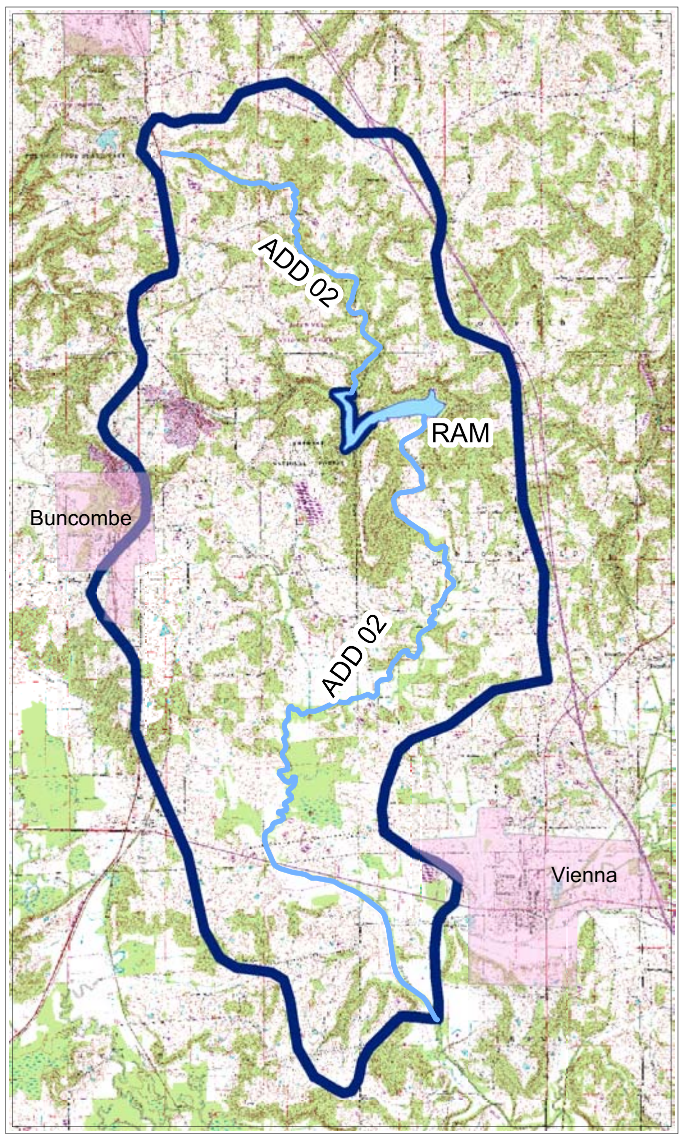
Illinois
Environmental
Protection Agency

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

October 2004

IEPA/BOW/04-009

DUTCHMAN CREEK TMDL REPORT



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

REPLY TO THE ATTENTION OF:
WW-16J

23 SEP 2004

Marcia Willhite, Chief
Bureau of Water
IEPA
P.O. Box 19276
1021 North Grand Avenue East
Springfield, Illinois 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has conducted a complete review of the final Total Maximum Daily Load (TMDL) for phosphorus, including supporting documentation, for Dutchman Lake, located in Johnson County, Illinois. Based on this review, U.S. EPA has determined that Illinois's TMDL for phosphorus for this waterbody 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, by this letter, U.S. EPA hereby approves the one TMDL for Dutchman Lake. The statutory and regulatory requirements, and U.S. EPA's review of Illinois's compliance with each requirement, are described in the enclosed decision document.

We wish to acknowledge Illinois's effort in this submitted TMDL, and look forward to future quality TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Wetlands and Watersheds 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 Inc. to develop Total Maximum Daily Loads (TMDLs) for Dutchman Creek (ADD01), Dutchman Creek (ADD02) and Dutchman Lake. In the 1998 Section 303(d) List, Dutchman Creek (ADD01) was listed as impaired for the parameters of phosphorus and nitrogen; Dutchman Creek (ADD02) was listed for low dissolved oxygen (DO), flow alterations, and other habitat alterations; Dutchman Lake was listed for nitrogen, siltation, DO, total suspended solids (TSS), noxious aquatic plants, excessive algal growth, and chlorophyll-a.

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, a TMDL will not be developed for Dutchman Creek (ADD01) at this time. TMDLs for Dutchman Creek (ADD02) and Dutchman Lake will only focus on low DO, for which a numeric water quality standard exists.

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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Contents

Figures

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Tables

Acronyms

°C	degrees Centrigrade
°F	degrees Fahrenheit
ALMP	Ambient Lake Monitoring Program
AWQMN	Ambient Water Quality Monitoring Network
BMP	best management practice
BOD	biochemical oxygen demand
BOD5	5-day 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 Report
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
MBI	Macroinvertebrate Biotic Index
mg/L	milligrams per liter
MOS	margin of safety
NASS	National Agricultural Statistics Service
NCDC	National Climatic Data Center
NPDES	National Pollutant Discharge Elimination System

NRC	National Research Council
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
PCS	permit compliance system
ppm	parts per million
SOD	sediment oxygen demand
SSRP	Streambank Stabilization and Restoration Practice
STATSGO	State Soil Geographic database
STORET	Storage and Retrieval database
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
WASCOBS	waterways, water and sediment control basins
WHIP	Wildlife Habitat Incentives Program
WLA	waste load allocation
WMM	Watershed Management Model
WRP	Wetlands Reserve Program

Executive Summary
Dutchman Creek Watershed

TMDL Fact Sheet

Basin Name:	Dutchman Lake	Dutchman Creek
Impaired Segments:	RAM	ADD02
Location:	Johnson County, Illinois	Johnson County, Illinois
Size:	118 acres at normal storage	14.8 miles
Primary Watershed Land Uses:	Forest, grassland, and agriculture	Forest, grassland, and agriculture
Criteria of Concern:	Dissolved oxygen (DO)	DO
Designated Uses Affected:	General use	General use
Environmental Indicators:	DO monitoring	DO monitoring
Major Sources:	Nonpoint source loading from agriculture and internal cycling	Stagnant stream conditions, elevated instream temperatures, and nonpoint source loading from agriculture
Loading Allocation:	3,294 pounds/year total phosphorus	No Allocation
Waste Load Allocation:	Zero; No point sources	No Allocation
Margin of Safety:	Implicit through conservative modeling; Additional explicit of 5 percent	No Allocation

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

A correlation between DO and total phosphorus was established for Dutchman Lake, and modeling demonstrates a reduction of 53 percent total phosphorus necessary so that DO water quality standards can be achieved. Primary sources of phosphorus loading to Dutchman Lake include internal cycling from the lake-bottom sediments and runoff from agricultural lands. Procedures outlined in the implementation plan to decrease phosphorus loading to the lake include in-lake measures as well as measures applied to the watershed to control nutrients in surface runoff and eroded sediment. In-lake mitigation practices include dredging the lake bottom and aerating the lake to eliminate internal cycling. Watershed controls include filter strips and wetlands to prevent phosphorus in surface runoff from reaching the lake, conservation tillage to decrease nutrient-rich soil erosion from agricultural fields, and development of nutrient management plans to ensure that excess phosphorus is not applied to agricultural fields.

The TMDL analysis for DO in Dutchman Creek segment ADD02 was made through investigation of the relationship between DO, total organic carbon (TOC), 5-day biochemical oxygen demand (BOD_5), and reaeration in the creek. The likely source of DO impairments in the segment is primarily a lack of aeration caused by stagnant stream conditions and elevated instream temperatures. BOD loadings in runoff from nonpoint source loads may also contribute to DO impairments. However, examination of BOD in the stream segment showed that the concentrations of BOD are low and likely represent ambient conditions in the stream; therefore, reductions in BOD concentrations are not recommended at this time. Due to data limitations and technical considerations of implementation difficulties, a load allocation cannot be developed for reaeration or temperature, so allocations were not developed for segment ADD02. Procedures to alleviate low DO caused by stagnant flows can be addressed with in-stream mitigation methods such as reaeration. Additionally, riparian buffer strips aid in decreasing instream temperatures, which could help to alleviate the DO impairment. Excess nutrients can cause excessive algal growth that can also deplete DO in streams; however, analytical tools were not used to assess nutrients, algae, and DO as no algal data was available for Dutchman Creek segment ADD02. Methods to control nutrients were still included in the implementation plan, such as buffer strips along the stream banks, which are similar to filter strips in their ability to remove nutrients from surface runoff. The potential contributions to BOD from nonpoint source loads are attributed to agricultural land uses requiring mitigation methods to control nutrients in sediment erosion and surface runoff from the land contributing to segment ADD02. These methods include filter strips, wetlands, conservation tillage, and nutrient management plans as discussed above.

Section 1
Goals and Objectives for Dutchman Creek Watershed (ILADD01)

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:

- To restore and maintain the chemical, physical, and biological integrity of the nation's waters , and
- 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, and
- 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 Dutchman Creek Watershed

The TMDL goals and objectives for the Dutchman 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 Dutchman Creek Watershed, which are also shown in Figure 1-1:

- Dutchman Lake (RAM)
- Dutchman Creek (ADD02)

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

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

These elements are combined into the following equation:

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

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

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Dutchman 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 Dutchman 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 Dutchman Creek Watershed Data Review** provides an overview of available data for the Dutchman Creek Watershed.
- **Section 6 Methodologies to Complete TMDLs for the Dutchman Creek Watershed** discusses the models and analyses needed for TMDL development.
- **Section 7 Model Development for Dutchman Lake** provides an explanation of model development for Dutchman Lake.
- **Section 8 Methodology Development for Dutchman Creek** describes the analytical procedures used to examine Dutchman Creek.
- **Section 9 Total Maximum Daily Load for the Dutchman 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 Dutchman Lake and Dutchman Creek** provides methods to reduce loadings to impaired water bodies.
- **Section 11 References** lists references used in this report.

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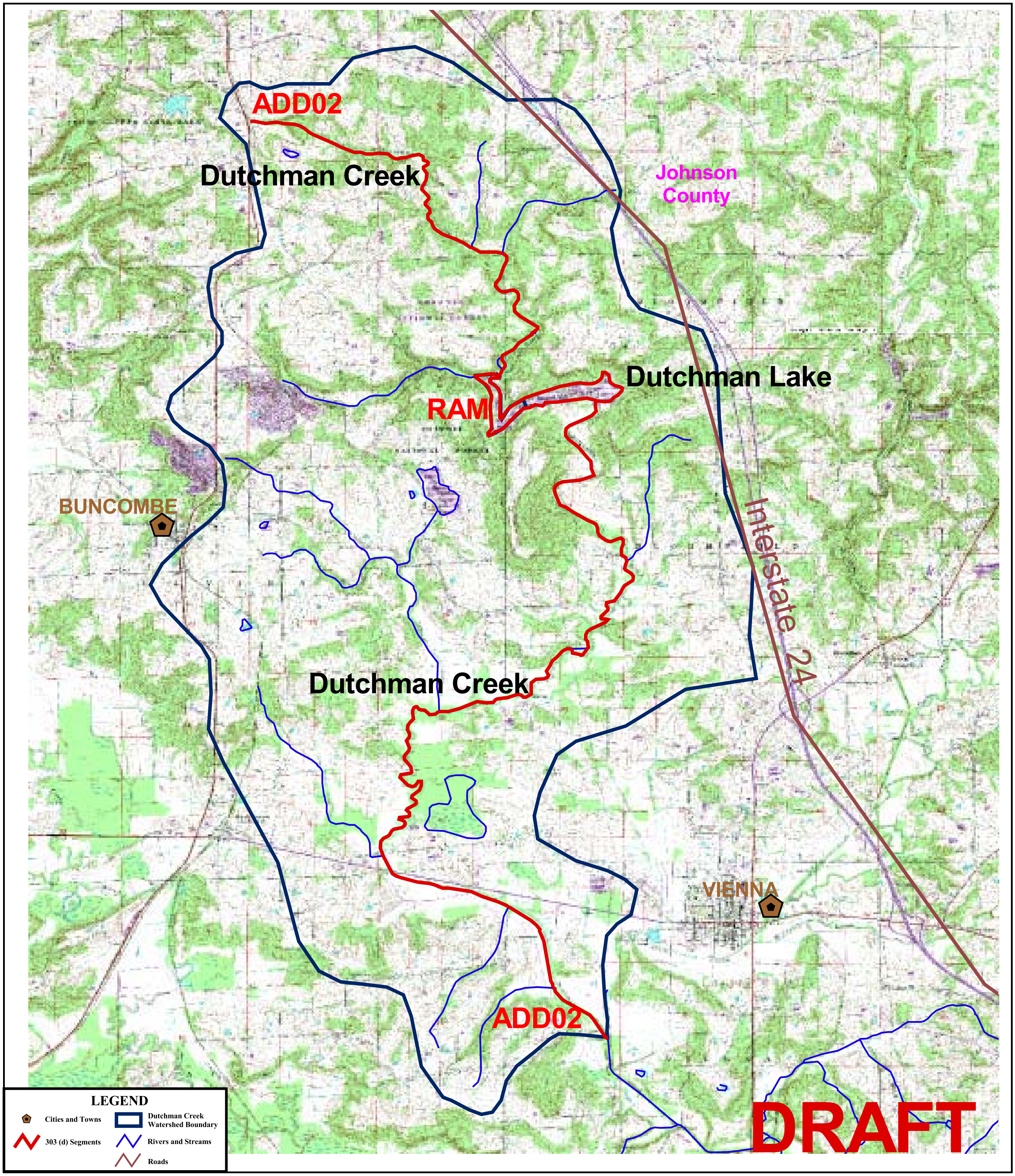

Figure 1-1
Dutchman Creek Watershed (ILADD01)
Impaired Segments

CDM

densvr01/projects/IEPA/gis_data/apr/dutchman 021203 MJF

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Section 2
Dutchman Creek Watershed Description

2.1 Dutchman Creek Watershed Overview

The Dutchman Creek Watershed originates in the north central portion of Johnson County, Illinois. The watershed is located within the U.S. Geological Survey (USGS) Lower Ohio Basin (Hydrologic Unit Code 05140206). The watershed encompasses an area of approximately 32 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 Dutchman Creek Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
RAM	Dutchman Lake	118 acres	Dissolved oxygen (DO)
ADD02	Dutchman Creek	14.8 miles	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 grassland followed by forested and agricultural land uses. Farmers in the area primarily raise cash crops, such as corn and soybeans.

Soils within the Dutchman Creek Watershed are primarily moderately well drained soils. The surface layer is typically brown friable silt loam about seven inches thick. The subsurface is yellowish brown friable silty loam about three inches thick. The subsoil extends below a depth of 60 inches and is comprised of a silty clay loam (U.S. Department of Agriculture [USDA] 1964).

The climate in the Dutchman Creek Watershed is cold in the winter and warm in the summer. In the winter, October through March, the average temperature is 44 degrees Fahrenheit (°F) and the average daily minimum temperature is 33°F according to data collected at New Burnside, Illinois. Summer temperatures are typically 70°F with an average daily maximum of 83°F. Annual precipitation is approximately 46 inches of which 23 inches, approximately 50 percent, usually falls in April through September (National Climatic Data Center [NCDC] 2002).

2.2 Stream Segment Site Reconnaissance of Dutchman Creek Watershed

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

Dutchman Creek upstream of Dutchman Lake, looking south from the low water crossing.

Table 2-1 lists the impaired stream segments in the Dutchman Creek Watershed. Based on the 1998 303(d) list, Illinois EPA determined that one segment of Dutchman Creek was impaired, Segment ADD02. This segment is shown in Figure 1-1. Segment ADD02 flows from north to south and is located within Johnson County, Illinois. This segment flows into and continues from Dutchman Lake. Observations of this segment were taken upstream of Dutchman Lake from the bridge east of Illinois Route 37 and west of Interstate 24, and downstream of Dutchman Lake at the crossing of County Road 600E, also called Brown Road. The observed portion of upper Dutchman Creek had little flow and a gravel stream bottom. The surrounding area was mostly forested, but did include some pastureland.

2.3 Lake Segment Site Reconnaissance of Dutchman Creek Watershed

Dutchman Creek downstream of Dutchman Lake, looking west (upstream) from the bridge.

Illinois EPA has listed one lake segment as impaired based on the 1998 303(d) list in the Dutchman Creek Watershed. Dutchman Lake, segment RAM, is located on Dutchman Creek in east central Johnson County as shown in Figure 1-1. Dam Number 12 was constructed on Dutchman Creek in 1974 creating Dutchman Lake. This dam is owned by the U.S. Forest Service. The structure is 1,450 feet in length and 54 feet tall enabling it to store a maximum volume of 2,740 acre-feet, although the normal storage capacity is 865 acre-feet. The lake is used for recreation. Dutchman Creek constitutes a majority of the 11 square miles of contributing drainage area (U.S. Army Corps of Engineers [USACE] 1999). Grasshopper Creek and direct drainage are other contributors to the lake.

Dutchman Lake, algal growth near the shore.

Dutchman Lake was observed on June 8, 2000 near the middle of the north bank of Dutchman Lake. The water in Dutchman Lake appeared clear, and the banks were heavily wooded. Some algal growth was present next to the shore in the observed area of the lake.

Section 3
Public Participation and Involvement

3.1 Dutchman 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 Dutchman Creek Watershed at 6:30 p.m. on December 11, 2001 at the Vienna City Hall in Vienna, Illinois. A total of 14 interested citizens including public officials and organizations other than Illinois EPA attended the public meeting.

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Section 4
Dutchman 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 Dutchman Creek 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 Dutchman 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 Dutchman 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 (Instantaneous) Greater than 6.0 mg/L (16 hours of any 24-hour period)

4.3.1 Phosphorus

Although phosphorous is not listed as a cause of impairment for Dutchman Creek or Dutchman Lake, elevated phosphorus levels can contribute to an increase in algal growth, which can impact DO concentrations. 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.

4.3.2 Dissolved Oxygen

DO is listed as a cause of impairment for Dutchman Creek and Dutchman 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 the Ambient Lake Monitoring Program (ALMP), Illinois Clean Lakes Program (ICLP), or if there was a known fish kill due to DO depletion.

4.3.3 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 Dutchman 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 303(d) list that do not currently have adopted water quality standards. For example, management measures such as filter strips will reduce nitrogen and phosphorus concentrations in Dutchman Creek. In addition, similar management measures (filter strips, nutrient management, tillage practices) will also address the Dutchman Lake impairments without water quality standards: nitrogen, siltation, TSS, noxious aquatic plants, excessive algal growth, and chlorophyll "a".

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
Agriculture Nonirrigated crop production Pasture land	DO Phosphorus
Contaminated Sediments	DO Phosphorous
Urban Runoff/Storm Sewers	DO Phosphorous

4.4.1 Agriculture

The southern Illinois area is largely in agriculture land use. However, the majority of the Dutchman Creek Watershed is forested. Agricultural land uses can potentially contribute sediment, TSS, nutrients, and biochemical oxygen demand (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 1995).

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.

4.4.2 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 water body. In lakes and reservoirs, phosphorous is commonly released from sediment into the water column especially when anoxic conditions persist.

4.4.3 Urban Runoff/Storm Sewers

Urban areas in the Dutchman 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
Dutchman 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 Dutchman Lake and impaired segment ADD02. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the *BASINS* database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic water quality gages for the Dutchman 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.

5.1.3 Flow Data

Analyses of the Dutchman Creek Watershed require an understanding of flow into Dutchman Lake and through Dutchman Creek. No gage for the tributary to Dutchman Lake exists and there is no stream gage within segment ADD02. 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 03612000 (Cache River at Forman, Illinois) is located on Dutchman Creek approximately 6.5 miles downstream of segment ADD02. This gage is also downstream of Dutchman Lake making it inappropriate for use to compute flows into the lake due to the fluctuations in flow through the river caused by reservoir releases. Therefore, USGS gage 05595820 (Casey Fork at Mt. Vernon, Illinois) was chosen as an appropriate gage from which to compute flow into Dutchman Lake. Gage 05595820 captures flow from a drainage area of 77 square miles in an upstream section of the Casey Fork Watershed, which is about 50 miles north of the Dutchman Lake Watershed. Daily streamflow data for the gage were downloaded from the USGS National Water Inventory System (NWIS) for the entire period of record from October 1, 1985 to September 30, 2000 (USGS 2002a). Figure 5-2 at the end of this section shows the average monthly flows over the period of record into Dutchman Lake calculated from the drainage area ratio method using gage 05595820.

USGS gage 03612000 was chosen as an appropriate gage from which to compute flow through Dutchman Creek segment ADD02. Gage 03612000 captures flow from a drainage area of 244.0 square miles including the segment ADD02 watershed. As mentioned previously, gage 03612000 is located approximately 6.5 miles downstream of segment ADD02. Daily streamflow data for the gage were downloaded from the USGS NWIS for the entire period of record from October 26, 1922 to September 30, 2000 (USGS 2002a), and flows for the segment ADD02 watershed were calculated with the drainage area ratio method. Figure 5-3 at the end of this section shows the seasonal patterns of streamflow through segment ADD02 between 1985 and 2000 calculated from gage 03612000. Flows are higher in the spring months of March through May. For Dutchman Creek segment ADD02, average monthly flows range from 2.9 to 67.4 cubic feet per second (cfs) with a mean annual flow of 33.5 cfs. The 7Q10 flow (lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years) is typically utilized as the critical low flow for National Pollutant Discharge Elimination System (NPDES) permitting and is estimated to be zero for segment ADD02 (ISWS 2000).

5.1.4 Precipitation, Temperature, and Evaporation Data

One site with historical temperature and precipitation data was identified in Johnson County through the NCDC database; however, data were only available through 1964. To provide current data, precipitation and temperature data for neighboring Pope County were used to develop a dataset for Johnson County for the years of 1985 through 2001. Two months of data were missing from the Pope County gage. Missing data were supplemented with data from gages in neighboring Williamson County and nearby Jackson County. Table 5-1 lists the station details for the Johnson County, Pope County, Williamson County, and Jackson County gages (NCDC 2002).

Table 5-1 Historical Precipitation Data for the Dutchman Creek Watershed (NCDC 2002)

NCDC Gage Number	Station Location (Name)	Period of Record
6096	Johnson County (New Burnside)	1901 to 1964
8020	Pope County (Smithland Lock and Dam)	1980 to present
5342	Williamson County (Marion 4NNE)	1948 to present
5983	Jackson County (Murphysboro 2SW)	1948 to present

Table 5-2 Average Monthly Precipitation in Johnson County from 1985 to 2001

Month	Average Precipitation (inches)
January	3.3
February	4.1
March	4.0
April	4.0
May	4.4
June	4.3
July	4.0
August	2.8
September	3.3
October	3.8
November	4.1
December	4.2
TOTAL	46.3

Table 5-2 shows the average monthly precipitation of the dataset developed for Johnson County for the years 1985 to 2001. The average annual precipitation over the same period is approximately 46 inches.

Pan evaporation data is available through the Illinois State Water Survey (ISWS) web site 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. Pan evaporation is utilized in modeling efforts as described in Section 7. The Carlyle station is approximately 80 miles northwest of the Dutchman Creek Watershed. The average monthly pan evaporation for the years 1980 to 2001 at the Carlyle station was downloaded from the ISWS web site 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

Five historic water quality stations exist within the Dutchman 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 Dutchman Creek Watershed

Location	Station Identification Number	Data Collection Agency
Dutchman Creek	ADD02 / ADD04	Illinois EPA Division of Water Pollution Control
Dutchman Lake	RAM-1	USEPA Region 5
Dutchman Lake	RAM-2	USEPA Region 5
Dutchman Lake	RAM-3	USEPA Region 5

The impaired waterbody segments in the Dutchman Creek Watershed were presented in Section 2. For Dutchman Lake, segment RAM, there are three historic water quality stations. For Dutchman Creek, segment ADD02, there are two historic water quality stations listed in Table 5-3 and shown in Figure 5-1. The Dutchman Lake stations have a concurrent period of record while the stations in segment ADD02 have different sampling periods. Table 5-4 summarizes available historic water quality data since 1988 from the USEPA Storage and Retrieval (*STORET*) database associated with impairments discussed in Section 2 for segments RAM and ADD02.

Table 5-4 Summary of Constituents Associated with Potential Impairments for Dutchman Creek Segments RAM and ADD02 (USEPA 2002b and Illinois EPA 2002)

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Dutchman Creek Segment ADD02; Sample Location ADD02, ADD04		
DO	6/11/92-1/18/00	5
Dutchman Lake Segment RAM; Sample Location RAM-1, RAM-2, RAM-3		
RAM-1		
DO	4/26/88-10/1/01	15
RAM-2		
DO	4/26/88-10/1/01	15
RAM-3		
DO	4/26/88-10/1/01	15

5.1.5.1 Dutchman Lake Water Quality Data

There are three active water quality stations in Dutchman Lake as shown in Figure 5-1 and listed in Table 5-4. The water quality station data for Dutchman Lake were downloaded from the *STORET* online database for the years of 1988 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 Dutchman Lake as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

Constituents are sampled at various depths throughout Dutchman 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 Dutchman 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 Dutchman 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 1988 at each water quality site in Dutchman 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. 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 1994 and 2001 were below the 6.0 mg/L limit. Specifically, the DO values recorded at stations RAM-2 and RAM-3 on October 18, 1994 were 4.7 mg/L and 3.7 mg/L, respectively. At station RAM-3, the DO value was measured as 4.1 mg/L on June 1, 2001. These DO violations were measured at one-foot depth. The raw data for all sample depths are contained in Appendix A.

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

	RAM-1	RAM-2	RAM-3	Lake Average
1988	8.4	8.8	8.2	8.5
1994	8.4	8.6	7.4	8.1
2001	9.7	9.9	8.2	9.3

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. The three samples that violate the TMDL endpoint were taken between 9:25 a.m. and 10:20 a.m., and although violation of the TMDL endpoint includes any instantaneous measurement, the daily average DO is probably higher than the sample value.

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 Dutchman Lake was investigated. The correlation between average DO and chlorophyll "a" is expected to be an inverse relationship whereas the correlation between chlorophyll "a" and average 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 one-foot depth for each year of available data from 1994 to 2001 at each monitoring site in Dutchman Lake are presented in Table 5-6. At station RAM-1, samples were taken at a one-foot depth from the lake surface and at the lake bottom. Samples at stations RAM-2 and RAM-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 one-foot depth. Although the majority of concentrations in Table 5-6 reflect compliance with the water quality standard, individual samples at each station did exceed the water quality standard. Specifically, the samples taken at station RAM-1 exceeded the endpoint on August 1, 2001 (0.053 mg/L) and October 1, 2001 (0.052 mg/L). At station RAM-2, the endpoint was exceeded on the same days as station RAM-1 with concentrations of 0.059 mg/L and 0.104 mg/L, respectively. The endpoint was exceeded at station RAM-3 on June 1, 2001 (0.058 mg/L), August 1, 2001 (0.076 mg/L), and October 1, 2001 (0.06 mg/L). The raw data for all sample depths are contained in Appendix A.

Table 5-6 Average Total Phosphorus Concentrations (mg/L) in Dutchman Lake at One-foot Depth (USEPA 2002b and Illinois EPA 2002)

Year	RAM-1	RAM-2	RAM-3	Lake Average
1994	0.03	0.03	0.04	0.03
2001	0.04	0.05	0.05	0.05

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 (PO_4). 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 are 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 1988 to 2001 at each monitoring site in Dutchman Lake are presented in Table 5-7. The raw data for all sample depths are contained in Appendix A. Chlorophyll "a" was evaluated to assess the amount of algal activity in Dutchman Lake in comparison to observed DO impairments.

Table 5-7 Average Chlorophyll "a" Concentrations (μg/L) in Dutchman Lake (USEPA 2002b and Illinois EPA 2002)

Year	RAM-1	RAM-2	RAM-3	Lake Average
1988	21.0	19.4	13.2	17.9
1994	34.3	34.4	17.2	28.6
2001	32.8	26.8	27.1	28.9

5.1.5.1.4 Tributary Data

There is no water quality data available for the tributaries to Dutchman Lake. The primary tributary to Dutchman Lake is Dutchman Creek. 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 desorption 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 Dutchman Creek Water Quality Data

There are two active water quality stations in Dutchman Creek segment ADD02 as shown in Figure 5-1. The water quality station data for segment ADD02 were downloaded from the *STORET* online database for the years of 1990 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in Dutchman Creek as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

5.1.5.2.1 DO and Total Organic Carbon

Table 5-8 summarizes the available historic DO data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Dutchman Creek segment ADD02 (raw data contained in Appendix A). The average DO concentration for segment ADD02 is above the water quality standard of 6.0 mg/L (16 hours of any 24-hour period), but the minimum values observed are less than the water quality standard of 6.0 mg/L.

Table 5-8 Existing DO Water Quality Data and TMDL Endpoints for Dutchman Creek Segment ADD02 (USEPA 2002b and Illinois EPA 2002)

Parameter	Endpoint (mg/L)	Period of Record Examined for Samples and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
DO	6.0 (16 hours of any 24-hour period)	6/11/92-1/18/00; 5	7.2	11.4	3.5

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events are presented in Table 5-9. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this comparison, all samples were taken at below average flow values. This could suggest that the DO impairments are occurring during low flow values for the segment. Low flow values within the stream segment can 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 degree Centigrade (°C) (32°F) and decreases to 8.6 mg O_2/L at 25°C (77°F) (Brown and Brazier 1972). Table 5-9 shows total organic carbon (TOC) sample results, which will be used in analyses presented in Section 8.

Table 5-9 DO Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	DO (mg/L)	TOC (mg/L)
Dutchman Creek (ADD02)	6/11/1992	1.43	4.2	4.0
Dutchman Creek (ADD02)	9/30/1992	2.34	7.0	7.0
Dutchman Creek (ADD02)	12/7/1992	3.90	10.1	1.0
Dutchman Creek (ADD04)	8/10/1999	0.44	3.5	7.0
Dutchman Creek (ADD04)	1/18/2000	5.58	11.4	5.5

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 Dutchman Lake and Dutchman Creek segment ADD02 were used to obtain the land use from the Critical Trends Assessment Land Cover grid. Tables 5-10 and 5-11 list the land uses contributing to the Dutchman Lake Watershed as well as each land use area and percent of total area.

Table 5-10 Critical Trends Assessment Land Uses in the Dutchman Lake Watershed (IDNR 1996)

Land Use	Acres	Percent of Area
Deciduous Forest	2,973	41%
Rural Grassland (pastureland, grassland, waterways, buffer strips, CRP land, etc.)*		
Hayland	1,127	16%
Grassland (CRP, waterways, etc.)	805	11%
Pasture	751	10%
Coniferous Forest	626	9%
Row Crop (corn, soybeans, and other tilled crops)	393	6%
Small Grains (wheat, oats, etc.)	360	5%
Open Water	93	1%
Barren Land	41	1%
Shallow Water/Wetlands	13	0%
Forested Wetlands	5	0%
TOTAL	**7,187**	**100%**

* Subclasses of rural grassland were estimated from maps provided by the Johnson County NRCS (2002a)

Table 5-11 Critical Trends Assessment Land Uses in the Dutchman Creek Segment ADD02 Watershed (IDNR 1996)

Land Use	Area (acres)	Percent of Area
Rural Grassland (pastureland, grassland, waterways, buffer strips, CRP land, etc.)	8,844	44%
Deciduous Forest	6,556	32%
Row Crop(corn, soybeans, and other tilled crops)	2,579	13%
Coniferous Forest	709	4%
Small Grains (wheat, oats, etc.)	679	3%
Forested Wetland	541	3%
Open Water	156	1%
Shallow Water/Wetlands	55	0%
Barren Land	41	0%
Swamp	18	0%
Medium Density	4	0%
Shallow Marsh/Wetlands	3	0%
High Density	1	0%
Urban Grassland (parks, lawns, golf courses, cemeteries, etc.)	<1	0%
TOTAL	**20,186**	**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) web site 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 5-12 shows the cropland use classes of the Cropland Data Layer and the Critical Trends Assessment classes to which they were applied.

Table 5-12 Comparison of Land Use Classes in the Dutchman 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 & Hay	Small Grains
Double-Cropped Winter Wheat/Soybeans	Half to Small Grains Half to Row Crops

5.1.7 Point Sources, Dairies, and Animal Confinement Operations

The USEPA *BASINS* database includes a GIS shapefile of facilities with NPDES permits as part of the Permit Compliance System (PCS) (2002a). No point sources were located in the Dutchman Creek Watershed from this database. The NPDES Discharge Monitoring Report (DMR) database was also reviewed and no dischargers were located within the Dutchman Creek Watershed. In addition, there are no Phase II Stormwater NPDES Permittees within the watershed.

The Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Cache River Watershed, which contains Dutchman Lake and Dutchman Creek. The Illinois EPA assessed the 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. No facilities were located in the watersheds for Dutchman Lake or segment ADD02.

Communication with watershed stakeholders revealed no other point sources within the Dutchman Creek Watershed.

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* web site (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, presented in Table 5-13, was generated by the Illinois Department of Agriculture from the 2001 County Transect Survey for Johnson County. Data specific to the Dutchman Lake Watershed were not available; however, the Johnson County NRCS office determined that the percentages of each tillage practice were acceptable for application to the Dutchman Lake Watershed (NRCS 2002a).

Table 5-13 Tillage Practices in Johnson County (Johnson County Soil & Water Conservation District 2001)

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	39%	11%	0%
Reduced Till	13%	8%	0%
Mulch-Till	0%	0%	0%
No-Till	48%	81%	0%

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

5.1.10 Reservoir Characteristics

Reservoir characteristics were obtained from GIS analysis, the Illinois EPA, and USEPA water quality data. The Illinois EPA reports a surface area of 118 acres, which corresponds to the surface area of 119 acres obtained from GIS analysis. The match between the Illinois EPA and GIS values validate their use.

The water quality dataset described in Section 5.1.5.1 was used to determine the average depth of Dutchman Lake. On each date sampled for water quality constituents, the total depth at the site was measured. Table 5-14 lists the average depth calculated for each water quality site in Dutchman Lake for each year of available data after 1988.

Table 5-14 Average Depths (feet) for Dutchman Lake (USEPA 2002b and Illinois EPA 2002)

	RAM-1	RAM-2	RAM-3	Lake Average
1988	20.1	9.8	6.8	12.2
1994	20.3	16.0	7.8	14.7
2001	18.4	12.2	6.8	12.5

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 Dutchman 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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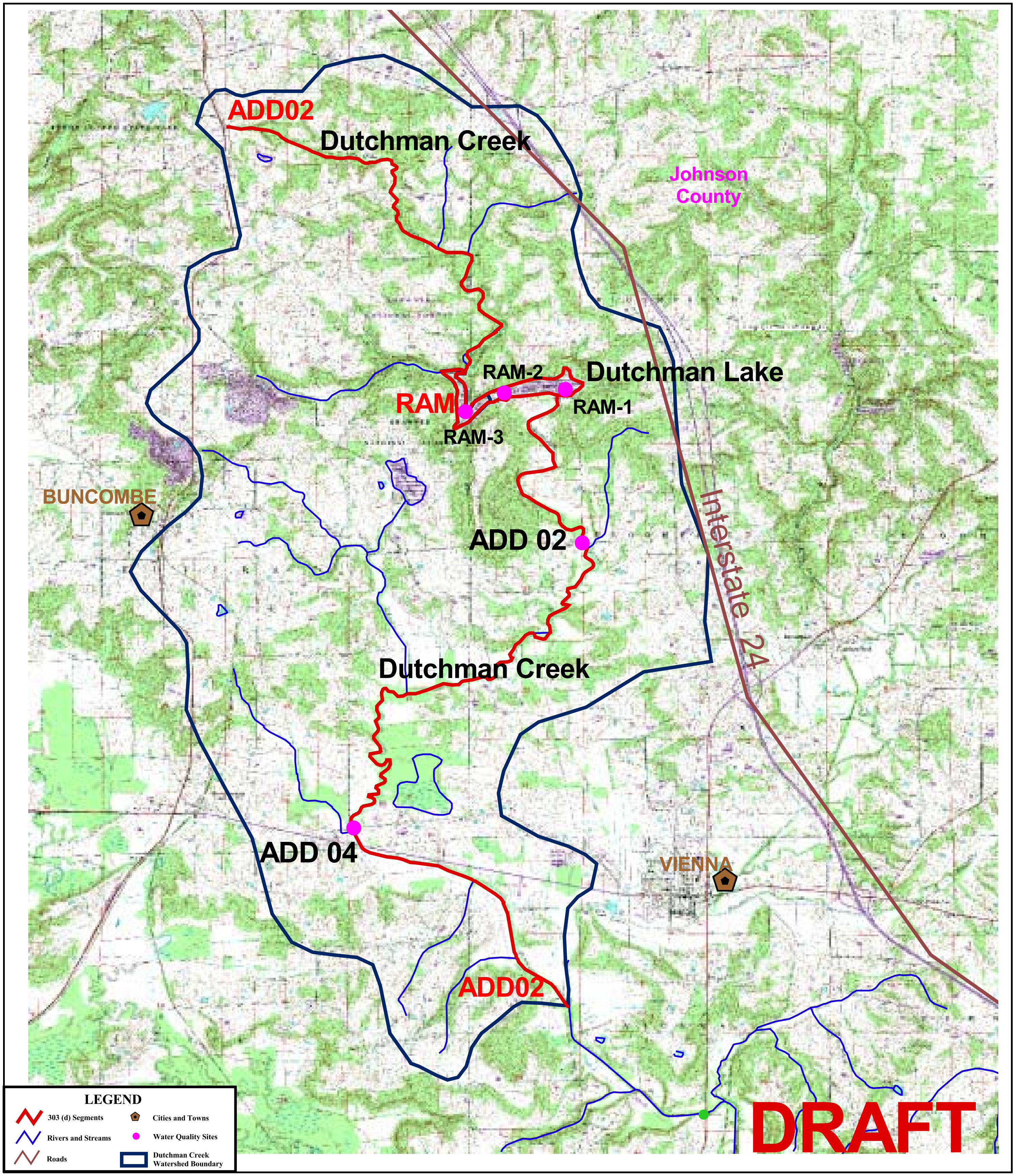

Figure 5-1
Dutchman Creek Watershed (ILADD01)
Historic Water Quality Stations

CDM

densvr01/projects/IEPA/gis_data/apr/dutchman 032103 MJF

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Figure 5-2: Estimated Streamflow Upstream of Dutchman Lake Calculated from Gage 05595820

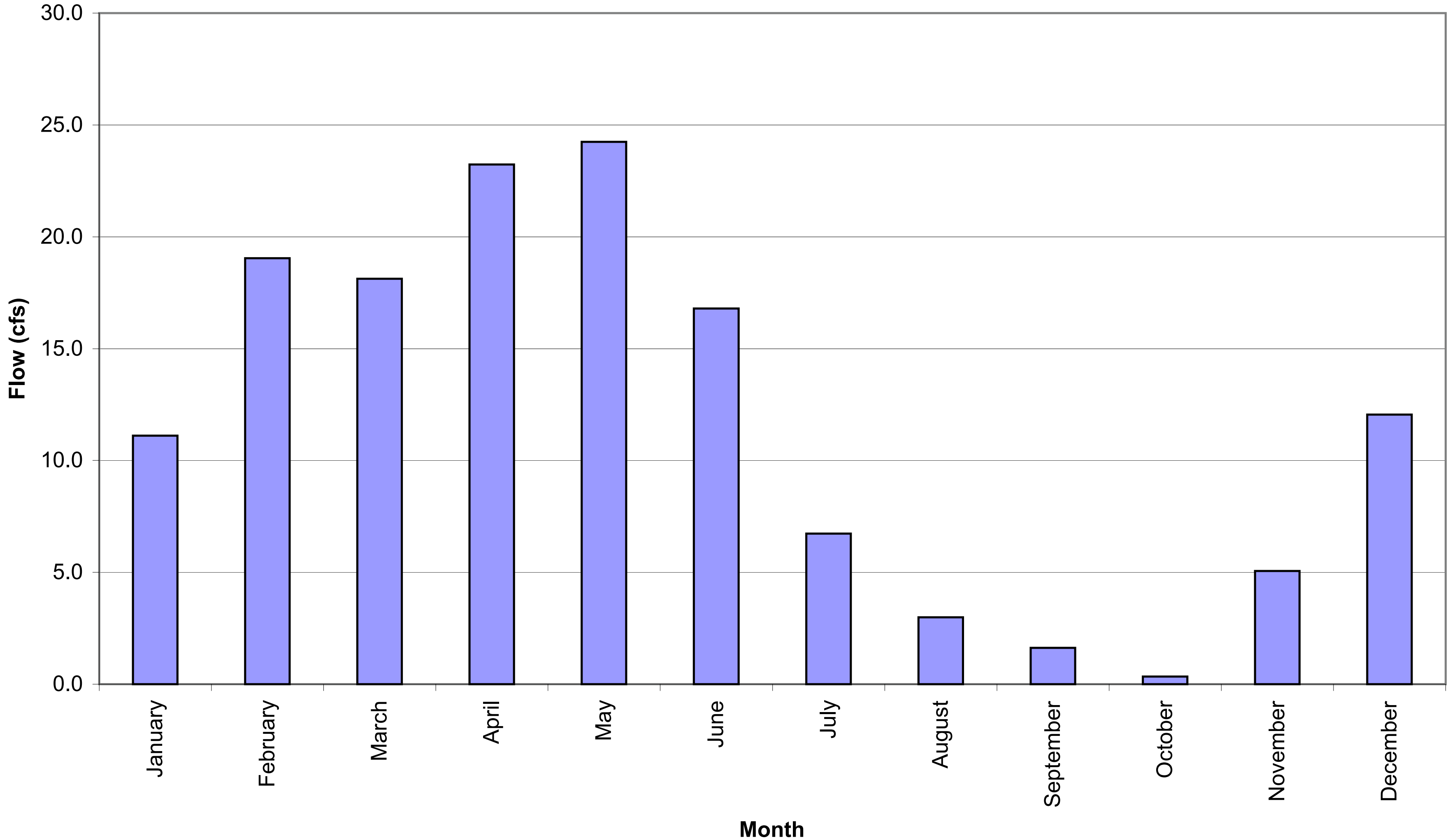

Figure 5-2
Period of Record
October 1, 1985 - Septmeber 30, 2000

CDM

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Figure 5-3: Estimated Streamflows in Dutchman Creek Segment ADD02 Calculated from Gage 03612000

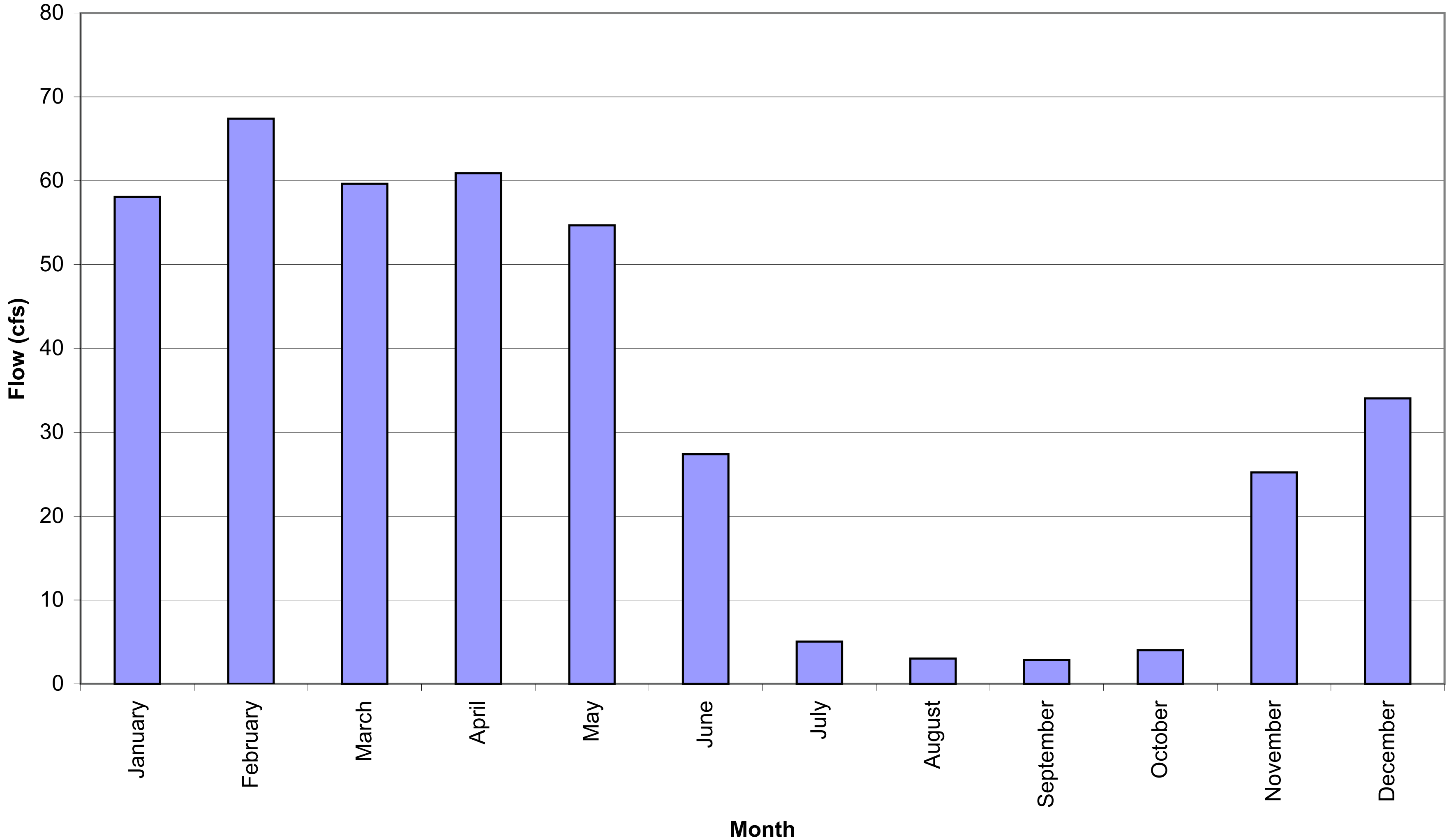

Figure 5-3
Period of Record
January 1, 1985 to September 30, 2000

CDM

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Section 6
Methodologies and Models to Complete TMDLs for the Dutchman 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 Dutchman Creek Watershed. The endpoints presented in Section 4, which are chemical endpoints of the following constituents, were targeted:

- Stream segment: DO
- Lake segment: DO

6.2 Methodologies and Models to Assess TMDL Endpoints

Methodologies and models were utilized to assess TMDL endpoints for the Dutchman 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 1997):

- 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 1997)

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 1997)

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 1997). 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 Dutchman 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 Dutchman Lake is the Generalized Watershed Loading Function (GWLF) model. No watershed models were utilized for stream TMDLs as methodologies were utilized for stream segments in the Dutchman Creek Watershed. The GWLF model was chosen for the Dutchman 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 Dutchman 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 1997).

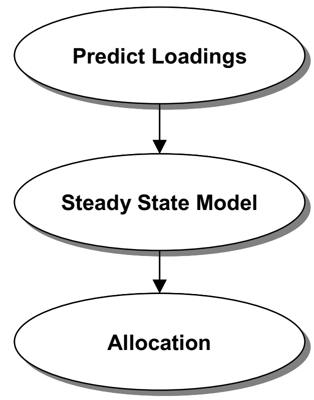
Because of the lack of spatial data sets for the stream segment within the Dutchman Creek Watershed, methodologies based on the USEPA Screening Methods was utilized for stream TMDL development as discussed in the following section.

6.2.3 Dutchman Lake TMDL

For Dutchman Lake, a TMDL for the following constituent was completed using a watershed/receiving water model combination:

- DO

The strategy for completing the watershed/receiving water model TMDL for Dutchman 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. A linkage was also made between phosphorus and DO. After phosphorus loads are predicted, the BATHTUB model was used to determine the resulting phosphorus concentrations within Dutchman Lake. Model development is discussed further in Section 7.



Schematic 1
Strategy for Lake TMDL Modeling

6.2.4 Stream TMDL for the Dutchman Creek Watershed

Because of limited data available for watershed and receiving water model development for the Dutchman Creek Watershed, the TMDL for DO was completed using methodologies. For DO, a Streeter-Phelps analysis based on the USEPA Screening Procedures was developed. This analysis is described in detail in Section 8. In addition, a screening level Watershed Management Model (WMM) analysis was conducted and is also discussed 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 is 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 Dutchman 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 Dutchman Lake, loads from a wet, normal, 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 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 Dutchman Creek Watershed, a plan of implementation was produced to support the developed TMDL analyses. 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 Dutchman 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. The implementation plan for the Dutchman Creek Watershed is presented in Section 10.

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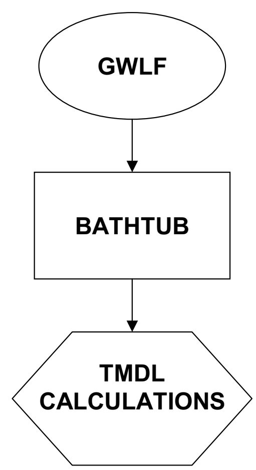
Section 7
Model Development for Dutchman Lake

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 Dutchman 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 Dutchman Lake be utilized so that the DO standard of 6.0 mg/L (16 hours of any 24-hour period) is achieved.

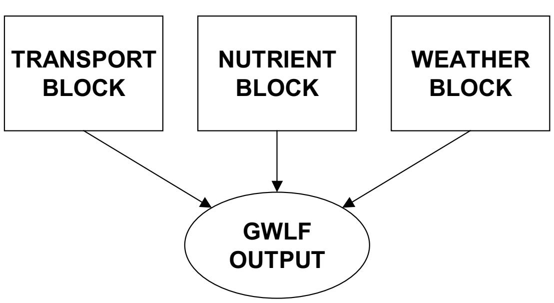
7.2 Model Overview

The models used for the TMDL analysis of Dutchman Lake were GWLF and BATHTUB. These models require input from several sources including online databases, GIS-compatible data, and hard-copy 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 Dutchman Lake TMDL calculation.

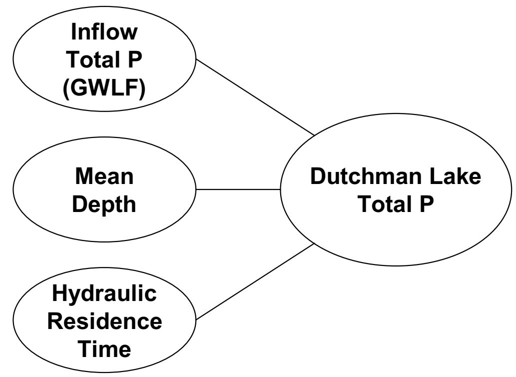
Schematic 1 shows how the GWLF model and BATHTUB model is utilized in calculating the TMDL. The GWLF model predicts phosphorus loads from the watershed. These loads are then inputted in the BATHTUB model to assess resulting phosphorus concentrations. The GWLF model outlined in Schematic 2 shows how GWLF 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 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



Schematic 2 GWLF Model.

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 Dutchman Lake Watershed and the multiple tributaries contributing to the lake, the watershed area was divided into four subwatersheds for accurate representation in the GWLF model. Flows within each of the subbasins were calculated from gage 05595820 with the drainage area ratio method presented in Section 5.1.3. To model Dutchman 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 Dutchman Lake was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation indicates that Dutchman Lake captures flows from a watershed of approximately 11.2 square miles. The flow through the lake is primarily from west to east. Figure 7-3 at the end of this section shows the location of each water quality station in Dutchman Lake, the boundary of the GIS-delineated watershed contributing to Dutchman Lake, the four 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 B. The GWLF manual is contained in Appendix C.

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 Dutchman Lake Watershed was extracted from the Critical Trends Assessment Database grid for Johnson 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 5-10.

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 5-10, was separated into three subclasses of pasture, hayland, and grassland

(CRP, waterways, etc.) based on the recommendation of the Johnson County NRCS (2002a). The GWLF model requires nutrient runoff concentrations for each land use, and the three subclasses of rural grassland have varying concentrations. The area of each subclass was estimated from the GIS-derived rural grassland area and maps provided by the Johnson County NRCS.

Due to the detailing of crops, the Cropland Data Layer land use classes, presented in Table 5-12, 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 D.

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 D.

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 D.

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 D.

Cropping Management Factor (C). The cropping management factor, C, represents the influence of ground cover, soil condition, and management practices on erosion. The Johnson County NRCS office provided a table of C factors for various crops and tillage practices (NRCS 2002a). The table is included as Appendix E. Although the percentage of each tillage practice for corn, soybeans, and small grains in Johnson County 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 Dutchman Lake Watershed.

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

Land Use	Area (acres)	C factor
Corn	105	0.21
Sorghum	0	–
Soybeans	103	0.08
Winter Wheat	6	0.04
Other Small Grains & Hay	414	0.14
Double-Cropped WW/SB	99	0.15
Other Crops	1	–
Idle Cropland/CRP	2	0.004
Fallow/Idle Cropland	585	0.004
Pasture/Grassland/Nonag	1,502	0.004
Woods	3,972	0.003
Clouds	0	–
Urban	282	–
Water	67	–
Buildings/Homes/Subdivisions	46	–
Wetlands	4	–

The identification of crops is more detailed in the Cropland Data Layer file than in 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. A more detailed description of the weighting procedure is provided in Appendix D.

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

Land Use	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4	
	Area (ac)	C Factor	Area (ac)	C Factor	Area (ac)	C Factor	Area (ac)	C Factor
Row Crop	224	0.145	162	0.145	0.5	0.121	6	0.145
Small Grains	126	0.141	232	0.139	0	–	1	0.140
Rural Grassland	1029	0.004	1588	0.004	9	0.004	56	0.004
Deciduous	665	0.003	1701	0.003	63	0.003	383	0.003
Deciduous	30	0.003	130	0.003	0	–	2	0.003
Coniferous	40	0.003	460	0.003	18	0.003	108	0.003
Open Water	8	–	12	–	31	–	42	–
Shallow Marsh/ Wetland	6	–	0	–	0	–	0	–
Forested Wetland	0	–	5	–	0	–	0	–
Shallow Water Wetland	0	–	7	–	0	–	0	–
Barren Land	41	–	0	–	0	–	0	–

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 Dutchman 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 Dutchman 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 the 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 D.

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 Dutchman Lake are presented in Table 7-4.

Table 7-4 Sediment Delivery Ratios in Dutchman Lake Watershed

Subbasin	Area (ac)	Sediment Delivery Ratio
1	2,169	0.23
2	4,297	0.19
3	120	0.40
4	599	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, dissolved-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 Dutchman Lake were obtained from the GWLF manual. Figure B-4 (page 39 of Appendix C) was utilized for determining solid-phase phosphorus concentrations in the soil. A mid-range value of 0.05 percent phosphate was selected and then converted to 500 parts per million (ppm) using the relationship 0.1 percent = 1,000 ppm. Phosphate is composed of 44 percent phosphorus, so the 500-ppm phosphate was multiplied by 0.44 to obtain a value of 220-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 440 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 pasture, hayland, and grassland under the rural grassland land use, which were provided by the Johnson County NRCS (2002a). Table 7-5 lists the land uses in the Dutchman 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 7-5 exceed the endpoint of 0.05 mg/L of total phosphorus, once the surface runoff reaches Dutchman Lake or its tributaries, it mixes with water already in the stream or lake and the concentration decreases. Therefore, it cannot be concluded without site-specific data by land use type that constituents with dissolved concentrations above the endpoint for total phosphorus are responsible for water quality impairments.

Table 7-5 Dissolved Phosphorus Concentrations in Runoff from the Dutchman Lake Watershed

Land Use	Dissolved Phosphorus (mg/L)
Row Crop	0.26
Small Grains	0.30
Rural Grasslands	
Pasture	0.25
Hayland	0.15
Grassland (CRP, waterways, etc.)	0.15
Deciduous Forest	0.009
Coniferous Forest	0.009
Barren Land	0.008

The GWLF model may overestimate the amount of solid-phase phosphorus that desorbs into the water column. Because no site-specific data was available, this cannot be quantified at this time.

The GWLF manual suggests nutrient concentrations in groundwater based on the percentage of agricultural useversus 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 7-6.

Table 7-6 Percentage of Agricultural and Forest Lands and Groundwater Phosphorus Concentrations in Dutchman Lake Watershed (Haith et al. 1996)

Subbasin	Agriculture	Forest	Dissolved Phosphorus (mg/L)
1	64%	34%	0.067
2	46%	53%	0.035
3	8%	67%	0.012
4	11%	82%	0.012

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 B. 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 B.

Table 7-7 Annual Precipitation in Johnson County

Model Year	Precipitation (inches)
1986	46
1987	33
1988	45
1989	57
1990	52
1991	47
1992	41
1993	42
1994	47
1995	49
1996	48
1997	54
1998	41
1999	39
2000	46
2001	33
Average	46

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 7-7 shows these annual and average annual precipitation values in Johnson County. Each water year was then classified as wet, dry, or normal based on a comparison to the average water year precipitation of 46 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 only years available for modeling Dutchman Lake are 1994 and 2001.

Based on Table 7-7, the precipitation is just above average for 1994. Therefore, 1994 is designated as an above normal 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 7-7. An average annual evaporation was determined from pan evaporation data as discussed in Section 7.3.2. 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.

Dutchman 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 5-6; 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 7-8 shows the average annual total phosphorus concentrations for all sample depths at each station in Dutchman Lake. As mentioned in Section 5.1.5.1.2, station RAM-1 had samples taken at one-foot depth from the surface and at the lake bottom whereas stations RAM-2 and RAM-3 were only sampled at one-foot depth. The raw data for all sample depths are contained in Appendix A.

Table 7-8 Average Total Phosphorus Concentrations in Dutchman Lake (mg/L) over all Depths

Year	RAM-1	RAM-2	RAM-3	Lake Average
1994	0.12	0.03	0.04	0.07
2001	0.07	0.05	0.05	0.06

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 5-14. 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 F.

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 Dutchman Lake watershed, the four 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 Dutchman 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 Dutchman Lake.

7.4.1 GWLF Calibration

The GWLF model must run from April to March to coincide with the soil erosion cycle, which is when the majority of erosion occurs in agricultural areas. 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.

In-stream 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 03612000 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 Dutchman Lake. The GWLF model for Dutchman Lake was visually calibrated with a resulting recession constant of 0.2 and a seepage constant of 0.1 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.

Although in-stream nutrient concentrations are not available for the tributaries to Dutchman Lake, Clean Lakes Studies have been conducted by Illinois EPA on various Illinois lake watersheds, which do provide in-stream nutrient data for lake tributaries including dissolved and total phosphorus. The dissolved and total phosphorus concentrations predicted by GWLF for tributaries to the Dutchman 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 Dutchman Lake Watershed are lower than those in the other lake watersheds shown in Figure 7-5. The lakes involved in the Clean Lakes Studies are further north than Dutchman Lake and have a higher percentage of agriculture land compared to the Dutchman Lake Watershed, which is primarily forest land. Therefore, it is expected that dissolved and total phosphorus concentrations in the Dutchman Lake Watershed are lower than those watersheds with more agricultural land.

Table 7-9 shows the comparison between dissolved and total phosphorus in watersheds from Clean Lakes Studies and in the Dutchman Lake Watershed. The dissolved phosphorus concentration in Subbasins 3 and 4 in the Dutchman Lake Watershed were too low to be calculated by GWLF, so they are assumed to be negligible and are presented as zero concentration.

Table 7-9 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Dutchman 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
Dutchman	1	0.07	0.17	0.39
	2	0.05	0.10	0.44
	3	0.00	0.01	0.00
	4	0.00	0.05	0.00

The ratio of dissolved to total phosphorus in Dutchman Lake Subbasins 1 and 2 is within the range of ratios represented by the Clean Lakes Studies. The ratios in the Dutchman Lake Watershed are lower than the majority of the Clean Lake Study watersheds, which is also due to a greater percentage of forested land in the Dutchman Lake Watershed.

A study of baseline loadings of total and dissolved phosphorus was conducted on Illinois watersheds. The study developed median concentrations of dissolved and total phosphorus concentrations and the ratio of dissolved to total phosphorus at water quality stations across Illinois over the period from October 1980 through September

1996. Concentrations of dissolved and total phosphorus modeled in the Dutchman Lake Watershed are within the range of concentrations provided in the study. The study also provides a spatial representation of mean total phosphorus concentrations across Illinois (Short 1999). The concentrations of total phosphorus modeled in the Dutchman Lake Watershed are consistent with those seen in the spatial representation for watersheds.

7.4.2 BATHTUB Comparison with Observed Data

The BATHTUB model's response to changes in the GWLF nutrient block were compared to known in-lake concentrations of total phosphorus and chlorophyll "a" for each year of simulation. These known concentrations were presented in Tables 5-6 and 5-7. 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 440 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 616 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 7-10). The calibration factor range for total phosphorus modeling in BATHTUB is 0.5 to 2 and use of the 440-ppm total phosphorus in the soil falls within this accepted range. Table 7-10 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 7-10 represent the average observed in-lake concentrations. The results of the modeling sensitivity analyses are contained in Appendix G.

Table 7-10 Dutchman 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 440 ppm							
1994	0.07	0.07	58	0.9	27.9	29.4	0.9
2001	0.06	0.06	42	1.0	29.3	24.4	1.2
Soil Total Phosphorus 616 ppm							
1994	0.07	0.08	54	0.8	27.9	31.3	0.9
2001	0.06	0.07	33	0.9	29.3	27.3	1.1

A robust calibration and validation of Dutchman 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 7-10 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 Dutchman Lake will be possible if data collection activities outlined in the future monitoring in Section 10 Implementation are implemented.

The preliminary calibration is considered sufficient to make "planning level" decisions regarding load reductions within the watershed required to meet water quality standards. As more data become available and BMPs are implemented within the watershed, the calibration can be supplemented and resulting impacts of improvements within the watershed can be quantified.

Based on modeling results, it appears the internal cycling is occurring in the near dam pool (RAM-1) of Dutchman Lake in 1994 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 5-14 notes a depth of approximately 20 feet for Dutchman Lake at site RAM-1, 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 7-10.

Because the modeling of Dutchman 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 Dutchman Lake

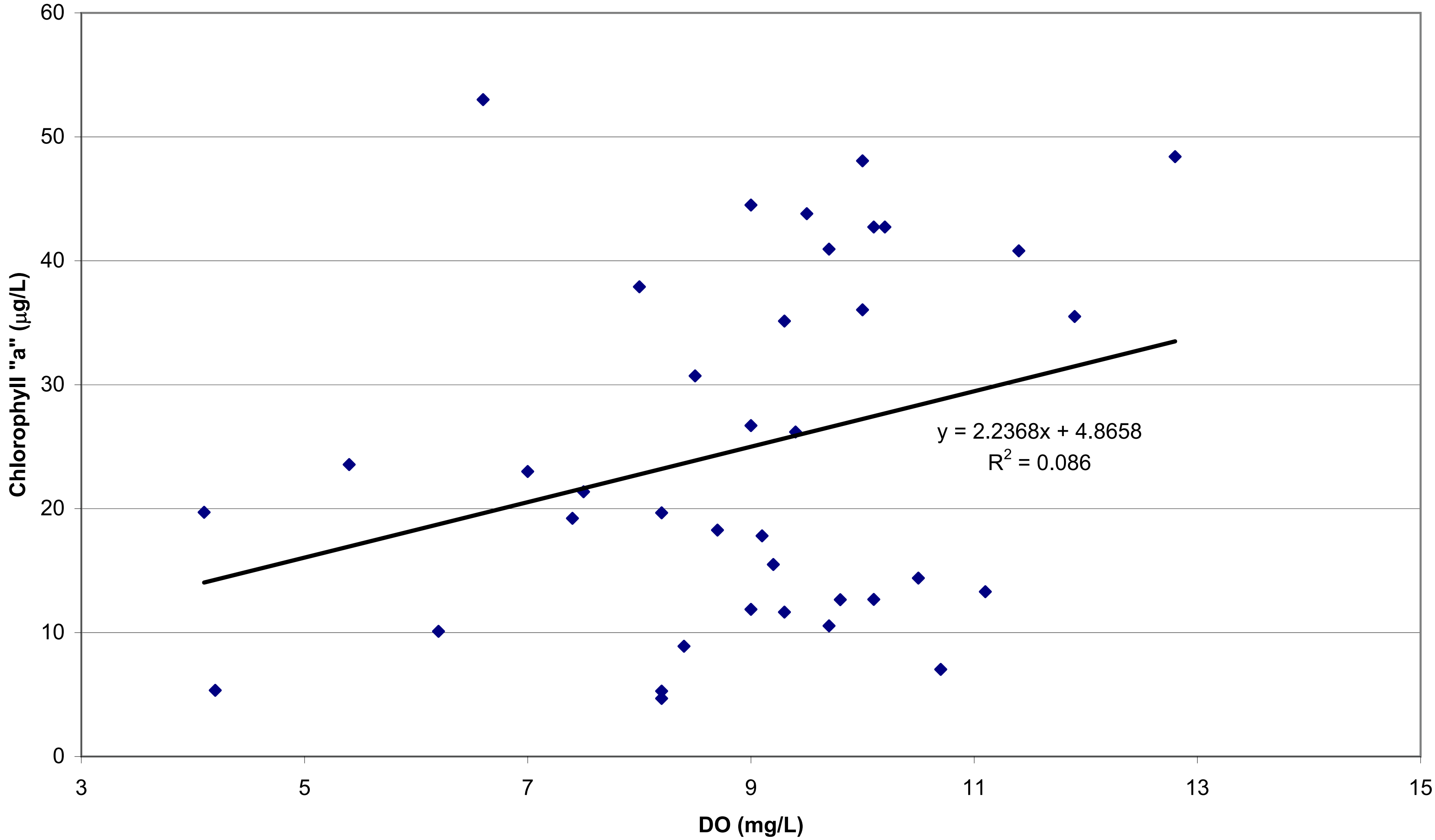


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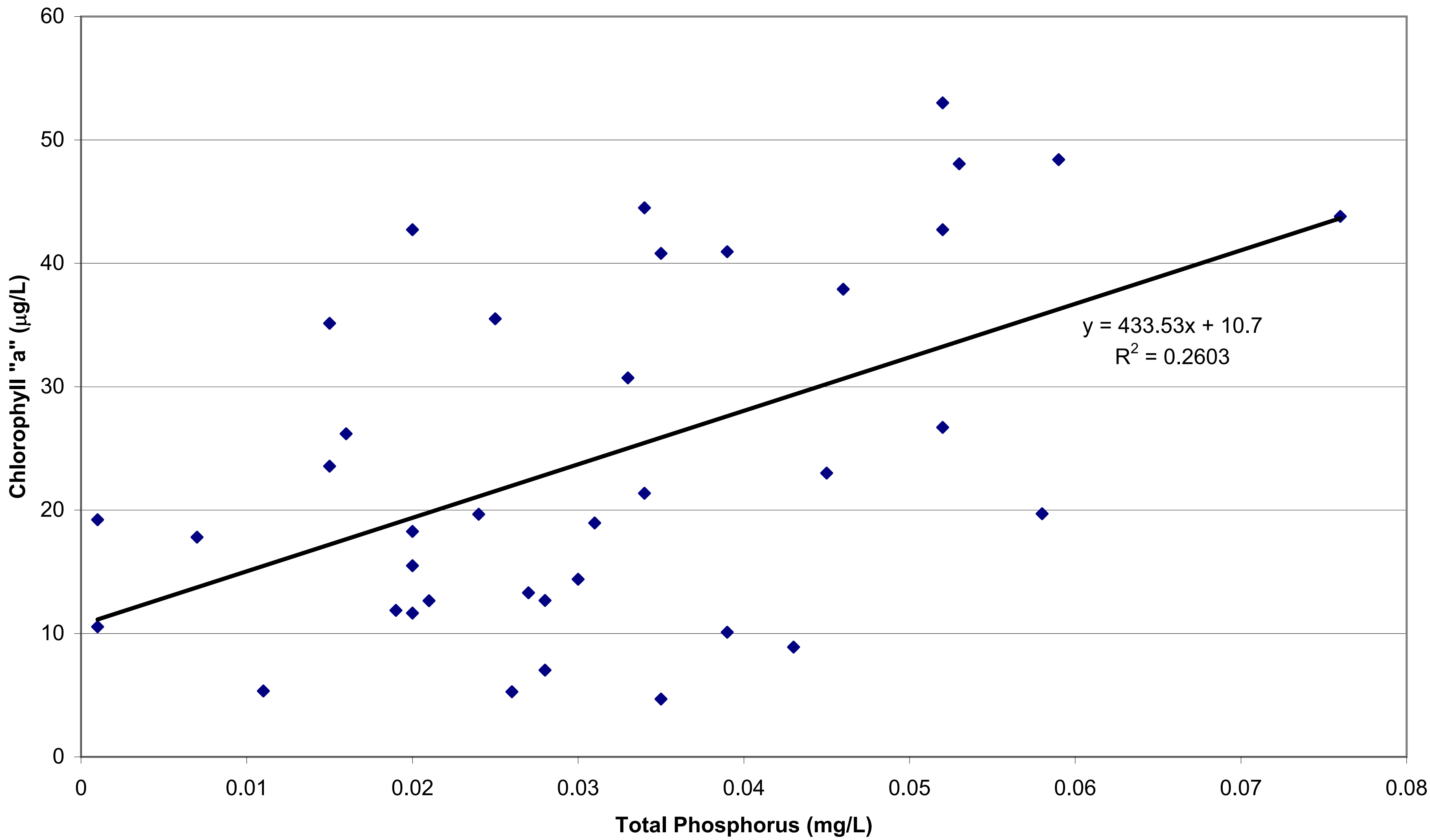
Figure 7-2: Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" in Dutchman Lake



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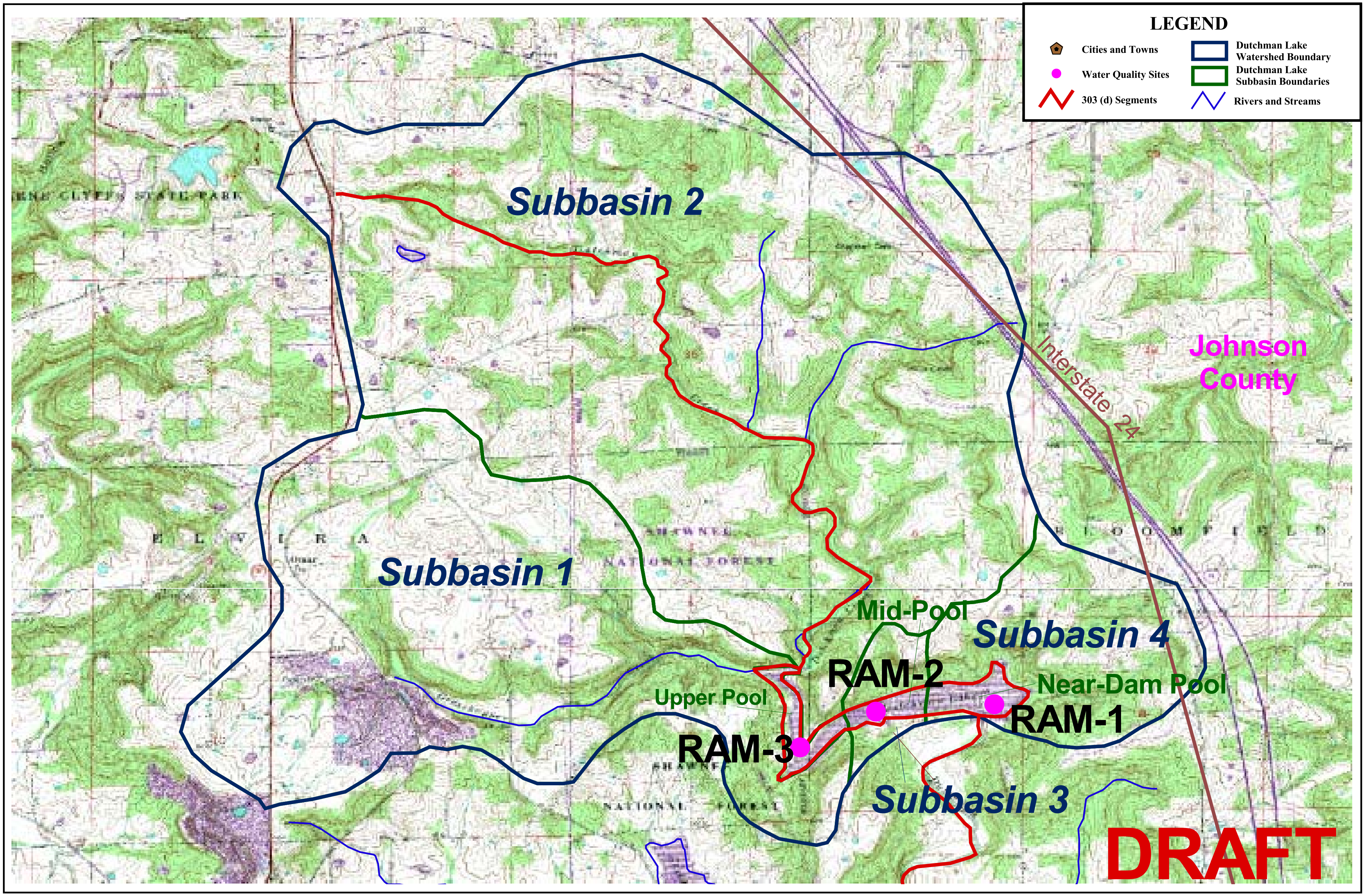

Figure 7-3
Dutchman Lake Watershed and Historic Sampling Locations

CDM

densvr01/projects/IEPA/gis_data/apr/dutchman 021203 MJF

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

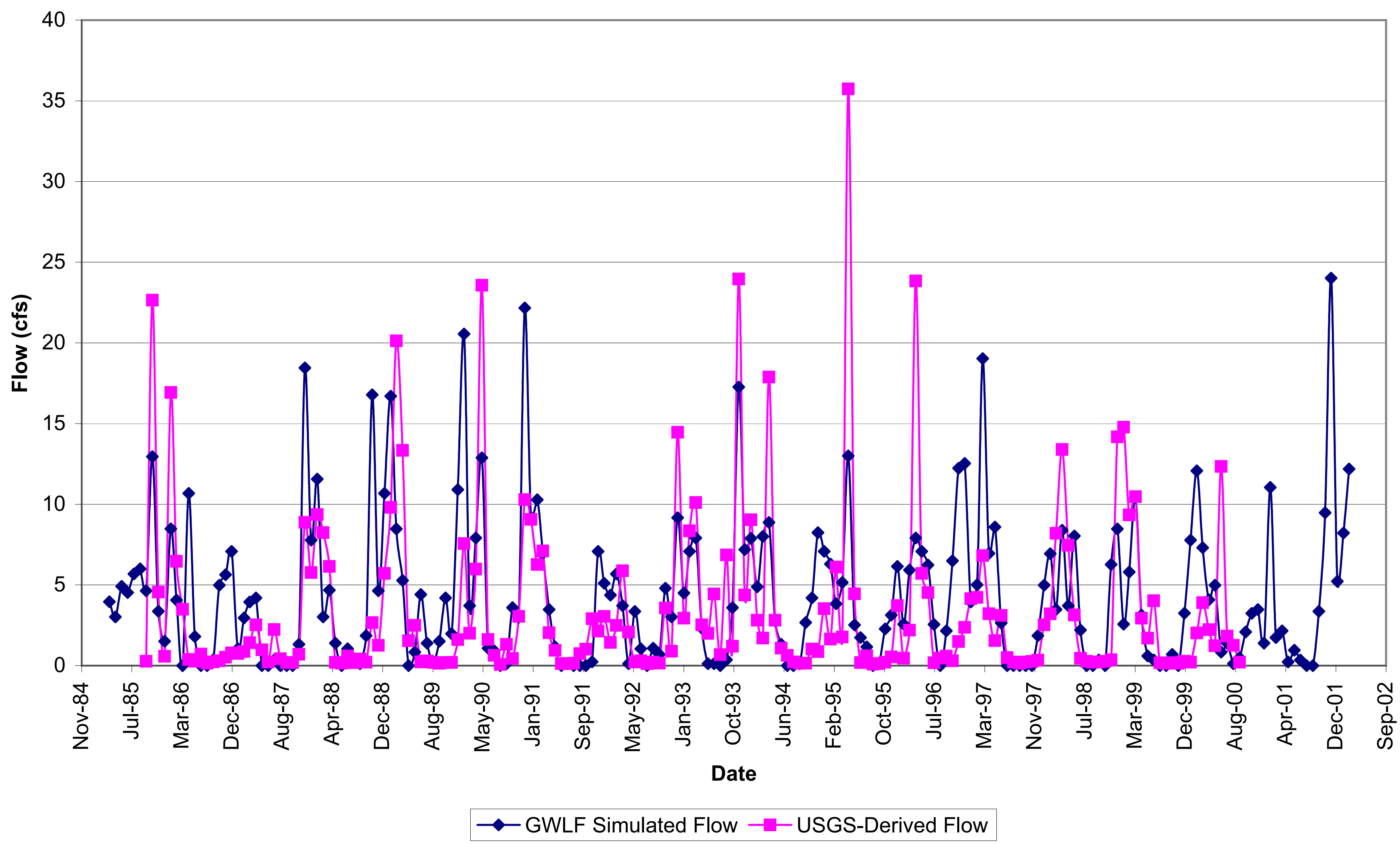

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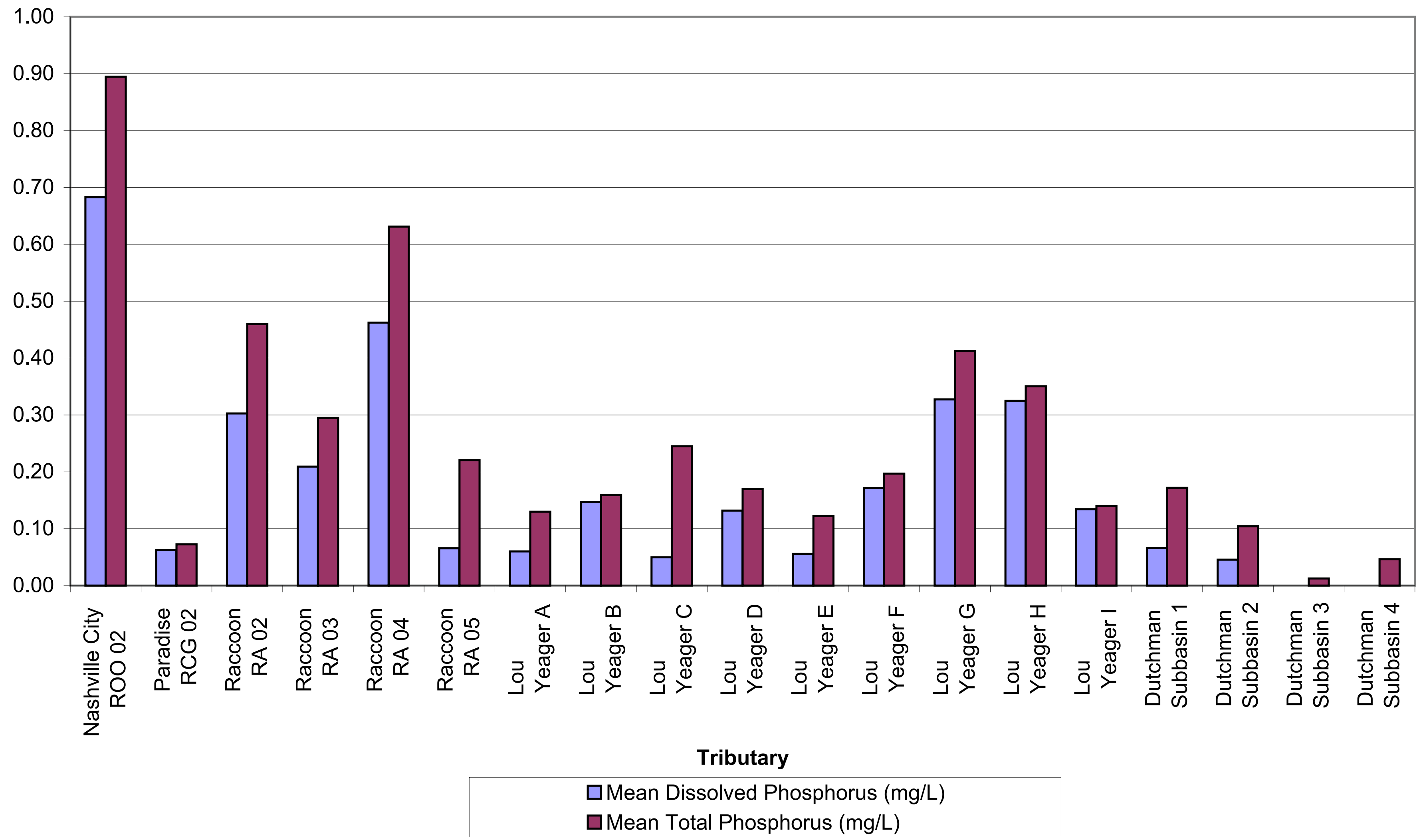
Figure 7-5: Mean Dissolved and Mean Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Dutchman Lake



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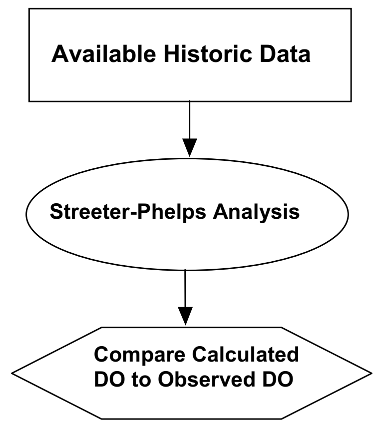
Section 8
Methodology Development for Dutchman Creek

8.1 Methodology Overview

Segment ADD02 in the Dutchman Creek Watershed is impaired for DO. Investigation of this constituent required a Streeter-Phelps analysis. The Streeter-Phelps analysis was conducted as illustrated in the schematic to the right. Observed data were utilized to set up a Streeter-Phelps analysis to predict stream coefficients that would be required to result in observed DO concentrations. This Streeter-Phelps analysis was based on USEPA's Screening Procedures (Mills et al. 1985). The 5-day biochemical oxygen demand (BOD_5) load and reaeration coefficient (k_a) utilized in the Streeter-Phelps analysis were examined in the TMDL for DO for segment ADD02.



Schematic 1

8.2 Watershed Delineation

A watershed for Dutchman Creek segment ADD02 was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation suggests that Dutchman Creek segment ADD02 captures flows from a watershed of approximately 32 square miles. Figure 8-1 at the end of this section shows the location of the water quality stations in Dutchman Creek and the boundary of the GIS-delineated watershed contributing to Dutchman Creek segment ADD02. Only the portion of segment ADD02 below Dutchman Lake was investigated for DO impairments. As shown on Figure 8-1, the water quality gage is in the downstream portion of segment ADD02, and it is assumed that measures outlined in the implementation plan in Section 10 to meet the DO requirement in Dutchman Lake will also mitigate DO impairments in the upper portion of segment ADD02.

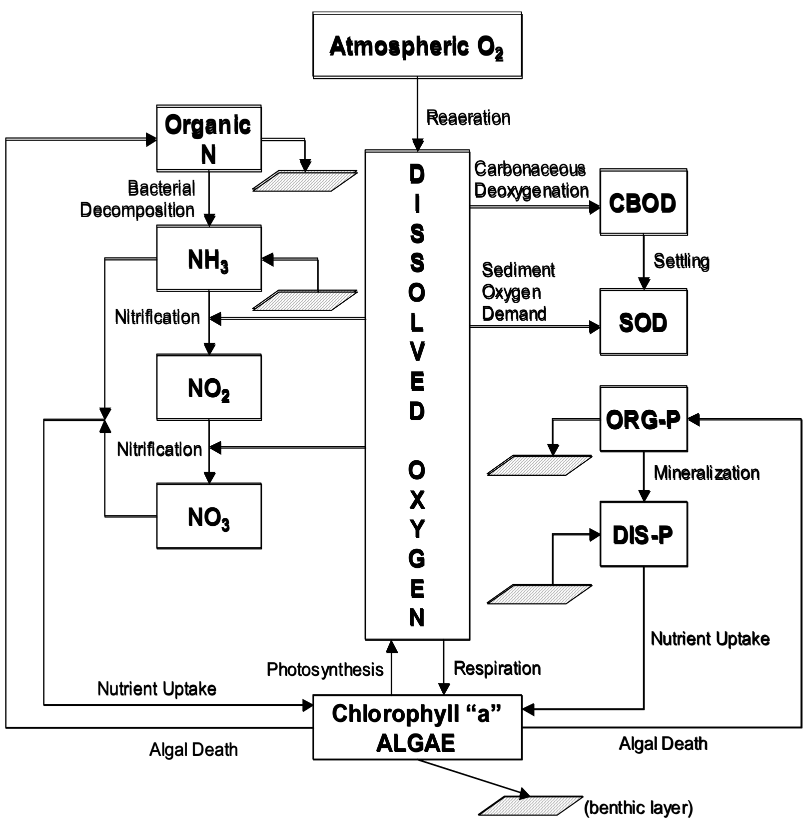
8.3 Methodology Development and Results

A Streeter-Phelps analysis was utilized for investigation of DO in the Dutchman Creek Watershed. Data availability useful for analyzing DO for this watershed is described in Table 8-1. The historic water quality data were investigated from 1990 to the present.

Table 8-1 Data Availability from 1990 to 2000

Model Parameter	Historic Data Available (Yes/No)
Flow	Yes
Stream temperature	Yes
DO	Yes
Carbonaceous BOD_5	No
BOD_5	No
Total nitrogen	Yes
Total organic carbon	Yes
Ammonia	Yes
Nitrate + Nitrite	Yes
Total Kjeldahl Nitrogen	Yes
Total Phosphorus	Yes
Dissolved Phosphorus	Yes
Orthophosphate	No
pH	Yes
Carbonaceous biochemical oxygen demand (20-day)	No
Daily minimum and maximum DO	No
Chlorophyll "a" / algae	No
Stream depth	Yes

The lack of various constituent samples from historic data sites ADD02 and ADD04 limits the modeling tools available for DO. Therefore, a Streeter-Phelps analysis was developed to examine the DO relationship with BOD_5 in Dutchman Creek. The diagram below shows the interactions of DO with different processes within the water column of the stream (USEPA 1997b). The consumers of DO include:



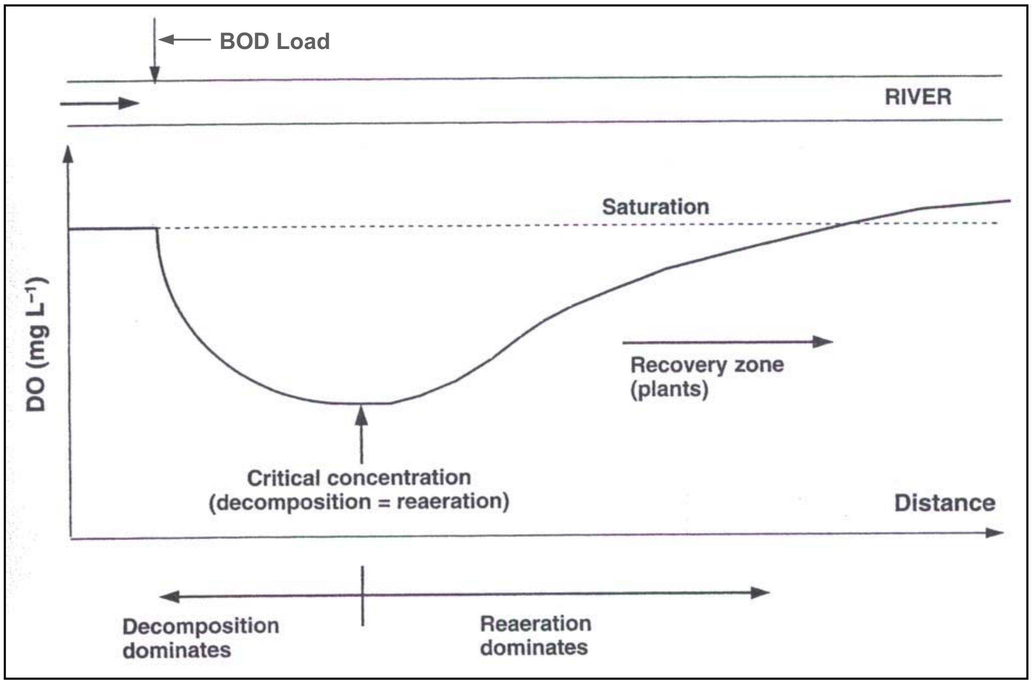
- deoxygenation of biodegradable organics whereby bacteria and fungi (decomposers) utilize oxygen in the bioxidation-decomposition process;
- sediment oxygen demand (SOD), where oxygen is utilized by organisms inhabiting the upper layers of the bottom sediment deposits;
- nitrification, in which oxygen 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; and
- 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. Organic matter also comes from nonpoint sources such as agricultural runoff, urban runoff, and livestock operations. Nonpoint sources can contribute significantly to the oxygen demand in a water body. The DO sag is shown in the following figure (Chapra 1997):



The impact of Dutchman reservoir on reaeration in segment ADD02 is important to note, as this has reduced flows downstream of the reservoir. This flow alteration, resulting in reduced streamflow, has impacted reaeration downstream of the reservoir.

Water quality models have built upon the Streeter-Phelps equation to evaluate the DO balance in streams. The analysis for Dutchman Creek segment ADD02 is based on BOD_5 and reaeration only. There is not enough coincident nutrient and algal historical data from this site to assess impacts of nutrient loads on algal growth that also impact DO levels. Free floating and attached algae as well as aquatic plants are of concern. The extent to which algae 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 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 8-1, 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 H.

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

$$k_{d20} = 0.3\left[\frac{H}{8}\right]^{-0.434} \text{ at } 20^\circ\text{C for } 0 < H < 8$$
$$= 0.3 \text{ for } H > 8$$

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).

Since no point sources were identified as contributing to the 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:

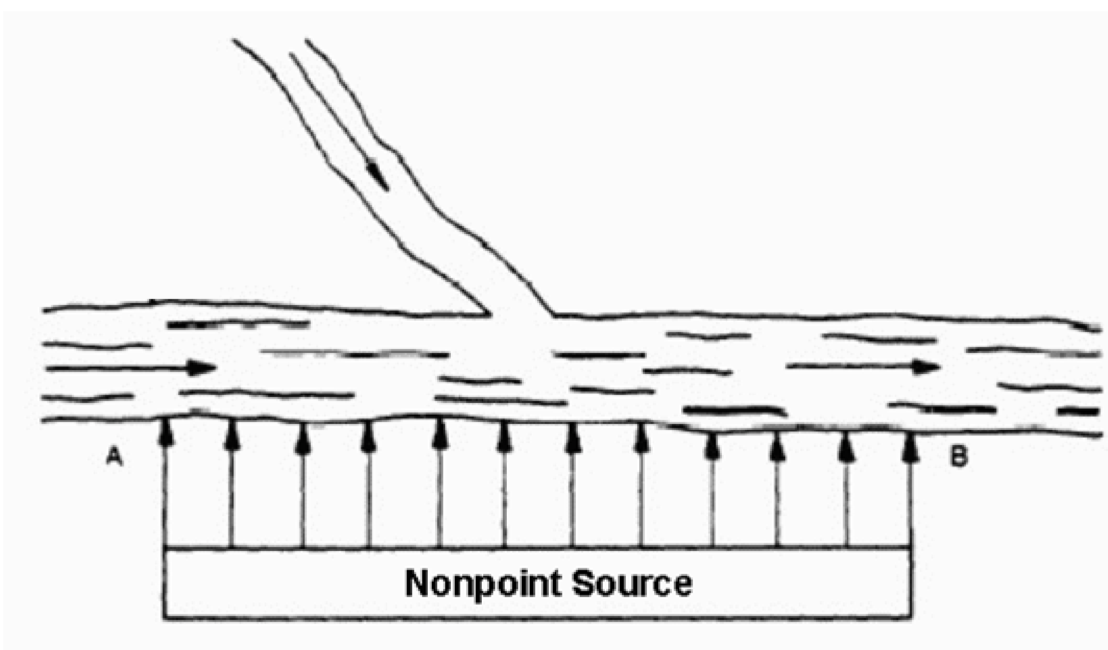


Table 8-2 shows the observed TOC data and the BOD_5 concentrations (L_0) calculated from observed TOC data. It also shows the k_a and k_d coefficients calculated with the above equations. In addition, the estimated BOD_5 load was calculated based on the calculated BOD_5 concentration and average daily flow on the day the sample was taken. Revised k_a and k_d values are also shown in Table 8-2. 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 8-2 also includes precipitation values near or on the sampling date so that estimates of pollutant loads from runoff can be compared to loads estimated based on the BOD_5/TOC ratio. Analysis details are contained in Appendix I.

Table 8-2 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations

Sample Location and Date	ADD02 6/11/1992	ADD02 9/30/1992	ADD02 12/7/1992	ADD02 8/10/1999	ADD02 1/18/2000
Measured DO (mg/L)	4.2	7	10.1	3.5	11.4
Measured TOC (mg/L)	4	7	1	7	5.5
Calculated BOD_5 Concentration (mg/L)	5.2	9.1	1.3	9.1	7.2
Calculated BOD_5 Load (lb/day)	40	115	27	22	217
Calculated k_a (1/day)	5.7	27.1	15.7	11.0	13.1
Revised k_a (1/day)	0.1	3.6	2.1	0.1	9.4
Calculated k_d (1/day)	0.70	0.80	0.44	0.85	0.42
Revised k_d (1/day)	0.98	0.80	0.44	1.03	0.42
Precipitation (in)	0.49	0.67	0.05	0.43	0.05
Dates Precipitation Occurred	4 days before sample	3 days before sample	On sample date	1 day before sample	On sample date
Flow (cfs)	1.4	2.3	3.9	0.4	5.6

Both sample dates that measured DO concentrations below the water quality standard of 6.0 mg/L, June 11, 1992 and August 10, 1999, required that both k_a and k_d be revised to obtain a match between the calculated and observed DO. In both cases, 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 each 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. Because BOD_5 was estimated based on actual data and k_a was estimated based on a depth calculation and not actual reaeration measurements in the field, this parameter was adjusted to determine impacts on the results. With further data collection efforts in the future, this assumption can be validated. 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. Based on the data available, this analysis showed the results are acceptable and the analysis is contained in Appendix J.

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 the event mean concentration (EMC) for the pollutant of concern. Land use for the watershed was presented in Table 5-11. The average monthly and annual precipitation for Johnson County was presented in Table 5-2. The EMCs used for each land use type are shown in Table 8-3.

Table 8-3 BOD_5 EMCs by Land Use Type for Dutchman Creek Segment ADD02 Watershed

Land Use	Area (acres)	Percent of Total	BOD_5 EMC (mg/L)	Source
Rural Grassland	8,844	44%	2.0	1
Deciduous	6,556	32%	2.0	1
Row Crop	2,579	13%	8.0	2
Coniferous	709	4%	2.0	1
Small Grains	679	3%	8.0	2
Forested Wetland	541	3%	0.0	1
Open Water	156	1%	0.0	1
Shallow Water/Wetlands	55	0%	0.0	1
Barren Land	41	0%	0.0	1
Swamp	18	0%	0.0	1
Medium Density	4	0%	14.1	1
Shallow Marsh/Wetlands	3	0%	0.0	1
High Density	1	0%	14.1	1
Urban Grassland	<1	0%	2.0	1
TOTAL	**20,186**	**100%**	**–**	**–**

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

Results of the WMM screening are shown in Table 8-4. The results are for the entire watershed contributing to segment ADD02. Results shown are an estimate of annual loads and loads from the precipitation events provided in Table 8-2. The loads estimated from WMM generated based on precipitation events near the sampling events are all greater than those shown in Table 8-2 except for the event on January 18, 2001. The WMM model files are contained in Appendix K. 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 Dutchman Creek Watershed.

Table 8-4 Results of WMM Screening Analysis for the Dutchman Creek Watershed

Event	Total BOD_5 Load (lb/day)	Precipitation (in)
Annual	122,563	46
6/11/1992	1,294	0.49
9/30/1992	1,770	0.67
12/7/1992	132	0.05
8/10/1999	1,136	0.43
1/18/2000	132	0.05

The estimated BOD_5 loads in Table 8-2 are low in comparison to the WMM loads predicted suggesting that they represent loadings occurring during ambient conditions or when the stream is not responding to nonpoint source runoff. Therefore, it is likely that further reductions in BOD concentrations could be achieved. The WMM results represent loadings from precipitation events shown in Table 8-2 that, in some cases, occurred before the sample date. On the two impaired dates, the precipitation occurred between one and four 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. As discussed in Section 5.1.5.2.1, 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 Dutchman Creek Watershed such as elevated stream temperatures during summer months and nutrient loads from nonpoint sources in the watershed.

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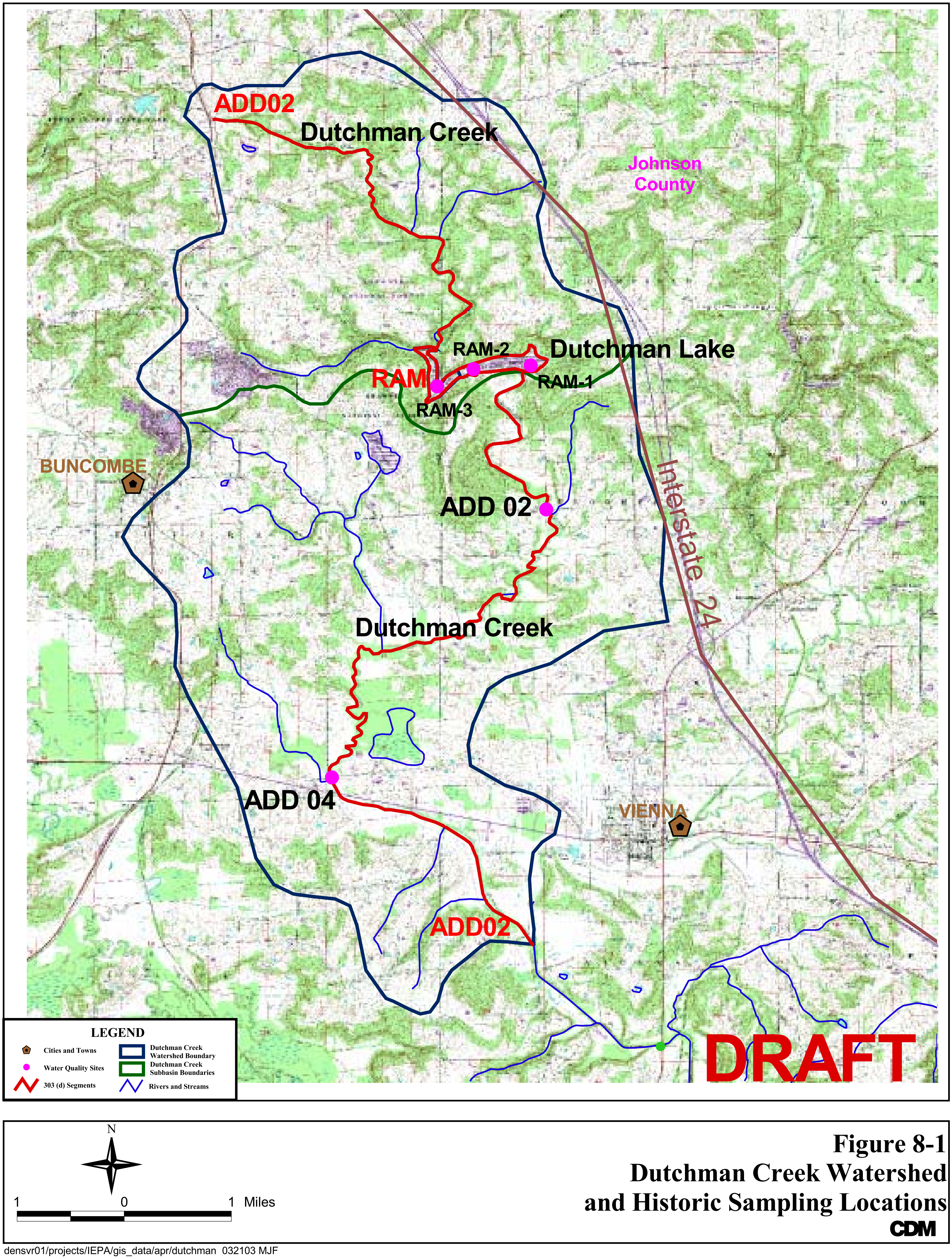

Figure 8-1
Dutchman Creek Watershed and Historic Sampling Locations

CDM

densvr01/projects/IEPA/gis_data/apr/dutchman 032103 MJF

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Section 9
Total Maximum Daily Load for the Dutchman Creek Watershed

9.1 TMDL Endpoints for Dutchman Lake

The desired in-lake water quality concentration for DO is above 6.0 mg/L for 16 hours of any 24-hour period. Table 5-5 in Section 5 summarized the average DO concentrations sampled in the Dutchman Lake Watershed. As noted in Section 5.1.5.1.1, all observed in-lake averages meet this target, but individual samples are below 6.0 mg/L, violating the endpoint. The 6.0 mg/L (16 hours of any 24-hour period) DO target is set to prevent eutrophic conditions in Dutchman Lake and maintain aquatic life.

9.1.1 Pollutant Sources and Linkages

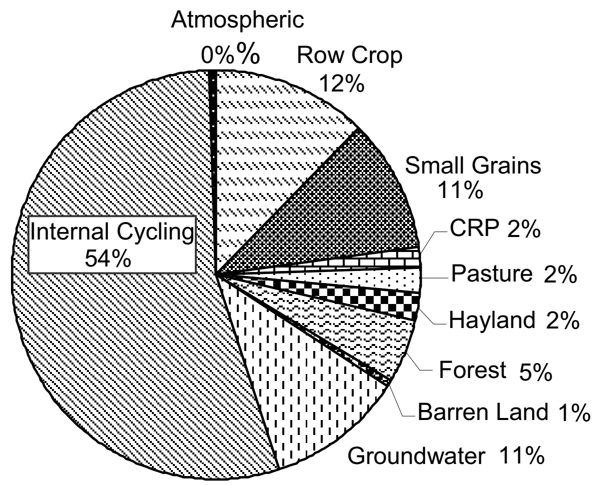
The TMDL for DO in Dutchman Lake is dependent on a relationship between DO, chlorophyll "a," and phosphorus as explained in Section 5.1.5.1.1 and Section 7.1. A general relationship between phosphorus and chlorophyll "a" was determined, but the relationship between chlorophyll "a" and DO is poor. This TMDL is based on the assumption that trends in Dutchman 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 Dutchman 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 and BATHTUB 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 Dutchman Lake Watershed. Only the above normal (1994) and dry (2001) years had violations of the DO standards, so the mean loads in Table 9-1 represent only the averages of 1994 and 2001.

Table 9-1 Modeled Total Phosphorus Loads by Source

Land Use	1994 (above normal)		2001 (dry)		Mean of 1994 and 2001	
	lb/yr	percent	lb/yr	percent	lb/yr	percent
Row Crop	1192	11%	414	15%	803	12%
Small Grains	1056	10%	368	13%	712	11%
Rural Grassland						
CRP	135	1%	84	3%	110	2%
Pastureland	135	1%	115	4%	125	2%
Hayland	190	2%	115	4%	152	2%
Forest	487	5%	153	5%	320	5%
Barren Land	54	1%	15	1%	35	1%
Groundwater	1,083	10%	345	12%	714	11%
Internal Cycling	6,025	58%	1,205	42%	3,615	55%
Atmospheric	32	0%	32	1%	32	0%
TOTAL	10,389	100%	2,846	100%	6,618	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 in 1994 and 2001. 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 phosphorus water quality standard of 0.05 mg/L in Dutchman Lake.

9.1.2 Allocation

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

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

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

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

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

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

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

9.1.2.1 Loading Capacity

The loading capacity of Dutchman 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 were 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 Dutchman Lake. Table 9-2 shows the allowable phosphorus loading determined for 1994 and 2001 by reducing modeled inputs to Dutchman Lake through GWLF and BATHTUB. The output files to BATHTUB showing the results of the load reductions for 1994 and 2001 are contained in Appendix L.

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

Model Year	Phosphorus (lb/yr)
1994	4,840
2001	1,747
Mean	3,294

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 Dutchman 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 Dutchman 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, and
- 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 Dutchman 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

There are no point sources in the watershed; therefore, no WLA will be established.

9.1.2.5 Load Allocation and TMDL Summary

Table 9-3 shows a summary of the TMDL for Dutchman Lake. On average, a total reduction of 53 percent of total phosphorus loads to Dutchman 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 Dutchman Lake

LC (lb/yr)	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	Reduction Needed (lb/yr)	Reduction Needed (percent)
3,294	0	3,129	165	3,485	53%

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 8 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	Percent Reduction	Current Load (lb/yr)	Load Reduction (lb/yr)
Internal Cycling	90%	3,615	3,254
Atmospheric	0%	32	0
Nonpoint Sources	8%	2,971	236

9.2 TMDL Endpoints for Dutchman Creek

The TMDL endpoints for DO concentrations in a stream must be greater than 6.0 mg/L for 16 hours of any 24-hour period. This endpoint is based on protection of aquatic life in Dutchman Creek. 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.

9.2.1 Pollutant Source and Linkages

Pollutant sources for Dutchman Creek were identified through the existing data review described in Section 5. Based on the data review, 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 may also contribute to low DO in the stream.

As discussed in Section 8.3, the BOD_5 loads in segment ADD02 likely represent background loadings, which suggests that the principle cause of DO impairments in segment ADD02 is a lack of aeration caused by low flows and stagnant pools. Table 9-5 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 9-5 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Dutchman 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)
ADD02	6/11/92	4.2	0.1	4.2
ADD02	8/10/99	3.5	0.1	4.4

Based on the data analysis, increases of aeration would be required in summer months but not during winter conditions. Monitoring data to make the analysis more robust will be discussed in Section 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 were used to estimate the BOD_5 loading required to meet the water quality standard on each sample date impaired for DO. Table 9-6 shows the BOD_5 loads estimated from TOC as discussed in Section 8.3 and the BOD_5 loading that would be necessary to meet water quality standards. The analysis showed that BOD_5 levels would have to be reduced to below zero in order to meet water quality standards. This is not physically possible. Therefore, reducing BOD_5 loads is not a feasible option for increasing DO in Dutchman Creek and other options for increasing reaeration should be investigated.

Table 9-6 Calculated BOD_5 Loads and Required BOD Loads in the Dutchman 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)
ADD02	6/11/92	4.2	40	-74
ADD02	8/10/99	3.5	22	-15

Section 10
Implementation Plan for Dutchman Lake and Dutchman Creek

10.1 Implementation Actions and Management Measures

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 Dutchman Lake was established in Section 7, so management measures for Dutchman Lake focus on phosphorus reduction. Analysis provided in Section 8 established a relationship between reaeration, BOD_5, and DO concentrations in Dutchman Creek segment ADD02, so management measures for Dutchman Creek 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 the Dutchman Lake Watershed originate from external and internal sources. From modeling estimates, internal phosphorus cycling from sediments accounts for approximately 55 percent of the loading to Dutchman Lake. External loads from nonpoint source runoff from agricultural crops and rural grassland potentially account for 23 percent and 6 percent, respectively, of the loading. The remainder of the loading is attributed to groundwater (11 percent), forest land (5 percent), and barren land (<1 percent). To achieve the 53 percent reduction of phosphorus established in Section 9 for Dutchman 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 Dutchman Creek are mostly attributed to low flow or stagnant conditions within the creek. Runoff from nonpoint sources may also contribute a BOD_5 load in Dutchman Creek segment ADD02. An additional contributor to low DO is increased water temperatures. Therefore, management measures for segment ADD02 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.

10.1.1 Nonpoint Source DO Concentration and Phosphorus Management

The sources of nonpoint source pollution in the Dutchman Creek and Dutchman Lake TMDL are divided between agricultural cropland and rural grasslands. BMPs evaluated for treatment of these nonpoint sources are:

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

Organic and nutrient loads originating from cropland are 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 Dutchman Creek and Dutchman 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 Dutchman Creek segment ADD02.

10.1.1.1 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to both Dutchman Lake and Dutchman 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 Dutchman

Lake and Dutchman 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 lakes 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 (NCSU 2000). Currently, approximately 53 percent of the fields in the Dutchman 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 Dutchman Creek. 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 by Illinois EPA in the future will affect this DO TMDL and would be expected to also help control exceedances of DO water quality criteria in Dutchman Creek segment ADD02.

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. 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 affect 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 Dutchman Creek and Dutchman 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).

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

To assess the percent of stream length with grass and riparian buffers, the GIS land use data described in Section 5 in conjunction with slope data near Dutchman Creek, Dutchman Lake, and the tributaries contributing to these segments were analyzed to estimate the amount of cropland that could be converted to filter strips. The weighted average slope of cropland area in the watershed that borders the stream is approximately 2 percent. Recommended filter strip lengths from Table 10-1 was utilized in the weighted average and the total amount of cropland recommended for consideration of filter strip development is 82 acres. This amounts to approximately 2.5 percent of the total cropland area (3,258 acres) in the Dutchman Creek and Dutchman Lake Watershed. Additionally, the existing land use for the Dutchman Creek Watershed is shown in Figure 10-1. The figure shows that the majority of land bordering Dutchman Creek and its tributaries is grassland and forest land allowing few cropland acres to be available for use as filter strips.

The percentages provided in Table 10-3 are used to calculate an approximation of BMP costs in Section 10.2.2 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 10.2.1.

10.1.1.2 Wetlands

The use of wetlands as a structural control are most applicable to nutrient reduction in Dutchman Lake and therefore this section only focuses on the Dutchman Lake Watershed. To treat loads from agricultural runoff, which is estimated to contribute approximately 20 percent of the current total phosphorus load to Dutchman Lake, 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; and
- 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).

Table 10-2 Acres of Wetland Required

Subbasin	Area (acres)	Wetland (acres)
1	2,175	13
2	4,310	26
3	121	1
4	603	4

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 based on these recommendations. A wetland system to treat agricultural runoff from the four subbasins comprising the 7,200-acre (11.2-square mile) Dutchman Lake Watershed would range between 1 to 26 acres (Denison and Tilton 1993).

10.1.1.3 Conservation Tillage Practices

For the Dutchman Lake Watershed, conservation tillage practices could help reduce nutrient loads in the lake. Nonpoint source runoff from 3,260 acres of row crops and small grain agriculture were estimated to contribute approximately 23 percent of the total phosphorus load to Dutchman 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 up to 45 percent of the dissolved and total phosphorus from runoff and approximately 75 percent of the sediment (NCSU 2000); however, filter strips are less effective at removing dissolved phosphorus only. Additionally, studies have found around 93 percent less erosion occurred from no-till acreage compared to acreage subject to moldboard plowing (NCSU 2000). According to the Johnson County NRCS, various methods of conservation tillage are presently utilized in the Dutchman Lake Watershed. 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 10.9 tons/acre/year. To achieve an 11 percent reduction in phosphorus load, the erosion rate for the watershed would need to be reduced to 9.7 tons/acre/year. Similarly, the C-factors for corn, soybeans, and small grains would need to be reduced from 0.21, 0.08, and 0.14 to 0.19, 0.07, and 0.12 respectively.

10.1.1.4 Nutrient Management

Nutrient management could result in reduced phosphorus and nitrogen loads to Dutchman 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; and
- 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).

10.1.1.5 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.

10.1.2 In-Lake Phosphorus

Internal cycling of phosphorus contributes approximately 55 percent of the phosphorus load to Dutchman Lake. 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 becomes 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 does not become 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 epilimnion, 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).

10.1.3 Implementation Actions and Management Measures Summary

To meet the reductions outlined in Section 9 for Dutchman Lake, 8 percent of the external loads of total phosphorus and 90 percent of the internal phosphorus loads 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; and
- nutrient management (assumed resulting 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, and wetlands are summarized in Table 10-3. 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. The lower bound of the literature value was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible.

Table 10-3 Summary of Total Phosphorus Load Reductions

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

* Literature value

A combination of implementing these external load reduction practices coupled with the available treatments for internal loads would allow the Dutchman Lake Watershed to meet its total goal of reducing phosphorus loads. As mentioned previously, approximately 53 percent of fields in the Dutchman Lake Watershed utilize filter strips (NRCS 2002a). Improving this percentage will further reduce the external phosphorus loads from the watershed. The next section outlines planning level costs and programs available to help with cost-sharing so that this goal can be achieved.

The reduction of nutrients via these measures should also help in reducing the number of DO impairments in Dutchman Creek.

10.2 Reasonable Assurance

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

10.2.1 Available Programs

Approximately 60 percent of the Dutchman Creek 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.

10.2.1.1 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, 3,260 acres of cropland have been targeted in the Dutchman 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.

10.2.1.2 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).

10.2.1.3 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).

10.2.1.4 Conservation Reserve Program

This voluntary program encourages landowners to plant long-term resource-conserving cover to improve soils, water, and wildlife resources. The 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.

Money for implementing CRP in Johnson County is not available at this time. The following discussion is available for reference if money does become available. Eligible land must be one of the following:

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

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 (USDA 1999). 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; and
- eligible acreage within an USEPA-designated wellhead protection area (FSA 1997).

10.2.1.5 Wetlands Reserve Program

The Wetlands Reserve Program (WRP) is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. Money for implementing WRP in Johnson County is not available at this time. The following discussion is available for reference if money does become available. 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 (2002b).

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 (NRCS 2002b). Since the program began in 1985, 32,000 acres have been enrolled in WRP. The average cost per acre is $1,100 in restorative costs and the average project size is 177 acres (NRCS 2002d; USDA 1996). The costs for each enrollment option follow in Table 10-4 (NRCS 2002b).

Table 10-4 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

10.2.1.6 Environmental Quality Incentive Program

The Environmental Quality Incentive Program (EQIP) is a voluntary USDA conservation program for farmers and private landowners engaged in livestock or agricultural production who are faced with serious threats to soil, water, and related natural resources. It provides technical, financial, and educational assistance primarily in designated "priority areas." Priority areas are defined as watersheds, 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 2002h,i).

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 $450,000 per individual over the period of the 2002 Farm Bill, regardless of the number of farms or contracts (NRCS 2002h).

10.2.1.7 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 most common practices used in Johnson County are the grassed waterways, pasture/hayland establishment, and WASCOBS. Johnson County NRCS provides a cost share of 60 percent to the landowner to help with the cost. The CPP program 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.

10.2.1.8 Wildlife Habitat Incentives Program

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan 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 funded. As of May 2002, approximately 8,700 acres in 80 counties have been restored (NRCS 2002g). 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 2002f).

The FSA administers the CRP. NRCS administers the EQIP, WRP, CPP, and WHIP. Local NRCS and FSA contact information in Johnson County are listed in the Table 10-5 below.

Table 10-5 Local NRCS and FSA Contact Information for Johnson County

Contact	Address	Phone
Local NRCS Office		
Thomas Harris	807 North 1st Street, Vienna, IL 62995	618-658-3411 x3
Local FSA Office		
Vienna Service Center	807 North 1st Street, Vienna, IL 62995	618-658-3411

10.2.2 Cost Estimates of BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 10-6 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Dutchman Creek and Dutchman Lake Watershed are presented in Section 10.2.2.6 and Table 10-7.

10.2.2.1 Streambank Stabilization

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.

10.2.2.2 Wetland

The price to establish a wetland is site specific. In general, to create wetland hydrology with a 6-foot to 8-foot berm, the cost is $2 to $2.50/cubic yard. Site preparation for planting is $33/acre, tree planting using bare root stock is $350/acre, and container plants are $7.50 to $8.50/tree with a labor cost of $3.00/tree. The average project cost to establish a wetland in Johnson County is $1,000/acre. It should be noted that the larger the wetland acreage to be established the more cost-effective the project (NRCS 2002c).

10.2.2.3 Filter Strips and Riparian Buffers

Johnson County NRCS estimates an average cost per acre to install and maintain a grass filter strip with a 10-year life span at $190/acre. This price quote accounts for seeding and mowing every other year to remove woody sprouts. A riparian buffer strip has a life span of 10 years and an installation cost of $384/acre.

10.2.2.4 Nutrient Management Plan - NRCS

Generally, agricultural land in Johnson County is comprised of cropland and cattle in open pastures. Few Nutrient Management Plans have been established. The Johnson County Extension Service estimates the average plan to cost $5 to $15/acre.

10.2.2.5 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 are 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.

10.2.2.6 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).

10.2.2.7 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).

10.2.2.8 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 10-6. The column labeled *Program* lists the financial assistance programs available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 10-6 Cost Estimate of Various BMP Measures in Johnson County

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	WRP	Wetland	10	$1,000	$100.00
	CRP	Grass Filter Strips	10	$190	$19.00
	CRP	Riparian Buffer	10	$384	$38.40
	CRP	Grassed Waterways	10	$1,200	$120.00
	319 or SSRP	Streambank Stabilization*	10	$40	$4.00
	NRCS	Nutrient Management Plan		$10	
	IDA and Illinois EPA	Nutrient Management Plan		$7	
	CRP	Conservation Tillage	1	$17	$17.35
Internal Cycling	319	Dredging	50	$8,000	$160.00
	319	Aeration	20	$583	$29.15

* Streambank Stabilization cost calculated on a linear foot basis

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $1,113,000. 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 10-7 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 10-7 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle.

Table 10-7 Cost Estimate of Implementation Measures for Dutchman Lake and Dutchman Creek Watersheds

		Capital Costs		Maintenance Costs*	
BMP	Treated Acres	Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Wetland on River	44	$1,000	$44,000	$100.00	$4,000
Grass Filter Strips	82	$190	$16,000	$19.00	$1,600
Streambank Stabilization**	19,000	$40	$760,000	$4.00	$76,000
Nutrient Management Plan	3,260	$7	$23,000		
Conservation Tillage	3,260	$17	$55,000	$17.35	$57,000
Dredging	118	$8,000	$944,000	–	$0
		Total	**$1,842,000**		**$183,600**

* Maintenance costs are generally calculated as 10% of the capital cost. There are no maintenance costs for dredging because it is a onetime procedure.
** Cost calculated on a linear foot basis

10.3 Monitoring Plan

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

- track implementation of management measures in the watershed;
- estimate effectiveness of management measures;

- continued monitoring of Dutchman Creek and Dutchman Lake; and
- tributary monitoring.

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; and
- 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 for Dutchman Lake could be conducted to determine site-specific removal efficiency. If aeration is used to control internal loading in Dutchman Lake, site-specific data would be needed to assess the effectiveness of this management measure.

Illinois EPA monitors Dutchman Lake from April through October approximately every three years. Dutchman Creek is monitored approximately every five years as part of the Cache 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} ; and
- chlorophyll 'a' or algae monitoring for Dutchman Creek.

Tributary monitoring is needed to better assess the contribution of internal loading to Dutchman Lake. By having further knowledge of actual contributions from external loads, a better estimate of internal loads could occur. Along with this tributary monitoring, a stage discharge relationship could be developed with the reservoir spillway so that flows into the reservoir could be paired with tributary water quality data to determine total phosphorus load from the watershed. Data on the different forms of phosphorus (dissolved, total, or orthophosphate) would also be beneficial to better assess reservoir response to phosphorus loading.

10.4 Implementation Time Line

Implementing the actions outlined in this section for the Dutchman 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 five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. Once improvements are implemented, it may take Dutchman Creek and Dutchman Lake 10 years or more to reach the water quality standard target of 0.05 mg/L for total phosphorus and associated target of 6 mg/L for DO (Wetzel 1983). If internal loads are not effectively controlled, this time frame could be even greater as Dutchman Lake will take time to "flush" out the phosphorus bound to bottom sediments as reductions in external loads take place. 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 Dutchman Creek Watershed may take up to 20 years to complete.

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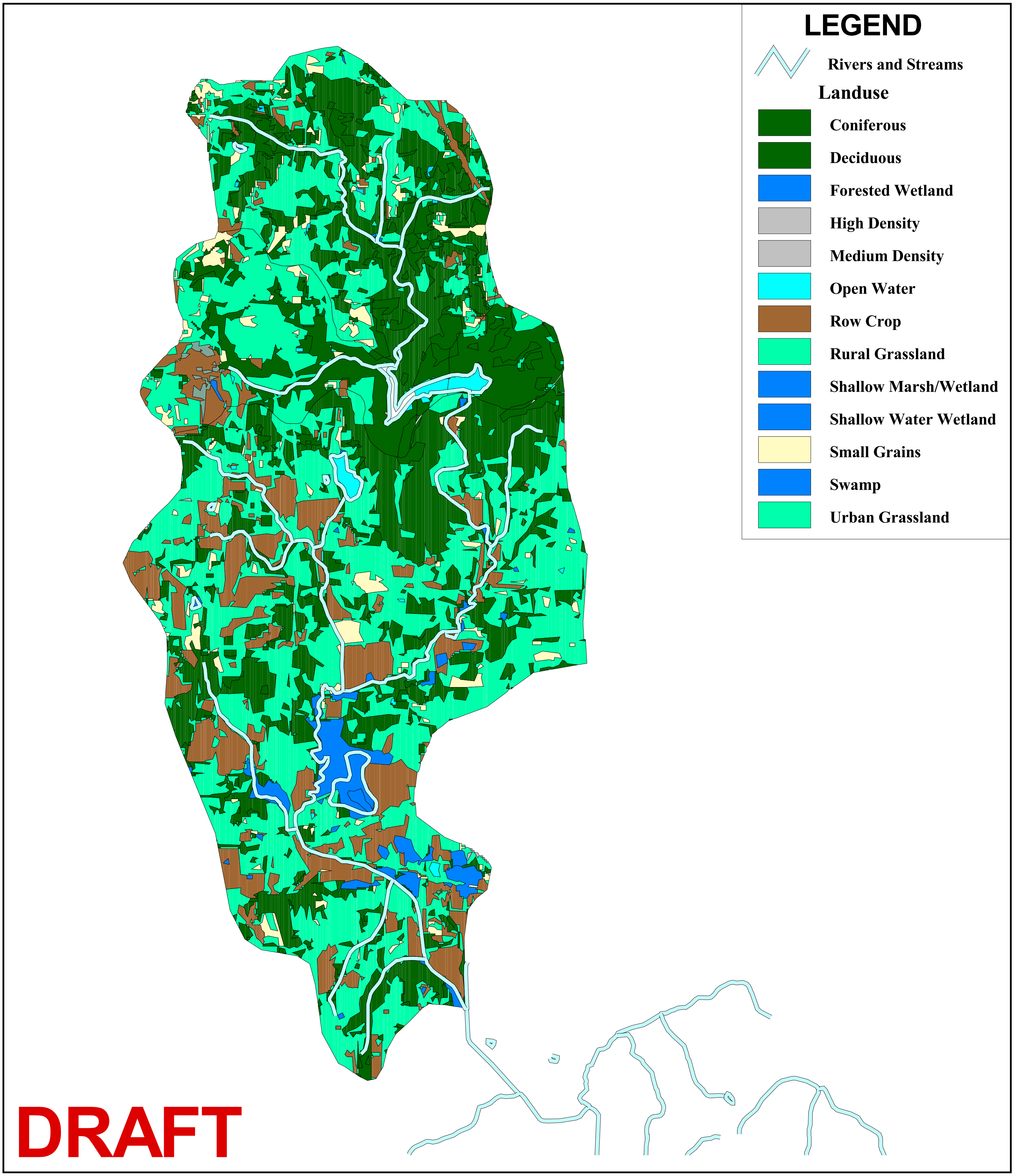

Figure 10-1
Landuse for Dutchman Creek Watershed

CDM

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Section 11
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Appendix A
Historic Water Quality Data

Station	Start Date	Parameter Long Name	Result Value
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.30
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.60
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.10
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.60
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.30
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.50
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.20
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.90
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.30
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.90
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.70
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.20
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.10
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.20
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.50
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.40
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.60
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.40
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.20
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.80

Station	Start Date	Parameter Long Name	Result Value
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.00
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.70
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.40
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.60
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.00
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.40
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.50
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.90
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.00
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.20
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.70
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.50
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.40
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.40
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.20
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.20
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.30
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.60
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.00
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.80
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10

Station	Start Date	Parameter Long Name	Result Value
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.10
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.10
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.40
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.80
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.10
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.6
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.5
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.4
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.3
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.6
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.7
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.9
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.5
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.6
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.2
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.3
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.8
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.7
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.4
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.4
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.7
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.2
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.2
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.4
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.4
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.5
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.5
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.4
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.3
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.2
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.4
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	13
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.1

Station	Start Date	Parameter Long Name	Result Value
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.6
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.6
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.9
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.1
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.2
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.6
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.5
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.60
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.60
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.60
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.00
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.70
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.90
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.30
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.40
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.40
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.50
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.60
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.80
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.00
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.40
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.20
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.60

Station	Start Date	Parameter Long Name	Result Value
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.70
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.60
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.50
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.60
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.80
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.90
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.70
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.20
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.70
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.60
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.20
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.10
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.4
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.1
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.9
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.8
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.7
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.6
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.5
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.6
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.2
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.3
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.9
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.9
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.2
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.4
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.8
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.9

Station	Start Date	Parameter Long Name	Result Value
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.3
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.9
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.2
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.4
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.8
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	14.3
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.1
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.6
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.7
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.3
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.5
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.6
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.6
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.30
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.10
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.30
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.80
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.30
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.30
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.90
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.50
RAM-3	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.50
RAM-3	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.50
RAM-3	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.70
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.10
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.70
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.50
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.10
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.90
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.40
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.90
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.40
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.40
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10

Station	Start Date	Parameter Long Name	Result Value
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.90
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.80
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.40
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.40
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20
RAM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.80
RAM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.70
RAM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.70
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.3
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.7
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.4
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.4
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.3
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.1
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.9
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.1
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.5
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.3
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.2
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.5
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.3
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.7
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.4
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.9

Sample Depth (ft)
0
1
3
5
7
9
11
13
15
17
19
21
21.5
0
1
3
5
7
9
11
13
15
17
17.5
0
1
3
5
7
9
11
13
15
17
0
1
3
5
7
9
11
13
15
17
0
1
3
5
7
9

Sample Depth (ft)
11
13
15
17
18
0
1
3
5
7
9
11
13
15
17
0
1
3
5
7
9
11
13
15
17
19
20
0
1
3
5
7
9
10
0
1
3
5
7
9
11
13
15
17
0
1
3
5
7
9

Sample Depth (ft)
11
13
15
17
19
20
0
1
3
5
7
9
11
13
15
17
18
0
1
3
5
7
9
11
13
15
16
0
1
3
5
7
9
11
13
15
17
0
1
3
5
7
9
11
13
15
16
0
1
3

Sample Depth (ft)
5
7
9
11
13
15
17
18
0
1
3
5
7
9
11
13
15
0
1
3
5
7
8
0
1
3
5
7
8
0
1
3
5
7
8
0
1
3
5
7
0
1
3
5
7
8
0
1
3
5

Sample Depth (ft)
7
9
11
13
15
17
0
1
3
5
7
9
11
13
15
17
18
0
1
3
5
7
9
11
13
15
17
0
1
3
5
7
9
9.5
0
1
3
5
7
9
10
0
1
3
5
7
9
11
0
1

Sample Depth (ft)
3
5
7
9
10
0
1
3
5
7
9
10
0
1
3
5
7
9
10
0
1
3
4
0
1
3
5
6
0
1
3
4
0
1
3
0
1
3
5
6.5
0
1
3
5
7
0
1
3
5
7

Sample Depth (ft)
8
0
1
3
5
7
0
1
3
5
6
0
1
3
0
1
3
4
0
1
3
5
0
1
3
5
0
1
3
5
0
1
3
5

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.30	0
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20	1
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.60	3
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00	5
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.10	7
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00	9
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.60	11
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.30	13
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.50	15
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40	17
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	19
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	21
RAM-1	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.20	21.5
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80	0
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20	1
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30	3
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70	5
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20	7
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.90	9
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.30	11
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	13
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	15
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	17
RAM-1	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	17.5
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70	0
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10	1
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50	3
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.90	5
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50	7
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20	9
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.70	11
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	13
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	15
RAM-1	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	17
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10	0
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10	1
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.20	3
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.10	5
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40	7
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40	9
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	11
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.30	13
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.20	15
RAM-1	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	17
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.50	0
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.40	1
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.60	3
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.40	5
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.20	7
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.80	9
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.00	11

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	13
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	15
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	17
RAM-1	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	18
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10	0
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00	1
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.70	3
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.40	5
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30	7
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20	9
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.60	11
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.00	13
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.40	15
RAM-1	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.50	17
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70	0
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70	1
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70	3
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.90	5
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.00	7
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.20	9
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.70	11
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	13
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	15
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	17
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	19
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	20
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80	0
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80	1
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80	3
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00	5
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.50	7
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.40	9
RAM-1	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	10
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.40	0
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.40	1
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50	3
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.20	5
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.20	7
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.30	9
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.60	11
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.00	13
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	15
RAM-1	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	17
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10	0
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00	1
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10	3
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.10	5
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.80	7
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	9
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	11
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	13

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	15
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	17
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	19
RAM-1	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	20
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.10	0
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.10	1
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00	3
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00	5
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.00	7
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.40	9
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.80	11
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.10	13
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	15
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	17
RAM-1	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	18
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.6	0
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.5	1
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.4	3
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.3	5
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.6	7
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.7	9
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.9	11
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.5	13
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.6	15
RAM-1	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.2	16
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.3	0
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7	1
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.8	3
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.7	5
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.4	7
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.4	9
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.7	11
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.2	13
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0	15
RAM-1	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0	17
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.2	0
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.4	1
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.4	3
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.5	5
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.5	7
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.4	9
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.3	11
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.2	13
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	15
RAM-1	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	16
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.4	0
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	13	1
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.1	3
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.6	5
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	7
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	9

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	11
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	13
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	15
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0	17
RAM-1	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0	18
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7	0
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.6	1
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.9	3
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.1	5
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.2	7
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5	9
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.6	11
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4	13
RAM-1	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.5	15
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20	0
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20	1
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20	3
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00	5
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.00	7
RAM-2	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.60	8
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.60	0
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20	1
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30	3
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80	5
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.60	7
RAM-2	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.00	8
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.50	0
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.10	1
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.70	3
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80	5
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.90	7
RAM-2	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.30	8
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00	0
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00	1
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00	3
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00	5
RAM-2	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.40	7
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.40	0
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50	1
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.50	3
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.60	5
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.80	7
RAM-2	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.00	8
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.40	0
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.20	1
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.00	3
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.60	5
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20	7
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80	9
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.70	11
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.60	13

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70	15
RAM-2	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.50	17
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30	0
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30	1
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.20	3
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00	5
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.60	7
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.80	9
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.90	11
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	13
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	15
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	17
RAM-2	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	18
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.70	0
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80	1
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.80	3
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.20	5
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.70	7
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	9
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	11
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	13
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	15
RAM-2	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.00	17
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70	0
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70	1
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70	3
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.70	5
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.60	7
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.20	9
RAM-2	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.10	9.5
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.4	0
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.1	1
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.9	3
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.8	5
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.7	7
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.6	9
RAM-2	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.5	10
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.6	0
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.2	1
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.3	3
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.9	5
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.9	7
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.2	9
RAM-2	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.4	11
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.8	0
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.9	1
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12	3
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.3	5
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9	7
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	2.9	9
RAM-2	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.2	10

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.4	0
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.8	1
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	14.3	3
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2	5
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.1	7
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	9
RAM-2	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.1	10
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.6	0
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.7	1
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2	3
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.3	5
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.5	7
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.6	9
RAM-2	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.6	10
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.30	0
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.10	1
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20	3
RAM-3	4/26/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.20	4
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10	0
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.30	1
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.10	3
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.80	5
RAM-3	6/2/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.30	6
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.30	0
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.80	1
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.90	3
RAM-3	7/8/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.50	4
RAM-3	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.50	0
RAM-3	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.50	1
RAM-3	8/12/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.70	3
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20	0
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20	1
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.10	3
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.70	5
RAM-3	10/3/1988	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.50	6.5
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.10	0
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.90	1
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.70	3
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.40	5
RAM-3	4/15/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.90	7
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50	0
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50	1
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.40	3
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.40	5
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	7
RAM-3	6/13/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	0.10	8
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00	0
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00	1
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.90	3
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.50	5
RAM-3	7/7/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	1.80	7

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.30	0
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.00	1
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.40	3
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.40	5
RAM-3	8/24/1994	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.20	6
RAM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.80	0
RAM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.70	1
RAM-3	########	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.70	3
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	11.3	0
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.7	1
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.4	3
RAM-3	4/2/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.4	4
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.3	0
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.1	1
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4	3
RAM-3	6/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	3.9	5
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.1	0
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8	1
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.5	3
RAM-3	7/5/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.3	5
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.2	0
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.5	1
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2	3
RAM-3	8/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.3	5
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.7	0
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8	1
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.4	3
RAM-3	10/1/2001	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.9	5

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-1	4/26/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-1	4/26/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.04	Lake Bottom
RAM-1	6/2/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-1	6/2/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.04	Lake Bottom
RAM-1	7/8/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.01	1
RAM-1	7/8/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.07	Lake Bottom
RAM-1	8/12/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-1	8/12/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.05	Lake Bottom
RAM-1	10/3/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-1	10/3/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.07	Lake Bottom
RAM-1	4/15/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.05	1
RAM-1	4/15/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.07	Lake Bottom
RAM-1	6/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-1	6/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.32	Lake Bottom
RAM-1	7/7/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-1	7/7/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.07	Lake Bottom
RAM-1	8/24/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-1	8/24/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.49	Lake Bottom
RAM-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.05	Lake Bottom
RAM-1	4/2/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-1	4/2/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	16
RAM-1	6/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.045	1
RAM-1	6/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.051	17
RAM-1	7/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.035	1
RAM-1	7/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.065	16
RAM-1	8/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.053	1
RAM-1	8/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.286	18
RAM-1	10/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.052	1
RAM-1	10/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	15
RAM-2	4/26/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-2	6/2/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-2	7/8/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.00	1
RAM-2	8/12/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.20	1
RAM-2	10/3/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.00	1
RAM-2	4/15/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.05	1
RAM-2	6/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-2	7/7/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-2	8/24/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.04	1
RAM-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-2	4/2/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	1
RAM-2	6/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.039	1
RAM-2	7/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
RAM-2	8/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	1
RAM-2	10/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.104	1
RAM-3	4/26/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.04	1
RAM-3	6/2/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-3	7/8/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-3	8/12/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-3	10/3/1988	PHOSPHORUS, TOTAL (MG/L AS P)	0.01	1
RAM-3	4/15/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.04	1
RAM-3	6/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.03	1
RAM-3	7/7/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.02	1
RAM-3	8/24/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.05	1

Station	Start Date	Parameter Long Name	Result Value	Sample Depth (ft)
RAM-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.04	1
RAM-3	4/2/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.028	1
RAM-3	6/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.058	1
RAM-3	7/5/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.046	1
RAM-3	8/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.076	1
RAM-3	10/1/2001	PHOSPHORUS, TOTAL (MG/L AS P)	0.06	1

Station	Start Date	Parameter	Parameter Long Name	Result Value
RAM-1	8/12/1978	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	83.07
RAM-1	4/26/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.28
RAM-1	6/2/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.49
RAM-1	7/8/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	17.80
RAM-1	8/12/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	42.72
RAM-1	10/3/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.56
RAM-1	4/15/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	48.06
RAM-1	6/13/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.27
RAM-1	7/7/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	26.18
RAM-1	8/24/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	44.50
RAM-1	4/2/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.4
RAM-1	6/1/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23
RAM-1	7/5/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	40.8
RAM-1	8/1/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	53
RAM-2	8/12/1978	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	70.65
RAM-2	4/26/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19.66
RAM-2	6/2/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.65
RAM-2	7/8/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.54
RAM-2	8/12/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	36.04
RAM-2	10/3/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19.22
RAM-2	4/15/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	42.72
RAM-2	6/13/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.95
RAM-2	7/7/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.13
RAM-2	8/24/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	40.94
RAM-2	4/2/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.3
RAM-2	6/1/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.1
RAM-2	7/5/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.5
RAM-2	8/1/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	48.4
RAM-3	4/26/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.69
RAM-3	6/2/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.68
RAM-3	7/8/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.65
RAM-3	8/12/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.71
RAM-3	10/3/1988	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.34
RAM-3	4/15/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.90
RAM-3	6/13/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	21.36
RAM-3	7/7/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.87
RAM-3	8/24/1994	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	26.70
RAM-3	4/2/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.03
RAM-3	6/1/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19.7
RAM-3	7/5/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	37.9
RAM-3	8/1/2001	32211	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	43.8

Station	Start Date	Parameter Long Name	Result Value
RAM-1	4/26/1988	DEPTH OF POND OR RESERVOIR IN FEET	21.50
RAM-1	4/26/1988	DEPTH OF POND OR RESERVOIR IN FEET	21.50
RAM-1	4/26/1988	DEPTH OF POND OR RESERVOIR IN FEET	21.50
RAM-1	6/2/1988	DEPTH OF POND OR RESERVOIR IN FEET	21.50
RAM-1	6/2/1988	DEPTH OF POND OR RESERVOIR IN FEET	21.50
RAM-1	6/2/1988	DEPTH OF POND OR RESERVOIR IN FEET	19.50
RAM-1	7/7/1988	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	7/8/1988	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	7/8/1988	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	8/12/1988	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	8/12/1988	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	8/12/1988	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	10/3/1988	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-1	10/3/1988	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-1	10/3/1988	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-1	4/15/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	4/15/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	4/15/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	6/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	22.00
RAM-1	6/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	22.00
RAM-1	6/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	22.00
RAM-1	7/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	7/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	17.00
RAM-1	7/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	8/24/1994	DEPTH OF POND OR RESERVOIR IN FEET	22.00
RAM-1	8/24/1994	DEPTH OF POND OR RESERVOIR IN FEET	22.00
RAM-1	8/24/1994	DEPTH OF POND OR RESERVOIR IN FEET	22.00
RAM-1	########	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-1	########	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-1	########	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-1	4/2/2001	DEPTH OF POND OR RESERVOIR IN FEET	18.00
RAM-1	6/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-1	7/5/2001	DEPTH OF POND OR RESERVOIR IN FEET	18.00
RAM-1	8/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-1	10/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	17.00
RAM-2	4/26/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	4/26/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	6/2/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	6/2/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	7/7/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	7/8/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	8/12/1988	DEPTH OF POND OR RESERVOIR IN FEET	9.00
RAM-2	8/12/1988	DEPTH OF POND OR RESERVOIR IN FEET	9.00
RAM-2	10/3/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	10/3/1988	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-2	4/15/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-2	4/15/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.00
RAM-2	6/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	12.00
RAM-2	6/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	12.00
RAM-2	7/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	1.00

Station	Start Date	Parameter Long Name	Result Value
RAM-2	7/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	20.00
RAM-2	8/24/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.50
RAM-2	8/24/1994	DEPTH OF POND OR RESERVOIR IN FEET	19.50
RAM-2	########	DEPTH OF POND OR RESERVOIR IN FEET	11.50
RAM-2	########	DEPTH OF POND OR RESERVOIR IN FEET	11.50
RAM-2	4/2/2001	DEPTH OF POND OR RESERVOIR IN FEET	12.00
RAM-2	6/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	13.00
RAM-2	7/5/2001	DEPTH OF POND OR RESERVOIR IN FEET	12.00
RAM-2	8/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	12.00
RAM-2	10/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	12.00
RAM-3	4/26/1988	DEPTH OF POND OR RESERVOIR IN FEET	6.00
RAM-3	4/26/1988	DEPTH OF POND OR RESERVOIR IN FEET	6.00
RAM-3	6/2/1988	DEPTH OF POND OR RESERVOIR IN FEET	8.00
RAM-3	6/2/1988	DEPTH OF POND OR RESERVOIR IN FEET	8.00
RAM-3	7/7/1988	DEPTH OF POND OR RESERVOIR IN FEET	6.50
RAM-3	7/8/1988	DEPTH OF POND OR RESERVOIR IN FEET	6.00
RAM-3	8/12/1988	DEPTH OF POND OR RESERVOIR IN FEET	5.00
RAM-3	8/12/1988	DEPTH OF POND OR RESERVOIR IN FEET	5.00
RAM-3	10/3/1988	DEPTH OF POND OR RESERVOIR IN FEET	8.50
RAM-3	10/3/1988	DEPTH OF POND OR RESERVOIR IN FEET	8.50
RAM-3	4/15/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.50
RAM-3	4/15/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.50
RAM-3	6/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.00
RAM-3	6/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	10.00
RAM-3	7/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	1.00
RAM-3	7/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	9.00
RAM-3	8/24/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.00
RAM-3	8/24/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.00
RAM-3	########	DEPTH OF POND OR RESERVOIR IN FEET	5.00
RAM-3	########	DEPTH OF POND OR RESERVOIR IN FEET	5.00
RAM-3	4/2/2001	DEPTH OF POND OR RESERVOIR IN FEET	6.00
RAM-3	6/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	7.00
RAM-3	7/5/2001	DEPTH OF POND OR RESERVOIR IN FEET	7.00
RAM-3	8/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	7.00
RAM-3	10/1/2001	DEPTH OF POND OR RESERVOIR IN FEET	7.00

Values assumed erroneous and removed from analysis

Segment	Start Date	Parameter Long Name		Result Value
ADD02	6/11/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	4.2
ADD02	9/30/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	7
ADD02	12/7/1992	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	10.1
ADD04	8/10/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	3.5
ADD04	1/18/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE	MG/L	11.4

Appendix B
GWLF Input Files and
BATHTUB Input and Output Files

Subbasin 1

Transprt.dat

```
8,3
0.2,0.1,10,0,0,0.23,10
0
0
0
0
0
"APR",0.65,13,0,0.27
"MAY",0.89,14,1,0.27
"JUN",0.9,14.5,1,0.27
"JUL",0.9,14.3,1,0.27
"AUG",0.89,13.4,1,0.27
"SEP",0.9,12.2,1,0.27
"OCT",0.85,11,1,0.14
"NOV",0.56,10,0,0.14
"DEC",0.5,9.4,0,0.14
"JAN",0.68,9.7,0,0.14
"FEB",0.71,10.6,0,0.14
"MAR",0.69,11.8,0,0.14
"Row-Crop",90.8,83.2,0.0518
"Small-Grains",51.2,79.1,0.0518
"CRP",125.0,71.7,0.0015
"Pasture",116.6,71.7,0.0015
"Hayland",175.0,71.7,0.0015
"Deciduous1",268.9,68,0.0028
"Deciduous2",12.1,70.1,0.0012
"Coniferous",16.1,70.8,0.0018
"Open-Water",3.1,89.8,0.0000
"Shallow-Wet",2.6,92.9,0.0000
"Barren-Land",16.6,94.1,0.0000
```

Nutrient.dat

```
3000,440,0.8,0.067
0,0,0
2.9,0.26
1.8,0.3
3,0.15
3,0.25
3,0.15
0.06,0.009
0.06,0.009
0.06,0.009
0,0
0,0
0.0743,0.00841
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subasin 2

Transprt.dat

```
8,3
0.2,0.1,10,0,0,0.19,10
0
0
0
0
0
"APR",0.54,13,0,0.27
"MAY",0.94,14,1,0.27
"JUN",0.95,14.5,1,0.27
"JUL",0.94,14.3,1,0.27
"AUG",0.94,13.4,1,0.27
"SEP",0.94,12.2,1,0.27
"OCT",0.92,11,1,0.14
"NOV",0.47,10,0,0.14
"DEC",0.43,9.4,0,0.14
"JAN",0.56,9.7,0,0.14
"FEB",0.58,10.6,0,0.14
"MAR",0.57,11.8,0,0.14
"Row-Crop",65.4,80.6,0.0579
"Small-Grains",94,78.9,0.0570
"CRP",192.8,71.8,0.0018
"Pasture",180.0,71.8,0.0018
"Hayland",269.9,71.8,0.0018
"Deciduous1",688.5,67.8,0.0025
"Deciduous2",52.6,70.3,0.0019
"Coniferous",186.1,70.4,0.0020
"Open-Water",5,87.1,0.0000
"Forested-Wet",2,86.8,0.0000
"Shallow-Wet",2.9,93.7,0.0000
```

Nutrient.dat

```
3000,440,0.45,0.035
0,0,0
2.9,0.26
1.8,0.3
3,0.15
3,0.25
3,0.15
0.06,0.009
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
```

Subbasin 3

Transprt.dat

```
6,1
0.2,0.1,10,0,0,0.4,10
0
0
0
0
0
"APR",0.49,13,0,0.27
"MAY",0.94,14,1,0.27
"JUN",0.93,14.5,1,0.27
"JUL",0.93,14.3,1,0.27
"AUG",0.93,13.4,1,0.27
"SEP",0.94,12.2,1,0.27
"OCT",0.94,11,1,0.14
"NOV",0.46,10,0,0.14
"DEC",0.44,9.4,0,0.14
"JAN",0.5,9.7,0,0.14
"FEB",0.51,10.6,0,0.14
"MAR",0.5,11.8,0,0.14
"Row-Crop",0.2,83.7,0.0221
"CRP",1.1,72.9,0.0018
"Pasture",1.0,72.9,0.0018
"Hayland",1.5,72.9,0.0018
"Deciduous",25.4,68.3,0.0034
"Coniferous",7.1,70.3,0.0018
"Open-Water",12.4,97.5,0.0000
```

Nutrient.dat

```
3000,440,0.1,0.012
0,0,0
2.9,0.26
3,0.15
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
```

Subbasin 4

Transprt.dat

```
8,1
0.2,0.1,10,0,0,0.33,10
0
0
0
0
0
"APR",0.4,13,0,0.27
"MAY",0.97,14,1,0.27
"JUN",0.97,14.5,1,0.27
"JUL",0.97,14.3,1,0.27
"AUG",0.97,13.4,1,0.27
"SEP",0.97,12.2,1,0.27
"OCT",0.96,11,1,0.14
"NOV",0.37,10,0,0.14
"DEC",0.36,9.4,0,0.14
"JAN",0.4,9.7,0,0.14
"FEB",0.41,10.6,0,0.14
"MAR",0.4,11.8,0,0.14
"Row-Crop",2.6,82.9,0.0343
"Small-Grains",0.5,81.5,0.0699
"CRP",6.8,71.5,0.0017
"Pasture",6.4,71.5,0.0017
"Hayland",9.6,71.5,0.0017
"Deciduous1",154.8,67.5,0.0026
"Deciduous2",0.8,67.2,0.0010
"Coniferous",43.9,70.3,0.0017
"Open-Water",17.1,97.7,0.0000
```

Nutrient.dat

```
3000,440,0.1,0.012
0,0,0
2.9,0.26
1.8,0.3
3,0.15
3,0.25
3,0.15
0.06,0.009
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
```

Weather.dat (excerpt)

```
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7.22,0.00
6.94,0.00
11.94,0.00
15.00,0.00
14.44,0.00
10.28,1.24
7.78,0.05
6.39,0.00
5.00,0.00
8.33,0.00
12.78,0.00
16.67,0.00
17.78,0.00
18.61,0.00
14.17,1.78
16.94,0.00
18.61,0.00
19.17,0.00
21.11,0.00
21.11,0.00
20.83,0.00
20.83,0.00
22.50,0.00
16.39,2.54
16.94,0.00
17.22,0.00
18.89,2.79
20.28,1.52
18.33,0.00
18.61,0.00
31
19.17,1.83
14.17,0.23
15.28,0.20
14.72,0.00
16.11,0.00
22.22,0.00
16.67,0.00
18.06,0.25
18.61,0.00
16.94,0.00
20.83,0.00
23.06,0.15
24.17,0.99
25.00,0.89
18.61,0.00
19.44,0.00
15.28,0.00
14.44,0.00
17.50,0.00
19.44,0.00
19.44,0.00
16.11,2.21
16.67,2.49
17.50,0.00
```
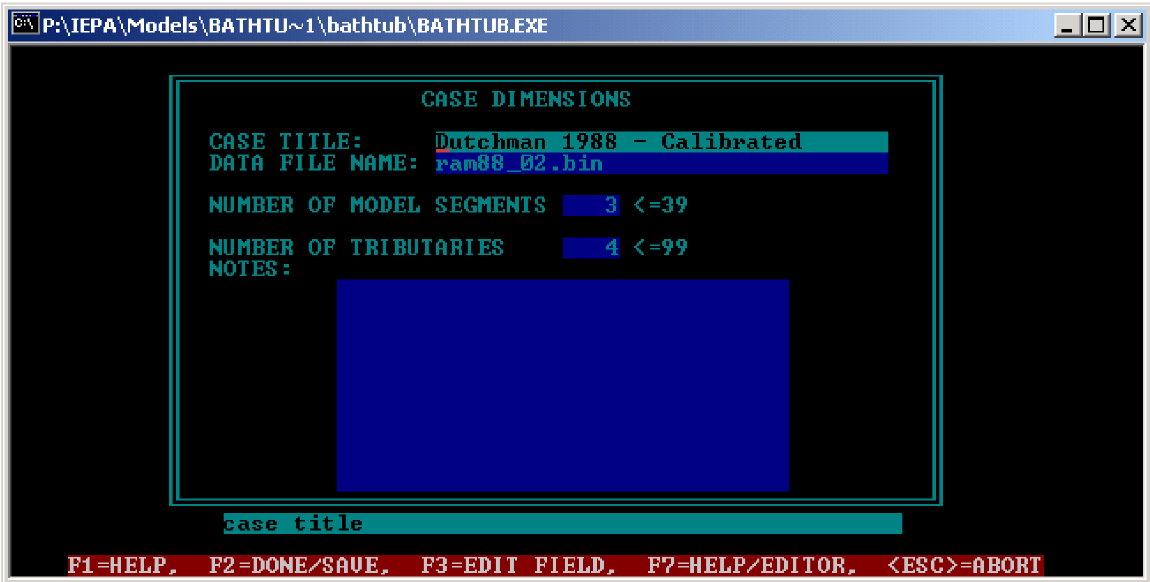
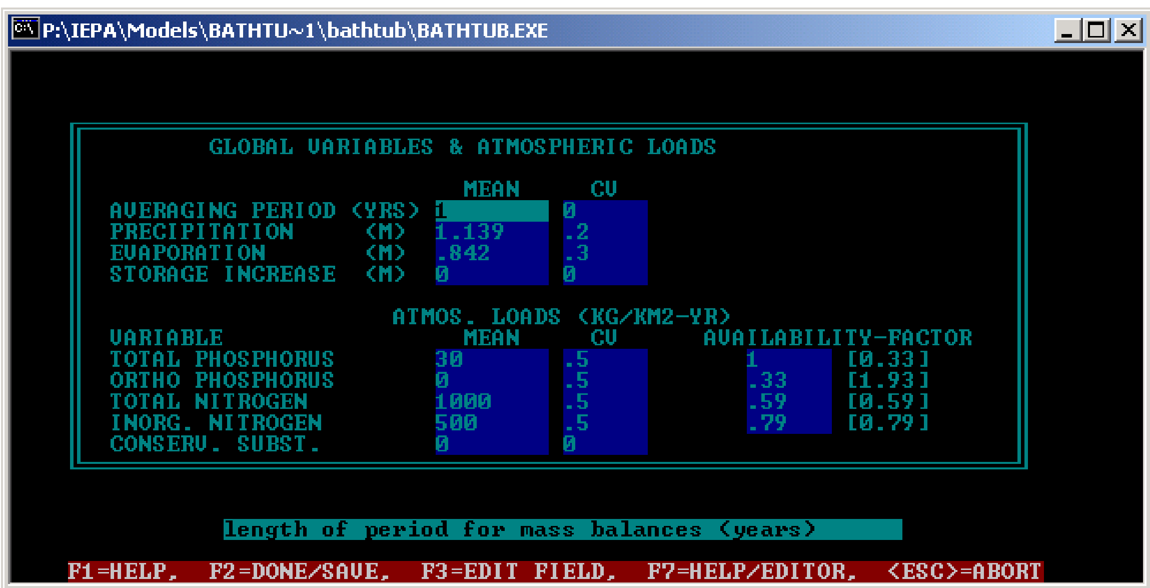
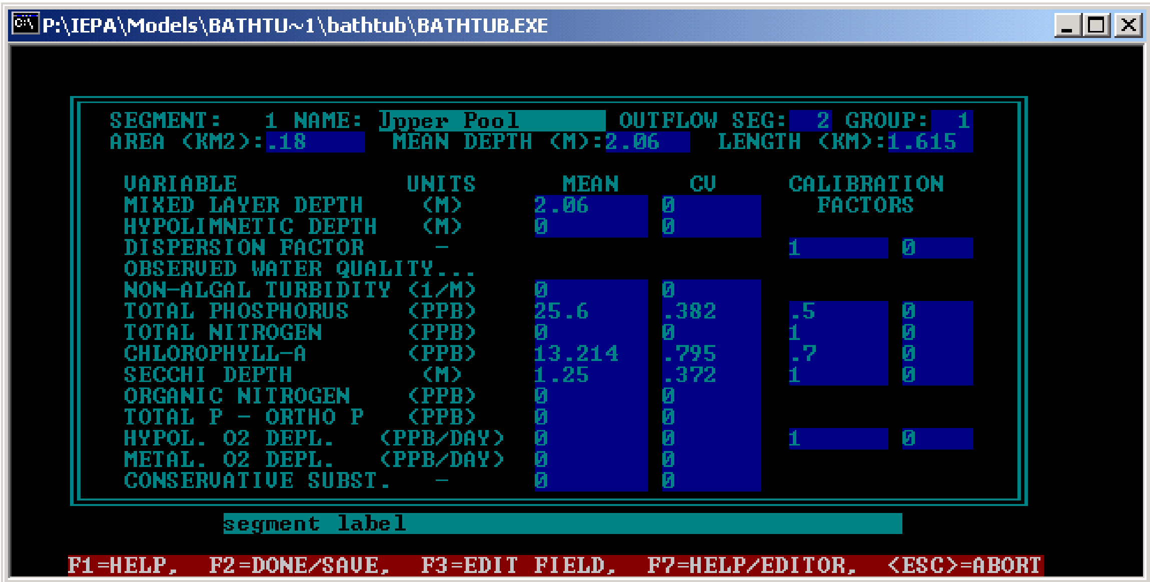
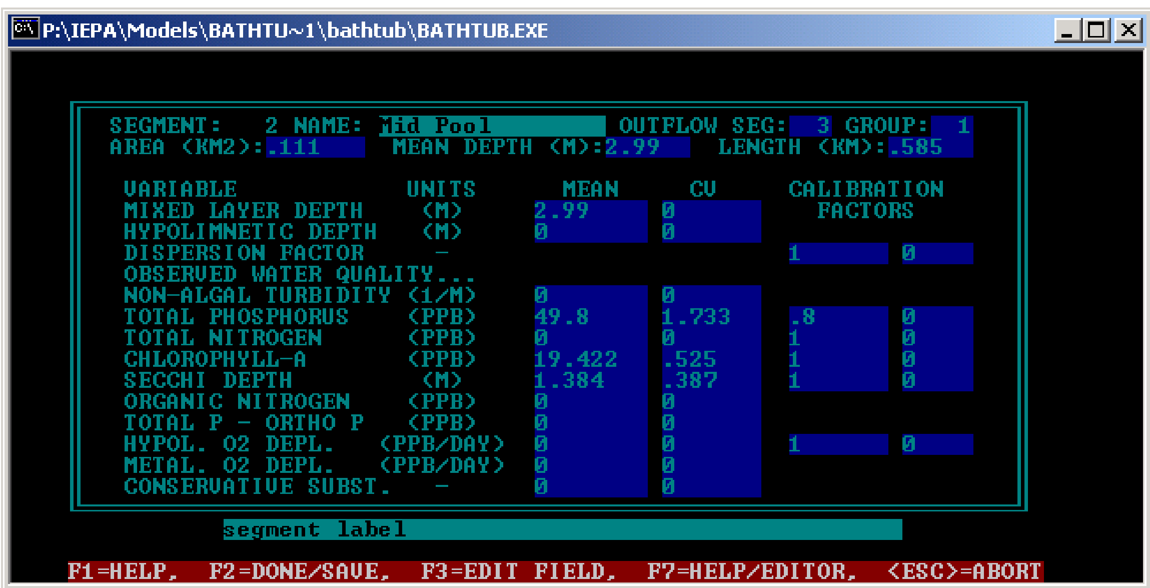

18.33,0.00
18.89,0.00
21.11,0.00
21.67,0.00
22.22,0.00
23.89,0.00
25.83,0.00
30
22.22,0.00
22.78,1.30
24.44,0.30
25.56,0.43
24.17,0.00
21.67,0.00
23.89,1.09
23.89,0.66
25.83,0.00
24.44,0.00
22.50,0.51
15.83,4.57
15.28,0.00
16.39,0.00
20.28,0.00
23.89,0.08
20.00,0.00
21.94,2.74
18.61,0.00
19.72,0.00
20.83,0.00
23.06,0.51
26.11,0.08
27.78,0.00
26.67,0.05
26.94,0.08
25.56,0.00
25.00,8.05
21.39,0.56
22.50,0.00

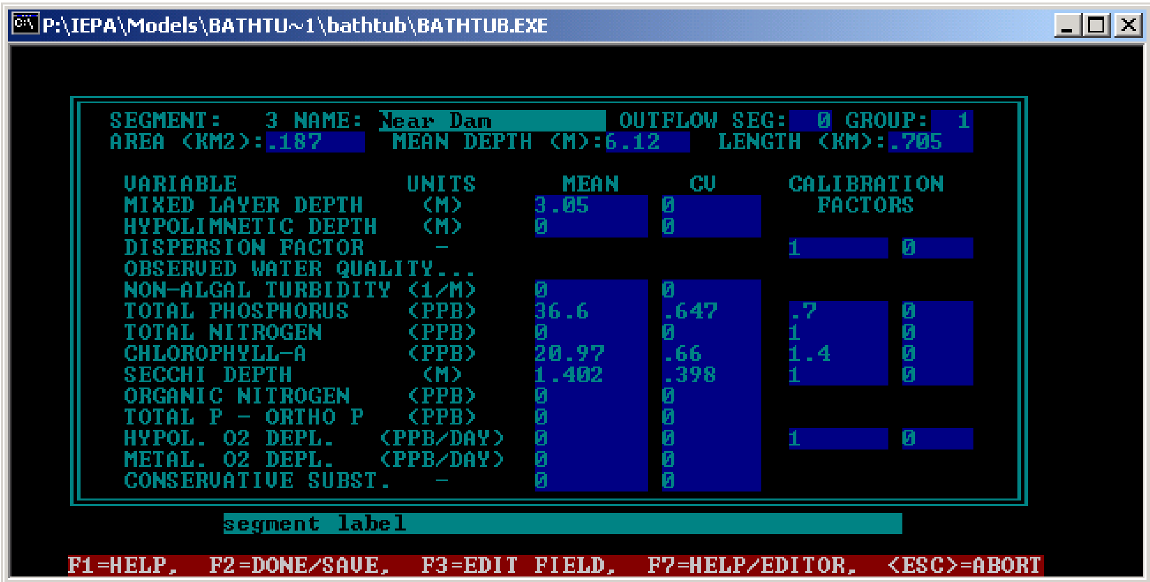
BATHTUB Input Screens for 1988 Model Simulation

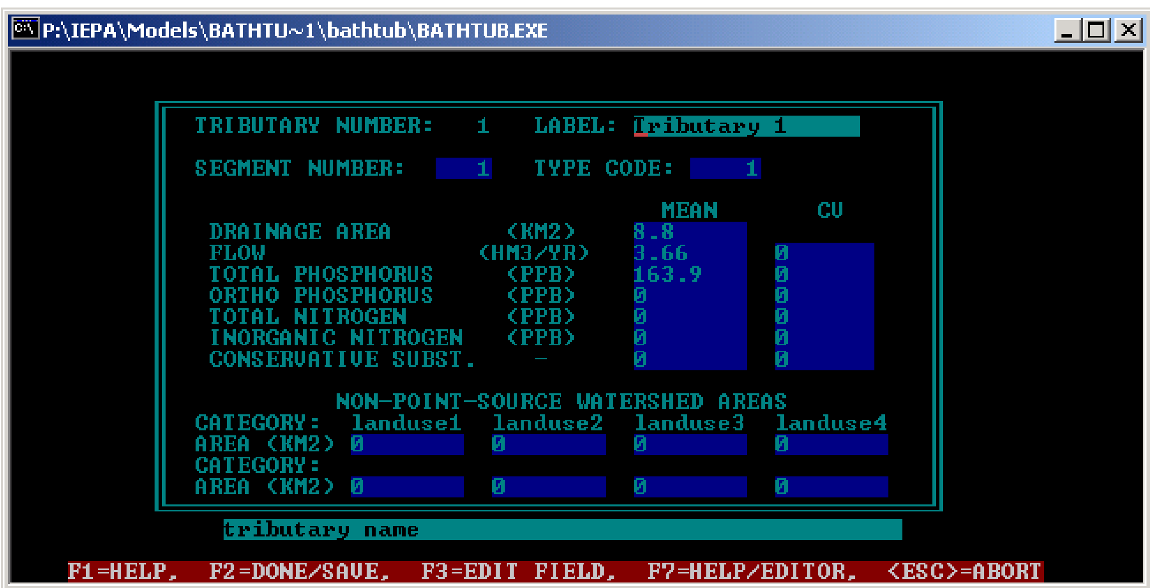


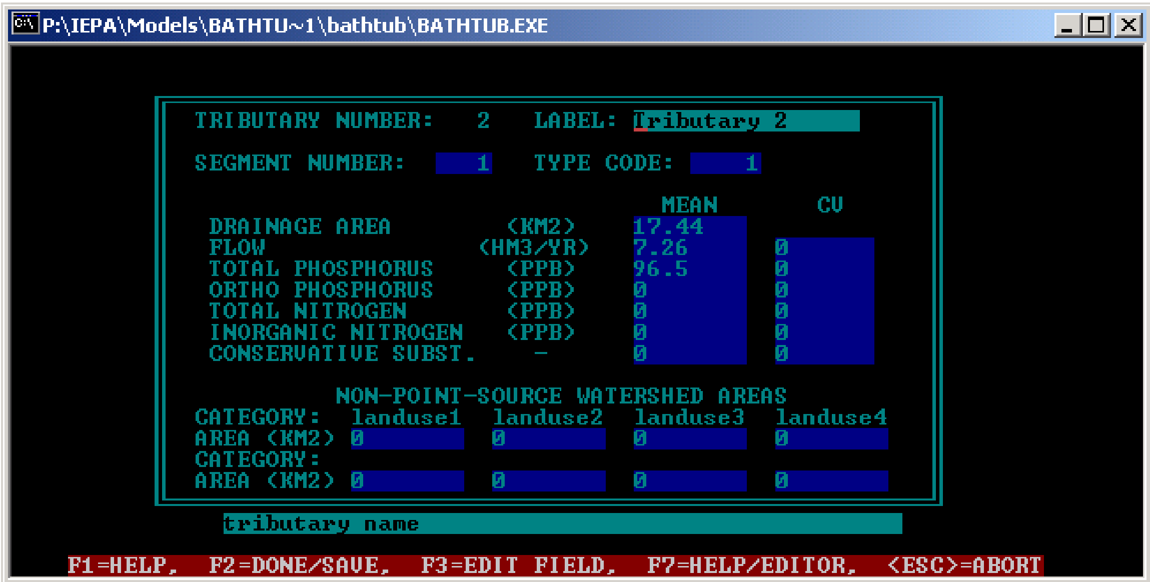


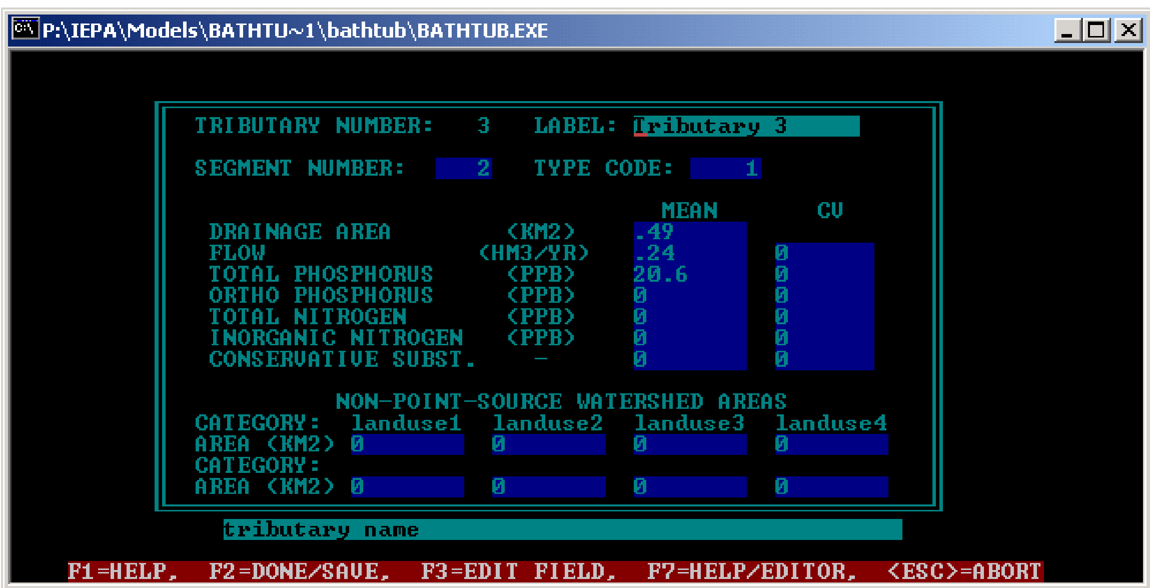

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2): .18 MEAN DEPTH (M): 2.06 LENGTH (KM): 1.615
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.06 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 25.6 .382 .5 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 13.214 .795 .7 0
SECCHI DEPTH (M) 1.25 .372 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

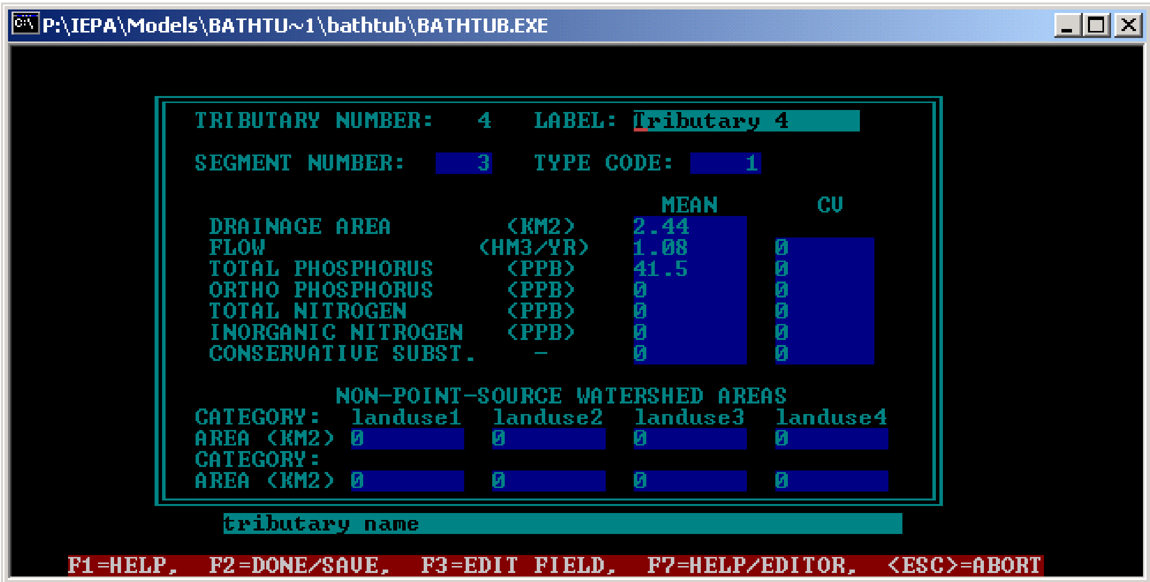

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2): .111 MEAN DEPTH (M): 2.99 LENGTH (KM): .585
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 2.99 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 49.8 1.733 .8 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 19.422 .525 1 0
SECCHI DEPTH (M) 1.384 .387 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .187 MEAN DEPTH (M): 6.12 LENGTH (KM): .705
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 3.05 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 36.6 .647 .7 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 20.97 .66 1.4 0
SECCHI DEPTH (M) 1.402 .398 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Tributary 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 8.8
FLOW (HM3/YR) 3.66 0
TOTAL PHOSPHORUS (PPB) 163.9 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: 2 LABEL: Tributary 2
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 17.44
FLOW (HM3/YR) 7.26 0
TOTAL PHOSPHORUS (PPB) 96.5 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 3 LABEL: Tributary 3
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) .49
FLOW (HM3/YR) .24 0
TOTAL PHOSPHORUS (PPB) 20.6 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Tributary 4
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.44
FLOW (HM3/YR) 1.08 0
TOTAL PHOSPHORUS (PPB) 41.5 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

BATHTUB Output for 1988 Simulation

CASE: Dutchman 1988 - 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	25.6	.38	44.5	.45	.58	-1.45	-2.05	-.94
CHL-A	MG/M3	13.2	.80	14.0	.64	.95	-.07	-.16	-.05
SECCHI	M	1.3	.37	1.2	.59	1.02	.06	.08	.03
ORGANIC N	MG/M3	.0	.00	510.4	.43	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	31.9	.63	.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	49.8	1.73	46.5	.46	1.07	.04	.26	.04
CHL-A	MG/M3	19.4	.52	20.8	.50	.93	-.13	-.20	-.09
SECCHI	M	1.4	.39	1.3	.48	1.05	.12	.16	.07
ORGANIC N	MG/M3	.0	.00	648.7	.37	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	38.5	.47	.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	36.6	.65	34.1	.45	1.07	.11	.26	.09
CHL-A	MG/M3	21.0	.66	22.5	.57	.93	-.10	-.20	-.08
SECCHI	M	1.4	.40	1.3	.55	1.05	.13	.18	.07
ORGANIC N	MG/M3	.0	.00	683.3	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.4	.52	.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	35.5	.93	40.9	.45	.87	-.15	-.52	-.14
CHL-A	MG/M3	17.7	.66	18.9	.54	.94	-.10	-.19	-.08
SECCHI	M	1.3	.39	1.3	.42	1.04	.10	.14	.07
ORGANIC N	MG/M3	.0	.00	610.2	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	36.7	.52	.00	.00	.00	.00

CASE: Dutchman 1988 - Calibrated

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	3.660	.000E+00	.000	.416
2	1	Tributary 2	17.440	7.260	.000E+00	.000	.416
3	1	Tributary 3	.490	.240	.000E+00	.000	.490
4	1	Tributary 4	2.440	1.080	.000E+00	.000	.443
PRECIPITATION			.478	.544	.119E-01	.200	1.139
TRIBUTARY INFLOW			29.170	12.240	.000E+00	.000	.420
***TOTAL INFLOW			29.648	12.784	.119E-01	.009	.431
ADVECTIVE OUTFLOW			29.648	12.382	.264E-01	.013	.418
***TOTAL OUTFLOW			29.648	12.382	.264E-01	.013	.418
***EVAPORATION			.000	.402	.146E-01	.300	.000

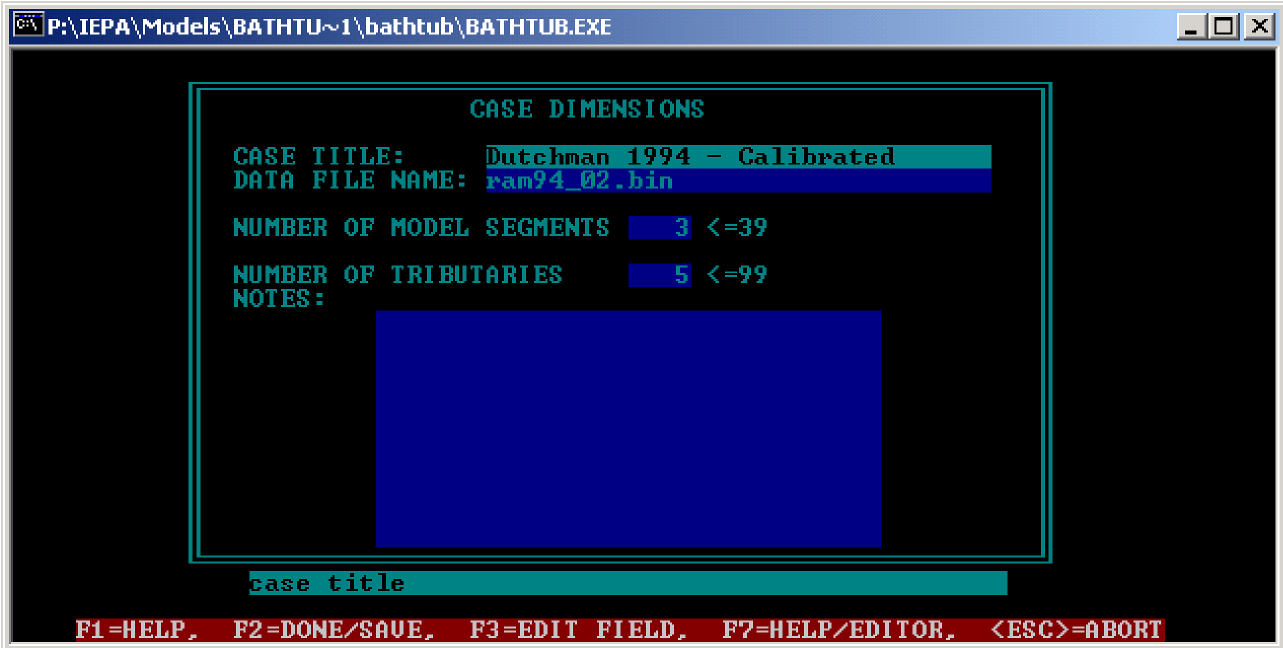
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

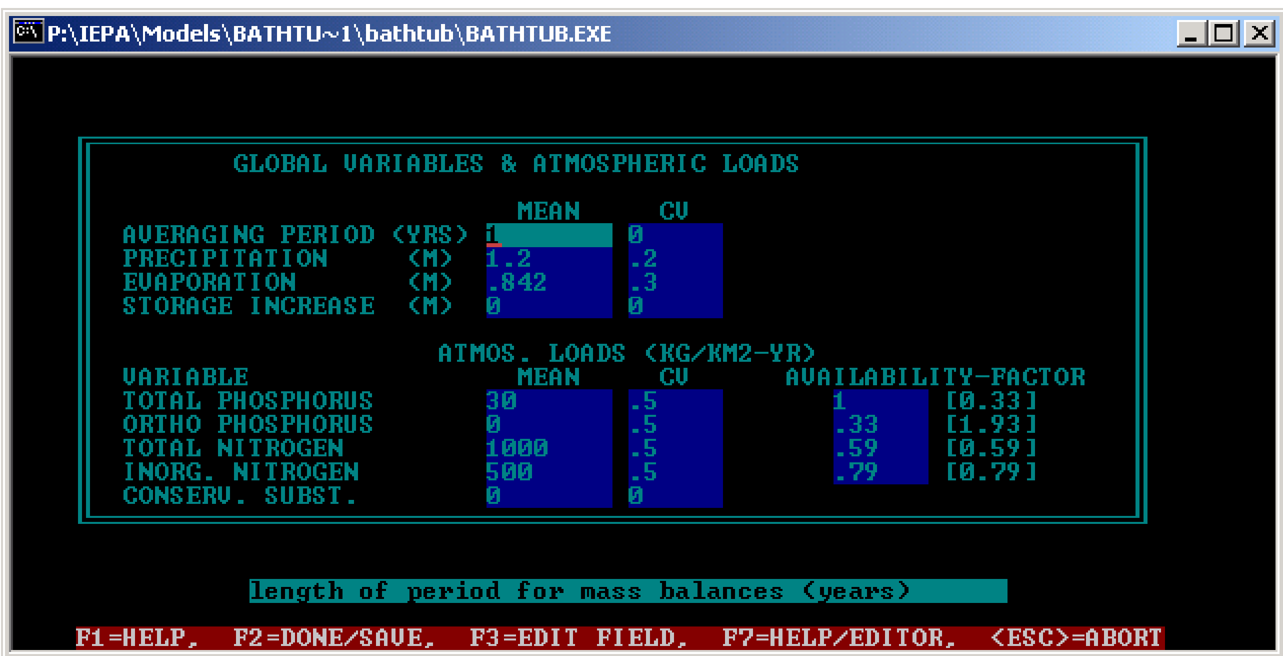
COMPONENT: TOTAL P

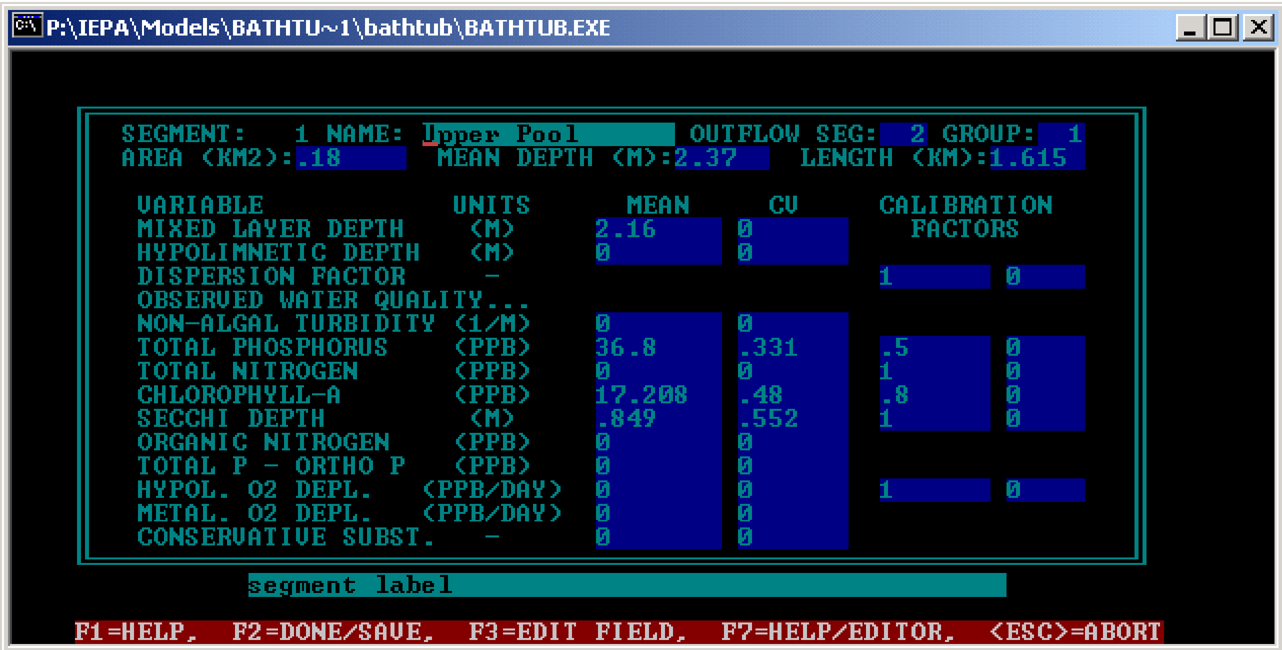
ID	T	LOCATION	----- LOADING ---- KG/YR	%(I)	--- VARIANCE --- KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Tributary 1	599.9	44.0	.000E+00	.0	.000	163.9	68.2
2	1	Tributary 2	700.6	51.3	.000E+00	.0	.000	96.5	40.2
3	1	Tributary 3	4.9	.4	.000E+00	.0	.000	20.6	10.1
4	1	Tributary 4	44.8	3.3	.000E+00	.0	.000	41.5	18.4
PRECIPITATION			14.3	1.1	.514E+02	100.0	.500	26.3	30.0
TRIBUTARY INFLOW			1350.2	98.9	.000E+00	.0	.000	110.3	46.3
***TOTAL INFLOW			1364.6	100.0	.514E+02	100.0	.005	106.7	46.0
ADVECTIVE OUTFLOW			422.5	31.0	.362E+05	70434.2	.450	34.1	14.3
***TOTAL OUTFLOW			422.5	31.0	.362E+05	70434.2	.450	34.1	14.3
***RETENTION			942.0	69.0	.362E+05	70483.9	.202	.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 -
25.90	.1492	35.5	.0481	20.7964	.6904

BATHTUB Input Screens for 1994 Simulation







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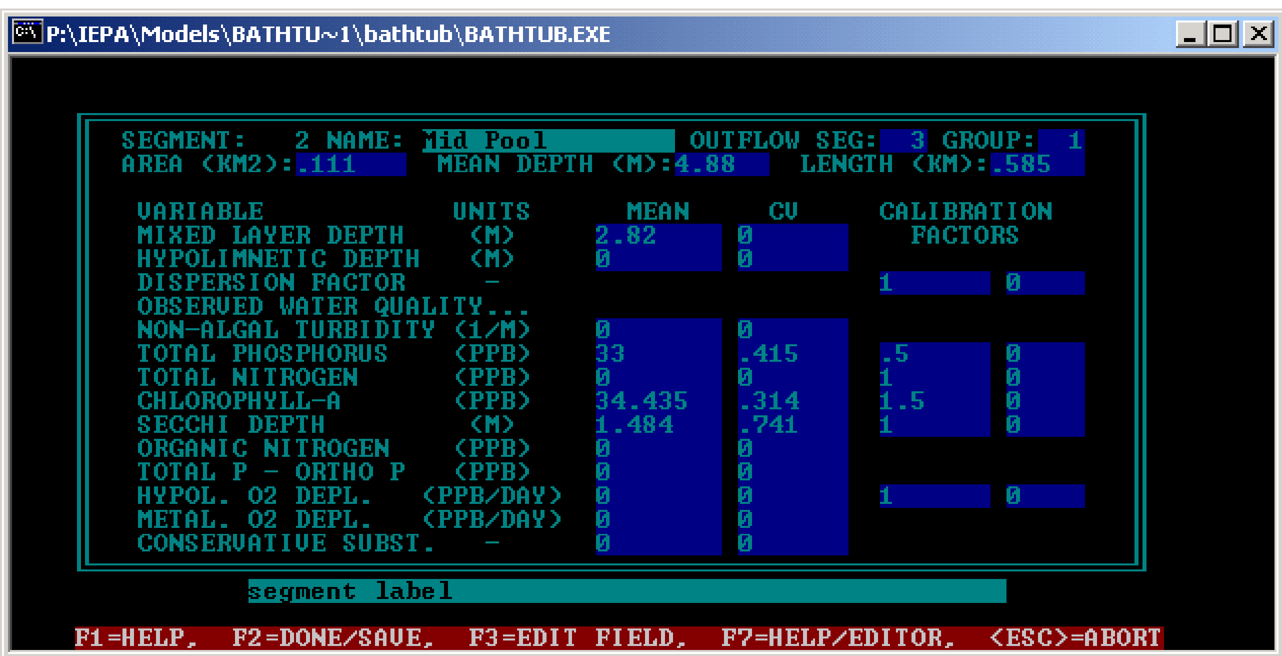
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2): .18 MEAN DEPTH (M): 2.37 LENGTH (KM): 1.615

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	2.16	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	36.8	.331	.5	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	17.208	.48	.8	0
SECCHI DEPTH	(M)	.849	.552	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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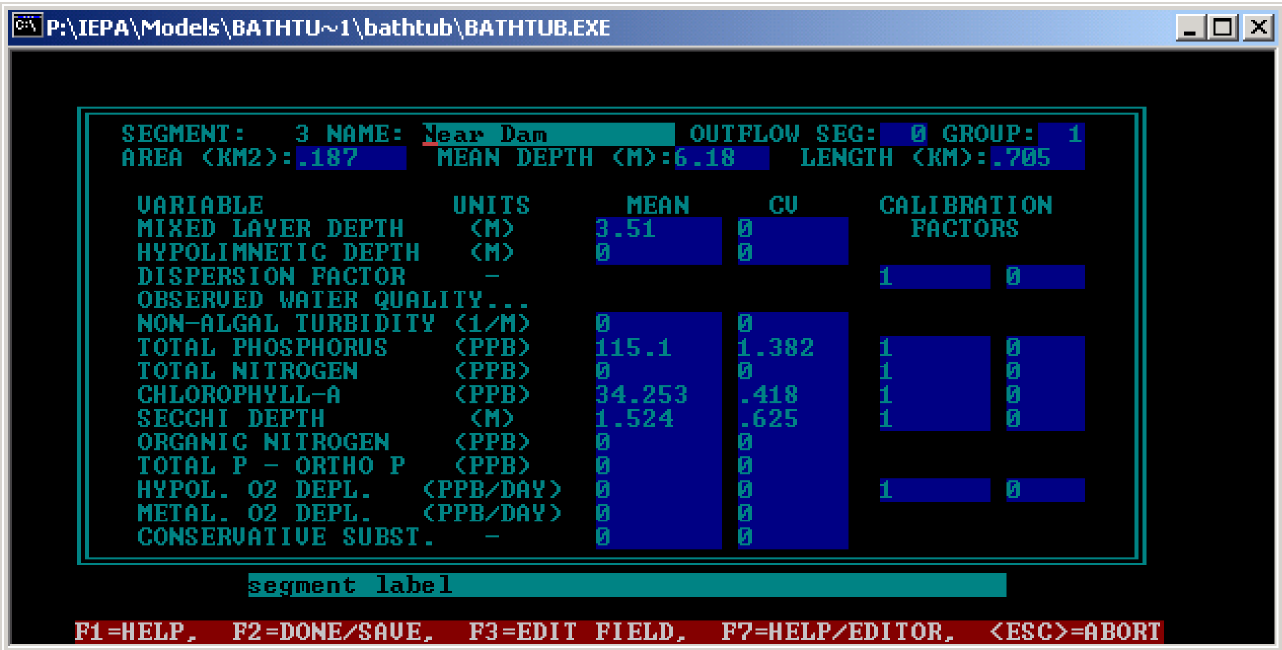
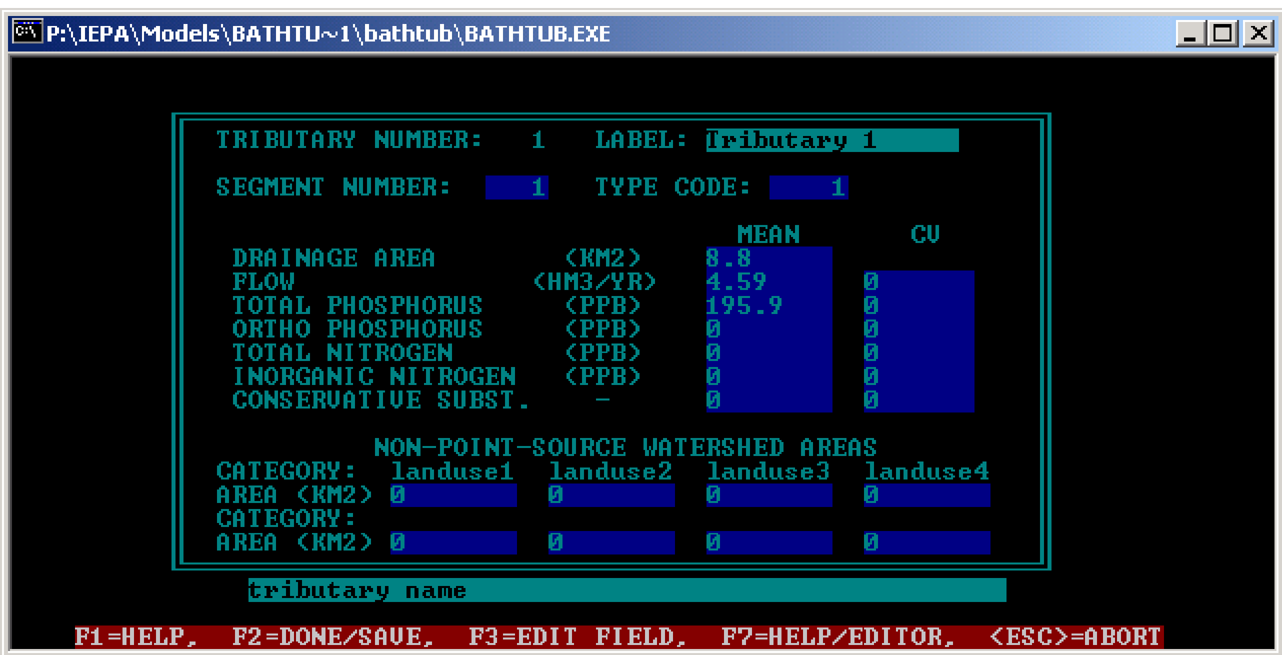
SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2): .111 MEAN DEPTH (M): 4.88 LENGTH (KM): .585

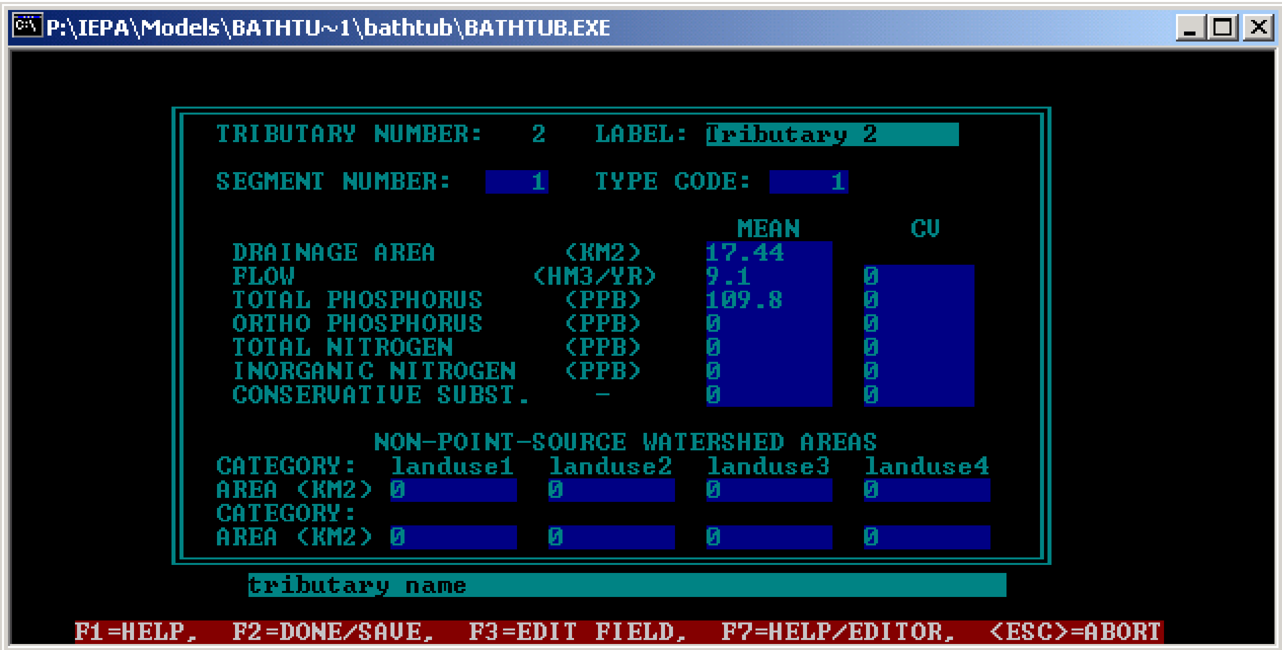
VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	2.82	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	33	.415	.5	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	34.435	.314	1.5	0
SECCHI DEPTH	(M)	1.484	.741	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		

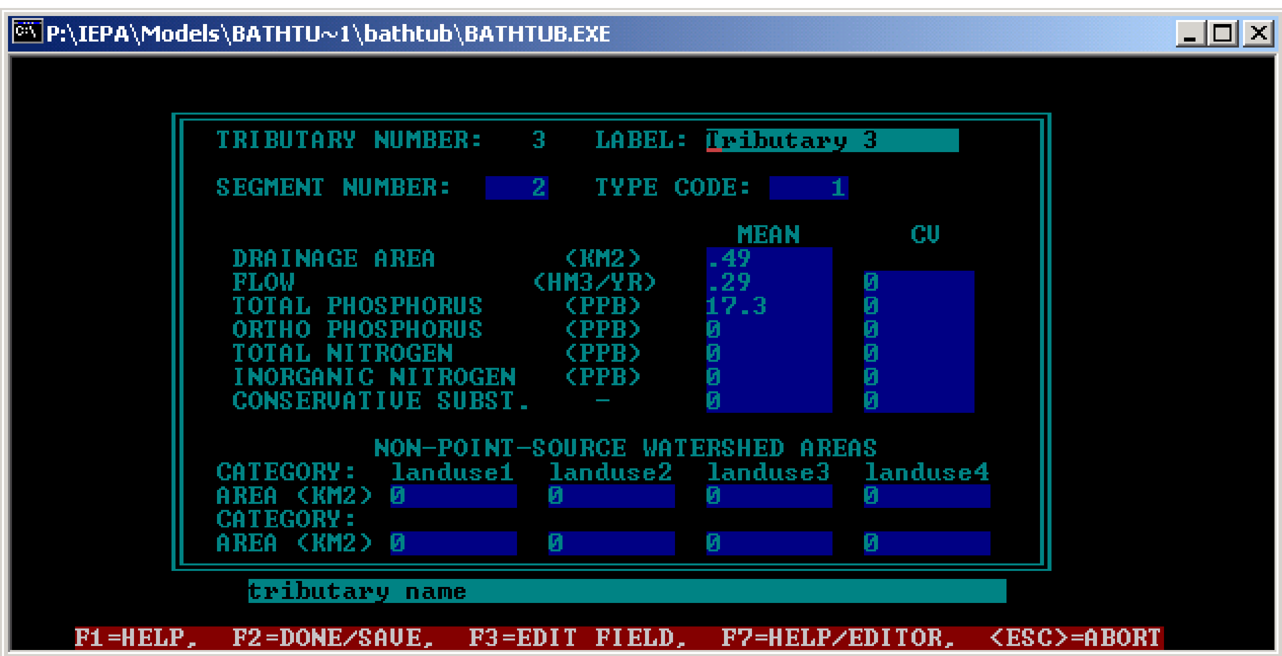
segment label

F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .187 MEAN DEPTH (M): 6.18 LENGTH (KM): .705
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 3.51 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 115.1 1.382 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 34.253 .418 1 0
SECCHI DEPTH (M) 1.524 .625 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Tributary 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 8.8
FLOW (HM3/YR) 4.59 0
TOTAL PHOSPHORUS (PPB) 195.9 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: 2 LABEL: Tributary 2
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 17.44
FLOW (HM3/YR) 9.1 0
TOTAL PHOSPHORUS (PPB) 109.8 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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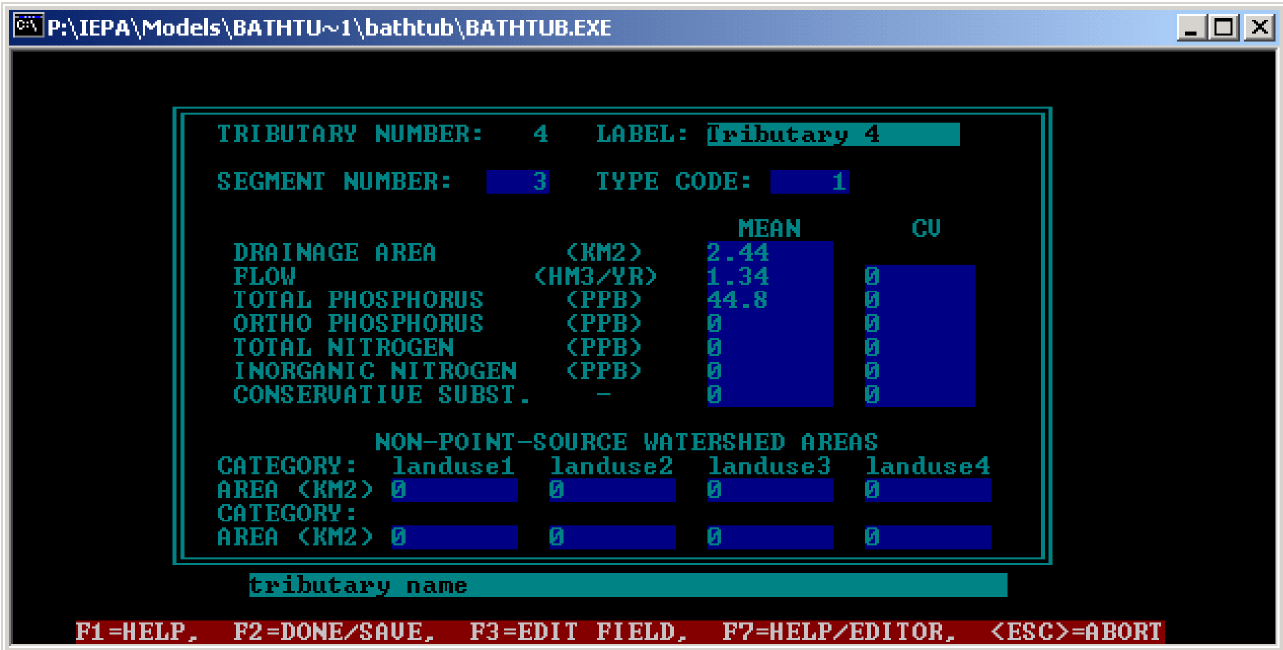
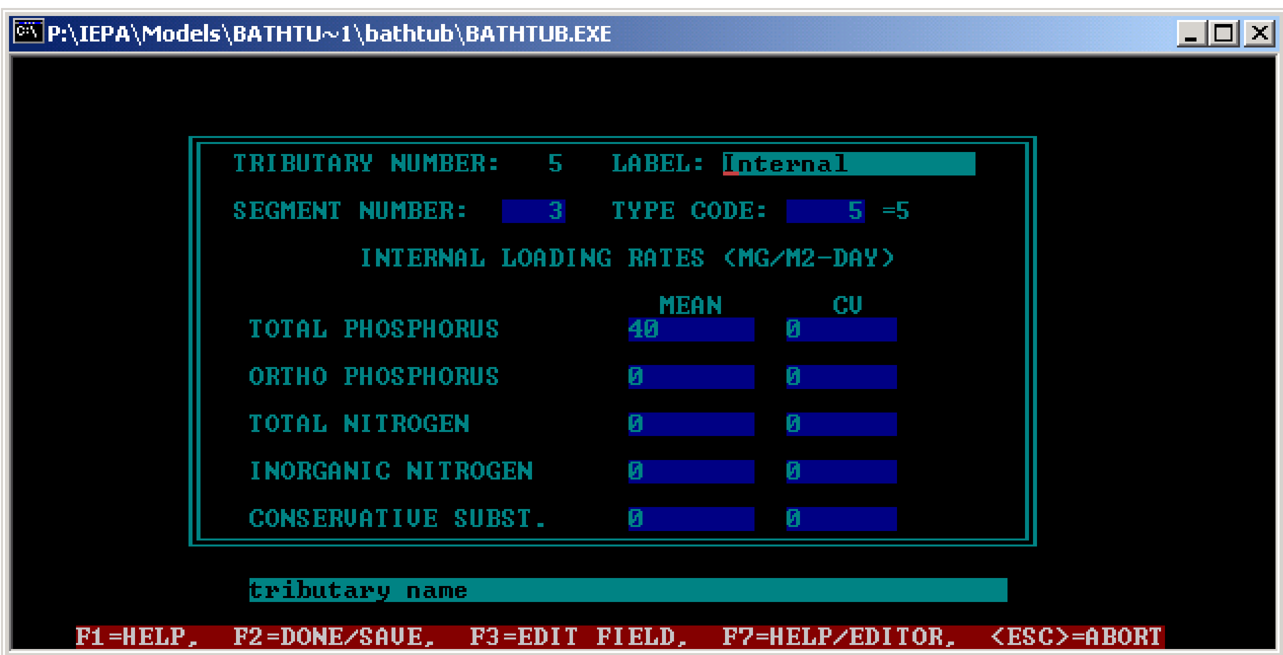
TRIBUTARY NUMBER: 3 LABEL: Tributary 3
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) .49
FLOW (HM3/YR) .29 0
TOTAL PHOSPHORUS (PPB) 17.3 0
ORTHO PHOSPHORUS (PPB) 0 0
TOTAL NITROGEN (PPB) 0 0
INORGANIC NITROGEN (PPB) 0 0
CONSERVATIVE SUBST. - 0 0
NON-POINT-SOURCE WATERSHED AREAS
CATEGORY: 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 4 LABEL: Tributary 4
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.44
FLOW (HM3/YR) 1.34 0
TOTAL PHOSPHORUS (PPB) 44.8 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 5 LABEL: Internal
SEGMENT NUMBER: 3 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 40 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 1994 Simulation

CASE: Dutchman 1994 - 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	36.8	.33	50.3	.45	.73	-.94	-1.16	-.56
CHL-A	MG/M3	17.2	.48	17.0	.53	1.01	.02	.03	.02
SECCHI	M	.8	.55	.9	.53	1.00	-.01	-.02	-.01
ORGANIC N	MG/M3	.0	.00	601.0	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.9	.42	.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	33.0	.41	45.0	.46	.73	-.75	-1.16	-.50
CHL-A	MG/M3	34.4	.31	34.0	.58	1.01	.04	.04	.02
SECCHI	M	1.5	.74	1.1	.53	1.38	.43	1.15	.35
ORGANIC N	MG/M3	.0	.00	938.0	.47	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	58.3	.53	.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	115.1	1.38	115.8	.45	.99	.00	-.02	.00
CHL-A	MG/M3	34.3	.42	35.4	.50	.97	-.08	-.09	-.05
SECCHI	M	1.5	.63	1.0	.36	1.47	.62	1.37	.54
ORGANIC N	MG/M3	.0	.00	969.3	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	60.7	.40	.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	66.5	1.05	74.7	.45	.89	-.11	-.43	-.10
CHL-A	MG/M3	27.9	.40	28.1	.44	.99	-.02	-.03	-.02
SECCHI	M	1.3	.64	1.0	.35	1.29	.40	.91	.35
ORGANIC N	MG/M3	.0	.00	823.4	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	53.8	.40	.00	.00	.00	.00

CASE: Dutchman 1994 - Calibrated

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	Tributary 1	8.800	4.590	.000E+00	.000	.522
2	1	Tributary 2	17.440	9.100	.000E+00	.000	.522
3	1	Tributary 3	.490	.290	.000E+00	.000	.592
4	1	Tributary 4	2.440	1.340	.000E+00	.000	.549
PRECIPITATION			.478	.574	.132E-01	.200	1.200
TRIBUTARY INFLOW			29.170	15.320	.000E+00	.000	.525
***TOTAL INFLOW			29.648	15.894	.132E-01	.007	.536
ADVECTIVE OUTFLOW			29.648	15.491	.277E-01	.011	.523
***TOTAL OUTFLOW			29.648	15.491	.277E-01	.011	.523
***EVAPORATION			.000	.402	.146E-01	.300	.000

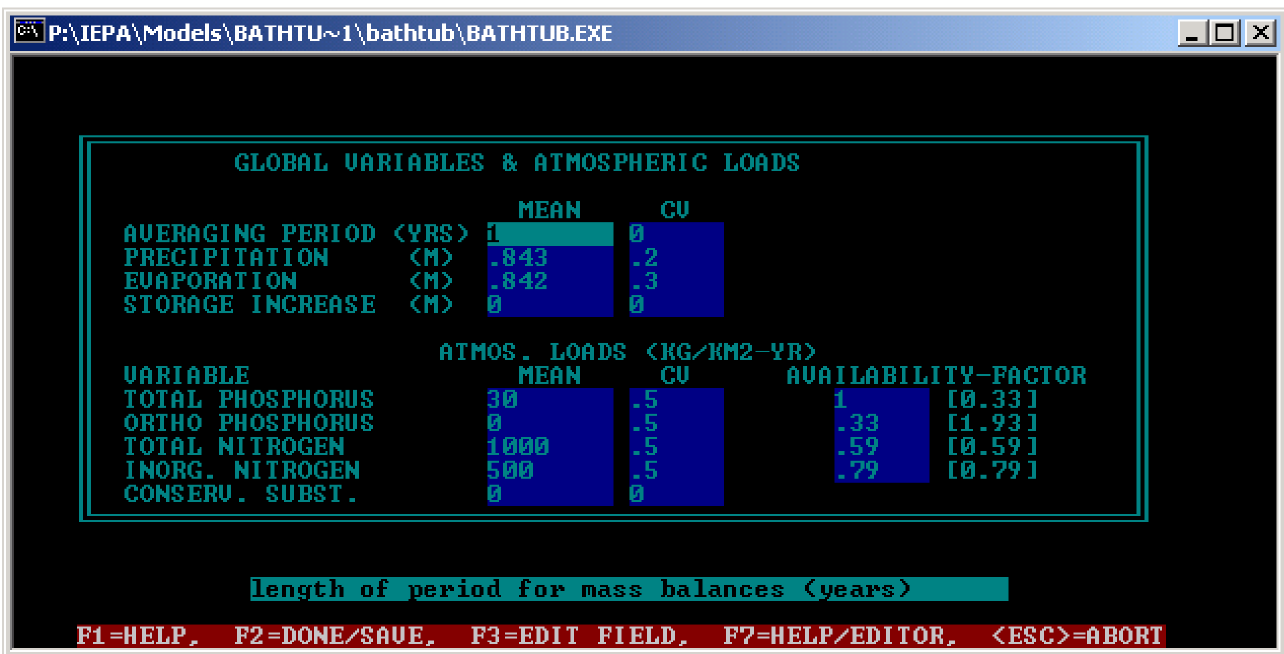
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

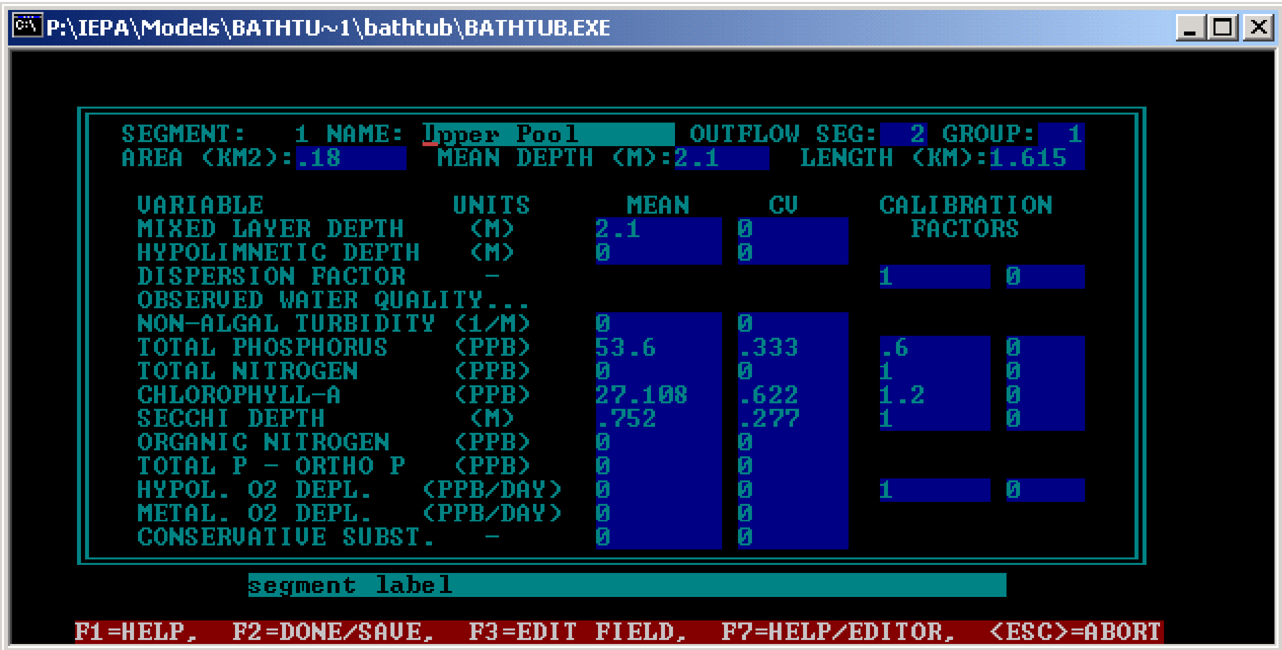
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Tributary 1	899.2	19.1	.000E+00	.0	.000	195.9	102.2
2	1	Tributary 2	999.2	21.2	.000E+00	.0	.000	109.8	57.3
3	1	Tributary 3	5.0	.1	.000E+00	.0	.000	17.3	10.2
4	1	Tributary 4	60.0	1.3	.000E+00	.0	.000	44.8	24.6
PRECIPITATION			14.3	.3	.514E+02	100.0	.500	25.0	30.0
INTERNAL LOAD			2732.1	58.0	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			1963.4	41.7	.000E+00	.0	.000	128.2	67.3
***TOTAL INFLOW			4709.8	100.0	.514E+02	100.0	.002	296.3	158.9
ADVECTIVE OUTFLOW			1793.2	38.1	.652E+06	*******	.450	115.8	60.5
***TOTAL OUTFLOW			1793.2	38.1	.652E+06	*******	.450	115.8	60.5
***RETENTION			2916.6	61.9	.652E+06	*******	.277	.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 -
32.41	.1371	66.5	.0300	33.3209	.6193

BATHTUB Input Screens for 2001 Simulation





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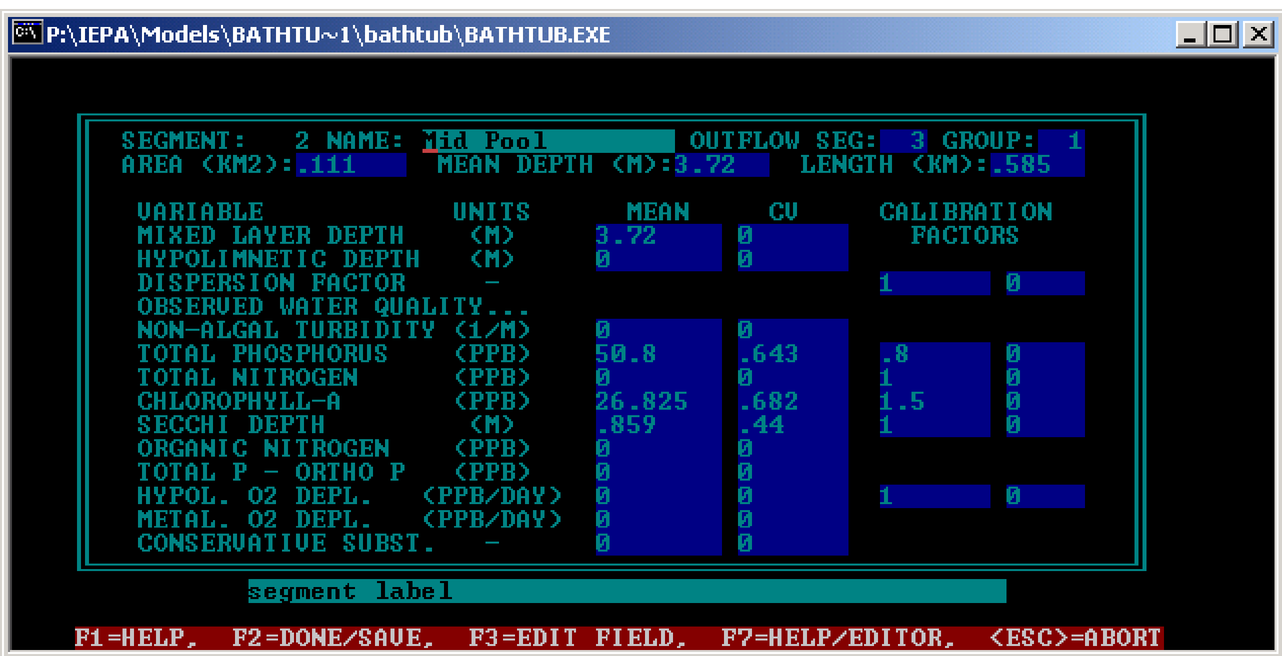
SEGMENT: 1 NAME: Upper Pool OUTFLOW SEG: 2 GROUP: 1
AREA (KM2): .18 MEAN DEPTH (M): 2.1 LENGTH (KM): 1.615

VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	2.1	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	53.6	.333	.6	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	27.108	.622	1.2	0
SECCHI DEPTH	(M)	.752	.277	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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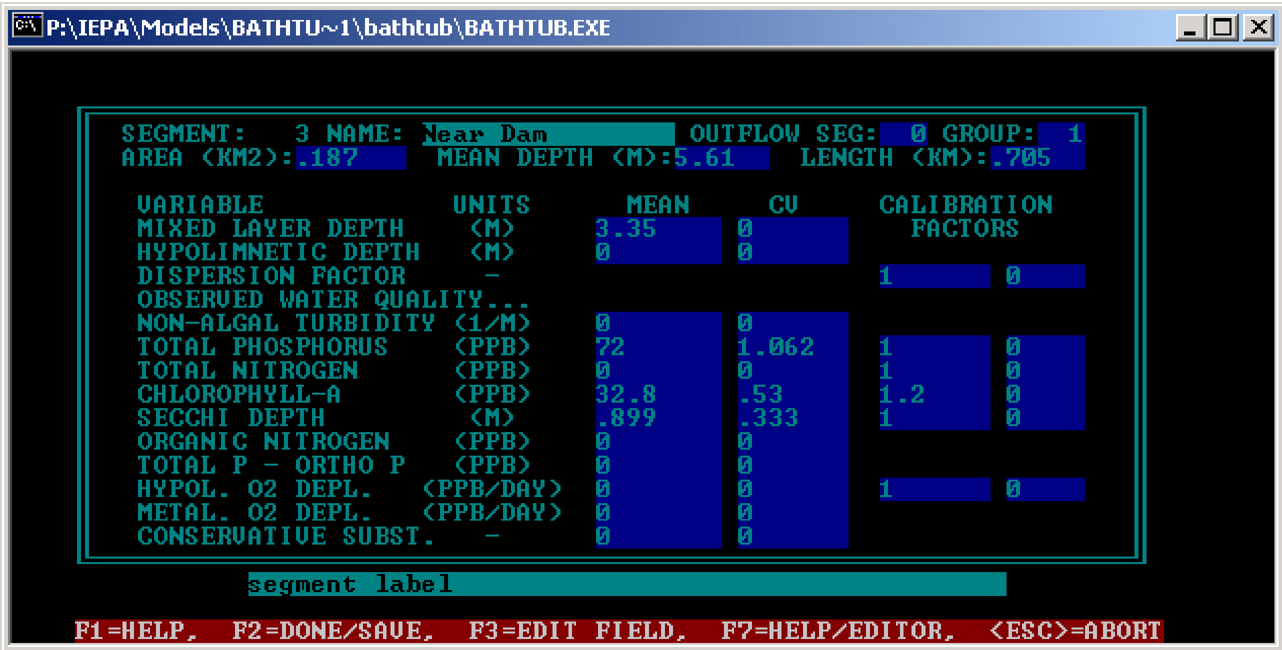
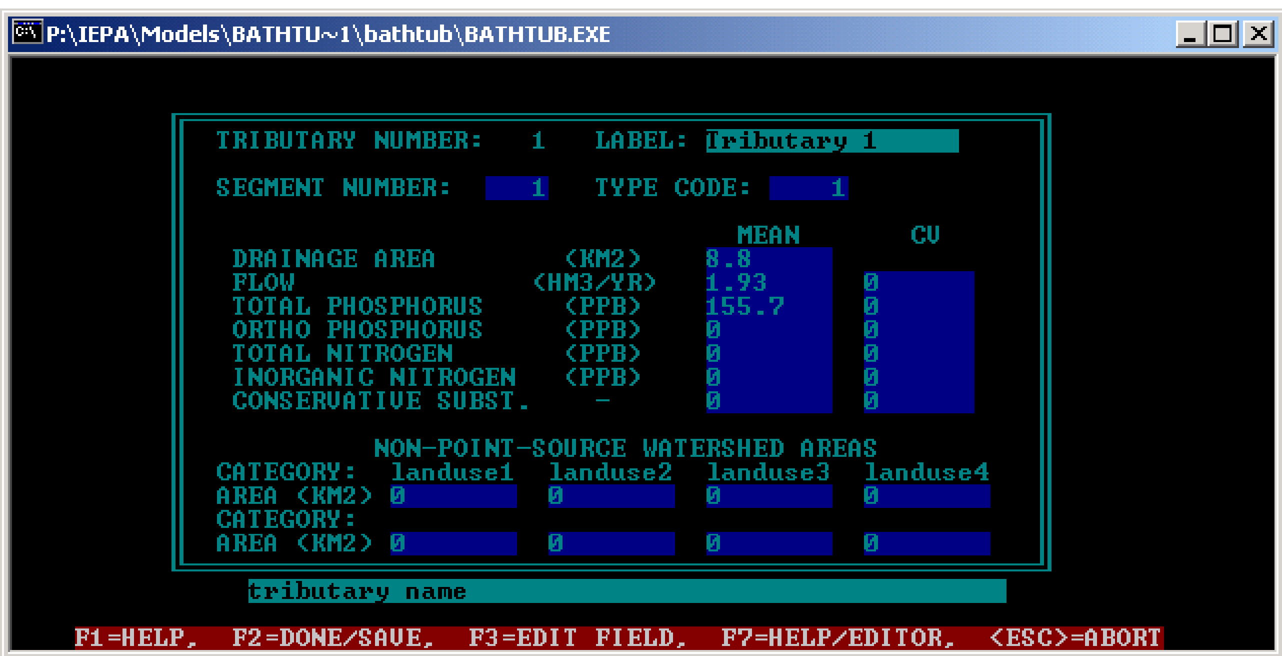
SEGMENT: 2 NAME: Mid Pool OUTFLOW SEG: 3 GROUP: 1
AREA (KM2): .111 MEAN DEPTH (M): 3.72 LENGTH (KM): .585

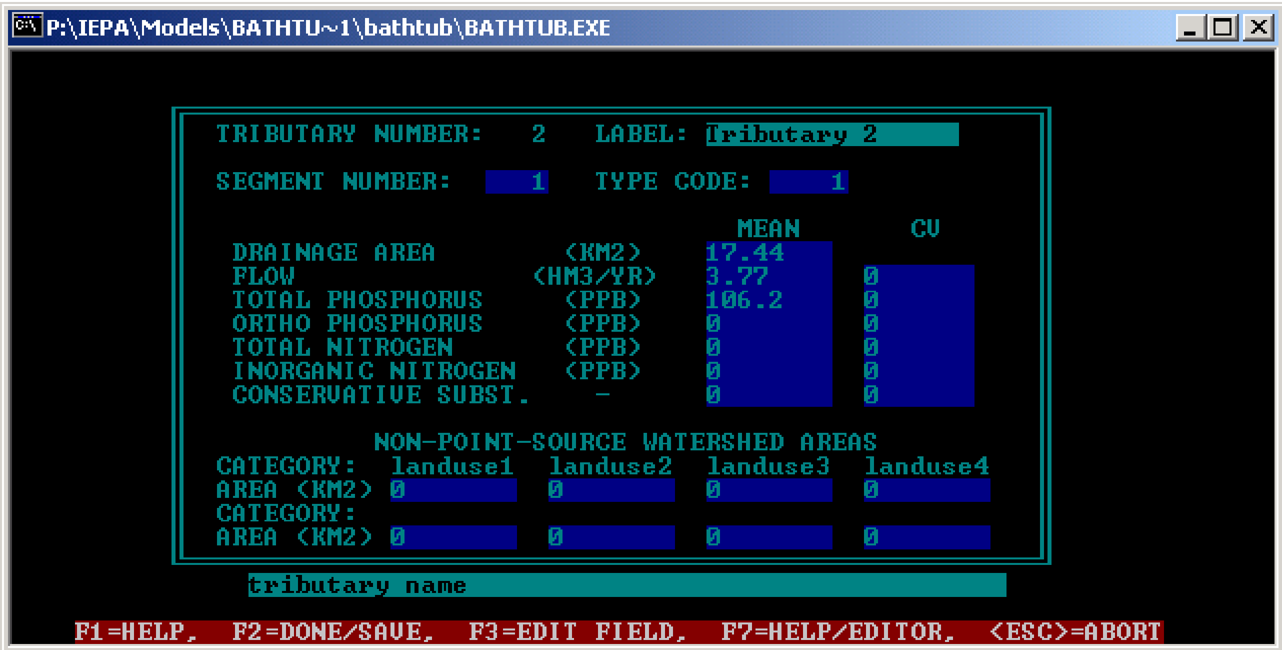
VARIABLE	UNITS	MEAN	CV	CALIBRATION FACTORS	
MIXED LAYER DEPTH	(M)	3.72	0		
HYPOLIMNETIC DEPTH	(M)	0	0		
DISPERSION FACTOR	-			1	0
OBSERVED WATER QUALITY...					
NON-ALGAL TURBIDITY	(1/M)	0	0		
TOTAL PHOSPHORUS	(PPB)	50.8	.643	.8	0
TOTAL NITROGEN	(PPB)	0	0	1	0
CHLOROPHYLL-A	(PPB)	26.825	.682	1.5	0
SECCHI DEPTH	(M)	.859	.44	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		

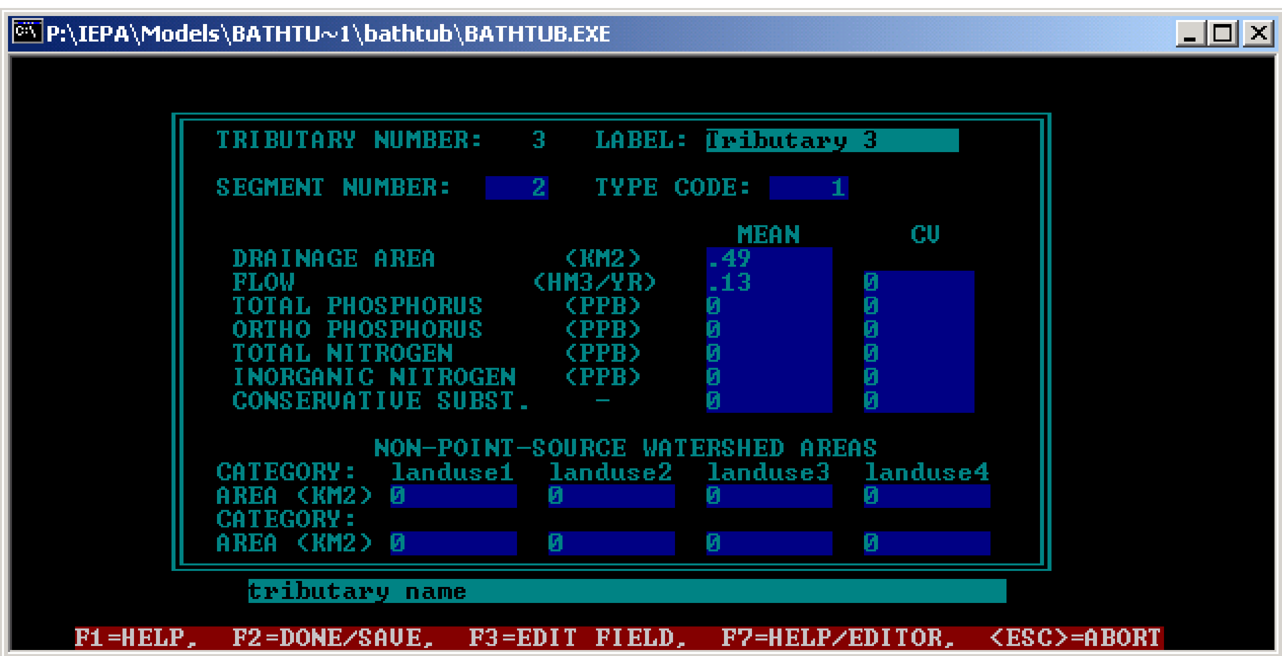
segment label

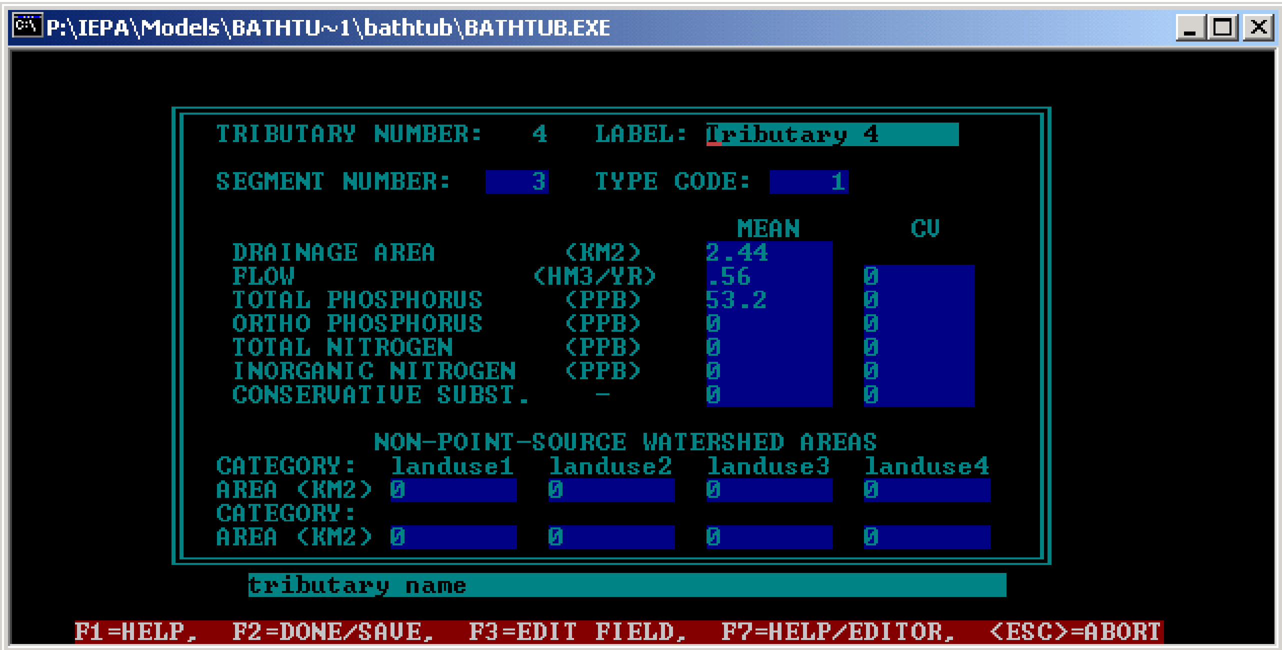
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT

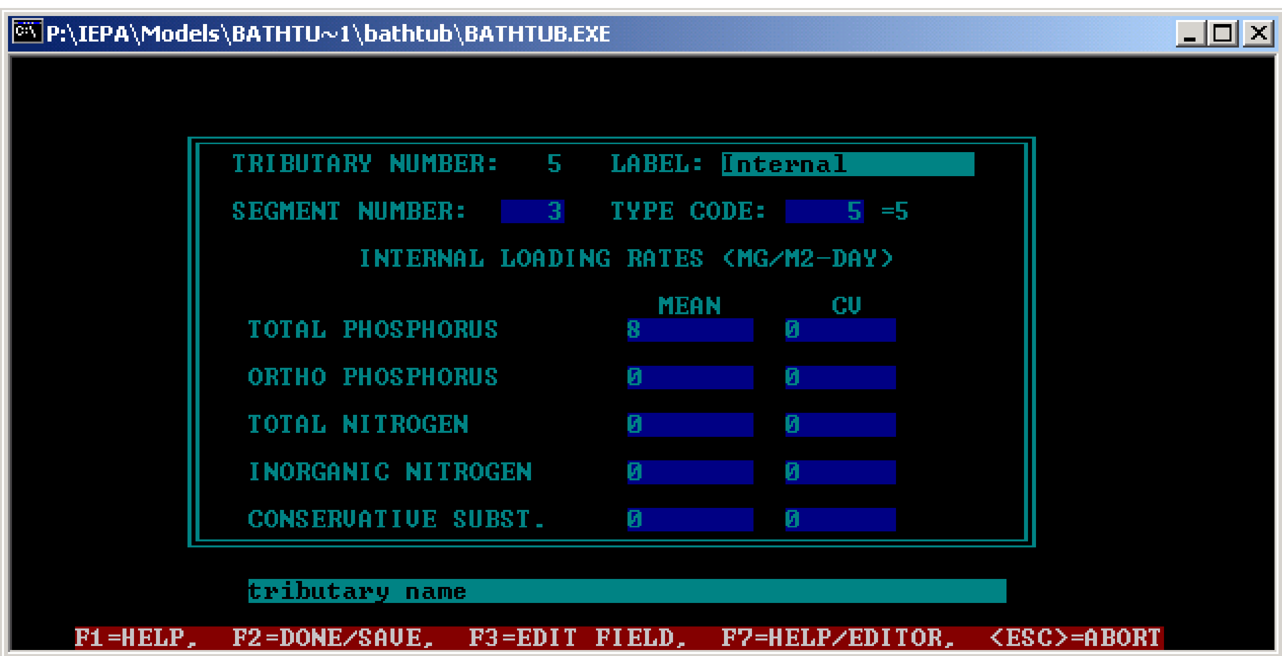

P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 3 NAME: Near Dam OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .187 MEAN DEPTH (M): 5.61 LENGTH (KM): .705
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 3.35 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 72 1.062 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 32.8 .53 1.2 0
SECCHI DEPTH (M) .899 .333 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


P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
TRIBUTARY NUMBER: 1 LABEL: Tributary 1
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 8.8
FLOW (HM3/YR) 1.93 0
TOTAL PHOSPHORUS (PPB) 155.7 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
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: 2 LABEL: Tributary 2
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 17.44
FLOW (HM3/YR) 3.77 0
TOTAL PHOSPHORUS (PPB) 106.2 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: 3 LABEL: Tributary 3
SEGMENT NUMBER: 2 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) .49
FLOW (HM3/YR) .13 0
TOTAL PHOSPHORUS (PPB) 0 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: 4 LABEL: Tributary 4
SEGMENT NUMBER: 3 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.44
FLOW (HM3/YR) .56 0
TOTAL PHOSPHORUS (PPB) 53.2 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: 5 LABEL: Internal
SEGMENT NUMBER: 3 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 8 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: Dutchman 2001 - No Calibration

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	53.6	.33	50.4	.45	1.06	.18	.23	.11
CHL-A	MG/M3	27.1	.62	28.0	.52	.97	-.05	-.10	-.04
SECCHI	M	.8	.28	.7	.41	1.02	.06	.06	.03
ORGANIC N	MG/M3	.0	.00	845.3	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	61.3	.43	.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	50.8	.64	52.5	.45	.97	-.05	-.12	-.04
CHL-A	MG/M3	26.8	.68	26.9	.56	1.00	-.01	-.01	.00
SECCHI	M	.9	.44	.9	.45	1.00	.01	.01	.00
ORGANIC N	MG/M3	.0	.00	808.2	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	55.5	.39	.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	72.0	1.06	71.4	.45	1.01	.01	.03	.01
CHL-A	MG/M3	32.8	.53	32.0	.50	1.02	.05	.07	.03
SECCHI	M	.9	.33	.9	.41	.98	-.05	-.06	-.03
ORGANIC N	MG/M3	.0	.00	909.2	.39	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	59.8	.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	60.1	.74	59.1	.45	1.02	.02	.06	.02
CHL-A	MG/M3	29.3	.59	29.3	.46	1.00	.00	-.01	.00
SECCHI	M	.8	.34	.8	.33	1.00	.00	.00	.00
ORGANIC N	MG/M3	.0	.00	861.6	.37	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	59.4	.40	.00	.00	.00	.00

CASE: Dutchman 2001 - No Calibration

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	1.930	.000E+00	.000	.219
2	1	Tributary 2	17.440	3.770	.000E+00	.000	.216
3	1	Tributary 3	.490	.130	.000E+00	.000	.265
4	1	Tributary 4	2.440	.560	.000E+00	.000	.230
PRECIPITATION			.478	.403	.649E-02	.200	.843
TRIBUTARY INFLOW			29.170	6.390	.000E+00	.000	.219
***TOTAL INFLOW			29.648	6.793	.649E-02	.012	.229
ADVECTIVE OUTFLOW			29.648	6.390	.211E-01	.023	.216
***TOTAL OUTFLOW			29.648	6.390	.211E-01	.023	.216
***EVAPORATION			.000	.402	.146E-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	Tributary 1	300.5	23.3	.000E+00	.0	.000	155.7	34.1
2	1	Tributary 2	400.4	31.0	.000E+00	.0	.000	106.2	23.0
3	1	Tributary 3	.0	.0	.000E+00	.0	.000	.0	.0
4	1	Tributary 4	29.8	2.3	.000E+00	.0	.000	53.2	12.2
PRECIPITATION			14.3	1.1	.514E+02	100.0	.500	35.6	30.0
INTERNAL LOAD			546.4	42.3	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			730.7	56.6	.000E+00	.0	.000	114.3	25.0
***TOTAL INFLOW			1291.4	100.0	.514E+02	100.0	.006	190.1	43.6
ADVECTIVE OUTFLOW			456.4	35.3	.422E+05	82159.3	.450	71.4	15.4
***TOTAL OUTFLOW			456.4	35.3	.422E+05	82159.3	.450	71.4	15.4
***RETENTION			835.0	64.7	.423E+05	82216.4	.246	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
13.37	.2879	60.1	.0857	11.6689	.6466

Appendix C
GWLF Manual

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

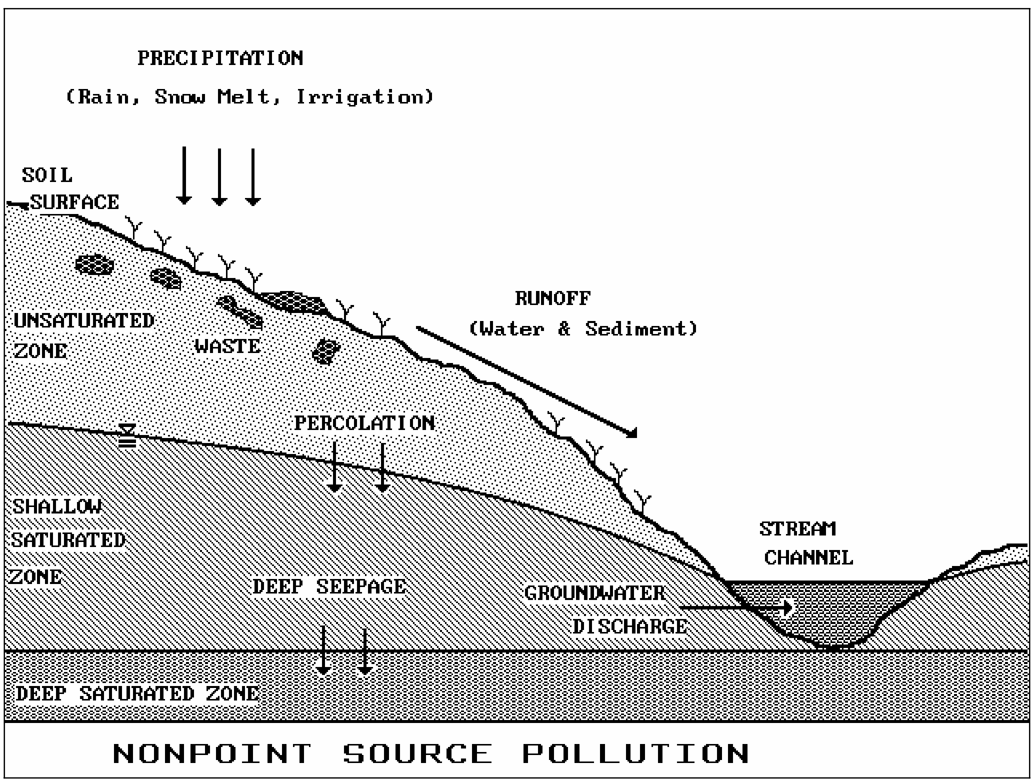


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TABLE OF CONTENTS

INTRODUCTION

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**, underline 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.

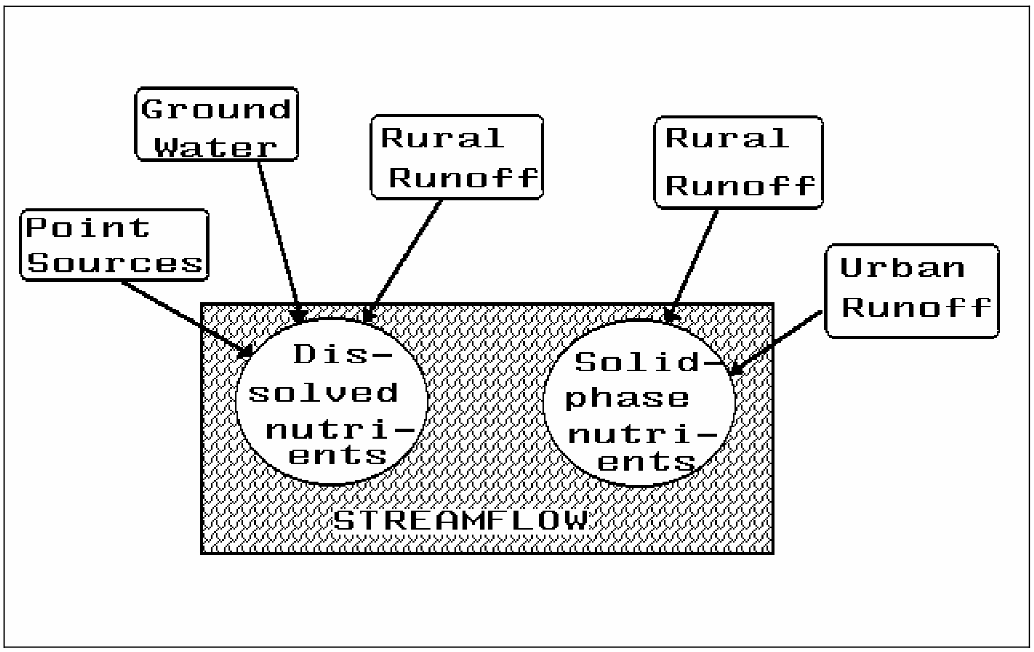

Figure 1. Nutrient Sources in GWLF.

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.

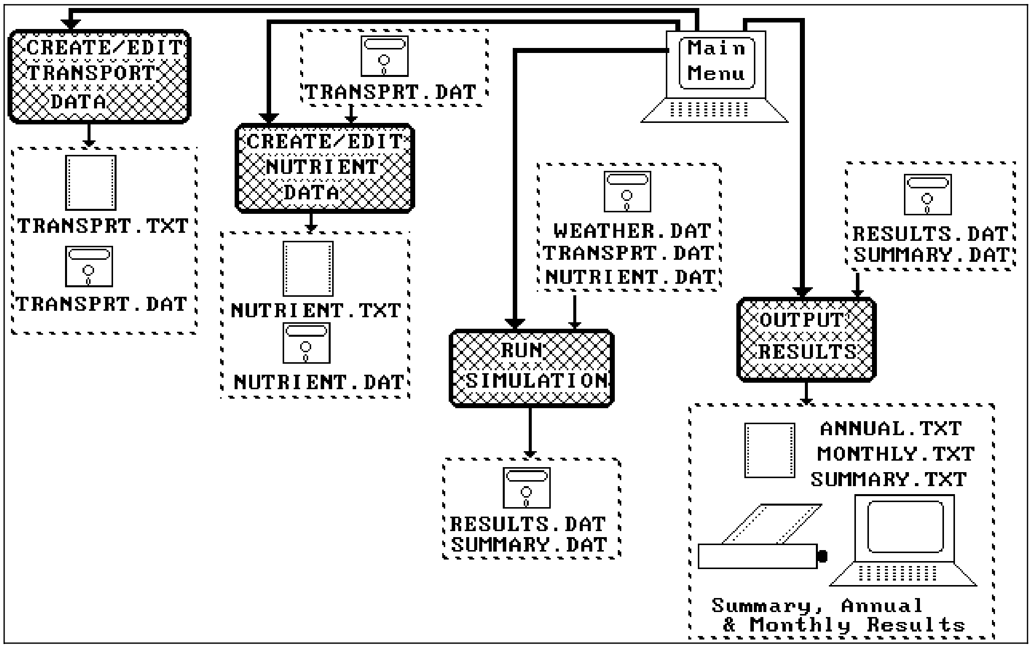

Figure 2. Structure of the GWLF Program.

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.

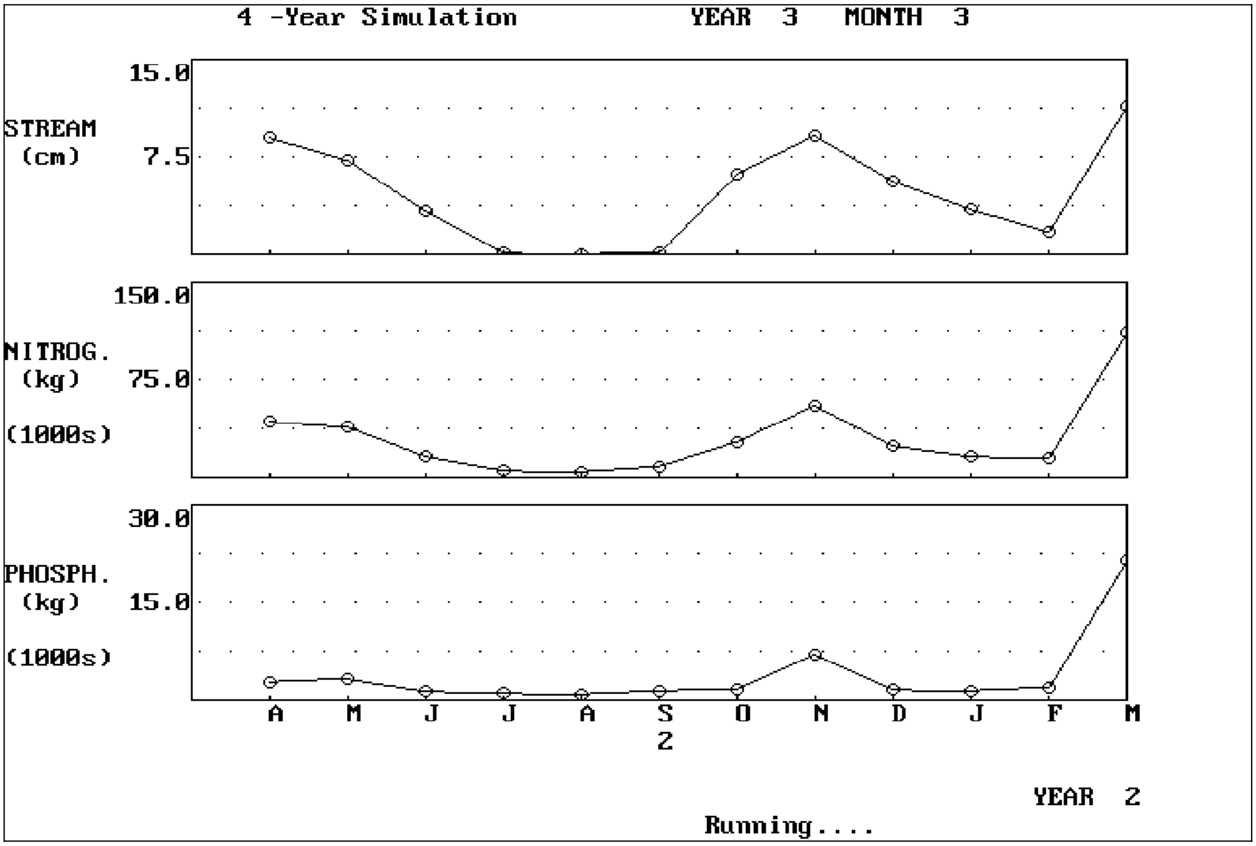

Figure 3. Screen Display during Simulation.

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**.

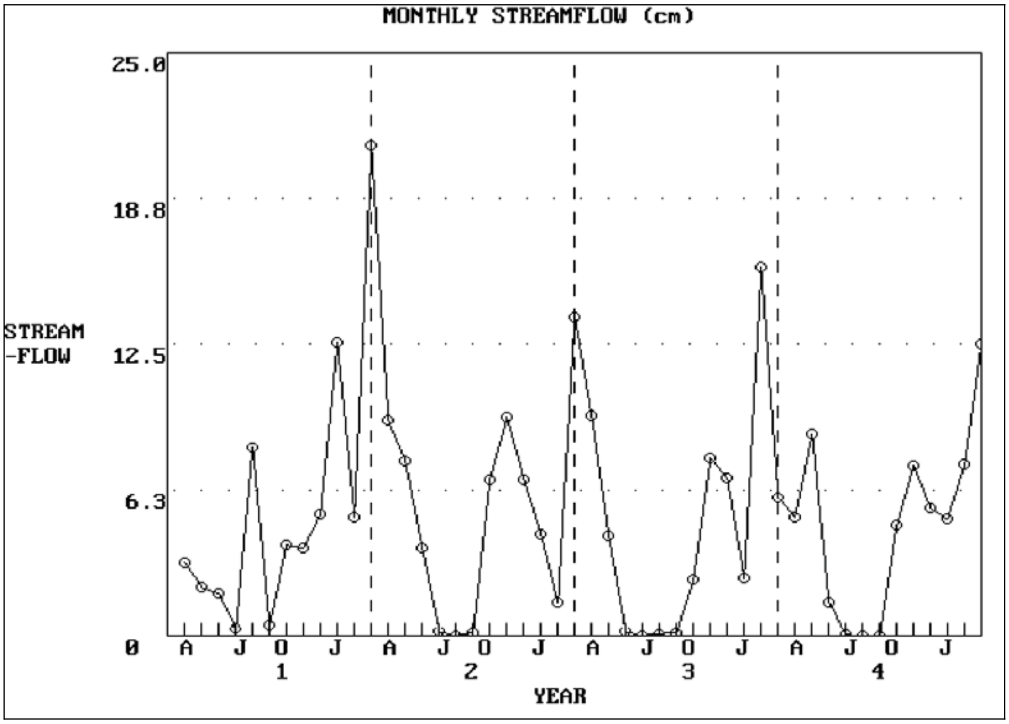

Figure 4. Monthly Streamflows for Example 1.

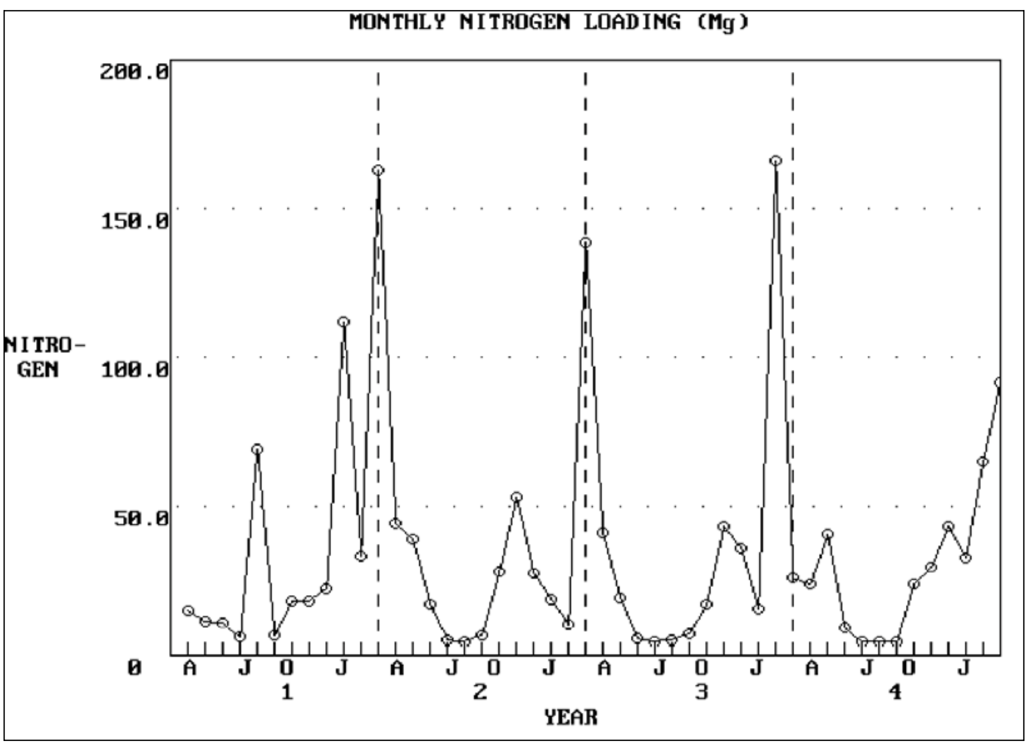

Figure 5. Monthly Nitrogen Loads for Example 1.

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.

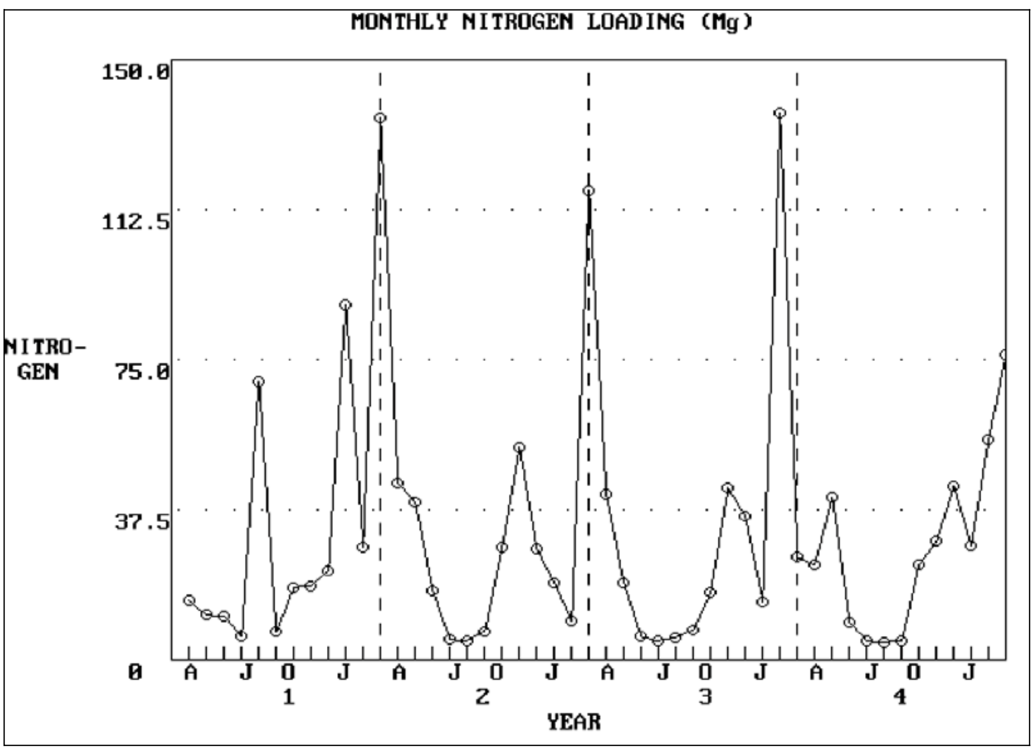

Figure 6. Monthly Nitrogen Loads with no Manure Spreading .

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.

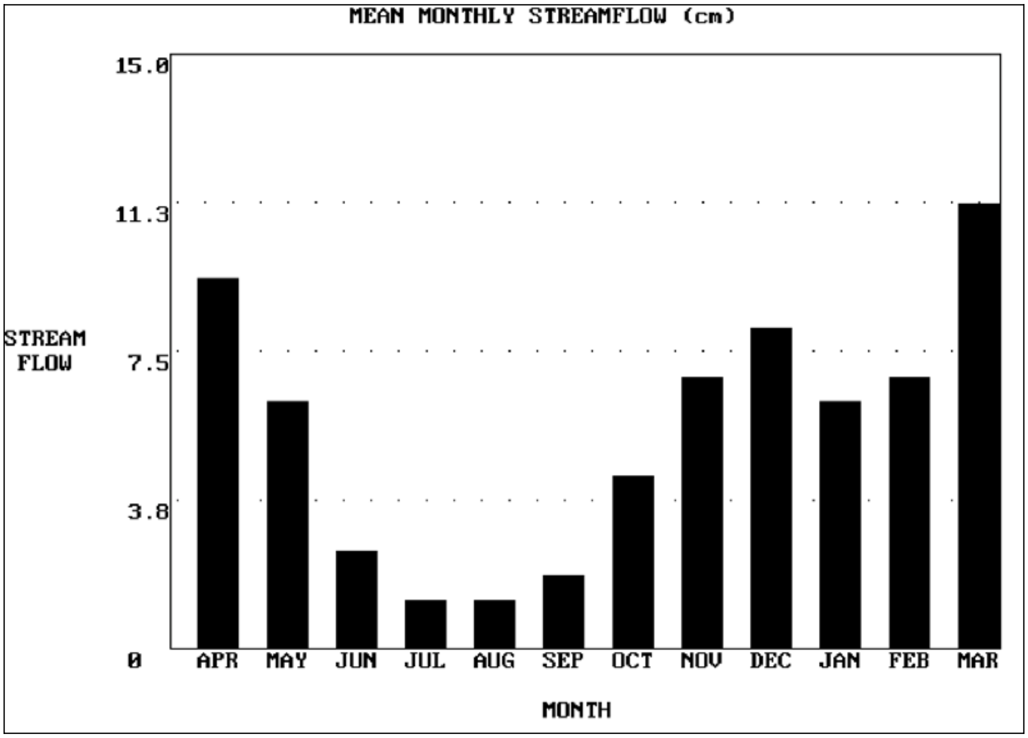

Figure 7. Mean Monthly Streamflows for 30-yr Simulation.

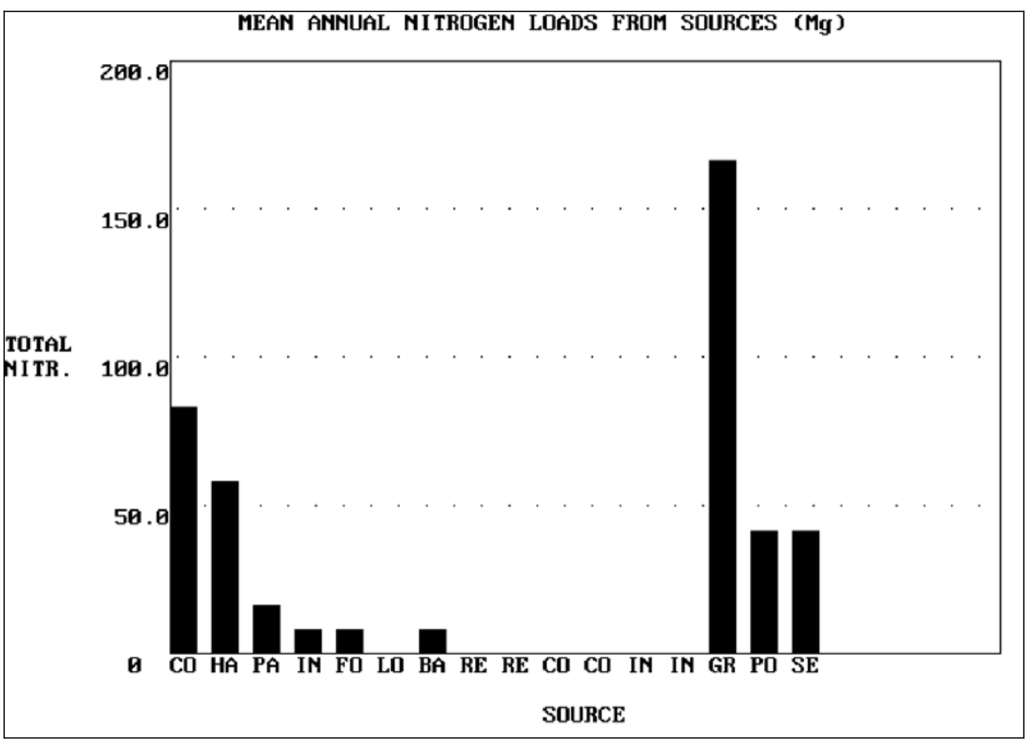

Figure 8. Mean Annual Nitrogen Load from Sources for 30-yr Simulation.

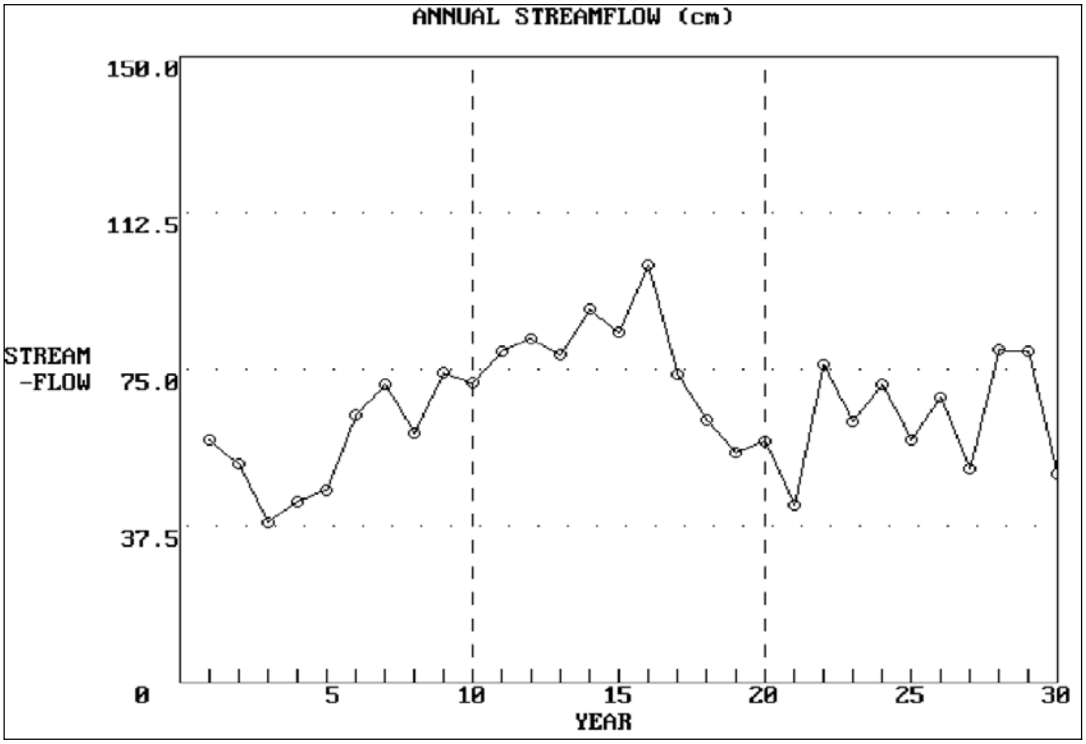

Figure 9. Annual Streamflows for 30-yr Simulation.

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

$$DS_{kt} = \frac{2540}{CN_{kt}} - 25.4 \qquad \text{(A-6)}$$

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):

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

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 $M_t > 0$.

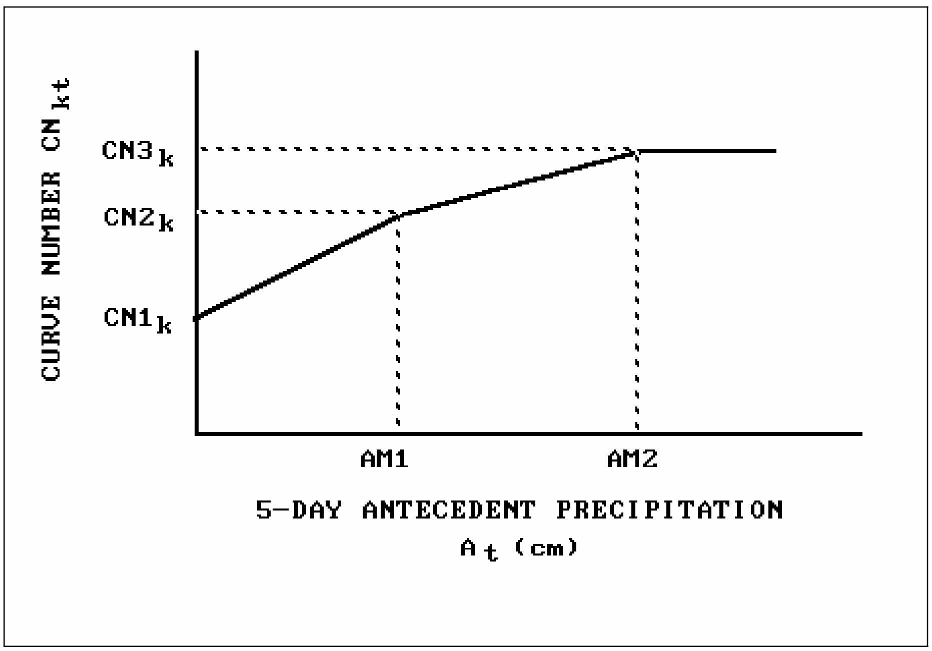

Figure A-1. Curve Number as Function of Antecedent Moisture.

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

$$CN1_k = \frac{CN2_k}{2.334 - 0.01334\, CN2_k} \qquad \text{(A-8)}$$

$$CN3_k = \frac{CN2_k}{} \qquad \text{(A-9)}$$

$0.4036 + 0.0059\ CN2_k$

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):

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

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

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

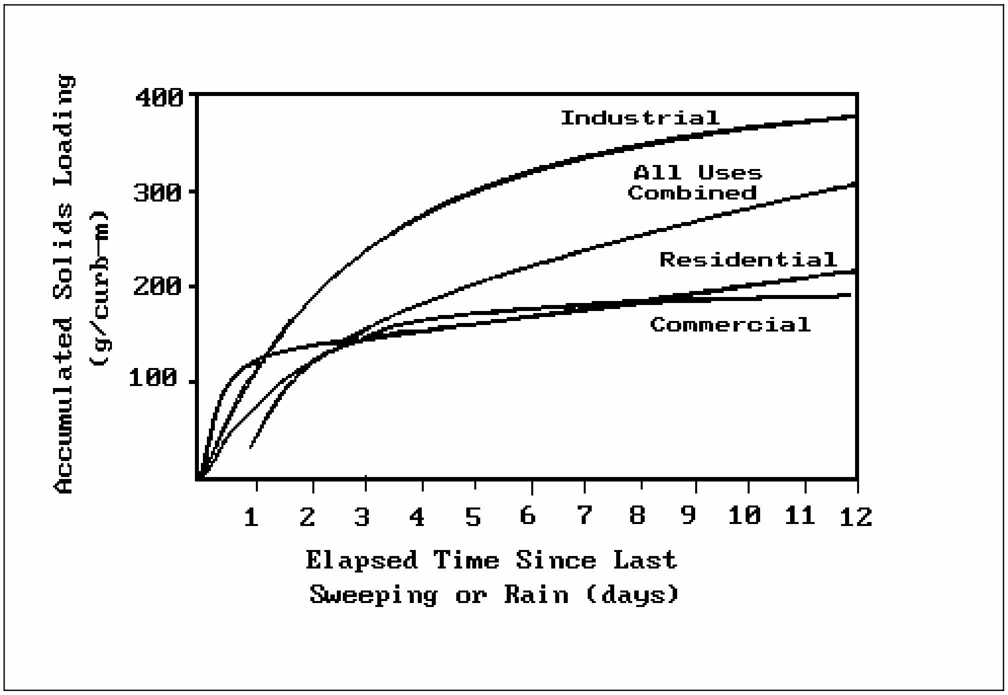

Figure A-2. Accumulation of Pollutants on Urban Surfaces (Sartor & Boyd, 1972; redrawn in Novotny & Chesters, 1981).

Groundwater Sources

The monthly groundwater nutrient load to the stream is

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

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

$$U_{t+1} = U_t + R_t + M_t - Q_t - E_t - PC_t \quad (A-27)$$

$$S_{t+1} = S_t + PC_t - G_t - D_t \quad (A-28)$$

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).

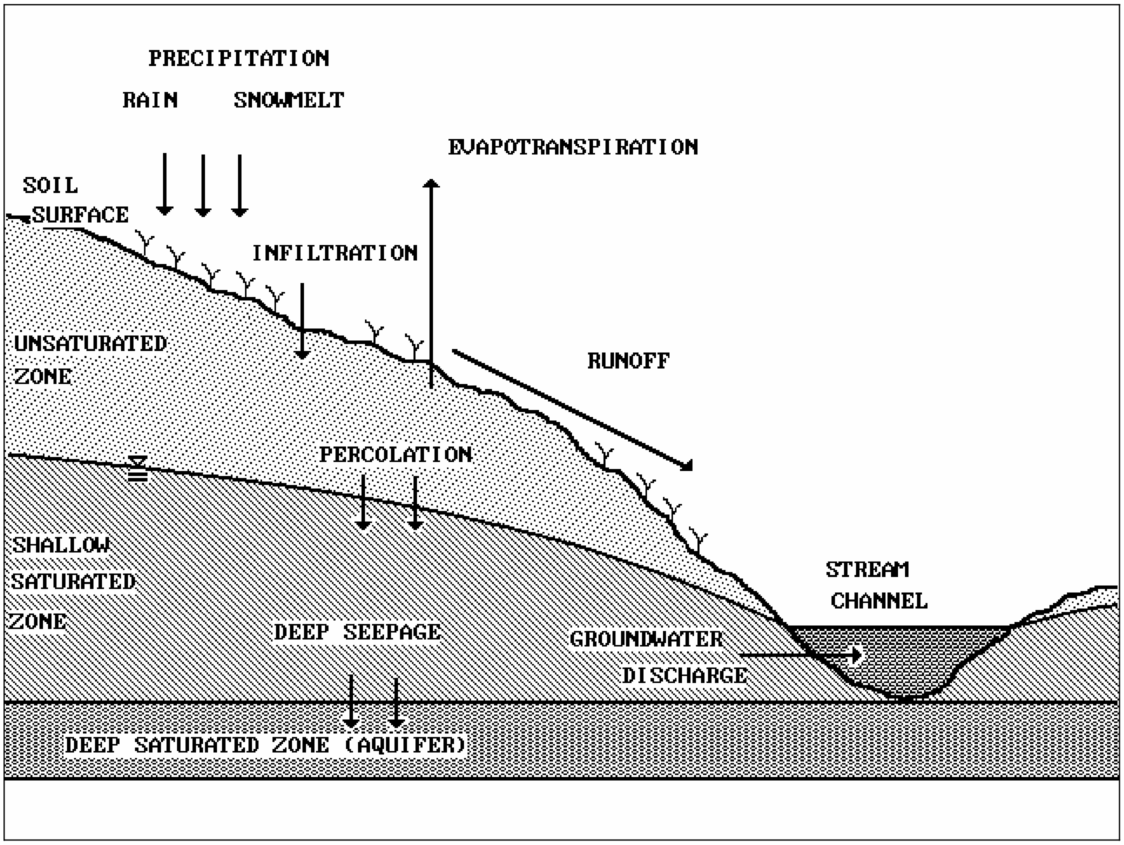

Figure A-3. Lumped Parameter Model for Groundwater Discharge.

Percolation occurs when unsaturated zone water exceeds available soil water capacity U^* (cm):

$$PC_t = \quad \text{Max}\ (0;\ U_t + R_t + M_t - Q_t - E_t - U^*) \quad (A-29)$$

Evapotranspiration is limited by available moisture in the unsaturated zone:

$$E_t = \quad \text{Min}\ (CV_t\ PE_t;\ U_t + R_t + M_t - Q_t) \quad (A-30)$$

for which CV_t is a cover coefficient and PE_t is potential evapotranspiration (cm) as given by Hamon (1961):

$$PE_t = \frac{0.021\ H_t^2\ e_t)}{T_t + 273} \quad (A-31)$$

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}).

<u>Septic (On-site Wastewater Disposal) Systems</u>

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 <u>nitrogen</u> 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	Poor[a/]	68	79	86	89
- continuous forage for grazing	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	Poor[b/]	48	67	77	83
with brush the major element	Fair	35	56	70	77
	Good	30	48	65	73
Woods/grass combination	Poor	57	73	82	86
(orchard or tree farm)[c/]	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 $3 \leq ps_k \leq 1$, 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.

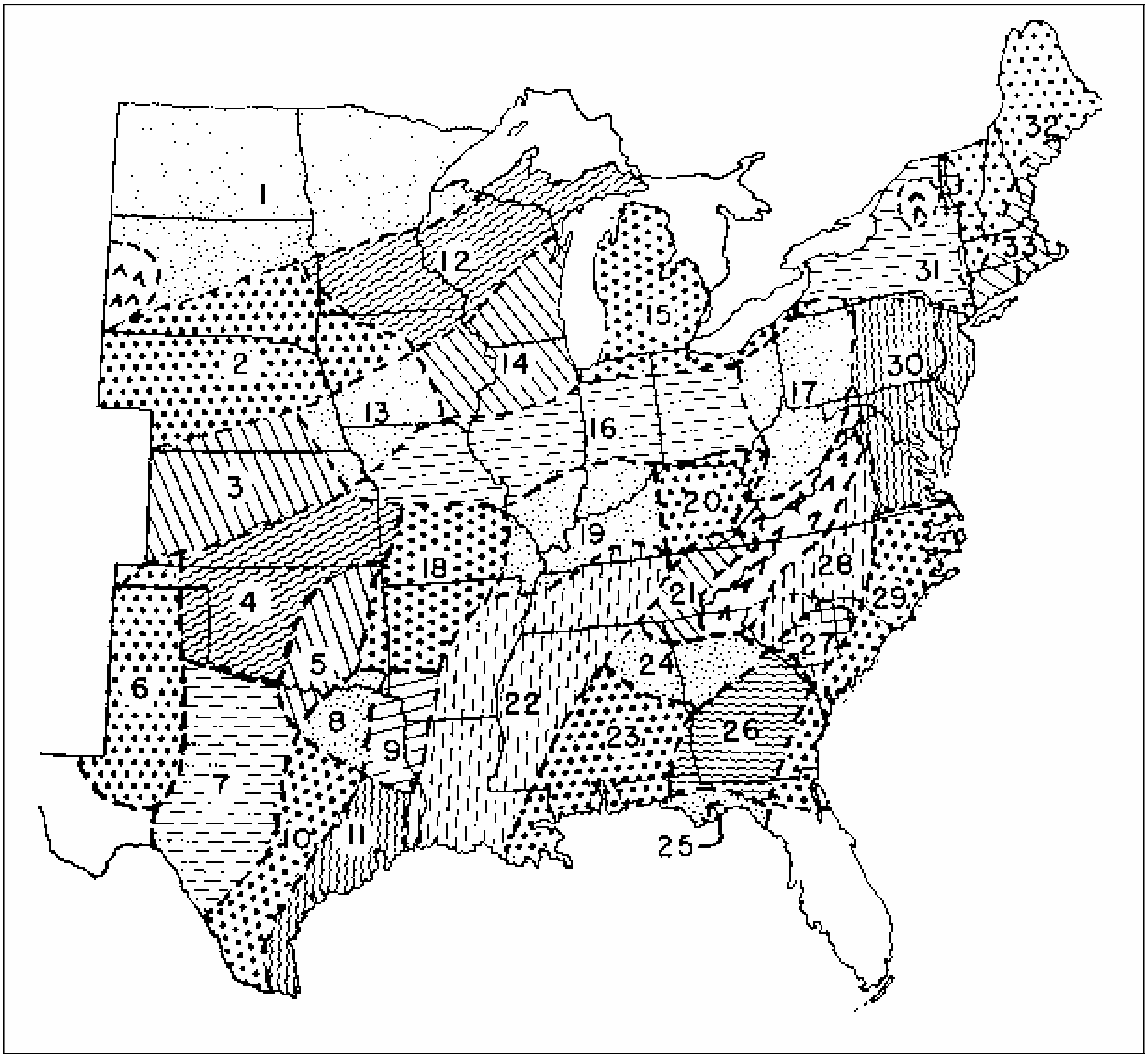

Figure B-1. Rainfall Erosivity Zones in Eastern U.S. (Wischmeier & Smith, 1978).

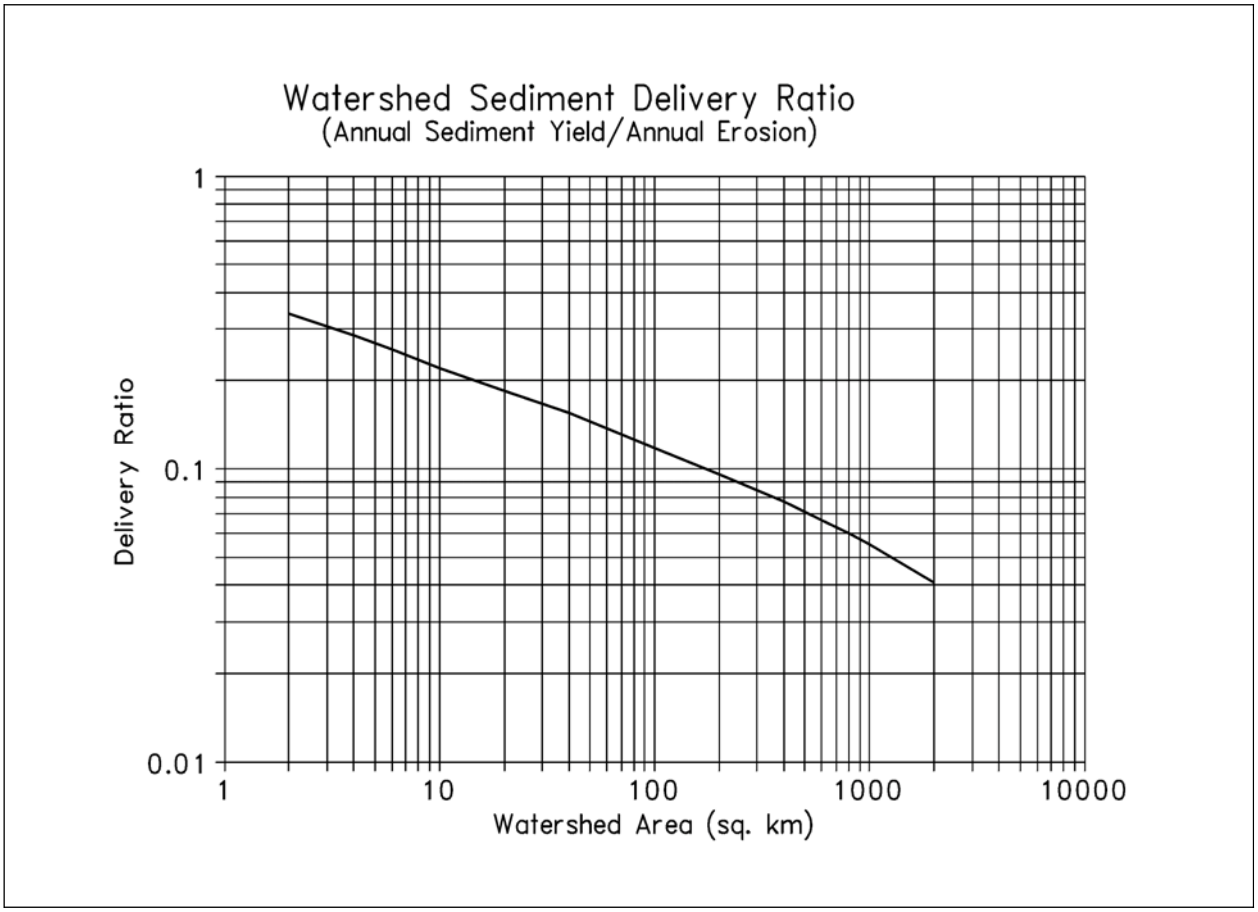

Figure B-2. Watershed Sediment Delivery Ratios (Vanoni, 1975).

	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).

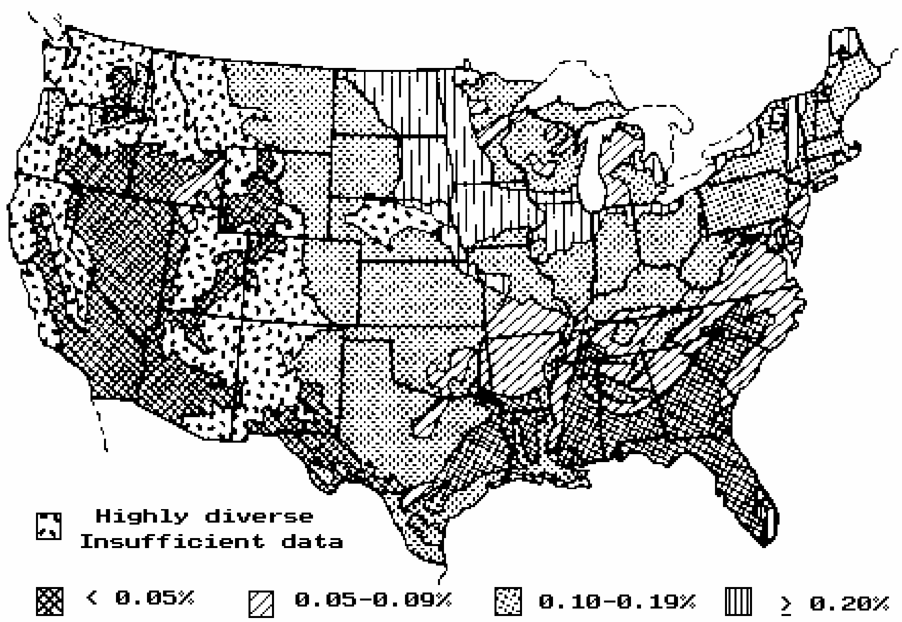

Figure B-3. Nitrogen in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

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.

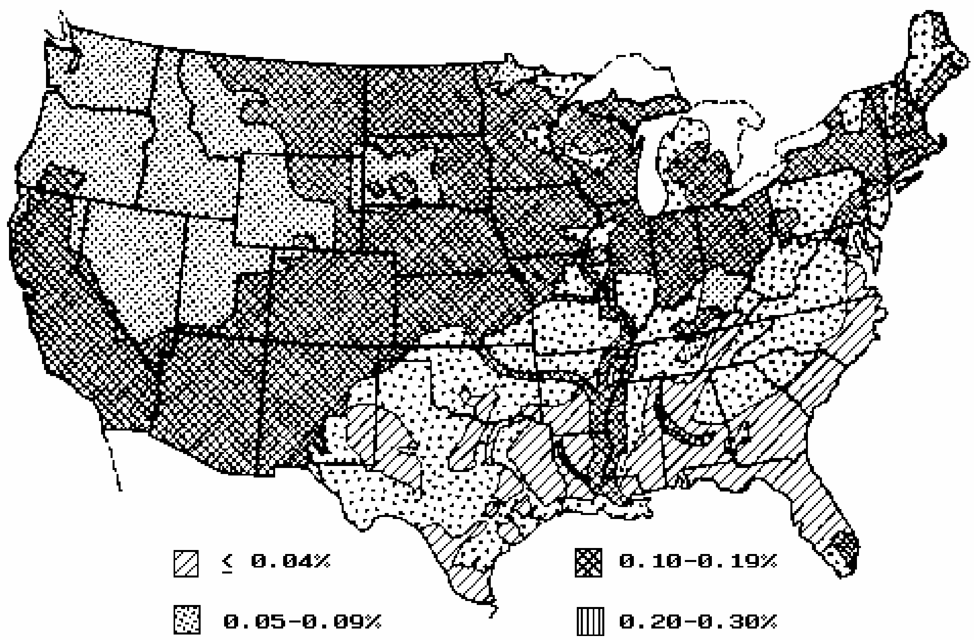

Figure B-4. P_2O_5 (44% phosphorus) in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

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.

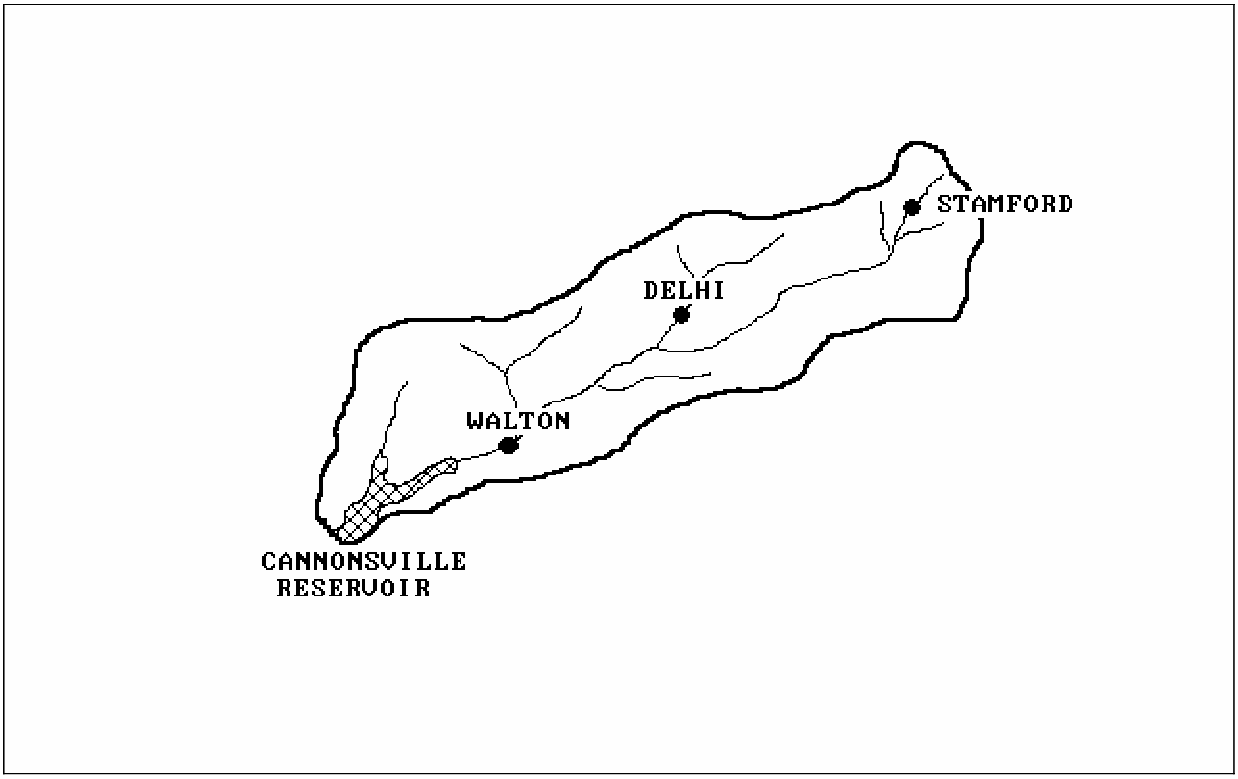

Figure C-1. West Branch Delaware River Watershed.

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	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.

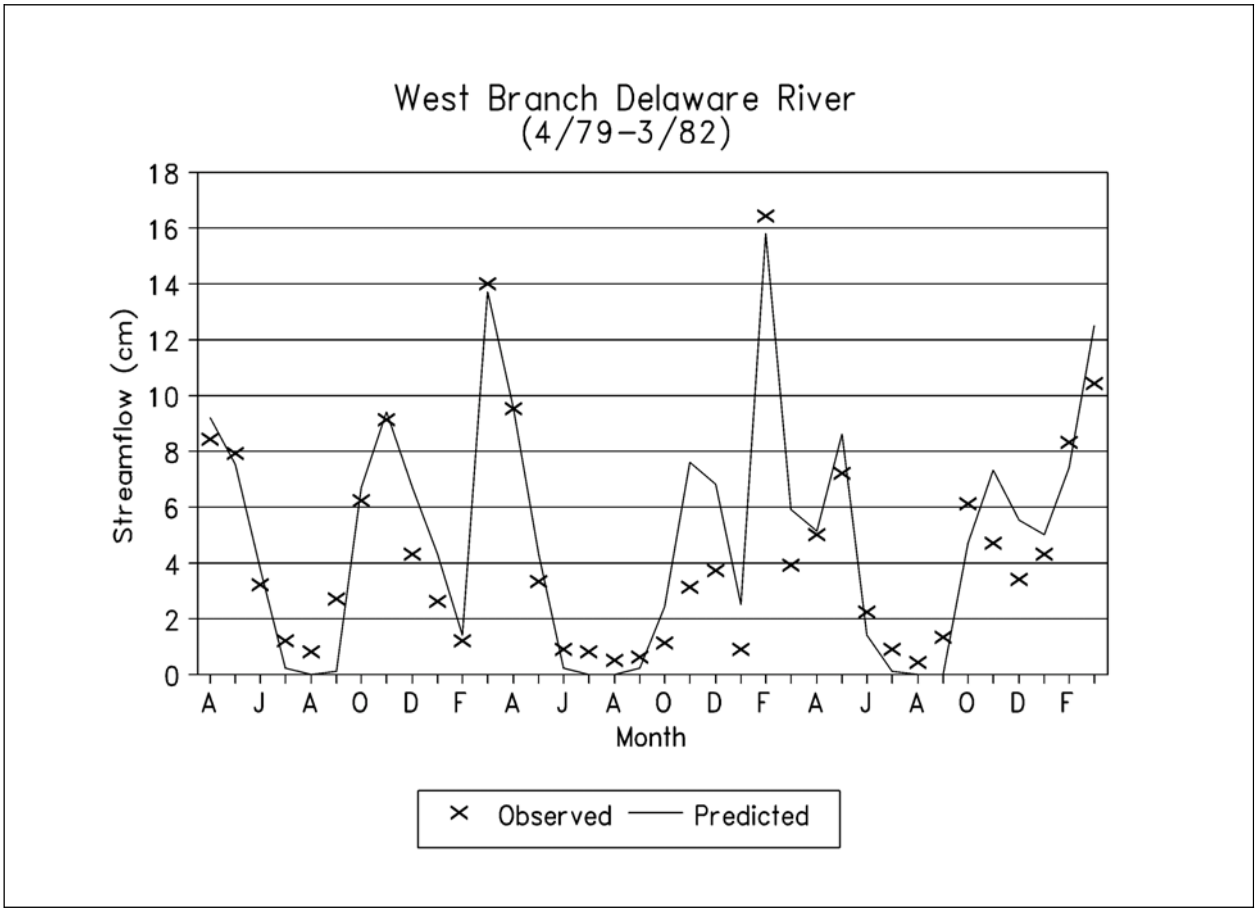

Figure C-2. Observed and Predicted Monthly Streamflow.

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.

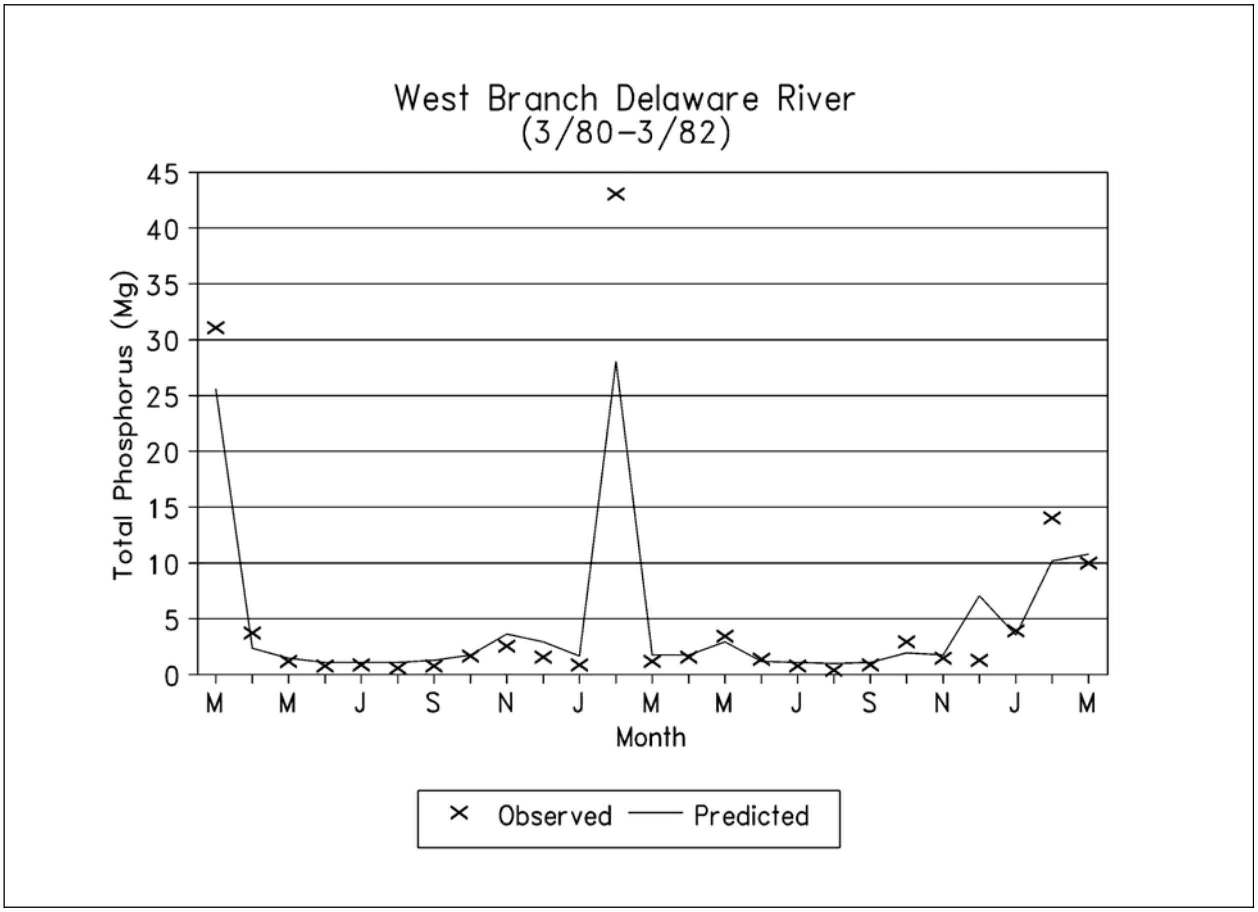

Figure C-3. Observed and Predicted Total Phosphorus in Streamflow.

Constituent	Validation Period	Monthly Means Predicted	Monthly Means 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.

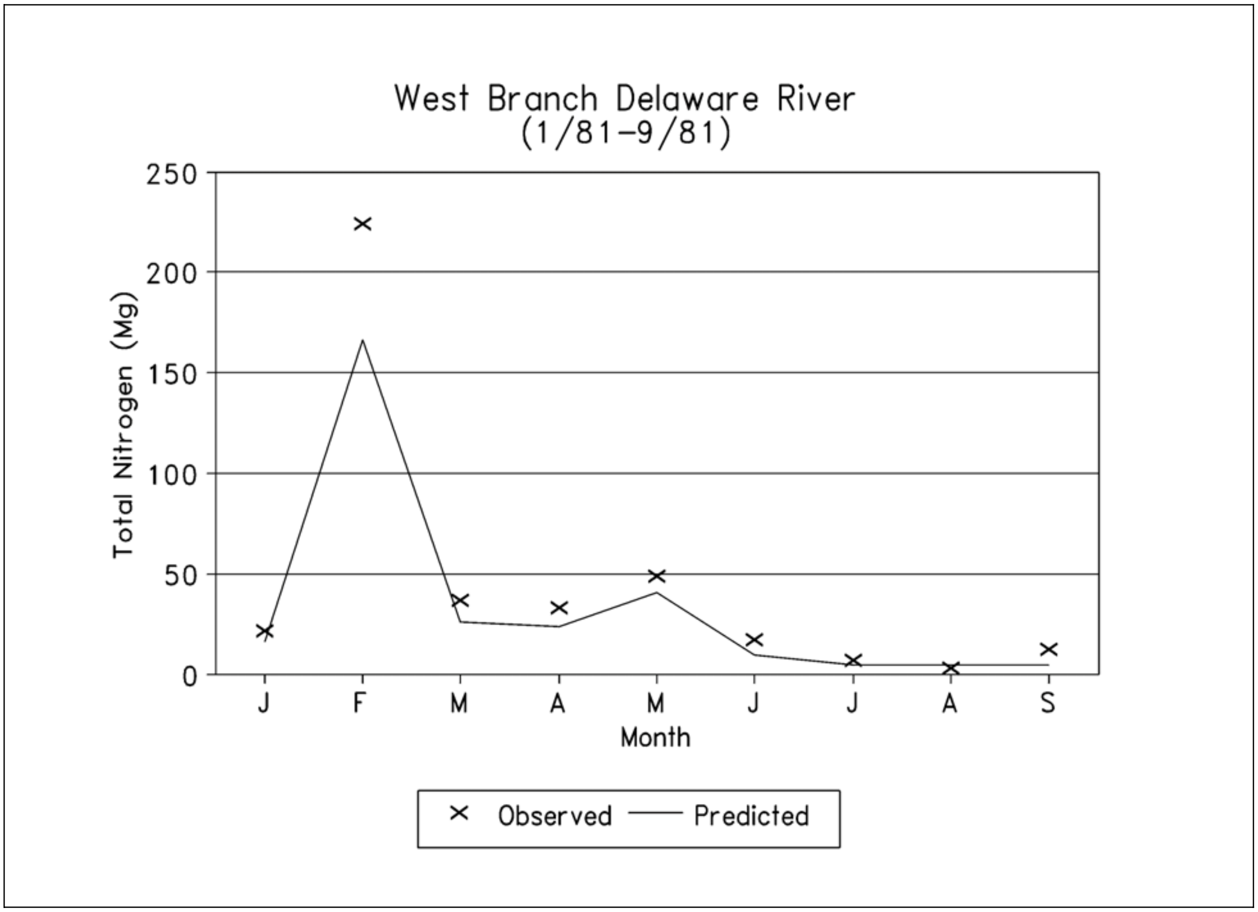

Figure C-4. Observed and Predicted Total Nitrogen in Streamflow.

<u>Conclusions</u>

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	Nitrogen (Mg) Total	Phosphorus (Mg) Dissolved	Phosphorus (Mg) 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

```
7,6
.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
3800,825
3800,825
3800,825
1
7572,881,88,264
7572,881,88,264
9407,1094,109,328
9407,1094,109,328
9407,1094,109,328
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
7572,881,88,264
12,2.5,1.6,.4
```

WEATHER.DAT

```
30
11,.2
2,.4
-3,.1
2,0
3,1
4,0
9,.4
2,.1
2,.1
4,0
12,.1
10,.6
12,0
5,.1
2,.1
5,0
4,0
5,.1
7,0
8,1.3
4,.4
6,.1
4,0
6,0
7,0
8,0
9,0
8,0
7,0
5,.1
31
-1,0
6,0
6,0
5,0
7,.3
6,1.3
11,.6
9,0
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

MONTHLY.TXT

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	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(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	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(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 D
Calculation Details

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.

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 D-1 presents the resulting K-factors associated with each landuse and used in the GWLF program.

Table D-1 Weighted K factors for the Dutchman Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.40	0.40	0.40	0.40
Small Grains	0.40	0.40	---	0.40
Rural Grassland	0.40	0.40	0.40	0.40
Deciduous	0.40	0.40	0.40	0.40
Barren Land	0.40	0.40	---	---

Topographic Factor (LS)

The topographic factor is calculated from a series of equations presented below.

$L = (\Lambda/72.6)^m$

$m = B/(1+B)$

$B = (\sin\Theta/0.0896) / (3.0(\sin\Theta)^{0.8} + 0.56)$

$\Theta = \arctan(slope/100)$

$S = 10.8\sin\Theta + 0.03$ where slope $\leq$ 9%

$S = 16.8\sin\Theta - 0.50$ where slope > 9%

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 D-2 presents the resulting LS factors for each landuse used in GWLF.

Table D-2 Weighted LS factors for the Dutchman Lake Watershed

Landuse	**Subbasin 1**	**Subbasin 2**	**Subbasin 3**	**Subbasin 4**
Row Crop	0.892	0.999	0.456	0.591
Small Grains	0.922	1.026	---	1.249
Rural Grassland	0.938	1.140	1.121	1.037
Deciduous	2.316	2.070	2.854	2.143
Deciduous2	0.983	1.572	---	0.867
Coniferous	1.527	1.702	1.481	1.409
Barren Land	0.766	---	---	---

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 Johnson County NRCS office included as Appendix E. The Johnson County NRCS office also provided an estimate of the percentage of each crop rotation across the Dutchman Lake Watershed. The spreadsheet used to calculate a weighted c-factor for corn, soybeans, and small grains is shown at the last page of this appendix. There is only one crop rotation in the Dutchman Lake Watershed, so the c-factors in column C of the spreadsheet are the same as those in

the first table of columns E-G. The values in the first table are then weighted by the percentage of each tillage practice in the table below them to determine a single c-factor for corn, soybeans, and small grains. The Johnson County transect survey determined that there were no small grains fields in the county; however some small grains do appear in the Cropland Data Layer landuse table of the Dutchman Lake Watershed. These grains were assigned a c-factor of 0.14 as seen in the spreadsheet.

The weighted C factor for each crop is then appended to the table of Cropland Data Layer landuses and areas in the Dutchman Lake watershed. Table D-3 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 E.

Table D-3 Cropland Data Layer Landuse Areas and C Factors in the Dutchman Lake Watershed

Landuse	Subbasin 1 Area (m2)	Subbasin 2 Area (m2)	Subbasin 3 Area (m2)	Subbasin 4 Area (m2)	C-factor
Corn	154800	264600	0	4500	0.21
Sorghum	0	0	0	0	---
Soybeans	152100	259200	900	4500	0.08
Winter Wheat	2700	23400	0	0	0.04
Other Small Grains & Hay	774900	838800	1800	60300	0.14
Double-Cropped WW/SB	145800	248400	2700	4500	0.15
Other Crops	1800	900	0	0	---
Idle Cropland/CRP	3600	2700	0	0	0.004
Fallow/Idle Cropland	1024200	1337400	0	5400	0.004
Pasture/Grassland/Nonag	2323800	3492900	64800	195300	0.004
Woods	3242700	10515600	325800	1988100	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 D-4 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 D-4 C Factors by Critical Trends Assessment Landuse Classes in the Dutchman Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.15	0.15	0.12	0.14
Small Grains	0.14	0.14	---	0.14
Rural Grassland	0.004	0.004	0.004	0.004
Deciduous	0.003	0.003	0.003	0.003
Coniferous	0.003	0.003	0.003	0.003
Barren Land	---	---	---	---

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 D-5 below shows the original and adjusted areas for Dutchman 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 D-5 Cropland Data Layer Adjusted Landuses for Dutchman Lake Watershed

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4	
Landuse	**Area (m2)**	**Adjusted area (m2)**	**Area (m2)**	**Adjusted area (m2)**	**Area (m2)**	**Adjusted area (m2)**	**Area (m2)**	**Adjusted area (m2)**
Corn	154800	154800	264600	264600	---	0	4500	4500
Sorghum	1800	776700	900	839700	---	1800	---	60300
Soybeans	152100	225000	259200	383400	900	2250	4500	6750
Winter Wheat	2700	75600	23400	147600	---	1350	---	2250
Other Small Grains & Hay	774900		838800		1800		60300	
Double-Cropped WW/SB	145800		248400		2700		4500	
Idle Cropland/CRP	3600	3600	2700	2700	---	0	---	0
Fallow/Idle Cropland	1024200	1024200	1337400	1337400	---	0	5400	5400
Pasture/Grassland/ Nonagricultural	2323800	2323800	3492900	3492900	64800	64800	195300	195300
Woods	3242700	3242700	10515600	10515600	325800	325800	1988100	1988100
Clouds	---	0	---	0	---	0	---	0
Urban	872100	872100	265500	265500	---	0	2700	2700
Water	7200	7200	18000	18000	88200	88200	157500	157500
Buildings/Homes/ Subdivisions	63900	63900	123300	123300	---	0	---	0
Wetlands	900	900	12600	12600	1800	1800	---	0
Total	8770500	8770500	17403300	17403300	486000	486000	2422800	2422800

Table D-6 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 D-5. 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 D-6 Calculation of the Monthly Crop Evapotranspiration Cover Coefficients for Subbasin 1 of the Dutchman 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	**0.37**	**0.37**	Nov - Apr
10	0.51	0.4	1.19	0.35	**0.45**		
20	0.58	0.65	1.29	0.58	**0.67**	**0.56**	May
30	0.66	0.9	1.35	1.05	**0.92**		
40	0.75	1.1	1.4	1.07	**1.07**	**1.00**	June
50	0.85	1.2	1.38	0.94	**1.12**	**1.12**	July
60	0.96	1.1	1.36	0.8	**1.04**		
70	1.08	0.95	1.23	0.66	**0.93**	**0.99**	August

80	1.2	0.8	1.1	0.53	**0.82**		
90	1.08	0.65	0.75	0.43	**0.67**	**0.74**	September
100	0.7	0.5	0.4	0.36	**0.49**		
					0.37	**0.43**	October

Table D-7 shows the calculation of a single area-weighted crop coefficient for each month. First, the crop coefficients from Table D-6 were entered into Column B of Table D-7. The monthly ET values in Columns C, D, and E 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 D-5 and the monthly crop cover coefficients in Table D-6.

Table D-7 Calculation of a Monthly ET Cover Coefficient in Subbasin 1 of the Dutchman Lake Watershed

A	B	C	D	E	F	G
	Crop	Pasture	Forest	Urban	Water/ Wetland	**Weighted Average ET**
April	0.37	1.09	0.3	0.7	0.75	**0.65**
May	0.56	0.95	1	0.7	0.75	**0.89**
June	1.00	0.83	1	0.7	0.75	**0.90**
July	1.12	0.79	1	0.7	0.75	**0.90**
August	0.99	0.8	1	0.7	0.75	**0.89**
September	0.74	0.91	1	0.7	0.75	**0.90**
October	0.43	0.91	1	0.7	0.75	**0.85**
November	0.37	0.83	0.3	0.7	0.75	**0.56**
December	0.37	0.69	0.3	0.7	0.75	**0.50**
January	0.37	1.16	0.3	0.7	0.75	**0.68**
February	0.37	1.23	0.3	0.7	0.75	**0.71**
March	0.37	1.19	0.3	0.7	0.75	**0.69**

Table D-8 shows the final calculated ET cover coefficients for each subbasin in the Dutchman Lake Watershed.

Table D-8 ET Cover Coefficients in the Dutchman Lake Watershed

Month	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
April	0.65	0.54	0.49	0.40
May	0.89	0.94	0.94	0.97
June	0.90	0.95	0.93	0.97
July	0.90	0.94	0.93	0.97
August	0.89	0.94	0.93	0.97
September	0.90	0.94	0.94	0.97
October	0.85	0.92	0.94	0.96
November	0.56	0.47	0.46	0.37
December	0.50	0.43	0.44	0.36
January	0.68	0.56	0.50	0.40
February	0.71	0.58	0.51	0.41
March	0.69	0.57	0.50	0.40

A B C D E F G

Corn-Soybean Rotation
100% of watershed

Conventional Till (Spring Plow)	
Corn after Soybean	0.3
Soybean after Corn[1]	0.31
Reduced-Till (40% Cover)	
Corn after Soybean	0.27
Soybean after Corn[1]	0.14
Mulch-Till (60% cover)	
Corn after Soybean	0.2
Soybean after Corn[1]	0.08
No-Till (80% Cover)	
Corn after Soybean[2]	0.12
Soybean after Corn[1]	0.04

[1]Assumed Wide-Row
[2]Used 40% Residue

Table 1 C-factors Weighted by Percent of Crop Rotation in the Watershed

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0.30	0.31	0.14
Reduced Till	0.27	0.14	0.14
Mulch-Till	0.20	0.08	0.14
No-Till	0.12	0.04	0.14

Table 2 Percent of Each Tillage Practice

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	39%	11%	0%
Reduced Till	13%	8%	0%
Mulch-Till	0%	0%	0%
No-Till	48%	81%	0%

C-factors Weighted by Percent of Each Tillage Practice

Corn	Soybeans	Small Grains
0.21	0.08	0.14

Appendix E
Crop Management "C" Factor Values
for Rainfall E.I. Distribution Curve #19

BLE 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 20%	30%	40%	50%	NO-Till % Cover After Plant 60%	70%	80%	90%
ORN after Soybeans		.43	.30	.35	.32	.27	---	20% .20	30% .16	40% .12	3/
ORN after Corn		.38	.25	.20	.18	.15	.13	.07	.05	.04	.03
ORN after Small Grain		.39	.25	.21	.18	.16	.14	.07	.05	.04	.03
ORN after Meadow 4/		.17	.11	.11	.09	.08	.07	.03	.02	.01	.01
ORN 2nd yr. after Meadow 4/		.33	.21	.18	.16	.14	.12	.06	.05	.04	.03
OYBEANS after Soybeans 5/	Wide Row	.48	.37	.37	.36	---	---	20% .22	30% .17	40% .13	3/ ---
	Drill	.42	.29	.34	.33	---	---	.19	.14	.10	
OYBEANS 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
YBEANS 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
YBEANS 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
BEANS after Corn d 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
ALL GRAIN after Corn (Grain) 6/		.16	.14	.11	.10	.09	.08	.06	.05	.04	.03
ALL GRAIN after Corn (Silage) 7/		.22	---	.22	---	---	---	.16	---	---	---
ALL GRAIN after Soybeans 6/		.17	.15	.13	.12	---	---	20% .10	30% .09	40% .08	3/

EAT/SOYBEANS (Double Crop)

		Tillage for Soybeans Plow	Disk	No-Till
.age	Plow	.32	.20	.16
	Disk	.24	.12	.08
t	No-Till	.20	.08	.04

Meadow (Full year-Established)

Grass-Legume	.004
Legume only	.02

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. 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.

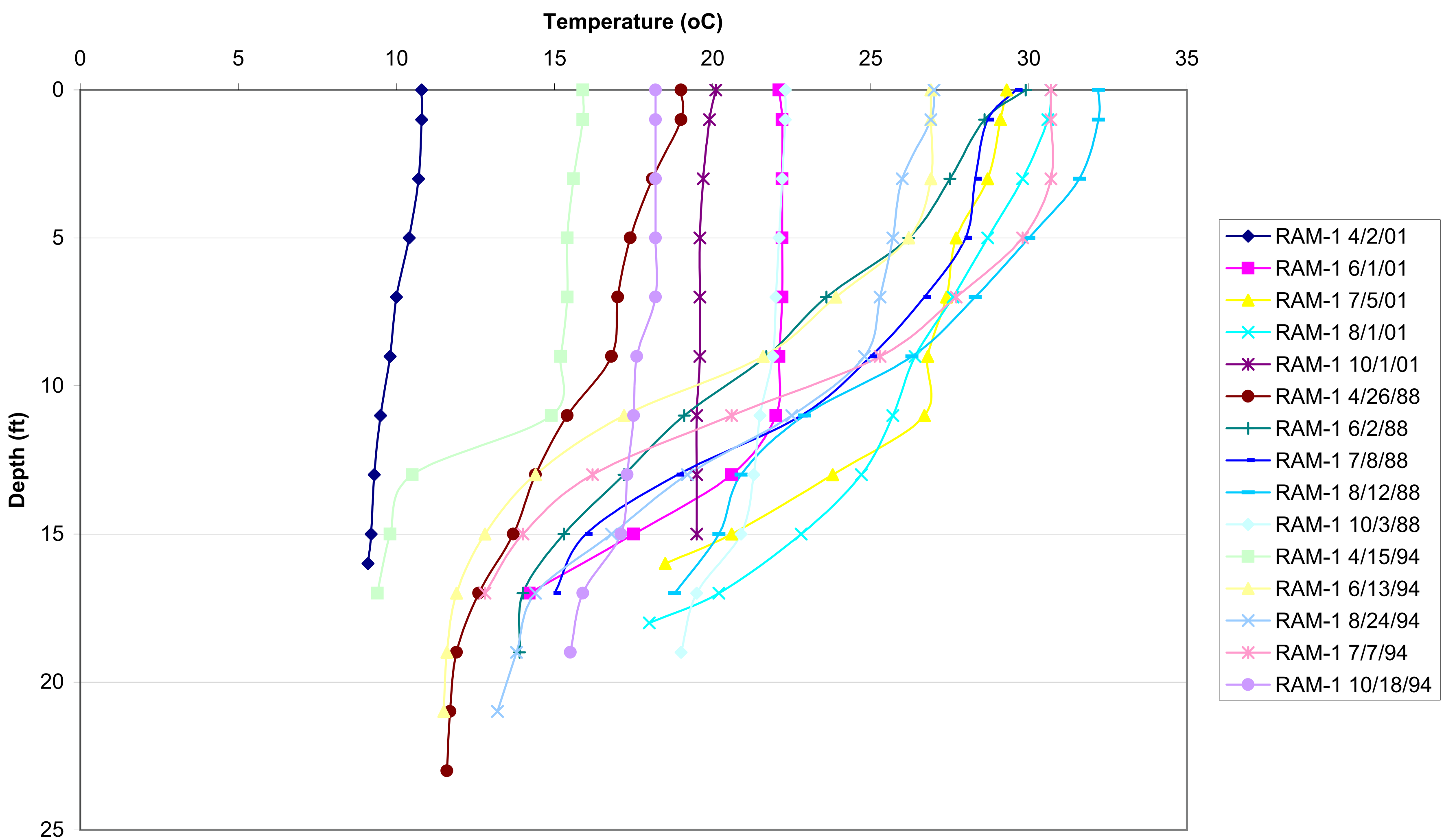
6. The same factors are applicable for both small grain with and without meadow seedings.

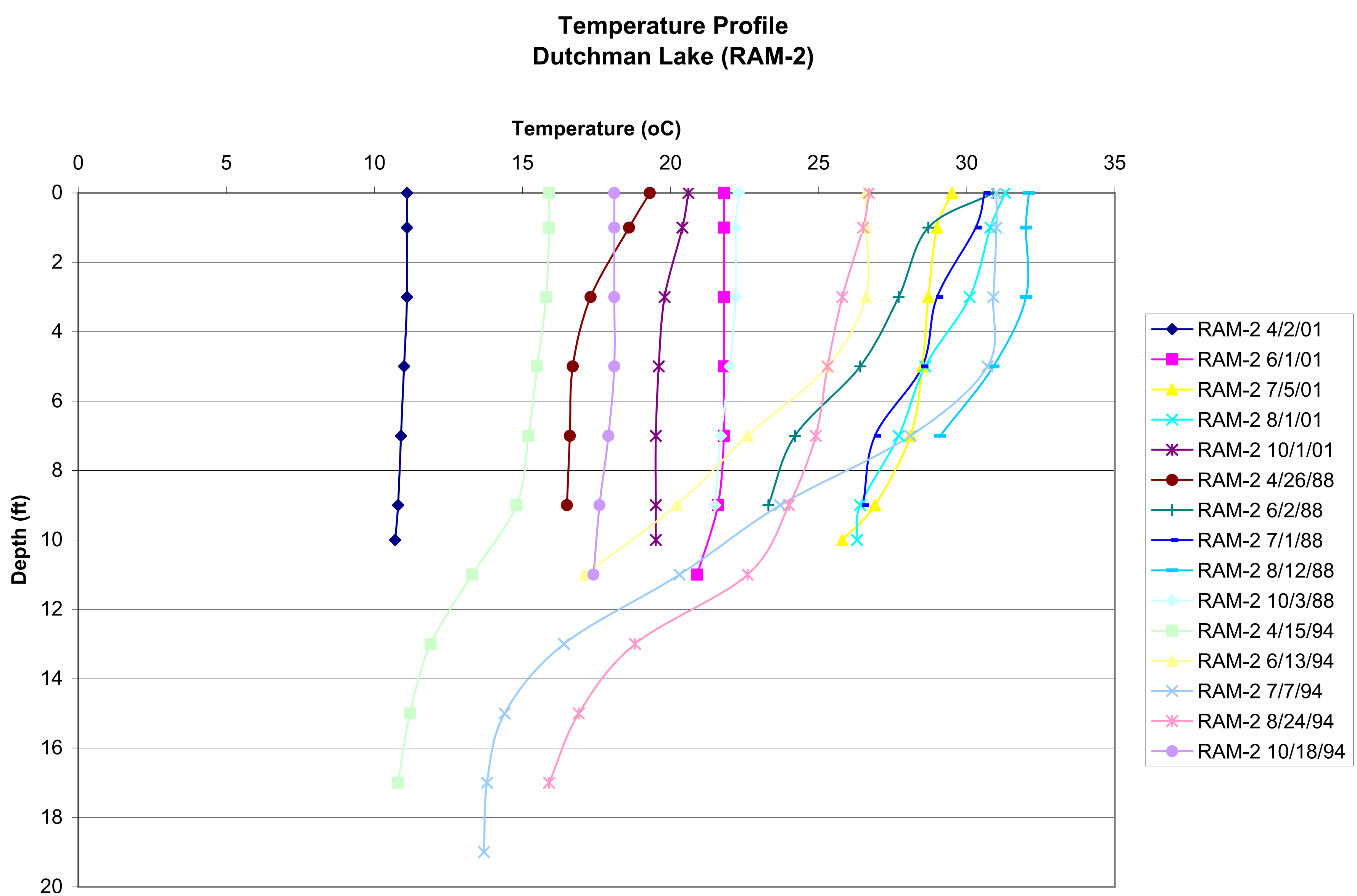
7. Factors for Disk and No-till are for the tillage system with no residue on surface after planting.

For use in our area.

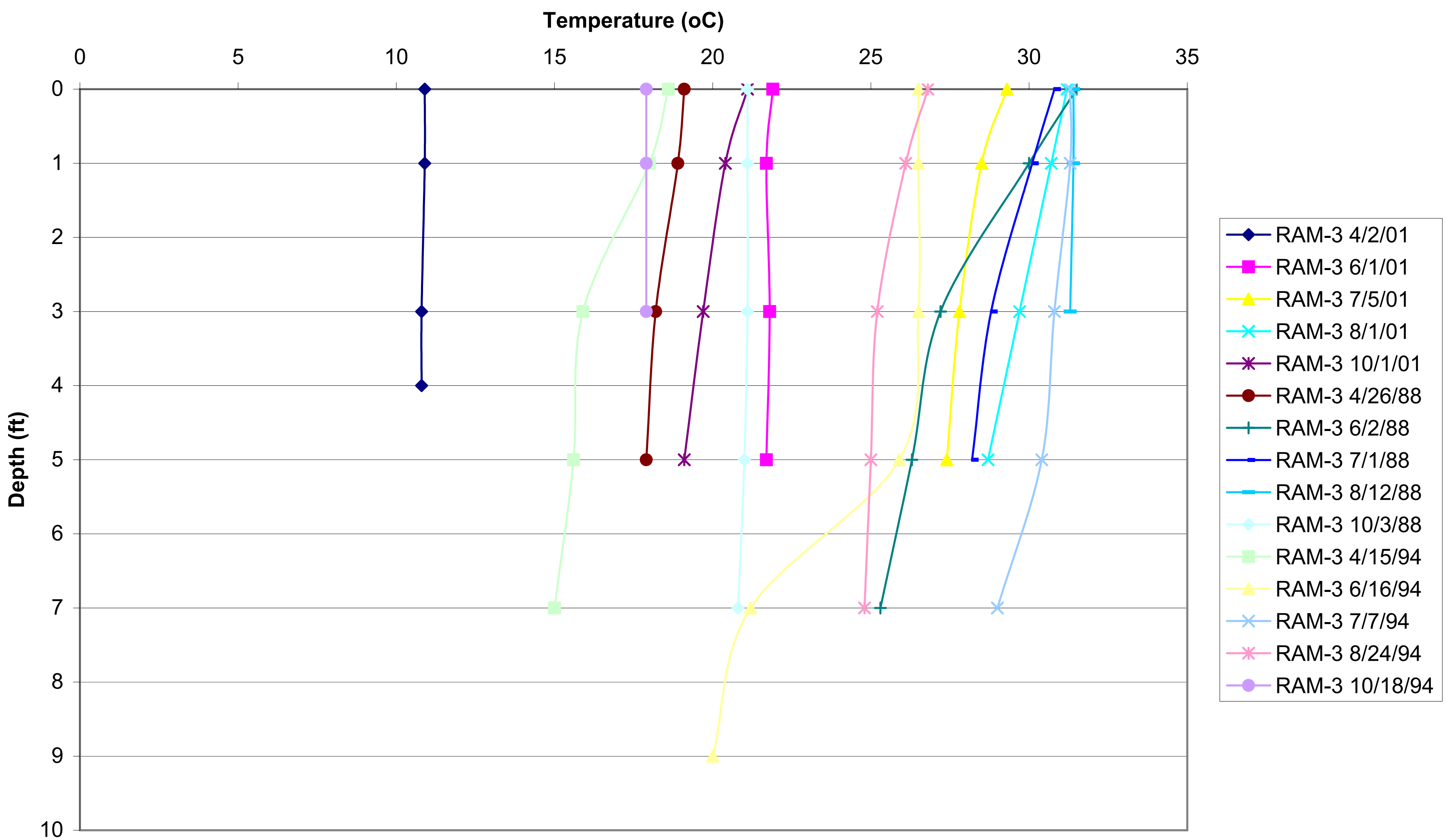
Appendix F
Metalimnion Charts

Temperature Profile
Dutchman Lake (RAM-1)




Temperature Profile
Dutchman Lake (RAM-2)
Temperature (oC)
Depth (ft)
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14
16
18
20
RAM-2 4/2/01
RAM-2 6/1/01
RAM-2 7/5/01
RAM-2 8/1/01
RAM-2 10/1/01
RAM-2 4/26/88
RAM-2 6/2/88
RAM-2 7/1/88
RAM-2 8/12/88
RAM-2 10/3/88
RAM-2 4/15/94
RAM-2 6/13/94
RAM-2 7/7/94
RAM-2 8/24/94
RAM-2 10/18/94

Temperature Profile
Dutchman Lake (RAM-3)



Station	Date	Temp	Depth	DO
RAM-1	4/2/2001	10.8	0	10.6
RAM-1	4/2/2001	10.8	1	10.5
RAM-1	4/2/2001	10.7	3	10.4
RAM-1	4/2/2001	10.4	5	10.3
RAM-1	4/2/2001	10	7	9.6
RAM-1	4/2/2001	9.8	9	8.7
RAM-1	4/2/2001	9.5	11	7.9
RAM-1	4/2/2001	9.3	13	6.5
RAM-1	4/2/2001	9.2	15	5.6
RAM-1	4/2/2001	9.1	16	5.2
RAM-1	6/1/2001	22.1	0	7.3
RAM-1	6/1/2001	22.2	1	7
RAM-1	6/1/2001	22.2	3	6.8
RAM-1	6/1/2001	22.2	5	6.7
RAM-1	6/1/2001	22.2	7	6.4
RAM-1	6/1/2001	22.1	9	6.4
RAM-1	6/1/2001	22	11	5.7
RAM-1	6/1/2001	20.6	13	0.2
RAM-1	6/1/2001	17.5	15	0
RAM-1	6/1/2001	14.2	17	0
RAM-1	7/5/2001	29.3	0	11.2
RAM-1	7/5/2001	29.1	1	11.4
RAM-1	7/5/2001	28.7	3	11.4
RAM-1	7/5/2001	27.7	5	9.5
RAM-1	7/5/2001	27.4	7	8.5
RAM-1	7/5/2001	26.8	9	7.4
RAM-1	7/5/2001	26.7	11	6.3
RAM-1	7/5/2001	23.8	13	0.2
RAM-1	7/5/2001	20.6	15	0.1
RAM-1	7/5/2001	18.5	16	0.1
RAM-1	8/1/2001	30.7	0	12.4
RAM-1	8/1/2001	30.6	1	13
RAM-1	8/1/2001	29.8	3	12.1
RAM-1	8/1/2001	28.7	5	3.6
RAM-1	8/1/2001	27.6	7	0.1
RAM-1	8/1/2001	26.4	9	0.1
RAM-1	8/1/2001	25.7	11	0.1
RAM-1	8/1/2001	24.7	13	0.1
RAM-1	8/1/2001	22.8	15	0.1
RAM-1	8/1/2001	20.2	17	0
RAM-1	8/1/2001	18	18	0
RAM-1	10/1/2001	20.1	0	7
RAM-1	10/1/2001	19.9	1	6.6
RAM-1	10/1/2001	19.7	3	5.9
RAM-1	10/1/2001	19.6	5	5.1
RAM-1	10/1/2001	19.6	7	5.2
RAM-1	10/1/2001	19.6	9	5
RAM-1	10/1/2001	19.5	11	5.6
RAM-1	10/1/2001	19.5	13	4
RAM-1	10/1/2001	19.5	15	3.5
RAM-2	4/2/2001	11.1	0	11.4

Depth	RAM-2 4/2/	Depth
0	11.1	0
1	11.1	1
3	11.1	3
5	11	4
7	10.9	
9	10.8	
10	10.7	

RAM-2	4/2/2001	11.1	1	11.1
RAM-2	4/2/2001	11.1	3	10.9
RAM-2	4/2/2001	11	5	10.8
RAM-2	4/2/2001	10.9	7	10.7
RAM-2	4/2/2001	10.8	9	10.6
RAM-2	4/2/2001	10.7	10	10.5
RAM-2	6/1/2001	21.8	0	6.6
RAM-2	6/1/2001	21.8	1	6.2
RAM-2	6/1/2001	21.8	3	6.3
RAM-2	6/1/2001	21.8	5	5.9
RAM-2	6/1/2001	21.8	7	5.9
RAM-2	6/1/2001	21.6	9	3.2
RAM-2	6/1/2001	20.9	11	0.4
RAM-2	7/5/2001	29.5	0	11.8
RAM-2	7/5/2001	29	1	11.9
RAM-2	7/5/2001	28.7	3	12
RAM-2	7/5/2001	28.5	5	11.3
RAM-2	7/5/2001	28.1	7	9
RAM-2	7/5/2001	26.9	9	2.9
RAM-2	7/5/2001	25.8	10	0.2
RAM-2	8/1/2001	31.3	0	12.4
RAM-2	8/1/2001	30.8	1	12.8
RAM-2	8/1/2001	30.1	3	14.3
RAM-2	8/1/2001	28.6	5	7.2
RAM-2	8/1/2001	27.7	7	1.1
RAM-2	8/1/2001	26.4	9	0.1
RAM-2	8/1/2001	26.3	10	0.1
RAM-2	10/1/2001	20.6	0	8.6
RAM-2	10/1/2001	20.4	1	7.7
RAM-2	10/1/2001	19.8	3	7.2
RAM-2	10/1/2001	19.6	5	5.3
RAM-2	10/1/2001	19.5	7	4.5
RAM-2	10/1/2001	19.5	9	4.6
RAM-2	10/1/2001	19.5	10	4.6
RAM-3	4/2/2001	10.9	0	11.3
RAM-3	4/2/2001	10.9	1	10.7
RAM-3	4/2/2001	10.8	3	10.4
RAM-3	4/2/2001	10.8	4	10.4
RAM-3	6/1/2001	21.9	0	4.3
RAM-3	6/1/2001	21.7	1	4.1
RAM-3	6/1/2001	21.8	3	4
RAM-3	6/1/2001	21.7	5	3.9
RAM-3	7/5/2001	29.3	0	9.1
RAM-3	7/5/2001	28.5	1	8
RAM-3	7/5/2001	27.8	3	6.5
RAM-3	7/5/2001	27.4	5	4.3
RAM-3	8/1/2001	31.2	0	10.2
RAM-3	8/1/2001	30.7	1	9.5
RAM-3	8/1/2001	29.7	3	7.2
RAM-3	8/1/2001	28.7	5	5.3
RAM-3	10/1/2001	21.1	0	8.7
RAM-3	10/1/2001	20.4	1	8.8

RAM-3	10/1/2001	19.7	3	8.4
RAM-3	10/1/2001	19.1	5	7.9

RAM-3 4/2	Depth	RAM-2 6/1	Depth	RAM-3 6/1	Depth	RAM-2 7/5	Depth	RAM-3 7/5
10.9	0	21.8	0	21.9	0	29.5	0	29.3
10.9	1	21.8	1	21.7	1	29	1	28.5
10.8	3	21.8	3	21.8	3	28.7	3	27.8
10.8	5	21.8	5	21.7	5	28.5	5	27.4
	7	21.8			7	28.1		
	9	21.6			9	26.9		
	11	20.9			10	25.8		

Depth	RAM-2 8/1/	Depth	RAM-3 8/1/	Depth	RAM-2 10/	Depth	RAM-3 10/1/01
0	31.3	0	31.2	0	20.6	0	21.1
1	30.8	1	30.7	1	20.4	1	20.4
3	30.1	3	29.7	3	19.8	3	19.7
5	28.6	5	28.7	5	19.6	5	19.1
7	27.7			7	19.5		
9	26.4			9	19.5		
10	26.3			10	19.5		

Depth	RAM-1 4/2	RAM-2 4/2	RAM-3 4/2	RAM-1 6/2	RAM-2 6/2	RAM-3 6/2	RAM-1 7/8	RAM-2 7/1
0.00	19.00	19.30	19.10	29.90	30.90	31.50	29.60	30.60
1.00	19.00	18.60	18.90	28.60	28.70	30.00	28.70	30.30
3.00	18.10	17.30	18.20	27.50	27.70	27.20	28.30	29.00
5.00	17.40	16.70	17.90	26.20	26.40	26.30	28.00	28.50
7.00	17.00	16.60		23.60	24.20	25.30	26.70	26.90
9.00	16.80	16.50		21.70	23.30		25.00	26.50
11.00	15.40			19.10			22.80	
13.00	14.40			17.20			18.90	
15.00	13.70			15.30			16.00	
17.00	12.60			14.00			15.00	
19.00	11.90			13.90				
21.00	11.70							
23.00	11.60							

RAM-3 7/1	RAM-1 8/1	RAM-2 8/1	RAM-3 8/1	RAM-1 10/	RAM-2 10/	RAM-3 10/3/88
30.80	32.20	32.10	31.40	22.30	22.30	21.10
30.10	32.20	32.00	31.40	22.30	22.20	21.10
28.80	31.60	32.00	31.30	22.20	22.20	21.10
28.20	30.00	30.90		22.10	22.00	21.00
	28.30	29.10		22.00	21.70	20.80
	26.30			21.90	21.50	
	22.90			21.50		
	20.90			21.30		
	20.20			20.90		
	18.80			19.50		
				19.00		

Depth	RAM-1 4/1	RAM-2 4/1	RAM-3 4/1	RAM-1 6/1	RAM-2 6/1	RAM-3 6/1	RAM-1 7/7
0.00	15.90	15.90	18.60	26.90	26.60	26.50	30.70
1.00	15.90	15.90	18.00	26.90	26.60	26.50	30.70
3.00	15.60	15.80	15.90	26.90	26.60	26.50	30.70
5.00	15.40	15.50	15.60	26.20	25.30	25.90	29.80
7.00	15.40	15.20	15.00	23.90	22.60	21.20	27.70
9.00	15.20	14.80		21.60	20.20	20.00	25.30
11.00	14.90	13.30		17.20	17.10		20.60
13.00	10.50	11.90		14.40			16.20
15.00	9.80	11.20		12.80			14.00
17.00	9.40	10.80		11.90			12.80
19.00				11.60			
21.00				11.50			
23.00							

RAM-2 7/7	RAM-3 7/7	RAM-1 8/2	RAM-2 8/2	RAM-3 8/2	RAM-1 10/	RAM-2 10/	RAM-3 10/18/94
31.00	31.30	27.00	26.70	26.80	18.20	18.10	17.90
31.00	31.30	26.90	26.50	26.10	18.20	18.10	17.90
30.90	30.80	26.00	25.80	25.20	18.20	18.10	17.90
30.70	30.40	25.70	25.30	25.00	18.20	18.10	
28.10	29.00	25.30	24.90	24.80	18.20	17.90	
23.70		24.80	24.00		17.60	17.60	
20.30		22.50	22.60		17.50	17.40	
16.40		19.20	18.80		17.30		
14.40		16.80	16.90		17.10		
13.80		14.40	15.90		15.90		
13.70		13.80			15.50		
		13.20					

Appendix G
Sensitivity Analysis - BATHTUB Output Files

G.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 440 ppm and 616 ppm. The output concentrations from BATHTUB were not calibrated so that the raw model results could be compared.

BATHTUB Output for 1988 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

CASE: Dutchman 1988 - No Calibration (sed 440)

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	25.6	.38	89.0	.45	.29	-3.26	-4.63	-2.11
CHL-A	MG/M3	13.2	.80	38.1	.42	.35	-1.33	-3.06	-1.18
SECCHI	M	1.3	.37	.7	.33	1.78	1.55	2.06	1.16
ORGANIC N	MG/M3	.0	.00	1061.6	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	74.9	.38	.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	49.8	1.73	58.1	.46	.86	-.09	-.57	-.09
CHL-A	MG/M3	19.4	.52	24.8	.47	.78	-.46	-.70	-.34
SECCHI	M	1.4	.39	1.2	.43	1.18	.44	.60	.29
ORGANIC N	MG/M3	.0	.00	739.2	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	45.6	.43	.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	36.6	.65	48.7	.45	.75	-.44	-1.07	-.36
CHL-A	MG/M3	21.0	.66	22.0	.52	.95	-.07	-.14	-.06
SECCHI	M	1.4	.40	1.4	.53	1.04	.09	.13	.05
ORGANIC N	MG/M3	.0	.00	672.6	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	39.5	.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	35.5	.93	66.1	.45	.54	-.67	-2.31	-.60
CHL-A	MG/M3	17.7	.66	28.7	.43	.62	-.73	-1.40	-.61
SECCHI	M	1.3	.39	1.1	.38	1.26	.59	.82	.42
ORGANIC N	MG/M3	.0	.00	834.5	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	54.2	.42	.00	.00	.00	.00

CASE: Dutchman 1988 - No Calibration (sed 440)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	3.660	.000E+00	.000	.416
2	1	Tributary 2	17.440	7.260	.000E+00	.000	.416
3	1	Tributary 3	.490	.240	.000E+00	.000	.490
4	1	Tributary 4	2.440	1.080	.000E+00	.000	.443
PRECIPITATION			.478	.544	.119E-01	.200	1.139
TRIBUTARY INFLOW			29.170	12.240	.000E+00	.000	.420
***TOTAL INFLOW			29.648	12.784	.119E-01	.009	.431
ADVECTIVE OUTFLOW			29.648	12.382	.264E-01	.013	.418
***TOTAL OUTFLOW			29.648	12.382	.264E-01	.013	.418
***EVAPORATION			.000	.402	.146E-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	Tributary 1	599.9	44.0	.000E+00	.0	.000	163.9	68.2
2	1	Tributary 2	700.6	51.3	.000E+00	.0	.000	96.5	40.2
3	1	Tributary 3	4.9	.4	.000E+00	.0	.000	20.6	10.1
4	1	Tributary 4	44.8	3.3	.000E+00	.0	.000	41.5	18.4
PRECIPITATION			14.3	1.1	.514E+02	100.0	.500	26.3	30.0
TRIBUTARY INFLOW			1350.2	98.9	.000E+00	.0	.000	110.3	46.3
***TOTAL INFLOW			1364.6	100.0	.514E+02	100.0	.005	106.7	46.0
ADVECTIVE OUTFLOW			603.6	44.2	.739E+05	*******	.450	48.7	20.4
***TOTAL OUTFLOW			603.6	44.2	.739E+05	*******	.450	48.7	20.4
***RETENTION			761.0	55.8	.739E+05	*******	.357	.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 -
25.90	.1492	35.5	.0481	20.7964	.5577

1988 – *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Dutchman 1988 - No Calib (sed 616)

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	25.6	.38	94.3	.45	.27	-3.41	-4.85	-2.21
CHL-A	MG/M3	13.2	.80	39.6	.41	.33	-1.38	-3.17	-1.23
SECCHI	M	1.3	.37	.7	.32	1.82	1.62	2.15	1.22
ORGANIC N	MG/M3	.0	.00	1095.2	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	77.5	.38	.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	49.8	1.73	61.1	.46	.82	-.12	-.76	-.11
CHL-A	MG/M3	19.4	.52	25.7	.46	.76	-.53	-.81	-.40
SECCHI	M	1.4	.39	1.1	.41	1.22	.51	.70	.34
ORGANIC N	MG/M3	.0	.00	759.9	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	47.2	.43	.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	36.6	.65	51.0	.45	.72	-.51	-1.23	-.42
CHL-A	MG/M3	21.0	.66	22.8	.51	.92	-.13	-.24	-.10
SECCHI	M	1.4	.40	1.3	.52	1.06	.15	.22	.09
ORGANIC N	MG/M3	.0	.00	690.6	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.9	.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	35.5	.93	69.7	.45	.51	-.73	-2.50	-.65
CHL-A	MG/M3	17.7	.66	29.8	.42	.59	-.79	-1.51	-.66
SECCHI	M	1.3	.39	1.0	.38	1.29	.66	.91	.47
ORGANIC N	MG/M3	.0	.00	859.1	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	56.2	.41	.00	.00	.00	.00

CASE: Dutchman 1988 - No Calib (sed 616)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	3.660	.000E+00	.000	.416
2	1	Tributary 2	17.440	7.260	.000E+00	.000	.416
3	1	Tributary 3	.490	.240	.000E+00	.000	.490
4	1	Tributary 4	2.440	1.080	.000E+00	.000	.443
PRECIPITATION			.478	.544	.119E-01	.200	1.139
TRIBUTARY INFLOW			29.170	12.240	.000E+00	.000	.420
***TOTAL INFLOW			29.648	12.784	.119E-01	.009	.431
ADVECTIVE OUTFLOW			29.648	12.382	.264E-01	.013	.418
***TOTAL OUTFLOW			29.648	12.382	.264E-01	.013	.418
***EVAPORATION			.000	.402	.146E-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	Tributary 1	599.9	40.7	.000E+00	.0	.000	163.9	68.2
2	1	Tributary 2	800.8	54.3	.000E+00	.0	.000	110.3	45.9
3	1	Tributary 3	9.9	.7	.000E+00	.0	.000	41.1	20.1
4	1	Tributary 4	49.9	3.4	.000E+00	.0	.000	46.2	20.4
PRECIPITATION			14.3	1.0	.514E+02	100.0	.500	26.3	30.0
TRIBUTARY INFLOW			1460.4	99.0	.000E+00	.0	.000	119.3	50.1
***TOTAL INFLOW			1474.8	100.0	.514E+02	100.0	.005	115.4	49.7
ADVECTIVE OUTFLOW			631.0	42.8	.808E+05	*******	.450	51.0	21.3
***TOTAL OUTFLOW			631.0	42.8	.808E+05	*******	.450	51.0	21.3
***RETENTION			843.7	57.2	.808E+05	*******	.337	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
25.90	.1492	35.5	.0445	22.4756	.5721

BATHTUB Output for 1994 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

CASE: Dutchman 1994 - No Calibration (sed 440)

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	36.8	.33	100.6	.45	.37	-3.04	-3.74	-1.80
CHL-A	MG/M3	17.2	.48	35.6	.44	.48	-1.51	-2.10	-1.12
SECCHI	M	.8	.55	.6	.36	1.39	.60	1.18	.50
ORGANIC N	MG/M3	.0	.00	1024.5	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	76.9	.34	.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	33.0	.41	64.9	.46	.51	-1.63	-2.51	-1.10
CHL-A	MG/M3	34.4	.31	30.1	.53	1.14	.43	.39	.22
SECCHI	M	1.5	.74	1.2	.53	1.24	.29	.76	.23
ORGANIC N	MG/M3	.0	.00	849.8	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	51.4	.46	.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	115.1	1.38	52.0	.45	2.21	.57	2.95	.55
CHL-A	MG/M3	34.3	.42	22.9	.57	1.50	.96	1.16	.57
SECCHI	M	1.5	.63	1.5	.61	.99	-.01	-.02	-.01
ORGANIC N	MG/M3	.0	.00	685.4	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	38.6	.47	.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	66.5	1.05	73.3	.45	.91	-.09	-.36	-.08
CHL-A	MG/M3	27.9	.40	29.4	.43	.95	-.13	-.15	-.09
SECCHI	M	1.3	.64	1.1	.44	1.14	.20	.46	.17
ORGANIC N	MG/M3	.0	.00	851.3	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	56.0	.39	.00	.00	.00	.00

CASE: Dutchman 1994 - No Calibration (sed 440)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	4.590	.000E+00	.000	.522
2	1	Tributary 2	17.440	9.100	.000E+00	.000	.522
3	1	Tributary 3	.490	.290	.000E+00	.000	.592
4	1	Tributary 4	2.440	1.340	.000E+00	.000	.549
PRECIPITATION			.478	.574	.132E-01	.200	1.200
TRIBUTARY INFLOW			29.170	15.320	.000E+00	.000	.525
***TOTAL INFLOW			29.648	15.894	.132E-01	.007	.536
ADVECTIVE OUTFLOW			29.648	15.491	.277E-01	.011	.523
***TOTAL OUTFLOW			29.648	15.491	.277E-01	.011	.523
***EVAPORATION			.000	.402	.146E-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	Tributary 1	899.2	45.5	.000E+00	.0	.000	195.9	102.2
2	1	Tributary 2	999.2	50.5	.000E+00	.0	.000	109.8	57.3
3	1	Tributary 3	5.0	.3	.000E+00	.0	.000	17.3	10.2
4	1	Tributary 4	60.0	3.0	.000E+00	.0	.000	44.8	24.6
PRECIPITATION			14.3	.7	.514E+02	100.0	.500	25.0	30.0
TRIBUTARY INFLOW			1963.4	99.3	.000E+00	.0	.000	128.2	67.3
***TOTAL INFLOW			1977.8	100.0	.514E+02	100.0	.004	124.4	66.7
ADVECTIVE OUTFLOW			805.8	40.7	.132E+06	*******	.451	52.0	27.2
***TOTAL OUTFLOW			805.8	40.7	.132E+06	*******	.451	52.0	27.2
***RETENTION			1171.9	59.3	.132E+06	*******	.310	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P: POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
32.41	.1371	66.5	.0715	13.9921	.5925

1994 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Dutchman 1994 - No Calib (sed 616)

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	36.8	.33	108.8	.45	.34	-3.27	-4.03	-1.94
CHL-A	MG/M3	17.2	.48	37.2	.43	.46	-1.61	-2.23	-1.20
SECCHI	M	.8	.55	.6	.35	1.42	.64	1.26	.54
ORGANIC N	MG/M3	.0	.00	1061.0	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	79.8	.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	33.0	.41	68.9	.46	.48	-1.77	-2.74	-1.19
CHL-A	MG/M3	34.4	.31	31.4	.52	1.10	.30	.27	.15
SECCHI	M	1.5	.74	1.2	.51	1.28	.34	.89	.28
ORGANIC N	MG/M3	.0	.00	878.5	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	53.7	.45	.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	115.1	1.38	54.7	.45	2.10	.54	2.76	.51
CHL-A	MG/M3	34.3	.42	23.8	.57	1.44	.88	1.06	.52
SECCHI	M	1.5	.63	1.5	.58	1.03	.04	.10	.03
ORGANIC N	MG/M3	.0	.00	704.6	.42	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.1	.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	66.5	1.05	78.4	.45	.85	-.16	-.61	-.14
CHL-A	MG/M3	27.9	.40	30.6	.42	.91	-.23	-.27	-.16
SECCHI	M	1.3	.64	1.1	.43	1.17	.25	.57	.21
ORGANIC N	MG/M3	.0	.00	879.2	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	58.2	.39	.00	.00	.00	.00

CASE: Dutchman 1994 - No Calib (sed 616)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	4.590	.000E+00	.000	.522
2	1	Tributary 2	17.440	9.100	.000E+00	.000	.522
3	1	Tributary 3	.490	.290	.000E+00	.000	.592
4	1	Tributary 4	2.440	1.340	.000E+00	.000	.549
		PRECIPITATION	.478	.574	.132E-01	.200	1.200
		TRIBUTARY INFLOW	29.170	15.320	.000E+00	.000	.525
		***TOTAL INFLOW	29.648	15.894	.132E-01	.007	.536
		ADVECTIVE OUTFLOW	29.648	15.491	.277E-01	.011	.523
		***TOTAL OUTFLOW	29.648	15.491	.277E-01	.011	.523
		***EVAPORATION	.000	.402	.146E-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	Tributary 1	999.2	45.8	.000E+00	.0	.000	217.7	113.6
2	1	Tributary 2	1099.3	50.4	.000E+00	.0	.000	120.8	63.0
3	1	Tributary 3	5.0	.2	.000E+00	.0	.000	17.3	10.2
4	1	Tributary 4	65.0	3.0	.000E+00	.0	.000	48.5	26.6
		PRECIPITATION	14.3	.7	.514E+02	100.0	.500	25.0	30.0
		TRIBUTARY INFLOW	2168.5	99.3	.000E+00	.0	.000	141.5	74.3
		***TOTAL INFLOW	2182.9	100.0	.514E+02	100.0	.003	137.3	73.6
		ADVECTIVE OUTFLOW	847.8	38.8	.146E+06	*******	.451	54.7	28.6
		***TOTAL OUTFLOW	847.8	38.8	.146E+06	*******	.451	54.7	28.6
		***RETENTION	1335.1	61.2	.146E+06	*******	.286	.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 -
32.41	.1371	66.5	.0648	15.4433	.6116

BATHTUB Output for 2001 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

CASE: Dutchman 2001 - No Calibration (sed 440)

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	53.6	.33	84.0	.45	.64	-1.35	-1.67	-.80
CHL-A	MG/M3	27.1	.62	35.5	.45	.76	-.43	-.78	-.35
SECCHI	M	.8	.28	.6	.36	1.16	.53	.52	.32
ORGANIC N	MG/M3	.0	.00	1015.1	.36	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	74.5	.38	.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	50.8	.64	51.6	.46	.98	-.02	-.06	-.02
CHL-A	MG/M3	26.8	.68	17.7	.56	1.51	.61	1.20	.47
SECCHI	M	.9	.44	1.1	.59	.80	-.49	-.78	-.30
ORGANIC N	MG/M3	.0	.00	598.3	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	39.1	.39	.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	72.0	1.06	41.8	.45	1.72	.51	2.02	.47
CHL-A	MG/M3	32.8	.53	17.9	.57	1.83	1.14	1.74	.78
SECCHI	M	.9	.33	1.3	.64	.67	-1.22	-1.45	-.56
ORGANIC N	MG/M3	.0	.00	588.1	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	34.8	.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	60.1	.74	60.0	.45	1.00	.00	.01	.00
CHL-A	MG/M3	29.3	.59	24.5	.45	1.19	.30	.51	.24
SECCHI	M	.8	.34	1.0	.42	.82	-.59	-.72	-.37
ORGANIC N	MG/M3	.0	.00	751.3	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	50.8	.40	.00	.00	.00	.00

CASE: Dutchman 2001 - No Calibration (sed 440)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	1.930	.000E+00	.000	.219
2	1	Tributary 2	17.440	3.770	.000E+00	.000	.216
3	1	Tributary 3	.490	.130	.000E+00	.000	.265
4	1	Tributary 4	2.440	.560	.000E+00	.000	.230
PRECIPITATION			.478	.403	.649E-02	.200	.843
TRIBUTARY INFLOW			29.170	6.390	.000E+00	.000	.219
***TOTAL INFLOW			29.648	6.793	.649E-02	.012	.229
ADVECTIVE OUTFLOW			29.648	6.390	.211E-01	.023	.216
***TOTAL OUTFLOW			29.648	6.390	.211E-01	.023	.216
***EVAPORATION			.000	.402	.146E-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	Tributary 1	300.5	40.3	.000E+00	.0	.000	155.7	34.1
2	1	Tributary 2	400.4	53.7	.000E+00	.0	.000	106.2	23.0
3	1	Tributary 3	.0	.0	.000E+00	.0	.000	.0	.0
4	1	Tributary 4	29.8	4.0	.000E+00	.0	.000	53.2	12.2
PRECIPITATION			14.3	1.9	.514E+02	100.0	.500	35.6	30.0
TRIBUTARY INFLOW			730.7	98.1	.000E+00	.0	.000	114.3	25.0
***TOTAL INFLOW			745.0	100.0	.514E+02	100.0	.010	109.7	25.1
ADVECTIVE OUTFLOW			267.4	35.9	.145E+05	28277.9	.451	41.8	9.0
***TOTAL OUTFLOW			267.4	35.9	.145E+05	28277.9	.451	41.8	9.0
***RETENTION			477.6	64.1	.146E+05	28318.1	.253	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
13.37	.2879	60.1	.1486	6.7317	.6411

2001 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

CASE: Dutchman 2001 - No Calib (sed 616)

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	53.6	.33	101.2	.45	.53	-1.91	-2.36	-1.13
CHL-A	MG/M3	27.1	.62	40.1	.42	.68	-.63	-1.13	-.52
SECCHI	M	.8	.28	.6	.33	1.24	.79	.78	.51
ORGANIC N	MG/M3	.0	.00	1120.3	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	82.7	.36	.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	50.8	.64	59.6	.46	.85	-.25	-.60	-.20
CHL-A	MG/M3	26.8	.68	19.6	.55	1.37	.46	.90	.36
SECCHI	M	.9	.44	1.0	.55	.85	-.38	-.60	-.24
ORGANIC N	MG/M3	.0	.00	641.5	.35	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	42.5	.37	.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	72.0	1.06	47.2	.45	1.53	.40	1.57	.37
CHL-A	MG/M3	32.8	.53	19.8	.55	1.65	.95	1.45	.66
SECCHI	M	.9	.33	1.3	.59	.71	-1.03	-1.23	-.51
ORGANIC N	MG/M3	.0	.00	631.3	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	38.1	.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	60.1	.74	70.4	.45	.85	-.21	-.58	-.18
CHL-A	MG/M3	29.3	.59	27.4	.43	1.07	.11	.19	.09
SECCHI	M	.8	.34	1.0	.40	.87	-.41	-.50	-.27
ORGANIC N	MG/M3	.0	.00	817.8	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	55.9	.38	.00	.00	.00	.00

CASE: Dutchman 2001 - No Calib (sed 616)

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	1.930	.000E+00	.000	.219
2	1	Tributary 2	17.440	3.770	.000E+00	.000	.216
3	1	Tributary 3	.490	.130	.000E+00	.000	.265
4	1	Tributary 4	2.440	.560	.000E+00	.000	.230
PRECIPITATION			.478	.403	.649E-02	.200	.843
TRIBUTARY INFLOW			29.170	6.390	.000E+00	.000	.219
***TOTAL INFLOW			29.648	6.793	.649E-02	.012	.229
ADVECTIVE OUTFLOW			29.648	6.390	.211E-01	.023	.216
***TOTAL OUTFLOW			29.648	6.390	.211E-01	.023	.216
***EVAPORATION			.000	.402	.146E-01	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

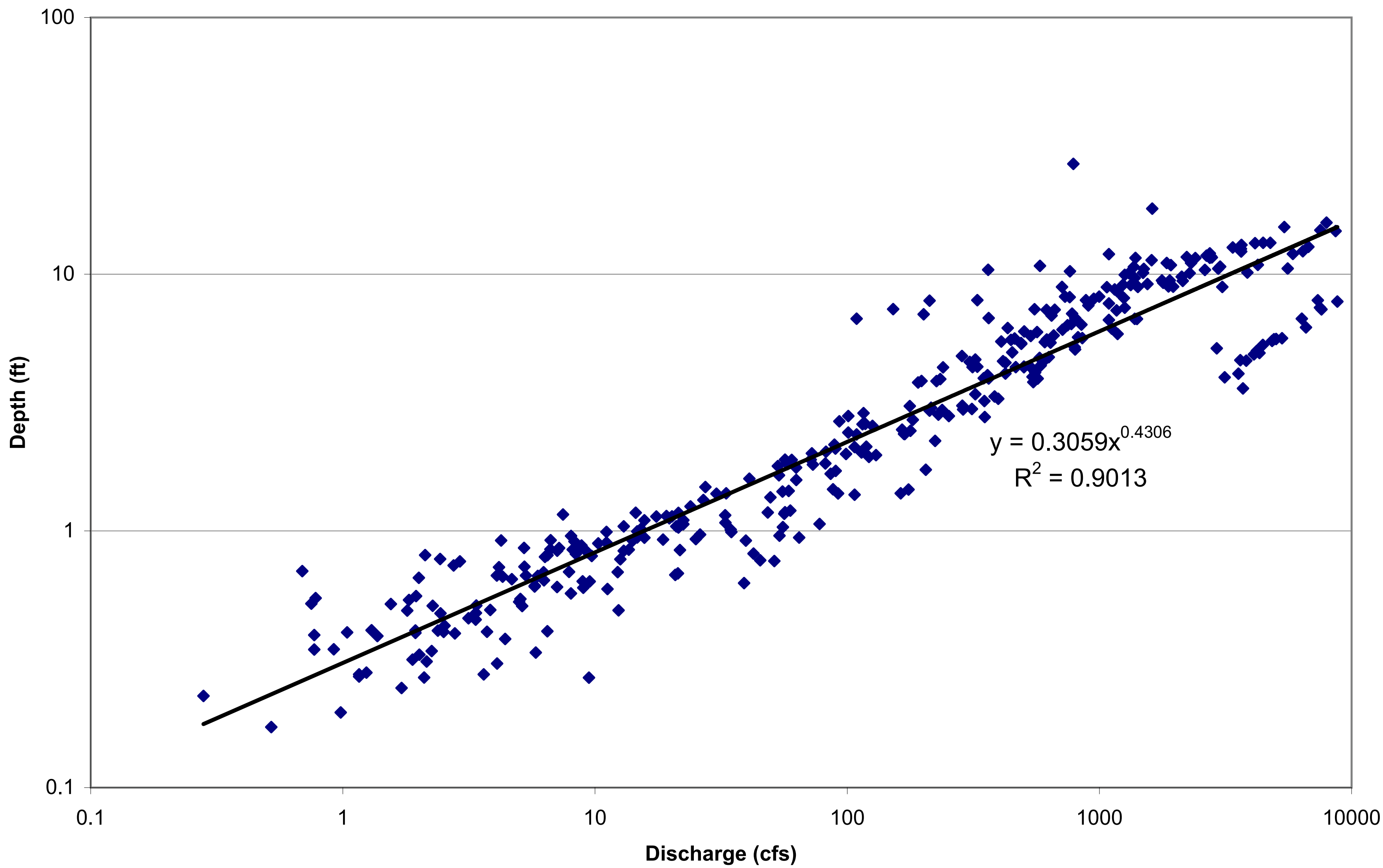
COMPONENT: TOTAL P

ID	T	LOCATION	LOADING KG/YR	%(I)	VARIANCE KG/YR**2	%(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Tributary 1	400.7	41.9	.000E+00	.0	.000	207.6	45.5
2	1	Tributary 2	500.3	52.4	.000E+00	.0	.000	132.7	28.7
3	1	Tributary 3	5.1	.5	.000E+00	.0	.000	39.2	10.4
4	1	Tributary 4	34.8	3.6	.000E+00	.0	.000	62.1	14.3
PRECIPITATION			14.3	1.5	.514E+02	100.0	.500	35.6	30.0
TRIBUTARY INFLOW			940.8	98.5	.000E+00	.0	.000	147.2	32.3
***TOTAL INFLOW			955.2	100.0	.514E+02	100.0	.008	140.6	32.2
ADVECTIVE OUTFLOW			301.4	31.6	.185E+05	35967.1	.451	47.2	10.2
***TOTAL OUTFLOW			301.4	31.6	.185E+05	35967.1	.451	47.2	10.2
***RETENTION			653.8	68.4	.185E+05	36012.9	.208	.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 -
13.37	.2879	60.1	.1159	8.6305	.6844

Appendix H
Rating Curves for Stream Depth

Depth Rating Curve for Dutchman Creek Segment ADD02



measurement_dt	channel_wi	xsec_area_	velocity_va	discharge_	Depth
19d	12s	12s	12s	12s	
4/1/1933	450	1850	1.93	3560	4.099021
3/15/1935	456	2100	1.82	3820	4.602853
1/15/1937	465	3400	2.24	7600	7.296467
1/16/1937	156	2300	3.76	8640	14.72995
1/18/1937	459	2590	2.05	5300	5.632605
1/19/1937	451	2390	1.86	4450	5.304818
4/10/1942	466	2180	1.68	3620	4.623953
3/20/1943	468	3360	2.16	7490	7.409386
3/20/1943	467	3390	1.99	7350	7.908924
3/21/1943	483	3240	1.96	6350	6.707652
3/22/1943	489	2700	1.8	4840	5.49875
3/22/1943	491	2430	1.78	4310	4.931463
3/23/1943	480	1910	1.65	3140	3.964646
4/12/1944	484	2440	1.73	4210	5.027946
2/27/1945	229	1170	2.48	2920	5.141569
3/9/1945	464	2590	1.9	4920	5.580762
4/17/1945	465	2600	1.93	5020	5.593626
1/5/1950	510	3990	2.2	8780	7.825312
1/8/1950	492	2400	1.71	4100	4.873294
4/5/1950	506	3090	2.1	6590	6.201769
1/24/1951	143	1680	1.65	2770	11.73978
2/22/1951	483	1730	2.14	3710	3.589327
4/6/1957	177	2350	2.03	4760	13.24761
4/8/1957	151	1900	1.92	3640	12.55519
11/15/1957	146	1660	1.62	2740	11.58464
3/20/1963	149	1940	1.89	3660	12.9967
3/10/1964	187	2780	2.71	7520	14.83908
3/11/1964	186	2950	2.69	7950	15.8892
6/25/1969	146	1790	2.04	3650	12.2549
1/14/1972	56	162	0.72	116	2.876984
2/25/1972	80	836	1.84	1490	10.12228
2/29/1972	62	498	1.51	762	8.139286
3/2/1972	92	928	2.1	1790	9.26501
3/8/1972	59	429	1.55	665	7.271733
4/25/1972	63	634	2.06	1310	10.09401
5/25/1972	20	13.8	0.57	7.89	0.692105
6/5/1972	11.5	7.73	0.69	5.32	0.670447
7/6/1972	20	13.8	0.89	12.3	0.691011
8/10/1972	19.5	12.5	0.72	8.93	0.63604
9/15/1972	9.3	3.81	0.51	1.94	0.409024
10/3/1972	23	19.3	1.12	21.7	0.842391
11/9/1972	59	428	1.44	617	7.262241
12/6/1972	53.5	205	0.96	197	3.83567
12/20/1972	66	670	1.82	1390	11.57176
1/4/1973	64.5	687	1.99	1370	10.67352
1/10/1973	55	264	1.08	285	4.79798
2/5/1973	54.5	253	1.27	322	4.652171
3/11/1973	75	828	2.23	1850	11.06129
4/5/1973	61.5	539	1.48	1090	11.97539

5/1/1973	59.5	436	1.34	711	8.917597
6/4/1973	62	490	1.8	884	7.921147
7/6/1973	18.5	11.7	0.81	9.52	0.635302
8/8/1973	18.5	12.3	0.48	5.93	0.667793
9/28/1973	4.9	1.93	0.4	0.77	0.392857
10/2/1973	18	15.5	0.56	8.67	0.860119
11/16/1973	11.5	4.68	0.54	2.51	0.404187
12/7/1973	60	334	1.34	446	5.547264
1/25/1974	66	631	1.92	1260	9.943182
2/12/1974	52	147	0.85	115	2.60181
3/7/1974	61	443	1.82	779	7.016754
4/2/1974	66	305	1.14	328	4.359383
5/15/1974	64	605	2.13	1240	9.096244
6/13/1974	54	180	1.07	177	3.063344
7/17/1974	25	23.2	0.29	6.67	0.92
8/8/1974	22.5	18.9	0.17	2.91	0.760784
9/5/1974	61	302	1.49	451	4.962042
10/3/1974	38	44.8	1.08	48.4	1.179337
11/27/1974	61	346	1.5	490	5.355191
12/5/1974	54	145	0.91	126	2.564103
1/9/1975	60	287	1.51	415	4.580574
2/6/1975	63	494	1.9	904	7.552214
2/26/1975	94	1130	2.42	2740	12.04501
3/6/1975	59	276	1.14	306	4.549509
3/31/1975	179	2460	1.98	5410	15.26438
4/4/1975	72	793	1.25	1620	18
4/9/1975	61	528	0.48	788	26.91257
5/30/1975	31	31.4	1.1	34.5	1.01173
6/18/1975	34	40.3	1.41	56.7	1.182728
7/10/1975	32	38.5	1.55	59.5	1.199597
7/17/1975	20.5	17.4	0.47	8.15	0.845874
8/14/1975	27	25.2	1	25.1	0.92963
10/3/1975	19.5	15.3	0.41	6.33	0.791745
11/25/1975	27	30.5	0.57	17.5	1.137102
12/31/1975	65	577	1.85	1070	8.898129
1/16/1976	52	198	0.97	191	3.786677
1/21/1976	42	60.9	1.44	87.8	1.45172
2/11/1976	38	53.2	1.73	92	1.399452
3/3/1976	42	72.7	2.82	205	1.730834
3/24/1976	72	404	1.14	461	5.616472
5/3/1976	34.5	40.3	1.4	56.3	1.165631
6/16/1976	57	328	1.63	534	5.747498
7/27/1976	23	13.7	0.82	11.2	0.593849
9/1/1976	9.2	4.54	0.4	1.8	0.48913
10/6/1976	15.5	12.4	0.17	2.12	0.804554
11/10/1976	15.5	7.48	0.33	2.44	0.477028
12/28/1976	12	6.14	0.55	3.38	0.512121
1/19/1977	14	7.18	0.72	5.14	0.509921
2/23/1977	21.5	14.7	1.45	21.3	0.68324
3/18/1977	57	308	1.59	489	5.395564
3/29/1977	182	2180	2.68	5850	11.9936

4/27/1977	58	346	1.45	503	5.980975
5/23/1977	24.5	16.5	1.26	20.8	0.673793
6/22/1977	11	4.22	0.32	1.37	0.389205
7/21/1977	11.2	4.61	0.52	2.38	0.408654
8/23/1977	28.5	22.3	0.57	12.6	0.775623
9/22/1977	38	43.8	0.75	32.8	1.150877
10/5/1977	28	41.4	0.66	27.4	1.482684
11/15/1977	13	13.2	1.15	15.2	1.016722
12/12/1977	60	413	1.56	646	6.901709
2/1/1978	32	30.2	2.14	64.5	0.941881
2/24/1978	37	51.1	2.09	107	1.38368
3/9/1978	68	656	2.1	1380	9.663866
3/30/1978	75	480	1.01	553	7.30033
5/3/1978	33	25.2	2.04	51.4	0.763518
6/21/1978	15.5	6.23	0.45	2.78	0.398566
8/1/1978	14	3.81	0.3	1.16	0.27619
9/7/1978	28	22.9	1.86	42.5	0.816052
10/4/1978	9.5	3.86	0.97	3.73	0.404775
11/9/1978	8.5	3.4	0.57	1.94	0.400413
12/14/1978	57	310	1.31	408	5.464042
1/31/1979	58	357	1.21	433	6.169849
3/2/1979	135	1202	2.55	3070	8.917938
3/14/1979	60	475	0.69	328	7.922705
4/3/1979	178	1870	2.98	5580	10.51957
5/2/1979	58	345	1.64	566	5.950378
6/14/1979	13	7.84	1.15	8.98	0.600669
8/7/1979	15.3	6.23	1.04	6.47	0.406611
10/10/1979	14.8	9.53	0.66	6.27	0.641892
11/14/1979	30	23.1	1.96	45.2	0.768707
12/11/1979	34	35.2	1.58	55.6	1.034996
2/7/1980	30	27.4	1.44	39.6	0.916667
3/10/1980	40	57.7	3.02	175	1.448675
4/21/1980	50	190	1.18	226	3.830508
6/2/1980	27	21.6	0.45	9.7	0.798354
7/15/1980	16	9.71	0.59	5.77	0.611229
8/18/1980	35	21.9	1.78	39	0.626003
10/1/1980	15	7.2	0.46	3.15	0.456522
10/3/1980	4.6	358	0.68	2.43	0.776854
11/12/1980	2.4	0.83	0.93	0.77	0.344982
12/8/1980	15.4	11.2	0.47	5.25	0.725338
1/15/1981	14.4	5.96	0.22	1.3	0.410354
2/12/1981	57	172	1.25	215	3.017544
2/26/1981	17.4	19.2	1.17	22.4	1.100305
3/26/1981	32	15.8	0.79	12.4	0.490506
4/29/1981	16.2	14.8	0.95	14.1	0.916179
5/14/1981	65	580	2.45	1420	8.916797
5/19/1981	63	683	2.81	1920	10.84562
6/3/1981	58	288	2.26	598	4.562099
7/13/1981	56	166	1.73	288	2.97275
8/25/1981	17.3	17.8	1.2	21.4	1.030829
10/5/1981	4.6	249	0.31	0.78	0.546985

11/13/1981	19.7	13.6	0.46	6.25	0.689693
12/7/1981	20.1	18.9	0.83	15.7	0.941078
1/19/1982	29	28	0.93	26.1	0.967742
2/22/1982	59	257	1.95	502	4.36332
3/3/1982	41	87.2	1.23	107	2.121753
4/5/1982	68	367	1.74	640	5.40906
6/8/1982	53	150	1.53	230	2.836355
7/16/1982	37	65.2	0.96	62.7	1.765203
9/2/1982	57	310	1.96	607	5.433226
10/13/1982	53	208	1.67	348	3.931759
11/23/1982	53	208	1.75	364	3.924528
11/24/1982	56	323	2.04	659	5.768557
12/6/1982	178	2190	2.93	6410	12.29052
12/14/1982	54	218	1.65	360	4.040404
1/14/1983	41	98.8	1.02	101	2.415112
2/22/1983	36.5	68.9	0.82	56.7	1.89442
3/28/1983	61	499	2	998	8.180328
5/6/1983	144	1460	2.64	3860	10.15362
5/23/1983	79	828	1.81	1500	10.49024
6/28/1983	75	674	2.09	1410	8.995215
7/29/1983	16.8	19.2	1	19.2	1.142857
9/7/1983	11.1	2.19	0.45	0.98	0.196196
10/4/1983	16	7.66	0.44	3.37	0.478693
11/21/1983	56	244	1.29	314	4.346622
1/16/1984	33.5	32.1	1.68	53.9	0.957711
2/14/1984	63	539	2.19	1180	8.552584
3/16/1984	73	590	2.12	1250	8.077022
3/26/1984	68	432	1.96	848	6.362545
5/9/1984	78	706	1.88	1330	9.069831
5/17/1984	64	505	0.42	212	7.886905
6/18/1984	21	20.8	1.67	34.7	0.98945
7/25/1984	16	4.85	0.84	4.09	0.304315
9/5/1984	14	3.45	0.5	1.71	0.244286
10/10/1984	21	17.5	0.74	13	0.836551
11/20/1984	59	358	1.99	714	6.081254
1/14/1985	54	160	1.49	238	2.957992
2/12/1985	64	557	2.06	1150	8.722694
3/25/1985	43	112	1.05	118	2.613511
5/1/1985	73	667	2.32	1550	9.152102
6/12/1985	65	500	2.18	1090	7.692308
7/22/1985	19	12.4	0.38	4.68	0.648199
9/4/1985	52	129	1.28	165	2.478966
10/30/1985	59	377	2.05	774	6.399339
12/4/1985	60	379	1.97	748	6.328257
1/21/1986	51	122	1.39	169	2.383975
3/5/1986	35	66.5	0.91	60.2	1.89011
4/8/1986	53	156	1.36	212	2.941176
5/12/1986	20	22.4	0.88	19.7	1.119318
5/16/1986	88	1040	2.56	2660	11.80753
6/24/1986	20.5	20.4	0.72	14.7	0.995935
8/7/1986	17.2	10.4	0.68	7.07	0.60448

9/4/1986	18	11.9	0.36	4.3	0.66358
10/20/1986	19.5	16.1	0.58	9.33	0.824934
12/2/1986	61	339	1.82	618	5.566565
1/20/1987	41	43.7	1.78	77.7	1.064675
2/19/1987	49	120	1.48	178	2.454495
3/24/1987	54	184	1.75	322	3.407407
5/4/1987	17	23.8	1.39	33.1	1.400762
6/11/1987 9:55	15.8	8.61	0.59	5.06	0.542802
7/22/1987 9:35	17.5	9.25	0.54	5	0.529101
9/2/1987 9:00	4.1	0.94	0.3	0.28	0.227642
10/14/1987 9:15	5.3	0.91	0.57	0.52	0.172128
11/9/1987 10:55	6.3	1.7	0.68	1.16	0.270775
12/16/1987 9:30	51	143	1.77	253	2.802703
1/19/1988 9:35	55	225	1.88	424	4.10058
2/3/1988 9:30	81	725	2.59	1880	8.961342
2/25/1988 9:20	37	87.8	1.24	109	2.375763
3/30/1988 10:20	62	449	2.61	1170	7.230256
3/31/1988 11:20	77	434	1.97	855	5.636495
5/23/1988 11:30	18.5	10.6	0.76	8.02	0.570413
6/9/1988 10:20	13.8	3.82	0.95	3.62	0.276125
6/20/1988 9:30	7.4	2.34	0.81	1.89	0.315315
7/19/1988 10:25	22.6	21.3	0.69	14.7	0.94267
8/8/1988 13:25	17	5.68	1.02	5.82	0.33564
8/29/1988 11:25	12.5	6.98	0.28	1.95	0.557143
9/20/1988 11:15	21.5	30.6	1.81	55.4	1.423616
10/14/1988 10:35	6.7	2.08	0.66	1.24	0.280416
11/18/1988 11:05	21	34.6	1.55	53.6	1.646697
1/4/1989 10:00	56	264	2.19	579	4.721135
2/14/1989 10:30	86	951	2.43	2310	11.05369
4/4/1989 11:35	84	847	2.69	2280	10.09028
5/25/1989 10:10	17	22.5	1.2	26.9	1.318627
6/15/1989 15:10	53	239	1.77	424	4.519774
6/20/1989 10:50	57	247	2.03	502	4.338432
7/26/1989 10:45	16.8	13.4	0.48	6.48	0.803571
8/3/1989 9:45	14.5	5.46	0.8	4.4	0.37931
9/12/1989 12:00	28	7.5	1.26	9.46	0.268141
10/5/1989 10:05	7	2.41	0.38	0.92	0.345865
11/21/1989 10:50	12	8.7	0.79	5.76	0.607595
12/20/1989 13:00	10.5	6.93	0.29	2	0.656814
1/10/1990 11:10	21	21.8	0.96	21	1.041667
2/23/1990 11:00	68	458	1.75	802	6.739496
4/9/1990 13:00	37	80	1.11	89	2.167032
5/30/1990 13:00	84	873	3	2620	10.39683
6/22/1990 12:15	15.6	16.8	1.96	32.9	1.076007
8/1/1990 8:45	19	17.4	0.48	8.29	0.908991
9/5/1990 10:00	9.5	2.95	0.73	2.15	0.310022
10/15/1990 11:50	19.5	22.2	0.91	20.2	1.138349
11/27/1990 9:40	19	23.7	1.01	23.9	1.24544
12/21/1990 12:45	65	614	2.88	1770	9.455128
1/2/1991 12:45	88	1020	2.36	2400	11.55624
3/12/1991 9:45	22	44.9	1.84	82.4	2.035573

5/10/1991 10:30	35	56.8	1.47	85.9	1.669582
7/2/1991 9:20	20.3	17.2	0.3	5.23	0.858785
8/27/1991 8:50	6.1	2.01	1	2.01	0.329508
10/1/1991 9:50	7.6	2.59	0.87	2.25	0.34029
11/18/1991 10:20	7.9	3.39	0.75	2.53	0.427004
11/21/1991 8:15	58	252	1.85	466	4.342964
1/15/1992 11:20	55	237	2.27	538	4.309171
3/10/1992 10:40	21.5	40.7	1.76	71.7	1.89482
3/10/1992 12:45	21.5	43	1.68	72.4	2.00443
3/23/1992 12:30	54	180	2.13	384	3.33855
5/5/1992 9:10	21	33.4	1.22	40.9	1.596409
6/29/1992 11:10	24	19.6	0.43	8.39	0.812984
8/25/1992 8:50	20	23.5	0.91	21.4	1.175824
10/1/1992 8:45	21	23	0.68	15.7	1.09944
11/19/1992 13:00	29	53.1	1.08	57.5	1.835888
1/12/1993 12:55	55	261	2.41	630	4.752923
3/12/1993 13:30	50	154	1.86	286	3.075269
5/17/1993 11:55	26	47.7	1.72	81.9	1.831395
6/28/1993 10:35	50	149	2.09	312	2.985646
8/30/1993 11:40	22	19.9	0.21	4.24	0.917749
10/6/1993 12:45	28	50.2	1.06	53.1	1.789084
12/10/1993 13:02	51	167	2.38	397	3.27072
2/17/1994 11:55	53	148	0.68	101	2.802442
3/7/1994 15:25	52	138	0.67	93.1	2.672216
3/17/1994 13:00	55	212	1.09	234	3.903253
3/23/1994 12:55	40	95.5	1.76	168	2.386364
4/19/1994 10:30	62	420	0.87	364	6.748239
5/9/1994 11:20	40	108	1.68	182	2.708333
7/18/1994 13:30	20	19.7	0.56	11.1	0.991071
9/26/1994 11:35	17	9.11	0.2	1.83	0.538235
10/25/1994 10:45	18	15.2	0.47	7.08	0.836879
11/22/1994 10:55	58	161	2.18	351	2.77602
1/11/1995 9:50	26	55.1	2.15	119	2.128801
3/10/1995 9:45	66	442	3.12	1380	6.701632
5/20/1995 12:20	99	1060	2.84	3010	10.70565
5/24/1995 13:30	60	491	1.49	731	8.176734
5/31/1995 13:50	65	472	0.32	152	7.307692
7/18/1995 8:52	18	16.2	0.64	10.3	0.894097
9/1/1995 8:22	3.9	1.92	2	3.84	0.492308
10/4/1995 14:20	16.5	12.1	0.06	0.69	0.69697
10/31/1995 9:51	3.6	1.87	0.83	1.55	0.518742
11/29/1995 9:28	4.6	2.07	1.62	3.36	0.450886
1/4/1996 11:20	36	71	1.83	130	1.973285
1/16/1996 10:25	32	63.8	1.55	98.9	1.993952
1/24/1996 7:40	56		2.37	585	4.407776
2/28/1996 9:15	77	450	2.62	1180	5.849113
3/21/1996 9:50	61	311	2.58	801	5.089592
4/23/1996 9:45	80	753	2.84	2140	9.419014
4/30/1996 9:05	93	976	3.03	2960	10.50428
5/1/1996 7:45	133	1440	2.94	4250	10.86901
5/2/1996 7:15	93	1180	2.86	3380	12.70772

5/7/1996 11:30	88	787	2.49	1960	8.94487
5/16/1996 9:26	79	633	1.5	950	8.016878
5/22/1996 11:15	65	441	0.25	109	6.707692
6/19/1996 8:30	48.9	68.5	2.38	163	1.40056
6/27/1996 10:00	20.1	21.3	1.05	22.4	1.06136
7/11/1996 12:35	28	23.8	0.3	7.2	0.857143
8/19/1996 10:52	8.6	1.91	0.91	2.1	0.268336
10/2/1996 10:20	26.8	24.1	0.46	11.1	0.900389
11/20/1996 10:39	22.1	20.4	0.91	18.6	0.924867
1/21/1997 10:45	45	195	1.23	240	4.336043
3/6/1997 11:15	85	966	1.67	1610	11.34202
3/9/1997 13:10	83	897	0.65	581	10.76923
3/11/1997 10:33	93	954	0.8	764	10.26882
3/13/1997 10:15	87	907	0.4	362	10.4023
3/17/1997 9:45	87	862	1.65	561	3.908046
3/19/1997 9:45	86	972	2.45	1410	6.691979
3/27/1997 9:05	60	418	0.48	201	6.979167
4/28/1997 9:00	50	112	1.99	223	2.241206
6/2/1997 13:00	93	1230	3.37	4140	13.20953
6/3/1997 11:30	102	1350	3.3	4460	13.25015
6/18/1997 12:45	52	167	2.1	350	3.205128
7/22/1997 12:00	34	46	1.08	49.6	1.350763
8/25/1997 13:15	24	21.2	0.42	8.84	0.876984
10/14/1997 11:10	11.7	6.02	0.38	2.27	0.510571
12/3/1997 12:10	30	62.6	1.43	89.8	2.09324
1/21/1998 12:55	34	53.8	1.17	62.8	1.578683
3/12/1998 10:10	39	75.7	1.61	122	1.942985
4/20/1998 11:50	69	391	2.1	823	5.679779
5/7/1998 11:30	87	821	2.31	1900	9.454147
6/18/1998 10:50	55	228	2.44	556	4.14307
6/30/1998 12:15	71	435	2.57	1120	6.137995
8/28/1998 11:10	23	27	0.28	7.46	1.158385
10/14/1998 10:40	28	26.8	0.3	8.03	0.955952
12/3/1998 11:30	28	32.8	0.44	14.5	1.176948
1/22/1999 16:30	92	1070	2.07	2220	11.65721
1/26/1999 10:05	100	1160	2.4	2790	11.625
3/8/1999 11:55	55	219	2.48	543	3.980938
6/3/1999 11:15	61	239	2.38	569	3.919273
8/2/1999 13:30	16	11.4	0.36	4.16	0.722222
9/3/1999 10:55	8	4.26	0.18	0.75	0.520833
10/13/1999 14:50	23	19.4	0.7	13.6	0.84472
12/6/1999 11:30	15	10.8	0.25	2.75	0.733333
1/7/2000 12:40	65	481	2.62	1260	7.398708
1/24/2000 11:05	31	43.2	0.7	30.3	1.396313
4/4/2000 14:15	28	50.6	1.44	73.1	1.812996
5/31/2000 14:20	60	311	2.56	798	5.195313
8/2/2000 10:50	36	61.7	1.46	90	1.712329
10/18/2000 12:55	7.6	3.02	0.34	1.04	0.402477
12/6/2000 12:30	24	24.9	0.52	13	1.041667
1/19/2001 13:05	31	62.6	1.82	114	2.02056
3/5/2001 11:45	55	209	2.62	547	3.795975

4/18/2001 12:55	32	45.9	1.28	58.6	1.430664
7/6/2001 11:05	14.5	9.8	0.42	4.08	0.669951
8/7/2001 15:00	14	11.9	0.56	6.65	0.848214
10/15/2001 13:30	60	397	2.74	1090	6.63017
11/28/2001 13:30	80	780	2.71	2120	9.778598
12/18/2001 15:30	180	2300	2.93	6740	12.77967
2/19/2002 13:30	27	49.2	1.18	58	1.820465

#
Surface water measurements
#
Further descriptions of the columns and codes used can be found at:
http://water.usgs.gov/nwis/help?streamflow_measurements_data
#
Stations in this file include:
USGS 03612000 CACHE RIVER AT FORMAN, IL
#
#

site_no	agency_cd	measurem	measurem	party_nm	channel_w	xsec_area_	velocity_va	inside_gag
15s	5s	5s	19d	12s	12s	12s	12s	12s
3612000	USGS	34	4/1/1933	??C	450	1850	1.93	
3612000	USGS	46	3/15/1935	??C	456	2100	1.82	
3612000	USGS	61	1/15/1937	HGS	465	3400	2.24	
3612000	USGS	62	1/16/1937	HGS	156	2300	3.76	
3612000	USGS	63	1/18/1937	HGS	459	2590	2.05	
3612000	USGS	64	1/19/1937	HGS	451	2390	1.86	
3612000	USGS	116	4/10/1942	??S	466	2180	1.68	
3612000	USGS	124	3/20/1943	??O	468	3360	2.16	
3612000	USGS	125	3/20/1943	??M/??O	467	3390	1.99	
3612000	USGS	126	3/21/1943	??O/??M	483	3240	1.96	
3612000	USGS	127	3/22/1943	??M/??O	489	2700	1.8	
3612000	USGS	128	3/22/1943	??M/??O	491	2430	1.78	
3612000	USGS	129	3/23/1943	??M/??O	480	1910	1.65	
3612000	USGS	136	4/12/1944	JMB	484	2440	1.73	
3612000	USGS	141	2/27/1945	JMB	229	1170	2.48	
3612000	USGS	142	3/9/1945	JMS	464	2590	1.9	
3612000	USGS	143	4/17/1945	JMS	465	2600	1.93	
3612000	USGS	189	1/5/1950	??W	510	3990	2.2	
3612000	USGS	190	1/8/1950	??C	492	2400	1.71	
3612000	USGS	192	4/5/1950	??W	506	3090	2.1	
3612000	USGS	280	1/24/1951	MWP	143	1680	1.65	
3612000	USGS	199	2/22/1951	??S/??W	483	1730	2.14	
3612000	USGS	255	4/6/1957	RLS/JWS	177	2350	2.03	
3612000	USGS	256	4/8/1957	RLS/JWS	151	1900	1.92	
3612000	USGS	264	########	MWP	146	1660	1.62	
3612000	USGS	328	3/20/1963	??S/??E	149	1940	1.89	
3612000	USGS	340	3/10/1964	??S/??M	187	2780	2.71	
3612000	USGS	341	3/11/1964	??S/??M	186	2950	2.69	
3612000	USGS	405	6/25/1969	MWP	146	1790	2.04	
3612000	USGS	440	1/14/1972	/	56	162	0.72	4.7
3612000	USGS	441	2/25/1972	/	80	836	1.84	15.46
3612000	USGS	442	2/29/1972	/	62	498	1.51	10.92
3612000	USGS	443	3/2/1972	/	92	928	2.1	16.94
3612000	USGS	444	3/8/1972	/	59	429	1.55	10.03
3612000	USGS	445	4/25/1972	/	63	634	2.06	13.4
3612000	USGS	446	5/25/1972	/	20	13.8	0.57	3.06
3612000	USGS	447	6/5/1972	/	11.5	7.73	0.69	2.38
3612000	USGS	448	7/6/1972	/	20	13.8	0.89	2.8
3612000	USGS	449	8/10/1972	/	19.5	12.5	0.72	2.3

3612000	USGS	450	9/15/1972	/	9.3	3.81	0.51	2.08
3612000	USGS	451	10/3/1972	/	23	19.3	1.12	2.83
3612000	USGS	452	11/9/1972	/	59	428	1.44	9.96
3612000	USGS	453	12/6/1972	/	53.5	205	0.96	6
3612000	USGS	454	########	/	66	670	1.82	13.94
3612000	USGS	455	1/4/1973	/	64.5	687	1.99	14
3612000	USGS	456	1/10/1973	/	55	264	1.08	6.96
3612000	USGS	457	2/5/1973	/	54.5	253	1.27	6.93
3612000	USGS	458	3/11/1973	/	75	828	2.23	15.67
3612000	USGS	459	4/5/1973	/	61.5	539	1.48	11.79
3612000	USGS	460	5/1/1973	/	59.5	436	1.34	10.13
3612000	USGS	461	6/4/1973	/	62	490	1.8	10.72
3612000	USGS	462	7/6/1973	/	18.5	11.7	0.81	2.69
3612000	USGS	463	8/8/1973	/	18.5	12.3	0.48	2.32
3612000	USGS	464	9/28/1973	/	4.9	1.93	0.4	2.18
3612000	USGS	465	10/2/1973	/	18	15.5	0.56	2.71
3612000	USGS	466	########	/	11.5	4.68	0.54	2.35
3612000	USGS	467	12/7/1973	/	60	334	1.34	8.5
3612000	USGS	468	1/25/1974	/	66	631	1.92	12.92
3612000	USGS	469	2/12/1974	/	52	147	0.85	4.9
3612000	USGS	470	3/7/1974	/	61	443	1.82	10.16
3612000	USGS	471	4/2/1974	/	66	305	1.14	7.34
3612000	USGS	472	5/15/1974	/	64	605	2.13	12.71
3612000	USGS	473	6/13/1974	/	54	180	1.07	5.58
3612000	USGS	474	7/17/1974	/	25	23.2	0.29	3.09
3612000	USGS	475	8/8/1974	/	22.5	18.9	0.17	2.16
3612000	USGS	476	9/5/1974	/	61	302	1.49	7.68
3612000	USGS	477	10/3/1974	/	38	44.8	1.08	3.8
3612000	USGS	478	########	/	61	346	1.5	8.31
3612000	USGS	479	12/5/1974	/	54	145	0.91	4.95
3612000	USGS	480	1/9/1975	/	60	287	1.51	7.64
3612000	USGS	481	2/6/1975	/	63	494	1.9	10.74
3612000	USGS	482	2/26/1975	/	94	1130	2.42	18.62
3612000	USGS	483	3/6/1975	/	59	276	1.14	6.99
3612000	USGS	484	3/31/1975	/	179	2460	1.98	24.53
3612000	USGS	485	4/4/1975	/	72	793	1.25	15.24
3612000	USGS	486	4/9/1975	/	61	528	0.48	11.4
3612000	USGS	487	5/30/1975	/	31	31.4	1.1	4.02
3612000	USGS	488	6/18/1975	/	34	40.3	1.41	4.89
3612000	USGS	489	7/10/1975	/	32	38.5	1.55	4.39
3612000	USGS	490	7/17/1975	/	20.5	17.4	0.47	2.89
3612000	USGS	491	8/14/1975	/	27	25.2	1	3.4
3612000	USGS	492	10/3/1975	/	19.5	15.3	0.41	3.25
3612000	USGS	493	########	/	27	30.5	0.57	3.98
3612000	USGS	494	########	/	65	577	1.85	12.29
3612000	USGS	495	1/16/1976	/	52	198	0.97	6.04
3612000	USGS	496	1/21/1976	/	42	60.9	1.44	4.74
3612000	USGS	497	2/11/1976	/	38	53.2	1.73	4.47
3612000	USGS	498	3/3/1976	/	42	72.7	2.82	6.04
3612000	USGS	499	3/24/1976	/	72	404	1.14	8
3612000	USGS	500	5/3/1976	/	34.5	40.3	1.4	3.83

3612000	USGS	501	6/16/1976	/	57	328	1.63	8.38
3612000	USGS	502	7/27/1976	/	23	13.7	0.82	2.64
3612000	USGS	503	9/1/1976	/	9.2	4.54	0.4	2.08
3612000	USGS	504	10/6/1976	/	15.5	12.4	0.17	2.42
3612000	USGS	505	########	/	15.5	7.48	0.33	2.95
3612000	USGS	506	########	/	12	6.14	0.55	2.64
3612000	USGS	507	1/19/1977	/	14	7.18	0.72	2.93
3612000	USGS	508	2/23/1977	/	21.5	14.7	1.45	3.36
3612000	USGS	509	3/18/1977	/	57	308	1.59	7.95
3612000	USGS	510	3/29/1977	/	182	2180	2.68	25.4
3612000	USGS	511	4/27/1977	/	58	346	1.45	8.32
3612000	USGS	512	5/23/1977	/	24.5	16.5	1.26	2.9
3612000	USGS	513	6/22/1977	/	11	4.22	0.32	1.96
3612000	USGS	514	7/21/1977	/	11.2	4.61	0.52	1.99
3612000	USGS	515	8/23/1977	/	28.5	22.3	0.57	2.47
3612000	USGS	516	9/22/1977	/	38	43.8	0.75	3.16
3612000	USGS	517	10/5/1977	/	28	41.4	0.66	2.96
3612000	USGS	518	########	/	13	13.2	1.15	2.65
3612000	USGS	519	########	/	60	413	1.56	9.67
3612000	USGS	520	2/1/1978	/	32	30.2	2.14	4.4
3612000	USGS	521	2/24/1978	/	37	51.1	2.09	4.98
3612000	USGS	522	3/9/1978	/	68	656	2.1	13.3
3612000	USGS	523	3/30/1978	/	75	480	1.01	8.67
3612000	USGS	524	5/3/1978	/	33	25.2	2.04	3.49
3612000	USGS	525	6/21/1978	/	15.5	6.23	0.45	2
3612000	USGS	526	8/1/1978	/	14	3.81	0.3	1.91
3612000	USGS	527	9/7/1978	/	28	22.9	1.86	3.21
3612000	USGS	528	10/4/1978	/	9.5	3.86	0.97	2.08
3612000	USGS	529	11/9/1978	/	8.5	3.4	0.57	2.44
3612000	USGS	530	########	/	57	310	1.31	7.98
3612000	USGS	531	1/31/1979	/	58	357	1.21	8.78
3612000	USGS	532	3/2/1979	/	135	1202	2.55	19.02
3612000	USGS	533	3/14/1979	/	60	475	0.69	10.56
3612000	USGS	534	4/3/1979	/	178	1870	2.98	23.57
3612000	USGS	535	5/2/1979	/	58	345	1.64	8.38
3612000	USGS	536	6/14/1979	/	13	7.84	1.15	2.9
3612000	USGS	537	8/7/1979	/	15.3	6.23	1.04	2.18
3612000	USGS	538	########	/	14.8	9.53	0.66	2.32
3612000	USGS	539	########	/	30	23.1	1.96	3.28
3612000	USGS	540	########	/	34	35.2	1.58	3.69
3612000	USGS	541	2/7/1980	/	30	27.4	1.44	3.34
3612000	USGS	542	3/10/1980	/	40	57.7	3.02	5.01
3612000	USGS	543	4/21/1980	/	50	190	1.18	5.62
3612000	USGS	544	6/2/1980	/	27	21.6	0.45	2.43
3612000	USGS	545	7/15/1980	/	16	9.71	0.59	1.83
3612000	USGS	546	8/18/1980	/	35	21.9	1.78	2.66
3612000	USGS	547	10/1/1980	/	15	7.2	0.46	1.72
3612000	USGS	548	10/3/1980	/	4.6	358	0.68	1.67
3612000	USGS	549	########	/	2.4	0.83	0.93	1.64
3612000	USGS	550	12/8/1980	/	15.4	11.2	0.47	1.95
3612000	USGS	551	1/15/1981	/	14.4	5.96	0.22	1.61

3612000	USGS	552	2/12/1981	/	57	172	1.25	5.12
3612000	USGS	553	2/26/1981	/	17.4	19.2	1.17	2.32
3612000	USGS	554	3/26/1981	/	32	15.8	0.79	2.01
3612000	USGS	555	4/29/1981	/	16.2	14.8	0.95	2.12
3612000	USGS	556	5/14/1981	/	65	580	2.45	12.17
3612000	USGS	557	5/19/1981	/	63	683	2.81	14.21
3612000	USGS	558	6/3/1981	/	58	288	2.26	7.49
3612000	USGS	559	7/13/1981	/	56	166	1.73	4.84
3612000	USGS	560	8/25/1981	/	17.3	17.8	1.2	2.22
3612000	USGS	561	10/5/1981	/	4.6	249	0.31	1.56
3612000	USGS	562	########	DCV	19.7	13.6	0.46	
3612000	USGS	563	12/7/1981	DCV	20.1	18.9	0.83	
3612000	USGS	564	1/19/1982	JCM/DCV	29	28	0.93	
3612000	USGS	565	2/22/1982	DCV	59	257	1.95	
3612000	USGS	566	3/3/1982	JCM/DCV	41	87.2	1.23	
3612000	USGS	567	4/5/1982	DCV	68	367	1.74	
3612000	USGS	568	6/8/1982	JCM	53	150	1.53	
3612000	USGS	569	7/16/1982	JCM	37	65.2	0.96	
3612000	USGS	570	9/2/1982	JCM	57	310	1.96	
3612000	USGS	571	########	JCM	53	208	1.67	
3612000	USGS	572	########	JCM	53	208	1.75	
3612000	USGS	573	########	JCM	56	323	2.04	
3612000	USGS	574	12/6/1982	JCM	178	2190	2.93	
3612000	USGS	575	########	JCM	54	218	1.65	
3612000	USGS	576	1/14/1983	JCM	41	98.8	1.02	
3612000	USGS	577	2/22/1983	JCM	36.5	68.9	0.82	
3612000	USGS	578	3/28/1983	JCM	61	499	2	
3612000	USGS	579	5/6/1983	JCM	144	1460	2.64	
3612000	USGS	580	5/23/1983	JCM	79	828	1.81	
3612000	USGS	581	6/28/1983	JCM	75	674	2.09	
3612000	USGS	582	7/29/1983	JCM/PJD	16.8	19.2	1	
3612000	USGS	583	9/7/1983	JCM	11.1	2.19	0.45	
3612000	USGS	584	10/4/1983	JCM	16	7.66	0.44	
3612000	USGS	585	########	JCM	56	244	1.29	
3612000	USGS	586	1/16/1984	JDD/JCM	33.5	32.1	1.68	
3612000	USGS	587	2/14/1984	JCM	63	539	2.19	
3612000	USGS	588	3/16/1984	JCM	73	590	2.12	
3612000	USGS	589	3/26/1984	JCM	68	432	1.96	
3612000	USGS	590	5/9/1984	JCM	78	706	1.88	
3612000	USGS	591	5/17/1984	JDD/JCM	64	505	0.42	
3612000	USGS	592	6/18/1984	JCM	21	20.8	1.67	
3612000	USGS	593	7/25/1984	JCM	16	4.85	0.84	
3612000	USGS	594	9/5/1984	JCM	14	3.45	0.5	
3612000	USGS	595	########	JCM	21	17.5	0.74	
3612000	USGS	596	########	JCM	59	358	1.99	
3612000	USGS	597	1/14/1985	JCM	54	160	1.49	
3612000	USGS	598	2/12/1985	JCM	64	557	2.06	
3612000	USGS	599	3/25/1985	JCM	43	112	1.05	
3612000	USGS	600	5/1/1985	JCM	73	667	2.32	
3612000	USGS	601	6/12/1985	JCM	65	500	2.18	
3612000	USGS	602	7/22/1985	JCM	19	12.4	0.38	

3612000	USGS	603	9/4/1985	JCM	52	129	1.28	
3612000	USGS	604	########	JCM	59	377	2.05	
3612000	USGS	605	12/4/1985	JCM/DJS	60	379	1.97	
3612000	USGS	606	1/21/1986	JCM	51	122	1.39	
3612000	USGS	607	3/5/1986	JCM	35	66.5	0.91	
3612000	USGS	608	4/8/1986	JCM	53	156	1.36	
3612000	USGS	609	5/12/1986	JCM	20	22.4	0.88	
3612000	USGS	610	5/16/1986	JCM/DJS	88	1040	2.56	
3612000	USGS	611	6/24/1986	JCM	20.5	20.4	0.72	
3612000	USGS	612	8/7/1986	JCM	17.2	10.4	0.68	
3612000	USGS	613	9/4/1986	JCM	18	11.9	0.36	
3612000	USGS	614	########	JCM	19.5	16.1	0.58	
3612000	USGS	615	12/2/1986	JCM	61	339	1.82	
3612000	USGS	616	1/20/1987	DJS	41	43.7	1.78	
3612000	USGS	617	2/19/1987	JCM	49	120	1.48	
3612000	USGS	618	3/24/1987	JCM	54	184	1.75	
3612000	USGS	619	5/4/1987	JCM	17	23.8	1.39	
3612000	USGS	620	########	JCM	15.8	8.61	0.59	1.14
3612000	USGS	621	########	JCM	17.5	9.25	0.54	1.13
3612000	USGS	622	########	JCM	4.1	0.94	0.3	
3612000	USGS	623	########	JCM	5.3	0.91	0.57	
3612000	USGS	624	########	JCM	6.3	1.7	0.68	
3612000	USGS	625	########	JCM	51	143	1.77	
3612000	USGS	626	########	JCM	55	225	1.88	
3612000	USGS	627	########	JCM	81	725	2.59	
3612000	USGS	628	########	JCM	37	87.8	1.24	
3612000	USGS	629	########	JCM	62	449	2.61	
3612000	USGS	630	########	DJS	77	434	1.97	
3612000	USGS	631	########	DJS/MAH	18.5	10.6	0.76	
3612000	USGS	632	########	JCM	13.8	3.82	0.95	
3612000	USGS	633	########	JCM/MAH	7.4	2.34	0.81	
3612000	USGS	634	########	JCM/MAH	22.6	21.3	0.69	
3612000	USGS	635	########	JCM	17	5.68	1.02	
3612000	USGS	636	########	DJS	12.5	6.98	0.28	
3612000	USGS	637	########	JCM	21.5	30.6	1.81	
3612000	USGS	638	########	JCM/JRN	6.7	2.08	0.66	
3612000	USGS	639	########	JCM	21	34.6	1.55	
3612000	USGS	640	########	JCM	56	264	2.19	
3612000	USGS	641	########	JCM	86	951	2.43	
3612000	USGS	642	########	JCM	84	847	2.69	
3612000	USGS	643	########	PJD	17	22.5	1.2	
3612000	USGS	644	########	PJD	53	239	1.77	
3612000	USGS	645	########	JCM	57	247	2.03	
3612000	USGS	646	########	PJD/MAH	16.8	13.4	0.48	
3612000	USGS	647	########	JCM	14.5	5.46	0.8	
3612000	USGS	648	########	JCM	28	7.5	1.26	
3612000	USGS	649	########	JCM	7	2.41	0.38	
3612000	USGS	650	########	PJD	12	8.7	0.79	
3612000	USGS	651	########	JRN	10.5	6.93	0.29	0.65
3612000	USGS	652	########	PJD	21	21.8	0.96	
3612000	USGS	653	########	PJD	68	458	1.75	

3612000	USGS	654	########	JRN	37	80	1.11
3612000	USGS	655	########	JRN	84	873	3
3612000	USGS	656	########	MAH/JCM	15.6	16.8	1.96
3612000	USGS	657	########	PJD	19	17.4	0.48
3612000	USGS	658	########	PJD	9.5	2.95	0.73
3612000	USGS	659	########	PJD	19.5	22.2	0.91
3612000	USGS	660	########	PJD	19	23.7	1.01
3612000	USGS	661	########	PJD/MAH	65	614	2.88
3612000	USGS	662	########	PJD	88	1020	2.36
3612000	USGS	663	########	PJD	22	44.9	1.84
3612000	USGS	664	########	PJD	35	56.8	1.47
3612000	USGS	665	########	PJD/ASD	20.3	17.2	0.3
3612000	USGS	666	########	PJD	6.1	2.01	1
3612000	USGS	667	########	PJD	7.6	2.59	0.87
3612000	USGS	668	########	PJD	7.9	3.39	0.75
3612000	USGS	669	########	PJD/SES	58	252	1.85
3612000	USGS	670	########	PJD	55	237	2.27
3612000	USGS	671	########	PJD	21.5	40.7	1.76
3612000	USGS	672	########	PJD	21.5	43	1.68
3612000	USGS	673	########	JRN	54	180	2.13
3612000	USGS	674	########	PJD	21	33.4	1.22
3612000	USGS	675	########	PJD	24	19.6	0.43
3612000	USGS	676	########	PJD	20	23.5	0.91
3612000	USGS	677	########	PJD	21	23	0.68
3612000	USGS	678	########	JRN	29	53.1	1.08
3612000	USGS	679	########	JRN	55	261	2.41
3612000	USGS	680	########	JRN	50	154	1.86
3612000	USGS	681	########	JRN	26	47.7	1.72
3612000	USGS	682	########	JRN	50	149	2.09
3612000	USGS	683	########	JRN	22	19.9	0.21
3612000	USGS	684	########	JRN	28	50.2	1.06
3612000	USGS	685	########	JRN	51	167	2.38
3612000	USGS	686	########	JRN	53	148	0.68
3612000	USGS	687	########	JRN	52	138	0.67
3612000	USGS	688	########	JRN	55	212	1.09
3612000	USGS	689	########	JRN	40	95.5	1.76
3612000	USGS	690	########	JRN	62	420	0.87
3612000	USGS	691	########	JRN	40	108	1.68
3612000	USGS	692	########	ASD/JWH	20	19.7	0.56
3612000	USGS	693	########	JRN	17	9.11	0.2
3612000	USGS	694	########	JRN	18	15.2	0.47
3612000	USGS	695	########	SES	58	161	2.18
3612000	USGS	696	########	SES	26	55.1	2.15
3612000	USGS	697	########	SES	66	442	3.12
3612000	USGS	698	########	SES	99	1060	2.84
3612000	USGS	699	########	SES	60	491	1.49
3612000	USGS	700	########	JRN	65	472	0.32
3612000	USGS	701	########	SES	18	16.2	0.64
3612000	USGS	702	########	SES	3.9	1.92	2
3612000	USGS	703	########	JRN	16.5	12.1	0.06
3612000	USGS	704	########	SES	3.6	1.87	0.83

3612000	USGS	705	########	SES	4.6	2.07	1.62
3612000	USGS	706	########	JRN/ASD	36	71	1.83
3612000	USGS	707	########	SES	32	63.8	1.55
3612000	USGS	708	########	JRN	56		2.37
3612000	USGS	709	########	SES	77	450	2.62
3612000	USGS	710	########	SES	61	311	2.58
3612000	USGS	711	########	JRN	80	753	2.84
3612000	USGS	712	########	SES	93	976	3.03
3612000	USGS	713	########	SES	133	1440	2.94
3612000	USGS	714	########	GPJ/JRN	93	1180	2.86
3612000	USGS	715	########	SES	88	787	2.49
3612000	USGS	716	########	SES	79	633	1.5
3612000	USGS	717	########	SES/JWH	65	441	0.25
3612000	USGS	718	########	SES	48.9	68.5	2.38
3612000	USGS	719	########	SES	20.1	21.3	1.05
3612000	USGS	720	########	PJD/SES	28	23.8	0.3
3612000	USGS	721	########	SES	8.6	1.91	0.91
3612000	USGS	722	########	SES	26.8	24.1	0.46
3612000	USGS	723	########	SES	22.1	20.4	0.91
3612000	USGS	724	########	SES	45	195	1.23
3612000	USGS	725	########	SES	85	966	1.67
3612000	USGS	726	########	PJD	83	897	0.65
3612000	USGS	727	########	SES	93	954	0.8
3612000	USGS	728	########	SES	87	907	0.4
3612000	USGS	729	########	SES	87	862	1.65
3612000	USGS	730	########	SES	86	972	2.45
3612000	USGS	731	########	SES	60	418	0.48
3612000	USGS	732	########	PJD	50	112	1.99
3612000	USGS	733	########	PJD/TAL	93	1230	3.37
3612000	USGS	734	########	PJD/TAL	102	1350	3.3
3612000	USGS	735	########	PJD/TAL	52	167	2.1
3612000	USGS	736	########	PJD/TAL	34	46	1.08
3612000	USGS	737	########	PJD	24	21.2	0.42
3612000	USGS	738	########	PJD	11.7	6.02	0.38
3612000	USGS	739	########	JRN	30	62.6	1.43
3612000	USGS	740	########	JRN	34	53.8	1.17
3612000	USGS	741	########	PJD	39	75.7	1.61
3612000	USGS	742	########	PJD	69	391	2.1
3612000	USGS	743	########	JRN	87	821	2.31
3612000	USGS	744	########	JCM	55	228	2.44
3612000	USGS	745	########	PJD	71	435	2.57
3612000	USGS	746	########	PJD	23	27	0.28
3612000	USGS	747	########	PJD	28	26.8	0.3
3612000	USGS	748	########	PJD	28	32.8	0.44
3612000	USGS	749	########	JRN	92	1070	2.07
3612000	USGS	750	########	GPJ/JRN	100	1160	2.4
3612000	USGS	751	########	PJD	55	219	2.48
3612000	USGS	752	########	PJD	61	239	2.38
3612000	USGS	753	########	PJD	16	11.4	0.36
3612000	USGS	754	########	PJD/JRN	8	4.26	0.18
3612000	USGS	755	########	PJD	23	19.4	0.7

3612000	USGS	756	########	PJD	15	10.8	0.25
3612000	USGS	757	########	JRN	65	481	2.62
3612000	USGS	758	########	PJD	31	43.2	0.7
3612000	USGS	759	########	JRN/SBM	28	50.6	1.44
3612000	USGS	760	########	JRN	60	311	2.56
3612000	USGS	761	########	JRN/SDE	36	61.7	1.46
3612000	USGS	762	########	JRN	7.6	3.02	0.34
3612000	USGS	763	########	JRN	24	24.9	0.52
3612000	USGS	764	########	JRN	31	62.6	1.82
3612000	USGS	765	########	JRN	55	209	2.62
3612000	USGS	766	########	JRN	32	45.9	1.28
3612000	USGS	767	########	JRN/JLG	14.5	9.8	0.42
3612000	USGS	768	########	JRN/JLG	14	11.9	0.56
3612000	USGS	769	########	JRN/JLG	60	397	2.74
3612000	USGS	770	########	JLG	80	780	2.71
3612000	USGS	771	########	JRN/JLG	180	2300	2.93
3612000	USGS	772	########	JRN	27	49.2	1.18

outside_ga	discharge_	measured_	sections_va	gage_va_c	gage_va_ti	measureme	control_type_cd
12s	12s	12s	2s	6s	6s	12s	12s
38.16	3560		39	0.01	3	BRG CRANE	
38.54	3820		35	-0.13	2.1	BRG CRANE	
41.18	7600		34		0	BRG CRANE	
41.6	8640		20		0	BRG CRANE	
39.55	5300		36		0	BRG CRANE	
39	4450		36		0	BRG CRANE	
38.34	3620	G	37	-0.03	4.1	BRG CRANE	
41.42	7490	F	32	0.18	5.4	BRG CRANE	
41.54	7350	G	36	-0.02	2.3	BRG CRANE	
40.51	6350	G	39	-0.1	1.7	BRG CRANE	
39.47	4840	G	38	-0.1	1.6	BRG CRANE	
39.01	4310	G	37	-0.07	1.4	BRG CRANE	
38.09	3140	G	37	-0.08	1.7	BRG CRANE	
38.81	4210	G	47	0.23	2.2	BRG CRANE	
37.89	2920	G	44	1.28	1.8	BRG CRANE	
39.41	4920	G	38	-0.12	1.8	BRG CRANE	
39.4	5020	G	38	-0.06	1.8	BRG CRANE	
42.25	8780	G	26	0.07	2.7	BRG CRANE	
38.69	4100	F	30	-0.12	1.9	BRG CRANE	
39.98	6590	G	30	-0.03	1.7	BRG CRANE	
29.72	2770	G	25	-0.07	1.3	BRG CRANE	
38.18	3710	G	44	0	1.1	BRG CRANE	
39.3	4760	G	27	-0.05	1.5	BRG CRANE	
38.11	3640	G	26	-0.02	1.3	BRG CRANE	
37.49	2740	F	23	0.08	1.5	BRG CRANE	
31.65	3660	G	27	-0.07	1.4	BRG CRANE	
36.88	7520	G	32	0.15	1.5	BRG CRANE	
37.52	7950	G	31	-0.08	2.4	BRG CRANE	
31.27	3650	G	25	-0.07	1.4	BRG CRANE	
	116	G	25	-0.01	1.1		
	1490	G	23	0.07	1.5		
	762	G	25	-0.01	1.2		
	1790	G	22	0.02	1.2		
	665	G	26	-0.06	1.3		
	1310	G	20	-0.05	0.8		
	7.89	G	21	-0.01	0.5		
	5.32	G	22	0	0.5		
	12.3	G	21	0	0.5		
	8.93	G	20	0	0.5		

1.94		21	0.01	0.6
21.7	G	22	0	0.5
617	G	26	-0.01	0.9
197	G	26	0.3	0.9
1390	G	27	-0.29	1.3
1370	G	27	-0.32	1.3
285	G	19	0.04	0.6
322	G	26	-0.04	0.9
1850	G	23	-0.02	1
1090	G	28	-0.04	1.3
711	G	26	0	1.3
884	G	24	-0.06	0.9
9.52	G	24	0	0.5
5.93	G	26	0	0.5
0.77		14	0	0.2
8.67	G	24	0	0.5
2.51	G	20	0	0.3
446	G	21	-0.05	0.8
1260	G	22	-0.05	1
115	G	27	-0.01	1
779	G	21	-0.15	0.9
328	G	23	-0.01	0.7
1240	G	22	0.05	1.1
177	G	22	-0.03	0.9
6.67	F	23	0	0.5
2.91	G	22	0	0.5
451		21	-0.1	1.5
48.4	F	26	0	0.8
490	G	21	-0.02	1.3
126	F	19	-0.03	0.7
415	G	25	0.07	1.2
904	G	26	-0.05	1.3
2740	G	25	-0.15	1.1
306	G	27	-0.02	1.3
5410	F	31	-0.2	2
1620	G	27	-0.09	1.3
788	F	18	-0.04	1
34.5	F	25	0	0.5
56.7	G	25	0.02	0.5
59.5	G	23	-0.02	0.5
8.15	G	22	0	0.5
25.1	G	27	-0.01	0.5
6.33	G	21	0	0.5
17.5	G	28	0	0.5
1070	G	28	0.59	1.5
191	P	18	-0.03	1.1
87.8	G	22	-0.03	0.5
92	G	25	0	0.5
205	G	22	-0.01	1.3
461	F	23	-0.05	1.5
56.3		26	0	0.7

534	F	24	0.72	1.1
11.2	G	23	0	0.3
1.8	G	19	0	0.5
2.12	F	23	0	0.5
2.44	F	25	0	0.5
3.38	G	21	0	0.5
5.14	P	17	0	0.5
21.3	F	21	0	0.5
489	G	20	0.02	0.9
5850		29	0.44	1.7
503	F	21	-0.05	1.3
20.8	F	25	0	0.5
1.37	G	23	0	0.5
2.38	F	22	0	0.5
12.6	F	28	0	0.8
32.8	G	30	0	0.7
27.4	G	24	-0.02	0.5
15.2	G	27	0	0.8
646	G	20	-0.02	0.9
64.5	G	23	0	0.3
107	G	28	-0.02	0.6
1380	F	22	-0.22	0.9
553	F	24	-0.06	1.1
51.4	F	25	0	0.6
2.78	G	26	0	0.6
1.16	F	23	0	0.5
42.5	G	23	-0.02	0.5
3.73	G	20	0	0.3
1.94	P	18	0	0.3
408	G	20	-0.04	0.8
433	F	19	-0.02	1
3070	F	28	-0.05	1.2
328	G	21	-0.01	0.9
5580	F	22	-0.14	1.3
566	G	20	-0.02	0.8
8.98	P	27	0	0.5
6.47	F	18	0	0.5
6.27	P	22	0	0.5
45.2	P	16	0	0.5
55.6	F	21	0	0.5
39.6	P	16	0	0.5
175	P	21	-0.2	0.8
226	G	21	0	0.7
9.7	G	30	0	0.7
5.77	P	19	0	0.5
39	P	19	0	0.5
3.15	F	24	0	0.5
2.43	F	13	0	0.3
0.77	P	10	0	0.3
5.25	P	18	0.02	0.6
1.3	P	16	0	0.5

	215	F	25	0.09	0.8		
	22.4	G	20	0	0.6		
	12.4	G	23	0	0.8		
	14.1	G	21	0	0.6		
	1420	P	21	0.2	0.8		
	1920	F	19	0.02	1		
	598	F	18	-0.01	0.7		
	288	F	29	-0.04	0.8		
	21.4	G	32	0	0.7		
	0.78	F	16	0	0.3		
1.9	6.25	G	23	0	0.5	WADING	LGT DEBRIS
2.11	15.7	F	22	0	0.5	WADING	MOD DEBRIS
2.44	26.1	P	25	0	0.5	WADING	ICE COVER
6.47	502	G	21	0	0.8	BRG CRAI	CLEAR
3.31	107	G	21	0	0.7	WADING	SUBMERGED
7.19	640	P	24	-0.02	1.2	BRG CRANE	
4.54	230	F	18	-0.03	1	BRG CRAI	SUBMERGED
2.87	62.7		20	0	0.5	WADING	
7.56	607	G	25	-0.06	0.9	BRG CRAI	CLEAR
5.74	348	G	18	-0.02	0.8	BRG CRAI	SUBMERGED
5.7	364	F	18	0.7	0.4	BRG CRAI	SUBMERGED
8.48	659	G	19	-0.21	0.8	BRG CRAI	SUBMERGED
24.86	6410	F	23	-0.05	1.2	BRG CRAI	SUBMERGED
5.63	360	F	17	-0.02	0.8	BRG CRAI	SUBMERGED
3.63	101	F	21	0	0.7	WADING	CLEAR
2.82	56.7	G	20	-0.01	0.6	WADING	CLEAR
10.52	998	F	20	-0.15	0.8	BRG CRAI	MOD DEBRIS
20.34	3860	F	22	-0.13	0.9	BRG CRAI	SUBMERGED
14.39	1500	F	28	-0.12	1.1	BRG CRAI	SUBMERGED
12.7	1410	F	25	0.2	0.6	BRG CRAI	SUBMERGED
1.95	19.2	F	22	0.02	0.4	BRG CRAI	LGT DEBRIS
1.22	0.98	P	23	-0.01	0.3	WADING	CLEAR
1.36	3.37	P	29	0.01	0.4	WADING	HVY DEBRIS
6.14	314	G	25	0.01	1	BRG CRAI	CLEAR
2.5	53.9	P	26	-0.01	0.5	WADING	LGT DEBRIS
11.07	1180	G	20	-0.16	0.8	BRG CRAI	CLEAR
11.46	1250	F	27	0	1	BRG CRAI	SUBMERGED
9.04	848	G	27	-0.03	1	BRG CRAI	SUBMERGED
12.86	1330	G	24	-0.05	0.9	BRG CRAI	SUBMERGED
10.67	212	P	13	-0.01	0.7	BRG CRANE	
2.11	34.7	F	22	-0.02	0.5	WADING	CLEAR
1.38	4.09	F	24	-0.01	0.5	WADING	LGT DEBRIS
1.2	1.71	F	19	0.01	0.3	WADING	CLEAR
1.7	13	F	22	0	0.4	WADING	CLEAR
8.18	714	G	20	-0.04	0.8	BRG CRAI	SUBMERGED
4.6	238	G	27	-0.01	0.8	BRG CRAI	SUBMERGED
11.43	1150	P	20	-0.1	0.7	BRG CRAI	ICE COVER
3.55	118	G	22	0	0.7	WADING	CLEAR
12.48	1550	F	25	0.16	1	BRG CRAI	SUBMERGED
10.4	1090	G	27	-0.08	1.1	BRG CRAI	SUBMERGED
1.35	4.68	F	26	0	0.4	WADING	CLEAR

3.77	165	F	23	0	0.8	BRG CRAN	SUBMERGED
8.56	774	G	23	0.17	0.8	BRG CRAN	SUBMERGED
8.22	748	G	24	-0.03	0.8	BRG CRAN	SUBMERGED
3.72	169	G	21	-0.03	0.7	BRG CRAN	LGT DEBRIS
2.55	60.2	G	24	0	0.7	WADING	CLEAR
4.39	212	G	21	-0.04	0.8	BRG CRAN	SUBMERGED
1.76	19.7	G	21	0.01	0.4	WADING	CLEAR
16.82	2660	F	20	0.06	0.6	BRG CRAN	SUBMERGED
1.61	14.7	F	21	0	0.3	WADING	CLEAR
1.24	7.07	G	25	0	0.4	WADING	CLEAR
1.14	4.3	G	28	0	0.5	WADING	CLEAR
1.32	9.33	G	28	0	0.5	WADING	CLEAR
7.64	618	G	26	-0.11	0.9	BRG CRAN	SUBMERGED
2.67	77.7	G	22	0.02	0.2	WADING	CLEAR
3.84	178	G	22	-0.02	0.8	BRG CRAN	CLEAR
5.04	322	G	24	-0.03	0.8	BRG CRAN	SUBMERGED
1.9	33.1	G	22	0	0.4	WADING	CLEAR
1.14	5.06	F	23	0	0.4	WADING	CLEAR
1.13	5	F	26	0	0	WADING	CLEAR
0.87	0.28	F	15	-0.02	0.2	WADING	LGT DEBRIS
0.81	0.52	F	18	-0.02	0.3	WADING	CLEAR
0.96	1.16	F	22	0	0.4	WADING	LGT DEBRIS
4.22	253	G	23	0.08	0.8	BRG CRAN	SUBMERGED
5.68	424	F	23	0.1	0.8	BRG CRAN	SUBMERGED
12.74	1880	G	23	-0.03	0.9	BRG CRAN	SUBMERGED
2.8	109	G	23	-0.01	0.7	WADING	CLEAR
9.48	1170	G	25	0	1	BRG CRAN	SUBMERGED
7.38	855	F	26	0.1	0.9	BRG CRAN	SUBMERGED
1.19	8.02	G	23	-0.01	0.3	WADING	CLEAR
0.96	3.62	G	21	-0.01	0.3	WADING	CLEAR
0.83	1.89	F	23	0	0.3	WADING	CLEAR
1.38	14.7	G	22	-0.02	0.4	WADING	CLEAR
1.03	5.82	F	24	0	0.3	WADING	CLEAR
0.77	1.95	F	25	0	0.4	WADING	CLEAR
1.93	55.4	G	22	0.08	0.3	WADING	CLEAR
0.72	1.24	G	22	0	0.3	WADING	LGT DEBRIS
2.1	53.6	F	22	0.04	0.3	WADING	CLEAR
6.29	579	F	24	-0.06	1	BRG CRAN	SUBMERGED
15.42	2310	G	23	-0.02	0.9	BRG CRAN	HVY DEBRIS
13.98	2280	G	24	-0.01	0.9	BRG CRAN	SUBMERGED
1.53	26.9	F	22	0	0.3	WADING	CLEAR
5.92	424	F	24	0	0.7	BRG CRAN	SUBMERGED
5.85	502	G	19	0	0.8	BRG CRAN	SUBMERGED
0.94	6.48	F	22	0	0.5	WADING	CLEAR
0.82	4.4	F	26	-0.01	0.4	WADING	CLEAR
1.08	9.46	F	24	0	0.4	WADING	CLEAR
0.54	0.92	F	24	-0.01	0.4	WADING	CLEAR
0.93	5.76	F	25	0	0.4	WADING	CLEAR
	2	F	21	0	0.5	WADING	SHORE ICE
1.29	21	F	22	0	0.3	WADING	LGT DEBRIS
9.34	802	G	25	-0.02	1	BRG CRAN	SUBMERGED

2.25	89	G	24	0	0.8	WADING	CLEAR
14.36	2620	G	26	-0.07	1.2	BRG CRAI	SUBMERGED
1.81	32.9	F	30	0.04	0.8	WADING	CLEAR
0.94	8.29	F	24	0	0.4	WADING	CLEAR
0.61	2.15	F	17	0	0.2	WADING	LGT DEBRIS
1.2	20.2	F	22	0	0.3	WADING	CLEAR
1.3	23.9	G	20	0	0.3	WADING	MOD DEBRIS
11.86	1770	G	22	0.43	0.7	BRG CRAI	SUBMERGED
16	2400	G	25	-0.07	1.2	BRG CRAI	SUBMERGED
1.97	82.4	F	22	0	1	WADING	MOD DEBRIS
2.16	85.9	G	39	0	1.2	WADING	CLEAR
0.9	5.23	G	27	0	0.3	WADING	LGT DEBRIS
0.65	2.01	F	23	0	0.6	WADING	LGT DEBRIS
0.58	2.25	G	19	0	0.5	WADING	CLEAR
0.64	2.53	G	29	0	0.4	WADING	CLEAR
5.8	466	G	25	0.01	0.9	BRG CRAI	SUBMERGED
5.78	538	G	27	-0.02	0.8	BRG CRAI	SUBMERGED
1.72	71.7	G	23	0.03	1.1	WADING	CLEAR
1.76	72.4		23	0.02	0.4	WADING	CLEAR
4.58	384	G	26	-0.04	1	BRG CRAI	SUBMERGED
1.44	40.9	G	28	0	0.5	WADING	CLEAR
0.78	8.39		22	-0.01	0.4	WADING	CLEAR
1.03	21.4	F	30	-0.04	0.5	WADING	
0.9	15.7	F	22	-0.01	0.5	WADING	CLEAR
1.62	57.5	G	23	-0.01	0.8	WADING	CLEAR
6.2	630	G	24	-0.06	1.1	BRG CRAI	SUBMERGED
4.06	286	G	26	-0.01	0.8	BRG CRAI	SUBMERGED
1.78	81.9	G	27	0	0.6	WADING	CLEAR
3.84	312		26	-0.13	0.9	BRG CRAI	CLEAR
0.49	4.24	G	24	0	0.5	WADING	CLEAR
1.43	53.1	G	26	0	0.7	WADING	CLEAR
4.28	397	G	25	-0.03	0.8	BRG CRAI	CLEAR
3.88	101	P	25	0.01	0.8	BRG CRAI	CLEAR
3.76	93.1	F	26	0	0.6	BRG CRAI	CLEAR
5.18	234	G	26	0	0.9	BRG CRAI	SUBMERGED
2.62	168	G	29	-0.04	0.9	BRG CRAI	CLEAR
8.72	364	G	26	0.01	0	BRG CRAI	SUBMERGED
2.93	182	G	31	-0.02	1	BRG CRAI	CLEAR
0.72	11.1	F	25	0	0.8	WADING	LGT DEBRIS
0.3	1.83	F	28	0	0.4	WADING	CLEAR
0.56	7.08		26	0	0.5	WADING	LGT DEBRIS
3.97	351	G	25	0	0.8	BRG CRAI	SUBMERGED
1.97	119	G	27	0.02	0.6	WADING	CLEAR
8.88	1380	F	28	0.13	1.6	BRG CRAI	SUBMERGED
15.1	3010	F	22	-0.05	0.8	BRG CRAI	SUBMERGED
10.04	731	F	24	-0.02	0.9	BRG CRAI	SUBMERGED
9.18	152	P	26	-0.01	0.9	BRG CRAI	SUBMERGED
0.52	10.3	G	29	0	0.4	WADING	MOD DEBRIS
0.25	3.84	F	14	0	0.2	WADING	CLEAR
0.1	0.69	F	26	0	0.7	WADING	LGT DEBRIS
0.15	1.55	P	13	0	0.3		CLEAR

0.24	3.36	P	16	-0.01	1	WADING	MOD DEBRIS
2.12	130	F	32	-0.05	0.9	BRG CRAI	CLEAR
1.68	98.9	G	36	0.01	1	WADING	CLEAR
5.65	585	G	27	-0.08	1.1	BRG CRAI	CLEAR
8.61	1180	G	27	-0.17	1.2	BRG CRAI	SUBMERGED
6.72	801	G	35	-0.1	1.3	BRG CRAI	CLEAR
12.06	2140	G	26	0.12	1.2	BRG CRAI	SUBMERGED
15.53	2960	F	24	0.32	1.8	BRG CRAI	SUBMERGED
18.92	4250	G	34	0.18	2.7	BRG CRAI	SUBMERGED
16.95	3380	G	25	-0.15	1.2	BRG CRAI	SUBMERGED
12.44	1960	G	30	-0.07	1.2	BRG CRAI	SUBMERGED
10.51	950	F	30	-0.02	1.3	BRG CRAI	SUBMERGED
8.28	109	F	25	-0.03	1.1	BRG CRAI	SUBMERGED
2.16	163	G	32	-0.03	0.7	WADING	CLEAR
0.56	22.4	G	30	0	0.5	WADING	CLEAR
0.25	7.2	F	24	0	0.4	WADING	CLEAR
-0.05	2.1	G	29	0	0.6	WADING	CLEAR
0.39	11.1	G	35	-0.1	0.7	WADING	LGT DEBRIS
0.66	18.6		31	-0.01	0.7	WADING	CLEAR
4.27	240	F	33	-0.08	0.8	BRG CRAI	SHORE ICE
14.84	1610	G	25	-0.03	0.8	WADING	SUBMERGED
13.88	581	G	29	0.09	1.1	WADING	SUBMERGED
14.43	764	F	32	0	1.1	BRG CRAI	SUBMERGED
13.94	362	F	32	0	1	BRG CRAI	SUBMERGED
13.64	561	F	32	-0.02	1.1	BRG CRAI	SUBMERGED
14.67	1410	G	30	-0.07	1	BRG CRAI	SUBMERGED
8.46	201	G	26	-0.04	1	BRG CRAI	SUBMERGED
2.64	223	G		-0.01	1	BRG CRAI	SUBMERGED
17.8	4140	G	28	-0.28	1.3	BRG CRAI	SUBMERGED
18.31	4460	G	28	-0.14	1.5	BRG CRAI	SUBMERGED
3.96	350	G	27	-0.07	0.9	BRG CRAI	SUBMERGED
0.91	49.6	G	32	-0.01	0.4	WADING	CLEAR
0.17	8.84	G	25	0	0.4	WADING	CLEAR
9.9	2.27	F	24	0	0.6	WADING	CLEAR
11.52	89.8	G	27	-0.03	0.6	BRG CRAI	CLEAR
11.12	62.8	G	29	0	0.6	WADING	CLEAR
11.64	122	G	29	-0.01	0.7	WADING	
17.57	823	G	28	0.01	1	BRG CRAI	SUBMERGED
22.12	1900	G	25	0.02	1.1	BRG CRAI	SUBMERGED
15.18	556	G	22	-0.04	0.9	BRG CRAI	SUBMERGED
17.97	1120	G	28	-0.11	1	BRG CRAI	SUBMERGED
10.1	7.46	G	29	0	0.6	WADING	
10.12	8.03	G	25	-0.01	0.5	WADING	
10.28	14.5	G	27	0	0.4	WADING	CLEAR
25.1	2220	G	24	0.01	0.8	BRG CRAI	SUBMERGED
26.15	2790	G	24	-0.12	1.4	BRG CRAI	SUBMERGED
14.76	543	G	27	-0.05	0.9	BRG CRAI	SUBMERGED
14.99	569	G	29	-0.02	1	INDIRECT	SUBMERGED
9.82	4.16	G	21	0	0.4	WADING	CLEAR
9.63	0.75	F	17	0	0.3	WADING	CLEAR
10.12	13.6	G	23	0	0.3	WADING	CLEAR

9.8	2.75		24	0	0.4	WADING	CLEAR
19.1	1260	G	25	-0.04	1.3	BRG CRAI	SUBMERGED
10.45	30.3	G	30	0	0.5	WADING	CLEAR
10.97	73.1	G	25	0	0.4	WADING	CLEAR
16.55	798	G	25	-0.04	0.8	BRG CRAI	SUBMERGED
11.02	90	G	25	-0.02	0.7	WADING	CLEAR
9.65	1.04	G	26	0	0.5	WADING	MOD DEBRIS
10.04	13	G	25	0	0.5	WADING	CLEAR
11.19	114	G	25	-0.02	0.8	WADING	CLEAR
14.65	547	G	25	0	1	BRG CRAI	SUBMERGED
10.67	58.6	G	25	-0.01	0.6	WADING	CLEAR
9.68	4.08	G	25	0	0.4	WADING	CLEAR
9.74	6.65	G	27	0	0.4	WADING	CLEAR
17.95	1090	G	25	-0.27	1.2	BRG CRAI	SUBMERGED
22.25	2120	G	22	0.48	1	BRG CRAI	SUBMERGED
34.05	6740	G	23		0	BRG CRAI	LGT DEBRIS
10.73	58	G	27	0	0.4	WADING	CLEAR

Appendix I
Streeter-Phelps Analysis

Dutchman Creek Segment ADD02
Aeration Coefficient Summary

Location	Date	DO observed	BOD @ DO observed	Ka @ DO observed	Ka at DO = 6 mg/L
ADD02	######	4.2	5.2	0.1	4.17
ADD02	######	7	9.1	3.57	1.11
ADD02	######	10.1	1.3	2.1	-5.53
ADD02	######	3.5	9.1	0.1	4.39
ADD02	######	11.4	7.2	9.4	-5.29

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 Determined from Transect Data. *Ka is lowest value and Kd is calculated from that .*

		20 °C	**@ T**									
D	**D_o**	**k_a**	**k_a**	**k_d**	**x**	**U**	**L_o**	**C_s**	**C**	**H**	**T**	**Q**
mg/L	**mg/L**	**1/day**	**1/day**	**1/day**	**ft**	**ft/s**	**mg/L**	**mg/L**	**mg/L**	**ft**	**°C**	**cfs**
4.58	4	5.44	0.1	0.98	5280	0.5	5.2	8.8	4.2	1.4	21.8	1.428
4.58												

x	y	m	b
20	9.2	-0.16	12.4
25	8.4		

DO @ Temp 8.9

x	y	m	b
0	9.2	-0.00035	9.2
2000	8.5		

Elevation	390	feet
DO @ Elev.	9.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.8	mg/L

Used Q from USGS Derived Flows and H Determined from Transect Data. *Kd is same as impaired sample 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
2.78	4	5.44	4.17	0.98	5280	0.5	5.2	8.8	6	1.4	21.8	1.428
2.78												

x	y	m	b
20	9.2	-0.16	12.4
25	8.4		

DO @ Temp 8.9

x	y	m	b
0	9.2	-0.00035	9.2
2000	8.5		

Elevation	390	feet
DO @ Elev.	9.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.8	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
3.28	4	31.44	3.57	0.80	5280	0.5	9.1	10.3	7	0.4	14	2.337
3.28												

x	y	m	b	
10	11.3	-0.22	13.5	
15	10.2			

DO @ Temp 10.4

x	y	m	b	
0	10.2	-0.00035	10.2	
2000	9.5			

Elevation	390	feet
DO @ Elev.	10.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	10.3	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
4.28	4	31.44	1.11	0.80	5280	0.5	9.1	10.3	6	0.4	14	2.337
4.28												

x	y	m	b
10	11.3	-0.22	13.5
15	10.2		

DO @ Temp 10.4

x	y	m	b
0	10.2	-0.00035	10.2
2000	9.5		

Elevation	390	feet
DO @ Elev.	10.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	10.3	mg/L

ADD02_093092 (2)

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
3.23	4	23.89	2.10	0.44	5280	0.6	1.3	13.3	10.1	0.5	3	3.895
3.25												

x	y	m	b
0	14.6	-0.36	14.6
5	12.8		

DO @ Temp 13.5

x	y	m	b
0	12.8	-0.00045	12.8
2000	11.9		

Elevation 390 feet
DO @ Elev. 12.6 mg/L
DO Elev Factor 0.99

DO @ Temp/Elev 13.3 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
7.33	4	23.89	-5.53	0.44	5280	0.6	1.3	13.3	6	0.5	3	3.895
7.33												

x	y		m	b
	0	14.6	-0.36	14.6
	5	12.8		

DO @ Temp 13.5

x	y		m	b
	0	12.8	-0.00045	12.8
	2000	11.9		

Elevation	390	feet
DO @ Elev.	12.6	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	13.3	mg/L

Used Q from USGS Derived Flows and H Determined from Transect Data. *Ka is lowest value possible and Kd is calculated 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
5.41	4	10.70	0.10	1.03	5280	0.4	9.1	8.9	3.5	0.8	21	0.441
5.40												

x	y	m	b	
	20	9.2	-0.16	12.4
	25	8.4		
DO @ Temp		9.0		
x	y	m	b	
	0	9.2	-0.00035	9.2
	2000	8.5		
Elevation		390 feet		
DO @ Elev.		9.1 mg/L		
DO Elev Factor		0.99		
DO @ Temp/Elev		8.9 mg/L		

Used Q from USGS Derived Flows and H Determined from Transect Data. *Kd is same as impaired sample 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**
2.91	4	10.70	4.39	1.03	5280	0.4	9.1	8.9	6	0.8	21	0.441
2.91												

x	y	m	b	
	20	9.2	-0.16	12.4
	25	8.4		
DO @ Temp		9.0		
x	y	m	b	
	0	9.2	-0.00035	9.2
	2000	8.5		

Elevation	390	feet
DO @ Elev.	9.1	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.9	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**
1.76	4	19.68	9.40	0.42	5280	0.6	7.2	13.2	11.4	0.6	3.5	5.583
1.76												

x	y	m	b	
0	14.6	-0.36	14.6	
5	12.8			

DO @ Temp	13.3	

x	y	m	b	
0	12.8	-0.00045	12.8	
2000	11.9			

Elevation	390	feet
DO @ Elev.	12.6	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	13.2	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
7.16	4	19.68	-5.29	0.42	5280	0.6	7.2	13.2	6	0.6	3.5	5.583
7.16												

x	y	m	b	
	0	14.6	-0.36	14.6
	5	12.8		

DO @ Temp 13.3

x	y	m	b	
	0	12.8	-0.00045	12.8
	2000	11.9		

Elevation	390	feet
DO @ Elev.	12.6	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	13.2	mg/L

ADD02_011800 (2)

Appendix J
Error Analyses

J.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 Dutchman 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 ADD02 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	0.5	5.2	8.8	4.2	1.428	=RiskTriang(0.01,0.1,100)	=RiskTriang(0.02,0.98,3.4)

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

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	3.19	0.03	0.03
Maximum =	8.78	99.77	3.39
Mean =	7.94	33.37	1.47
Std Deviation =	1.13	23.54	0.71
Variance =	1.29	554.31	0.50
Skewness =	-1.87	0.57	0.36
Kurtosis =	5.77	2.43	2.39
Errors Calculated =	0.00	0.00	0.00
Mode =	7.46	19.21	0.79

95th Percent Confidence Interval

5.71	10.16

99.9% Confidence Interval

4.19	11.68

	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	9.1	10.3	7	2.34	=RiskTriang(0.01,3.57,100)	=RiskTriang(0.02,0.801209,3.4)

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

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	3.84	0.12	0.03
Maximum =	10.27	98.92	3.37
Mean =	9.32	34.46	1.41
Std Deviation =	1.12	23.13	0.72
Variance =	1.24	534.99	0.52
Skewness =	-1.71	0.55	0.46
Kurtosis =	5.32	2.38	2.41
Errors Calculated =	0.00	0.00	0.00
Mode =	8.86	70.59	0.86

95th Percent Confidence Interval

7.13	11.50

99.9% Confidence Interval

5.64	13.00

	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	1.3	13.3	10.1	3.895	=RiskTriang(0.01,2.1,100)	=RiskTriang(0.02,0.439,3.4)

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 =	9.10	0.09	0.03
Maximum =	13.33	99.09	3.38
Mean =	12.67	34.11	1.29
Std Deviation =	0.92	23.32	0.76
Variance =	0.85	543.72	0.57
Skewness =	-1.67	0.55	0.53
Kurtosis =	4.90	2.36	2.39
Errors Calculated =	0.00	0.00	0.00
Mode =	13.32	54.32	0.42

95th Percent Confidence Interval

10.86	14.48

99.9% Confidence Interval

9.62	15.71

	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	9.1	8.9	3.5	0.441	=RiskTriang(0.01,0.1,100)	=RiskTriang(0.02,1.03,3.4)

DO= =$G$3-(($C$3*EXP((-$J$3*$D$3)/($E$3*86400)))+($F$3*$K$3/($J$3-$K$3))*(EXP(-$K$3*$D$3/($E$3*86400))-EXP(-$J$3*$D$3/($E$3*86400))))

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	1.29	0.04	0.05
Maximum =	8.90	98.51	3.39
Mean =	7.91	33.04	1.49
Std Deviation =	1.33	23.46	0.70
Variance =	1.77	550.51	0.50
Skewness =	-2.07	0.56	0.36
Kurtosis =	6.84	2.38	2.42
Errors Calculated =	0.00	0.00	0.00
Mode =	8.21	84.66	1.00

95th Percent Confidence Interval

5.30	10.51

99.9% Confidence Interval

3.52	12.29

	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	7.2	13.2	11.4	5.583	=RiskTriang(0.01,9.4,100)	=RiskTriang(0.02,0.42,3.4)

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 =	7.6	0.2	0.03
Maximum =	13.2	99.1	3.4
Mean =	12.4	36.4	1.3
Std Deviation =	0.9	22.5	0.8
Variance =	0.7	505.2	0.6
Skewness =	-1.7	0.5	0.5
Kurtosis =	5.8	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	12.0	7.5	1.3

95% Confidence Interval

10.69	14.08

99.9% Confidence Interval

9.53	15.24

Appendix K
Watershed Management Model (WMM) Analyses

K.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 Dutchman Creek segment ADD02 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
DUTCHMAN CREEK WATERSHED
AVERAGE DUTCHMAN 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)	Dutchman Creek	Jackson	0	0	0	2	0	0	0	0	0	0	3	11	0	1	0	0	0	0	16
BOD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	45	0	0	0	0	0	0	0	57	10	19	0	0	0	0	132
COD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	289	0	0	0	0	0	0	0	1,466	57	114	0	4	0	0	1,930
TSS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	1,816	0	0	0	0	0	0	0	2,507	22	43	0	6	0	0	4,394
TDS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	568	0	0	0	0	0	0	0	2,875	69	137	0	7	0	0	3,655
Total-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	15	0	0	0	0	0	0	0	3	0	0	0	0	0	0	19
Dissolved-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Total-N	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	52	0	0	0	0	0	0	8	37	1	1	0	0	0	0	100
TKN	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	26	0	0	0	0	0	0	5	10	1	1	0	0	0	0	43
NO2+NO3	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	26	0	0	0	0	0	0	3	27	0	0	0	0	0	0	57
Lead	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Copper	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3
Manganese	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
DUTCHMAN CREEK WATERSHED
AVERAGE DUTCHMAN 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)	Dutchman Creek	Jackson	0	0	0	20	0	0	0	0	0	0	28	104	2	5	0	0	0	0	160
BOD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	445	0	0	0	0	0	0	0	563	95	190	0	1	0	0	1,294
COD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	2,837	0	0	0	0	0	0	0	14,368	558	1,116	0	35	0	0	18,915
TSS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	17,800	0	0	0	0	0	0	0	24,567	211	422	0	60	0	0	43,060
TDS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	5,563	0	0	0	0	0	0	0	28,173	672	1,345	0	69	0	0	35,822
Total-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	142	0	0	0	0	0	0	3	34	1	2	0	0	0	0	183
Dissolved-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	5	0	0	0	0	0	0	3	8	2	4	0	0	0	0	22
Total-N	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	512	0	0	0	0	0	0	79	365	10	13	0	1	0	0	980
TKN	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	258	0	0	0	0	0	0	46	101	7	9	0	0	0	0	422
NO2+NO3	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	254	0	0	0	0	0	0	34	263	3	4	0	1	0	0	558
Lead	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	10
Copper	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	4
Zinc	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	4	24	1	1	0	0	0	0	30
Manganese	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
DUTCHMAN CREEK WATERSHED
AVERAGE DUTCHMAN 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)	Dutchman Creek	Jackson	0	0	0	18	0	0	0	0	0	0	25	91	2	4	0	0	0	0	123
BOD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	391	0	0	0	0	0	0	0	494	83	166	0	1	0	0	745
COD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	2,490	0	0	0	0	0	0	0	12,609	490	980	0	31	0	0	14,109
TSS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	15,621	0	0	0	0	0	0	0	21,559	185	370	0	53	0	0	22,167
TDS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	4,881	0	0	0	0	0	0	0	24,724	590	1,180	0	60	0	0	26,554
Total-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	125	0	0	0	0	0	0	3	30	1	1	0	0	0	0	35
Dissolved-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	4	0	0	0	0	0	0	3	7	2	3	0	0	0	0	15
Total-N	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	449	0	0	0	0	0	0	70	320	9	11	0	1	0	0	411
TKN	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	226	0	0	0	0	0	0	40	89	6	8	0	0	0	0	143
NO2+NO3	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	223	0	0	0	0	0	0	29	231	3	3	0	1	0	0	267
Lead	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	9
Copper	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	3
Zinc	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	4	21	1	1	0	0	0	0	26
Manganese	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
DUTCHMAN CREEK WATERSHED
AVERAGE DUTCHMAN 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)	Dutchman Creek	Jackson	0	0	0	28	0	0	0	0	0	0	39	142	3	7	0	0	0	0	219
BOD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	608	0	0	0	0	0	0	0	770	130	259	0	2	0	0	1,770
COD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	3,879	0	0	0	0	0	0	0	19,647	763	1,526	0	48	0	0	25,863
TSS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	24,339	0	0	0	0	0	0	0	33,592	288	577	0	82	0	0	58,878
TDS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	7,606	0	0	0	0	0	0	0	38,523	920	1,839	0	94	0	0	48,981
Total-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	195	0	0	0	0	0	0	4	46	2	2	0	0	0	0	250
Dissolved-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	7	0	0	0	0	0	0	4	12	2	5	0	0	0	0	30
Total-N	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	700	0	0	0	0	0	0	108	499	14	18	0	1	0	0	1,339
TKN	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	353	0	0	0	0	0	0	63	139	9	13	0	0	0	0	576
NO2+NO3	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	347	0	0	0	0	0	0	46	360	5	5	0	1	0	0	763
Lead	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	14
Copper	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	5
Zinc	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	6	33	1	1	0	0	0	0	41
Manganese	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
DUTCHMAN CREEK WATERSHED
AVERAGE DUTCHMAN 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)	Dutchman Creek	Jackson	0	0	0	2	0	0	0	0	0	0	3	11	0	1	0	0	0	0	16
BOD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	45	0	0	0	0	0	0	0	57	10	19	0	0	0	0	132
COD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	289	0	0	0	0	0	0	0	1,466	57	114	0	4	0	0	1,930
TSS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	1,816	0	0	0	0	0	0	0	2,507	22	43	0	6	0	0	4,394
TDS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	568	0	0	0	0	0	0	0	2,875	69	137	0	7	0	0	3,655
Total-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	15	0	0	0	0	0	0	0	3	0	0	0	0	0	0	19
Dissolved-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Total-N	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	52	0	0	0	0	0	0	8	37	1	1	0	0	0	0	100
TKN	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	26	0	0	0	0	0	0	5	10	1	1	0	0	0	0	43
NO2+NO3	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	26	0	0	0	0	0	0	3	27	0	0	0	0	0	0	57
Lead	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Copper	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinc	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	3
Manganese	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 1-A
DUTCHMAN CREEK WATERSHED
AVERAGE DUTCHMAN 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)	Dutchman Creek	Jackson	0	0	0	1,933	0	0	0	0	0	0	2,685	9,790	234	467	0	24	0	0	15,133
BOD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	42,048	0	0	0	0	0	0	0	53,242	8,959	17,919	0	130	0	0	122,299
COD	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	268,058	0	0	0	0	0	0	0	1,357,669	52,740	105,480	0	3,322	0	0	1,787,269
TSS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	1,681,934	0	0	0	0	0	0	0	2,321,348	19,927	39,854	0	5,679	0	0	4,068,742
TDS	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	525,604	0	0	0	0	0	0	0	2,662,097	63,542	127,084	0	6,513	0	0	3,384,840
Total-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	13,455	0	0	0	0	0	0	299	3,203	128	160	0	8	0	0	17,254
Dissolved-P	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	473	0	0	0	0	0	0	292	799	172	343	0	2	0	0	2,080
Total-N	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	48,356	0	0	0	0	0	0	7,496	34,458	955	1,214	0	84	0	0	92,563
TKN	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	24,388	0	0	0	0	0	0	4,328	9,573	638	879	0	23	0	0	39,829
NO2+NO3	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	23,968	0	0	0	0	0	0	3,168	24,885	318	334	0	61	0	0	52,734
Lead	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	9	891	20	34	0	4	0	0	958
Copper	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	10	336	5	7	0	1	0	0	359
Zinc	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	390	2,264	84	82	0	6	0	0	2,826
Manganese	(lbs/yr)	Dutchman Creek	Jackson	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix L
Phosphorus Reduction – BATHTUB Output Files

BATHTUB Output for 1988 Reduction Analysis

NO REDUCTION REQUIRED

BATHTUB Output for 1994 Reduction Analysis

CASE: Dutchman 1994 - 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	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	36.8	.33	49.1	.45	.75	-.87	-1.07	-.52
CHL-A	MG/M3	17.2	.48	16.6	.54	1.03	.07	.10	.05
SECCHI	M	.8	.55	.9	.53	.99	-.02	-.04	-.02
ORGANIC N	MG/M3	.0	.00	592.9	.34	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.3	.42	.00	.00	.00	.00

SEGMENT: 2 Mid Pool

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	33.0	.41	33.5	.45	.99	-.04	-.06	-.02
CHL-A	MG/M3	34.4	.31	25.8	.61	1.33	.91	.83	.42
SECCHI	M	1.5	.74	1.4	.66	1.08	.10	.27	.07
ORGANIC N	MG/M3	.0	.00	752.2	.47	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.8	.56	.00	.00	.00	.00

SEGMENT: 3 Near Dam

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	115.1	1.38	59.2	.45	1.94	.48	2.47	.46
CHL-A	MG/M3	34.3	.42	25.1	.56	1.37	.75	.90	.45
SECCHI	M	1.5	.63	1.4	.55	1.08	.12	.26	.09
ORGANIC N	MG/M3	.0	.00	734.5	.41	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	42.4	.45	.00	.00	.00	.00

SEGMENT: 4 AREA-WTD MEAN

VARIABLE		OBSERVED MEAN	CV	ESTIMATED MEAN	CV	RATIO	T STATISTICS 1	2	3
TOTAL P	MG/M3	66.5	1.05	49.4	.45	1.35	.28	1.10	.26
CHL-A	MG/M3	27.9	.40	22.1	.50	1.26	.58	.67	.37
SECCHI	M	1.3	.64	1.2	.43	1.05	.08	.18	.07
ORGANIC N	MG/M3	.0	.00	685.3	.37	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.0	.45	.00	.00	.00	.00

CASE: Dutchman 1994 - Reduced

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	4.590	.000E+00	.000	.522
2	1	Tributary 2	17.440	9.100	.000E+00	.000	.522
3	1	Tributary 3	.490	.290	.000E+00	.000	.592
4	1	Tributary 4	2.440	1.340	.000E+00	.000	.549
PRECIPITATION			.478	.574	.132E-01	.200	1.200
TRIBUTARY INFLOW			29.170	15.320	.000E+00	.000	.525
***TOTAL INFLOW			29.648	15.894	.132E-01	.007	.536
ADVECTIVE OUTFLOW			29.648	15.491	.277E-01	.011	.523
***TOTAL OUTFLOW			29.648	15.491	.277E-01	.011	.523
***EVAPORATION			.000	.402	.146E-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	Tributary 1	872.1	39.7	.000E+00	.0	.000	190.0	99.1
2	1	Tributary 2	970.1	44.2	.000E+00	.0	.000	106.6	55.6
3	1	Tributary 3	5.0	.2	.000E+00	.0	.000	17.3	10.2
4	1	Tributary 4	60.0	2.7	.000E+00	.0	.000	44.8	24.6
PRECIPITATION			14.3	.7	.514E+02	100.0	.500	25.0	30.0
INTERNAL LOAD			273.2	12.4	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			1907.2	86.9	.000E+00	.0	.000	124.5	65.4
***TOTAL INFLOW			2194.8	100.0	.514E+02	100.0	.003	138.1	74.0
ADVECTIVE OUTFLOW			917.2	41.8	.171E+06	*******	.450	59.2	30.9
***TOTAL OUTFLOW			917.2	41.8	.171E+06	*******	.450	59.2	30.9
***RETENTION			1277.6	58.2	.171E+06	*******	.323	.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 -
32.41	.1371	66.5	.0644	15.5274	.5821

BATHTUB Output for 2001 Reduction Analysis

CASE: Dutchman 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	53.6	.33	50.0	.45	1.07	.21	.26	.12
CHL-A	MG/M3	27.1	.62	27.8	.53	.97	-.04	-.08	-.03
SECCHI	M	.8	.28	.7	.41	1.01	.05	.05	.03
ORGANIC N	MG/M3	.0	.00	840.6	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	60.9	.43	.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	50.8	.64	42.4	.45	1.20	.28	.67	.23
CHL-A	MG/M3	26.8	.68	22.8	.59	1.18	.24	.47	.18
SECCHI	M	.9	.44	.9	.51	.91	-.21	-.32	-.13
ORGANIC N	MG/M3	.0	.00	714.1	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	48.2	.41	.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	72.0	1.06	45.1	.45	1.60	.44	1.74	.41
CHL-A	MG/M3	32.8	.53	22.9	.56	1.43	.67	1.03	.47
SECCHI	M	.9	.33	1.2	.54	.78	-.75	-.90	-.39
ORGANIC N	MG/M3	.0	.00	702.0	.40	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	43.7	.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	60.1	.74	46.3	.45	1.30	.36	.97	.30
CHL-A	MG/M3	29.3	.59	24.7	.50	1.18	.28	.48	.22
SECCHI	M	.8	.34	.9	.38	.88	-.38	-.46	-.25
ORGANIC N	MG/M3	.0	.00	757.0	.38	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	51.2	.43	.00	.00	.00	.00

CASE: Dutchman 2001 - Reduced

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Tributary 1	8.800	1.930	.000E+00	.000	.219
2	1	Tributary 2	17.440	3.770	.000E+00	.000	.216
3	1	Tributary 3	.490	.130	.000E+00	.000	.265
4	1	Tributary 4	2.440	.560	.000E+00	.000	.230
PRECIPITATION			.478	.403	.649E-02	.200	.843
TRIBUTARY INFLOW			29.170	6.390	.000E+00	.000	.219
***TOTAL INFLOW			29.648	6.793	.649E-02	.012	.229
ADVECTIVE OUTFLOW			29.648	6.390	.211E-01	.023	.216
***TOTAL OUTFLOW			29.648	6.390	.211E-01	.023	.216
***EVAPORATION			.000	.402	.146E-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	Tributary 1	297.4	37.5	.000E+00	.0	.000	154.1	33.8
2	1	Tributary 2	396.2	50.0	.000E+00	.0	.000	105.1	22.7
3	1	Tributary 3	.0	.0	.000E+00	.0	.000	.0	.0
4	1	Tributary 4	29.8	3.8	.000E+00	.0	.000	53.2	12.2
PRECIPITATION			14.3	1.8	.514E+02	100.0	.500	35.6	30.0
INTERNAL LOAD			54.6	6.9	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			723.4	91.3	.000E+00	.0	.000	113.2	24.8
***TOTAL INFLOW			792.4	100.0	.514E+02	100.0	.009	116.7	26.7
ADVECTIVE OUTFLOW			288.1	36.4	.169E+05	32772.1	.451	45.1	9.7
***TOTAL OUTFLOW			288.1	36.4	.169E+05	32772.1	.451	45.1	9.7
***RETENTION			504.3	63.6	.169E+05	32814.6	.258	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
13.37	.2879	60.1	.1397	7.1600	.6364

Appendix M
Responsiveness Summary

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Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from November 20, 2003 through January 20, 2004 postmarked, including those from the December 15, 2003 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 Dutchman 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 Dutchman Creek (ILADD01), which originates in the north central portion of Johnson County, Illinois. The watershed encompasses an area of approximately 32 square miles. Land use in the watershed is predominately grassland followed by forestland and agricultural land uses. TMDLs developed for impaired water bodies in the Dutchman Creek watershed include Dutchman Creek segment ADD02 and Dutchman Lake (RAM). In the 1998 Section 303(d) List, and subsequent 2002 303(d) List, Dutchman Creek ADD02 was listed as impaired for the following parameters: low dissolved oxygen (DO), flow alterations, and other habitat alterations; Dutchman Lake was listed for nitrogen, siltation, DO, total suspended solids (TSS), noxious aquatic plants, 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 only developed for DO for both Dutchman Creek ADD02 and Dutchman Lake. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Dutchman Creek watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001, and in the city of Vienna on December 11, 2001 and December 15, 2003. The Illinois EPA provided public notice for the December 15, 2003 meeting by placing display ads in the "The Vienna Times" on November 20, 2003. 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 40 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the Vienna City Hall offices and also on the Agency's web page at http://www.epa.state.il.us/water/tmdl .

The final public meeting started at 6:30 p.m. on Monday, December 15, 2003. It was attended by approximately five people and concluded at 7:55 p.m. with the meeting record remaining open until midnight, January 20, 2004.

Questions and Comments

1. It should be noted that money for implementing the Conservation Reserve Program and the Wetland Reserve Program is not available for Johnson County at this time. Money used for implementing filter strips and grass waterways could come from the Conservation Practices Program.

Response: Thank you for your comment. This will be noted in the final version of the report.

2. The Johnson County SWCD Board has been reluctant to endorse the use of the IEPA/IDA Nutrient Management Planning project, since there is no way to confirm that producers are following the plan correctly.

Response: IEPA has sponsored nutrient management pilot projects in the past. For those projects, NRCS staff compared producers' fertilizer receipts with past receipts to see how much total fertilizers were applied to a farm, and the subsequent reductions in application.

3. Where would the money come from to pay for dredging the lake?

Response: Although listed as an eligible practice for the EPA 319 program, since dredging does not control or correct the original cause of the problem, it not likely to get funding. However, 319 money can be used for installing an aeration system, which is recommended in the Implementation Plan.
319 money and the Stream Bank Stabilization Program could also be used to fund the installation of riffles and reareation structures within the impaired stream segment.

4. Was there a monitoring station above and below the lake for segment ADD02?

Response: The monitoring station from which water quality data were taken is located downstream of the lake. Currently, there are no monitoring stations for the stream located above the lake.

5. Does Dutchman Lake stratify?

Response: Yes, it stratifies at the deeper area of the lake, near the dam. During lake turnover, the water with low DO rises to the surface, causing impairment. The implementation of an aeration system could curtail DO impairment.

6. How do aeration systems in a lake work, and how effective are they?

Response: Aeration systems add oxygen to stagnant portions of the lake that are considered anoxic (without oxygen). When levels of oxygen are low, especially near the bottom sediments of the lake, desorption of phosphorus from the bottom sediments can occur. This is called internal cycling. Aeration systems help prevent

internal cycling from occurring. Determination of percent reduction of internal cycling is site-specific.

7. What is the most effective way to control phosphorus loadings?

Response: The land management practices described in the Implementation Plan, such as conservation tillage practices and filter strips, could help prevent the runoff of phosphorus particulate matter from nonpoint sources.

8. Dutchman stream segment ADD02 is flashy—that is, it floods quickly and then the water recedes quickly. There is not a constant flow of water in the creek, often leaving it stagnant in between rain events. Could this be adding to causes of impairment?

Response: Yes, low flow and stagnant conditions could be causing low DO within the stream.

9. Why was habitat alterations listed as a cause of impairment for ADD02?

Response: Habitat alteration was listed as cause of impairment for segment ADD 02 based on observations of less than 50% vegetative cover on streambanks and a moderately disturbed riparian zone at station ADD-04.

10. Does the report indicate where the worst parts of the impaired stream are located, so that stream bank stabilization measures can be implemented specifically in those areas that need it most?

Response: For this study, we did not assess the entire length of the stream banks for this segment. Landowners along the streams should assess their streambanks and seek assistance for the areas that need improvement.

11. Staff at NRCS in Johnson County have access to GPS equipment. Could this equipment be used to survey Dutchman Creek segment ADD02 and note areas that could be improved through stream bank restoration or other BMPs?

Response: Yes, that could be a very useful component of the Implementation Plan.

12. In the past, landowners have expressed interest in stream bank stabilization, but funds were not available for such a practice. Since then, programs have been established to fund stream bank stabilization. Landowners need to be aware of this and pursue these programs where applicable.

Response: Thank you for your comment.

13. If all of the management measures suggested in the Implementation Plan are implemented in the watershed, would the lake and stream come into compliance with the water quality standards?

Response: Potentially, yes. As stated in the report, an adaptive management approach is recommended. Not all of these practices need to be implemented all at once, but rather done in stages and then followed up with water quality monitoring.

14. What kind of soils data were used in the modeling?

Response: Since SURRGO data were not available for this watershed, STATSGO GIS coverage was used. The STATSGO data were compared with available SURRGO data from a nearby watershed, and the results were very similar, lending confidence in using the STATSGO data.

15. Could you provide a reference to the specific regulation that allows IEPA to base a pollution control action on a single lowest measured data point that obviously has no defined level of confidence rather than using a measured mean value with a defined level of confidence?

Response: For the purposes of assessing the support of designated uses and for identifying potential causes of impairment, Illinois EPA relies on rules and regulations adopted by the Illinois Pollution Control Board (IPCB). The IPCB has established narrative and numeric water quality standards designed to help protect particular beneficial uses in particular water bodies. In addition, the Agency is required under Section 305 of the Federal Clean Water Act to assess the waters and determine if the designated uses are met. The manner in which these waters are assessed and the applicable water quality standards can be found in the Illinois Water Quality Report 2002. Many water quality standards do not allow any exceedances of a standard, so even if one data point exceeds the standard, the water body is deemed impaired. Once a water body is determined to be impaired, it is placed on the Section 303(d) List. Section 303(d) of the Clean Water Act states that a TMDL be performed for water bodies on this list. As stated in this report, Illinois EPA has determined that it will only develop TMDLs for those parameters which have numeric standards.

16. How sure are you that the data points you claim document poor water quality are not just poor data quality instead?

Response: All data used in this assessment were generated from samples collected by IEPA staff and analyzed in the IEPA laboratories. The data were quality-assured by IEPA Bureau of Water (BOW) staff and entered into the USEPA STORET national database from which they were retrieved. The IEPA Quality Management Plan (QMP), approved by USEPA in 2001, covers the overall quality assurance practices within the Agency. All IEPA BOW sample collection staff follow procedures in the *Bureau of Water Quality Assurance Project Plan* (QAPP, approved by USEPA in 1997) and the *Bureau of Water* Field Methods Manual (1994). Each BOW field staff member receives extensive training before being allowed to collect samples on his/her own. The IEPA laboratories are accredited by the National Environmental Laboratory Accreditation Program (NELAP) and they have their own QMP and conduct analyses using USEPA methods.

17. What is the method detection limit for phosphorous and dissolved oxygen for the method used to collect the data in the Dutchman Creek Watershed? How is the detection limit defined (What is the mathematical formula with definition of the terms?) and what data are the detection limits based on?

Response: The answers to this question is contained in the BOW QAPP (to obtain a copy of the BOW QAPP, call 217-782-3362). Total phosphorus is determined by the IEPA Champaign Laboratory using USEPA Method 365.1. The detection limit for total phosphorus at the IL EPA Champaign Laboratory ranges from 0.005 milligrams per liter (mg/L, Table 1.3 BOW QAPP, 1994) to the current 0.001 mg/L.

Dissolved oxygen (DO) is measured in the field with a HydroLab instrument using a membrane electrode method equivalent to Standard Method 4500-0 G (Standard Methods, 1998) and USEPA Method 360.1. The instrument is calibrated daily before DO field measurements are taken and the calibration results are recorded in a permanently bound logbook. The detection limit that IEPA uses for the membrane electrode method for DO is 0.1 mg/L (Table 1.3 BOW QAPP). The detection limit for this method is given as 0.05 mg/L by the National Environmental Methods Index (NEMI, www.nemi.gov).

Method Detection Limits (MDLs) are statistical figures generated from an 'ideal' instrument/method situation and state that at the MDL level we have 99% confidence that the analyte in question is present (above zero).

MDL studies usually consist of 7 replicate analysis of a known value (approximately 3-5 times the IDL/noise level). The standard deviation is obtained and then multiplied by 3.14 (students 'T' value for 7 replicates). This is the MDL.

18. What are the coefficients of variation for the DO & Phosphorous measured data at the national water quality limit concentrations and what quality control data are those statistics based on?

Response: The coefficient of variation is equivalent to the calculations that IEPA uses for analytical precision (calculations in Section 12.0 of the BOW QAPP). Standard Methods (1998) gives the precision of the membrane electrode method for DO as ±0.05 mg/L. The manufacturer of the instrument that we use for determining DO (HydroLab) says their precision is ±0.2 mg/L Table 3.1 of the BOW QAPP lists the precision for total phosphorus analysis as ≤20%. This precision should be achieved at a concentration that encompasses the water quality standard of 0.05 mg/L. Near the detection limit the precision probably would be less, thus the coefficient of variation would be larger. Section 12 of the BOW QAPP discusses what quality control data are used in the calculation of laboratory precision. To obtain information on the quality control data used for determining DO by the Hydrolab, contact Hydrolab-Hach Company at 1-800-949-3766 or www.hydrolab.com.

19. How many significant figures do the chemists record when the Phosphorus & DO data are collected?
Response: Phosphorus data is reported by the Champaign Laboratory to the nearest 0.01 mg/L. Bureau of Water field staff report DO data to the nearest 0.01 mg/L.

20. What do you estimate it would cost to have collected sufficient data (Phosphorus and DO for the streams emptying into the lake and Dutchman Creek downstream of the lake) to perform a defensible scientific evaluation rather than to proceed with all the estimates in the current draft of the report?

Response: The current TMDL was designed to use readily available data. We have no estimate for collecting data that reduce the margin of error or otherwise improve the TMDL. Additional monitoring, as described in the Implementation Plan, could be used to pinpoint pollutant sources and fill data gaps.

21. Dutchman Lake was established by the Federal Government specifically to stop downstream flooding and that it is and was well known that upstream dams cause increased silting both above and below the dams. Why not just remove the lake dam and return the land to the original owners and the original conditions where the sediment is removed each spring by the floods?

Response: The process of dam removal and subsequent lake removal is beyond the scope of this TMDL study. The purpose of this study is to restore the designated uses to both the stream and the lake through the implementation of best management practices. The practice of dam removal brings with it other environmental consequences that would need to be studied further.

22. Currently there is a proposal for an enormous dredging project downstream in the Cache River basin. The sediment in that streambed and in the creek downstream of the lake dam was partly caused by constructing the dam to form Dutchman Lake. I have not yet seen anything about that in this report.

Response: This TMDL study only focused on the watershed area that affects the water quality of Dutchman Lake and Dutchman Creek segment ADD 02. It is outside the scope of this study to address sedimentation issues affecting other water bodies.

23. The treatment of particulate and dissolved phosphorus in all models used in developing TMDLs remains problematic. Much of the phosphorus measured as total phosphorus is irreversibly bound and not subject to desorption in water (total phosphorus in soils is measured through an acid-extraction process).

Response: This issue could be addressed through further data collection in the tributaries contributing to the lake. This would improve the calibration of the model and would allow additional confidence in the model for predicting

total versus dissolved phosphorus concentrations. The Agency recommends use of an adaptive management approach, concurrent with new data collection and evaluation.

24. It is not apparent how the "Potential Percent Reduction" values in Table 10.3 were derived. For example, what is the basis for the statement in the preceding paragraph, 3rd bullet: "Nutrient management (reduction of total phosphorus in sediment by 20 percent)"? No citations to the scientific literature are provided. While there are several small plot studies that show a generally linear relationship between soil test phosphorus (STP) levels and dissolved phosphorus in runoff and recent watershed-scale work in Iowa showing significant relationships between various measures of STP and total phosphorus in surface water, no data or analysis are presented in support of this statement.

Response: This was a best professional judgment estimate by the consultant as an initial goal to target for nutrient reduction. As nutrient management plans are implemented, the effectiveness on reducing phosphorus concentrations can be further assessed against this initial target goal. The Agency's ongoing nutrient management plan program has also shown an average 20 percent reduction in phosphorus use.

25. Table 10.3 shows a potential reduction of 11 percent for "tillage practices" without specifying what residue levels would be required to achieve that reduction. Table 10.7 indicates that 3,260 acres of conservation tillage should be implemented on the 3,260 acres of cropland in the watershed. Table 5-3 indicates that 61 percent of the corn acres and 89 percent of the soybean acres are currently under no-till.

Response: The tillage practices category listed in Table 10.3 refers to conservation tillage practices, and the report has since been changed to reflect that. Table 10.7 in the report suggests that it would be beneficial for all of the cropland in the watershed to have some form of conservation tillage implemented. Section 10.2.2.6 on page 10-14 of the report states "Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted." The GWLF model took into account those cropland acres in which conservation tillage practices, including no-till, have already been implemented.

26. Conservation tillage systems can result in reductions in sediment-bound phosphorus roughly proportional to the sediment load reductions. However, conservation tillage may also result in increased losses of dissolved phosphorus, primarily due to stratification of P at the soil surface. Because no data are available on phosphorus in the streams within the watershed, it is not possible to determine whether particulate phosphorus or dissolved phosphorus is the form of phosphorus that is of greater concern.

Response: The Agency concurs with this statement. The model used in the analysis focused on total phosphorus, and the load reduction is based on total phosphorus. While data are available for the concentration of total and dissolved phosphorus found within the lake, the type and amount of phosphorus entering the lake from streams is not. The monitoring section of the Implementation Plan proposes that tributary monitoring is needed to assess the total and dissolved phosphorus loads

entering the lake. Besides conservation tillage, other practices for reducing phosphorus loads, such as filter strips, wetlands, and nutrient management plans, are also recommended.

27. Estimations of the effectiveness of management practices such as wetlands or filter strips must account for the proportion of the total runoff in the watershed that will be transported through and effectively treated by the wetland or filter strip. For example, the only water that a filter strip can effectively treat is runoff water that moves through the strip as sheet flow. Water in a concentrated flow channel will not be treated. In addition, for both strips and wetlands, vegetation must be harvested or they will become sources of phosphorus rather than sinks.

Response: Section 10.1.1.1, on page 10-3 of the report states: "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."