum =	1.84E-02	0.6818777	0.4219898	1.018786	1571.723	1730.073
Maximum =	0.652654	0.7351404	0.425261	2.878974	1887.792	1739.92
Mean =	0.463036	0.7105591	0.423625	1.94321	1729.94	1734.984
Std Deviation =	0.116423	1.10E-02	6.72E-04	0.384951	65.31935	2.022096
Variance =	1.36E-02	1.20E-04	4.51E-07	0.148188	4266.618	4.088871
Skewness =	-0.919086	-0.1610025	1.09E-02	0.00124	-4.88E-04	1.59E-02
Kurtosis =	3.557432	2.447171	2.424911	2.384175	2.412002	2.42504
Errors Calculated =	0	0	0	0	0	0
Mode =	0.402861	0.6903654	0.4236566	1.674653	1614.793	1734.45
5% Perc =	0.232304	0.6915148	0.4224985	1.302598	1620.824	1731.597
10% Perc =	0.295667	0.6953566	0.4227164	1.419782	1641.263	1732.251
15% Perc =	0.340577	0.698383	0.4228834	1.516477	1657.731	1732.752
20% Perc =	0.37228	0.7008599	0.4230234	1.593068	1671.458	1733.173
25% Perc =	0.400479	0.7029877	0.4231492	1.667999	1683.432	1733.551
30% Perc =	0.423173	0.7048557	0.423256	1.733622	1694.086	1733.872
35% Perc =	0.44113	0.7065778	0.4233612	1.789323	1704.029	1734.188
40% Perc =	0.458057	0.7080351	0.4234495	1.845211	1712.534	1734.453
45% Perc =	0.47177	0.7095641	0.423534	1.893113	1721.55	1734.708
50% Perc =	0.485023	0.7108952	0.42362	1.941833	1729.477	1734.966
55% Perc =	0.497898	0.7123538	0.4237038	1.991625	1738.246	1735.219
60% Perc =	0.510885	0.7138289	0.4237916	2.044507	1747.207	1735.483
65% Perc =	0.523683	0.7152836	0.4238892	2.099444	1756.134	1735.777
70% Perc =	0.536288	0.7168267	0.4239971	2.156511	1765.703	1736.102
75% Perc =	0.54915	0.7186471	0.4241028	2.21803	1777.128	1736.421
80% Perc =	0.563359	0.7205025	0.4242272	2.290212	1788.925	1736.796
85% Perc =	0.578591	0.7225158	0.4243674	2.372992	1801.904	1737.219
90% Perc =	0.594588	0.7249318	0.4245296	2.466628	1817.731	1737.709
95% Perc =	0.612507	0.7280928	0.4247546	2.580693	1838.863	1738.389
Filter Minimum =						
Filter Maximum =						
Type (1 or 2) =						
# Values Filtered =	0	0	0	0	0	0
Scenario #1 =	>75%	>75%	>75%			
Scenario #2 =	<25%	<25%	<25%			
Scenario #3 =	>90%	>90%	>90%			
Target #1 (Value)=	0.637122	0.732377708	0.425052136	2.755749	1868.305	1739.288
Target #1 (Perc%)=	99%	99%	99%	99%	99%	99%
Target #2 (Value)=	0.649162	0.73443836	0.425210059	2.850321	1882.802	1739.766
Target #2 (Perc%)=	99.90%	99.90%	99.90%	99.90%	99.90%	99.90%

Simulation Sensitivities for PR (Mn) in Cell B18
(From @RISK Simulation of Book2- Run on 7/11/2002, 3:35:34 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity	Rank Correlation Coefficient
#1	B12	Cd (Mn)	0.969125	1
#2	B50	Cd (Sulfate	0	-2.47E-03
#3	B88	Cd (TSS)	0	7.28E-03

Simulation Sensitivities for PR (Sulfate) in Cell B56
(From @RISK Simulation of Book2- Run on 7/11/2002, 3:35:34 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity	Rank Correlation Coefficient
#1	B50	Cd (Sulfate	0.998989	1
#2	B12	Cd (Mn)	0	-2.47E-03
#3	B88	Cd (TSS)	0	1.47E-02

Simulation Sensitivities for PR (TSS) in Cell B94
(From @RISK Simulation of Book2- Run on 7/11/2002, 3:35:34 PM, Simulations= 1, Iterations= 10000)

Rank	Cell	Name	Sensitivity	Rank Correlation Coefficient
#1	B88	Cd (TSS)	0.999999	1
#2	B50	Cd (Sulfate	-2.41E-05	1.47E-02
#3	B12	Cd (Mn)	-2.16E-08	7.28E-03

Simulation Variables for Book2
(From @RISK Simulation of Book2- Run on 7/11/2002, 3:35:34 PM, Simulations= 1, Iterations= 10000)
Outputs:

Cell	Name	Current
B18	PR (Mn)	0.487179487
B56	PR (Sulfate)	0.421965318
B94	PR (TSS)	0.711815562

Input Variables:

Cell	Name	Current	Worksheet	Formula in Cell
! B12	Cd (Mn)	Triang(1,1.95,2.9)	[IEPA_Monte_Carlo_NCC01.xls]NCC01	'=RiskTriang(1,1.95,2.9)
! B50	Cd (Sulfate)	Triang(1570,1730,1890)	[IEPA_Monte_Carlo_NCC01.xls]NCC01	'=RiskTriang(1570,1730,1890)
! B88	Cd (TSS)	Triang(1730,1735,1740)	[IEPA_Monte_Carlo_NCC01.xls]NCC01	'=RiskTriang(1730,1735,1740)

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Appendix J
Rating Curve for Depth

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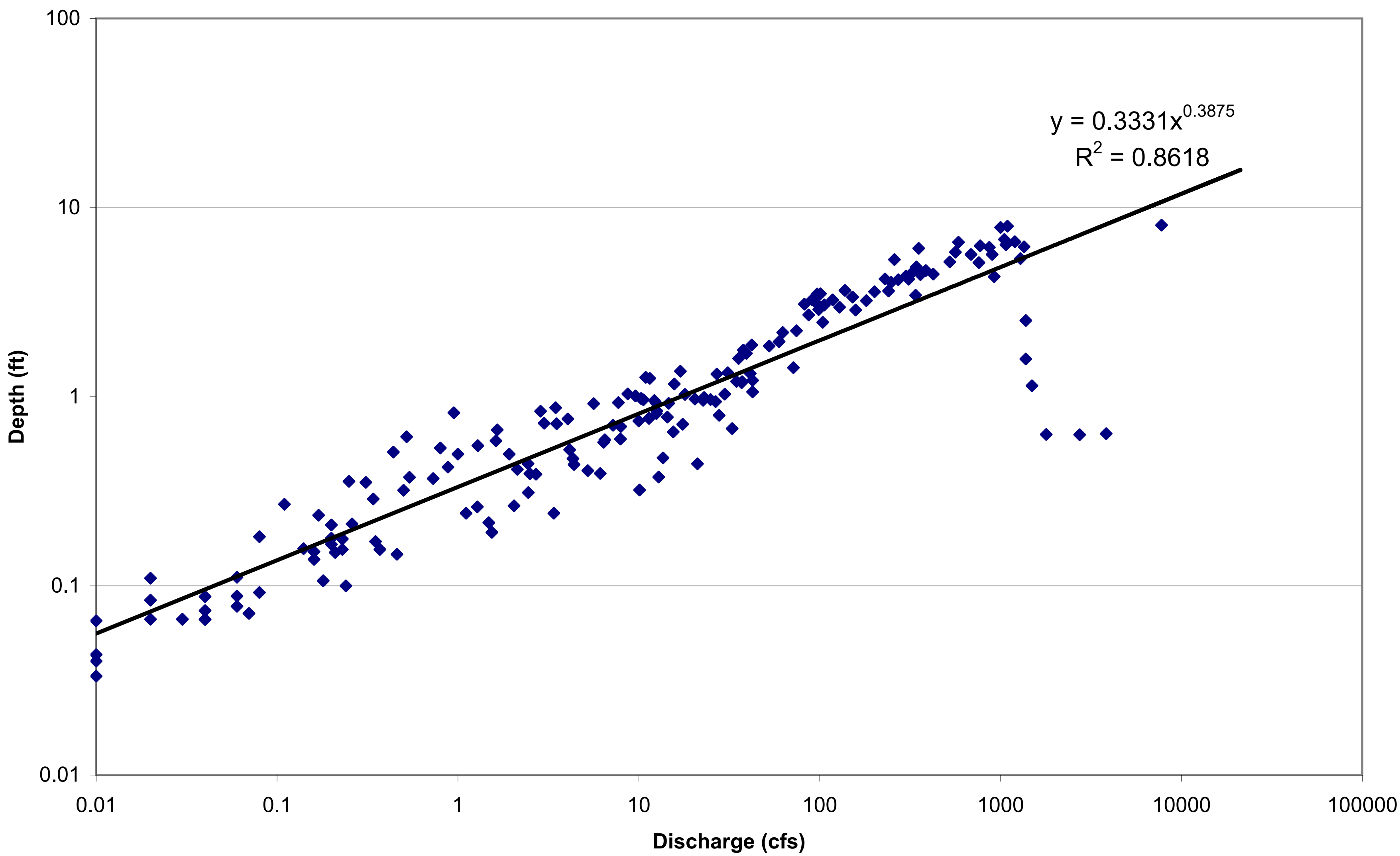
Depth Rating Curve for Beaucoup Creek Watershed



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Appendix K
Streeter-Phelps Analyses

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Beaucoup Creek Watershed
Aeration Coefficient Summary

Location	Date	DO observed	BOD @ DO observed	Ka @ DO observed	Ka at DO = 6 mg/L
NC03	3/14/1996	9.9	11.05	16.3	-3.3
NC03	8/16/2000	4.7	8.84	5.8	14.0
NC03	9/19/2000	7	6.11	7.6	3.8
NC10	9/11/1995	4.7	8.32	0.8	2.6
NC10	3/14/1996	10.4	11.83	18.0	-3.8
NCI01	8/4/1995	1.5	12.74	0.1	11.9
NCI01	3/5/1996	10.1	9.75	10.9	-0.7
NCK01	7/24/1995	2.6	13.39	0.8	9.9
NCK01	3/5/1996	10.6	7.02	20.1	-1.2

Definitions

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

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	D_o	k_a	k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
1.51	4	12.39	16.3	0.45	5280	0.9	11.05	11.4	9.9	1.0	9.1	16.5
1.51												

x	y	m	b	
	5	12.8	-0.3	14.3
	10	11.3		

DO @ Temp 11.6

x	y	m	b	
	0	11.3	-0.0004	11.3
	2000	10.5		

Elevation	400	feet
DO @ Elev.	11.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	11.4	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	D_o	k_a	k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
5.41	4	12.39	-3.32	0.45	5280	0.9	11.05	11.4	6	1.0	9.1	16.5
5.41												

x	y	m	b	
	5	12.8	-0.3	14.3
	10	11.3		

DO @ Temp 11.6

x	y	m	b	
	0	11.3	-0.0004	11.3
	2000	10.5		

Elevation	400	feet
DO @ Elev.	11.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	11.4	mg/L

Using Depth Determined from Transect Data and Q from Habitat Survey. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
2.88	4	1.52	5.79	0.64	5280	0.8	8.84	7.6	4.7	3.8	29.5	7.5
2.88												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 7.7

x	y	m	b
0	7.6	-0.00025	7.6
2000	7.1		

Elevation	400	feet
DO @ Elev.	7.5	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	7.6	mg/L

Using Depth Determined from Transect Data and Q from Habitat Survey. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	D_o	k_a	k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
1.58	4	1.52	14.03	0.64	5280	0.8	8.84	7.6	6	3.8	29.5	7.5
1.58												

x	y		m	b
	25	8.4	-0.16	12.4
	30	7.6		

DO @ Temp 7.7

x	y		m	b
	0	7.6	-0.00025	7.6
	2000	7.1		

Elevation	400	feet
DO @ Elev.	7.5	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	7.6	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.22	4	42.77	7.62	1.10	5280	0.6	6.11	9.2	7	0.4	19.2	1.3
2.22												

x	y	m	b
15	10.2	-0.2	13.2
20	9.2		

DO @ Temp 9.4

x	y	m	b
0	9.2	-0.00035	9.2
2000	8.5		

Elevation 400 feet
DO @ Elev. 9.1 mg/L
DO Elev Factor 0.98

DO @ Temp/Elev 9.2 mg/L

Used Q from USGS Derived Flows and H calculated from Q. Ka and Kd are from NC03 8/16/00.

		20 °C	@ T									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
3.22	4	42.77	3.78	1.10	5280	0.6	6.11	9.2	6	0.4	19.2	1.3
3.22												

x	y	m	b	
15	10.2	-0.2	13.2	
20	9.2			

DO @ Temp 9.4

x	y	m	b	
0	9.2	-0.00035	9.2	
2000	8.5			

Elevation	400	feet
DO @ Elev.	9.1	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	9.2	mg/L

Using Depth Determined from Transect Data and Q from last day of recorded data before sample date. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
4.44	4	5.69	0.78	0.69	5280	0.3	8.32	9.1	4.7	1.13	19.5	0.027
4.43												

x	y	m	b	
20	9.2	-0.16	12.4	
25	8.4			

DO @ Temp 9.3

x	y	m	b	
0	9.2	-0.00035	9.2	
2000	8.5			

Elevation	400	feet
DO @ Elev.	9.1	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	9.1	mg/L

Using Depth Determined from Transect Data and Q from last day of recorded data before sample date. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	D_o	k_a	k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
3.14	4	5.69	2.61	0.69	5280	0.3	8.32	9.1	6	1.13	19.5	0.027
3.14												

x	y	m	b	
20	9.2	-0.16	12.4	
25	8.4			

DO @ Temp 9.3

x	y	m	b	
0	9.2	-0.00035	9.2	
2000	8.5			

Elevation	400	feet
DO @ Elev.	9.1	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	9.1	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
1.30	4	14.33	17.95	0.45	5280	0.8	11.83	11.7	10.4	0.9	8.1	12.3
1.30												

x	y	m	b
5	12.8	-0.3	14.3
10	11.3		

DO @ Temp 11.9

x	y	m	b
0	11.3	-0.0004	11.3
2000	10.5		

Elevation	400	feet
DO @ Elev.	11.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	11.7	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
5.70	4	14.33	-3.78	0.45	5280	0.8	11.83	11.7	6	0.9	8.1	12.3
5.70												

x	y	m	b
5	12.8	-0.3	14.3
10	11.3		

DO @ Temp 11.9

x	y	m	b
0	11.3	-0.0004	11.3
2000	10.5		

Elevation 400 feet
DO @ Elev. 11.1 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 11.7 mg/L

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

		20 °C	**@ T**									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
6.86	4	65.42	0.10	2.08	5280	0.5	12.74	8.4	1.5	0.3	24.4	0.56
6.87												

x	y	m	b	
25	8.4	-0.16	12.4	
30	7.6			

DO @ Temp 8.5

x	y	m	b	
0	8.4	-0.0003	8.4	
2000	7.8			

Elevation	435	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	8.4	mg/L

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

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
2.36	4	65.42	11.91	2.08	5280	0.5	12.74	8.4	6	0.3	24.4	0.56
2.36												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.5

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	435 feet
DO @ Elev.	8.3 mg/L
DO Elev Factor	0.98
DO @ Temp/Elev	8.4 mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	D_o	k_a	k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
1.44	4	85.35	10.85	0.85	5280	0.4	9.75	11.5	10.1	0.2	8.6	0.326

1.44

x	y	m	b	
	5	12.8	-0.3	14.3
	10	11.3		

DO @ Temp 11.7

x	y	m	b	
	0	11.3	-0.0004	11.3
	2000	10.5		

Elevation	435	feet
DO @ Elev.	11.1	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	11.5	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
5.54	4	85.35	-0.68	0.85	5280	0.4	9.75	11.5	6	0.2	8.6	0.326
5.54												

x	y	m	b	
	5	12.8	-0.3	14.3
	10	11.3		

DO @ Temp 11.7

x	y	m	b	
	0	11.3	-0.0004	11.3
	2000	10.5		

Elevation 435 feet
DO @ Elev. 11.1 mg/L
DO Elev Factor 0.98

DO @ Temp/Elev 11.5 mg/L

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

		20 °C	@ T									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
5.16	4	4.14	0.76	0.89	5280	0.4	13.39	7.8	2.6	1.58	28.3	0.2
5.16												

x	y	m	b	
	25	8.4	-0.16	12.4
	30	7.6		

DO @ Temp 7.9

x	y	m	b	
	0	7.6	-0.00025	7.6
	2000	7.1		

Elevation	435 feet
DO @ Elev.	7.5 mg/L
DO Elev Factor	0.99
DO @ Temp/Elev	7.8 mg/L

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

		20 °C	@ T									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
1.76	4	4.14	9.85	0.89	5280	0.4	13.39	7.8	6	1.58	28.3	0.2
1.76												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 7.9

x	y	m	b
0	7.6	-0.00025	7.6
2000	7.1		

Elevation	435	feet
DO @ Elev.	7.5	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	7.8	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
0.61	4	52.50	20.05	0.76	5280	0.5	7.02	11.2	10.6	0.3	9.7	0.876
0.61												

x	y	m	b
5	12.8	-0.3	14.3
10	11.3		

DO @ Temp 11.4

x	y	m	b
0	11.3	-0.0004	11.3
2000	10.5		

Elevation	435	feet
DO @ Elev.	11.1	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	11.2	mg/L

Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
5.21	4	52.50	-1.16	0.76	5280	0.5	7.02	11.2	6	0.3	9.7	0.876
5.21												

x	y	m	b	
	5	12.8	-0.3	14.3
	10	11.3		

DO @ Temp 11.4

x	y	m	b	
	0	11.3	-0.0004	11.3
	2000	10.5		

Elevation	435	feet
DO @ Elev.	11.1	mg/L
DO Elev Factor	0.98	
DO @ Temp/Elev	11.2	mg/L

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Appendix L
Error Analyses

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L.1 Monte Carlo Analysis Development and Results

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

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

A triangular distribution assumes that the values of a given data set are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. Water quality data were not available to determine the actual k_a and k_d, so the estimated values discussed in Section 8.3 and shown in Table 8-2 were used as the mode for each sample date.

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

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

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

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.9	11.05	11.4	9.9	16.5	=RiskTriang(0.01,16.3,100)	=RiskTriang(0.02,0.45079,3.4)

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

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	5.7	0.5	0.0
Maximum =	11.4	99.3	3.4
Mean =	10.4	39.0	1.3
Std Deviation =	0.9	21.8	0.7
Variance =	0.8	475.4	0.6
Skewness =	-1.4	0.5	0.5
Kurtosis =	4.9	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	10.3	50.6	0.5

95th Percent Confidence Interval

8.7	12.2

99.9% Confidence Interval

7.5	13.3

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.8	8.84	7.6	4.7	7.5	=RiskTriang(0,5.79,100)	=RiskTriang(0.02,0.640374966,3.4)

DO= =F3-((B3*EXP((-I3*C3)/(D3*86400)))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	2.0	0.3	0.0
Maximum =	7.6	99.5	3.4
Mean =	6.5	35.1	1.4
Std Deviation =	1.1	23.1	0.7
Variance =	1.1	533.2	0.5
Skewness =	-1.2	0.6	0.4
Kurtosis =	3.7	2.4	2.3
Errors Calculated =	0.0	0.0	0.0
Mode =	4.4	17.5	0.8

95th Percent Confidence Interval

4.39	8.56

99.9% Confidence Interval

2.96	9.99

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.6	6.11	9.2	7	1.3	=RiskTriang(0,5.76,100)	=RiskTriang(0.02,0.64037497,3.4)

DO= =F3-((B3*EXP((-I3*C3)/(D3*86400)))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	4.0	0.7	0.1
Maximum =	9.2	86.8	3.1
Mean =	8.5	35.5	1.4
Std Deviation =	0.9	21.3	0.8
Variance =	0.9	455.7	0.7
Skewness =	-2.5	0.5	0.4
Kurtosis =	9.9	2.4	2.1
Errors Calculated =	0.0	0.0	0.0
Mode =	8.8	29.4	1.4

95th Percent Confidence Interval

6.67	10.30

99.9% Confidence Interval

5.43	11.55

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.3	8.32	9.1	4.7	0.0267	=RiskTriang(0,0.78,100)	=RiskTriang(0.02,0.685571766,3.4)

DO= =F3-((B3*EXP((-I3*C3)/(D3*86400)))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	1.7	0.1	0.0
Maximum =	9.1	99.6	3.4
Mean =	8.3	33.8	1.4
Std Deviatior	1.2	23.6	0.7
Variance =	1.4	558.2	0.5
Skewness =	-2.4	0.6	0.5
Kurtosis =	8.8	2.4	2.4
Errors Calcul	0.0	0.0	0.0
Mode =	9.0	5.2	1.2

95th Percent Confidence Interval

6.04	10.65

99.9% Confidence Interval

4.46	12.23

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.8	11.83	11.7	10.4	12.3	=RiskTriang(0,17.95,100)	=RiskTriang(0.02,0.45256,3.4)

DO= =F3-((B3*EXP((-I3*C3)/(D3*86400)))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	5.4	0.3	0.0
Maximum =	11.7	99.0	3.4
Mean =	10.7	39.1	1.3
Std Deviation =	0.9	21.8	0.8
Variance =	0.8	475.0	0.6
Skewness =	-1.5	0.5	0.5
Kurtosis =	5.4	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	8.7	17.7	0.5

95th Percent Confidence Interval

9.01	12.45

99.9% Confidence Interval

7.83	13.63

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	k_a	k_d
Row 3	=F3-G3	4	5280	0.5	12.74	8.4	1.5	0.56	=RiskTriang(0,0.1,100)	=RiskTriang(0.02,2.08,3.4)

DO = =F3-(B3*EXP(-I3*C3/(D3*86400))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	0.1	0.0	0.1
Maximum =	8.4	99.0	3.4
Mean =	6.9	33.2	1.8
Std Deviation =	1.6	23.3	0.7
Variance =	2.4	543.8	0.5
Skewness =	-1.7	0.6	-0.2
Kurtosis =	5.2	2.4	2.5
Errors Calculated =	0.0	0.0	0.0
Mode =	2.4	22.2	2.2

95th Percent Confidence Interval

3.88	9.98

99.9% Confidence Interval

1.79	12.07

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.4	9.75	11.5	10.1	0.326	=RiskTriang(0,10.85,100)	=RiskTriang(0.02,0.85258,3.4)

DO= =F3-((B3*EXP((-I3*C3)/(D3*86400)))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	5.0	0.4	0.0
Maximum =	11.5	98.7	3.4
Mean =	10.8	36.3	1.4
Std Deviation =	0.8	22.3	0.7
Variance =	0.7	496.0	0.5
Skewness =	-2.2	0.6	0.4
Kurtosis =	8.7	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	10.8	16.1	1.2

95th Percent Confidence Interval

9.14	12.45

99.9% Confidence Interval

8.01	13.58

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.4	13.39	7.8	2.6	0.2	=RiskTriang(0,0.76,100)	=RiskTriang(0.02,0.889093682,3.4)

DO= =F3-((B3*EXP((-I3*C3)/(D3*86400)))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	-0.9	0.0	0.0
Maximum =	7.8	98.3	3.4
Mean =	6.6	34.1	1.4
Std Deviatioı	1.4	23.3	0.7
Variance =	2.1	542.6	0.5
Skewness =	-2.0	0.5	0.4
Kurtosis =	6.9	2.4	2.4
Errors Calcu	0.0	0.0	0.0
Mode =	5.1	19.6	0.5

95th Percent Confidence Interval

3.76	9.40

99.9% Confidence Interval

1.84	11.32

	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J
	D	D_o	x	U	L_o	D_s	DO_{obs}	Q		
	mg/L	mg/L	ft	ft/s	mg/L	mg/L	mg/L	cfs	Ka	Kd
Row 3	=F3-G3	4	5280	0.5	7.02	11.2	10.6	0.876	=RiskTriang(0,20.05,100)	=RiskTriang(0.02,0.759422516,3.4)

DO= =F3-((B3*EXP((-I3*C3)/(D3*86400)))+(E3*J3/(I3-J3))*(EXP(-J3*C3/(D3*86400))-EXP(-I3*C3/(D3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	5.7	0.4	0.0
Maximum =	11.2	99.6	3.4
Mean =	10.7	40.2	1.4
Std Deviation =	0.6	21.7	0.7
Variance =	0.4	470.0	0.5
Skewness =	-2.8	0.5	0.4
Kurtosis =	12.8	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	10.4	23.9	0.6

95th Percent Confidence Interval

9.43	11.94

99.9% Confidence Interval

8.58	12.80

Appendix M
Watershed Management Model (WMM) Analyses

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M.1 Watershed Management Model (WMM)

As discussed in Sections 6.2.3 and 8.3, the WMM model was run as a screening tool to assess the BOD_5 loads that are typically generated annually for the watershed. This appendix provides the output files from the WMM analysis for each sampled date in the Beaucoup Creek watershed and for the average annual precipitation event.

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

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

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	56,312	0	0	0	0	0	0	54,372	51,263	227	680	0	35	0	0	162,889
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	1,225,013	0	0	0	0	0	0	0	278,793	8,686	26,059	0	189	0	0	1,538,740
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	7,809,456	0	0	0	0	0	0	0	7,109,217	51,132	153,396	0	4,831	0	0	15,128,032
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	49,000,510	0	0	0	0	0	0	0	12,155,367	19,319	57,958	0	8,259	0	0	61,241,413
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	15,312,659	0	0	0	0	0	0	0	13,939,641	61,605	184,815	0	9,472	0	0	29,508,191
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	392,004	0	0	0	0	0	0	6,056	16,772	124	233	0	11	0	0	415,201
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	13,781	0	0	0	0	0	0	5,914	4,182	166	499	0	3	0	0	24,545
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	1,408,765	0	0	0	0	0	0	151,802	180,435	926	1,765	0	123	0	0	1,743,816
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	710,507	0	0	0	0	0	0	87,641	50,127	618	1,279	0	34	0	0	850,206
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	698,257	0	0	0	0	0	0	64,162	130,308	308	486	0	89	0	0	893,610
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	181	4,668	19	50	0	6	0	0	4,924
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	208	1,758	5	10	0	2	0	0	1,983
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	7,905	11,853	82	120	0	8	0	0	19,968
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	1,890	0	0	0	0	0	0	1,825	1,720	8	23	0	1	0	0	5,466
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	41,108	0	0	0	0	0	0	0	9,355	291	874	0	6	0	0	51,636
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	262,062	0	0	0	0	0	0	0	238,564	1,716	5,148	0	162	0	0	507,652
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	1,644,312	0	0	0	0	0	0	0	407,898	648	1,945	0	277	0	0	2,055,081
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	513,848	0	0	0	0	0	0	0	467,773	2,067	6,202	0	318	0	0	990,208
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	13,154	0	0	0	0	0	0	203	563	4	8	0	0	0	0	13,933
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	462	0	0	0	0	0	0	198	140	6	17	0	0	0	0	824
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	47,274	0	0	0	0	0	0	5,094	6,055	31	59	0	4	0	0	58,517
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	23,843	0	0	0	0	0	0	2,941	1,682	21	43	0	1	0	0	28,530
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	23,431	0	0	0	0	0	0	2,153	4,373	10	16	0	3	0	0	29,987
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	6	157	1	2	0	0	0	0	165
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	7	59	0	0	0	0	0	0	67
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	265	398	3	4	0	0	0	0	670
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	176	0	0	0	0	0	0	170	161	1	2	0	0	0	0	510
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	3,837	0	0	0	0	0	0	0	873	27	82	0	1	0	0	4,819
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	24,459	0	0	0	0	0	0	0	22,266	160	480	0	15	0	0	47,381
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	153,469	0	0	0	0	0	0	0	38,071	61	182	0	26	0	0	191,808
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	47,959	0	0	0	0	0	0	0	43,659	193	579	0	30	0	0	92,419
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	1,228	0	0	0	0	0	0	19	53	0	1	0	0	0	0	1,300
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	43	0	0	0	0	0	0	19	13	1	2	0	0	0	0	77
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	4,412	0	0	0	0	0	0	475	565	3	6	0	0	0	0	5,462
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	2,225	0	0	0	0	0	0	274	157	2	4	0	0	0	0	2,663
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	2,187	0	0	0	0	0	0	201	408	1	2	0	0	0	0	2,799
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	15	0	0	0	0	0	0	15
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	6
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	25	37	0	0	0	0	0	0	63
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	403	0	0	0	0	0	0	389	367	2	5	0	0	0	0	1,166
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	8,770	0	0	0	0	0	0	0	1,996	62	187	0	1	0	0	11,016
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	55,907	0	0	0	0	0	0	0	50,894	366	1,098	0	35	0	0	108,299
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	350,787	0	0	0	0	0	0	0	87,018	138	415	0	59	0	0	438,417
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	109,621	0	0	0	0	0	0	0	99,792	441	1,323	0	68	0	0	211,244
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	2,806	0	0	0	0	0	0	43	120	1	2	0	0	0	0	2,972
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	99	0	0	0	0	0	0	42	30	1	4	0	0	0	0	176
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	10,085	0	0	0	0	0	0	1,087	1,292	7	13	0	1	0	0	12,484
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	5,086	0	0	0	0	0	0	627	359	4	9	0	0	0	0	6,086
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	4,999	0	0	0	0	0	0	459	933	2	3	0	1	0	0	6,397
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	33	0	0	0	0	0	0	35
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	13	0	0	0	0	0	0	14
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	57	85	1	1	0	0	0	0	143
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	693	0	0	0	0	0	0	669	631	3	8	0	0	0	0	2,004
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	15,073	0	0	0	0	0	0	0	3,430	107	321	0	2	0	0	18,933
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	96,090	0	0	0	0	0	0	0	87,474	629	1,887	0	59	0	0	186,139
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	602,915	0	0	0	0	0	0	0	149,563	238	713	0	102	0	0	753,530
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	188,411	0	0	0	0	0	0	0	171,517	758	2,274	0	117	0	0	363,076
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	4,823	0	0	0	0	0	0	75	206	2	3	0	0	0	0	5,109
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	170	0	0	0	0	0	0	73	51	2	6	0	0	0	0	302
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	17,334	0	0	0	0	0	0	1,868	2,220	11	22	0	2	0	0	21,456
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	8,742	0	0	0	0	0	0	1,078	617	8	16	0	0	0	0	10,461
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	8,592	0	0	0	0	0	0	789	1,603	4	6	0	1	0	0	10,995
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	2	57	0	1	0	0	0	0	61
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	3	22	0	0	0	0	0	0	24
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	97	146	1	1	0	0	0	0	246
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	38	0	0	0	0	0	0	36	34	0	0	0	0	0	0	109
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	822	0	0	0	0	0	0	0	187	6	17	0	0	0	0	1,033
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	5,241	0	0	0	0	0	0	0	4,771	34	103	0	3	0	0	10,153
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	32,886	0	0	0	0	0	0	0	8,158	13	39	0	6	0	0	41,102
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	10,277	0	0	0	0	0	0	0	9,355	41	124	0	6	0	0	19,804
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	263	0	0	0	0	0	0	4	11	0	0	0	0	0	0	279
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	9	0	0	0	0	0	0	4	3	0	0	0	0	0	0	16
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	945	0	0	0	0	0	0	102	121	1	1	0	0	0	0	1,170
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	477	0	0	0	0	0	0	59	34	0	1	0	0	0	0	571
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	469	0	0	0	0	0	0	43	87	0	0	0	0	0	0	600
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	5	8	0	0	0	0	0	0	13
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	176	0	0	0	0	0	0	170	161	1	2	0	0	0	0	510
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	3,837	0	0	0	0	0	0	0	873	27	82	0	1	0	0	4,819
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	24,459	0	0	0	0	0	0	0	22,266	160	480	0	15	0	0	47,381
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	153,469	0	0	0	0	0	0	0	38,071	61	182	0	26	0	0	191,808
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	47,959	0	0	0	0	0	0	0	43,659	193	579	0	30	0	0	92,419
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	1,228	0	0	0	0	0	0	19	53	0	1	0	0	0	0	1,300
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	43	0	0	0	0	0	0	19	13	1	2	0	0	0	0	77
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	4,412	0	0	0	0	0	0	475	565	3	6	0	0	0	0	5,462
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	2,225	0	0	0	0	0	0	274	157	2	4	0	0	0	0	2,663
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	2,187	0	0	0	0	0	0	201	408	1	2	0	0	0	0	2,799
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	15	0	0	0	0	0	0	15
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	6	0	0	0	0	0	0	6
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	25	37	0	0	0	0	0	0	63
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	227	0	0	0	0	0	0	219	206	1	3	0	0	0	0	656
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	4,933	0	0	0	0	0	0	0	1,123	35	105	0	1	0	0	6,196
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	31,447	0	0	0	0	0	0	0	28,628	206	618	0	19	0	0	60,918
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	197,317	0	0	0	0	0	0	0	48,948	78	233	0	33	0	0	246,610
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	61,662	0	0	0	0	0	0	0	56,133	248	744	0	38	0	0	118,825
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	1,579	0	0	0	0	0	0	24	68	1	1	0	0	0	0	1,672
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	55	0	0	0	0	0	0	24	17	1	2	0	0	0	0	99
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	5,673	0	0	0	0	0	0	611	727	4	7	0	0	0	0	7,022
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	2,861	0	0	0	0	0	0	353	202	2	5	0	0	0	0	3,424
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	2,812	0	0	0	0	0	0	258	525	1	2	0	0	0	0	3,598
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	19	0	0	0	0	0	0	20
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	1	7	0	0	0	0	0	0	8
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	32	48	0	0	0	0	0	0	80
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	642	0	0	0	0	0	0	620	585	3	8	0	0	0	0	1,858
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	13,977	0	0	0	0	0	0	0	3,181	99	297	0	2	0	0	17,556
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	89,101	0	0	0	0	0	0	0	81,112	583	1,750	0	55	0	0	172,602
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	559,066	0	0	0	0	0	0	0	138,685	220	661	0	94	0	0	698,728
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	174,708	0	0	0	0	0	0	0	159,043	703	2,109	0	108	0	0	336,671
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	4,473	0	0	0	0	0	0	69	191	1	3	0	0	0	0	4,737
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	157	0	0	0	0	0	0	67	48	2	6	0	0	0	0	280
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	16,073	0	0	0	0	0	0	1,732	2,059	11	20	0	1	0	0	19,896
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	8,106	0	0	0	0	0	0	1,000	572	7	15	0	0	0	0	9,700
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	7,967	0	0	0	0	0	0	732	1,487	4	6	0	1	0	0	10,196
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	2	53	0	1	0	0	0	0	56
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	2	20	0	0	0	0	0	0	23
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	90	135	1	1	0	0	0	0	228
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
BEAUCOUP CREEK WATERSHED
AVERAGE BEAUCOUP CREEK LOADS BY SUBBASIN
ANNUAL

Constituent	(units)	Basin	Jurisdiction	Baseflow	Point Source	ISDS	Agriculture	COM	Extractive	Farm	IND	Institutional	Roads	Water	Forest	Res High	Res Med	Urban Open	Vacant	LU1	LU2	Total
Runoff	(ac-ft/yr)	Beaucoup Creek	Perry	0	0	0	642	0	0	0	0	0	0	620	585	3	8	0	0	0	0	1,858
BOD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	13,977	0	0	0	0	0	0	0	3,181	99	297	0	2	0	0	17,556
COD	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	89,101	0	0	0	0	0	0	0	81,112	583	1,750	0	55	0	0	172,602
TSS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	559,066	0	0	0	0	0	0	0	138,685	220	661	0	94	0	0	698,728
TDS	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	174,708	0	0	0	0	0	0	0	159,043	703	2,109	0	108	0	0	336,671
Total-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	4,473	0	0	0	0	0	0	69	191	1	3	0	0	0	0	4,737
Dissolved-P	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	157	0	0	0	0	0	0	67	48	2	6	0	0	0	0	280
Total-N	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	16,073	0	0	0	0	0	0	1,732	2,059	11	20	0	1	0	0	19,896
TKN	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	8,106	0	0	0	0	0	0	1,000	572	7	15	0	0	0	0	9,700
NO2+NO3	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	7,967	0	0	0	0	0	0	732	1,487	4	6	0	1	0	0	10,196
Lead	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	2	53	0	1	0	0	0	0	56
Copper	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	2	20	0	0	0	0	0	0	23
Zinc	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	90	135	1	1	0	0	0	0	228
Manganese	(lbs/yr)	Beaucoup Creek	Perry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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Appendix N
Reduction Analyses -
BATHTUB Output Files

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BATHTUB Output for 1990 Reduction Analysis

CASE: WC Lake 1990 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	198.6	.26	41.6	.45	4.78	6.11	5.81	3.01
CHL-A	MG/M3	98.6	.27	35.3	.61	2.79	3.76	2.97	1.54
SECCHI	M	.4	.13	1.0	.66	.40	-7.31	-3.31	-1.37
ORGANIC N	MG/M3	.0	.00	967.3	.49	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	60.6	.56	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	170.0	.36	49.6	.45	3.43	3.42	4.58	2.13
CHL-A	MG/M3	66.4	.38	18.3	.77	3.62	3.38	3.72	1.50
SECCHI	M	.6	.16	1.7	1.47	.33	-6.93	-3.98	-.75
ORGANIC N	MG/M3	.0	.00	584.9	.60	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	31.6	1.08	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	221.8	.79	58.3	.45	3.80	1.70	4.97	1.47
CHL-A	MG/M3	61.9	.35	27.3	.74	2.27	2.36	2.36	1.00
SECCHI	M	.6	.13	1.3	1.04	.49	-5.52	-2.56	-.69
ORGANIC N	MG/M3	.0	.00	785.6	.61	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	46.4	.87	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	188.8	.45	49.7	.45	3.80	2.96	4.96	2.09
CHL-A	MG/M3	73.0	.34	24.4	.67	2.99	3.22	3.16	1.45
SECCHI	M	.5	.15	1.5	1.04	.37	-6.74	-3.52	-.94
ORGANIC N	MG/M3	.0	.00	721.9	.54	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	41.9	.77	.00	.00	.00	.00

CASE: WC Lake 1990 - Reduced

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	2.320	.000E+00	.000	.400
2	1	Subbasin 2	6.220	2.530	.000E+00	.000	.407
3	1	Subbasin 3	4.580	1.760	.000E+00	.000	.384
4	1	Subbasin 4	3.330	1.340	.000E+00	.000	.402
5	1	Subbasin 5	4.420	1.800	.000E+00	.000	.407
6	1	Subbasin 6	2.340	.940	.000E+00	.000	.402
		PRECIPITATION	.979	.989	.391E-01	.200	1.010
		TRIBUTARY INFLOW	26.690	10.690	.000E+00	.000	.401
		***TOTAL INFLOW	27.669	11.679	.391E-01	.017	.422
		ADVECTIVE OUTFLOW	27.669	10.854	.100E+00	.029	.392
		***TOTAL OUTFLOW	27.669	10.854	.100E+00	.029	.392
		***EVAPORATION	.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	78.0	5.1	.000E+00	.0	.000	33.6	13.4
2	1	Subbasin 2	77.9	5.1	.000E+00	.0	.000	30.8	12.5
3	1	Subbasin 3	70.2	4.6	.000E+00	.0	.000	39.9	15.3
4	1	Subbasin 4	13.0	.8	.000E+00	.0	.000	9.7	3.9
5	1	Subbasin 5	10.1	.7	.000E+00	.0	.000	5.6	2.3
6	1	Subbasin 6	10.0	.6	.000E+00	.0	.000	10.6	4.3
		PRECIPITATION	29.4	1.9	.216E+03	100.0	.500	29.7	30.0
		INTERNAL LOAD	1245.6	81.2	.000E+00	.0	.000	.0	.0
		TRIBUTARY INFLOW	259.1	16.9	.000E+00	.0	.000	24.2	9.7
		***TOTAL INFLOW	1534.1	100.0	.216E+03	100.0	.010	131.4	55.4
		ADVECTIVE OUTFLOW	632.8	41.2	.817E+05	37892.7	.452	58.3	22.9
		***TOTAL OUTFLOW	632.8	41.2	.817E+05	37892.7	.452	58.3	22.9
		***RETENTION	901.3	58.8	.818E+05	37946.8	.317	.0	.0

BATHTUB Output for 1995 Reduction Analysis

CASE: WC Lake 1995 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	185.2	.25	40.1	.46	4.62	6.22	5.69	2.95
CHL-A	MG/M3	55.7	.46	16.0	.61	3.48	2.69	3.61	1.63
SECCHI	M	.4	.32	.6	.59	.62	-1.46	-1.68	-.70
ORGANIC N	MG/M3	.0	.00	616.3	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	54.1	.45	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	146.6	.26	48.9	.46	3.00	4.23	4.09	2.09
CHL-A	MG/M3	55.2	.50	24.9	.75	2.21	1.60	2.30	.88
SECCHI	M	36.0	.86	1.4	1.20	25.35	3.75	11.55	2.19
ORGANIC N	MG/M3	.0	.00	731.4	.61	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	42.2	.91	.00	.00	.00	.00

SEGMENT: 3 Near Dam

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	269.6	1.05	61.9	.45	4.36	1.40	5.47	1.29
CHL-A	MG/M3	50.5	.73	33.0	.59	1.53	.59	1.23	.45
SECCHI	M	.7	.07	1.0	.72	.70	-5.11	-1.30	-.50
ORGANIC N	MG/M3	.0	.00	921.8	.45	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	58.7	.48	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	184.4	.53	49.8	.45	3.70	2.49	4.86	1.89
CHL-A	MG/M3	54.2	.54	24.7	.64	2.20	1.46	2.27	.94
SECCHI	M	19.4	.85	1.1	.87	17.15	3.34	10.15	2.33
ORGANIC N	MG/M3	.0	.00	748.6	.49	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	48.8	.62	.00	.00	.00	.00

CASE: WC Lake 1995 - Reduced

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	3.400	.000E+00	.000	.586
2	1	Subbasin 2	6.220	3.730	.000E+00	.000	.600
3	1	Subbasin 3	4.580	2.630	.000E+00	.000	.574
4	1	Subbasin 4	3.330	1.940	.000E+00	.000	.583
5	1	Subbasin 5	4.420	2.570	.000E+00	.000	.581
6	1	Subbasin 6	2.340	1.350	.000E+00	.000	.577
		PRECIPITATION	.979	1.165	.543E-01	.200	1.190
		TRIBUTARY INFLOW	26.690	15.620	.000E+00	.000	.585
		***TOTAL INFLOW	27.669	16.785	.543E-01	.014	.607
		ADVECTIVE OUTFLOW	27.669	15.961	.115E+00	.021	.577
		***TOTAL OUTFLOW	27.669	15.961	.115E+00	.021	.577
		***EVAPORATION	.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	149.9	7.4	.000E+00	.0	.000	44.1	25.9
2	1	Subbasin 2	195.1	9.7	.000E+00	.0	.000	52.3	31.4
3	1	Subbasin 3	156.0	7.7	.000E+00	.0	.000	59.3	34.1
4	1	Subbasin 4	75.1	3.7	.000E+00	.0	.000	38.7	22.5
5	1	Subbasin 5	59.9	3.0	.000E+00	.0	.000	23.3	13.5
6	1	Subbasin 6	20.0	1.0	.000E+00	.0	.000	14.8	8.5
		PRECIPITATION	29.4	1.5	.216E+03	100.0	.500	25.2	30.0
		INTERNAL LOAD	1332.4	66.0	.000E+00	.0	.000	.0	.0
		TRIBUTARY INFLOW	655.9	32.5	.000E+00	.0	.000	42.0	24.6
		***TOTAL INFLOW	2017.7	100.0	.216E+03	100.0	.007	120.2	72.9
		ADVECTIVE OUTFLOW	987.6	48.9	.200E+0692652.0		.453	61.9	35.7
		***TOTAL OUTFLOW	987.6	48.9	.200E+0692652.0		.453	61.9	35.7
		***RETENTION	1030.2	51.1	.200E+0692694.7		.434	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
16.30	.2480	184.4	.3616	2.7653	.5106

BATHTUB Output for 2001 Reduction Analysis

CASE: WC Lake 2001 - Reduced

T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
USING THE FOLLOWING ERROR TERMS:
1 = OBSERVED WATER QUALITY ERROR ONLY
2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
3 = OBSERVED AND PREDICTED ERROR

SEGMENT: 1 Upper Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	105.6	.33	49.4	.45	2.14	2.31	2.83	1.36
CHL-A	MG/M3	38.2	.74	21.1	.57	1.81	.80	1.71	.63
SECCHI	M	.5	.34	.6	.54	.80	-.66	-.80	-.35
ORGANIC N	MG/M3	.0	.00	726.5	.37	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	61.1	.42	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	70.8	.26	47.4	.45	1.49	1.54	1.49	.77
CHL-A	MG/M3	36.0	.86	22.7	.67	1.59	.54	1.34	.42
SECCHI	M	.7	.34	.9	.92	.77	-.76	-.93	-.27
ORGANIC N	MG/M3	.0	.00	715.9	.52	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	49.5	.76	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	88.1	.94	47.4	.45	1.86	.66	2.30	.59
CHL-A	MG/M3	35.9	.55	19.2	.63	1.87	1.13	1.82	.75
SECCHI	M	.8	.57	1.1	1.07	.68	-.67	-1.36	-.31
ORGANIC N	MG/M3	.0	.00	625.8	.48	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.0	.80	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	83.0	.45	47.9	.45	1.73	1.23	2.05	.87
CHL-A	MG/M3	36.5	.76	21.5	.63	1.70	.70	1.53	.54
SECCHI	M	.7	.40	.9	.64	.75	-.72	-1.03	-.38
ORGANIC N	MG/M3	.0	.00	697.5	.46	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	50.0	.58	.00	.00	.00	.00

CASE: WC Lake 2001 - Reduced

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Subbasin 1	5.800	.860	.000E+00	.000	.148
2	1	Subbasin 2	6.220	.950	.000E+00	.000	.153
3	1	Subbasin 3	4.580	.610	.000E+00	.000	.133
4	1	Subbasin 4	3.330	.540	.000E+00	.000	.162
5	1	Subbasin 5	4.420	.730	.000E+00	.000	.165
6	1	Subbasin 6	2.340	.390	.000E+00	.000	.167
PRECIPITATION			.979	.764	.233E-01	.200	.780
TRIBUTARY INFLOW			26.690	4.080	.000E+00	.000	.153
***TOTAL INFLOW			27.669	4.844	.233E-01	.032	.175
ADVECTIVE OUTFLOW			27.669	4.019	.845E-01	.072	.145
***TOTAL OUTFLOW			27.669	4.019	.845E-01	.072	.145
***EVAPORATION			.000	.824	.612E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Subbasin 1	35.1	6.1	.000E+00	.0	.000	40.8	6.0
2	1	Subbasin 2	139.8	24.4	.000E+00	.0	.000	147.2	22.5
3	1	Subbasin 3	100.8	17.6	.000E+00	.0	.000	165.3	22.0
4	1	Subbasin 4	35.0	6.1	.000E+00	.0	.000	64.8	10.5
5	1	Subbasin 5	104.4	18.3	.000E+00	.0	.000	143.0	23.6
6	1	Subbasin 6	69.2	12.1	.000E+00	.0	.000	177.4	29.6
PRECIPITATION			29.4	5.1	.216E+03	100.0	.500	38.5	30.0
INTERNAL LOAD			58.3	10.2	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			484.3	84.7	.000E+00	.0	.000	118.7	18.1
***TOTAL INFLOW			572.0	100.0	.216E+03	100.0	.026	118.1	20.7
ADVECTIVE OUTFLOW			190.7	33.3	.742E+04	3439.9	.452	47.4	6.9
***TOTAL OUTFLOW			190.7	33.3	.742E+04	3439.9	.452	47.4	6.9
***RETENTION			381.3	66.7	.755E+04	3499.4	.228	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	---- TOTAL P ---- POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
4.11	.9750	83.0	.5689	1.7579	.6666

Appendix O
Responsiveness Summary

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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from January 23 to March 29 postmarked, including those from the February 25, 2004 public meeting discussed below.

What is a TMDL?

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

Background

The watershed targeted for TMDL development is Beaucoup Creek (ILNC05), which originates in the south central portion of Washington County, Illinois. The watershed encompasses an area of approximately 320 square miles. Land use in the watershed is predominately agriculture, followed by grassland and forested land uses. TMDLs developed for impaired water bodies in the Beaucoup Creek watershed include Beaucoup Creek segments NC10 and NC03; Little Beaucoup Creek segment NCI01; Swanwick Creek segment NCK01; Walkers Creek segment NCC01, and Washington County Lake (RNM). In the 2002 Section 303(d) List, Beaucoup Creek (NC03) was listed as impaired for low dissolved oxygen (DO), sulfates, and total dissolved solids (TDS); Beaucoup Creek (NC10) was listed for nitrogen, nitrates, phosphorus, DO, other habitat alterations, and total suspended solids (TSS); Little Beaucoup Creek (NCI01) was listed for manganese, nitrogen, DO, and other habitat alterations; Swanwick Creek (NCK01) was listed for manganese, sulfates, nitrogen, siltation, DO, and other habitat alterations; Walkers Creek (NCC01) was listed for manganese, sulfates, TDS, and other habitat alterations; Washington County Lake was listed from Alpha BHC, phosphorus, nitrogen, siltation, DO, TSS, excessive algal growth, and chlorophyll-a. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were developed for the following: Beaucoup Creek (NC03): DO, sulfates, TDS; Beaucoup Creek (NC10): DO; Little Beaucoup Creek (NCI01): manganese, DO; Swanwick Creek (NCK01): manganese, sulfates, DO; Walkers Creek (NCC01): manganese, sulfates, TDS; Washington County Lake (RNM): Phosphorus, DO. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Beaucoup Creek watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001 and in the city of Pinkneyville on December 13, 2001 and February 25, 2004. The Illinois EPA provided public notice for the February 25, 2004 meeting by placing display ads in the Southern Illinoisan and DuQuoin Evening Call on January 27, 2004 and The Democrat and Sparta News Plaindealer on January 25, 2004. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 47 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the Pinkneyville Community High School office and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 6:00 p.m. on Wednesday, February 25, 2004. It was attended by approximately 22 people and concluded at 7:30 p.m. with the meeting record remaining open until midnight, March 29, 2004.

Questions and Comments

1. When will the impaired streams be retested?

Response: Beaucoup Creek was sampled in 2003 and may be sampled again in 2008. Swanwick Creek, Walkers Creek, and Little Beaucoup Creek have not been sampled since 1995 and are not currently scheduled for resampling. It is unknown at this time when those streams will be re-sampled.

2. How often are water quality samples taken in these streams?

Response: There is no regular sampling schedule for these stream segments. In general, the Illinois EPA attempts to monitor streams in each major basin every five years. However, the particular streams and stations which are monitored may vary each time a basin is sampled. When streams are monitored as part of the rotating basin plan, there are usually two or three water samples taken during a summer/fall sampling period. Samples of the fish community, macroinvertebrate community, habitat, and sediment are also collected once during survey.

3. Where are those samples taken from?

Response: Past sampling has occurred at the following stations:

Beaucoup Cr, NC-10: 5S 2W SW19, Field Rd via E Grand St, SE edge Pinckneyville
Beaucoup Cr, NC-03: 6S 2W SW29, Rt 13-127, 6 mi NW DuQuoin
Beaucoup Cr, NC-05: 5S 2W NW19, Rt 154, E Pinckneyville
Little Beaucoup Cr, NCI-01: 4S 2W SW21, Rd 6 mi NNE Pinckneyville
Swanwick Cr, NCK-01: 4S 3W NW25, Rt 127, 5 mi N Pinckneyville
Walkers Cr, NCC-01: 6S 2W NE32, Rd 1 mi E Matthews

4. Why weren't data used from Beaucoup Creek station NC07?

Response: Station NC07 is located outside of Beaucoup Creek Watershed ILNC05, which was the focus of this report. Station NC07 is located on Beaucoup Creek segment NC07, which is downstream of the impaired segments for which TMDLs were developed.

5. Right now all of the practices recommended in the Implementation Plan are voluntary. If the impaired segments don't improved, would that change?

Response: At this time, the Agency does not foresee any of the recommended actions in the Implementation Plan becoming mandatory for the pollutants addressed in this TMDL report.

6. Explain why groundwater is listed as a source of pollutants.

Response: Shallow groundwater can contribute to the pollutant load of streams and lakes. This source is particularly important during low flow periods since groundwater may then contribute a relatively high proportion of the stream flow.

7. Did any of the stream samples taken include sediment samples?

Response: Sediment was collected at all the sites listed in response number three, except NC-05.

8. The Implementation Plan's cost estimates are skewed, in that it doesn't take into account the cost of employee salaries who provide technical assistance for BMPs.

Response: As stated in the report, the costs of implementation are based on an order of magnitude to give a general idea of how much the management measures will cost. The costs are broken down between capital costs to install the structure or practices and the annual costs to maintain them. Costs for technical expertise for each practice were not included.

9. What's the source of phosphorus in Washington County Lake?

Response: The report states that 78 percent of the phosphorus load is caused by internal cycling, with 17 percent being attributed to row crop and small grain agriculture production. The remaining 5 percent is attributed to pastureland, animal facilities, and groundwater.

10. Since most of the phosphorus is in sediment at the bottom of the lake, wouldn't it make sense to dredge?

Response: While dredging is mentioned in the report, it would not be a practical application from an economic standpoint. Dredging is quite expensive, costing an average of $8,000 per acre.

11. How can aeration be increased in the streams?
Response: One method suggested in the report is installing a series of rock riffles, which increases stream turbulence, adding oxygen to the water.

12. What can be done with the manganese, sulfates, and TDS coming from mining areas?

Response: The Implementation Plan lists several management measures that could be implemented to control runoff from mining areas, such as aerobic and anaerobic wetlands, open and anoxic limestone channels, diversion wells, vertical flow reactors, and pyroclastic process.

13. Swanwick Creek is listed for manganese, but no mines exist in that subwatershed.

Response: There is one pre-law mine site tributary to Swanwick Creek. Manganese levels may be naturally elevated in this area as well.

14. If a mine is found to contribute to a pollutant, wouldn't that be counted as a point source?

Response: An active mine that is permitted to discharge wastewater is considered a point source, and is subject to regulations imposed by the State. However, runoff from abandoned mines in the watershed is considered non-point source pollution, and is not addressed through a wastewater permit.

15. Will NPDES permits be issued for 303(d) listed streams in this watershed?

Response: NPDES permits cannot be issued to facilities that will discharge pollutants that we identified as a cause of impairment. Until practices are in place and further stream monitoring indicates attainment of the applicable standard, no new load can be added to these streams.

16. Where were the land use data taken from?

Response: Land use data were obtained from the Critical Trends Assessment Land Cover Database of Illinois, which was provided by Illinois Department of Natural Resources.

17. For Walkers Creek, the study recommends that sulfate be reduced to 460 mg/l and TDS reduced to 997 mg/l. It appears that the report has a goal of using new NPDES discharges to reduce the total loading in the stream by requiring a more restrictive value than is the minimum recommended value. The general use minimum water quality standard recommended values are: sulfate 500mg/l, and TDS 1,000 mg/l. This places the clean up burden on new permit requests. Overall, the data is too old and not comprehensive enough to make sound recommendations. It appears the entire report is based on two samples that are eight to nine years old. The few data points are extrapolated to produce the recommended results. If the draft TMDL report is approved as published at the public meetings, the effect on future NPDES permits will be devastating. Future permits will be responsible for reducing their TDS and sulfates below general water quality standards to satisfy the improvement of previously affects watersheds. This is an unfair and unreasonable burden to place on future permit requests.

RESPONSE: Due to the limited data set, the Monte Carlo analysis was used to determine load allocations for sulfates, TDS, and manganese. This analysis determined the long-term averages (LTA) needed for the impaired stream segments to comply with water quality standards. The analysis also determined the actual loading capacities that need to occur in the impaired stream segments. The LTAs for Walkers Creek, taking into account the margin of safety, are as follows:

Manganese: 0.6 mg/L

Sulfates: 414 mg/L
TDS: 897 mg/L

The loading capacities for Walkers Creek are:

Manganese: 37 lb/day
Sulfates: 24,811 lb/day
TDS: 53,776 lb/day

Section 9.2.1 of the report states "Based on the data review, the source of manganese, sulfates, and TDS in the Beaucoup Creek Watershed is groundwater potentially contaminated by oil and gas activities and coal mines. One of the samples in Walkers Creek showing impairments was taken at above average flow conditions suggesting that sources may include surface runoff from mining activities." The report also suggests abandoned mines as being a possible source of impairment. Table 9-7 of the draft final report erroneously shows a waste load allocation of 287 mg/L for Walkers Creek segment NCC01. This misprint will be corrected in the final version of this report to reflect a waste load allocation of zero.

The Agency recognizes the age of the limited data set used to develop TMDLs in this watershed. The report stresses the need for future monitoring to occur in order to increase the data set and to further refine our understanding of the contribution from abandoned mines. Effluent concentration levels for future permits will be determined during the permitting process. The loading capacity stated in Table 9-7 of the report will be used for calculating the effluent limitations for future permits within the watersheds. Possible trading scenarios between dischargers could be implemented to meet the required loading capacity.

DISTRIBUTION OF RESPONSIVENESS SUMMARY

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

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

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