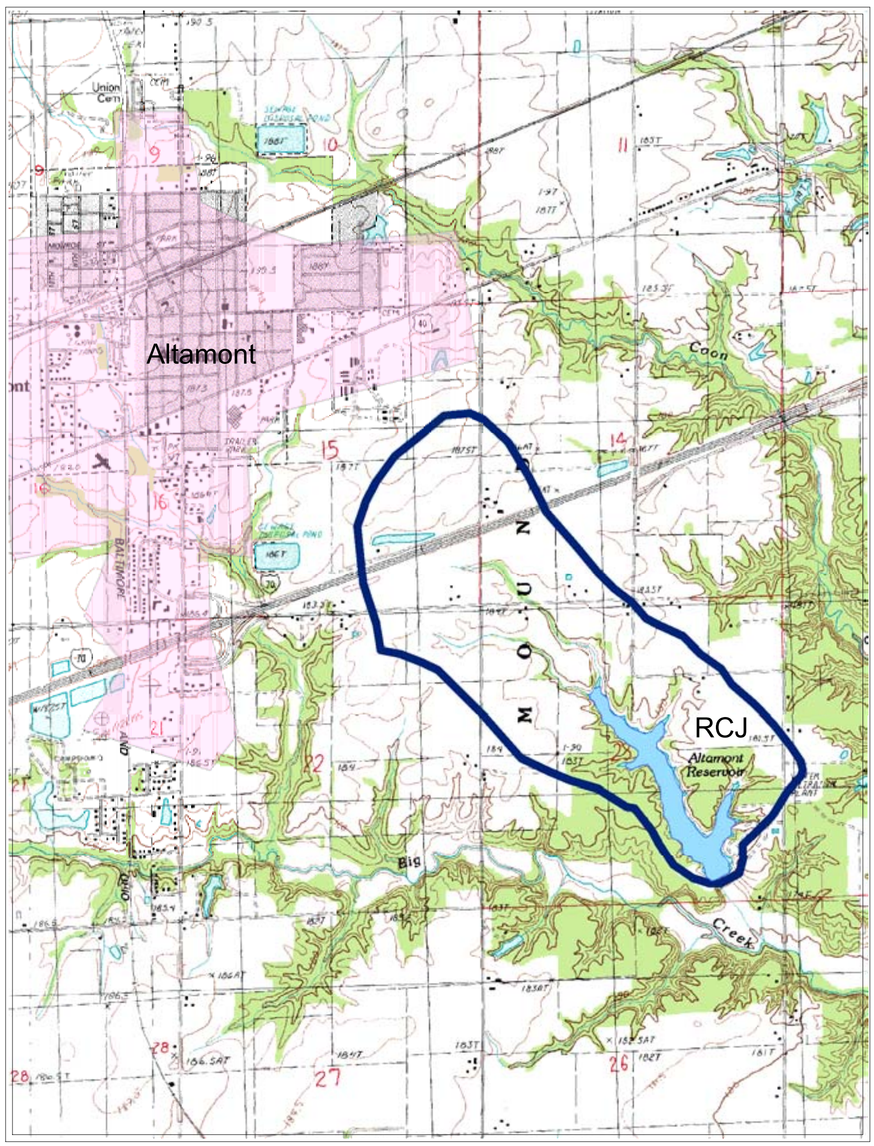
Illinois
Environmental
Protection Agency

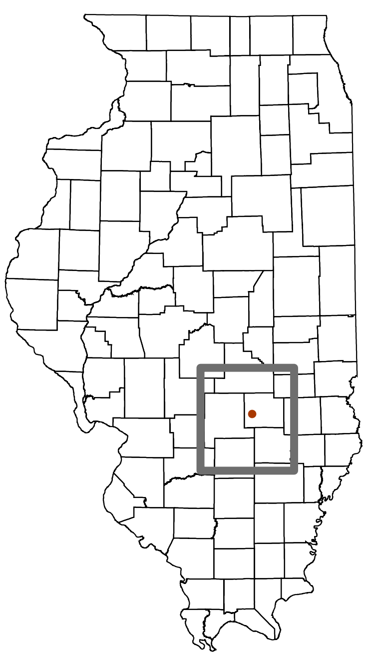
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

October 2004

IEPA/BOW/03-011

ALTAMONT NEW RESERVOIR TMDL REPORT





Printed on Recycled Paper

THIS PAGE INTENTIONALLY LEFT BLANK

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 T. Willhite, Chief
Bureau of Water
Illinois Environmental Protection Agency
1021 North Grand Ave. East
P.O. Box 19276
Springfield, IL 62794-9276

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has reviewed the final Total Maximum Daily Load (TMDL) for Altamont New Reservoir, including supporting documentation and follow up information. IEPA's submitted TMDL addresses the presence of elevated levels of phosphorus that impairs the General Use and the Public and Food Processing Water Supplies Use in approximately 57 acres of Altamont New Reservoir. Based on this review, U.S. EPA has determined that Illinois's TMDL for phosphorus meets the requirements of Section 303(d) of the Clean Water Act and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, U.S. EPA hereby approves Illinois's TMDL for the impaired Altamont New Reservoir, segment RCJ. 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 TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Watersheds and Wetlands Branch at 312-886-4448.

Sincerely yours,

Jo Lynn Traub
Director, Water Division

Enclosure

THIS PAGE INTENTIONALLY LEFT BLANK

Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDLs) for Altamont New Reservoir. In the 1998 Section 303(d) List, Altamont New Reservoir was listed as impaired for the following parameters: aldrin (sediment), copper (sediment), phosphorus, nitrogen, excessive algal growth, and chlorophyll-a. Since then, new data assessed in 2002 showed that Altamont New Reservoir is currently impaired for aldrin (sediment), copper (sediment), phosphorus, total ammonia-N, un-ionized ammonia, 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, this TMDL will only focus on the parameter of phosphorus, for which a numeric water quality standard exists. The un-ionized ammonia cause is being re-evaluated and Illinois EPA plans to continue monitoring for this parameter in Altamont New Reservoir.

Causes of impairment not based on numeric water quality standards will be assigned a lower priority for TMDL development. Pending 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.

THIS PAGE INTENTIONALLY LEFT BLANK

Contents

Executive Summary

Section 1 Goals and Objectives for Altamont New Reservoir Watershed (RCJ21)
1.1 Total Maximum Daily Load (TMDL) Overview 1-1
1.2 TMDL Goals and Objectives for Altamont New Reservoir Watershed 1-2
1.3 Report Overview 1-3

Section 2 Altamont New Reservoir Watershed Description
2.1 Altamont New Reservoir Watershed Overview 2-1
2.2 Lake Segment Site Reconnaissance of the Altamont New Reservoir Watershed 2-1

Section 3 Public Participation and Involvement
3.1 Altamont New Reservoir Watershed Public Participation and Involvement... 3-1

Section 4 Altamont New Reservoir Watershed Water Quality Standards
4.1 Illinois Water Quality Standards 4-1
4.2 Designated Uses 4-1
4.2.1 General Use 4-1
4.2.2 Public and Food Processing Water Supplies 4-1
4.3 Illinois Water Quality Standards 4-1
4.3.1 Phosphorus 4-2
4.3.2 Parameters without Water Quality Standards 4-2
4.4 Pollutant Sources 4-2
4.4.1 Agriculture 4-3
4.4.2 Contaminated Sediments 4-3

Section 5 Altamont New Reservoir Watershed Data Review
5.1 Existing Data Review 5-1
5.1.1 Mapping Data 5-1
5.1.2 Topography Data 5-1
5.1.3 Flow Data 5-2
5.1.4 Precipitation, Temperature, and Evaporation Data 5-2
5.1.5 Water Quality Data 5-3
5.1.5.1 Altamont New Reservoir Water Quality Data 5-4
5.1.5.1.1 Total Phosphorus 5-4
5.1.5.1.2 Tributary Data 5-5
5.1.6 Land Use 5-5
5.1.7 Point Sources and Animal Confinement Operations 5-6
5.1.7.1 Animal Confinement Operations 5-6

5.1.8 Soil Data 5-6
5.1.9 Cropping Practices 5-7
5.1.10 Reservoir Characteristics 5-7
5.1.11 Septic Systems 5-8
5.1.12 Aerial Photography 5-8

Section 6 Methodologies and Models to Complete TMDLs for the Altamont New Reservoir Watershed

6.1 Set Endpoints for TMDLs 6-1
6.2 Methodologies and Models to Assess TMDL Endpoints 6-1
6.2.1 Watershed Models 6-2
6.2.1.1 Watershed Model Recommendation 6-5
6.2.2 Receiving Water Quality Models 6-5
6.2.2.1 Receiving Water Model Recommendation 6-7
6.2.3 Altamont New Reservoir TMDL 6-7
6.2.4 Calibration and Validation of Models 6-7
6.2.5 Seasonal Variation 6-8
6.2.6 Allocation 6-8
6.2.7 Implementation and Monitoring 6-8

Section 7 Model Development for Altamont New Reservoir

7.1 Model Overview 7-1
7.2 Model Development and Inputs 7-2
7.2.1 Watershed Delineation 7-2
7.2.2 GWLF Inputs 7-2
7.2.2.1 Transport Data File 7-2
7.2.2.1.1 Land Use 7-3
7.2.2.1.2 Land Use Area 7-4
7.2.2.1.3 Curve Number 7-4
7.2.2.1.4 KLSCP 7-4
7.2.2.1.5 Erosivity Coefficient 7-6
7.2.2.1.6 Evapotranspiration (ET) Cover Coefficient 7-6
7.2.2.1.7 Recession Constant 7-6
7.2.2.1.8 Seepage Constant 7-7
7.2.2.1.9 Sediment Delivery Ratio 7-7
7.2.2.2 Nutrient Data File 7-7
7.2.2.3 Weather Data File 7-8
7.2.3 BATHTUB Inputs 7-8
7.2.3.1 Global Inputs 7-9
7.2.3.2 Reservoir Segment Inputs 7-9

7.2.3.3 Tributary Inputs ... 7-10
7.3 Model Calibration and Verification ... 7-10
7.3.1 GWLF Calibration ... 7-10
7.3.2 BATHTUB Comparison with Observed Data ... 7-12

Section 8 Total Maximum Daily Load for Altamont New Reservoir
8.1 TMDL Endpoints for Altamont New Reservoir ... 8-1
8.2 Pollutant Source and Linkages ... 8-1
8.3 Allocation ... 8-2
8.3.1 Loading Capacity ... 8-2
8.3.2 Seasonal Variation ... 8-3
8.3.3 Margin of Safety ... 8-3
8.3.4 Waste Load Allocation ... 8-4
8.3.5 Load Allocation and TMDL Summary ... 8-4

Section 9 Implementation Plan for Altamont New Reservoir
9.1 Implementation Actions and Management Measures ... 9-1
9.1.1 Nonpoint Source Phosphorus Management ... 9-1
9.1.1.1 Wetlands ... 9-2
9.1.1.2 Filter Strips ... 9-3
9.1.1.3 Conservation Tillage Practices ... 9-4
9.1.1.4 Nutrient Management ... 9-4
9.1.2 In-Lake Phosphorus ... 9-5
9.1.3 Implementation Actions and Management Measures Summary ... 9-6
9.2 Reasonable Assurance ... 9-6
9.2.1 Available Programs for Phosphorus TMDL ... 9-7
9.2.1.1 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project ... 9-7
9.2.1.2 Clean Water Act Section 319 Grants ... 9-7
9.2.1.3 Conservation Reserve Program (CRP) ... 9-8
9.2.1.4 Wetlands Reserve Program (WRP) ... 9-8
9.2.1.5 Environmental Quality Incentive Program (EQIP) ... 9-9
9.2.1.6 Conservation Practices Program ... 9-10
9.2.1.7 Wildlife Habitat Incentive Program (WHIP) ... 9-10
9.2.2 Cost Estimates of BMPs ... 9-11
9.2.2.1 Wetland ... 9-11
9.2.2.2 Filter Strips and Riparian Buffers ... 9-11
9.2.2.3 Nutrient Management Plan - NRCS ... 9-11
9.2.2.4 Nutrient Management Plan - IDA and Illinois EPA ... 9-11
9.2.2.5 Conservation Tillage ... 9-11
9.2.2.6 Internal Cycling ... 9-12

9.2.2.7 Planning Level Cost Estimates for Implementation Measures 9-12
9.3 Monitoring Plan 9-13
9.4 Implementation Time Line 9-14

Section 10 References

Appendices

Appendix A Historic Water Quality Data
Appendix B GWLF and BATHTUB Input and Output Files
Appendix C GWLF Manual
Appendix D Calculation Details
Appendix E Crop Management "C" Factor Values for Rainfall E.I. Distribution Curve #16
Appendix F Metalimnion Charts
Appendix G Sensitivity Analysis - BATHTUB Output Files
Appendix H Phosphorus Reductions - BATHTUB Output Files
Appendix I Responsiveness Summary

Figures

1-1 Altamont New Reservoir Watershed (ILC21) Impaired Water Bodies........... 1-5
5-1 Altamont New Reservoir Watershed and Historic Sampling Locations 5-9
5-2 Estimated Streamflows in the Altamont New Reservoir Watershed Calculated from Gage 05595820 5-11
5-3 Location of Dairy in Altamont New Reservoir Watershed 5-13
7-1 Altamont New Reservoir Watershed and Historic Sampling Locations 7-15
7-2 Altamont New Reservoir Inflows Monthly Flow Comparison...................... 7-17
7-3 Dissolved and Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Altamont New Reservoir.. 7-19

THIS PAGE INTENTIONALLY LEFT BLANK

Tables

2-1 Impaired Water Bodies in Altamont New Reservoir Watershed 2-1
4-1 Summary of General Use Water Quality Standards for Altamont New Reservoir Watershed 4-2
4-2 Summary of Potential Sources of Pollutants 4-3
5-1 Historical Precipitation Data for the Altamont New Reservoir Watershed 5-2
5-2 Average Monthly Precipitation in Effingham County from 1985 to 2001 5-3
5-3 Historic Water Quality Stations for Altamont New Reservoir 5-3
5-4 Summary of Constituents Associated with Impairments in the Altamont New Reservoir 5-4
5-5 Average Total Phosphorus Concentrations (mg/L) in Altamont New Reservoir at One-Foot Depth (Illinois EPA 2002 and USEPA 2002b) 5-5
5-6 Critical Trends Assessment Land Uses in Altamont New Reservoir (IDNR 1996) 5-6
5-7 Comparison of Land Use Classes in Altamont New Reservoir Watershed 5-6
5-8 Tillage Practices in Effingham County (Effingham County Soil & Water Conservation District 2001) 5-7
5-9 Average Depths (ft) for Altamont New Reservoir (Illinois EPA 2002 and USEPA 2002a) 5-8
6-1 Evaluation of Watershed Model Capabilities - Simple Models (USEPA 1997) 6-3
6-2 Evaluation of Watershed Model Capabilities - Mid-Range Models (USEPA 1997) 6-4
6-3 General Receiving Water Quality Model Characteristics 6-5
6-4 Descriptive List of Model Components - Steady State Water Quality Models 6-6
7-1 Data Needs for GWLF Transport File (Haith et al. 1996) 7-3
7-2 Cropland Data Layer Land Uses and C Factors 7-5
7-3 Critical Trends Land Assessment Land Uses and C Factors 7-6
7-4 Dissolved Phosphorus Concentrations in Runoff from the Altamont New Reservoir Watershed 7-8
7-5 Annual Precipitation in Effingham County 7-9
7-6 Average Total Phosphorus Concentrations in Altamont New Reservoir (mg/L) over All Depths 7-10
7-7 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Altamont New Reservoir Watershed 7-11
7-8 Altamont New Reservoir Calibration Sensitivity Analysis 7-21
8-1 Modeled Total Phosphorus Load by Source 8-1

8-2 Allowable Total Phosphorus Load by Model Year for Altamont New Reservoir ... 8-3
8-3 TMDL Summary for Total Phosphorus in Altamont New Reservoir ... 8-4
8-4 Sources for Total Phosphorus Reductions ... 8-4
9-1 Filter Strip Flow Lengths Based on Land Slope ... 9-4
9-2 Summary of Total Phosphorus Load Reductions ... 9-6
9-3 Costs for Enrollment Options of WRP Program ... 9-9
9-4 Local NRCS and FSA Contact Information ... 9-11
9-5 Cost Estimate of Various BMP Measures in Effingham County ... 9-12
9-6 Cost Estimate of Implementation Measures in the Altamont New Reservoir Watershed ... 9-13

Acronyms

°F	Fahrenheit
µg/L	micrograms per liter
ALMP	Ambient Lake Monitoring Program
BMP	best management practices
CCC	Commodity Credit Corporation
CPP	Conservation Practices Program
CRP	Conservation Reserve Program
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
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 Climate Data Center
NCSU	North Carolina State University
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
ppm	parts per million
STATSGO	State Soil Geographic database
STORET	USEPA *Storage and Retrieval* database
TMDL	Total Maximum Daily Load

USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WHIP	Wildlife Habitat Incentives Program
WLA	Waste Load Allocation
WRP	Wetlands Reserve Program

Executive Summary
Altamont New Reservoir Watershed

TMDL Fact Sheet

Basin Name:	Altamont New Reservoir
Impaired Segment:	RCJ
Location:	Effingham County, Illinois
Size:	57 acres at normal stage
Primary Watershed Land Uses:	Grassland, agriculture, and forest
Criteria of Concern:	Phosphorus
Designated Uses Affected:	General use
Environmental Indicators:	Phosphorus monitoring
Major Sources:	Nonpoint source loading from agricultural and internal cycling
Loading Allocation:	510 pounds/year total phosphorus
Waste Load Allocation:	Zero; No point sources
Margin of Safety:	Implicit through conservative modeling; additional explicit of five percent

This Total Maximum Daily Load (TMDL) assessment for impaired water bodies in the Altamont New Reservoir 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.

Primary sources of phosphorus loading to Altamont New Reservoir 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.

THIS PAGE INTENTIONALLY LEFT BLANK

Section 1
Goals and Objectives for Altamont New Reservoir Watershed (RCJ21)

1.1 Total Maximum Daily Load (TMDL) Overview

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

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

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

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

Water quality standards consist of three elements:

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

Examples of designated uses are recreation, drinking water, 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 Altamont New Reservoir Watershed

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

- Altamont New Reservoir (RCJ)

The TMDL for each segment 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 Altamont New Reservoir Watershed describes how water quality standards will be attained. This implementation plan includes recommendations for implementing best management practices (BMP), cost estimates, institutional needs to implement BMPs and controls throughout the watershed, and timeframe for completion of implementation activities.

1.3 Report Overview

The remaining sections of this report contain:

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

THIS PAGE INTENTIONALLY LEFT BLANK

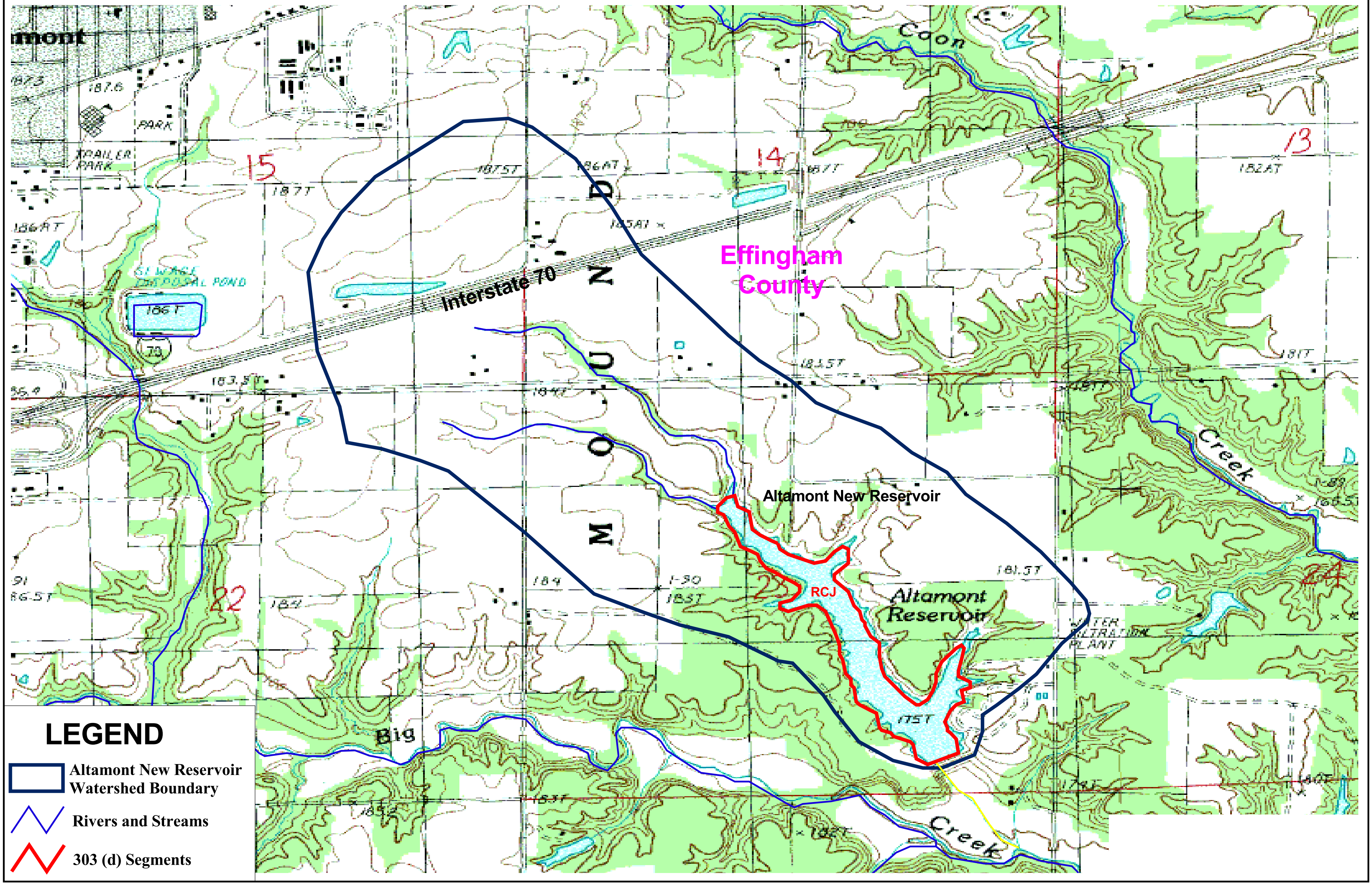


Figure 1-1
Little Wabash River Watershed (ILC21)
Impaired Water Bodies

CDM

iepa\gis_data\apr\altamont.apr 041003 mjf

THIS PAGE INTENTIONALLY LEFT BLANK

Section 2
Altamont New Reservoir Watershed Description

2.1 Altamont New Reservoir Watershed Overview

The Altamont New Reservoir Watershed originates in southwest Effingham County. The watershed encompasses an area of approximately one square mile, and is located within the U.S. Geological Survey (USGS) Little Wabash Basin (Hydrologic Unit Code [HUC] 05120114). Figure 1-1 shows the impaired lake segments within the watershed. Impaired segments are shown in red. Table 2-1 lists the water body segment, water body size, and potential causes of impairment.

Table 2-1 Impaired Water Bodies in Altamont New Reservoir Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
RCJ	Altamont New Reservoir	57 acres	Phosphorus

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

Soils within the Altamont New Reservoir Watershed are primarily comprised of silty and loamy soils. The surface layer is made up of grayish silt loam extending about nine inches. The underlying material is a firm clay loam extending more than 60 inches. Soils are classified as well drained to somewhat poorly drained (U.S. Department of Agriculture [USDA] 1991).

The climate in the Altamont New Reservoir Watershed is typically cold in the winter and warm in the summer. In the winter, the average temperature is 39 degrees Fahrenheit (°F) and the average daily minimum temperature is 29°F according to data collected in Effingham, Illinois. Summer temperatures are typically 68°F with an average daily maximum of 80°F. Annual precipitation is 42 inches of which 24 inches, approximately 56 percent, usually falls in April to September (National Climate Data Center [NCDC] 2002).

2.2 Lake Segment Site Reconnaissance of the Altamont New Reservoir Watershed

The project team conducted a site reconnaissance of the Altamont New Reservoir Watershed on June 18, 2001. This section briefly describes the lake segment and the site reconnaissance.

Table 2-1 lists the impaired stream segments in the Altamont New Reservoir Watershed. Illinois EPA has listed one lake segment as impaired based on the 1998 and 2002 303(d) list for the Altamont New Reservoir Watershed. The Altamont New Reservoir, Segment RCJ, is located on Big Creek, a tributary to the Little Wabash River, in west central Effingham County as shown in Figure 1-1. Altamont Reservoir Dam was constructed on an unnamed tributary of Big Creek in 1972. The dam is owned by the city of Altamont. The dam structure is 506 feet in length and 42 feet tall enabling it to store a maximum volume of 1,255 acre-feet, although the normal storage capacity is 950 acre-feet. The lake is used for both recreation and a local drinking water supply. A few small tributaries and direct drainage constitutes a majority of the 1.1 square miles of contributing drainage area (U.S. Army Corps of Engineers [USACE] 1999a).

Altamont New Reservoir, looking north-northwest at the aerator from the dam.

Altamont New Reservoir was observed on June 18, 2001 at the southern end of the lake from the Altamont Reservoir Dam, which is located off of 500 E Road. The observed surrounding land was primarily farmland with wooded areas surrounding the lake. No residential areas were observed near the lake. The Altamont water treatment plant has an intake in the reservoir, and the facility is located nearby. The reservoir has a volunteer sampling program, and the sign noting this was observed at the reservoir. An aerator was present in the lake. The spillway was dry at the time of the observation. Some algal growth was observed on the rocks near the shore of the reservoir. Riprap had been placed on the slope of the road over the dam for bank stabilization.

Section 3
Public Participation and Involvement

3.1 Altamont New Reservoir 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 Altamont New Reservoir Watershed at 6:30 p.m. on December 6, 2001 at the Effingham County Building in Effingham, Illinois. A total of 25 interested citizens including public officials and organizations other than Illinois EPA attended the public meeting.

THIS PAGE INTENTIONALLY LEFT BLANK

Section 4
Altamont New Reservoir 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. The only designated uses applicable to the Altamont New Lake (Reservoir) Watershed are the General Use and Public and Food Processing Water Supplies.

4.2.1 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).

4.2.2 Public and Food Processing Water Supplies

The Public and Food Processing Water Supplies classification was developed for the protection of potable water supplies and water used for food processing purposes. These waters have more stringent water quality standards and they apply at any point from which water is withdrawn for these uses (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 Altamont New

Lake (Reservoir) 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 Altamont New Reservoir Watershed

Parameter	General Use Water Quality Standard
Phosphorous	0.05 mg/L Lakes/reservoirs >20 acres and streams entering lakes or reservoirs

4.3.1 Phosphorus

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.

Phosphorous is listed as a cause of less than full support use attainment in lakes or reservoirs if the surface total phosphorous concentration is greater than 0.05 mg/L based on Ambient Lake Monitoring Program (ALMP) or Illinois Clean Lakes Program (ICLP) data.

4.3.2 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 Altamont New Reservoir Watershed, many of the management measures discussed in Section 9 of this report will result in reductions of the parameters listed in the 1998 and 2002 303(d) lists that do not currently have adopted water quality standards. For example, many of the management measures that will be discussed in Section 9 address the other parameters of concern for the watershed. For total ammonia-N and un-ionized ammonia management measures that control erosion will reduce these pollutants from entering the reservoir. All management measures discussed in Section 9 will help reduced chlorophyll-a and excessive algal growth within in the reservoir as the BMPs discussed are based on controlling nutrient levels in the reservoir. For copper and aldrin, dredging of the reservoir which, is discussed in Section 9, is a management measure that would address these impairments.

4.4 Pollutant 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 Animal holding/management areas	Phosphorous
Contaminated Sediments	Phosphorous

4.4.1 Agriculture

The southern Illinois area is largely agriculture land use. Rural grassland is the largest single category land use in the basin. Agricultural land uses potentially contribute nutrients and pesticides to stream and lake loadings. 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 nutrients and pesticides. This can also be caused by livestock on pastures and feedlots. Wastes from livestock can enter streams or lakes, which can contribute a phosphorus load.

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 metals, pesticides, and nutrients. Contaminated sediments containing metals can originate from urban areas or mining locations, while the contaminated sediments containing pesticides are typically from agricultural lands. Both agricultural lands and urban areas can 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. Phosphorous is commonly released from sediment into the water column especially when anoxic conditions persist.

THIS PAGE INTENTIONALLY LEFT BLANK

Section 5
Altamont New Reservoir 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 Altamont New Reservoir, Segment RCJ. 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 water quality stations for the Altamont New Reservoir Watershed and the watershed boundary. 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 Altamont New Reservoir Watershed require an understanding of flow into Altamont New Reservoir. No gage for the tributary to Altamont New Reservoir exists, and there is no active stream gage within the impaired segment. 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 05595820 (Casey Fork at Mount Vernon, Illinois) was chosen as an appropriate gage from which to compute flow into Altamont New Reservoir. 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 southwest of the Altamont New Reservoir 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 average monthly flows over the period of record into Altamont New Reservoir calculated from the drainage area ratio method using gage 05595820.

5.1.4 Precipitation, Temperature, and Evaporation Data

As discussed in Section 2.1, the Altamont New Reservoir Watershed is located entirely within Effingham County as shown in Figure 5-1. Daily precipitation and temperature data for Effingham County were extracted from the NCDC database for the years of 1985 through 2001. Two months of data were missing from the Effingham County gage. Missing data were supplemented with data from a gage in neighboring Fayette County. Table 5-1 lists the station details for the Effingham County and Fayette County gages.

Table 5-1 Historical Precipitation Data for the Altamont New Reservoir Watershed

NCDC Gage Number	Station Location	Period of Record
2687	Effingham County (Effingham)	1901-present
8781	Fayette County (Vandalia)	1948-present

Table 5-2 shows the average monthly precipitation of the dataset developed for Effingham County for the years 1985 to 2001. The average annual precipitation over the same period is approximately 42 inches for Effingham County.

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

Month	Average Precipitation (inches)
January	2.7
February	2.6
March	2.8
April	4.1
May	4.8
June	4.2
July	4.8
August	2.8
September	3.0
October	3.1
November	4.5
December	2.8
TOTAL	**42.2**

Pan evaporation data is available through the Illinois State Water Survey (ISWS) website at nine locations across Illinois (ISWS 2002). The Carlyle station was chosen for its proximity to the 303(d)-listed water bodies and stream segments in southern Illinois and the completeness of the dataset as compared to other stations. The Carlyle station is approximately 45 miles southwest of the Altamont New Reservoir Watershed. The average monthly pan evaporation for the years 1980 to 2001 at the Carlyle station was downloaded from the ISWS website and summed to produce an average annual pan evaporation of 44.2 inches. Actual evaporation is typically less than pan evaporation, so the average annual pan evaporation was multiplied by 0.75 to calculate an average annual evaporation of 33.2 inches (ISWS 2002).

5.1.5 Water Quality Data

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

Table 5-3 Historic Water Quality Stations for Altamont New Reservoir

Location	Station Identification Number	Data Collection Agency
Altamont Lake	RC-A09-J-1	Illinois EPA Division of Water Pollution Control
Altamont Lake	RC-A09-J-2	Illinois EPA Division of Water Pollution Control
Altamont Lake	RC-A09-J-3	Illinois EPA Division of Water Pollution Control

The impaired water body segment in the Altamont New Reservoir Watershed was presented in Section 2. For Altamont New Reservoir, segment RCJ, there are three historic water quality stations. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA *Storage and Retrieval (STORET)* database associated with impairments discussed in Section 2 for the Altamont New Reservoir Watershed.

Table 5-4 Summary of Constituents Associated with Impairments in the Altamont New Reservoir

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined for Samples	Number of Samples
Altamont New Reservoir Segment RCJ; Sample Locations RCJ-1, RCJ-2, and RCJ-3			
RCJ-1			
Phosphorus	0.05	4/13/90-8/22/01	51
RCJ-2			
Phosphorus	0.05	4/13/90-8/22/01	14
RCJ-3			
Phosphorus	0.05	4/13/90-8/22/01	20

5.1.5.1 Altamont New Reservoir Water Quality Data

There are three water quality stations in Altamont New Reservoir as shown in Figure 5-1 and listed in Table 5-3. The water quality station data for Altamont New Reservoir were downloaded from the *STORET* online database (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 Altamont New Reservoir as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

Constituents are sampled at various depths throughout Altamont New Reservoir, 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 Altamont New Reservoir. 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 7.2.3.2.

5.1.5.1.1 Total Phosphorus

The average total phosphorus concentrations at one-foot depth for each year of available data from 1990 to 2001 at each monitoring site in Altamont New Reservoir are presented in Table 5-5. At station RCJ-1, samples were taken at a one-foot depth from the lake surface and at the lake bottom. Beginning in 2001, samples include a mid-depth sample at RCJ-1 because Altamont New Reservoir is a public water supply. Samples at stations RCJ-2, and RCJ-3 were only taken at a one-foot depth from the lake surface. The water quality standard for total phosphorus is less than or equal to 0.05 mg/L at a one-foot depth. The TMDL endpoint for total phosphorus in lakes is 0.05 mg/L. The raw data for all samples are contained in Appendix A.

Table 5-5 Average Total Phosphorus Concentrations (mg/L) in Altamont New Reservoir at One-Foot Depth (Illinois EPA 2002 and USEPA 2002b)

Year	RCJ-1	RCJ-2	RCJ-3	Lake Average
1990	0.11	0.18	0.17	0.15
1993	0.12		0.13	0.12
1995	0.08			0.08
1997	0.09			0.09
1998	0.12	0.15	0.18	0.15
2001	0.13	0.11	0.11	0.12

The annual averages for total phosphorus at all three stations and the annual lake averages are all greater than the endpoint of 0.05 mg/L. It is apparent from Table 5-5 that concentrations at all stations repeatedly violate the phosphorus standard. The raw data for all sample depths are contained in Appendix A.

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

5.1.5.1.2 Tributary Data

There is no water quality data available for the unnamed tributaries to Altamont New Reservoir. 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 dissolved oxygen conditions near lake sediments, which promote re-suspension of phosphorus from the sediments into the water column. External versus internal loads will be discussed further in Section 7.3.2.

5.1.6 Land Use

The Illinois Natural Resources Geospatial Clearinghouse distributes the Critical Trends Assessment Land Cover Database of Illinois. This database represents 23 land use classes created by satellite imagery captured between 1991 and 1995. The data were published in 1996 and are distributed by county in grid format for use in GIS. The GIS-delineated watershed for Altamont New Reservoir was used to obtain the land use from the Critical Trends Assessment Land Cover grid. Table 5-6 lists the land uses contributing to the Altamont New Reservoir Watershed as well as each land use area and percent of total area.

Table 5-6 Critical Trends Assessment Land Uses in Altamont New Reservoir (IDNR 1996)

Land Use	Acres	Percent of Area
Rural Grassland (pastureland, grassland, waterways, buffer strips, CRP land, etc.)	227	36%
Row Crop (corn, soybeans, and other tilled crops)	219	35%
Deciduous Forest	101	16%
Small Grains (wheat, oats, etc.)	81	13%
Total	**628**	**100%**

Additional land use data were obtained from the Spatial Analysis Research Center's Cropland Data Layer to supplement the Critical Trends Assessment dataset. The data were requested from the National Agricultural Statistics Service (NASS) website for the years of 1999 and 2000 (NASS 2002). The Cropland Data Layer is also derived from satellite imagery, but the land use classes for crops are more detailed than those presented in the Critical Trends Assessment dataset. The detailing of crops in the Cropland Data Layer land use classes makes it a more accurate dataset for calculation of crop-related parameters. The dataset was also used to verify the land use obtained from the Critical Trends Assessment. Table 5-7 shows the cropland use classes of the Cropland Data Layer and the Critical Trends Assessment classes to which they were applied.

Table 5-7 Comparison of Land Use Classes in Altamont New Reservoir 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 and Animal Confinement Operations

5.1.7.1 Animal Confinement Operations

The presence of a dairy farm in the watershed was discussed in a public meeting held on December 6, 2001. The location of the dairy was confirmed with aerial photographs as shown in Figure 5-3 at the end of this section. Illinois EPA has confirmed that this dairy is no longer producing milk, but the cows associated with the dairy operation are potentially still located on the property. No other point sources were identified in the Altamont New Reservoir 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 HUC from the USEPA *BASINS* website (USEPA 2002a). *STATSGO* data are presented as map units of soils in which each map unit has a unique code linking it to attribute tables listing percentages of soil types within a map unit, soil layer depths, hydrologic soil groups, and soil texture among other soil properties.

5.1.9 Cropping Practices

Tillage practices can be categorized as conventional till, reduced till, mulch-till, and no-till. The percentage of each tillage practice for corn, soybeans, and small grains, presented in Table 5-8, was generated by the Illinois Department of Agriculture from the 2001 County Transect Survey for Effingham County. Data specific to the Altamont New Reservoir Watershed were not available; however, the Effingham County NRCS office verified that the percentages of each tillage practice were acceptable for application to the Altamont New Reservoir Watershed as shown in Table 5-8 (NRCS 2002a).

Table 5-8 Tillage Practices in Effingham County (Effingham County Soil & Water Conservation District 2001)

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	91%	48%	89%
Reduced Till	4%	18%	4%
Mulch-Till	2%	8%	0%
No-Till	3%	26%	7%

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

5.1.10 Reservoir Characteristics

Reservoir characteristics were obtained from the GIS analysis, the Illinois EPA, and USEPA water quality data. The Illinois EPA reports a surface area of 57 acres, which was used to validate the surface area of 57 acres obtained from GIS analysis.

The water quality dataset described in Section 5.1.5.1 was used to determine the average depth of Altamont New Reservoir. On each date sampled for water quality constituents, the total depth at the site was measured. Table 5-9 lists the average depth calculated for each water quality site in Altamont New Reservoir for each year of available data after 1990.

Table 5-9 Average Depths (ft) for Altamont New Reservoir (Illinois EPA 2002 and USEPA 2002a)

Year	RCJ-1	RCJ-2	RCJ-3	Lake Average
1990	28.9	16.8	7.8	17.8
1991	27.0	15.5	6.8	16.4
1992	25.5	13.5	4.2	14.4
1993	29.2	17.9	8.4	18.5
1994	27.9	16.7	7.0	17.2
1995	28.2	16.6	6.9	17.2
1996	27.7	16.7	7.1	17.2
1997	27.5	16.3	6.9	16.9
1998	28.3	16.7	8.1	17.7
2001	28.5	15.8	8.0	17.4

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 watershed could not be confirmed from available data sources. There were no residences observed near the reservoir during the site visit described in Section 2.2. 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 Altamont New Reservoir Watershed were obtained from the Illinois Natural Resources Geospatial Data Clearinghouse. The photographs were used to supplement the USGS quadrangle maps when locating facilities.

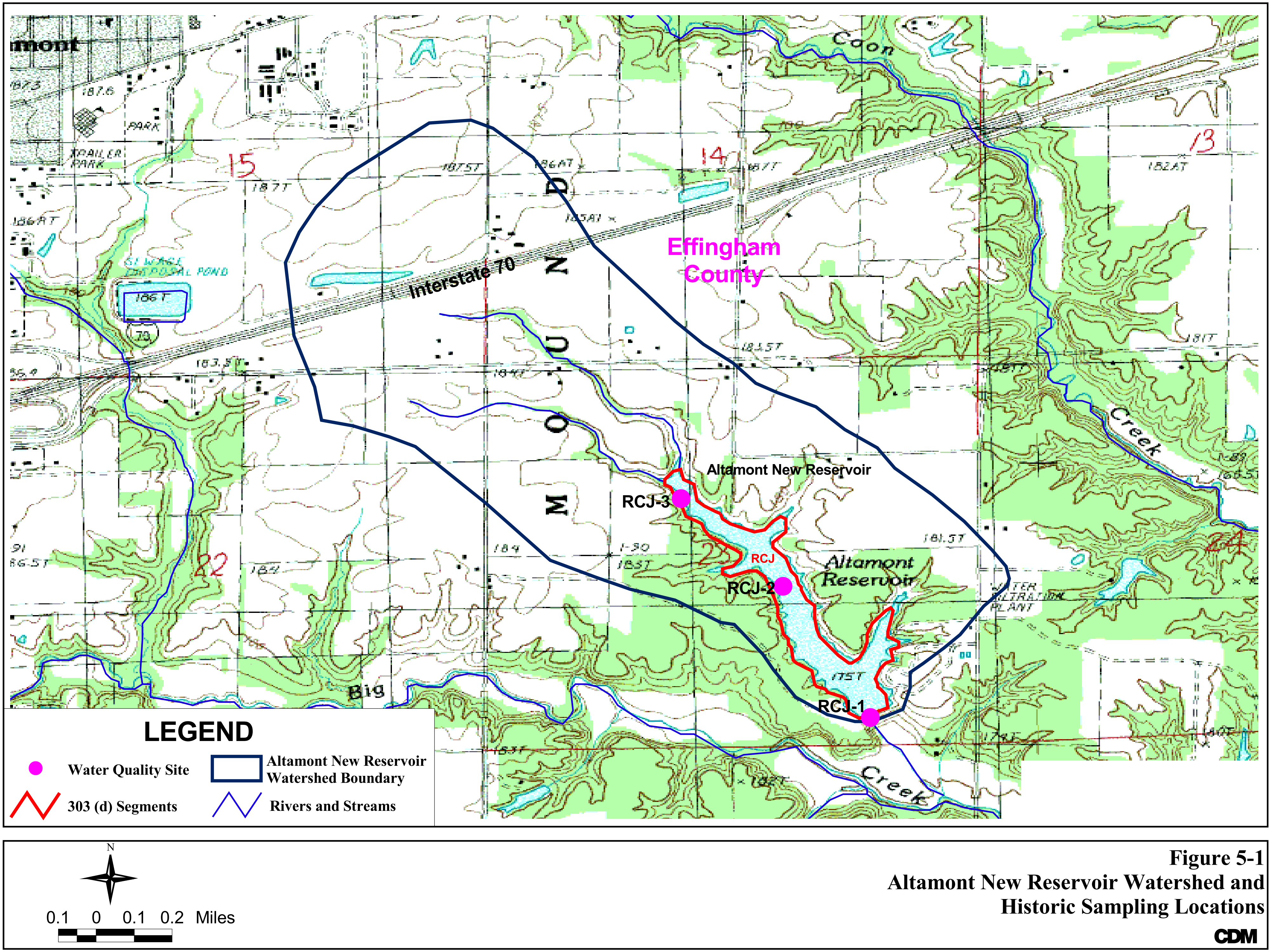


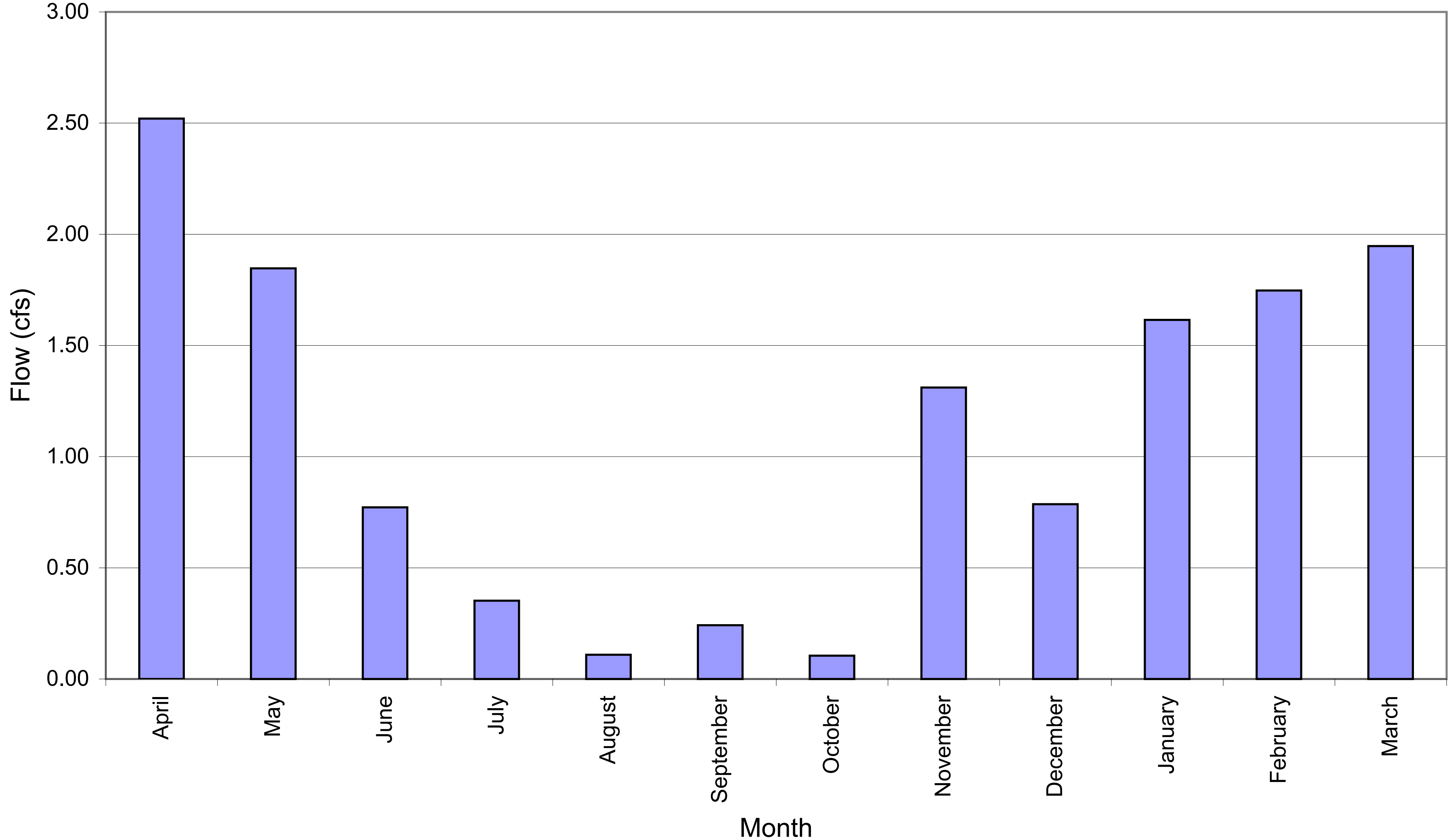
Figure 5-1
Altamont New Reservoir Watershed and Historic Sampling Locations

CDM

iepa\gis_data\apr\altamont

THIS PAGE INTENTIONALLY LEFT BLANK

Figure 5-2: Estimated Streamflows in the Altamont New Reservoir Watershed Calculated from Gage 05595820



Period of Record
October 1, 1985 to September 30, 2000

THIS PAGE INTENTIONALLY LEFT BLANK

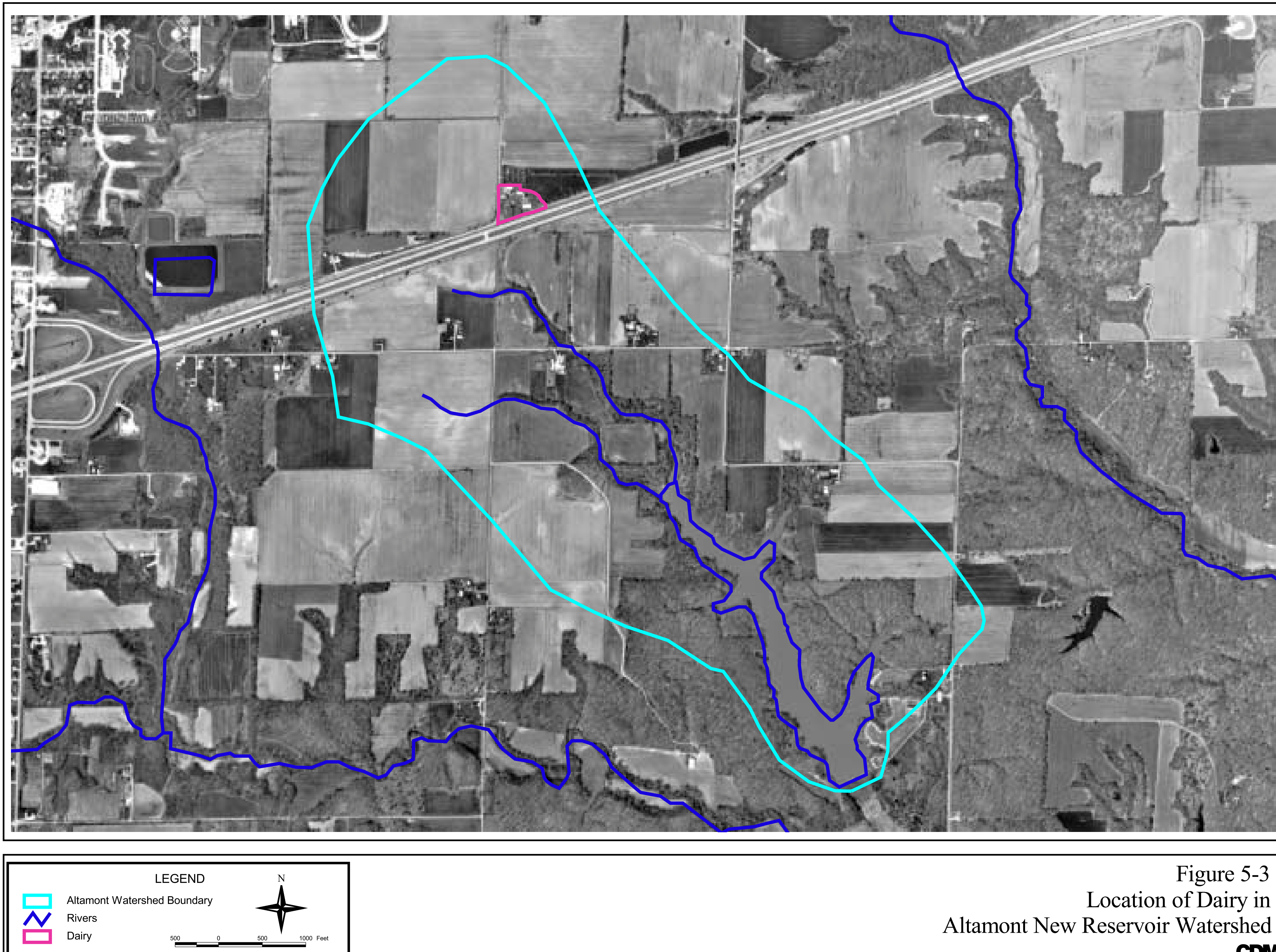


Figure 5-3
Location of Dairy in
Altamont New Reservoir Watershed

CDM

iepa\gis_data\apr\altamont.apr 041103 mjf

THIS PAGE INTENTIONALLY LEFT BLANK

Section 6
Methodologies and Models to Complete TMDLs for the Altamont New Reservoir 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 Altamont New Reservoir Watershed. The endpoint presented in Section 4, which is a chemical endpoint of the following constituents, was targeted: phosphorus.

6.2 Methodologies and Models to Assess TMDL Endpoints

Methodologies and models were utilized to assess TMDL endpoints for the Altamont New Reservoir 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 Altamont New Reservoir 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 Altamont New Reservoir is the Generalized Watershed Loading Function (GWLF) model. The GWLF model was chosen for the Altamont New Reservoir 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 decisionmaking

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 dissolved oxygen (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

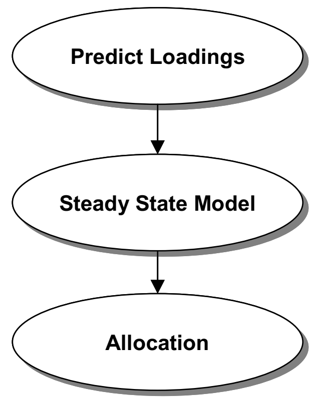
The receiving water model recommended for Altamont New Reservoir is BATHTUB, which applies a series of empirical eutrophication models to reservoirs and lakes. The program performs steady state water and nutrient balance calculations in a spatially segmented hydraulic network that accounts for advective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

6.2.3 Altamont New Reservoir TMDL

For Altamont New Reservoir, a TMDL for the following constituent was completed using a watershed/receiving water model combination:

- phosphorus

The strategy for completing the watershed/receiving water model TMDL for Altamont New Reservoir is shown in Schematic 1 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 were predicted, the BATHTUB model was used to determine the resulting phosphorus concentrations within Altamont New Reservoir. Model development is discussed further in Section 7.



Schematic 1

6.2.4 Calibration and Validation of Models

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

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 Altamont New Reservoir 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 9 Implementation Plan. The calibration process for the BATHTUB model is also outlined in Section 7. For Altamont New Reservoir, 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.

6.2.5 Seasonal Variation

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

6.2.6 Allocation

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

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

6.2.7 Implementation and Monitoring

For the Altamont New Reservoir 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 Altamont New Reservoir Watershed, the time frame for achieving water quality standards has been developed.

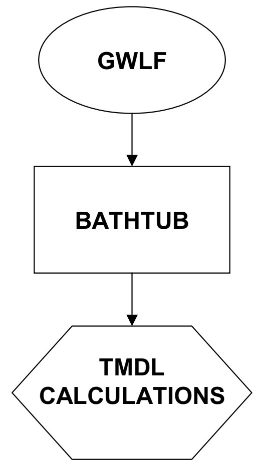
The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. Reductions from point sources through waste stream management, pretreatment controls, and other structural and nonstructural programs were also identified as applicable. The implementation plan for the Altamont New Reservoir Watershed is presented in Section 9.

THIS PAGE INTENTIONALLY LEFT BLANK

Section 7
Model Development for Altamont New Reservoir

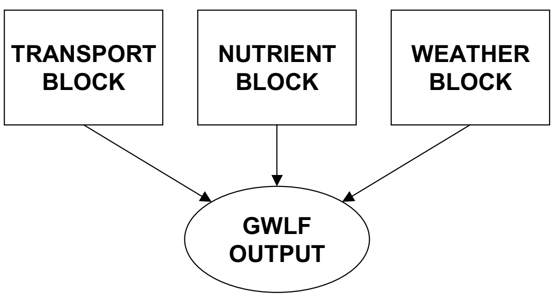
7.1 Model Overview

The models used for the TMDL analysis of Altamont New Reservoir 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.



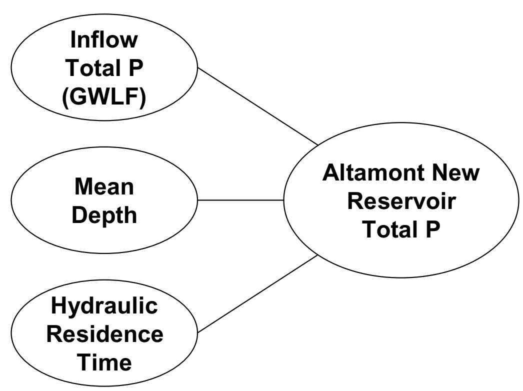
Schematic 1
Models used for Altamont New Reservoir TMDL calculation.

Schematic 1 shows how the GWLF model and BATHTUB model are 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 conjunction with the weather block predict both solid and dissolved phosphorus loads.



Schematic 2
GWLF Model.

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.

7.2 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.

7.2.1 Watershed Delineation

Prior to developing input parameters for the GWLF or BATHTUB models, a watershed for Altamont New Reservoir was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation indicates that Altamont New Reservoir captures flows from a watershed of approximately one square mile. The flow through the lake is primarily from northwest to southeast. Figure 7-1 at the end of this section shows the location of each water quality station in Altamont New Reservoir, the boundary of the GIS-delineated watershed contributing to Altamont New Reservoir used in GWLF modeling, and the outline of the lake for BATHTUB modeling purposes.

7.2.2 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).

7.2.2.1 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

7.2.2.1.1 Land Use

Land use for the Altamont New Reservoir Watershed was extracted from the Critical Trends Assessment Database grid for Effingham 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 5-6.

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.

The GWLF model requires nutrient runoff concentrations for each land use. The rural grassland category provided in Table 5-6 represents multiple land uses such as the Conservation Reserve Program (CRP), grassland, waterways, pasture land, and buffer strips, which may have varying runoff concentrations. To provide accurate modeling in GWLF, the Effingham County NRCS office was contacted to provide more information about the rural grassland land use class. The Effingham County NRCS recommended the category be considered idle grassland as it primarily represents areas around the lake that are owned by the city of Altamont and allowed to remain idle (2002a).

Due to the detailing of crops, the Cropland Data Layer land use classes, presented in Table 5-8, 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.

7.2.2.1.2 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.

7.2.2.1.3 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.

7.2.2.1.4 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 following paragraphs. GWLF calculates the rainfall energy factor (R) with precipitation and a rainfall erosivity coefficient that will be discussed in Section 7.2.2.1.5.

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 the 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 Effingham 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 Effingham 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 Altamont New Reservoir Watershed.

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

Land Use	Area (acres)	C factor
Corn	140	0.32
Soybeans	98	0.20
Winter Wheat	22	0.11
Other Small Grains & Hay	16	0.11
Double-Cropped WW/SB	47	0.09
Idle Cropland/CRP	0	0.004
Fallow/Idle Cropland	35	0.004
Pasture/Grassland/ Nonagricultural	153	0.004
Woods	122	0.003
Urban	10	–
Water	24	–
Buildings/Homes/Subdivisions	7	–
Wetlands	1	–

The identification of crops is more detailed in the Cropland Data Layer file than the Critical Trends Land Assessment file, but the latter is used for GWLF input. Therefore, the C factor associated with the Cropland Data Layer land uses was weighted by area to create a C factor for the Critical Trends Land Assessment land uses shown in Table 7-3. 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	Area (acres)	C factor
Row Crop	219	0.25
Small Grains	81	0.10
Rural Grassland	227	0.004
Deciduous Forest	101	0.003

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 Altamont New Reservoir Watershed, so a P factor of one was assigned to each land use.

7.2.2.1.5 Erosivity Coefficient

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

7.2.2.1.6 Evapotranspiration (ET) Cover Coefficient

An ET cover coefficient for each month is required as an input parameter to GWLF representing the effects of ground cover on evapotranspiration. Ground cover changes with land use and growing season, so the computation of a single cover coefficient for each month required a series of calculations. ET cover coefficients for corn, winter wheat, sorghum, and soybeans at 10 percent increments of the growing season were obtained from GWLF Manual, page 29. These coefficients were weighted by the area of each crop in the Cropland Data Layer land use file to compute a single crop ET cover coefficient for each 10 percent increment of the growing season. The crop coefficients for each portion of the growing season were averaged to obtain a single crop coefficient for each calendar month. Monthly ET cover coefficients for pasture, woods, and urban areas were also obtained from pages 29 and 30 of the GWLF Manual. A monthly cover coefficient for water and wetlands was assumed to be 0.75. Weighting the coefficient for each land use by the Cropland Data Layer land use area created a single ET cover coefficient for each month. Details of the ET cover coefficient calculation are provided in Appendix D.

7.2.2.1.7 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 7.3.1.

7.2.2.1.8 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 7.3.1.

7.2.2.1.9 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 ratio for Altamont New Reservoir is 0.33 representing the annual sediment yield per annual erosion.

7.2.2.2 Nutrient Data File

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

All solid-phase nutrient concentrations from runoff for Altamont New Reservoir 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 0.07-percent phosphate was selected and then converted to 700 parts per million (ppm) using the relationship 0.1 percent = 1,000 ppm. Phosphate is composed of 44 percent phosphorus, so the 700-ppm phosphate was multiplied by 0.44 to obtain a value of 308-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 616 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 the rural grassland land use and concentrations from the dairy. The rural grassland dissolved phosphorus concentration was estimated from the dissolved phosphorus concentration for pasture. The idle grassland is assumed to have less animals, and therefore animal waste, than pasture land, so the concentration was reduced for the rural grassland land use class. The selection of dissolved phosphorus concentrations will be confirmed in Section 7.3.1. The concentration from the dairy was obtained from USEPA, which provides a range of 5 to 500 mg/L for dairy barnyards (2000). The concentration used to model the dairy was 123.75 mg/L, which was determined through calibration analyses discussed in Section 7.3.2.

Table 7-4 Dissolved Phosphorus Concentrations in Runoff from the Altamont New Reservoir Watershed

Land Use	Dissolved Phosphorus (mg/L)
Row Crop	0.26
Small Grains	0.3
Rural Grasslands	0.15
Deciduous Forest	0.009
Dairy Farm	123.75

Table 7-4 lists the land uses in the Altamont New Reservoir 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 7-4 exceed the endpoint of 0.05 mg/L of total phosphorus, once the surface runoff reaches Altamont New Reservoir or its tributaries, it mixes with water already in the stream or lake and the concentration decreases. Therefore, it cannot be concluded without analysis that constituents with dissolved concentrations above the endpoint for total phosphorus are responsible for water quality impairments.

The GWLF manual suggests nutrient concentrations in groundwater based on the percentage of agricultural versus forestlands. These percentages were calculated from the land use areas in the watershed, and the appropriate groundwater concentrations were selected from the GWLF manual, page 41. The Altamont New Reservoir watershed is 48 percent agricultural lands, which corresponds to a phosphorus concentration of 0.067 mg/L in the groundwater.

7.2.2.3 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.

7.2.3 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 7-5 Annual Precipitation in Effingham County

Year	Precipitation (inches)
1986	38
1987	34
1988	36
1989	46
1990	44
1991	47
1992	38
1993	59
1994	46
1995	40
1996	41
1997	37
1998	48
1999	43
2000	54
2001	36
Annual Average	**42**

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 7-5 shows these annual and average annual precipitation values in Effingham County. Each water year was then classified as wet, dry, or normal based on a comparison to the average water year precipitation of 42 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 wet, normal, and dry years were chosen as 1993, 1998, and 2001, respectively, for Altamont New Reservoir based Table 7-5.

7.2.3.1 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 7-5 for the model years 1993, 1998, and 2001. An average annual evaporation was determined from pan evaporation data as discussed in Section 5.1.4. The default atmospheric phosphorus deposition rate suggested in the BATHTUB model was used in absence of site-specific data, which is a value of 30 kg/km^2-yr (USACE 1999b).

7.2.3.2 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.

Altamont New Reservoir was modeled as a single segment in BATHTUB because it is a small reservoir. To represent the average reservoir characteristics, an average annual value of total phosphorus was calculated for the entire reservoir for input of observed data. The averages of total phosphorus sampled at one-foot depth were presented in Table 5-5; 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 7-6 shows the average annual total phosphorus concentrations for all sample depths at each station in the Altamont New Reservoir. As mentioned in Section 5.1.5.1.1, station RCJ-1 had samples taken at one-foot depth from the surface and at the lake bottom whereas stations RJC-2 and RJC-3 were only sampled at one-foot depth. The raw data for all sample depths are contained in Appendix A.

Table 7-6 Average Total Phosphorus Concentrations in Altamont New Reservoir (mg/L) over All Depths

Year	RCJ-1	RCJ-2	RCJ-3	Lake Average
1993	0.12		0.13	0.12
1998	0.14	0.15	0.18	0.15
2001	0.14	0.11	0.11	0.12

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 5-9. 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.

7.2.3.3 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 Altamont New Reservoir Watershed, the single basin modeled in GWLF represents the tributary input. 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.

7.3 Model Calibration and Verification

The GWLF model was calibrated prior to BATHTUB calibration. The GWLF model for the Altamont New Reservoir 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 Altamont New Reservoir.

7.3.1 GWLF Calibration

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

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 05595820 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 7-2 (at the end of this section) shows the comparison between the two flows for Altamont New Reservoir. The GWLF model for Altamont New Reservoir was visually calibrated with a resulting recession constant of 0.1 and a seepage constant of 0.05. 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 17 years of observed flow.

Although in-stream nutrient concentrations are not available for the tributaries to Altamont New Reservoir, 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 Altamont New Reservoir, were compared to the measured dissolved and total phosphorus concentrations from tributaries to lakes observed in the Clean Lakes studies as shown in Figure 7-3. The concentrations within the Altamont New Reservoir Watershed are within the ranges of those in the other lake watersheds shown in Figure 7-3.

Table 7-7 shows the comparison between dissolved and total phosphorus in watersheds from Clean Lakes Studies and in the Altamont New Reservoir Watershed.

Table 7-7 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Altamont New Reservoir 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
Altamont New Reservoir	1	0.19	0.32	0.61

The ratio of dissolved to total phosphorus in the Altamont New Reservoir Watershed are within the ranges of the Clean Lake Study watersheds.

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 Altamont New Reservoir 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 Altamont New Reservoir Watershed are consistent with those seen in the spatial representation for watersheds.

7.3.2 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 5-4 and 5-5. 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 1999b). The calibration limits for chlorophyll "a" are not defined in the BATHTUB manual.

Because independent measurements of internal nutrient loading are not available, these values were estimated based on varying concentration from the inactive dairy located within the watershed and total phosphorus concentration in the soil as shown in Table 7-8 (at the end of this section). The internal loads were entered into the BATHTUB model so that agreement between the observed and estimated in-lake values matched. To establish at what levels the appropriate dairy dissolved phosphorus concentration and soil total phosphorus concentration occur, the calibration factors that would need to be applied for each scenario outlined were calculated as presented in Table 7-8.

The GWLF model was set at a total phosphorus soil concentration of 616 ppm and the dairy dissolved phosphorus concentration of 123.75 mg/L 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 792 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 7-8). The calibration factor range for total phosphorus modeling in BATHTUB is 0.5 to 2 and use of the 616-ppm total phosphorus in the soil falls within this accepted range. Table 7-8 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 7-8 represent the average observed in-lake concentrations. The results of the modeling sensitivity analyses are contained in Appendix G.

A robust calibration and validation of Altamont New Reservoir 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 7-8 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 1999b). A robust calibration and validation of Altamont New Reservoir will be possible if data collection activities outlined in the future monitoring in Section 9 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 that internal cycling is occurring in Altamont New Reservoir in 1993, 1998, 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 1999b and 2003). Table 5-10 notes a depth of approximately 17 feet for Altamont New Reservoir, 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 7-8.

Because the modeling of Altamont New Reservoir changes is 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 8. 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.

THIS PAGE INTENTIONALLY LEFT BLANK

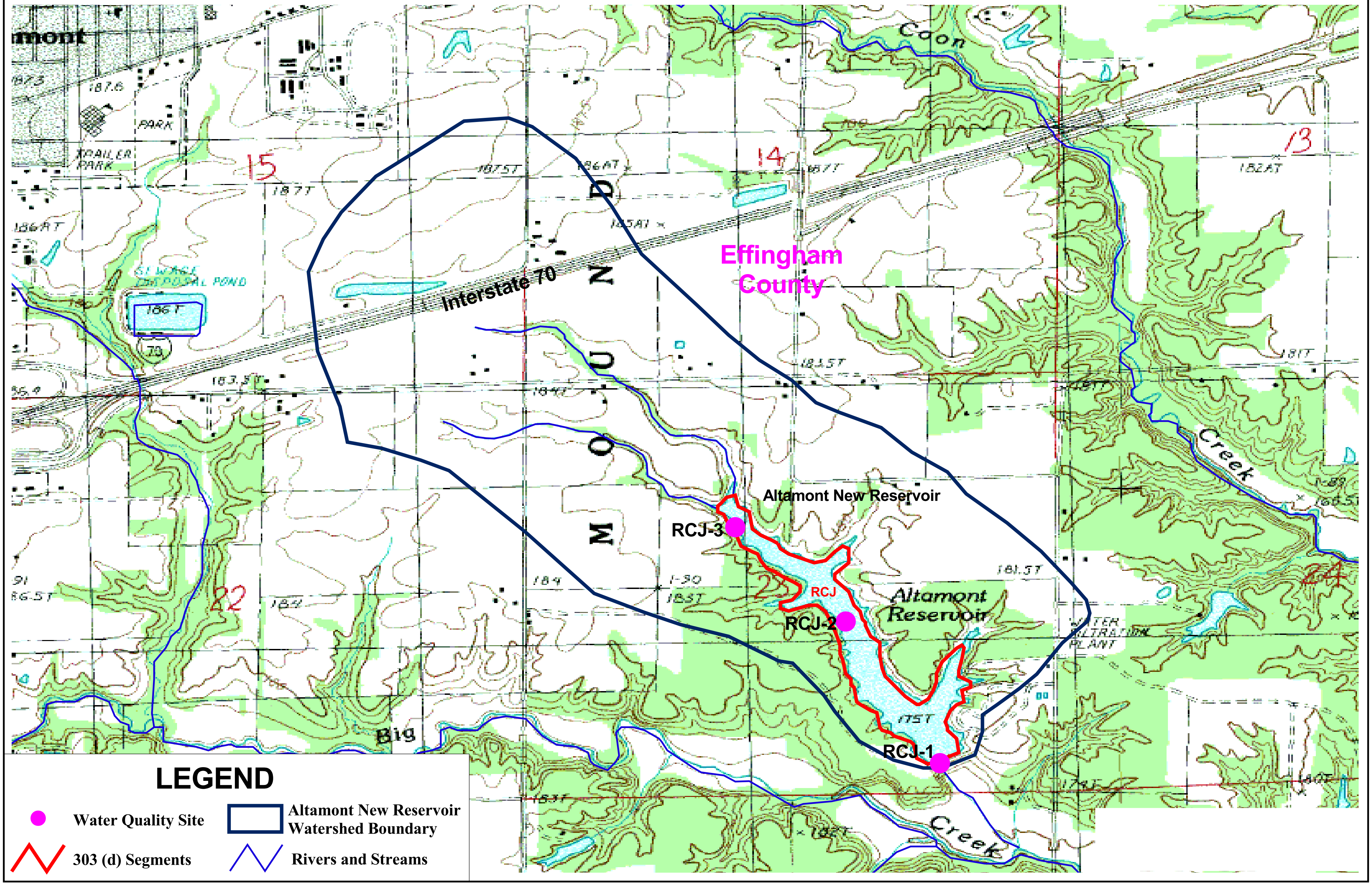


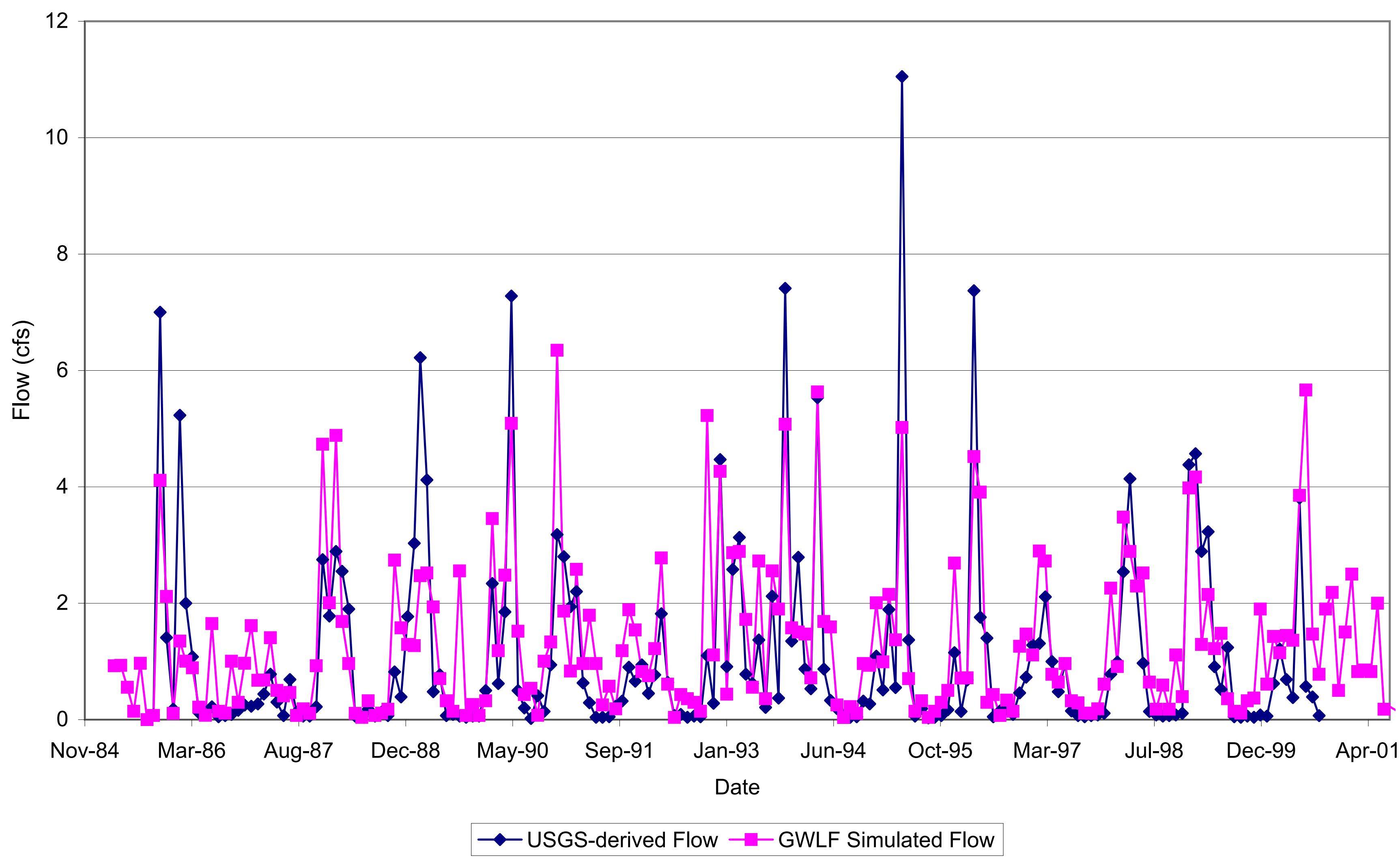
Figure 7-1
Altamont New Reservoir Watershed and Historic Sampling Locations

CDM

iepa\gis_data\apr\altamont

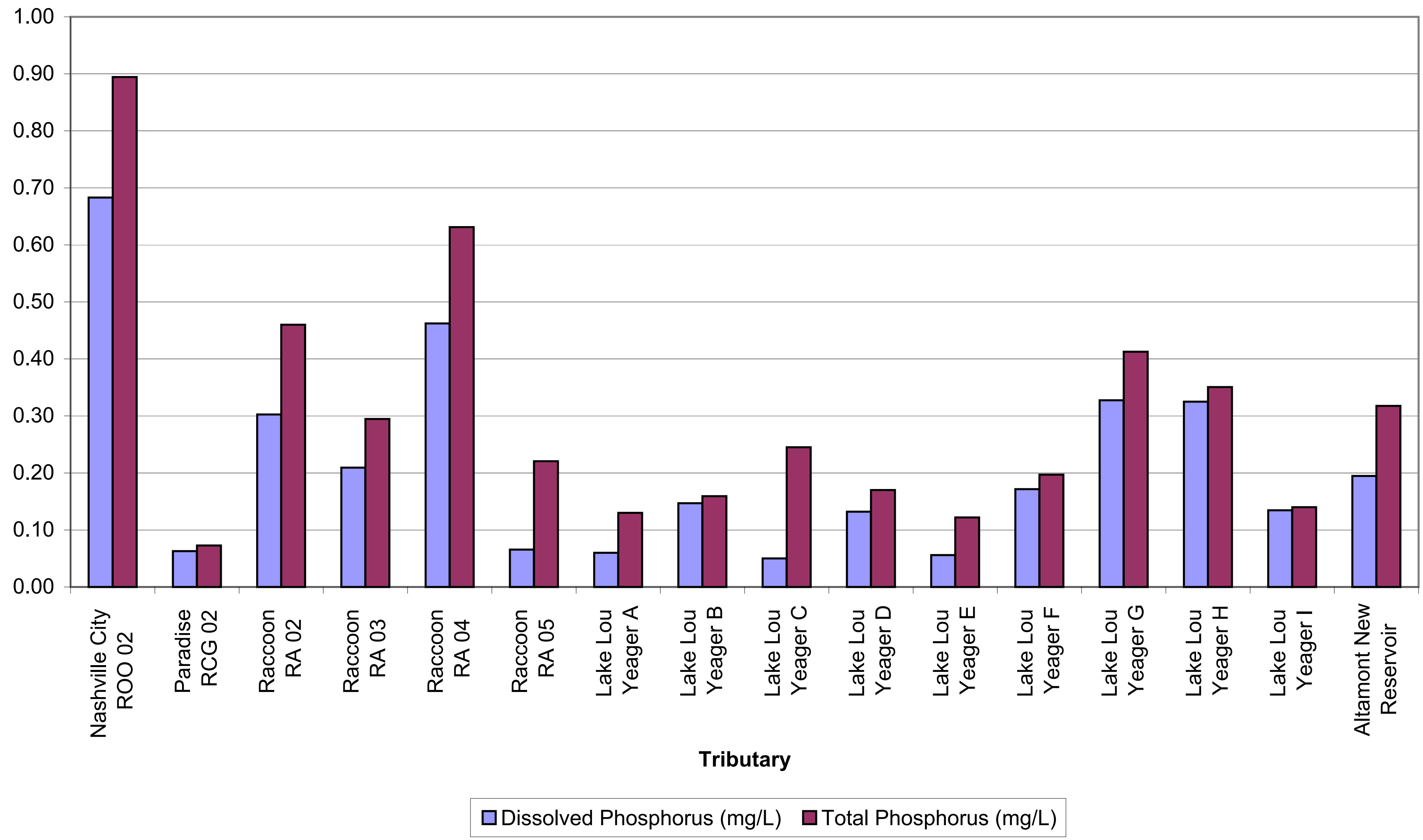
THIS PAGE INTENTIONALLY LEFT BLANK

Figure 7-2: Altamont New Reservoir Inflows
Monthly Flow Comparison



THIS PAGE INTENTIONALLY LEFT BLANK

Figure 7-3: Dissolved and Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Altamont New Reservoir



THIS PAGE INTENTIONALLY LEFT BLANK

Table 7-8 Altamont New Reservoir Calibration Sensitivity Analysis

				Dairy Dissolved Phosphorus 5 mg/L					Dairy Dissolved Phosphorus 82.5 mg/L				
Year	In-Lake Target Total Phosphorus (mg/L)	In-Lake Target Chlorophyll "a" (µg/L)		In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Estimated Chlorophyll "a" (µg/L)	Chlorophyll "a" Calibration Factor	In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Estimated Chlorophyll "a" (µg/L)	Chlorophyll "a" Calibration Factor
1993	0.12	61	Soil Total Phosphorus 616 ppm	0.05	81%	2.5	17.9	3.4	0.07	63%	1.7	22.1	2.8
1998	0.15	61		0.03	94%	4.7	13.0	4.7	0.03	94%	4.7	13.0	4.7
2001	0.13	22		0.04	88%	3.5	10.4	2.1	0.04	88%	3.5	10.4	2.1
1993	0.12	61	Soil Total Phosphorus 792 ppm	0.06	74%	2.1	19.7	3.1	0.07	63%	1.7	22.1	2.8
1998	0.15	61		0.03	94%	4.7	13.0	4.7	0.05	88%	3.2	17.5	3.5
2001	0.13	22		0.04	88%	3.5	10.4	2.1	0.05	77%	2.4	13.6	1.6

Table 7-8 Altamont New Reservoir Calibration Sensitivity Analysis (continued)

				Dairy Dissolved Phosphorus 123.75 mg/L					Dairy Dissolved P 247.25 mg/L				
Year	In-Lake Target Total Phosphorus (mg/L)	In-Lake Target Chlorophyll "a" (µg/L)		In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Estimated Chlorophyll "a" (µg/L)	Chlorophyll "a" Calibration Factor	In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Estimated Chlorophyll "a" (µg/L)	Chlorophyll "a" Calibration Factor
1993	0.12	61	Soil Total Phosphorus 616 ppm	0.09	49%	1.4	23.7	2.6	0.10	37%	1.3	24.8	2.5
1998	0.15	61		0.07	77%	2.2	21.8	2.8	0.09	66%	1.7	24.1	2.5
2001	0.13	22		0.05	77	2.4	13.6	1.6	0.07	66%	1.9	15.5	1.4
1993	0.12	61	Soil Total Phosphorus 792 ppm	0.09	49%	1.4	23.7	2.6	0.10	31%	1.2	25.2	2.4
1998	0.15	61		0.07	77	2.2	21.8	2.8	0.09	66%	1.7	24.1	2.5
2001	0.13	22		0.05	77	2.4	21.3	1.0	0.09	40%	1.4	17.5	1.2

THIS PAGE INTENTIONALLY LEFT BLANK

Section 8
Total Maximum Daily Load for Altamont New Reservoir

8.1 TMDL Endpoints for Altamont New Reservoir

The desired in-lake water quality concentration for total phosphorus is less than or equal to 0.05 mg/L. Table 5-5 in Section 5 summarized the average total phosphorus concentrations sampled in the Altamont New Reservoir Watershed. As noted in Section 5.1.5.1.1, all observed in-lake total phosphorus averages have exceeded the target. The total phosphorus target is set to prevent eutrophic conditions in the Altamont New Reservoir and maintain aquatic life. Phosphorus is a concern as nuisance plant growth and algal concentrations in many freshwater lakes are enhanced by the availability of phosphorus. Additionally, excess phosphorus can cause large DO fluctuations.

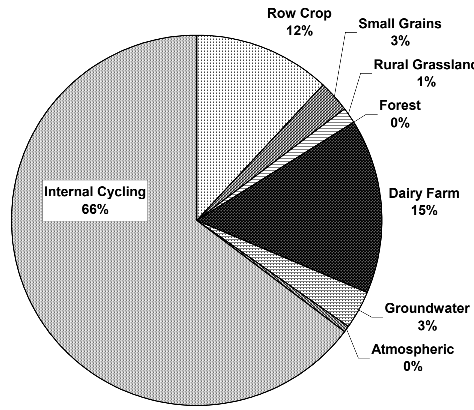
8.2 Pollutant Sources and Linkages

Pollutant sources and their linkages to Altamont New Reservoir were established through the GWLF and BATHTUB modeling techniques described in Section 7. Pollutant sources of phosphorus include nonpoint source runoff from agriculture and an inactive dairy. Atmospheric deposition and internal cycling are also potential sources of loads. The predicted phosphorus loads from GWLF modeling and their sources are presented in Table 8-1. The mean loads presented in Table 8-1 will be used in the overall TMDL calculation for the amount of reductions that need to occur in the Altamont New Reservoir Watershed.

Table 8-1 Modeled Total Phosphorus Load by Source

Land Use	1993 (wet)		1998 (normal)		2001 (dry)		Mean	
	lb/yr	**percent**	**lb/yr**	**percent**	**lb/yr**	**percent**	**lb/yr**	**percent**
Row Crop	570	17%	322	8%	244	11%	379	12%
Small Grains	136	4%	68	2%	70	3%	91	3%
Rural Grassland	54	2%	34	1%	35	2%	41	1%
Forest	0	0%	0	0%	0	0%	0	0%
Dairy Farm	841	24%	356	9%	261	12%	486	15%
Groundwater	163	5%	102	3%	52	2%	106	3%
Atmospheric	15	0%	15	0%	15	1%	15	0%
Internal Cycling	1,675	48%	2,977	77%	1,488	69%	2,047	66%
TOTAL	**3,454**	**100%**	**3,874**	**100%**	**2,165**	**100%**	**3,164**	**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 8-1 and the pie chart were entered into the BATHTUB model as explained in Section 7 to determine resulting in-lake total phosphorus concentration in mg/L. As explained in Section 7, these loads result in in-lake concentrations that exceed the total phosphorus target of 0.05 mg/L. The TMDL explained throughout the remainder of this section will examine how much both the external and internal loads need to be reduced in order to meet the total phosphorus water quality standard of 0.05 mg/L in the Altamont New Reservoir.



8.3 Allocation

As explained in Section 1, the TMDL for the Altamont New Reservoir will address the following equation:

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

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

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

8.3.1 Loading Capacity

The LC of Altamont New Reservoir is the pounds per year of total phosphorus that can be allowed as input to the lake and still meet the water quality standard of 0.05-mg/L total phosphorus. The allowable phosphorus loads that can be generated in the watershed and still maintain water quality standards was determined with the models that were set up and calibrated as discussed in Section 7. To accomplish this, the loads presented in Table 8-1 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 Altamont New Reservoir. Table 8-2 shows the allowable phosphorus loading determined for 1993, 1998, and 2001 by reducing modeled inputs to Altamont New

Reservoir through GWLF and BATHTUB. The output files to BATHTUB showing the results of the load reductions for 1993, 1998, and 2001 are contained in Appendix H. 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.

Table 8-2 Allowable Total Phosphorus Load by Model Year for Altamont New Reservoir

Model Year	Phosphorus (lb/yr)
1993	694
1998	507
2001	408
Mean	536

8.3.2 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 Altamont New Reservoir 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.

8.3.3 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 Altamont New Reservoir TMDL should be based on a combination of both. Model inputs were selected from the GWLF manual when site-specific data were unavailable. These default input values are assumed to be conservative, which implicitly includes a MOS in the modeling effort. Because the default input values are not site-specific, they are assumed more conservative and therefore a MOS can be implicitly assumed. Default input values include:

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

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

Due to uncertainty with nutrient model inputs as explained in Section 7.3, 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 Altamont New Reservoir (Section 7.3). 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.

8.3.4 Waste Load Allocation

There are no point sources in the watershed; therefore, no WLA (WLA = 0 pounds) is recommended at this time.

8.3.5 Load Allocation and TMDL Summary

Table 8-3 shows a summary of the TMDL for Altamont New Reservoir. On average, a total reduction of 84 percent of total phosphorus loads to Altamont New Reservoir would result in compliance with the water quality standard of 0.05 mg/L total phosphorus.

Table 8-3 TMDL Summary for Total Phosphorus in Altamont New Reservoir

LC (lb/yr)	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	Reduction Needed (lb/yr)	Reduction Needed (percent)
537	0	510	27	2,654	84%

Table 8-4 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 9. An approximate 74 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 8-3. Methods to meet these targets will be outlined in Section 9.

Table 8-4 Sources for Total Phosphorus Reductions

Source	Current Load (lb/yr)	Load Reduction (lb/yr)	Percent Reduction
Atmospheric	15	0	0
Internal Cycling	2,047	1,842	90%
Nonpoint Sources	1,103	812	74%

Section 9
Implementation Plan for Altamont New Reservoir

9.1 Implementation Actions and Management Measures

Phosphorus loads in the Altamont Reservoir Watershed originate from external and internal sources. From modeling estimates, internal phosphorus cycling from sediments accounts for approximately 66 percent of the loading to Altamont New Reservoir. External loads from nonpoint source runoff from agricultural crops, a non-operational dairy facility, and rural grassland potentially account for 15 percent, 15 percent, and 1 percent, respectively, of the loading. The remainder of the loading is attributed to groundwater (3 percent). To achieve the 84 percent reduction of phosphorus established in Section 8 (Table 8-3), 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.

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, 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 a non-operational dairy facility. The final source is internal phosphorus cycled from lake sediments.

9.1.1 Nonpoint Source Phosphorus Management

The sources of nonpoint source pollution in the Altamont New Reservoir TMDL are divided between a non-operational dairy farm and agricultural cropland. BMPs evaluated that could be utilized to treat these nonpoint sources are:

- wetlands
- filter strips
- conservation tillage practices
- nutrient management

Total and dissolved phosphorus originating from dairy operations can be treated with a combination of a wetland and grass filter strip. Total phosphorus originating from cropland is most efficiently treated with no-till or conservation tillage practices. Wetlands located upstream of the reservoir provide further reductions in total and dissolved phosphorus in runoff from croplands. Nutrient management focuses on source control of nonpoint source contributions to Altamont New Reservoir.

9.1.1.1 Wetlands

The use of wetlands as a structural control is most applicable to nutrient reduction from agricultural lands and an inactive dairy facility in Altamont New Reservoir Watershed. Therefore this section focuses on the use of wetlands to treat runoff from a dairy and agricultural lands. Wetlands are assumed to be an effective BMP because they:

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

To treat loads from the inactive dairy, a wetland could be constructed between the dairy and the reservoir. Treatment of phosphorus from livestock waste could be accomplished through a combination of wetlands and filter strips. Wetland design is critical to establishing a properly functioning and effective pollution control structure. Critical elements in wetland design are substrate composition, water budget, solids removal from wastewater, size determination, and physical characteristics such as shape, slope, and embankments. An overview of wetland design guidelines is presented in the Ohio State University Fact Sheet: Using Constructed Wetlands for Removing Contaminants from Livestock Wastewater (Simeral 1998).

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

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

Guidelines for wetland design suggest a wetland to watershed ratio of 0.6 percent for nutrient and sediment removal from agricultural runoff. Table 10-3 outlines estimated wetland areas for each subbasin based on these recommendations. A wetland system to treat agricultural runoff from the 640-acre Altamont New Reservoir Watershed would need to be approximately 3.8 acres based on these recommendations (Denison and Tilton 1993).

9.1.1.2 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to Altamont New Reservoir Watershed. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff 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 Altamont New Reservoir Watershed. 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 Altamont New Reservoir will reduce the amount of algal growth in the lake system, which can cause depletion of DO when algae expire and cause more significant diurnal fluctuations from photosynthesis. Filter strips reduce nutrient and sediment loads to lakes by establishing ground depressions and roughness that settles sediment out of runoff and providing vegetation to filter nutrients out of overland flow. As much as 75 percent of sediment and 45 percent of total phosphorus can be removed from runoff by a grass filter strip (North Carolina State University [NCSU] 2000). In addition, filter strips should be harvested periodically so that removal rate efficiencies over extended periods of time remain high (USEPA 1993).

Filter strip widths for the Altamont New Reservoir TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on this guidance, two filter strips were examined for the basin. Based on slope, the southern tributary would need a filter strip with 72 feet on each side of the tributary for a length of 902 feet. The northern tributary would need a filter strip that encompassed 108 feet on each side of the tributary for a length of 1,017 feet.

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

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

The filter strip lengths and widths presented above are used to calculate an approximation of BMP costs in Section 9.2.2.7 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips according to the NRCS guidance presented in Table 9-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.2.

9.1.1.3 Conservation Tillage Practices

For the Altamont New Reservoir Watershed, conservation tillage practices could help reduce nutrient loads in the lake. Nonpoint source runoff from 300 acres of row crops and small grain agriculture were estimated to contribute 15 percent of the total phosphorus load to Altamont New Reservoir. Total phosphorus loading from cropland is controlled through management BMPs, such as conservation tillage. Conservation tillage maintains at least 30 percent of the soil surface covered by residue after planting. Crop residuals or living vegetation cover on the soil surface protect against soil detachment from water and wind erosion. Conservation tillage practices can remove 45 percent of the dissolved and total phosphorus from runoff and 75 percent of the sediment (NCSU 2000); however, filter strips are less effective at removing dissolved phosphorus only. Additionally, studies have found 93 percent less erosion occurred from no-till acreage compared to acreage subject to moldboard plowing (NCSU 2000). Various methods of conservation tillage are presently utilized in the Altamont New Reservoir Watershed as were shown in Table 5-8. 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 two tons/acre/year. To achieve a 38 percent reduction in phosphorus load, the erosion rate for the watershed would need to be reduced to 1.2 tons/acre/year. Similarly, the C-factors for corn, soybeans, and small grains would need to be reduced from 0.32, 0.20, and 0.11 to 0.20, 0.12, and 0.07, respectively.

9.1.1.4 Nutrient Management

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

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

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

Bray P1 soil data tested during the period of 1991 through 2001 on cropland located in the Altamont New Reservoir watershed indicate an average soil phosphorus of 44 ppm and 88 ppm (lb/acre) (Hirschi 2002). The Bray P1 test measures the amount of phosphorus available for plant uptake. This Bray P1 test exceeds the level of 70 lb/acre recommended by Illinois NRCS practice standard 590, the University of Illinois Agronomy Handbook, and Illinois Department of Agriculture nutrient management practice guidelines. This guidance recommends that no additional phosphorus be applied until further soil tests are conducted (University of Illinois 2004).

9.1.2 In-Lake Phosphorus

Internal cycling of phosphorus contributes approximately 65 percent of the phosphorus load to Altamont New Reservoir Watershed. Reduction of phosphorus from in-lake cycling through management strategies is necessary for attainment of the TMDL load allocation. Internal phosphorus loading occurs when the water above the sediments 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 never becomes anaerobic, the ferric phosphate will not be reduced to bioavailable phosphorus. Aeration, which simulates lake mixing and keeps oxygen conditions from being depleted in the epilimnon, can be very effective at preventing re-release of bound phosphorus. Reduction of internal phosphorus cycling from this measure is typically determined based on site-specific studies.

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

9.1.3 Implementation Actions and Management Measures Summary

To meet the reductions outlined in Section 8 for Altamont New Reservoir, 84 percent of the phosphorus loaded from nonpoint source pollution and 90 percent of the phosphorus from internal loads would need to be reduced in order to meet the TMDL target of a total phosphorus concentration less than 0.05 mg/L. The GWLF model was used to model the following practices to estimate achievable reductions in total phosphorus:

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

The modeling effort showed that filter strips do not provide much total phosphorus reduction, most likely due to routing constraints of the GWLF model as discussed in Section 7.2.2.1.1 and the small magnitude of area available for filter strip development. Reductions of external loads by conservation tillage, nutrient management, filter strips, and wetlands are summarized in Table 9-2. 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 for wetlands was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible.

Table 9-2 Summary of Total Phosphorus Load Reductions

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

* Literature value utilized for estimation

A combination of implementing these external load reduction practices coupled with the available treatments for internal loads would allow the Altamont New Reservoir Watershed to meet its total goal of reducing phosphorus loads. Section 9.2 outlines planning level costs and programs available to help with cost-sharing so that this goal can be achieved.

9.2 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 9.1 provided a means for obtaining the reductions necessary. The remainder of this section discusses an estimate of costs to the watershed for implementing these practices and programs available to assist with funding.

9.2.1 Available Programs for Phosphorus TMDL

Approximately 84 percent of the Altamont New Reservoir Watershed is classified as rural grassland (pasture land, CRP, waterways, buffers 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 paragraphs.

9.2.1.1 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, 300 acres of cropland have been targeted in the Altamont New Reservoir 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.

9.2.1.2 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).

9.2.1.3 Conservation Reserve Program (CRP)

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

Eligible land must be either:

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

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

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

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

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

9.2.1.4 Wetlands Reserve Program (WRP)

The Wetlands Reserve Program (WRP) is a voluntary program that provides technical and financial assistance to eligible landowners to restore, enhance, and protect wetlands. The goal of WRP is to achieve the greatest wetland functions and values, along with optimum wildlife habitat, on every acre enrolled in the program. At least 70 percent of each project area will be restored to the original natural condition, to the extent practicable. The remaining 30 percent of each area may be restored to other than natural conditions. Landowners have the option of enrolling eligible lands through permanent easements, 30-year easements, or restoration cost-share agreements. The program is offered on a continuous sign-up basis and is available nationwide. WRP offers landowners an opportunity to establish, at minimal cost, long-term conservation and wildlife habitat enhancement practices and protection. It is administered through the NRCS (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. The program offers three enrollment options: permanent easements, 30-year conservation easements, and 10-year restoration cost-share agreements. Since the program began in 1985, the average cost per acre is $1,100 in restorative costs and the average project size is 177 acres. The costs for each enrollment option follow in Table 9-3 (USDA 1996).

Table 9-3 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	1. Lump Sum	1. Lump Sum if less than $50,000	NA
Restoration Payments	100% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements	75% Restoration Cost Reimbursements

9.2.1.5 Environmental Quality Incentive Program (EQIP)

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

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

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

9.2.1.6 Conservation Practices Program

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

9.2.1.7 Wildlife Habitat Incentives Program (WHIP)

The Wildlife Habitat Incentives Program (WHIP) is a voluntary program that encourages the creation of high quality wildlife habitat of national, state, tribal, or local significance. WHIP is administered through NRCS, which provides technical and financial assistance to landowners for development of upland, riparian, and aquatic habitat areas on their property. NRCS works with the participant to develop a wildlife habitat development plan, 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. Under the agreement:

- the landowner agrees to maintain the cost-shared practices and allow NRCS or its agent access to monitor its effectiveness, and
- 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 2002d).

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Effingham County are listed in Table 9-4 below.

Table 9-4 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
Bart Pals	2301 Hoffman Drive Effingham, Illinois 62401	(217) 347-7107, x 3
Local FSA Office		
Effingham Service Center	2301 Hoffman Drive Effingham, Illinois 62401	(217) 347-7107, x 2

9.2.2 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 9-5 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Altamont New Reservoir Watershed are presented in Section 9.2.2.7 and Table 9-6.

9.2.2.1 Wetland

The price to establish a wetland is very site-specific. In general, the cost to restore hydrology with a six-inch to two-foot berm is $4 to $5/linear foot. A water control structure, if required, would cost approximately $500 to $1,000. Finally, tree planting using bare root stock is $435/acre. This equates to an average cost of $1,250/acre to construct a wetland in Effingham County.

9.2.2.2 Filter Strips and Riparian Buffers

Effingham County NRCS estimates an average cost per acre to install and maintain a grass filter strip with a 15-year life span at $120/acre. This price quote accounts for seeding, fertilization, and labor. A riparian buffer strip established with bare root stock has a life span of 15-years and an installation cost of $435/acre. The cost is based on utilization of professional contractors at a plant cost of $0.35/seedlings and labor of $0.65/acre and an average number of trees per acre of 435.

9.2.2.3 Nutrient Management Plan - NRCS

Generally, agricultural land in Effingham County is comprised of livestock and cropland. The Nutrient Management Program in Effingham County consists of soil testing and site-specific recommendations for manure and fertilizer application based on determined credits and realistic crop yields. The service averages $10/acre.

9.2.2.4 Nutrient Management Plan - IDA and Illinois EPA

The costs associated with development of Nutrient Management Plans co-sponsored by the IDA and the Illinois EPA 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.

9.2.2.5 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. Net costs for conservation tillage often approach zero or are negative due to savings in labor and energy. 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).

9.2.2.6 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. Altamont currently has an aeration system installed in the reservoir for drinking water treatment purposes. The aeration system, consisting of a floating dock equipped with a fan to mix the water column, costs approximately $12,000 for material and installation (Whitton 2002). The system keeps approximately half of the lake area (25 acres) destratefied throughout the year. Maintenance costs are approximately 5 percent of the installation costs. 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).

9.2.2.7 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 9-5. The column labeled *Program or Sponsor* lists the financial assistance program or sponsor available for various BMPs. The programs represented in the table are the WRP, CRP, and the IDA.

Table 9-5 Cost Estimate of Various BMP Measures in Effingham County

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	WRP	Wetland	10	$1,250.00	$125.00
	CRP	Grass Filter Strips	15	$120.00	$8.00
	CRP	Riparian Buffer	15	$400.00	$26.67
	CRP	Grassed Waterways	10	$1,800.00	$180.00
	NRCS	Nutrient Management Plan		$10.00	
	IDA and Illinois EPA	Nutrient Management Plan		$7.00	
	CRP	Conservation Tillage	1	$17.00	$17.35
Internal Cycling	319	Dredging	50	$8,000.00	$160.00
	319	Aeration	20	$480.00	$24.00

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $499,500. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 9-6 summarizes the number of acres each BMP is applied to in the basin and the corresponding cost. The acreages reported in Table 9-6 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle.

Table 9-6 Cost Estimate of Implementation Measures in the Altamont New Reservoir Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Wetland	3.8	$1,250.00	$5,000.00	$125.00	$500.00
Grass Filter Strips	8	$120.00	$1,000.00	$8.00	$100.00
Nutrient Management Plan	300	$7.00	$2,000.00		
Conservation Tillage	230	$17.00	$4,000.00	$17.35	$4,000.00
Aeration	57	$480.00	$27,000.00	$24.00	$11,500.00
Dredging *	57	$8,000.00	$456,000.00	$160.00	$9,000.00
Total			**$495,000.00**		**$25,100.00**

* One time cost

9.3 Monitoring Plan

The purpose of the monitoring plan for Altamont New Reservoir 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
- continue ambient monitoring of Altamont New Reservoir
- tributary monitoring

Tracking the implementation of management measures can be used to address the following goals (USEPA 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 work-load and costing analysis for assistance or regulatory programs
- determine the extent to which management measures are properly maintained and operated

Estimating the effectiveness of the BMPs implemented in the watershed could be completed by monitoring before and after the BMP is incorporated into the watershed. Additional monitoring could be conducted on specific structural systems such as a constructed wetland. Inflow and outflow measurements could be conducted to determine site-specific removal efficiency. If aeration is used to control internal loading, site-specific data would be needed to assess the effectiveness of this management measure.

Illinois EPA monitors Altamont New Reservoir from April through October approximately every three years. Continuation of this monitoring will assess in-lake water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the reservoir are being attained.

Tributary monitoring is needed to better assess the contribution of internal loading to the Altamont New Reservoir. By having further knowledge on 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. In addition, a better assessment of the inactive dairy is needed and confirmation of its contribution of phosphorus loadings to the reservoir is needed prior to specific improvements being implemented near that facility.

9.4 Implementation Time Line

Implementing the actions outlined in this section for the Altamont New Reservoir Watershed should occur in phases and assessing effectiveness of the management actions 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 the Altamont New reservoir 10 years or more to reach its water quality standard target of 0.05 mg/L (Wetzel 1983). If internal loads are not effectively controlled, this time frame could be even greater as the reservoir will take time to "flush" out the phosphorus bound to bottom sediments as reductions in external loads take place. In summary, to meet water quality standards in the Altamont New Reservoir may take up to 20 years to complete.

Section 10
References

Bass, K.L. 2000. Evaluation of a Small In-Stream Constructed Wetland in North Carolina's Coastal Plain. North Carolina State University: Thesis. http://www.bae.ncsu.edu/research/evans_web/etd/klbass.pdf

Cortell, J. 2002. Personal communication regarding Marine Biochemists aeration systems. www.marinebiochemists.com.

Chapra, S.C. 1997. *Surface Water-Quality Modeling*. McGraw-Hill. New York.

Denison, D. and D. Tilton. 1993. Rouge River National Wet Weather Demonstration Program: Technical Memorandum. Rouge River Project: RPO-NPS-TM-12.01. August.

EC SWCD (Effingham County Soil and Water Conservation District). 2001. 2001 *County Transect Summary Reports*. Illinois Department of Agriculture.

FSA (Farm Service Agency). 1997. *Conservation Reserve Program: Continuous Sign-Up for High Priority Conservation Practices*. USDA. February.

Geney, R. 2002. Personal communication regarding GES aeration systems. www.airation.com.

Haith et al. 1996. GWLF: Generalized Watershed Loading Functions. Department of Agricultural and Biological Engineering. Cornell University. Ithaca, New York.

Hirschi, M.C. 2002. Personal e-mail regarding Altamont phosphorus data. February.

IDNR (Illinois Department of Natural Resources). 1996: Illinois Clearinghouse: Natural History Data. Download: Critical Trends Assessment Land Cover Database. http://www.isgs.uiuc.edu/nsdihome/webdocs/st-naths.html.

Illinois EPA (Illinois Environmental Protection Agency) 2002. Monitoring Water Quality Data Sheets.

________. 2000. *Annual Illinois Water Quality Report, 2000*. IEPA/BOW/00-005

IPCB (Illinois Pollution Control Board). 1999. *Illinois Administrative Rules, Title 35: Environmental Protection; Part 302: Water Quality Standards.*

ISWS (Illinois State Water Survey). 2000. Pan Evaporation in Illinois. Download: Pan Evaporation in Illinois. http://www.sws.uiuc.edu/atmos/statecli/Pan_Evap/Panevap.htm.

Johnson, R., R. Evans, and K. Bass. 1996. Constructed Wetlands Demonstration Project for NPS Pollution Control. North Carolina Department of Natural Resources: Division of Water Quality. http://h2o.enr.state.nc.us/nps/edenton96.pdf

Kovosic, D.A., M.B. David, L.E. Gentry, K.M. Starks, and R.A. Cooke. 2000.Effectiveness of constructed wetlands in reducing N and P export from agricultural tile drainage. *J. Environmental Quality*. 29:1262-1274.

Moore, J.A. 1993. Using Constructed Wetlands to Improve Water Quality. Oregon State University Extension Service, EC1408: June. http://eesc.orst.edu/agcomwebfile/edmat/ec1408.pdf

Muir, D.B., M.M. King, M.R. Matson, G.L. Minton, S.P. Shasteen, M.D. Bundren, R.L. Hite, and L.J. Pitcher. 1997. An Intensive Survey of the Big Muddy River Basin – Summer 1995.

NASS (National Agricultural Statistics Service). 2002. USDA-NASS-RDD Spatial Analysis Research Section. http://www.nass.usda.gov/research/Cropland/SARS1a.htm.

NCDC (National Climatic Data Center). 2002. Weather stations.

NCSU (North Carolina State University) Water Quality Group. 2000. National Management Measures to Control Nonpoint Source Pollution from Agriculture. United States Environmental Protection Agency: Contract #68-C99-249.

________. 1994. Functions of Wetlands (Processes). WATERSHEDSS. NCSU Water Quality Group. August.

Novotny and Olem. 1994. *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*. Van Nostrand Reinhold. New York.

NRC (National Research Council). 1992. "Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy." *National Academy of Sciences*. Washington, D.C.

NRCS (Natural Resources Conservation Service). 2002a. Personal Communication with Bart Pals of Effingham County NRCS.

________. 2002b. Farm Bill 2002: Wetlands Reserve Program Fact Sheet. http://www.nrcs.usda.gov/programs/farmbill/ 2002/pdf/WRPFct.pdf. May.

________. 2002c. Farm Bill 2002: Conservation of Private Grazing Land Program Fact Sheet. http://www.nrcs.usda.gov/programs/farmbill/2002/pdf/CPGLFct.pdf. May.

________. 2002d. Farm Bill 2002: Wildlife Habitat Incentives Program Fact Sheet. http://www.nrcs.usda.gov/programs/farmbill/2002/pdf/WHIPFct.pdf. May.

________. 2002e. The Environmental Quality Incentives Program. USDA. April.

________. 2002f. 2001 Environmental Quality Incentives Program: Illinois Summary. http://www.nrcs.usda.gov/programs/eqip/2001summaries/ILEQIP%20doc.pdf. USDA. January.

________. 1999. Filter Strip Conservation Practice Standard. National Resources Conservation Service: Code 393. May. http://www.il.nrcs.usda.gov/resources/fotg/section4/393/393.pdf

________. 1994. Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater. Natural Resources Conservation Service (formerly Soil Conservation Service), U.S. Department of Agriculture, Washington, DC. http://www.abe.msstate.edu/Tools/csd/p-dm/

Olivera, Francisco et al. 1998. CRWR-PrePro: An ArcView Preprocessor for Hydrologic, Hydraulic and Environmental Modeling. Download: ArcView Project Prepro3a.apr. http://www.ce.utexas.edu/prof/olivera/prepro/prepro.htm.

Osmond, D.L., J. Spooner, and D.E. Line. 1995. Systems of Best Management Practices for Controlling Agricultural Nonpoint Source Pollution: The Rural Clean Water Program Experience. North Carolina State University Water Quality Control Group: brochure 6. March.

Sharpley, A.N., T. Daniel, T. Sims, J. Lemunyon, R. Stevens, and R. Parry. 1999. Agricultural Phosphorus and Eutrophication. United States Department of Agriculture: ARS-149. July. http://www.ars.usda.gov/is/np/Phos&Eutro/phos%26eutro.pdf

Short, Matthew B. 1999. Baseline Loadings of Nitrogen, Phosphorus, and Sediments from Illinois Watersheds: October 1980-September 1996. Illinois Environmental Protection Agency. Bureau of Water. Division of Water Pollution Control. Surface Water Selection. Central Monitoring Unit.

Simeral, K.D. 1998. Using Constructed Wetlands for Removing Contaminants from Livestock Wastewater. Ohio State University Fact Sheet. http://ohioline.osu.edu/a-fact/0005.html. May.

Tomkins, S. 1994. Section 319 Success Stories, Volume III: Lake Pittsfield Project. USEPA. www.epa.gov/owow/nps/Section319III/IL.htm.

USACE (U.S. Army Corps of Engineers). 2003. Lake Astabula/Baldhill Dam Brochure. http://www.mvp.usace.army.mil/docs/rec/ashtabula.pdf

________. 1999a. National Inventory of Dams. Download: Reservoir Characteristics. http://crunch.tec.army.mil/nid/webpages/ nid.cfm.

________. 1999b. Simplified Procedures for Eutrophication Assessment and Prediction: User Manual. William Walker. Instruction Report W-96-2. Waterways Experiment Station. USACE Headquarters.

USDA (United States Department of Agriculture). 1999. Farm Service Agency Online: Conservation Reserve Program Fact Sheet. http://www.fsa.usda.gov/pas/publications/facts/html/crp99.htm. October.

________. 1996. Restoring Wetlands with the Wetland Reserve Program. http://www.il.nrcs.udsa.gov/resources/farmbill/inahgeh.htm.

________. 1991. Soil Survey of Effingham County, Illinois. Washington D.C.

USEPA (U.S. Environmental Protection Agency). 2003. Applying for and Administering CWA Section 319 Grants: A Guide for State Nonpoint Source Agencies. State-EPA NPS Partnership. March. http://www.epa.gov/owow/nps/319/319stateguide-revised.pdf

USEPA. 2002a. *BASINS - Better Assessment Science Integrating Point and Nonpoint Sources*. Download: BASINS Data. http://www.epa.gov/OST/BASINS/.

________. 2002b. *STORET – Storage and Retrieva*l. Download: Water Quality Data. http://www.epa.gov/storet/.

________. 2002c. Supplemental Guidelines for the Award of Section 319 Nonpoint Source Grants to States and Territories in FY 2003. EPA. August. http://www.epa.gov/owow/nps/Section319/319guide03.html

________. 2001. *EPA Exposure Assessment Models: TMDL USLE*. Download: TMDL USLE Model and User's Manual. http://www.epa.gov/ceampubl/swater/usle/index.htm.

________. 2000. *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. Office of Water. USEPA Contract #68-C99-249.

________. 1998. *Report of the Federal Advisory Committee on the Total Maximum Daily Load (TMDL) Program.* EPA/100/R/98/006. Office of Administrator. July.

________. 1997. *Compendium of Tools for Watershed Assessment and TMDL Development*. Office of Water. EPA/841/B/97/006.

________. 1993. Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters: Management Measures for Wetlands, Riparian Areas, and Vegetated Treatment Systems. EPA 840-B-92-002. January. http://www.epa.gov/nps/MMGI/Chapter7/ch7-2c.html

USGS (U.S. Geological Survey). 2002a. Daily Streamflow. Download: Daily Flows for Stream Gage 05595820. http://waterdata.usgs.gov/nwis.

________. 2002b. Seamless Data Distribution System. Download: National Elevation Dataset. http://edcnts14.cr.usgs.gov/Website/seamless.htm.

University of Illinois. 2004. Agronomy Handbook. http://www.ag.uiuc.edu/iah/pdf/agronomy%20HB/11chapter.pdf

Wetzel, R.G. 1983. Limnology. Saunders College Publishing. Orlando, Florida. pp. 289-297.

Whitton, K. 2002. Personal communication.

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix A
Historic Water Quality Data

Secondary ID .1	Start Date	Parameter Long Name	Result Value
RCJ-1	5/2/1989	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	5/16/1989	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	6/5/1989	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	6/26/1989	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	7/10/1989	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/24/1989	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/8/1989	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/28/1989	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	9/11/1989	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	9/25/1989	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	10/11/1989	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	10/23/1989	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	4/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	4/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	4/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	5/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	5/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	6/8/1990	DEPTH OF POND OR RESERVOIR IN FEET	30.5
RCJ-1	6/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	6/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	6/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	6/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	7/9/1990	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	7/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	7/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	7/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	7/19/1990	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	8/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	8/10/1990	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	8/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	8/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	8/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	9/12/1990	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	10/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/12/1990	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	10/22/1990	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	5/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	5/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/25/1991	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	7/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	7/26/1991	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	8/12/1991	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	8/27/1991	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	9/6/1991	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RCJ-1	9/27/1991	DEPTH OF POND OR RESERVOIR IN FEET	24
RCJ-1	10/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	24.5

RCJ-1	10/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	24
RCJ-1	5/8/1992	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	5/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	6/8/1992	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	6/22/1992	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/22/1992	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/22/1992	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RCJ-1	7/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	7/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	8/10/1992	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	8/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	25
RCJ-1	9/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	24
RCJ-1	9/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	24
RCJ-1	10/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	24
RCJ-1	10/21/1992	DEPTH OF POND OR RESERVOIR IN FEET	22.5
RCJ-1	5/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	5/28/1993	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	6/9/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/21/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	8/5/1993	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	8/16/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	9/15/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	9/28/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	10/6/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	10/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	5/4/1994	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	5/20/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/28/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/18/1994	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	8/29/1994	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	9/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	9/30/1994	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	10/31/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	5/12/1995	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	5/22/1995	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	6/7/1995	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	6/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/6/1995	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/19/1995	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/4/1995	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/30/1995	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	9/15/1995	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	9/27/1995	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/11/1995	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/25/1995	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	29.5

RCJ-1	5/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/25/1996	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/8/1996	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	7/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	8/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	9/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RCJ-1	9/24/1996	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RCJ-1	10/14/1996	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	10/24/1996	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	4/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	5/12/1997	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	5/16/1997	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	6/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	7/28/1997	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	8/13/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	8/26/1997	DEPTH OF POND OR RESERVOIR IN FEET	27.5
RCJ-1	9/8/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	9/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RCJ-1	10/6/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RCJ-1	10/16/1997	DEPTH OF POND OR RESERVOIR IN FEET	25
RCJ-1	10/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	26
RCJ-1	4/16/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	4/16/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	4/16/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RCJ-1	5/13/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	5/29/1998	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RCJ-1	6/8/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/8/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/8/1998	DEPTH OF POND OR RESERVOIR IN FEET	19
RCJ-1	6/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	6/19/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/6/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/17/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	8/11/1998	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	8/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	8/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	8/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	8/27/1998	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	9/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RCJ-1	9/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/12/1998	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/20/1998	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/20/1998	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/20/1998	DEPTH OF POND OR RESERVOIR IN FEET	27
RCJ-1	10/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	27

RCJ-1	6/5/2001	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-1	7/10/2001	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	8/22/2001	DEPTH OF POND OR RESERVOIR IN FEET	28
RCJ-1	4/18//01	DEPTH OF POND OR RESERVOIR IN FEET	29
RCJ-2	5/2/1989	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	5/16/1989	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	6/5/1989	DEPTH OF POND OR RESERVOIR IN FEET	18.5
RCJ-2	6/26/1989	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	7/10/1989	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	7/24/1989	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/8/1989	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	8/28/1989	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/11/1989	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/25/1989	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	10/11/1989	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	10/23/1989	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	4/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	15.5
RCJ-2	4/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	5/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	5/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	6/8/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	6/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	6/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	6/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	7/9/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	7/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	7/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	7/19/1990	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	8/10/1990	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	8/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	8/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	8/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/12/1990	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	10/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	14.5
RCJ-2	10/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	14.5
RCJ-2	10/12/1990	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	10/22/1990	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	5/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	5/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	6/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	6/25/1991	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	7/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	7/26/1991	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	8/12/1991	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	8/27/1991	DEPTH OF POND OR RESERVOIR IN FEET	14
RCJ-2	9/6/1991	DEPTH OF POND OR RESERVOIR IN FEET	14.5
RCJ-2	9/27/1991	DEPTH OF POND OR RESERVOIR IN FEET	13.5
RCJ-2	10/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	13
RCJ-2	5/8/1992	DEPTH OF POND OR RESERVOIR IN FEET	15

RCJ-2	5/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	6/8/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	6/22/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	7/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RCJ-2	7/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RCJ-2	8/10/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RCJ-2	8/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RCJ-2	9/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	12
RCJ-2	9/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RCJ-2	10/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RCJ-2	10/21/1992	DEPTH OF POND OR RESERVOIR IN FEET	11
RCJ-2	5/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	5/28/1993	DEPTH OF POND OR RESERVOIR IN FEET	18.5
RCJ-2	6/9/1993	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	6/21/1993	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	7/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	8/5/1993	DEPTH OF POND OR RESERVOIR IN FEET	18.5
RCJ-2	8/16/1993	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	9/15/1993	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	9/28/1993	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	10/6/1993	DEPTH OF POND OR RESERVOIR IN FEET	18.5
RCJ-2	10/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	18.5
RCJ-2	5/4/1994	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	5/20/1994	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	6/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	6/28/1994	DEPTH OF POND OR RESERVOIR IN FEET	18.5
RCJ-2	7/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	7/18/1994	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	8/29/1994	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	15.5
RCJ-2	9/30/1994	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	10/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/31/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	5/12/1995	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	5/22/1995	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	6/7/1995	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	6/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	7/6/1995	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	7/19/1995	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/4/1995	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/30/1995	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	9/15/1995	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/27/1995	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/11/1995	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	10/25/1995	DEPTH OF POND OR RESERVOIR IN FEET	15.5
RCJ-2	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	19
RCJ-2	5/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	18.5
RCJ-2	6/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	6/25/1996	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	7/8/1996	DEPTH OF POND OR RESERVOIR IN FEET	18

RCJ-2	7/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	15.5
RCJ-2	8/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	9/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/24/1996	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/14/1996	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/24/1996	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	4/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	5/12/1997	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	5/16/1997	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	6/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	6/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	17.5
RCJ-2	7/28/1997	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/13/1997	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/26/1997	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/8/1997	DEPTH OF POND OR RESERVOIR IN FEET	15.5
RCJ-2	9/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/6/1997	DEPTH OF POND OR RESERVOIR IN FEET	14.5
RCJ-2	10/16/1997	DEPTH OF POND OR RESERVOIR IN FEET	14
RCJ-2	10/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	14
RCJ-2	4/16/1998	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	4/16/1998	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	5/13/1998	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	5/29/1998	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	6/8/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	6/8/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	6/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	6/19/1998	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	7/6/1998	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	7/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	7/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	7/17/1998	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-2	8/11/1998	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	8/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	8/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	8/27/1998	DEPTH OF POND OR RESERVOIR IN FEET	18
RCJ-2	9/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	9/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	10/12/1998	DEPTH OF POND OR RESERVOIR IN FEET	16.5
RCJ-2	10/20/1998	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/20/1998	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	10/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	6/5/2001	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	7/10/2001	DEPTH OF POND OR RESERVOIR IN FEET	15
RCJ-2	8/22/2001	DEPTH OF POND OR RESERVOIR IN FEET	16
RCJ-2	4/18//01	DEPTH OF POND OR RESERVOIR IN FEET	17
RCJ-3	5/2/1989	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	5/16/1989	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	6/5/1989	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	6/26/1989	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	7/10/1989	DEPTH OF POND OR RESERVOIR IN FEET	7.5

RCJ-3	7/24/1989	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/8/1989	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/28/1989	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RCJ-3	9/11/1989	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	9/25/1989	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	10/11/1989	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	10/23/1989	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	4/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	4/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	5/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	5/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	6/8/1990	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	6/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	6/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	6/25/1990	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	7/9/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/11/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/19/1990	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	8/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/10/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/24/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	8/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	9/12/1990	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	10/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	10/3/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	10/12/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	10/22/1990	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	5/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	5/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	6/7/1991	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	6/25/1991	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/26/1991	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	8/12/1991	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	8/27/1991	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	9/6/1991	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	9/27/1991	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RCJ-3	10/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RCJ-3	10/28/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RCJ-3	5/8/1992	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	5/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	6/8/1992	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	6/22/1992	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	7/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RCJ-3	7/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RCJ-3	8/10/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RCJ-3	8/28/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RCJ-3	9/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RCJ-3	9/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	2.5

RCJ-3	10/6/1992	DEPTH OF POND OR RESERVOIR IN FEET	2.5
RCJ-3	10/21/1992	DEPTH OF POND OR RESERVOIR IN FEET	2
RCJ-3	5/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	5/28/1993	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	6/9/1993	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	6/21/1993	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/7/1993	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	9.5
RCJ-3	8/5/1993	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	8/16/1993	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	9/15/1993	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	9/28/1993	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	10/6/1993	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	10/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	9.5
RCJ-3	5/4/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	5/20/1994	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	6/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	6/28/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	7/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/18/1994	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	8/8/1994	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/29/1994	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	9/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RCJ-3	9/30/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	10/7/1994	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	10/31/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	5/12/1995	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	5/22/1995	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	6/7/1995	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	6/21/1995	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	7/6/1995	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	7/19/1995	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/4/1995	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/30/1995	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	9/15/1995	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	9/27/1995	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	10/11/1995	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	10/25/1995	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	5/9/1996	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	5/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	6/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	6/25/1996	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RCJ-3	7/8/1996	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	8/12/1996	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	8/22/1996	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	9/4/1996	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	9/24/1996	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	10/14/1996	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RCJ-3	10/24/1996	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	4/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	5/12/1997	DEPTH OF POND OR RESERVOIR IN FEET	8

RCJ-3	5/16/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	6/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	6/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/28/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	8/13/1997	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RCJ-3	8/26/1997	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RCJ-3	9/8/1997	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	9/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	10/6/1997	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	10/16/1997	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	10/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	5
RCJ-3	4/16/1998	DEPTH OF POND OR RESERVOIR IN FEET	10
RCJ-3	4/16/1998	DEPTH OF POND OR RESERVOIR IN FEET	10
RCJ-3	5/13/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	5/29/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	6/8/1998	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	6/8/1998	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	6/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	6/19/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	7/6/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	7/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	7/10/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	7/17/1998	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	8/11/1998	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	8/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	8/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	8/27/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	9/9/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	9/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	10/12/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	10/20/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	10/20/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RCJ-3	10/23/1998	DEPTH OF POND OR RESERVOIR IN FEET	6
RCJ-3	6/5/2001	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	7/10/2001	DEPTH OF POND OR RESERVOIR IN FEET	9
RCJ-3	8/22/2001	DEPTH OF POND OR RESERVOIR IN FEET	8
RCJ-3	4/18//01	DEPTH OF POND OR RESERVOIR IN FEET	7

Appendix B
GWLF and BATHTUB Input and Output Files

GWLF Data Input File Template

Transprt.dat

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

Nutrient.dat

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

Weather.dat

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

GWLF Input Data Files

Subbasin 1

Transprt.dat

```
6,2
0.1,0.05,10,0,0,0.33,10
0
0
0
0
0
"APR",0.63,13,0,0.27
"MAY",0.78,14.1,1,0.27
"JUNE",0.91,14.6,1,0.27
"JULY",0.91,14.4,1,0.27
"AUG",0.90,13.5,1,0.27
"SEPT",0.88,12.2,1,0.27
"OCT",0.72,11,1,0.14
"NOV",0.56,9.9,0,0.14
"DEC",0.52,9.3,0,0.14
"JAN",0.65,9.6,0,0.14
"FEB",0.67,10.6,0,0.14
"MAR",0.66,11.8,0,0.14
"Row-Crop",88.8,86.5,0.0138
"Small-Grains",32.8,84.6,0.0055
"Rural-Grass",90.4,75.9,0.0003
"Deciduous",35.9,71.3,0.0004
"Deciduous2",5.0,74.3,0.0004
"Dairy-Farm",1.5,78.0,0.0001
"Open-Wat",16.8,100.0,0.0000
"Shall-Wat/Wet",1.4,100.0,0.0000
```

Nutrient.dat

```
3000,616,0.8,0.067
0,0,0
2.9,0.26
1.8,0.3
3,0.15
0.06,0.009
0.06,0.009
1000,123.75
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Weather.dat (excerpt)

```
30
5.28,0.00
3.89,0.00
6.39,0.00
12.78,0.81
16.11,1.22
6.39,0.89
6.94,0.64
5.56,0.00
2.22,0.00
3.61,0.00
6.67,0.64
14.17,0.00
16.67,0.00
18.61,0.00
13.61,0.91
13.61,0.00
13.89,0.00
16.94,0.00
21.94,0.00
21.67,0.00
21.94,0.00
22.50,0.00
22.22,0.00
20.00,0.15
13.89,0.00
18.61,0.00
21.67,0.00
19.17,0.00
15.56,0.00
16.67,0.00
31
17.50,1.85
16.67,4.06
11.67,0.38
13.33,0.00
15.56,0.00
18.33,0.00
18.61,0.00
14.72,0.00
16.67,0.00
18.33,0.00
18.61,0.00
20.28,0.00
22.78,0.00
21.11,0.64
21.94,0.03
17.22,0.00
14.17,0.13
11.39,0.00
16.67,0.00
18.89,0.00
21.39,0.00
18.89,0.00
12.22,0.08
16.67,0.00
```

18.61,0.00
20.56,0.00
24.17,0.00
19.72,0.00
17.50,0.00
20.00,0.00
24.17,0.00
30
23.06,0.00
22.50,1.98
23.06,0.97
19.44,0.13
20.00,1.65
16.67,0.46
16.94,0.91
20.00,0.00
23.33,0.00
25.00,0.00
23.33,1.93
16.94,1.09
12.50,0.00
16.11,0.00
16.94,0.56
20.83,0.51
23.33,0.61
19.72,0.00
18.61,0.08
17.50,0.00
20.83,0.00
23.61,0.13
22.50,0.00
25.00,1.14
23.61,0.33
24.17,0.00
26.67,0.00
24.17,2.49
18.61,1.68
20.28,0.81

GWLF Output File

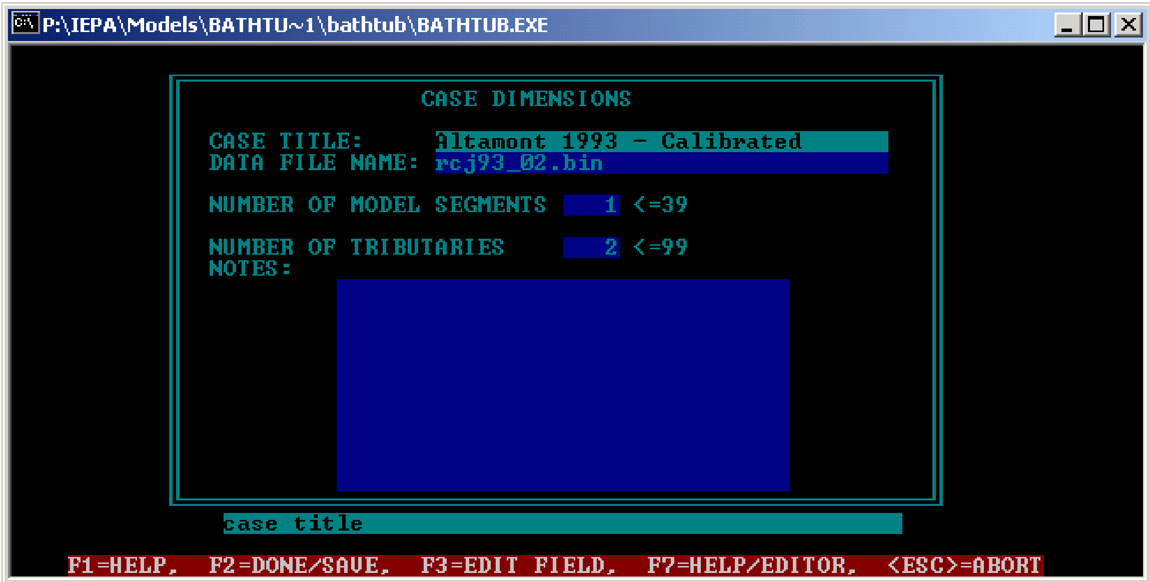
rcj 17 -year means

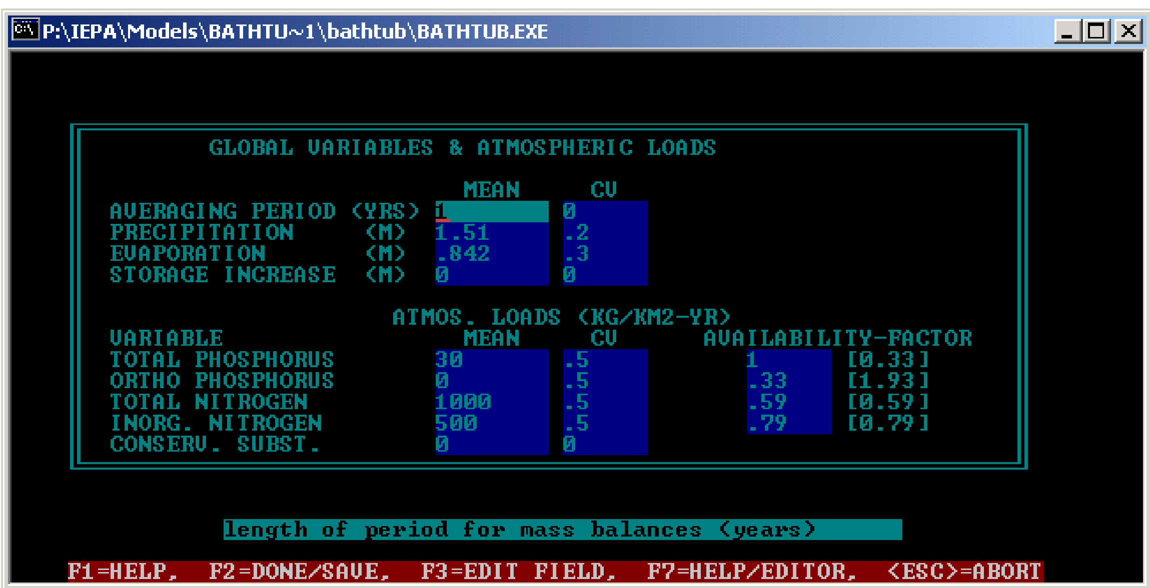
	PRECIP	EVAPOTRANS	GR.WAT.FLOW	RUNOFF	STREAMFLOW
	(cm)				
APR	10.4	3.4	3.5	2.1	5.6
MAY	12.1	7.3	3.1	1.8	4.9
JUNE	10.7	11.0	1.3	1.6	2.9
JULY	12.2	12.0	0.4	2.0	2.4
AUG	7.2	7.1	0.1	0.8	1.0
SEPT	7.6	4.7	0.2	1.1	1.3
OCT	8.0	2.9	0.5	1.3	1.8
NOV	11.5	1.2	1.9	2.7	4.6
DEC	7.2	0.5	3.1	1.7	4.8
JAN	6.9	0.5	2.7	1.9	4.7
FEB	6.5	0.8	3.1	1.3	4.4
MAR	7.2	1.8	3.1	1.3	4.4
ANNUAL	107.6	53.2	23.2	19.6	42.8

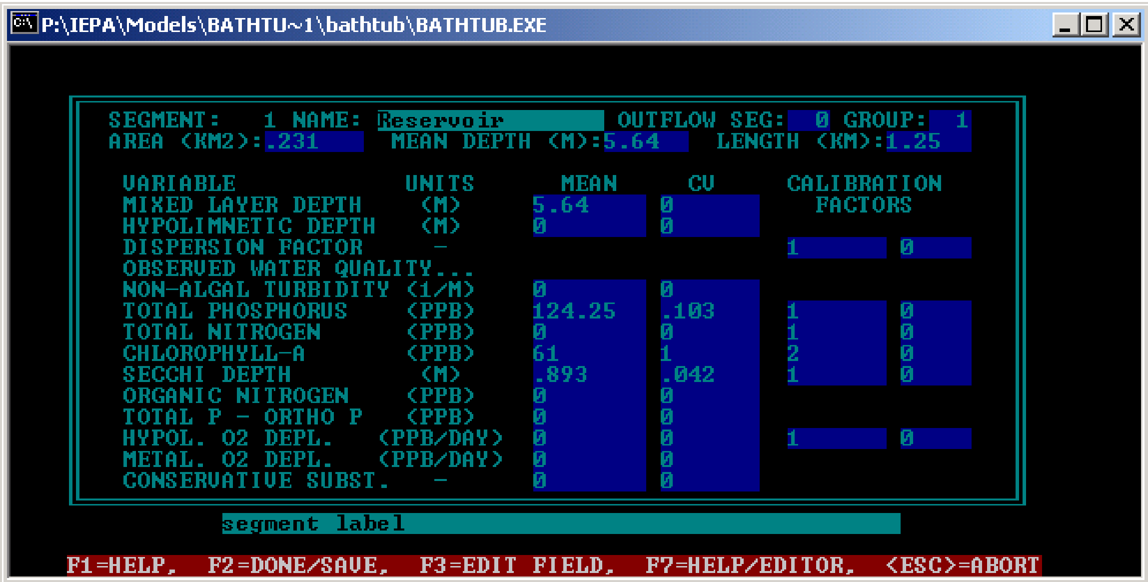
	EROSION	SEDIMENT	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(1000 Mg)		(Mg)			
APR	0.1	0.0	0.4	0.4	0.0	0.0
MAY	0.1	0.0	0.3	0.3	0.0	0.0
JUNE	0.1	0.0	0.2	0.2	0.0	0.0
JULY	0.1	0.0	0.2	0.3	0.0	0.0
AUG	0.0	0.0	0.1	0.1	0.0	0.0
SEPT	0.1	0.0	0.1	0.2	0.0	0.0
OCT	0.0	0.0	0.2	0.2	0.0	0.0
NOV	0.0	0.0	0.4	0.5	0.0	0.1
DEC	0.0	0.0	0.3	0.4	0.0	0.0
JAN	0.0	0.0	0.3	0.4	0.0	0.1
FEB	0.0	0.0	0.2	0.3	0.0	0.0
MAR	0.0	0.0	0.2	0.3	0.0	0.0
ANNUAL	0.6	0.2	2.9	3.4	0.3	0.4

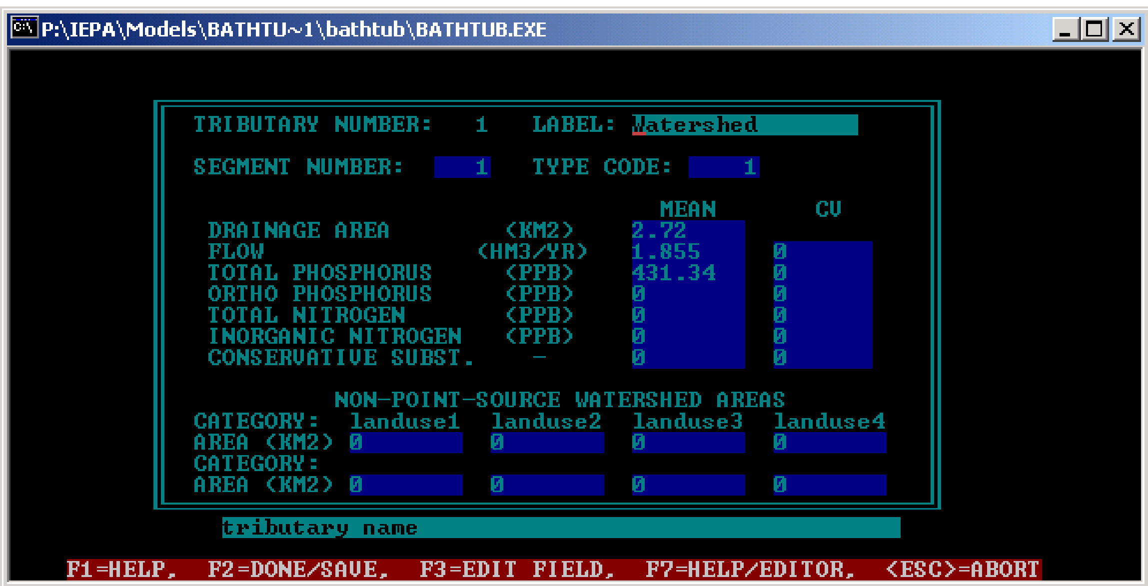
SOURCE	AREA (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
Row-Crop	89.	19.85	5.44	0.51	0.99	0.05	0.14
Small-Grains	33.	16.95	2.17	0.10	0.17	0.02	0.03
Rural-Grass	90.	8.73	0.12	0.24	0.25	0.01	0.01
Deciduous	36.	6.26	0.16	0.00	0.01	0.00	0.00
Deciduous2	5.	7.77	0.16	0.00	0.00	0.00	0.00
Dairy-Farm	2.	10.18	0.04	1.53	1.53	0.19	0.19
Open-Wat	17.	107.60	0.00	0.00	0.00	0.00	0.00
Shall-Wat/Wet	1.	107.60	0.00	0.00	0.00	0.00	0.00
GROUNDWATER				0.51	0.51	0.04	0.04
POINT SOURCE				0.00	0.00	0.00	0.00
TOTAL				2.88	3.45	0.31	0.42

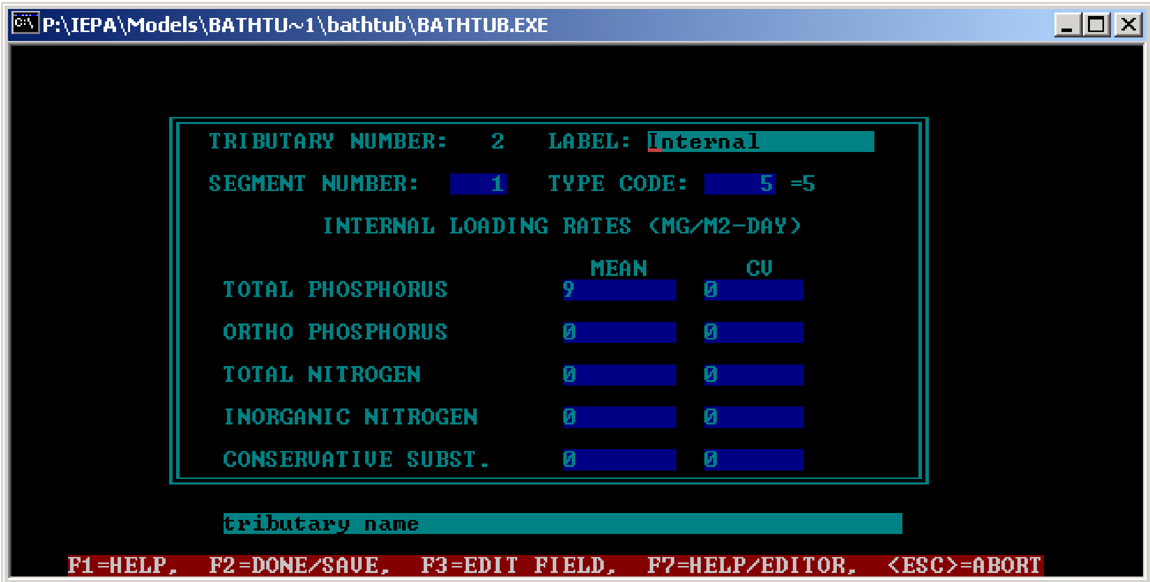
BATHTUB Input Screens for 1993 Model Simulation






P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Reservoir OUTFLOW SEG: 0 GROUP: 1
AREA (KM2):.231 MEAN DEPTH (M):5.64 LENGTH (KM):1.25
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.64 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 124.25 .103 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 61 1 2 0
SECCHI DEPTH (M) .893 .042 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: Watershed
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.72
FLOW (HM3/YR) 1.855 0
TOTAL PHOSPHORUS (PPB) 431.34 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: Internal
SEGMENT NUMBER: 1 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 9 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 1993 Simulation

CASE: Altamont 1993 - 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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	124.3	.10	122.8	.45	1.01	.12	.04	.03
CHL-A	MG/M3	61.0	1.00	53.4	1.58	1.14	.13	.39	.07
SECCHI	M	.9	.04	.7	.48	1.26	5.57	.84	.49
ORGANIC N	MG/M3	.0	.00	1380.4	1.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	92.8	1.24	.00	.00	.00	.00

CASE: Altamont 1993 - Calibrated
GROSS WATER BALANCE:

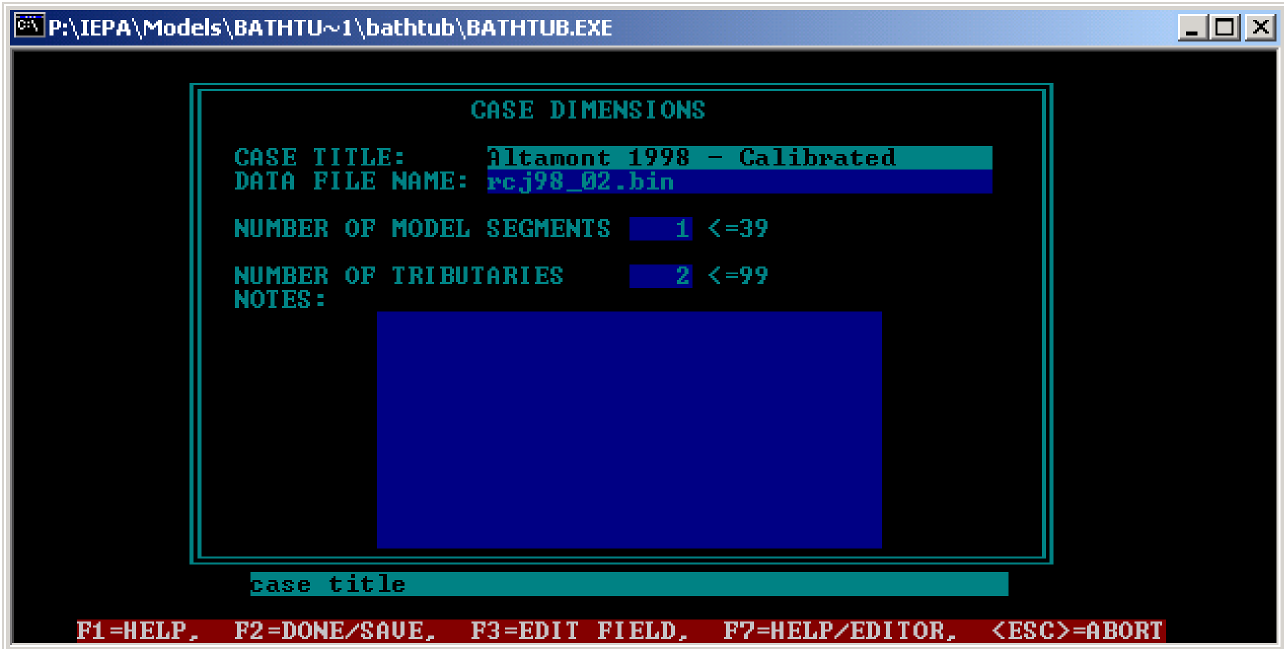
ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1	1	Watershed	2.720	1.855	.000E+00	.000	.682
PRECIPITATION			.231	.349	.487E-02	.200	1.510
TRIBUTARY INFLOW			2.720	1.855	.000E+00	.000	.682
***TOTAL INFLOW			2.951	2.204	.487E-02	.032	.747
ADVECTIVE OUTFLOW			2.951	2.009	.827E-02	.045	.681
***TOTAL OUTFLOW			2.951	2.009	.827E-02	.045	.681
***EVAPORATION			.000	.195	.340E-02	.300	.000

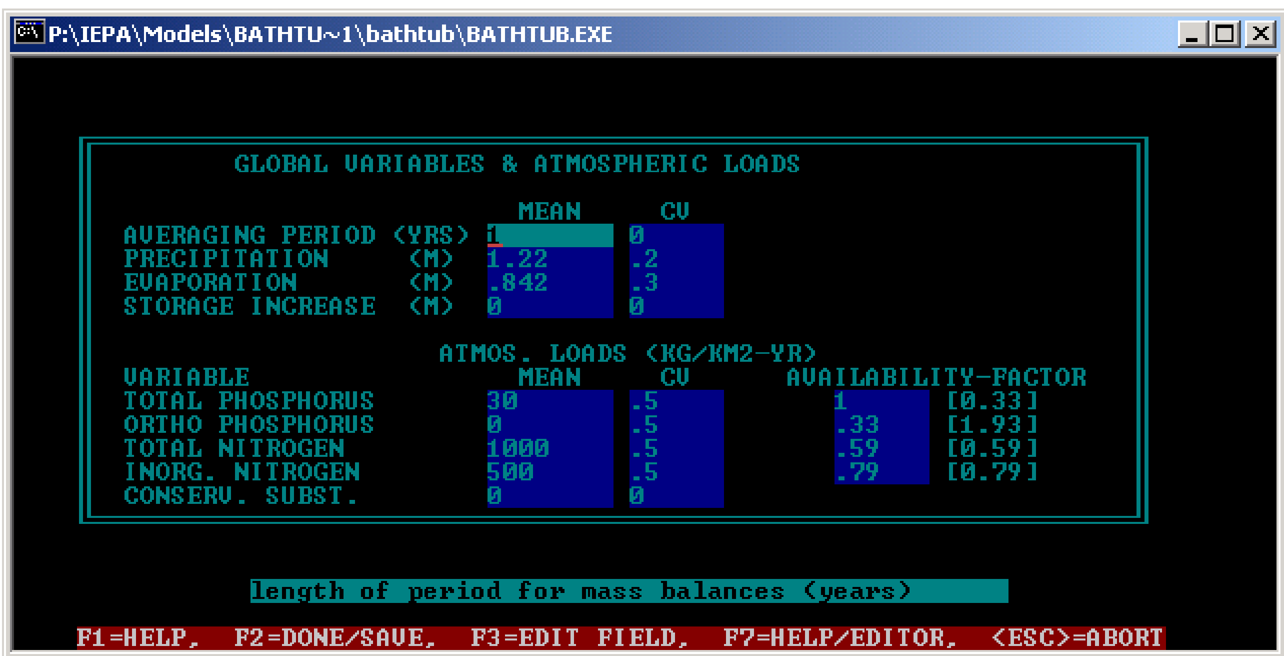
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

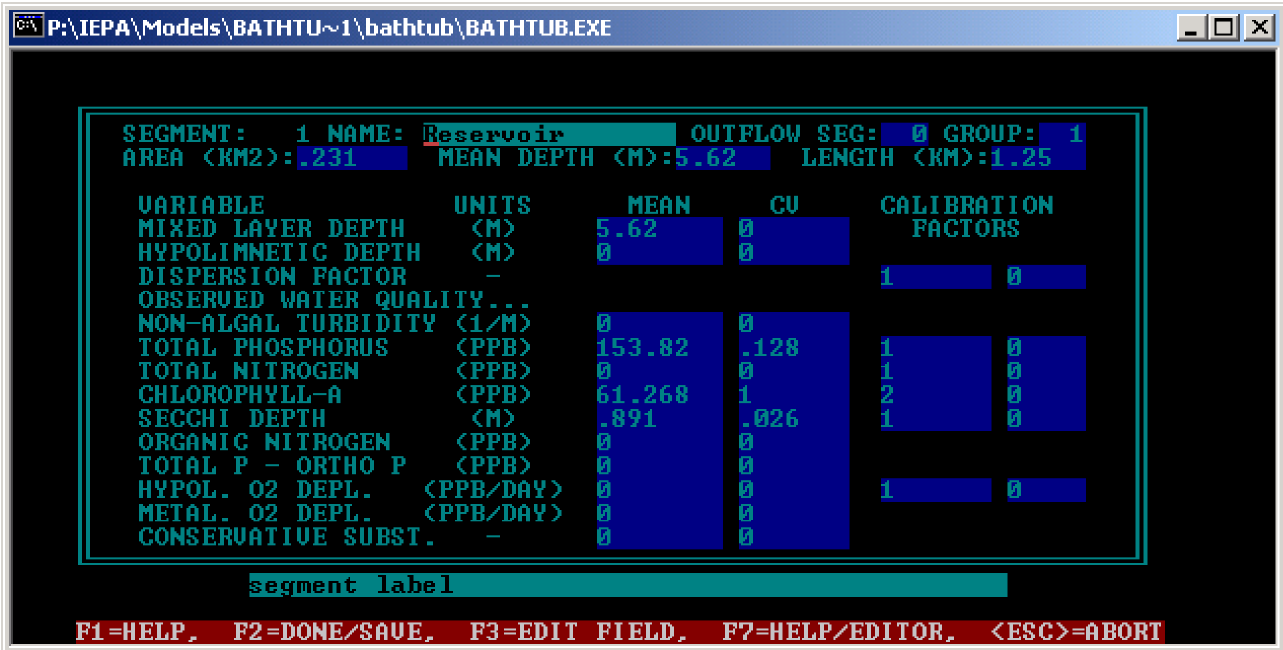
ID	T	LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1	1	Watershed	800.1	51.1	.000E+00	.0	.000	431.3	294.2
PRECIPITATION			6.9	.4	.120E+02	100.0	.500	19.9	30.0
INTERNAL LOAD			759.4	48.5	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			800.1	51.1	.000E+00	.0	.000	431.3	294.2
***TOTAL INFLOW			1566.4	100.0	.120E+02	100.0	.002	710.8	530.8
ADVECTIVE OUTFLOW			246.7	15.7	.124E+05	*******	.451	122.8	83.6
***TOTAL OUTFLOW			246.7	15.7	.124E+05	*******	.451	122.8	83.6
***RETENTION			1319.8	84.3	.124E+05	*******	.084	.0	.0

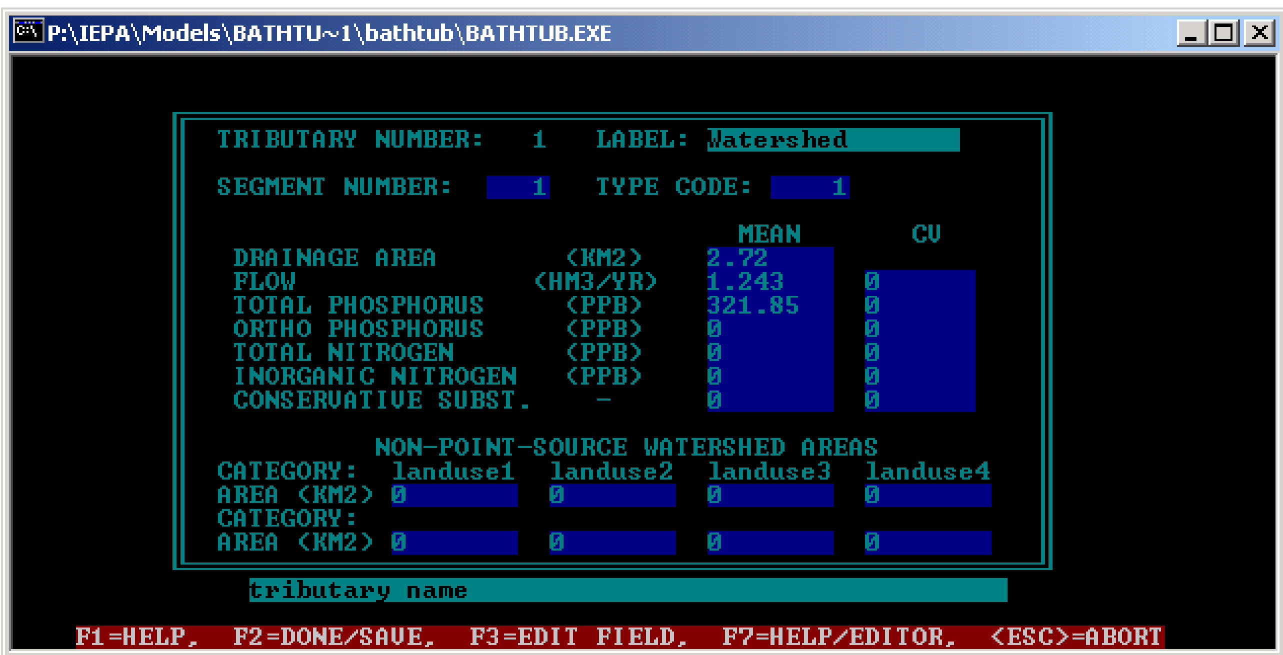
OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
8.70	.6484	124.3	.1033	9.6766	.8425

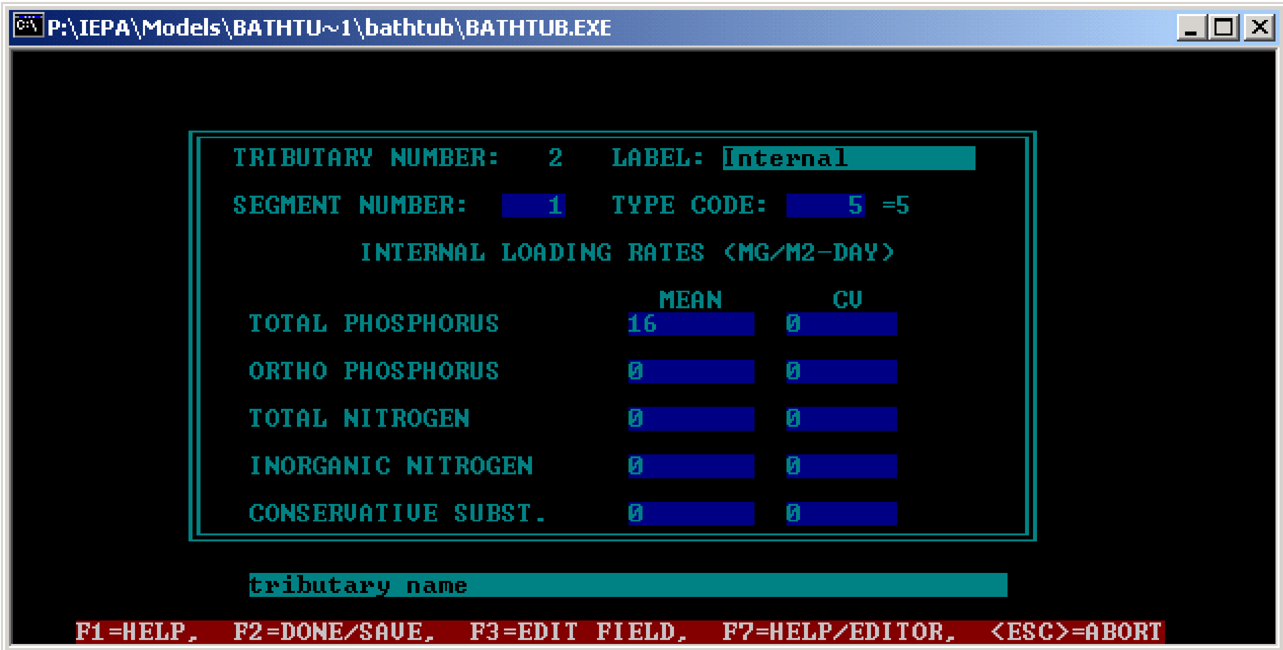
BATHTUB Input Screens for 1998 Model Simulation






P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Reservoir OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .231 MEAN DEPTH (M): 5.62 LENGTH (KM): 1.25
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.62 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 153.82 .128 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 61.268 1 2 0
SECCHI DEPTH (M) .891 .026 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: Watershed
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.72
FLOW (HM3/YR) 1.243 0
TOTAL PHOSPHORUS (PPB) 321.85 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: Internal
SEGMENT NUMBER: 1 TYPE CODE: 5 =5
INTERNAL LOADING RATES (MG/M2-DAY)
MEAN CV
TOTAL PHOSPHORUS 16 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 1998 Simulation

CASE: Altamont 1998 - 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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	152.6	.45	1.01	.06	.03	.02
CHL-A	MG/M3	61.3	1.00	57.0	1.56	1.08	.07	.21	.04
SECCHI	M	.9	.03	.7	.51	1.34	11.28	1.05	.57
ORGANIC N	MG/M3	.0	.00	1462.4	1.31	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	99.2	1.24	.00	.00	.00	.00

CASE: Altamont 1998 - Calibrated
GROSS WATER BALANCE:

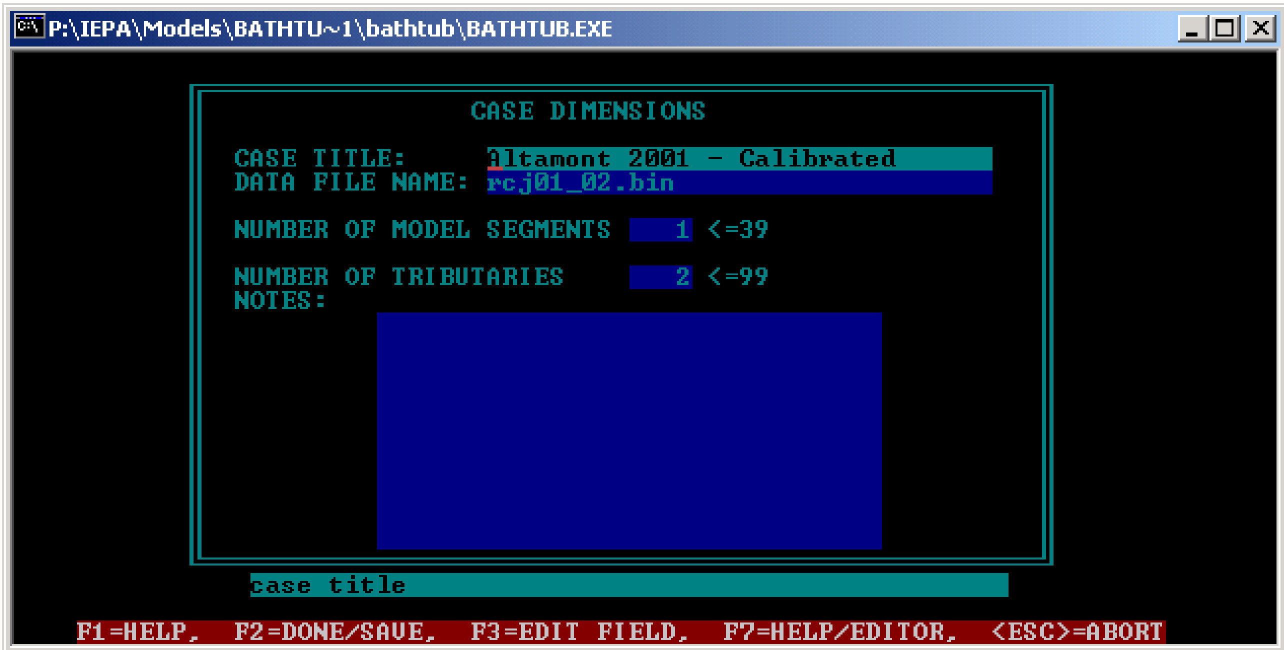
ID T LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	FLOW (HM3/YR) VARIANCE	FLOW (HM3/YR) CV	RUNOFF M/YR
1 1 Watershed	2.720	1.243	.000E+00	.000	.457
PRECIPITATION	.231	.282	.318E-02	.200	1.220
TRIBUTARY INFLOW	2.720	1.243	.000E+00	.000	.457
***TOTAL INFLOW	2.951	1.525	.318E-02	.037	.517
ADVECTIVE OUTFLOW	2.951	1.330	.658E-02	.061	.451
***TOTAL OUTFLOW	2.951	1.330	.658E-02	.061	.451
***EVAPORATION	.000	.195	.340E-02	.300	.000

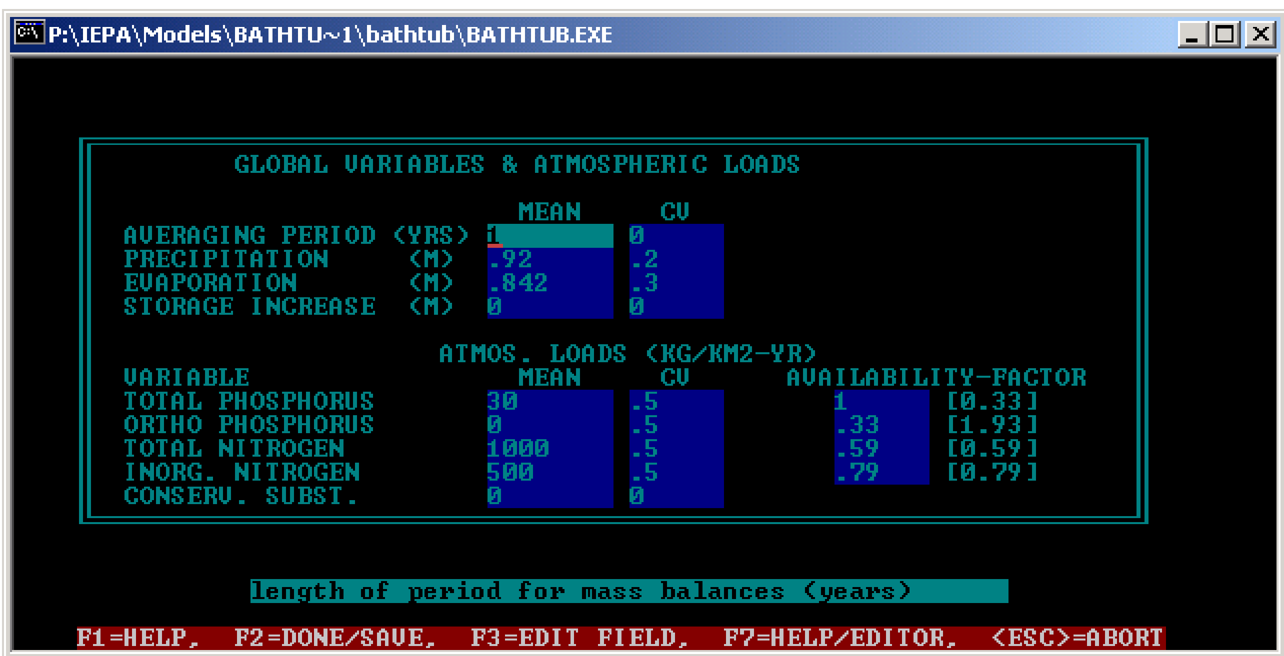
GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

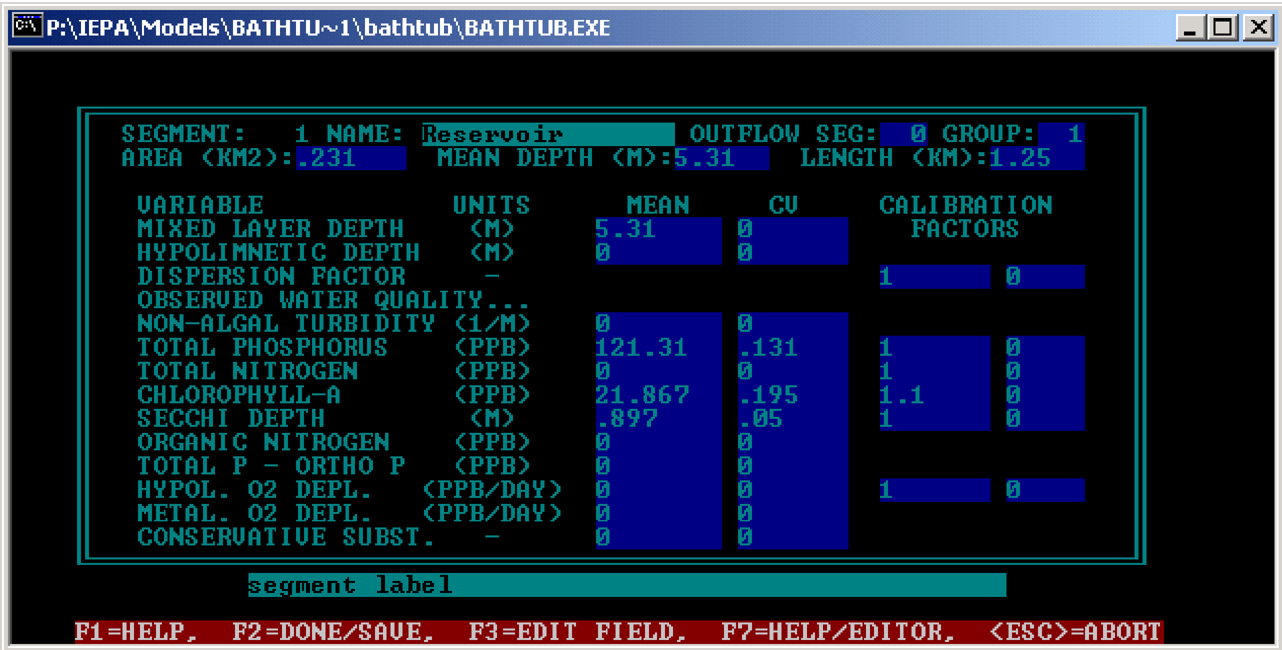
ID T LOCATION	LOADING KG/YR	LOADING %(I)	VARIANCE KG/YR**2	VARIANCE %(I)	CV	CONC MG/M3	EXPORT KG/KM2
1 1 Watershed	400.1	22.8	.000E+00	.0	.000	321.9	147.1
PRECIPITATION	6.9	.4	.120E+02	100.0	.500	24.6	30.0
INTERNAL LOAD	1350.0	76.8	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW	400.1	22.8	.000E+00	.0	.000	321.9	147.1
***TOTAL INFLOW	1757.0	100.0	.120E+02	100.0	.002	1152.2	595.4
ADVECTIVE OUTFLOW	203.1	11.6	.841E+04	70038.5	.452	152.6	68.8
***TOTAL OUTFLOW	203.1	11.6	.841E+04	70038.5	.452	152.6	68.8
***RETENTION	1553.9	88.4	.842E+04	70125.6	.059	.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 -
5.76	.9759	153.8	.1137	8.7983	.8844

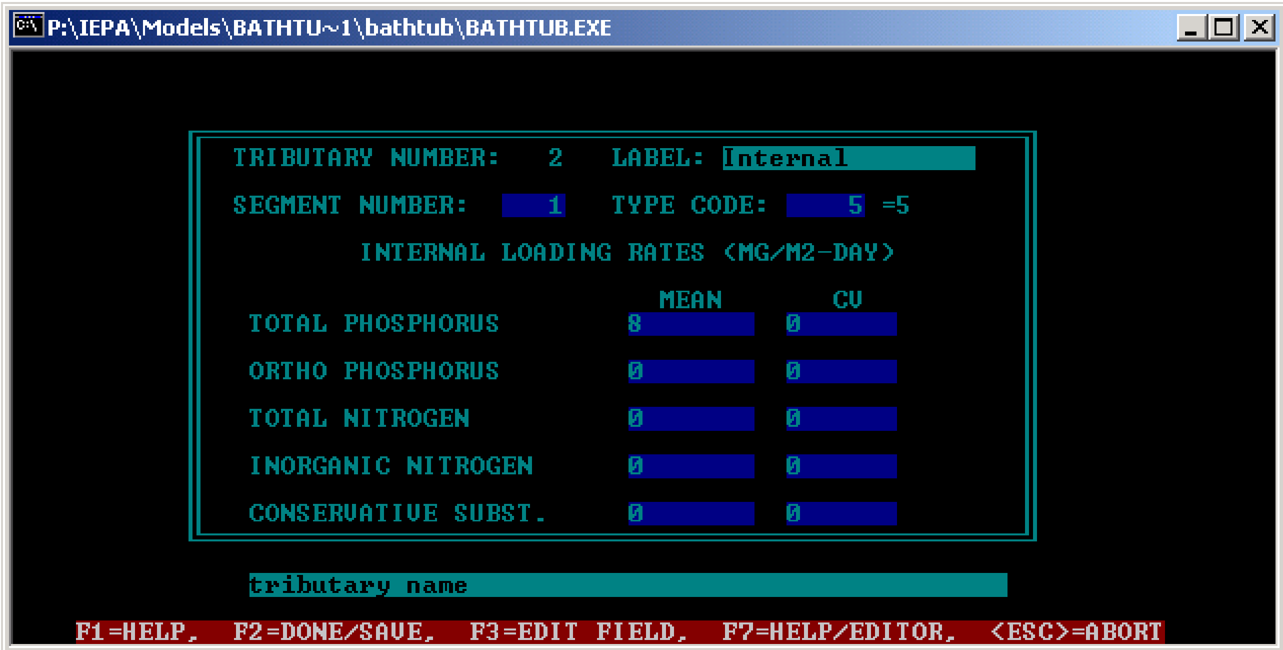
BATHTUB Input Screens for 2001 Model Simulation






P:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE
SEGMENT: 1 NAME: Reservoir OUTFLOW SEG: 0 GROUP: 1
AREA (KM2): .231 MEAN DEPTH (M): 5.31 LENGTH (KM): 1.25
VARIABLE UNITS MEAN CV CALIBRATION FACTORS
MIXED LAYER DEPTH (M) 5.31 0
HYPOLIMNETIC DEPTH (M) 0 0
DISPERSION FACTOR - 1 0
OBSERVED WATER QUALITY...
NON-ALGAL TURBIDITY (1/M) 0 0
TOTAL PHOSPHORUS (PPB) 121.31 .131 1 0
TOTAL NITROGEN (PPB) 0 0 1 0
CHLOROPHYLL-A (PPB) 21.867 .195 1.1 0
SECCHI DEPTH (M) .897 .05 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: Watershed
SEGMENT NUMBER: 1 TYPE CODE: 1
MEAN CV
DRAINAGE AREA (KM2) 2.72
FLOW (HM3/YR) 1.004 0
TOTAL PHOSPHORUS (PPB) 199.3 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: 2 LABEL: Internal
SEGMENT NUMBER: 1 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: Altamont 2001 - Calibrated

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

SEGMENT: 1 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	121.3	.13	120.7	.45	1.00	.04	.02	.01
CHL-A	MG/M3	21.9	.19	21.3	.30	1.02	.13	.07	.07
SECCHI	M	.9	.05	.9	.18	.99	-.24	-.04	-.06
ORGANIC N	MG/M3	.0	.00	686.3	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	47.3	.28	.00	.00	.00	.00

CASE: Altamont 2001 - Calibrated
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Watershed	2.720	1.004	.000E+00	.000	.369
PRECIPITATION			.231	.213	.181E-02	.200	.920
TRIBUTARY INFLOW			2.720	1.004	.000E+00	.000	.369
***TOTAL INFLOW			2.951	1.217	.181E-02	.035	.412
ADVECTIVE OUTFLOW			2.951	1.022	.521E-02	.071	.346
***TOTAL OUTFLOW			2.951	1.022	.521E-02	.071	.346
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	200.1	22.7	.000E+00	.0	.000	199.3	73.6
PRECIPITATION			6.9	.8	.120E+02	100.0	.500	32.6	30.0
INTERNAL LOAD			675.0	76.5	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			200.1	22.7	.000E+00	.0	.000	199.3	73.6
***TOTAL INFLOW			882.0	100.0	.120E+02	100.0	.004	725.0	298.9
ADVECTIVE OUTFLOW			123.4	14.0	.311E+04	25891.6	.452	120.7	41.8
***TOTAL OUTFLOW			123.4	14.0	.311E+04	25891.6	.452	120.7	41.8
***RETENTION			758.6	86.0	.312E+04	25976.4	.074	.0	.0

	HYDRAULIC	-------------- TOTAL P	--------------		
OVERFLOW	RESIDENCE	POOL	RESIDENCE	TURNOVER	RETENTION
RATE	TIME	CONC	TIME	RATIO	COEF
M/YR	YRS	MG/M3	YRS	-	-
4.42	1.2002	121.3	.1687	5.9275	.8601

Appendix C
GWLF Manual

G W L F

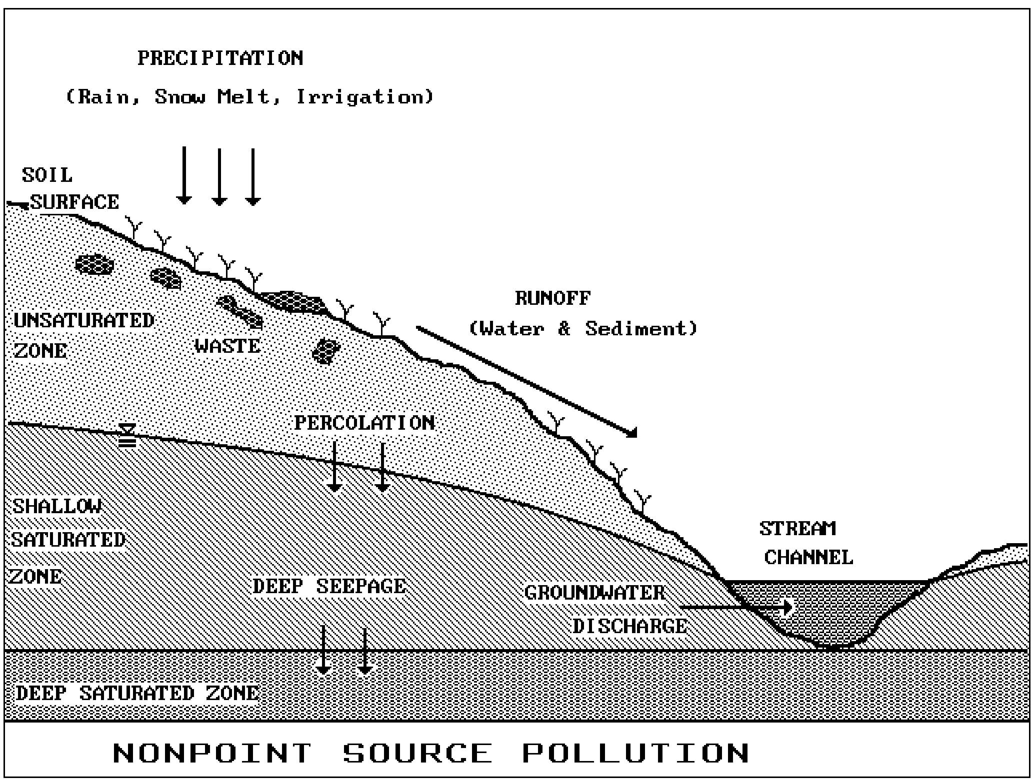
GENERALIZED WATERSHED LOADING FUNCTIONS

VERSION 2.0

USER'S MANUAL

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

Douglas A. Haith, Ross Mandel & Ray Shyan Wu



Department of Agricultural & Biological Engineering
Cornell University
Riley-Robb Hall
Ithaca NY USA 14853

TABLE OF CONTENTS

INTRODUCTION 2

MODEL DESCRIPTION 3

- Model Structure 3
- Input Data 3
- Model Output 4

GWLF PROGRAM 4

- Required Files 4
- Program Structure 5
- Transport Data Manipulation 5
- Nutrient Data Manipulation 6
- Simulation 7
- Results Output 7

EXAMPLE 1: 4-YEAR STUDY IN WEST BRANCH DELAWARE BASIN 7

- Simulation 8
- Results Generation 8

EXAMPLE 2: EFFECTS OF ELIMINATION OF WINTER MANURE SPREADING 9

- Nutrient Parameters Modification 9
- Simulation and Results Generation 12

EXAMPLE 3: A 30-YEAR SIMULATION STUDY 13

APPENDIX A: MATHEMATICAL DESCRIPTION OF GWLF 16

- General Structure 16
- Rural Runoff Loads 16
- Urban Runoff 19
- Groundwater Sources 20
- Septic (On-site Wastewater Disposal) Systems 22

APPENDIX B: DATA SOURCES & PARAMETER ESTIMATION 24

- Land Use Data 24
- Weather Data 24
- Transport Parameters 24
- Nutrient Parameters 38

APPENDIX C: VALIDATION STUDY 43

- Water Quality Observations 43
- Watershed Data 44
- Validation Results 48
- Conclusions 50

APPENDIX D: DATA AND OUTPUT LISTINGS FOR VALIDATON STUDY (EXAMPLE 1) 52

REFERENCES 61

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**, <u>underline</u> and *italic*, respectively.

MODEL DESCRIPTION

Model Structure

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

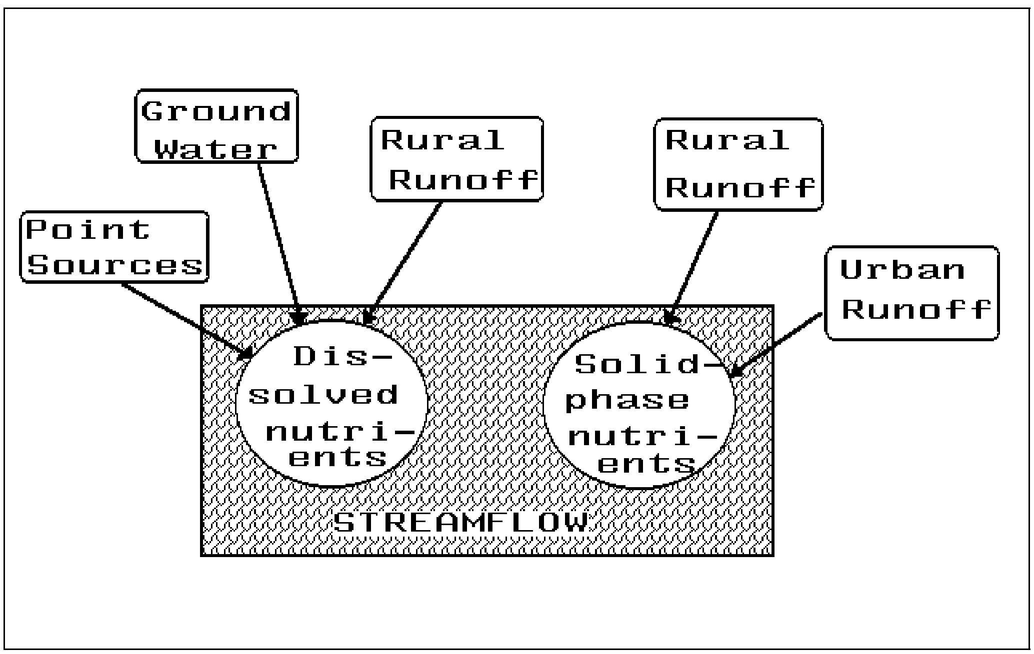


Figure 1. Nutrient Sources in GWLF.

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

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

Input Data

The GWLF model requires daily precipitation and temperature data, runoff sources and transport and chemical parameters. Transport parameters include areas, runoff curve numbers for antecedent moisture condition II and the erosion product ḲḶṢC̣P 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.

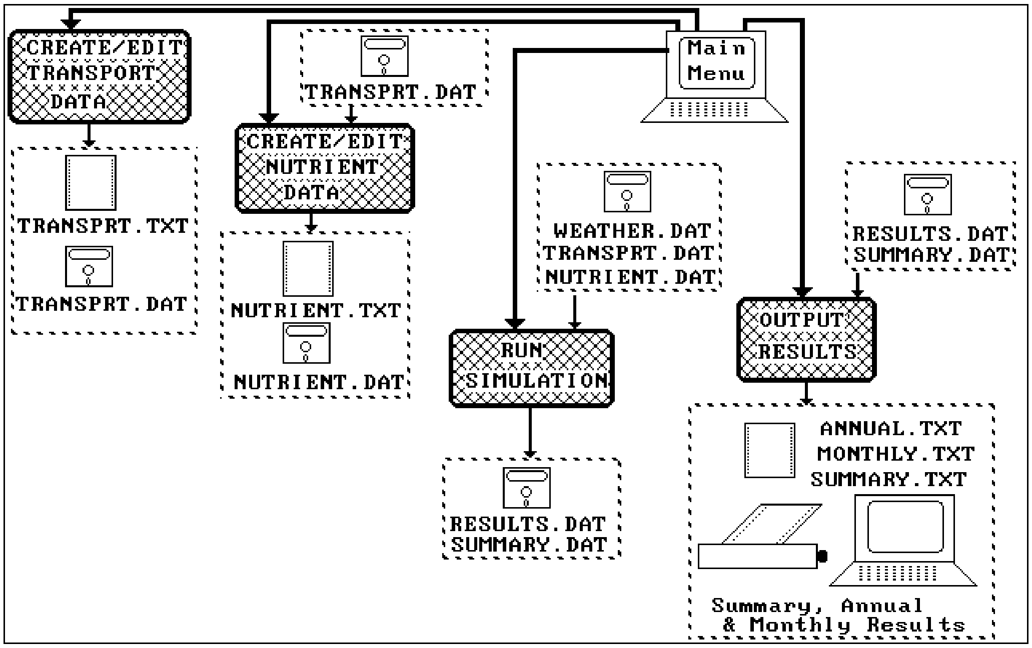


Figure 2. Structure of the GWLF Program.

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

When 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.

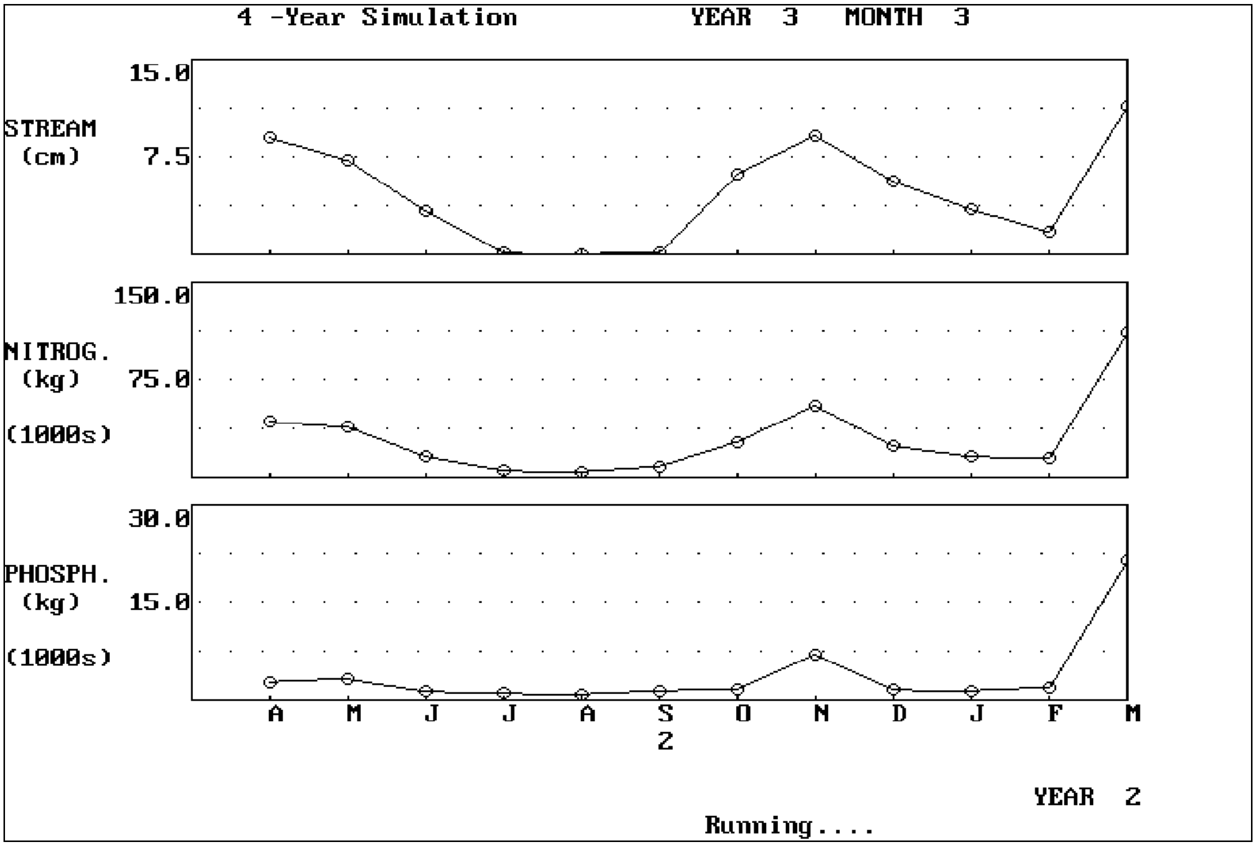


Figure 3. Screen Display during Simulation.

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**.

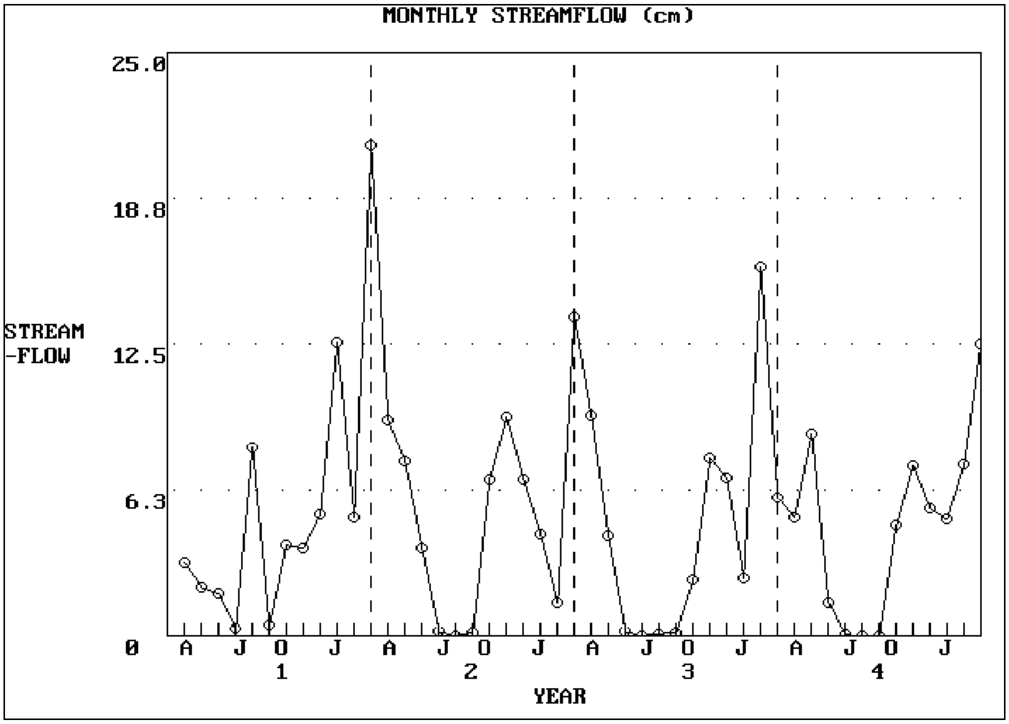


Figure 4. Monthly Streamflows for Example 1.

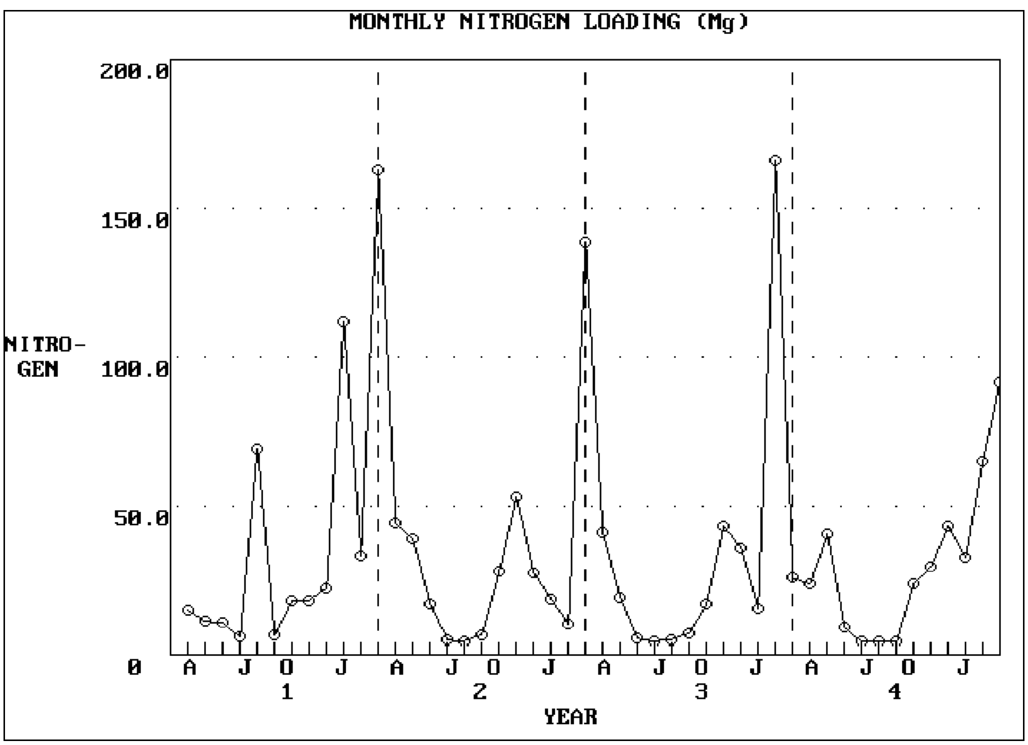


Figure 5. Monthly Nitrogen Loads for Example 1.

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.

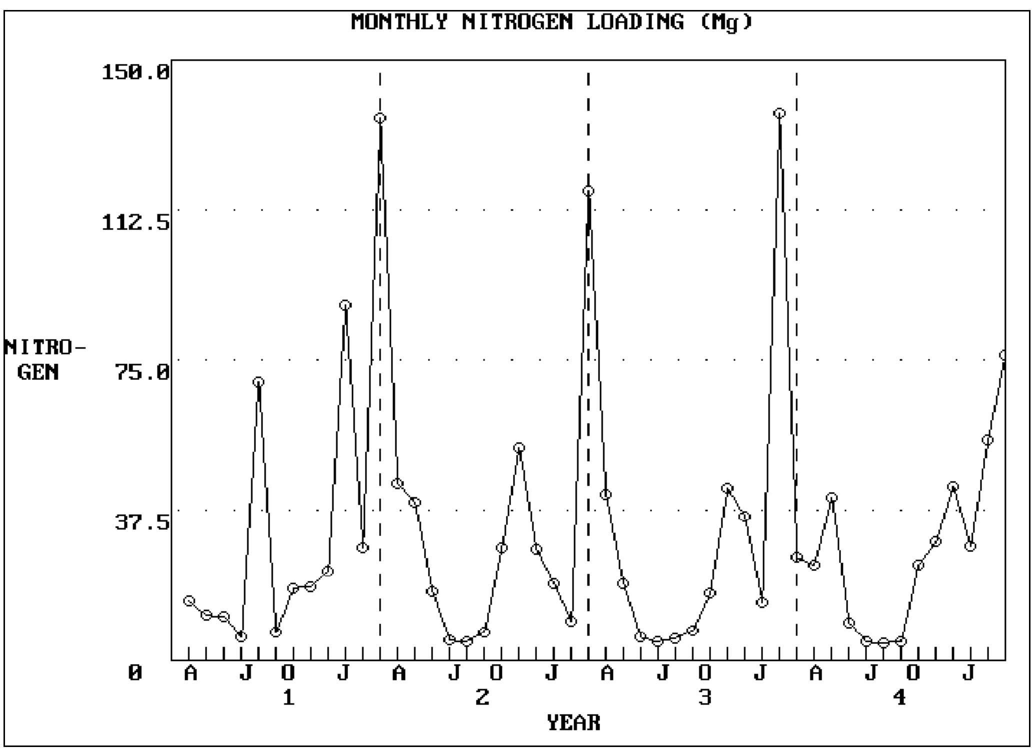


Figure 6. Monthly Nitrogen Loads with no Manure Spreading.

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.

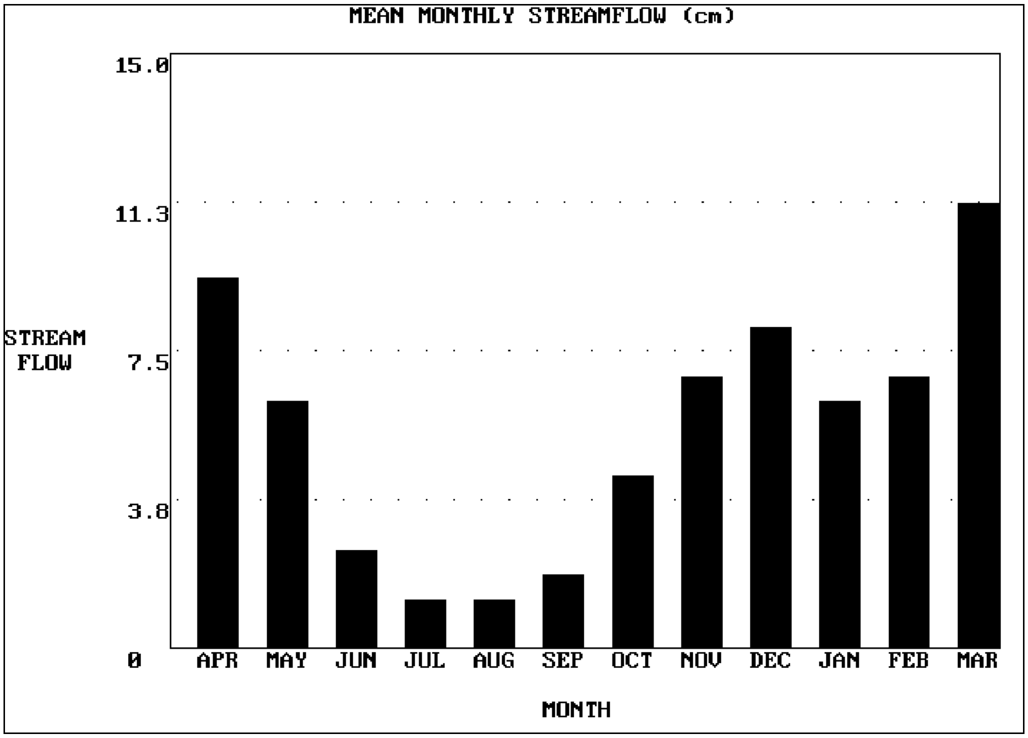


Figure 7. Mean Monthly Streamflows for 30-yr Simulation.

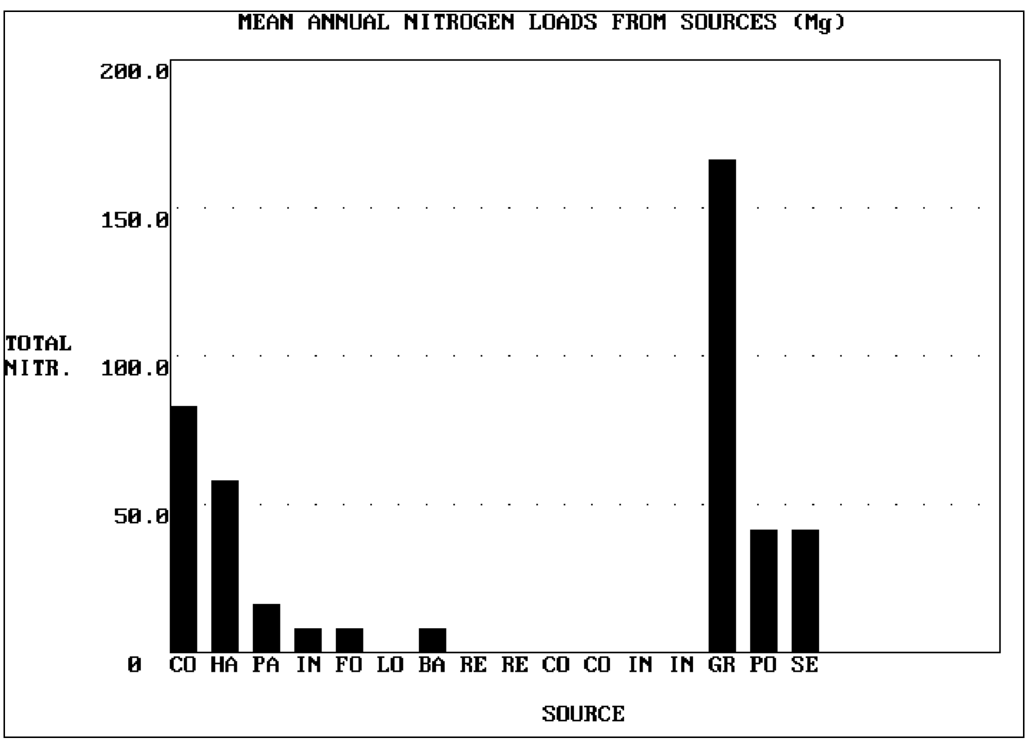


Figure 8. Mean Annual Nitrogen Load from Sources for 30-yr Simulation.

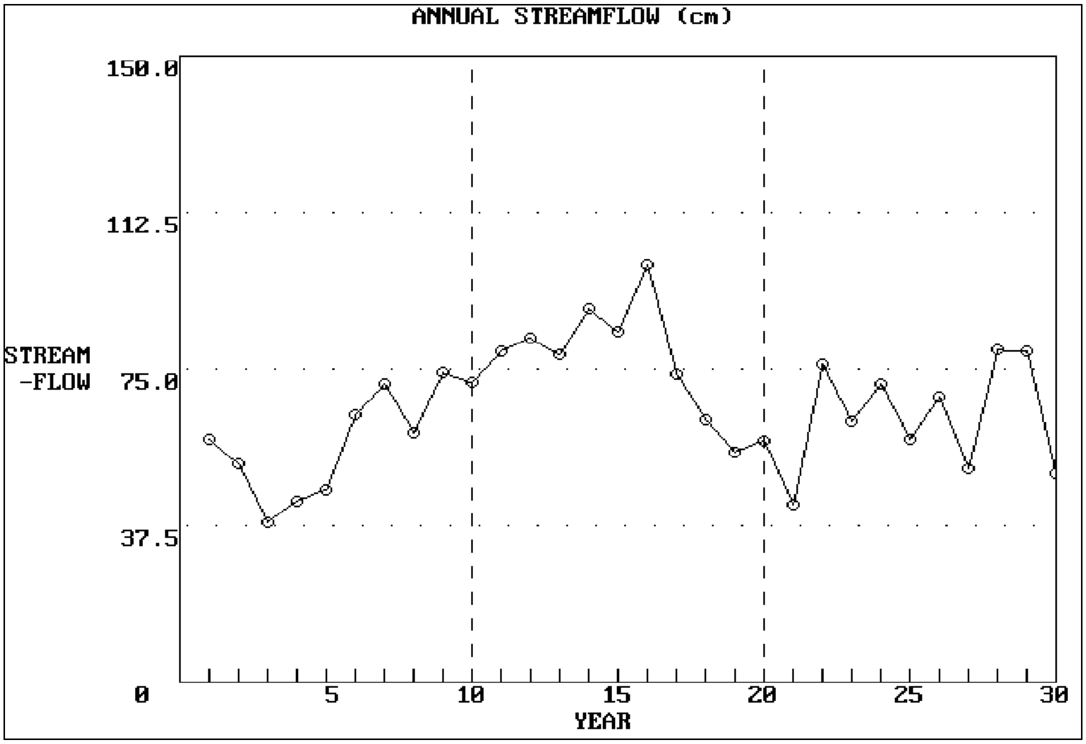


Figure 9. Annual Streamflows for 30-yr Simulation.

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 $M_t > 0$.

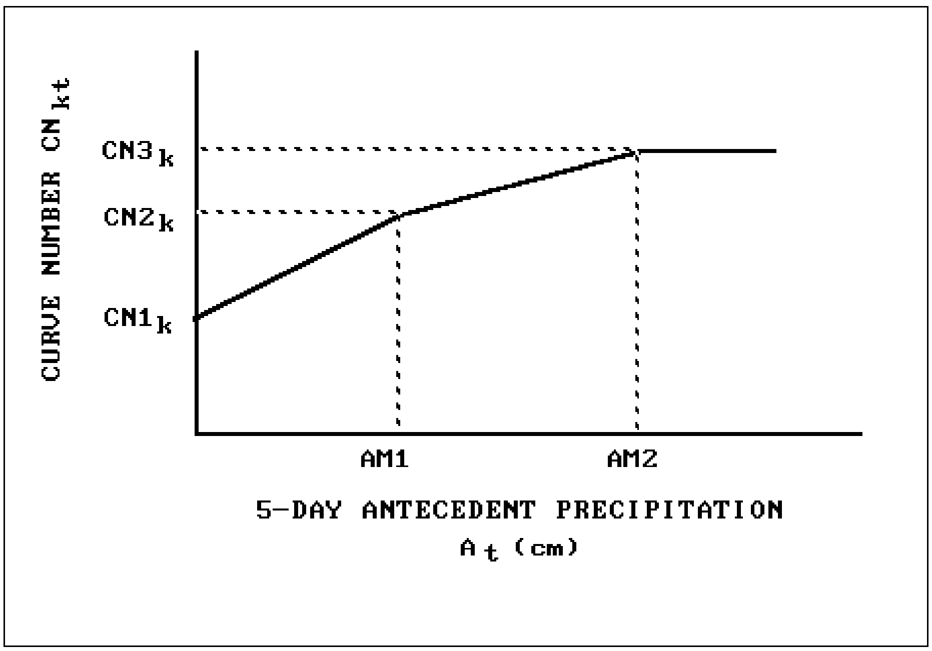


Figure A-1. Curve Number as Function of Antecedent Moisture.

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

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

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

$0.4036 + 0.0059\ CN2_k$

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):

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

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

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

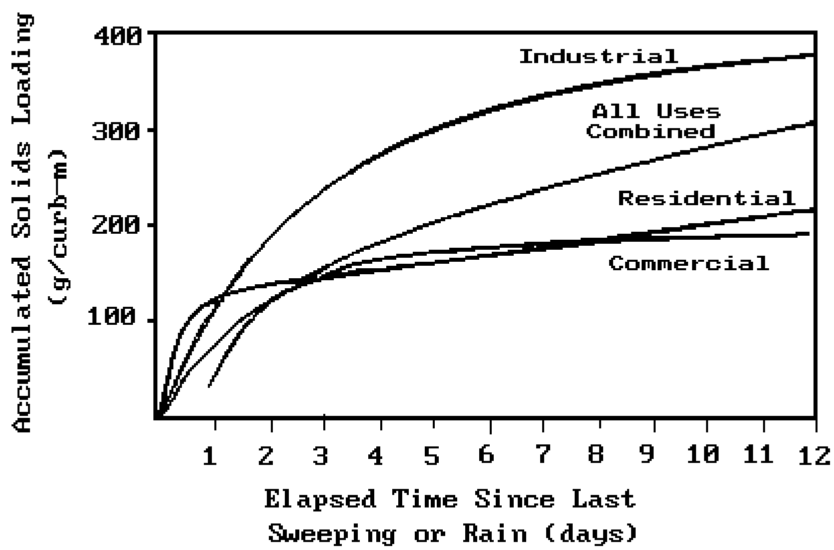


Figure A-2. Accumulation of Pollutants on Urban Surfaces (Sartor & Boyd, 1972; redrawn in Novotny & Chesters, 1981).

Groundwater Sources

The monthly groundwater nutrient load to the stream is

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

in which C_g = nutrient concentration in groundwater (mg/*l*), AT = watershed area (ha), and G_t = groundwater discharge to the stream on day t (cm).

Groundwater discharge is described by the lumped parameter model shown in Figure A-3. Streamflow consists of total watershed runoff from all source areas plus groundwater discharge from a shallow saturated zone. The division of soil moisture into unsaturated, shallow saturated and deep saturated zones is similar to that used by Haan (1972).

Daily water balances for the unsaturated and shallow saturated zones are

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

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

In these equations, U_t and S_t are the unsaturated and shallow saturated zone soil moistures at the beginning of day t and Q_t, E_t, PC_t, G_t and D_t are watershed runoff, evapotranspiration, percolation into the shallow saturated zone, groundwater discharge to the stream and seepage flow to the deep saturated zone, respectively, on day t (cm).

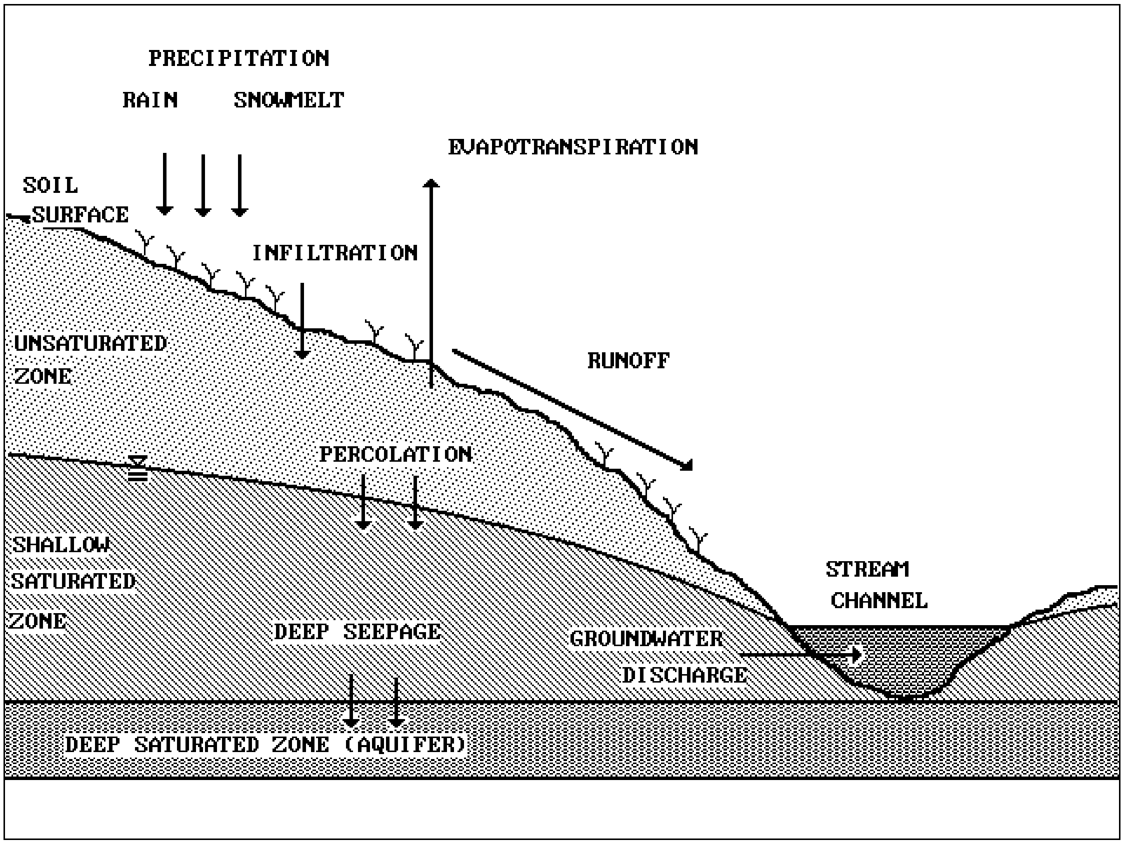


Figure A-3. Lumped Parameter Model for Groundwater Discharge.

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

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

Evapotranspiration is limited by available moisture in the unsaturated zone:

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

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

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

In this equation, H_t is the number of daylight hours per day during the month containing day t, e_t is the saturated water vapor pressure in millibars on day t and T_t is the temperature on day t (°C). When $T_t \leq 0$, PE_t is set to zero. Saturated vapor pressure can be approximated as in (Bosen, 1960):

$$e_t = 33.8639\,[\,(0.00738\,T_t + 0.8072)^8 - 0.000019\,(1.8\,T_t + 48) + 0.001316\,]\,,\quad T_t \geq 0 \qquad \text{(A-32)}$$

As in Haan (1972), the shallow unsaturated zone is modeled as a simple linear reservoir. Groundwater discharge and deep seepage are

$$G_t = r\,S_t \qquad \text{(A-33)}$$

and

$$D_t = s\,S_t \qquad \text{(A-34)}$$

where r and s are groundwater recession and seepage constants, respectively (day^{-1}).

Septic (On-site Wastewater Disposal) Systems

The septic system component of GWLF is based on the model developed by Mandel (1993). For purposes of assessing watershed water quality impacts, septic systems loads can be divided into four types:

$$DS_m = DS_{1m} + DS_{2m} + DS_{3m} + DS_{4m} \qquad \text{(A-35)}$$

where DS_{1m}, DS_{2m}, DS_{3m} and DS_{4m} are the dissolved nutrient load to streamflow from normal, short-circuited, ponded and direct discharge systems, respectively in month m (kg). These loads are computed from per capita daily effluent loads and monthly populations served a_{jm} for each system (j =1,2,3,4).

Normal Systems. A normal septic system is a system whose construction and operation conforms to recommended procedures such as those suggested by the EPA design manual for on-site wastewater disposal systems (U. S. Environmental Protection Agency, 1980). Effluents from such systems infiltrate into the soil and enter the shallow saturated zone. Effluent nitrogen is converted to nitrate, and except for removal by plant uptake, the nitrogen is transported to the stream by groundwater discharge. Conversely, phosphates in the effluent are adsorbed and retained by the soil and hence normal systems provide no phosphorus loads to streamflow. The nitrogen load to groundwater from normal systems in month m (kg) is

$$SL_{1m} = 0.001\;a_{1m}\,d_m\,(e - u_m) \qquad \text{(A-36)}$$

in which e = per capita daily nutrient load in septic tank effluent (g/day) and u_m = per capita daily nutrient uptake by plants in month m (g/day).

Normal systems are generally some distance from streams and their effluent mixes with other groundwater. Monthly nutrient loads are thus proportional to groundwater discharge to the stream. The portion of the annual load delivered in month m is equivalent to the portion of annual groundwater discharge which occurs in that month. Thus the load in month m of any year is

$$DS_{1m} = \frac{GR_m \sum_{m=1}^{12} SL_{1m}}{\sum_{m=1}^{12} GR_m} \qquad \text{(A-37)}$$

where GR_m = total groundwater discharge to streamflow in month m (cm), obtained by summing the daily values G_t for the month. Equation A-37 applies only for nitrogen. In the case of phosphorus, DS_{1m} = 0.

Short-Circuited Systems. These systems are located close enough to surface waters (< 15 m) so that negligible adsorption of phosphorus takes place. The only nutrient removal mechanism is plant uptake, and the watershed load for both nitrogen and phosphorus is

$$DS_{2m} = 0.001\, a_{2m}\, d_m\, (e - u_m) \tag{A-38}$$

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

$$DS_{3m} = 0.001 \sum_{t=1}^{d_m} PN_t \tag{A-39}$$

where PN_t = watershed nutrient load in runoff from ponded systems on day t (g). Nutrient accumulation under freezing conditions is

$$FN_{t+1} = \begin{cases} FN_t + a_{3m}\, e \ , & SN_t > 0 \text{ or } T_t \leq 0 \\ 0 \ , & \text{otherwise} \end{cases} \tag{A-40}$$

where FN_t = frozen nutrient accumulation in ponded systems at the beginning of day t (g). The runoff load is thus

$$PN_t = \begin{cases} a_{3m}\, e + FN_t - u_m \ , & SN_t = 0 \text{ and } T_t > 0 \\ 0 \ , & \text{otherwise} \end{cases} \tag{A-41}$$

Direct Discharge Systems. These illegal systems discharge septic tank effluent directly into surface waters. Thus,

$$DS_{4m} = 0.001\, a_{4m}\, d_m\, e \tag{A-42}$$

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 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	A	B	C	D
Fallow	Bare Soil	-	77	86	91	94
Crop residue cover (CR)		Poor[a/]	76	85	90	93
		Good	74	83	88	90
Row Crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T + CR	Poor	65	73	79	81
		Good	61	70	77	80
Small Grains	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

[a/] Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good $ 20%), and (e) degree of surface roughness.

Table B-2. Runoff Curve Numbers (Antecedent Moisture Condition II) for Cultivated Agricultural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Pasture, grassland or range - continuous forage for grazing	Poor[a/]	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow - continuous grass, protected from grazing, generally mowed for hay	-	30	58	71	78
Brush - brush/weeds/grass mixture with brush the major element	Poor[b/]	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods/grass combination (orchard or tree farm)[c/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods	Poor[/d]	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads - buildings, lanes, driveways and surrounding lots	-	59	74	82	86

[a/] Poor: < 50% ground cover or heavily grazed with no mulch; Fair: 50 to 75% ground cover and not heavily grazed; Good: > 75% ground cover and lightly or only occasionally grazed.

[b/] Poor: < 50% ground cover; Fair: 50 to 75% ground cover; Good: > 75% ground cover.

[c/] Estimated as 50% woods, 50% pasture.

[d/] Poor: forest litter, small trees and brush are destroyed by heavy grazing or regular burning; Fair: woods are grazed but not burned and some forest litter covers the soil; Good: Woods are protected from grazing and litter and brush adequately cover the soil.

Table B-3. Runoff Curve Numbers (Antecedent Moisture Condition II) for other Rural Land (Soil Conservation Service, 1986).

Land Use/Cover	Hydrologic Condition	Soil Hydrologic Group A	B	C	D
Herbaceous - grass, weeds & low-growing brush; brush the minor component	Poor[a/]	-	80	87	93
	Fair	-	71	81	89
	Good	-	62	74	85
Oak/aspen - oak brush, aspen, mountain mahogany, bitter brush, maple and other brush	Poor	-	66	74	79
	Fair	-	48	57	63
	Good	-	30	41	48
Pinyon/juniper - pinyon, juniper or both; grass understory	Poor	-	75	85	89
	Fair	-	58	73	80
	Good	-	41	61	71
Sagebrush with grass understory	Poor	-	67	80	85
	Fair	-	51	63	70
	Good	-	35	47	55
Desert scrub - saltbush, greasewood, creosotebrush, blackbrush, bursage, palo verde, mesquite and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[a/] Poor: < 30% ground cover (litter, grass and brush overstory); Fair: 30 to 70% ground cover; Good: > 70% ground cover.

Table B-4. Runoff Curve Numbers (Antecedent Moisture Condition II) for Arid and Semiarid Rangelands (Soil Conservation Service, 1986).

Land Use	Soil Hydrologic Group A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.):				
Poor condition (grass cover < 50%)	68	79	86	89
Fair condition (grass cover 50-75%)	49	69	79	84
Good condition (grass cover > 75%)	39	61	74	80
Impervious areas:				
Paved parking lots, roofs, driveways, etc.)	98	98	98	98
Streets and roads:				
Paved with curbs & storm sewers	98	98	98	98
Paved with open ditches	83	89	92	93
Gravel	76	85	89	91
Dirt	72	82	87	89
Western desert urban areas:				
Natural desert landscaping (pervious areas, only)	63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1-2 in sand or gravel mulch and basin borders)	96	96	96	96

Table B-5. Runoff Curve Numbers (Antecedent Moisture Condition II) for Urban Areas (Soil Conservation Service, 1986).

Crop	% of Growing Season 0	10	20	30	40	50	60	70	80	90	100

Field corn	0.45	0.51	0.58	0.66	0.75	0.85	0.96	1.08	1.20	1.08	0.70
Grain sorghum	0.30	0.40	0.65	0.90	1.10	1.20	1.10	0.95	0.80	0.65	0.50
Winter wheat	1.08	1.19	1.29	1.35	1.40	1.38	1.36	1.23	1.10	0.75	0.40
Cotton	0.40	0.45	0.56	0.76	1.00	1.14	1.19	1.11	0.83	0.58	0.40
Sugar beets	0.30	0.35	0.41	0.56	0.73	0.90	1.08	1.26	1.44	1.30	1.10
Cantaloupe	0.30	0.30	0.32	0.35	0.46	0.70	1.05	1.22	1.13	0.82	0.44
Potatoes	0.30	0.40	0.62	0.87	1.06	1.24	1.40	1.50	1.50	1.40	1.26
Papago peas	0.30	0.40	0.66	0.89	1.04	1.16	1.26	1.25	0.63	0.28	0.16
Beans	0.30	0.35	0.58	1.05	1.07	0.94	0.80	0.66	0.53	0.43	0.36
Rice	1.00	1.06	1.13	1.24	1.38	1.55	1.58	1.57	1.47	1.27	1.00

Table B-6. Evapotranspiration Cover Coefficients for Annual Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

	Alfalfa	Pasture	Grapes	Citrus Orchards	Deciduous Orchards	Sugarcane
Jan	0.83	1.16	-	0.58	-	0.65
Feb	0.90	1.23	-	0.53	-	0.50
Mar	0.96	1.19	0.15	0.65	-	0.80
Apr	1.02	1.09	0.50	0.74	0.60	1.17
May	1.08	0.95	0.80	0.73	0.80	1.21
June	1.14	0.83	0.70	0.70	0.90	1.22
July	1.20	0.79	0.45	0.81	0.90	1.23
Aug	1.25	0.80	-	0.96	0.80	1.24
Sept	1.22	0.91	-	1.08	0.50	1.26
Oct	1.18	0.91	-	1.03	0.20	1.27
Nov	1.12	0.83	-	0.82	0.20	1.28
Dec	0.86	0.69	-	0.65	-	0.80

Table B-7. Evapotranspiration Cover Coefficients for Perennial Crops - Measured as Ratio of Evapotranspiration to Lake Evaporation (Davis & Sorensen, 1969; cited in Novotny & Chesters, 1981).

In urban areas, ground cover is a mixture of trees and grass. It follows that cover factors for pervious areas are weighted averages of the perennial crop, hardwood, and softwood cover factors. It may be difficult to determine the relative fractions of urban areas with these covers. Since these covers would have different values only during dormant seasons, it is reasonable to assume a constant month value of 1.0 for urban pervious surfaces and zero for impervious surfaces.

These approximate cover coefficients are given in Table B-8. Table B-9 list mean monthly values of daylight hours (H_t) for use in Equation A-31.

Cover	Dormant Season	Growing Season
Annual crops (foliage only in growing season)	0.3	1.0
Perennial crops (year-round foliage: grass, pasture, meadow, etc.)	1.0	1.0

Saturated crops (rice)	1.0	1.0
Hardwood (deciduous) forests & orchards	0.3	1.0
Softwood (conifer) forests & orchards	1.0	1.0
Disturbed areas & bare soil (barn yards, fallow, logging trails, construction and mining)	0.3	0.3
Urban areas (I = impervious fraction)	1 - I	1 - I

Table B-8. Approximate Values for Evapotranspiration Cover Coefficients.

	Latitude North (E)						
	48	46	44	42	40	38	36
	(----------------------------- hr/day ------------------------------)						
Jan	8.7	8.9	9.2	9.3	9.5	9.7	9.9
Feb	10.0	10.2	10.3	10.4	10.5	10.6	10.7
Mar	11.7	11.7	11.7	11.7	11.8	11.8	11.8
Apr	13.4	13.3	13.2	13.1	13.0	13.0	12.9
May	14.9	14.7	14.5	14.3	14.1	14.0	13.8
Jun	15.7	15.4	15.2	15.0	14.7	14.5	14.3
Jul	15.3	15.0	14.8	14.6	14.4	14.3	14.1
Aug	14.0	13.8	13.7	13.6	13.6	13.4	13.3
Sep	12.3	12.3	12.3	12.3	12.2	12.2	12.2
Oct	10.6	10.7	10.8	10.9	11.0	11.0	11.1
Nov	9.1	9.3	9.5	9.7	9.8	10.0	10.1
Dec	8.3	8.5	8.8	9.0	9.2	9.4	9.6

	34	32	30	28	26	24
Jan	10.0	10.2	10.3	10.5	10.6	10.7
Feb	10.8	10.9	11.0	11.1	11.1	11.2
Mar	11.8	11.8	11.8	11.8	11.8	11.9
Apr	12.8	12.8	12.7	12.7	12.6	12.6
May	13.7	13.6	13.5	13.4	13.2	13.1
Jun	14.2	14.0	13.9	13.7	13.6	13.4
Jul	14.0	13.8	13.7	13.5	13.4	13.3
Aug	13.2	13.3	13.0	13.0	12.9	12.8
Sep	12.2	12.2	12.2	12.1	12.1	12.1
Oct	11.2	11.2	11.3	11.3	11.4	11.4
Nov	10.2	10.4	10.5	10.6	10.7	10.9
Dec	9.8	10.0	10.1	10.3	10.4	10.6

Table B-9. Mean Daylight Hours (Mills et al., 1985).

Groundwater. The groundwater portion of GWLF requires estimates of available unsaturated zone available soil moisture capacity U^* , recession constant r and seepage constant s.

In principle, U^* is equivalent to a mean watershed maximum rooting depth multiplied by a mean volumetric soil available water capacity. The latter also requires determination of a mean unsaturated zone depth, and this is probably impractical for most watershed studies. A default value of 10 cm can be assumed for pervious areas, corresponding to a 100 cm rooting depth and a 0.1 cm/cm volumetric available water capacity. These values appear typical for a wide range of plants (Jensen et al., 1989; U.S. Forest Service, 1980) and soils (Rawls et al., 1982).

Estimates of the recession constant r can be estimated from streamflow records by standard hydrograph separation techniques (Chow, 1964). During a period of hydrograph recession, the rate of change in shallow saturated zone water S(t) (cm) is given by the linear reservoir relationship

$$\frac{dS}{dt} = -r\,S \qquad \text{(B-1)}$$

or,

$$S(t) = S(0)\,e^{-rt} \qquad \text{(B-2)}$$

where S(0) is the shallow saturated zone moisture at t = 0. Groundwater discharge to the stream G(t) (cm) at time t is

$$G(t) = r\,S(t) = r\,S(0)\,e^{-rt} \qquad \text{(B-3)}$$

During periods of streamflow recession, it is assumed that runoff is negligible, and hence streamflow F(t) (cm) consists of groundwater discharge given by Equation B-3; i.e., F(t) = G(t). A recession constant can be estimated from two streamflows $F(t_1)$, $F(t_2)$ measured on days t_1 and t_2 ($t_2 > t_1$) during the hydrograph recession. The ratio $F(t_1)/F(t_2)$ is

$$\frac{F(t_1)}{F(t_2)} = \frac{r\,S(0)\,e^{-rt_1}}{r\,S(0)\,e^{-rt_2}} = e^{r(t_2 - t_1)} \qquad \text{(B-4)}$$

The recession constant is thus given by

$$r = \frac{\ln\,[F(t_1)/F(t_2)]}{t_2 - t_1} \qquad \text{(B-5)}$$

Recession constants are measured for a number of hydrographs and an average value is used for the simulations. Typical values range from 0.01 to 0.2

No standard techniques are available for estimating the rate constant for deep seepage loss (s). The most conservative approach is to assume that s = 0 (all precipitation exits the watershed in evapotranspiration or streamflow). Otherwise the constant must be determined by calibration.

Erosion and Sediment. The factors K_k, $(LS)_k$, C_k and P_k for the Universal Soil Loss Equation must be specified as the product $K_k\,(LS)_k\,C_k\,P_k$ for each rural runoff source area. Values K_k, C_k and P_k are given for a range of soils and conditions in Tables B-10 - B-13. More complete sets of values are provided in Mills et al. (1985) and Wischmeier & Smith (1978). The $(LS)_k$ factor is calculated for each source area k as in Wischmeier & Smith (1978):

$$LS = (0.045x_k)^b\,(65.41 \sin^2\theta_k + 4.56 \sin\theta_k + 0.065) \qquad \text{(B-6)}$$

$$\theta_k = \tan^{-1}(ps_k/100) \qquad \text{(B-7)}$$

in which x_k = slope length (m) and ps_k = per cent slope. The exponent in Equation B-6 is given by b = 0.5 for ps_k $ 5, b = 0.4 for 5 < ps_k < 3, b = 0.3 for 3 ≤ ps_k ≤ 1, and b = 0.2 for ps_k < 1 (Wischmeier & Smith, 1978).

The rainfall erosivity coefficient a_t for Equation A-12 can be estimated using methods developed by Selker et al. (1990). General values for the rainfall erosivity zones shown in Figure B-1 are given in Table B-14. Watershed sediment delivery ratios are most commonly obtained from the area-based relationship shown in

Figure B-2.

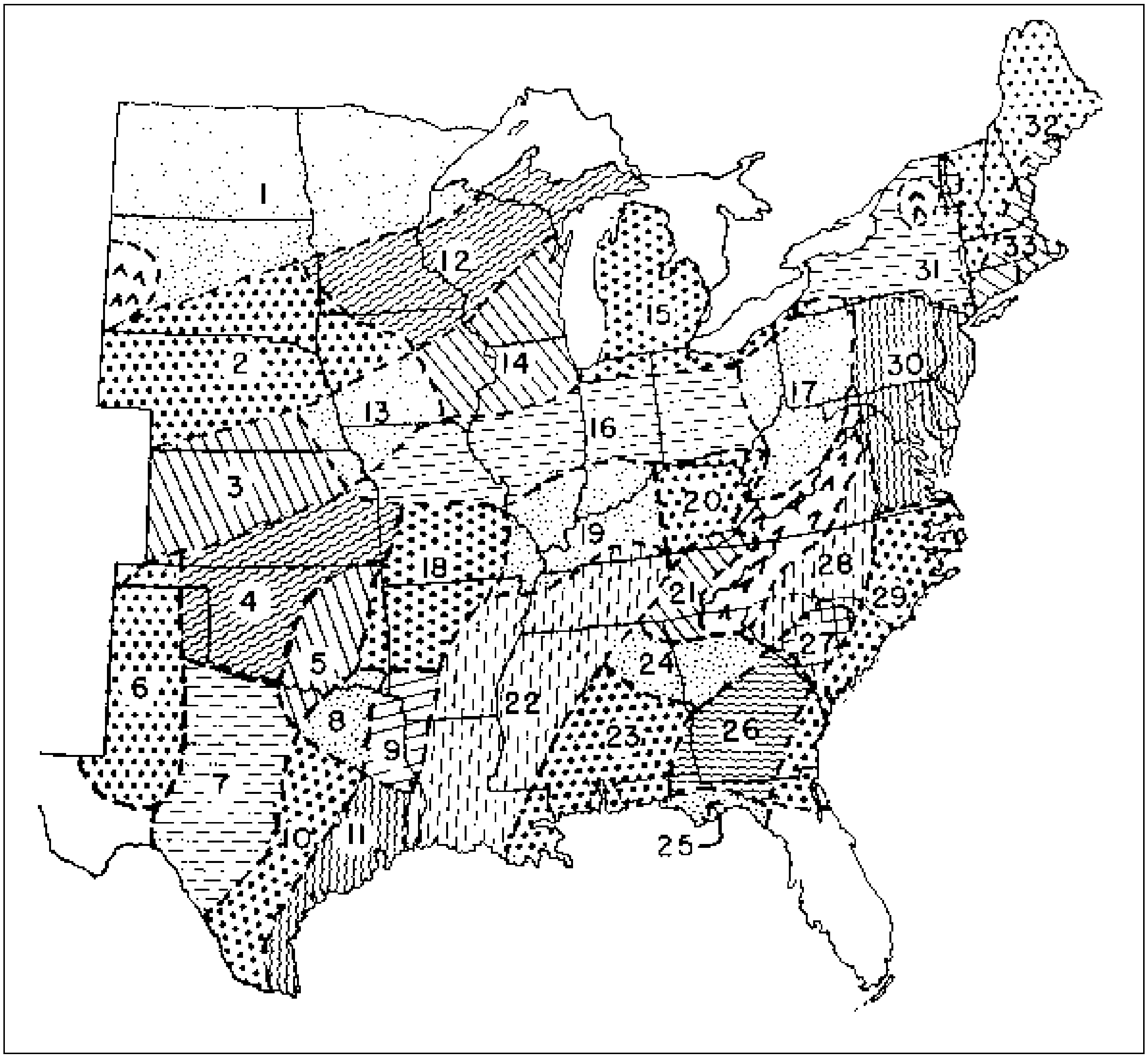


Figure B-1. Rainfall Erosivity Zones in Eastern U.S. (Wischmeier & Smith, 1978).

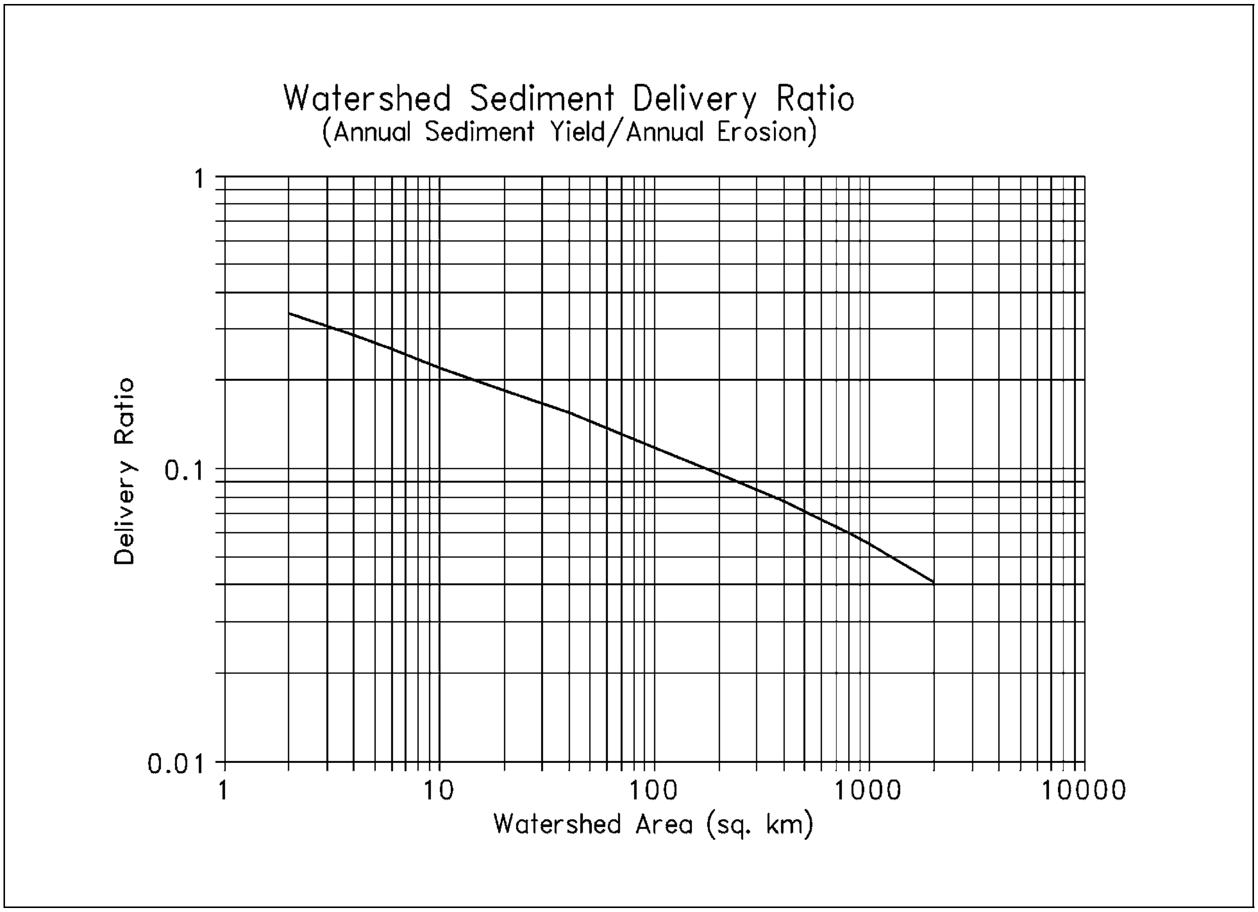


Figure B-2. Watershed Sediment Delivery Ratios (Vanoni, 1975).

Texture	Organic Matter Content (%) <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).

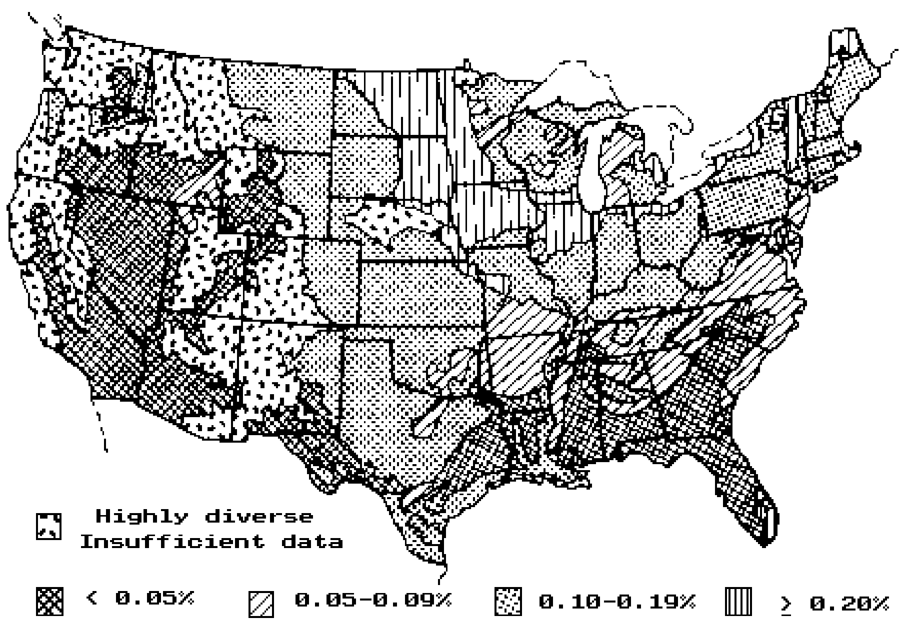


Figure B-3. Nitrogen in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

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.

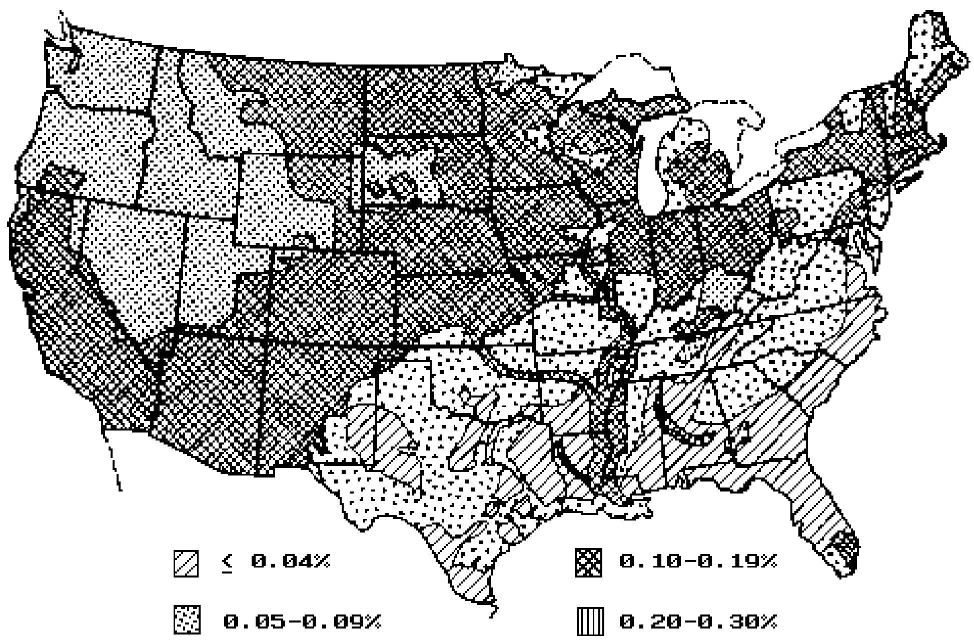


Figure B-4. P_2O_5 (44% phosphorus) in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

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.

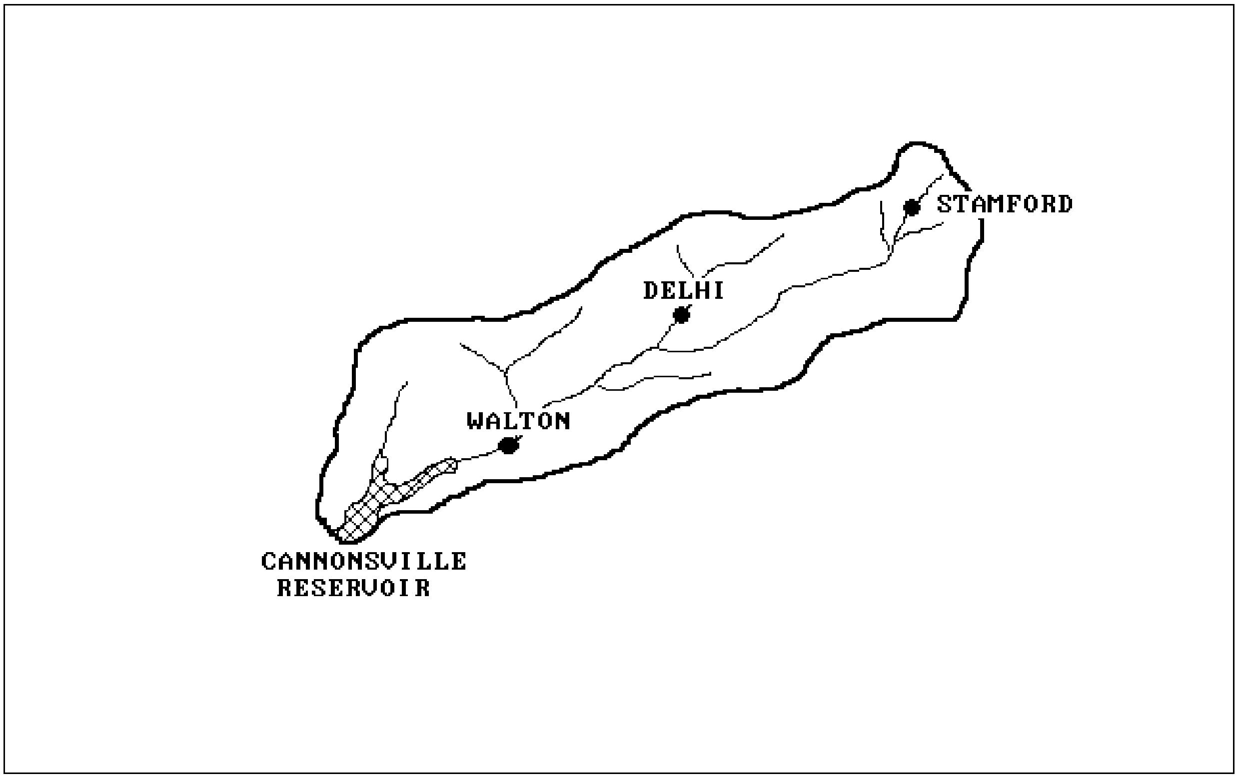


Figure C-1. West Branch Delaware River Watershed.

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.

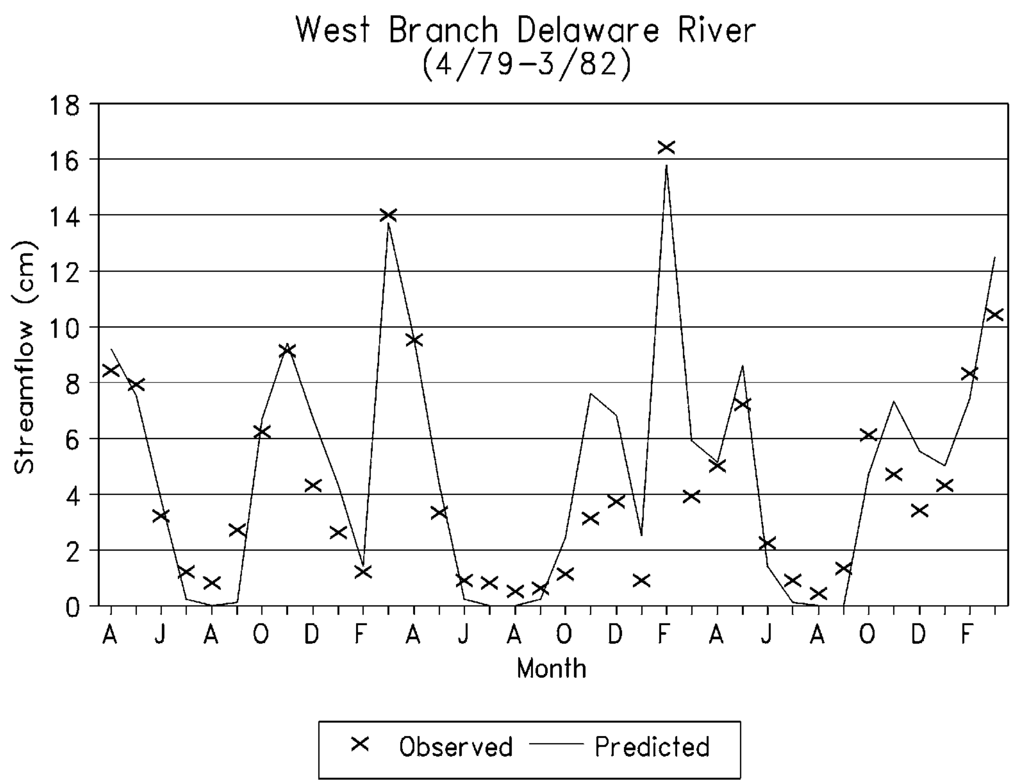


Figure C-2. Observed and Predicted Monthly Streamflow.

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.

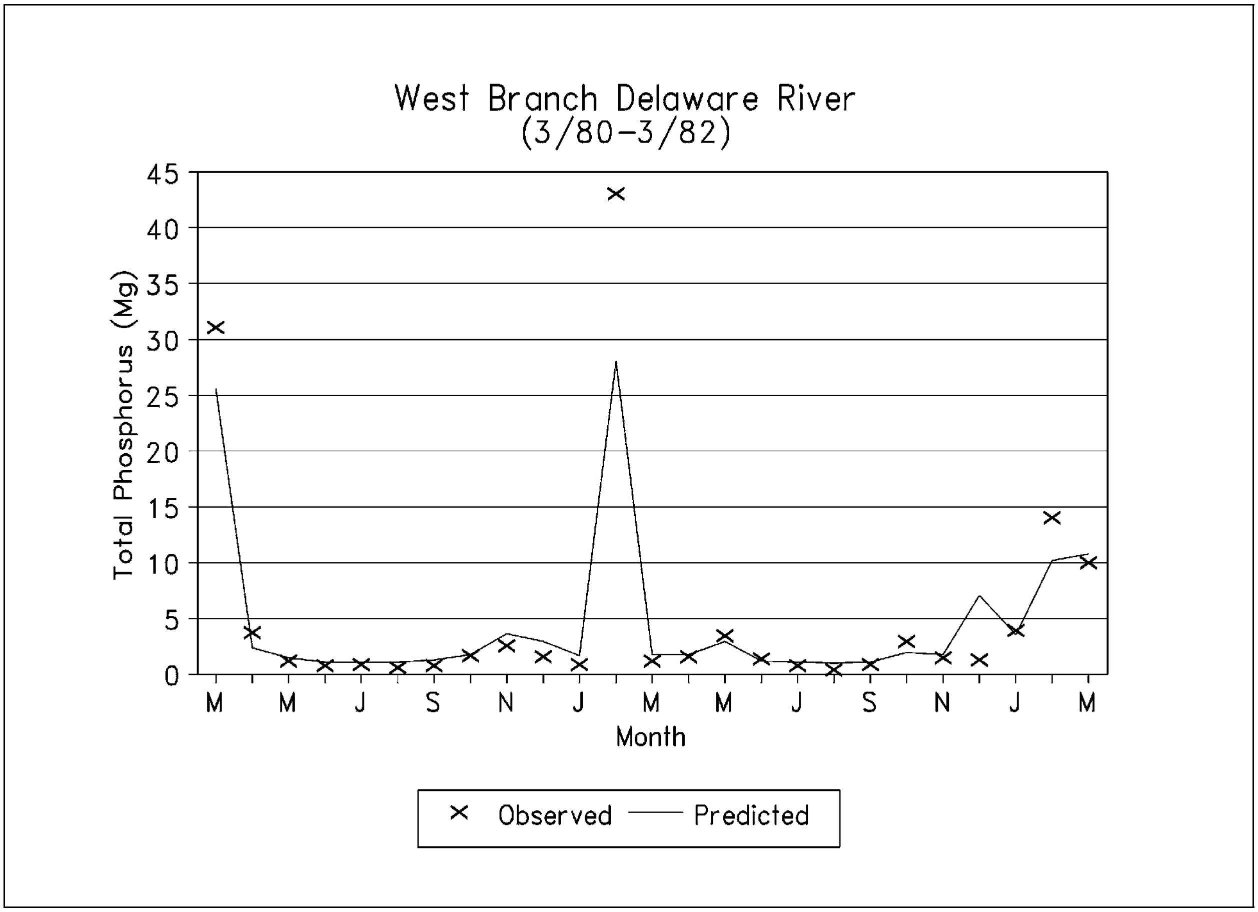


Figure C-3. Observed and Predicted Total Phosphorus in Streamflow.

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.

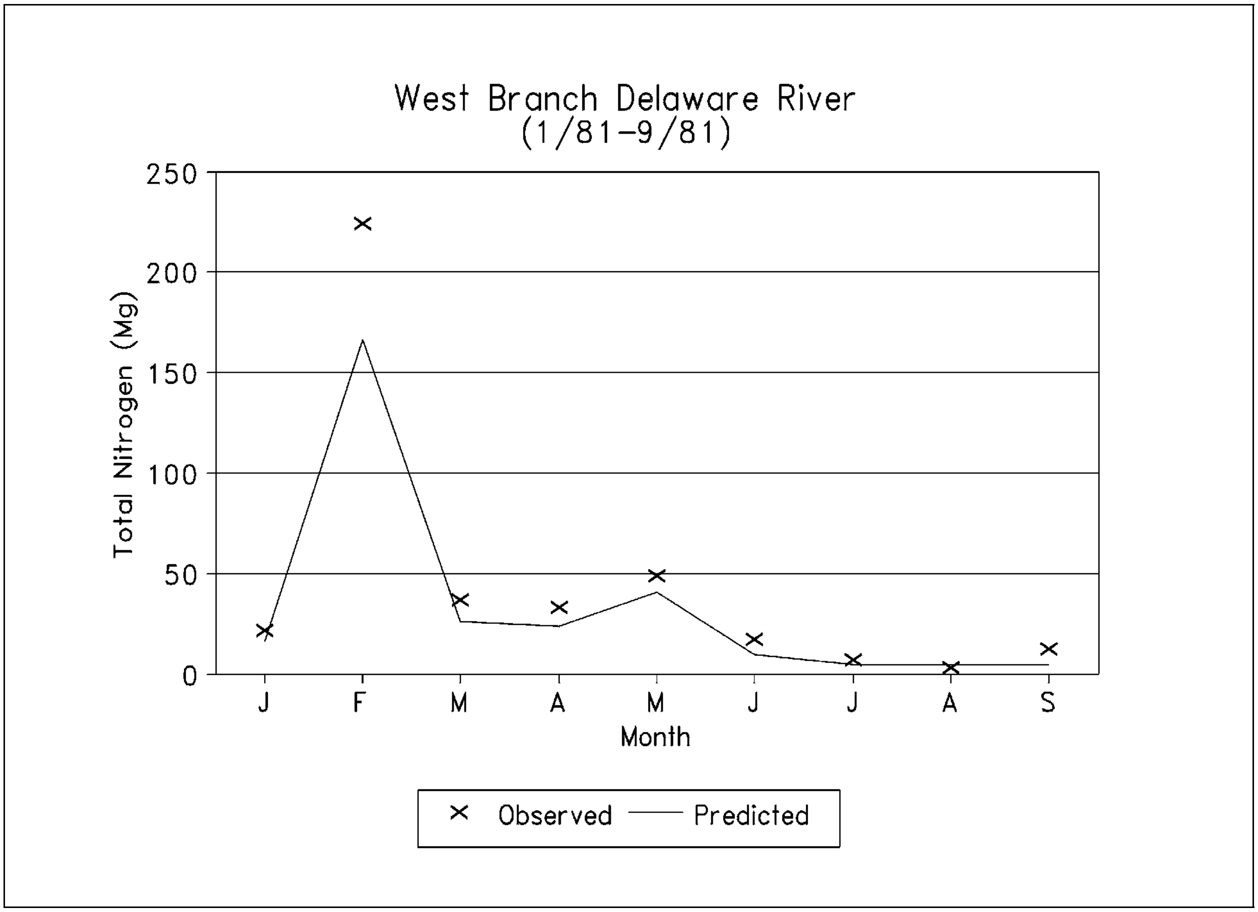


Figure C-4. Observed and Predicted Total Nitrogen in Streamflow.

Conclusions

The watershed loading functions model GWLF is based on simple runoff, sediment and groundwater relationships combined with empirical chemical parameters. The model is unique in its ability to estimate monthly nutrient fluxes in streamflow without calibration. Validation studies in a large New York watershed indicated that the model possesses a high degree of predictive accuracy. Although better results could perhaps be obtained by more detailed chemical simulation models, such models have substantially greater data and computational requirements and must be calibrated from water quality sampling data.

The GWLF model has several limitations. Peak monthly nutrient fluxes were underestimated by as much as 35%. Since nutrient chemistry is not modeled explicitly, the model cannot be used to estimate the effects of fertilizer management or urban storm water storage and treatment. The model has only been validated for a largely rural watershed in which agricultural runoff and groundwater discharge provided most of the nutrient load. Although the urban runoff component is based on well-known relationships which have been used previously in such models as STORM and SWMM, GWLF performance in more urban watersheds is uncertain.

Source	Nitrogen (Mg) Dissolved	Total	Phosphorus (Mg) Dissolved	Total
Runoff				
Corn	52.9	84.6	7.8	21.5
Hay	48.6	55.4	2.6	5.5
Pasture	13.2	16.7	1.1	2.6
Inactive Agriculture	5.1	7.8	0.4	1.6
Forest & logging	5.9	6.1	0.2	0.3
Barn yards	4.3	4.3	0.8	0.8
Urban	--	2.8	--	0.3
Groundwater, Point Sources, & Septic Systems				
Groundwater Discharge	149.6	149.6	5.7	5.7
Point sources	45.6	45.6	9.9	9.9
Septic systems	38.1	38.1	1.1	1.1
Watershed Total	363.4	411.1	29.6	48.3

Table C-6. Mean Annual Nutrient Loads Estimated from GWLF for the West Branch Delaware River Watershed: 4/78 - 3/82.

APPENDIX D: DATA AND OUTPUT LISTINGS FOR VALIDATION STUDY (EXAMPLE 1)

The first listing in this appendix is the set of sequential data input files **TRANSPRT.DAT**, **NUTRIENT.DAT** and **WEATHER.DAT** used in the validation study and Example 1. The first two files are constructed by selecting the appropriate option from GWLF menus. The weather file is arranged by months (April - March, in this application) with the first entry for each month being the number of days in the month, and subsequent entries being temperature (EC) and precipitation (cm) for each day. Only a partial listing of **WEATHER.DAT** is given. The next listings are the text files for the transport and nutrient data (**TRANSPRT.TXT** and **NUTRIENT.TXT**). The remaining listings are text files of the several program outputs (**SUMMARY.TXT** and **MONTHLY.TXT**).

TRANSPRT.DAT

```
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	RUNOFF	EROSION	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
	(ha)	(cm)	(Mg/ha)	(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 (ha)	RUNOFF (cm)	EROSION (Mg/ha)	DIS.NITR	TOT.NITR	DIS.PHOS	TOT.PHOS
				(Mg)			
CORN	3430.	14.66	38.98	44.57	70.64	6.60	17.89
HAY	13085.	10.52	2.19	38.54	44.12	2.06	4.48
PASTURE	5093.	6.48	2.91	9.90	12.79	0.82	2.08
INACTIVE	3681.	6.48	3.10	3.81	6.04	0.31	1.27
FOREST	56682.	3.67	0.00	3.95	3.95	0.12	0.12
LOGGING	20.	0.00	39.52	0.00	0.15	0.00	0.07
BARN YARDS	41.	31.05	0.00	3.73	3.73	0.65	0.65
RES-imperv	104.	68.27	0.00	0.00	0.87	0.00	0.09
RES-perv	546.	6.96	0.00	0.00	0.30	0.00	0.04
COMM-imperv	49.	68.27	0.00	0.00	0.92	0.00	0.10
COMM-perv	41.	6.96	0.00	0.00	0.02	0.00	0.00
INDUS-imperv	34.	68.27	0.00	0.00	0.64	0.00	0.07
INDUS-perv	67.	6.96	0.00	0.00	0.04	0.00	0.01
GROUNDWATER				146.50	146.50	5.60	5.60
POINT SOURCE				45.60	45.60	9.90	9.90
SEPTIC SYSTEMS				38.10	38.10	1.11	1.11
TOTAL				334.70	374.40	27.18	43.49

REFERENCES

Alhajjar, B. J., Harkin, J. H., Chesters, G. 1989. Detergent formula and characteristics of wastewater in septic tanks. Journal of the Water Pollution Control Federation 61(5): 605-613.

Amy, G., Pitt, R., Singh, R., Bradford, W. L., LaGraffi, M. B. 1974. Water quality management planning for urban runoff. EPA-440/9-75-004. U.S. Environmental Protection Agency, Washington DC.

Bosen, J. F. 1960. A formula for approximation of saturation vapor pressure over water. Monthly Weather Reviews 88(8):275-276).

Brown, K. W., Thomas, J. C. 1978. Uptake of N by grass from septic fields in three soils. Agronomy Journal 70(6): 1037-1040.

Brown, M. P., Rafferty, M.R. 1980. A historical perspective of phosphorus loading to the Cannonsville Reservoir as it relates to the West Branch Delaware River Model Implementation Program. Technical Report 62. N.Y. Department of Environmental Conservation, Albany NY.

Brown, M. P., Rafferty, M. R., Longabucco, P. 1985. Nonpoint source control of phosphorus - a watershed evaluation. Report to the U.S. Environmental Protection Agency, Ada, OK.

Bureau of the Census. 1980. 1978 census of agriculture, Delaware County, NY. U.S. Department of Commerce, Washington, DC.

Chow, V. T. 1964. Runoff. In: V. T. Chow (ed.). Handbook of Applied Hydrology. McGraw-Hill, New York NY, Chapter 14.

Davis, C. V., Sorensen, K. E. 1969. Handbook of Applied Hydraulics. McGraw-Hill, New York NY.

Delwiche, L. L. D., Haith, D. A. 1983. Loading functions for predicting nutrient losses from complex watersheds. Water Resources Bulletin 19(6):951-959.

Dickerhoff, L. L. 1981. A methodology for predicting runoff and nutrient losses from a heterogeneous watershed. M. S. Dissertation. Department of Agricultural Engineering, Cornell University, Ithaca NY.

Dornbush, J. N., Anderson, J. R., Harms L. L. 1974. Quantification of pollutants in agricultural runoff. EPA-660/2-74-005, U. S. Environmental Protection Agency, Washington DC.

Edwards, W. M., Simpson, E. C, Frere, M. H. 1972. Nutrient content of barnyard runoff water. Journal of Environmental Quality 1(4): 401-405.

Gilbertson, C. B., Norstadt, F. A., Mathers, A. C., Holt, R. F., Barnett, A. P., McCalla, T. M., Onstadt, C. A., Young, R. A. 1979. Animal waste utilization on crop land and pasture land. EPA-600/2-79-059, U. S. Environmental Protection Agency, Washington DC.

Haan, C. T. 1972. A water yield model for small watersheds. Water Resources Research 8(1): 58-69.

Haith, D. A. 1985. An event-based procedure for estimating monthly sediment yields. Transactions of the American Society of Agricultural Engineers 28(6): 1916-1920.

Haith, D. A., Merrill, D. E. 1987. Evaluation of a daily rainfall erosivity model. Transactions of the American Society of Agricultural Engineers 30(1):90-93.

Haith, D. A., Shoemaker, L. L. 1987. Generalized watershed loading functions for stream flow nutrients. Water Resources Bulletin 23(3):471-478.

Haith, D. A., Tubbs, L. J. 1981. Watershed loading functions for nonpoint sources. Proceedings of the

American Society of Civil Engineers, Journal of the Environmental Engineering Division 107(EE1):121-137.

Hamon, W. R. 1961. Estimating potential evapotranspiration. Proceedings of the American Society of Civil Engineers, Journal of the Hydraulics Division 87(HY3):107-120.

Hawkins, R. H. 1978. Runoff curve numbers with varying site moisture. Proceedings of the American Society of Civil Engineers, Journal of the Irrigation and Drainage Division 104(IR4):389-398.

Huber, W. C., Dickinson, R. E. 1988. Storm water management model, version 4: User's manual. Cooperative agreement CR-811607. U.S. Environmental Protection Agency, Athens, GA.

Hydrologic Engineering Center. 1977. Storage, treatment, overflow, runoff model `STORM'. 723-S8-L7520. U.S. Army Corps of Engineers, Davis CA.

Jensen, M. E., Burman, R. D., Allen, R. G. (ed.) 1989. Evapotranspiration and irrigation water requirements. ASCE Manual No. 70. American Society of Civil Engineers, New York, NY.

Knoblauch, W. 1976. New York's changing agriculture census data. Extension Bulletin 76-35. Department of Agricultural Economics, Cornell University, Ithaca, NY.

Kuo, C. Y., Cave, K. A., Loganathan, G. V. 1988. Planning of urban best management practices. Water Resources Bulletin 24(1):125-132.

Mandel, R. 1993. The impact of septic systems on surface water quality. Unpublished M.S. dissertation. School of Civil & Environmental Engineering, Cornell University, Ithaca, NY.

McElroy, A. D., Chiu, S. Y., Nebgen, J. W., Aleti, A., Bennett, F. W. 1976. Loading functions for assessment of water pollution from nonpoint sources. EPA-600/2-76-151. U.S. Environmental Protection Agency, Washington DC.

Meyer, L. D., Wischmeier, W. H. 1969. Mathematical simulation of the process of soil erosion by water. Transactions of the American Society of Agricultural Engineers 12(6):754-758.

Mills, W. B., Porcella, D. B, Ungs, M. J., Gherini, S. A., Summers, K. V., Mok, L., Rupp, G. L., Bowie, G. L., Haith, D. A. 1985. Water quality assessment: A screening procedure for toxic and conventional pollutants in surface and ground water. EPA/600/6-85/002, U. S. Environmental Protection Agency, Athens GA.

Novotny, V., Chesters, G. 1981. Handbook of Nonpoint Pollution. Van Nostrand Reinhold, New York NY.

Ogrosky, H. O., Mockus, V. 1964. Hydrology of agricultural lands. In: V. T. Chow (ed.). Handbook of Applied Hydrology. McGraw-Hill, New York. Ch. 21.

Omernik, J. M. 1977. Nonpoint source - stream nutrient level relationships: a nationwide study. EPA-600/3-77-105. U.S. Environmental Protection Agency, Corvallis OR.

Overcash, M. R., Phillips, R. L. 1978. Dairy feedlot hydrology. Transactions of the American Society of Agricultural Engineers 21(5):1193-1198.

Overton, D. E., Meadows, M. E. 1976. Stormwater Modeling. Academic Press. New York, NY.

Parker, C. A., et al. 1946. Fertilizers and lime in the United States. Misc. Publication No. 586. U.S. Department of Agriculture, Washington, DC.

Petrovic, A. M., Cornman, J. F. 1982. Home lawns. Information Bulletin 185. Cornell Cooperative Extension, Cornell University, Ithaca, NY.

Reed, S. C., Middlebrooks, E. J., Crites, R. W. 1988. Natural Systems for Waste Management and Treatment.

McGraw-Hill, New York.

Rawls, W. J., Brakensiek, D. L. , Saxton, K. E. 1982. Estimation of soil water properties. Transactions of the American Society of Agricultural Engineers 25(5): 1316-1320, 1328.

Richardson, C. W., Foster, G. R., Wright, D. A. 1983. Estimation of erosion index from daily rainfall amount. Transactions of the American Society of Agricultural Engineers 26(1):153-157,160.

Sartor, J. D., Boyd, G. B. 1972. Water pollution aspects of street surface contaminants. EPA-R2/72-081. U.S. Environmental Protection Agency, Washington DC.

Selker, J. S., Haith, D. A., Reynolds, J. E. 1990. Calibration and testing of daily rainfall erosivity model. Transactions of the American Society of Agricultural Engineers 33(5): 1612-1618.

Slavicek, R. L. 1980. The West Branch of the Delaware River model implementation program, survey of logging road erosion and sediment production. U.S. Forest Service, Stamford, NY.

Soil Conservation Service. 1976. Potential nonpoint sources of agricultural pollution, West Branch Delaware River watershed. U.S. Department of Agriculture, Syracuse, NY.

Soil Conservation Service. 1986. Urban hydrology for small watersheds. Technical Release No. 55 (2nd edition). U.S. Department of Agriculture, Washington, DC.

Stewart, B. A., Woolhiser, D. A., Wischmeier, W. H., Caro, J. H., Frere, M. H. 1975. Control of water pollution from cropland. Volume I: A manual for guideline development. EPA-600/2-75-026a. U.S. Environmental Protection Agency, Washington DC.

U. S. Environmental Protection Agency. 1980. Design manual: Onsite wastewater treatment and disposal systems. EPA-625/1-80-012. U. S. Environmental Protection Agency, Washington DC.

U. S. Forest Service. 1980. An approach to water resources evaluation of nonpoint silvicultural sources. EPA-600/8-80-012. U.S. Environmental Protection Agency, Athens GA.

U. S. Public Health Service. 1967. Manual of septic tank practice. National Center for Urban and Industrial Health, Cincinnati, OH.

Vanoni, V. A. (Ed.). 1975. Sedimentation Engineering. American Society of Civil Engineers, New York NY.

Wischmeier, W. H., Smith, D. D. 1978. Predicting rainfall erosion losses - a guide to conservation planning. Agricultural Handbook 537, U.S. Department of Agriculture, Washington DC.

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.

Table D-1 presents the resulting curve numbers associated with each landuse and used in the GWLF program.

Table D-1 Curve Numbers in the Altamont New Reservoir Watershed

Landuse	Curve Number
Row Crop	86.5
Small Grains	84.6
Rural Grassland	75.9
Deciduous1	71.3
Deciduous2	74.3
Open Water	100.0
Shallow Water Wetland	100.0
Dairy	78.0

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-2 presents the resulting K-factors associated with each landuse and used in the GWLF program.

Table D-2 Weighted K factors for the Altamont New Reservoir Watershed

Landuse	K factor
Row Crop	0.40
Small Grains	0.40
Rural Grassland	0.41
Deciduous1	0.42
Deciduous2	0.42
Open Water	0
Shallow Water Wetland	0
Dairy	0.37

Topographic Factor (LS)

Computation of the LS factor is done in the ArcView project *iepa_prepro.apr*.

1. In ArcView, add the Digital Elevation Model (DEM) to the View.
2. Set the analysis extent and cell size to the DEM.
3. Select "Fill Sinks" from the CRWR-PrePro menu to fill sinks in the DEM. Save the temporary grid as a permanent grid named *Fill_grid*.
4. Open the script "New_Slope" from the project window, and press the "Run" button to compute percent slopes from the filled DEM. Save the temporary grid as a permanent grid named *Slope_grid*.
5. Select "Flow Direction" from the CRWR-PrePro menu to derive the direction of flow through each grid cell. Save the temporary grid as a permanent grid named *Fdr_grid*.
6. Compute the theta grid (in radians) with the map calculator.
   - Map Calc. Statement: (([slope_grid] / 100)).Atan
   - Save Map Calc 1 as a permanent grid named *Theta_grid*.
7. Compute the S grid with the map calculator and a succession of calculations.
   - Map Calc. 1: ([slope_grid] <= 9)
     - Output: 1 in cells where slope is less or equal to 9; zero elsewhere
   - Map Calc. 2: ((([theta_grid].Sin) * 10.8) + 0.03)
     - Output: S-value computed for slopes <= 9 in all cells
   - Map Calc. 3: ([Map Calculation 2 * [Map Calculation 1])
     - Output: Correct S-value in cells with slope <= 9; zero elsewhere
   - Map Calc. 4: ([slope_grid] > 9)
     - Output: 1 in cells where slope > 9, zero elsewhere
   - Map Calc. 5: ((([theta_grid].Sin) * 16.8) – 0.5)
     - Output: S-value computed for slopes > 9 in all cells
   - Map Calc. 6: ([Map Calculation 5] * [Map Calculation 4])
     - Output: Correct S-value in cells with slope > 9; zero elsewhere
   - Map Calc. 7: ([Map Calculation 3] + [Map Calculation 6])
     - Output: Correct S-value in each cell
   - Save Map Calculation 7 as a permanent grid named *S_grid*.
8. Compute the Beta grid with the map calculator.

Map Calc. 1: ((([theta_grid].Sin) / 0.0896) / ((([theta_grid].Sin).Pow(0.8)) * 3.0 + 0.56)

Save Map Calculation 1 as a permanent grid named *Beta_grid*.

9. Compute the M grid with the map calculator.

   Map Calc. 1: ([beta_grid] / ([beta_grid] + 1))

   Save Map Calculation 1 as permanent grid named *M_grid*.

10. Compute the flow length (Lambda) grid with the map calculator and a succession of calculations.

    Map Calc. 1: ([fdr] = 1 OR [fdr] = 4 OR [fdr] = 16 OF [fdr] = 64)

    Output: 1 in cells flowing in cardinal direction and 0 in other cells

    Map Calc. 2: ([Map Calculation 1] * 30.8875)

    {30.885 = cell length}

    Output: 30.885 in cells flowing in cardinal direction and 0 in others.

    Map Calc. 3: ([Map Calculation 2] = 0)

    Output: 0 in cells flowing in cardinal direction and 1 in others

    Map Calc. 4: ([Map Calculation 3] * 43.682)

    {43.682= length across cell diagonal}

    Output: 43.682 in cells flowing in non-cardinal direction, 0 in others.

    Map Calc. 5: ([Map Calculation 4] + [Map Calculation 2])

    Output: correct flow lengths in each cell – 30.885 in cardinal, 43.682 in others

    Map Calc. 6: ([Map Calculation 5] * 100 / 2.54 / 12

    Output: flow length grid in feet

    Save Map Calculation 6 as a permanent grid named *Lambda_grid*

11. Compute the L with the map calculator.

    Map Calc. Statement: ([lambda_grid] / 72.6).Pow([m_grid])

    Save Map Calculation 1 as a permanent grid named *L_grid*.

12. Compute the LS grid with the map calculator.

    Map Calc. Statement: ([L-grid] * [S_grid])

    Save Map Calculation 1 as a permanent grid named *LS_grid*.

13. To average the LS grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

Table D-3 presents the resulting LS factors for each landuse used in GWLF.

Table D-3 Weighted LS factors for the Altamont New Reservoir Watershed

Landuse	LS factor
Row Crop	0.14
Small Grains	0.13
Rural Grassland	0.17
Deciduous1	0.32
Deciduous2	0.34
Open Water	0
Shallow Water Wetland	0
Dairy	0.11

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 Effingham County NRCS office included as Appendix E. The spreadsheet used to calculate a weighted c-factor for corn, soybeans, and small grains is shown at the end of this appendix. The values in the Table 1 of the spreadsheet are a weighted average of values from columns C and F. This weighted average allows the influence of crop rotations to be included in the c-factors for the Altamont New Reservoir Watershed. The values in the Table 1 are then weighted by the percentage of each tillage practice in Table 2 to determine a single c-factor for corn, soybeans, and small grains.

The weighted C factor for each crop is then appended to the table of Cropland Data Layer landuses and areas in the Altamont New Reservoir Watershed. Table D-4 shows the Cropland Data Layer landuse areas, and C factors. C factors for landuses other than corn, soybean, and small grains were obtained from the table included as Appendix E.

Table D-4 Cropland Data Layer C factors for Altamont New Reservoir Watershed

Landuse	C-factor
Corn	0.32
Soybeans	0.2
Winter Wheat	0.11
Other Small Grains & Hay	0.11
Double-Cropped WW/SB	0.09
Idle Cropland/CRP	0.004
Fallow/Idle Cropland	0.004
Pasture/Grassland/Nonagriculture	0.004
Woods	0.003

The landuse classes in GWLF are represented by the Critical Trends Land Assessment classes rather than the Cropland Data Layer classes, so an area-weighted average was used to calculate the C factor coefficients for “Row Crop” and “Small Grains” in the Critical Trends Land Assessment landuse file. Table D-5 shows the Critical Trends Land Assessment landuse classes and the calculated C factor coefficients. The coefficient for “Row Crop” was calculated with an area-weighed average of the C factors for corn, soybeans, and half of the double-cropped WW/SB area in the Cropland Data Layer. The coefficient for "Small Grains" was calculated with an area-weighted average of the C factors for winter wheat, other small grains and hay, and half of double-cropped WW/SB area from the Cropland Data Layer.

Table D-5 C Factors by Critical Trends Assessment Landuse Classes in the Altamont New Reservoir Watershed

Landuse	C Factor
Row Crop	0.25
Small Grains	0.10
Rural Grassland	0.004
Deciduous	0.003

Evapotranspiration (ET) Cover Coefficient

The ET cover coefficient was calculated in an Excel spreadsheet. The cover coefficients for crops available in the GWLF Manual and the crops listed in the Cropland Data Layer landuse file differ. Therefore, crops in the Cropland Data Layer file were summed into classes matching the available crop cover coefficients. Table D-6 shows the original and adjusted areas for Altamont New Reservoir Watershed. 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-6 Cropland Data Layer Adjusted Landuse Areas

Landuse	Area (m^2)	**Adjusted area (m^2)**
Corn	566100	**566100**
Sorghum		**66600**
Soybeans	396900	**491400**
Winter Wheat	89100	**183600**
Other Small Grains & Hay	66600	
Double-Cropped WW/SB	189000	
Idle Cropland/CRP	900	**900**
Fallow/Idle Cropland	142200	**142200**
Pasture/Grassland/Nonagricultural	618300	**618300**
Woods	495000	**495000**
Clouds		**0**
Urban	39600	**39600**
Water	98100	**98100**
Buildings/Homes/Subdivisions	29700	**29700**
Wetlands	3600	**3600**
Total	2735100	**2735100**

Table D-7 shows the calculation of a single crop coefficient for each 10 percent 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 percent of the growing season, each crop coefficient in columns B-E was weighted by its corresponding area in Table D-6. 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-7 Calculation of a Monthly Crop Evapotranspiration Cover Coefficient

A	B	C	D	E	F	G	H
% of Growing Season	Field Corn	Grain Sorghum	Winter Wheat	Soybeans	**Weighted Average ET Coeff.**	**Average Monthly ET Coeff.**	Month
0	0.45	0.3	1.08	0.3	**0.47**	**0.47**	Nov - Apr
10	0.51	0.4	1.19	0.35	**0.54**		
20	0.58	0.65	1.29	0.58	**0.68**	**0.61**	May
30	0.66	0.9	1.35	1.05	**0.92**		
40	0.75	1.1	1.4	1.07	**0.98**	**0.95**	June
50	0.85	1.2	1.38	0.94	**0.98**	**0.98**	July
60	0.96	1.1	1.36	0.8	**0.96**		
70	1.08	0.95	1.23	0.66	**0.94**	**0.95**	Aug
80	1.2	0.8	1.1	0.53	**0.91**		
90	1.08	0.65	0.75	0.43	**0.77**	**0.84**	Sep
100	0.7	0.5	0.4	0.36	**0.52**		
					0.47	**0.50**	Oct

Table D-8 shows the calculation of a single area-weighted crop coefficient for each month. First, the crop coefficients from Table D-7 were entered into Column B of Table D-8. The monthly ET values in Columns C, D, E, and F were obtained from the GWLF Manual, pages 29 and 30. A monthly cover coefficient for water and wetlands was assumed to be 0.75. Finally, a single area-weighted crop coefficient for each month was calculated (Column G) from the adjusted areas in Table D-6 and the monthly ET cover coefficients in Table D-8.

Table D-8 Calculation of a Monthly ET Cover Coefficient in the Altamont New Reservoir Watershed

A	B	C	D	E	F	G
	Crop	Pasture	Forest	Urban 30%	Water/ Wetland	**Weighted Average ET**
Apr	0.47	1.09	0.3	0.7	0.75	**0.63**
May	0.61	0.95	1	0.7	0.75	**0.78**
Jun	0.95	0.83	1	0.7	0.75	**0.91**
Jul	0.98	0.79	1	0.7	0.75	**0.91**
Aug	0.95	0.8	1	0.7	0.75	**0.90**
Sep	0.84	0.91	1	0.7	0.75	**0.88**
Oct	0.50	0.91	1	0.7	0.75	**0.72**
Nov	0.47	0.83	0.3	0.7	0.75	**0.56**
Dec	0.47	0.69	0.3	0.7	0.75	**0.52**
Jan	0.47	1.16	0.3	0.7	0.75	**0.65**
Feb	0.47	1.23	0.3	0.7	0.75	**0.67**
Mar	0.47	1.19	0.3	0.7	0.75	**0.66**

A B C D E F G H I J

Corn-Soybean Rotation
60% of watershed

Conventional Till (Spring Plow)	
Corn after Soybean	0.36
Soybean after Corn*	0.33
Average	**0.35**
Reduced-Till (40% Cover)	
Corn after Soybean	0.25
Soybean after Corn*	0.14
Average	**0.20**
Mulch-Till (60% cover)	
Corn after Soybean	0.25
Soybean after Corn*	0.10
Average	**0.18**
No-Till (80% Cover)	
Corn after Soybean	0.14
Soybean after Corn*	0.05
Average	**0.10**

*Assumed Wide-Row

Corn-Soybean-Wheat Rotation
40% of watershed

Conventional Till (Spring Plow)	
Corn after Wheat**	0.30
Soybean after Corn*	0.33
Wheat after Soybean#	0.12
Average	**0.25**
Reduced-Till (40% Cover)	
Corn after Wheat**	0.16
Soybean after Corn*	0.14
Wheat after Soybean#+	0.09
Average	**0.13**
Mulch-Till (60% cover)	
Corn after Wheat**	0.09
Soybean after Corn*	0.10
Wheat after Soybean#	0.09
Average	**0.09**
No-Till (80% Cover)	
Corn after Wheat**	0.05
Soybean after Corn*	0.05
Wheat after Soybean#	0.05
Average	**0.05**

*Assumed Wide-Row
**Used Corn after Small Grain
#Used Small Grain after Soybean
+Used 30% Cover per NRCS Recommendation

C-factors Weighted by Percent of Crop Rotation in the Watersh

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	0.34	0.33	0.12
Reduced Till	0.21	0.12	0.09
Mulch-Till	0.19	0.10	0.09
No-Till	0.10	0.05	0.05

Percent of Each Tillage Practice in Effingham County

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	91%	48%	89%
Reduced Till	4%	18%	4%
Mulch-Till	2%	8%	0%
No-Till	3%	26%	7%

C-factors Weighted by Percent of Each Tillage Practice

Corn	Soybeans	Small Grains
0.32	0.20	0.11

Appendix E
Crop Management "C" Factor Values for Rainfall E.I. Distribution Curve #16

TABLE 2 - CROP MANAGEMENT "C" FACTOR VALUES FOR RAINFALL "E.I." DISTRIBUTION CURVE #16 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%
CORN after Soybeans		.42	.36	.36	.30	.25	---	20% .25	30% .19	40% .14	3/ --
CORN after Corn		.36	.29	.21	.18	.15	.12	.09	.06	.05	.03
CORN after Small Grain		.37	.30	.23	.20	.16	.13	.09	.06	.05	.03
CORN after Meadow 4/		.17	.13	.12	.10	.09	.08	---	.02	.02	.01
CORN 2nd yr. after Meadow 4/		.32	.24	.19	.16	.15	.14	.06	.05	.04	.03
SOYBEANS after Soybeans 5/	Wide Row	.48	.41	.37	.35	---	---	20% .26	30% .20	40% .16	3/
	Drill	.38	.30	.31	.30	---	---	.20	.16	.13	
SOYBEANS after Corn 5/	Wide Row	.40	.33	.20	.17	.14	.12	.10	.07	.05	.03
	Drill	.30	.25	.18	.15	.13	.10	.08	.06	.04	.03
SOYBEANS after Sm. Grain 5/	Wide Row	.42	.30	.24	.20	.17	.14	.09	.06	.04	.03
	Drill	.32	.23	.19	.16	.14	.12	.08	.06	.04	.03
SOYBEANS after Meadow 4,5/	Wide Row	.20	.15	.12	.10	.09	.08	.03	.02	.01	.01
	Drill	.15	.12	.11	.09	.08	.08	.03	.02	.01	.01
SOYBEANS after Corn 2nd year after meadow 5/	Wide Row	.36	.27	.18	.15	.12	.10	.08	.06	.04	.03
	Drill	.27	.22	.15	.13	.11	.10	.08	.06	.04	.03
SMALL GRAIN after Corn (Grain) 6/		.12	.11	.09	.08	.07	.06	.08	.06	.04	.03
SMALL GRAIN after Corn (Silage) 7/		.17	---	.17	---	---	---	.13	---	---	---
SMALL GRAIN after Soybeans 6/		.13	.12	.10	.09	.08	.07	20% .09	30% .07	40% .05	3/ ---

WHEAT/SOYBEANS (Double Crop)

		Tillage for Soybeans Plow	Disk	No-Till
Tillage	Plow	.28	.16	.13
for	Disk	.23	.10	.07
Wheat	No-Till	.20	.08	.04

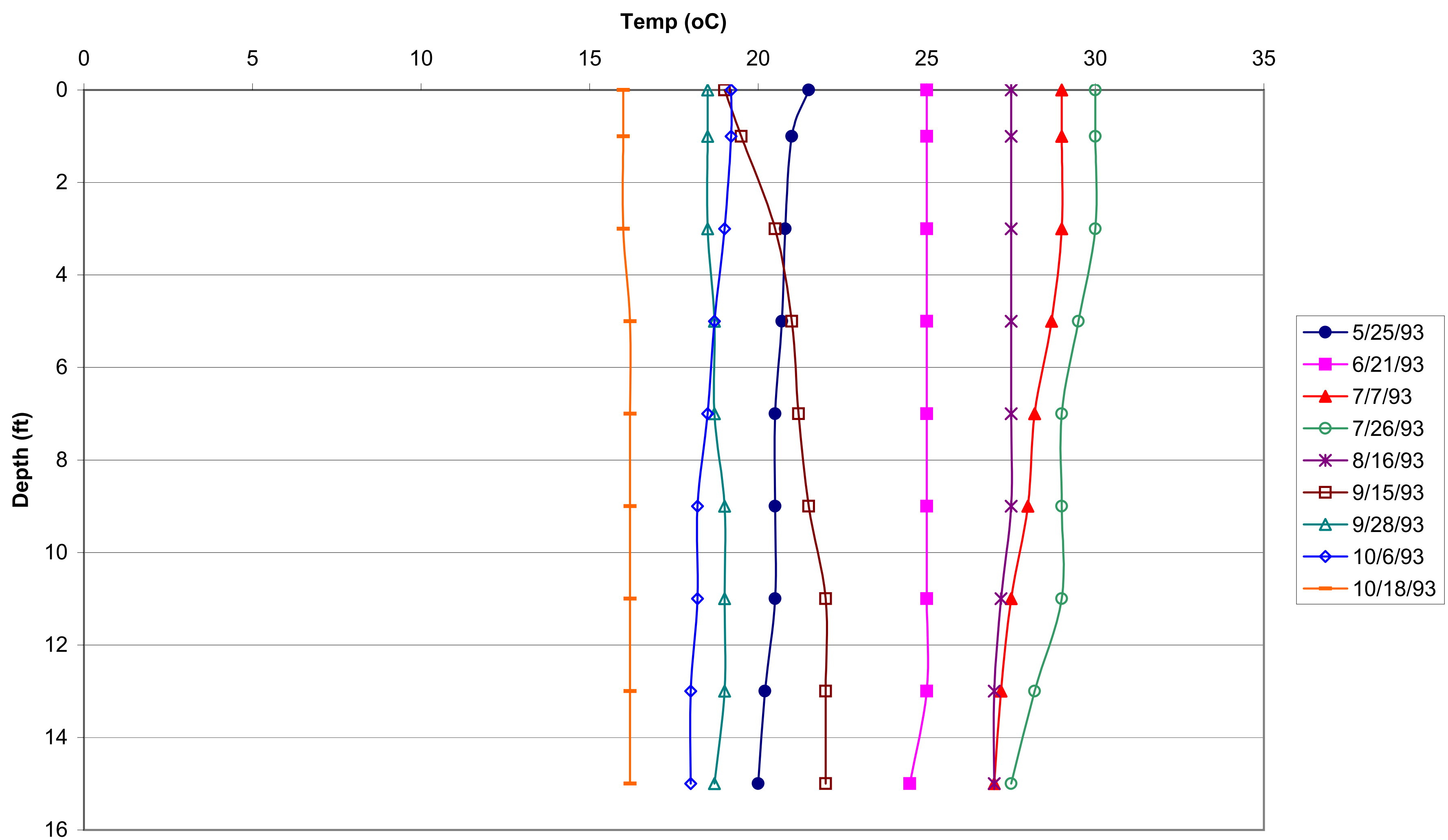
Meadow (Full year-Established)

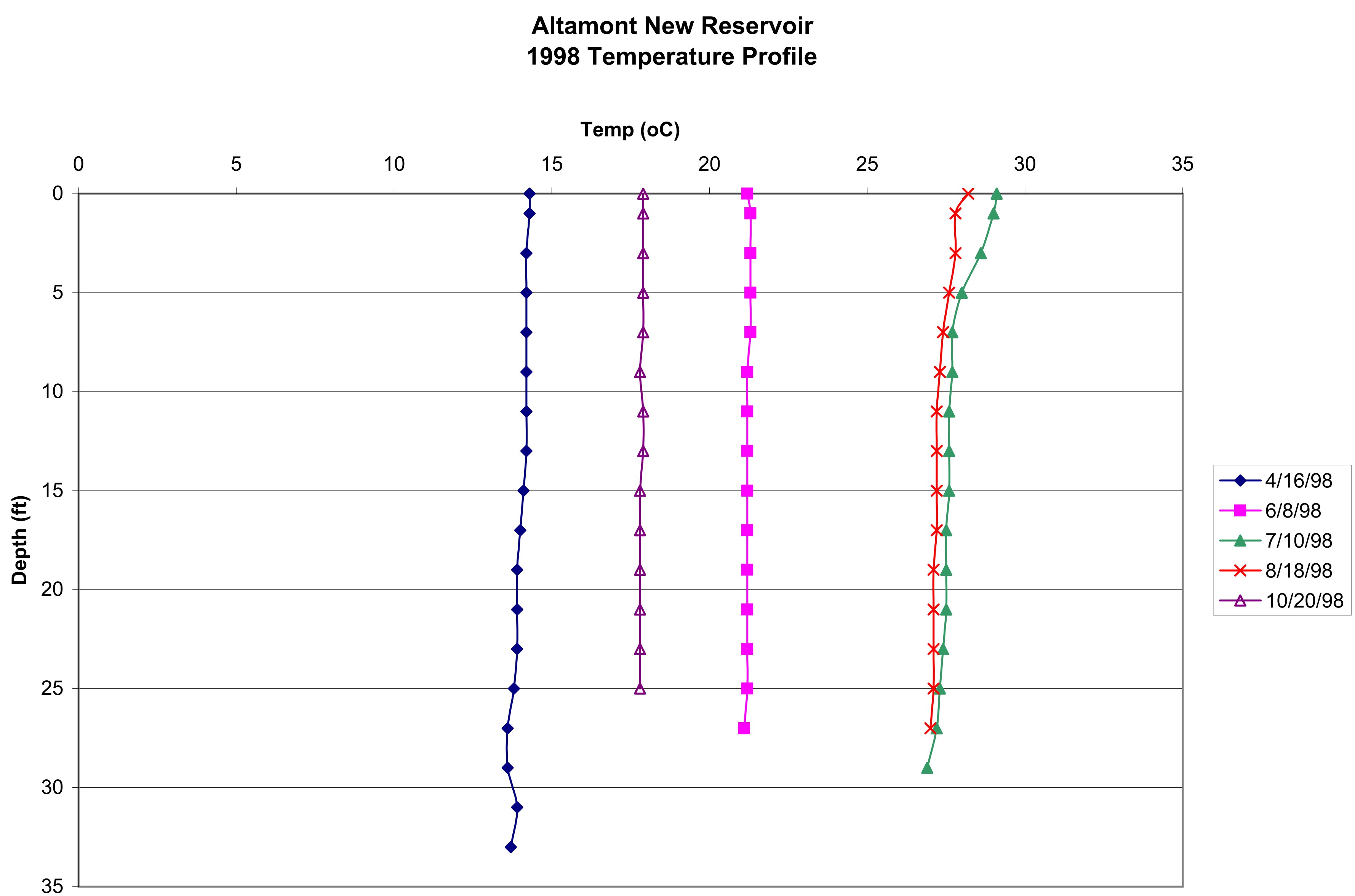
Grass-Legume	.004
Legume only	.02

SCS-IL, September, 1992

Appendix F
Metalimnion Charts

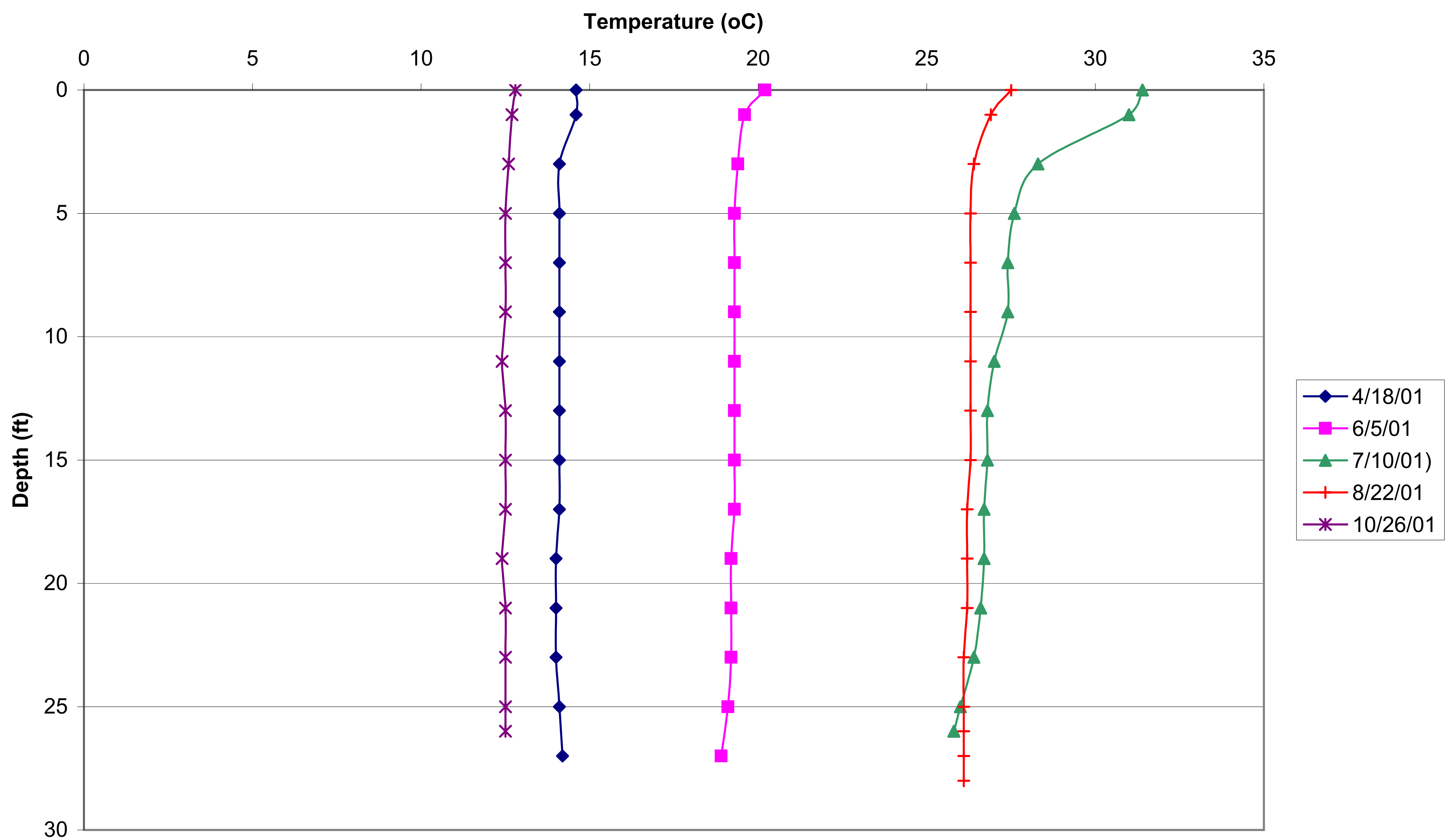
Altamont New Reservoir
1993 Temperature Profile





Altamont New Reservoir
1998 Temperature Profile
Temp (oC)
Depth (ft)
0
5
10
15
20
25
30
35
4/16/98
6/8/98
7/10/98
8/18/98
10/20/98

Altamont New Reservoir
2001 Temperature Profile



Appendix G
Sensitivity Analysis - BATHTUB Output Files

G.1 BATHTUB Sensitivity

This appendix provides the BATHTUB output files for the soil phosphorus and dairy concentration sensitivity analysis. For each modeled year, the BATHTUB model was run with soil phosphorus values of 616 ppm and 792 ppm as well as dairy concentrations of 5, 82.5, 123.75, and 247.5 mg/L. The output concentrations from BATHTUB were not calibrated so that the raw model results could be compared.

BATHTUB Output for 1993 Sensitivity Analysis

Varying Dairy Phosphorus Concentrations; Constant Sediment Phosphorus Concentration of 616 mg/kg

CASE: 1993 - Dairy at 5 mg/L, Sediment at 616mg/kg, No Internal Cycling
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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	124.3	.10	48.8	.45	2.54	9.06	3.47	2.02
CHL-A	MG/M3	61.0	1.00	17.9	1.60	3.41	1.23	3.55	.65
SECCHI	M	.9	.04	1.9	1.61	.47	-17.96	-2.69	-.47
ORGANIC N	MG/M3	.0	.00	570.5	.95	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	29.6	.62	.00	.00	.00	.00

CASE: 1993 - Dairy at 5 mg/L, Sediment at 616mg/kg, No Internal Cycling
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	Watershed	2.720	1.855	.000E+00	.000	.682
PRECIPITATION			.231	.349	.487E-02	.200	1.510
TRIBUTARY INFLOW			2.720	1.855	.000E+00	.000	.682
***TOTAL INFLOW			2.951	2.204	.487E-02	.032	.747
ADVECTIVE OUTFLOW			2.951	2.009	.827E-02	.045	.681
***TOTAL OUTFLOW			2.951	2.009	.827E-02	.045	.681
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	300.1	97.7	.000E+00	.0	.000	161.8	110.3
PRECIPITATION			6.9	2.3	.120E+02	100.0	.500	19.9	30.0
TRIBUTARY INFLOW			300.1	97.7	.000E+00	.0	.000	161.8	110.3
***TOTAL INFLOW			307.1	100.0	.120E+02	100.0	.011	139.3	104.1
ADVECTIVE OUTFLOW			98.1	32.0	.196E+04	16298.6	.451	48.8	33.3
***TOTAL OUTFLOW			98.1	32.0	.196E+04	16298.6	.451	48.8	33.3
***RETENTION			208.9	68.0	.196E+04	16360.6	.212	.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 -
8.70	.6484	124.3	.5272	1.8969	.6804

CASE: 1993 - Dairy at 82.5 mg/L, Sediment at 616mg/kg, No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	124.3	.10	72.6	.45	1.71	5.22	2.00	1.16
CHL-A	MG/M3	61.0	1.00	22.1	1.58	2.75	1.01	2.93	.54
SECCHI	M	.9	.04	1.6	1.09	.57	-13.56	-2.03	-.52
ORGANIC N	MG/M3	.0	.00	667.9	1.04	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.2	.77	.00	.00	.00	.00

CASE: 1993 - Dairy at 82.5 mg/L, Sediment at 616mg/kg, No Internal Cycling

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	Watershed	2.720	1.855	.000E+00	.000	.682
		PRECIPITATION	.231	.349	.487E-02	.200	1.510
		TRIBUTARY INFLOW	2.720	1.855	.000E+00	.000	.682
		***TOTAL INFLOW	2.951	2.204	.487E-02	.032	.747
		ADVECTIVE OUTFLOW	2.951	2.009	.827E-02	.045	.681
		***TOTAL OUTFLOW	2.951	2.009	.827E-02	.045	.681
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	600.1	98.9	.000E+00	.0	.000	323.5	220.6
		PRECIPITATION	6.9	1.1	.120E+02	100.0	.500	19.9	30.0
		TRIBUTARY INFLOW	600.1	98.9	.000E+00	.0	.000	323.5	220.6
		***TOTAL INFLOW	607.0	100.0	.120E+02	100.0	.006	275.4	205.7
		ADVECTIVE OUTFLOW	145.8	24.0	.432E+04	35999.5	.451	72.6	49.4
		***TOTAL OUTFLOW	145.8	24.0	.432E+04	35999.5	.451	72.6	49.4
		***RETENTION	461.2	76.0	.433E+04	36072.2	.143	.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 -
8.70	.6484	124.3	.2667	3.7499	.7598

CASE: 1993 - Dairy at 123.75 mg/L, Sediment at 616mg/kg, No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	124.3	.10	85.2	.20	1.46	3.66	1.40	1.71
CHL-A	MG/M3	61.0	1.00	23.7	1.57	2.57	.95	2.73	.51
SECCHI	M	.9	.04	1.5	.94	.60	-12.14	-1.82	-.54
ORGANIC N	MG/M3	.0	.00	703.3	1.05	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.0	.80	.00	.00	.00	.00

CASE: 1993 - Dairy at 123.75 mg/L, Sediment at 616mg/kg, No Internal Cycling

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	Watershed	2.720	1.855	.000E+00	.000	.682
PRECIPITATION			.231	.349	.487E-02	.200	1.510
TRIBUTARY INFLOW			2.720	1.855	.000E+00	.000	.682
***TOTAL INFLOW			2.951	2.204	.487E-02	.032	.747
ADVECTIVE OUTFLOW			2.951	2.009	.827E-02	.045	.681
***TOTAL OUTFLOW			2.951	2.009	.827E-02	.045	.681
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	800.1	99.1	.000E+00	.0	.000	431.3	294.2
PRECIPITATION			6.9	.9	.120E+02	100.0	.500	19.9	30.0
TRIBUTARY INFLOW			800.1	99.1	.000E+00	.0	.000	431.3	294.2
***TOTAL INFLOW			807.1	100.0	.120E+02	100.0	.004	366.2	273.5
ADVECTIVE OUTFLOW			171.2	21.2	.113E+04	9409.7	.196	85.2	58.0
***TOTAL OUTFLOW			171.2	21.2	.113E+04	9409.7	.196	85.2	58.0
***RETENTION			635.9	78.8	.114E+04	9486.5	.053	.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 -
8.70	.6484	124.3	.2006	4.9856	.7879

CASE: 1993 - Dairy at 247.5 mg/L, Sediment at 616mg/kg, No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	124.3	.10	96.4	.45	1.29	2.47	.94	.55
CHL-A	MG/M3	61.0	1.00	24.8	1.58	2.46	.90	2.60	.48
SECCHI	M	.9	.04	1.4	.85	.63	-11.19	-1.68	-.55
ORGANIC N	MG/M3	.0	.00	728.4	1.08	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	41.9	.84	.00	.00	.00	.00

CASE: 1993 - Dairy at 247.5 mg/L, Sediment at 616mg/kg, No Internal Cycling
GROSS WATER BALANCE:

ID	T LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1 Watershed	2.720	1.855	.000E+00	.000	.682
	PRECIPITATION	.231	.349	.487E-02	.200	1.510
	TRIBUTARY INFLOW	2.720	1.855	.000E+00	.000	.682
	***TOTAL INFLOW	2.951	2.204	.487E-02	.032	.747
	ADVECTIVE OUTFLOW	2.951	2.009	.827E-02	.045	.681
	***TOTAL OUTFLOW	2.951	2.009	.827E-02	.045	.681
	***EVAPORATION	.000	.195	.340E-02	.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 Watershed	1000.2	99.3	.000E+00	.0	.000	539.2	367.7
	PRECIPITATION	6.9	.7	.120E+02	100.0	.500	19.9	30.0
	TRIBUTARY INFLOW	1000.2	99.3	.000E+00	.0	.000	539.2	367.7
	***TOTAL INFLOW	1007.1	100.0	.120E+02	100.0	.003	457.0	341.3
	ADVECTIVE OUTFLOW	193.7	19.2	.762E+04	63511.1	.451	96.4	65.6
	***TOTAL OUTFLOW	193.7	19.2	.762E+04	63511.1	.451	96.4	65.6
	***RETENTION	813.5	80.8	.763E+04	63589.1	.107	.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 -
8.70	.6484	124.3	.1607	6.2216	.8077

1993 – *Varying Dairy Phosphorus Concentrations; Constant Sediment Phosphorus Concentration of 792 mg/kg*

CASE: 1993 - Dairy at 5mg/L, Sediment at 792mg/kg; No Internal Cycling
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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	124.3	.10	57.7	.45	2.15	7.45	2.85	1.66
CHL-A	MG/M3	61.0	1.00	19.7	1.59	3.09	1.13	3.26	.60
SECCHI	M	.9	.04	1.7	1.36	.51	-15.96	-2.39	-.49
ORGANIC N	MG/M3	.0	.00	612.6	.99	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	32.9	.69	.00	.00	.00	.00

CASE: 1993 - Dairy at 5mg/L, Sediment at 792mg/kg; No Internal Cycling
GROSS WATER BALANCE:

	DRAINAGE AREA	---- FLOW (HM3/YR) ----			RUNOFF
ID T LOCATION	KM2	MEAN	VARIANCE	CV	M/YR
1 1 Watershed	2.720	1.855	.000E+00	.000	.682
PRECIPITATION	.231	.349	.487E-02	.200	1.510
TRIBUTARY INFLOW	2.720	1.855	.000E+00	.000	.682
***TOTAL INFLOW	2.951	2.204	.487E-02	.032	.747
ADVECTIVE OUTFLOW	2.951	2.009	.827E-02	.045	.681
***TOTAL OUTFLOW	2.951	2.009	.827E-02	.045	.681
***EVAPORATION	.000	.195	.340E-02	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

	----- LOADING ----		--- VARIANCE ---			CONC	EXPORT
ID T LOCATION	KG/YR	%(I)	KG/YR**2	%(I)	CV	MG/M3	KG/KM2
1 1 Watershed	400.1	98.3	.000E+00	.0	.000	215.7	147.1
PRECIPITATION	6.9	1.7	.120E+02	100.0	.500	19.9	30.0
TRIBUTARY INFLOW	400.1	98.3	.000E+00	.0	.000	215.7	147.1
***TOTAL INFLOW	407.0	100.0	.120E+02	100.0	.009	184.7	137.9
ADVECTIVE OUTFLOW	115.9	28.5	.273E+0422714.5		.451	57.7	39.3
***TOTAL OUTFLOW	115.9	28.5	.273E+0422714.5		.451	57.7	39.3
***RETENTION	291.1	71.5	.274E+0422781.6		.180	.0	.0

	HYDRAULIC	-------------- TOTAL P	--------------		
OVERFLOW	RESIDENCE	POOL	RESIDENCE	TURNOVER	RETENTION
RATE	TIME	CONC	TIME	RATIO	COEF
M/YR	YRS	MG/M3	YRS	-	-
8.70	.6484	124.3	.3977	2.5142	.7153

CASE: 1993 - Dairy at 82.5mg/L, Sediment at 792mg/kg; No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	124.3	.10	72.6	.45	1.71	5.22	2.00	1.16
CHL-A	MG/M3	61.0	1.00	22.1	1.58	2.75	1.01	2.93	.54
SECCHI	M	.9	.04	1.6	1.09	.57	-13.56	-2.03	-.52
ORGANIC N	MG/M3	.0	.00	667.9	1.04	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	37.2	.77	.00	.00	.00	.00

CASE: 1993 - Dairy at 82.5mg/L, Sediment at 792mg/kg; No Internal Cycling
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	Watershed	2.720	1.855	.000E+00	.000	.682
PRECIPITATION			.231	.349	.487E-02	.200	1.510
TRIBUTARY INFLOW			2.720	1.855	.000E+00	.000	.682
***TOTAL INFLOW			2.951	2.204	.487E-02	.032	.747
ADVECTIVE OUTFLOW			2.951	2.009	.827E-02	.045	.681
***TOTAL OUTFLOW			2.951	2.009	.827E-02	.045	.681
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	600.1	98.9	.000E+00	.0	.000	323.5	220.6
PRECIPITATION			6.9	1.1	.120E+02	100.0	.500	19.9	30.0
TRIBUTARY INFLOW			600.1	98.9	.000E+00	.0	.000	323.5	220.6
***TOTAL INFLOW			607.0	100.0	.120E+02	100.0	.006	275.4	205.7
ADVECTIVE OUTFLOW			145.8	24.0	.432E+04	35999.5	.451	72.6	49.4
***TOTAL OUTFLOW			145.8	24.0	.432E+04	35999.5	.451	72.6	49.4
***RETENTION			461.2	76.0	.433E+04	36072.2	.143	.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 -
8.70	.6484	124.3	.2667	3.7499	.7598

CASE: 1993 - Dairy at 123.75mg/L; Sediment at 792 mg/kg; No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	124.3	.10	85.2	.45	1.46	3.66	1.40	.82
CHL-A	MG/M3	61.0	1.00	23.7	1.58	2.57	.95	2.73	.51
SECCHI	M	.9	.04	1.5	.95	.60	-12.14	-1.82	-.54
ORGANIC N	MG/M3	.0	.00	703.3	1.06	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.0	.81	.00	.00	.00	.00

CASE: 1993 - Dairy at 123.75mg/L; Sediment at 792 mg/kg; No Internal Cycling

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	Watershed	2.720	1.855	.000E+00	.000	.682
		PRECIPITATION	.231	.349	.487E-02	.200	1.510
		TRIBUTARY INFLOW	2.720	1.855	.000E+00	.000	.682
		***TOTAL INFLOW	2.951	2.204	.487E-02	.032	.747
		ADVECTIVE OUTFLOW	2.951	2.009	.827E-02	.045	.681
		***TOTAL OUTFLOW	2.951	2.009	.827E-02	.045	.681
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	800.1	99.1	.000E+00	.0	.000	431.3	294.2
		PRECIPITATION	6.9	.9	.120E+02	100.0	.500	19.9	30.0
		TRIBUTARY INFLOW	800.1	99.1	.000E+00	.0	.000	431.3	294.2
		***TOTAL INFLOW	807.1	100.0	.120E+02	100.0	.004	366.2	273.5
		ADVECTIVE OUTFLOW	171.2	21.2	.596E+04	49637.8	.451	85.2	58.0
		***TOTAL OUTFLOW	171.2	21.2	.596E+04	49637.8	.451	85.2	58.0
		***RETENTION	635.9	78.8	.597E+04	49713.2	.121	.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 -
8.70	.6484	124.3	.2006	4.9856	.7879

CASE: 1993 - Dairy at 247.5mg/L; Sediment at 792 mg/kg; No Internal Cycling

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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	124.3	.10	101.5	.45	1.22	1.96	.75	.44
CHL-A	MG/M3	61.0	1.00	25.2	1.58	2.42	.88	2.55	.47
SECCHI	M	.9	.04	1.4	.82	.63	-10.82	-1.62	-.55
ORGANIC N	MG/M3	.0	.00	738.4	1.08	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	42.7	.86	.00	.00	.00	.00

CASE: 1993 - Dairy at 247.5mg/L; Sediment at 792 mg/kg; No Internal Cycling

GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	FLOW (HM3/YR) MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Watershed	2.720	1.855	.000E+00	.000	.682
PRECIPITATION			.231	.349	.487E-02	.200	1.510
TRIBUTARY INFLOW			2.720	1.855	.000E+00	.000	.682
***TOTAL INFLOW			2.951	2.204	.487E-02	.032	.747
ADVECTIVE OUTFLOW			2.951	2.009	.827E-02	.045	.681
***TOTAL OUTFLOW			2.951	2.009	.827E-02	.045	.681
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	1100.2	99.4	.000E+00	.0	.000	593.1	404.5
PRECIPITATION			6.9	.6	.120E+02	100.0	.500	19.9	30.0
TRIBUTARY INFLOW			1100.2	99.4	.000E+00	.0	.000	593.1	404.5
***TOTAL INFLOW			1107.1	100.0	.120E+02	100.0	.003	502.4	375.2
ADVECTIVE OUTFLOW			204.0	18.4	.846E+04	70509.0	.451	101.5	69.1
***TOTAL OUTFLOW			204.0	18.4	.846E+04	70509.0	.451	101.5	69.1
***RETENTION			903.1	81.6	.847E+04	70589.4	.102	.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 -
8.70	.6484	124.3	.1462	6.8393	.8157

BATHTUB Output for 1998 Sensitivity Analysis

Varying Dairy Phosphorus Concentrations; Constant Sediment Phosphorus Concentration of 616 mg/kg

CASE: 1998 - Dairy at 5 mg/L, Sediment at 616mg/kg, No Internal Cycling
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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	153.8	.13	31.3	.45	4.91	12.44	5.92	3.39
CHL-A	MG/M3	61.3	1.00	13.0	1.60	4.72	1.55	4.49	.82
SECCHI	M	.9	.03	2.5	2.58	.36	-39.27	-3.65	-.40
ORGANIC N	MG/M3	.0	.00	458.8	.80	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	20.9	.53	.00	.00	.00	.00

CASE: 1998 - Dairy at 5 mg/L, Sediment at 616mg/kg, No Internal Cycling
GROSS WATER BALANCE:

	DRAINAGE AREA	---- FLOW (HM3/YR) ----			RUNOFF
ID T LOCATION	KM2	MEAN	VARIANCE	CV	M/YR
1 1 Watershed	2.720	1.243	.000E+00	.000	.457
PRECIPITATION	.231	.282	.318E-02	.200	1.220
TRIBUTARY INFLOW	2.720	1.243	.000E+00	.000	.457
***TOTAL INFLOW	2.951	1.525	.318E-02	.037	.517
ADVECTIVE OUTFLOW	2.951	1.330	.658E-02	.061	.451
***TOTAL OUTFLOW	2.951	1.330	.658E-02	.061	.451
***EVAPORATION	.000	.195	.340E-02	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

	----- LOADING ----		--- VARIANCE ---			CONC	EXPORT
ID T LOCATION	KG/YR	%(I)	KG/YR**2	%(I)	CV	MG/M3	KG/KM2
1 1 Watershed	100.1	93.5	.000E+00	.0	.000	80.5	36.8
PRECIPITATION	6.9	6.5	.120E+02	100.0	.500	24.6	30.0
TRIBUTARY INFLOW	100.1	93.5	.000E+00	.0	.000	80.5	36.8
***TOTAL INFLOW	107.0	100.0	.120E+02	100.0	.032	70.2	36.3
ADVECTIVE OUTFLOW	41.6	38.9	.353E+03	2943.8	.451	31.3	14.1
***TOTAL OUTFLOW	41.6	38.9	.353E+03	2943.8	.451	31.3	14.1
***RETENTION	65.3	61.1	.360E+03	2995.5	.290	.0	.0

	HYDRAULIC	--------------	TOTAL P	--------------	
OVERFLOW	RESIDENCE	POOL	RESIDENCE	TURNOVER	RETENTION
RATE	TIME	CONC	TIME	RATIO	COEF
M/YR	YRS	MG/M3	YRS	-	-
5.76	.9759	153.8	1.8664	.5358	.6108

CASE: 1998 - Dairy at 82.5 mg/L, Sediment at 616mg/kg, No Internal Cycling

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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	153.8	.13	31.3	.45	4.91	12.44	5.92	3.39
CHL-A	MG/M3	61.3	1.00	13.0	1.60	4.72	1.55	4.49	.82
SECCHI	M	.9	.03	2.5	2.58	.36	-39.27	-3.65	-.40
ORGANIC N	MG/M3	.0	.00	458.8	.80	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	20.9	.53	.00	.00	.00	.00

CASE: 1998 - Dairy at 82.5 mg/L, Sediment at 616mg/kg, No Internal Cycling

GROSS WATER BALANCE:

		DRAINAGE AREA	---- FLOW (HM3/YR) ----			RUNOFF
ID	T LOCATION	KM2	MEAN	VARIANCE	CV	M/YR
1	1 Watershed	2.720	1.243	.000E+00	.000	.457
PRECIPITATION		.231	.282	.318E-02	.200	1.220
TRIBUTARY INFLOW		2.720	1.243	.000E+00	.000	.457
***TOTAL INFLOW		2.951	1.525	.318E-02	.037	.517
ADVECTIVE OUTFLOW		2.951	1.330	.658E-02	.061	.451
***TOTAL OUTFLOW		2.951	1.330	.658E-02	.061	.451
***EVAPORATION		.000	.195	.340E-02	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS

COMPONENT: TOTAL P

		----- LOADING ----		--- VARIANCE ---			CONC	EXPORT
ID	T LOCATION	KG/YR	%(I)	KG/YR**2	%(I)	CV	MG/M3	KG/KM2
1	1 Watershed	100.1	93.5	.000E+00	.0	.000	80.5	36.8
PRECIPITATION		6.9	6.5	.120E+02	100.0	.500	24.6	30.0
TRIBUTARY INFLOW		100.1	93.5	.000E+00	.0	.000	80.5	36.8
***TOTAL INFLOW		107.0	100.0	.120E+02	100.0	.032	70.2	36.3
ADVECTIVE OUTFLOW		41.6	38.9	.353E+03	2943.8	.451	31.3	14.1
***TOTAL OUTFLOW		41.6	38.9	.353E+03	2943.8	.451	31.3	14.1
***RETENTION		65.3	61.1	.360E+03	2995.5	.290	.0	.0

	HYDRAULIC	-------------- TOTAL P	--------------		
OVERFLOW	RESIDENCE	POOL	RESIDENCE	TURNOVER	RETENTION
RATE	TIME	CONC	TIME	RATIO	COEF
M/YR	YRS	MG/M3	YRS	-	-
5.76	.9759	153.8	1.8664	.5358	.6108

CASE: 1998 - Dairy at 123.75 mg/L, Sediment at 616mg/kg, No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	68.8	.45	2.24	6.29	2.99	1.72
CHL-A	MG/M3	61.3	1.00	21.8	1.57	2.81	1.03	2.98	.55
SECCHI	M	.9	.03	1.6	1.15	.56	-22.47	-2.09	-.51
ORGANIC N	MG/M3	.0	.00	660.8	1.02	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	36.7	.74	.00	.00	.00	.00

CASE: 1998 - Dairy at 123.75 mg/L, Sediment at 616mg/kg, No Internal Cycling
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	Watershed	2.720	1.243	.000E+00	.000	.457
PRECIPITATION			.231	.282	.318E-02	.200	1.220
TRIBUTARY INFLOW			2.720	1.243	.000E+00	.000	.457
***TOTAL INFLOW			2.951	1.525	.318E-02	.037	.517
ADVECTIVE OUTFLOW			2.951	1.330	.658E-02	.061	.451
***TOTAL OUTFLOW			2.951	1.330	.658E-02	.061	.451
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	400.1	98.3	.000E+00	.0	.000	321.9	147.1
PRECIPITATION			6.9	1.7	.120E+02	100.0	.500	24.6	30.0
TRIBUTARY INFLOW			400.1	98.3	.000E+00	.0	.000	321.9	147.1
***TOTAL INFLOW			407.0	100.0	.120E+02	100.0	.009	266.9	137.9
ADVECTIVE OUTFLOW			91.5	22.5	.171E+04	14204.4	.451	68.8	31.0
***TOTAL OUTFLOW			91.5	22.5	.171E+04	14204.4	.451	68.8	31.0
***RETENTION			315.5	77.5	.171E+04	14279.3	.131	.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 -
5.76	.9759	153.8	.4907	2.0381	.7752

CASE: 1998 - Dairy at 247.5 mg/L, Sediment at 616mg/kg, No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	86.0	.45	1.79	4.55	2.16	1.24
CHL-A	MG/M3	61.3	1.00	24.1	1.57	2.55	.93	2.70	.50
SECCHI	M	.9	.03	1.5	.94	.61	-19.19	-1.78	-.53
ORGANIC N	MG/M3	.0	.00	711.6	1.06	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.6	.81	.00	.00	.00	.00

CASE: 1998 - Dairy at 247.5 mg/L, Sediment at 616mg/kg, No Internal Cycling
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	Watershed	2.720	1.243	.000E+00	.000	.457
		PRECIPITATION	.231	.282	.318E-02	.200	1.220
		TRIBUTARY INFLOW	2.720	1.243	.000E+00	.000	.457
		***TOTAL INFLOW	2.951	1.525	.318E-02	.037	.517
		ADVECTIVE OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***TOTAL OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	600.1	98.9	.000E+00	.0	.000	482.8	220.6
		PRECIPITATION	6.9	1.1	.120E+02	100.0	.500	24.6	30.0
		TRIBUTARY INFLOW	600.1	98.9	.000E+00	.0	.000	482.8	220.6
		***TOTAL INFLOW	607.1	100.0	.120E+02	100.0	.006	398.1	205.7
		ADVECTIVE OUTFLOW	114.3	18.8	.266E+04	22195.2	.451	86.0	38.7
		***TOTAL OUTFLOW	114.3	18.8	.266E+04	22195.2	.451	86.0	38.7
		***RETENTION	492.7	81.2	.267E+04	22274.3	.105	.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 -
5.76	.9759	153.8	.3290	3.0399	.8116

1998 - *Varying Dairy Phosphorus Concentrations; Constant Sediment Phosphorus Concentration of 792 mg/kg*

```
CASE: 1998 - Dairy at 5mg/L; Sediment at 792mg/kg; No Internal Cycling
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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	31.3	.45	4.91	12.44	5.92	3.39
CHL-A	MG/M3	61.3	1.00	13.0	1.60	4.72	1.55	4.49	.82
SECCHI	M	.9	.03	2.5	2.58	.36	-39.27	-3.65	-.40
ORGANIC N	MG/M3	.0	.00	458.8	.80	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	20.9	.53	.00	.00	.00	.00

CASE: 1998 - Dairy at 5mg/L; Sediment at 792mg/kg; No Internal Cycling

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	Watershed	2.720	1.243	.000E+00	.000	.457
		PRECIPITATION	.231	.282	.318E-02	.200	1.220
		TRIBUTARY INFLOW	2.720	1.243	.000E+00	.000	.457
		***TOTAL INFLOW	2.951	1.525	.318E-02	.037	.517
		ADVECTIVE OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***TOTAL OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	100.1	93.5	.000E+00	.0	.000	80.5	36.8
		PRECIPITATION	6.9	6.5	.120E+02	100.0	.500	24.6	30.0
		TRIBUTARY INFLOW	100.1	93.5	.000E+00	.0	.000	80.5	36.8
		***TOTAL INFLOW	107.0	100.0	.120E+02	100.0	.032	70.2	36.3
		ADVECTIVE OUTFLOW	41.6	38.9	.353E+03	2943.8	.451	31.3	14.1
		***TOTAL OUTFLOW	41.6	38.9	.353E+03	2943.8	.451	31.3	14.1
		***RETENTION	65.3	61.1	.360E+03	2995.5	.290	.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 -
5.76	.9759	153.8	1.8664	.5358	.6108

CASE: 1998 – Dairy at 82.5mg/L; Sediment at 792mg/kg; No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	46.6	.45	3.30	9.33	4.44	2.55
CHL-A	MG/M3	61.3	1.00	17.5	1.58	3.50	1.25	3.62	.67
SECCHI	M	.9	.03	1.9	1.69	.46	-29.78	-2.77	-.46
ORGANIC N	MG/M3	.0	.00	561.9	.93	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	28.9	.60	.00	.00	.00	.00

CASE: 1998 – Dairy at 82.5mg/L; Sediment at 792mg/kg; No Internal Cycling

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	Watershed	2.720	1.243	.000E+00	.000	.457
PRECIPITATION			.231	.282	.318E-02	.200	1.220
TRIBUTARY INFLOW			2.720	1.243	.000E+00	.000	.457
***TOTAL INFLOW			2.951	1.525	.318E-02	.037	.517
ADVECTIVE OUTFLOW			2.951	1.330	.658E-02	.061	.451
***TOTAL OUTFLOW			2.951	1.330	.658E-02	.061	.451
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	200.0	96.7	.000E+00	.0	.000	160.9	73.5
PRECIPITATION			6.9	3.3	.120E+02	100.0	.500	24.6	30.0
TRIBUTARY INFLOW			200.0	96.7	.000E+00	.0	.000	160.9	73.5
***TOTAL INFLOW			206.9	100.0	.120E+02	100.0	.017	135.7	70.1
ADVECTIVE OUTFLOW			62.0	30.0	.783E+03	6524.6	.451	46.6	21.0
***TOTAL OUTFLOW			62.0	30.0	.783E+03	6524.6	.451	46.6	21.0
***RETENTION			144.9	70.0	.791E+03	6589.4	.194	.0	.0

	HYDRAULIC	TOTAL P			
OVERFLOW RATE M/YR	RESIDENCE TIME YRS	POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
5.76	.9759	153.8	.9650	1.0362	.7003

CASE: 1998 - Dairy at 123.75mg/L; Sediment at 792mg/kg; No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	68.8	.45	2.24	6.29	2.99	1.72
CHL-A	MG/M3	61.3	1.00	21.8	1.57	2.81	1.03	2.98	.55
SECCHI	M	.9	.03	1.6	1.15	.56	-22.47	-2.09	-.51
ORGANIC N	MG/M3	.0	.00	660.8	1.02	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	36.7	.74	.00	.00	.00	.00

CASE: 1998 - Dairy at 123.75mg/L; Sediment at 792mg/kg; No Internal Cycling

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	Watershed	2.720	1.243	.000E+00	.000	.457
		PRECIPITATION	.231	.282	.318E-02	.200	1.220
		TRIBUTARY INFLOW	2.720	1.243	.000E+00	.000	.457
		***TOTAL INFLOW	2.951	1.525	.318E-02	.037	.517
		ADVECTIVE OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***TOTAL OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	400.1	98.3	.000E+00	.0	.000	321.9	147.1
		PRECIPITATION	6.9	1.7	.120E+02	100.0	.500	24.6	30.0
		TRIBUTARY INFLOW	400.1	98.3	.000E+00	.0	.000	321.9	147.1
		***TOTAL INFLOW	407.0	100.0	.120E+02	100.0	.009	266.9	137.9
		ADVECTIVE OUTFLOW	91.5	22.5	.171E+04	14204.4	.451	68.8	31.0
		***TOTAL OUTFLOW	91.5	22.5	.171E+04	14204.4	.451	68.8	31.0
		***RETENTION	315.5	77.5	.171E+04	14279.3	.131	.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 -
5.76	.9759	153.8	.4907	2.0381	.7752

CASE: 1998 - Dairy at 247.5mg/L; Sediment at 792mg/kg; No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	86.0	.45	1.79	4.55	2.16	1.24
CHL-A	MG/M3	61.3	1.00	24.1	1.57	2.55	.93	2.70	.50
SECCHI	M	.9	.03	1.5	.94	.61	-19.19	-1.78	-.53
ORGANIC N	MG/M3	.0	.00	711.6	1.06	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.6	.81	.00	.00	.00	.00

CASE: 1998 - Dairy at 247.5mg/L; Sediment at 792mg/kg; No Internal Cycling
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	Watershed	2.720	1.243	.000E+00	.000	.457
		PRECIPITATION	.231	.282	.318E-02	.200	1.220
		TRIBUTARY INFLOW	2.720	1.243	.000E+00	.000	.457
		***TOTAL INFLOW	2.951	1.525	.318E-02	.037	.517
		ADVECTIVE OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***TOTAL OUTFLOW	2.951	1.330	.658E-02	.061	.451
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	600.1	98.9	.000E+00	.0	.000	482.8	220.6
		PRECIPITATION	6.9	1.1	.120E+02	100.0	.500	24.6	30.0
		TRIBUTARY INFLOW	600.1	98.9	.000E+00	.0	.000	482.8	220.6
		***TOTAL INFLOW	607.1	100.0	.120E+02	100.0	.006	398.1	205.7
		ADVECTIVE OUTFLOW	114.3	18.8	.266E+04	22195.2	.451	86.0	38.7
		***TOTAL OUTFLOW	114.3	18.8	.266E+04	22195.2	.451	86.0	38.7
		***RETENTION	492.7	81.2	.267E+04	22274.3	.105	.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 -
5.76	.9759	153.8	.3290	3.0399	.8116

BATHTUB Output for 2001 Sensitivity Analysis

Varying Dairy Phosphorus Concentrations; Constant Sediment Phosphorus Concentration of 616 mg/kg

```
CASE: Dairy at 5 mg/L, Sediment at 616 mg/kg, No Internal Cycling
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 Reservoir
                      OBSERVED     ESTIMATED                T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 ------------------------------------------------------------------------
 TOTAL P     MG/M3   121.3   .13    36.6   .45    3.32    9.15    4.46    2.55
 CHL-A       MG/M3    21.9   .19    10.4   .45    2.11    3.83    2.16    1.53
 SECCHI          M      .9   .05     1.2   .21     .74   -5.97   -1.07   -1.40
 ORGANIC N   MG/M3      .0   .00   436.1   .27     .00     .00     .00     .00
 TP-ORTHO-P MG/M3       .0   .00    27.8   .33     .00     .00     .00     .00
 ------------------------------------------------------------------------
CASE: Dairy at 5 mg/L, Sediment at 616 mg/kg, No Internal Cycling
 GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
 ID  T LOCATION                 KM2         MEAN  VARIANCE    CV         M/YR
 ---------------------------------------------------------------------------
  1  1 Watershed              2.720        1.004  .000E+00  .000         .369
 ---------------------------------------------------------------------------
 PRECIPITATION                 .231         .213  .181E-02  .200         .920
 TRIBUTARY INFLOW             2.720        1.004  .000E+00  .000         .369
 ***TOTAL INFLOW              2.951        1.217  .181E-02  .035         .412
 ADVECTIVE OUTFLOW            2.951        1.022  .521E-02  .071         .346
 ***TOTAL OUTFLOW             2.951        1.022  .521E-02  .071         .346
 ***EVAPORATION                .000         .195  .340E-02  .300         .000
 ---------------------------------------------------------------------------

 GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
 COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
 ID T LOCATION              KG/YR   %(I)  KG/YR**2   %(I)     CV   MG/M3  KG/KM2
 ------------------------------------------------------------------------------
  1 1 Watershed             100.1   93.5  .000E+00     .0   .000    99.7    36.8
 ------------------------------------------------------------------------------
 PRECIPITATION                6.9    6.5  .120E+02  100.0   .500    32.6    30.0
 TRIBUTARY INFLOW           100.1   93.5  .000E+00     .0   .000    99.7    36.8
 ***TOTAL INFLOW            107.0  100.0  .120E+02  100.0   .032    88.0    36.3
 ADVECTIVE OUTFLOW           37.4   34.9  .285E+03 2375.7   .452    36.6    12.7
 ***TOTAL OUTFLOW            37.4   34.9  .285E+03 2375.7   .452    36.6    12.7
 ***RETENTION                69.6   65.1  .292E+03 2433.4   .245      .0      .0
 ------------------------------------------------------------------------------

           HYDRAULIC    -------------- TOTAL P  --------------
  OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
      RATE      TIME      CONC      TIME     RATIO      COEF
      M/YR       YRS     MG/M3       YRS         -         -
      4.42    1.2002     121.3    1.3903     .7193     .6507
```

CASE: Dairy at 82.5 mg/L, Sediment at 616 mg/kg, No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	121.3	.13	36.6	.45	3.32	9.15	4.46	2.55
CHL-A	MG/M3	21.9	.19	10.4	.45	2.11	3.83	2.16	1.53
SECCHI	M	.9	.05	1.2	.21	.74	-5.97	-1.07	-1.40
ORGANIC N	MG/M3	.0	.00	436.1	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	27.8	.33	.00	.00	.00	.00

CASE: Alt 01; Dairy 5; Sed 616
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	Watershed	2.720	1.004	.000E+00	.000	.369
		PRECIPITATION	.231	.213	.181E-02	.200	.920
		TRIBUTARY INFLOW	2.720	1.004	.000E+00	.000	.369
		***TOTAL INFLOW	2.951	1.217	.181E-02	.035	.412
		ADVECTIVE OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***TOTAL OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	100.1	93.5	.000E+00	.0	.000	99.7	36.8
		PRECIPITATION	6.9	6.5	.120E+02	100.0	.500	32.6	30.0
		TRIBUTARY INFLOW	100.1	93.5	.000E+00	.0	.000	99.7	36.8
		***TOTAL INFLOW	107.0	100.0	.120E+02	100.0	.032	88.0	36.3
		ADVECTIVE OUTFLOW	37.4	34.9	.285E+03	2375.7	.452	36.6	12.7
		***TOTAL OUTFLOW	37.4	34.9	.285E+03	2375.7	.452	36.6	12.7
		***RETENTION	69.6	65.1	.292E+03	2433.4	.245	.0	.0

OVERFLOW RATE	HYDRAULIC RESIDENCE TIME	TOTAL P POOL CONC	TOTAL P RESIDENCE TIME	TOTAL P TURNOVER RATIO	TOTAL P RETENTION COEF
M/YR	YRS	MG/M3	YRS	-	-
4.42	1.2002	121.3	1.3903	.7193	.6507

CASE: Dairy at 123.75 mg/L, Sediment at 616 mg/kg, No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	121.3	.13	54.0	.19	2.25	6.18	3.01	3.51
CHL-A	MG/M3	21.9	.19	13.6	.30	1.60	2.43	1.37	1.34
SECCHI	M	.9	.05	1.1	.18	.82	-4.09	-.73	-1.11
ORGANIC N	MG/M3	.0	.00	510.5	.21	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.6	.26	.00	.00	.00	.00

CASE: Dairy at 123.75 mg/L, Sediment at 616 mg/kg, No Internal Cycling

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	Watershed	2.720	1.004	.000E+00	.000	.369
		PRECIPITATION	.231	.213	.181E-02	.200	.920
		TRIBUTARY INFLOW	2.720	1.004	.000E+00	.000	.369
		***TOTAL INFLOW	2.951	1.217	.181E-02	.035	.412
		ADVECTIVE OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***TOTAL OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	200.1	96.7	.000E+00	.0	.000	199.3	73.6
		PRECIPITATION	6.9	3.3	.120E+02	100.0	.500	32.6	30.0
		TRIBUTARY INFLOW	200.1	96.7	.000E+00	.0	.000	199.3	73.6
		***TOTAL INFLOW	207.0	100.0	.120E+02	100.0	.017	170.2	70.2
		ADVECTIVE OUTFLOW	55.2	26.7	.111E+03	922.0	.191	54.0	18.7
		***TOTAL OUTFLOW	55.2	26.7	.111E+03	922.0	.191	54.0	18.7
		***RETENTION	151.8	73.3	.119E+03	991.2	.072	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
4.42	1.2002	121.3	.7187	1.3913	.7334

CASE: Dairy at 247.5 mg/L, Sediment at 616 mg/kg, No Internal Cycling

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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	121.3	.13	67.6	.45	1.79	4.46	2.17	1.24
CHL-A	MG/M3	21.9	.19	15.5	.35	1.42	1.78	1.00	.86
SECCHI	M	.9	.05	1.0	.19	.86	-3.11	-.55	-.77
ORGANIC N	MG/M3	.0	.00	552.1	.25	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	36.9	.30	.00	.00	.00	.00

CASE: Dairy at 247.5 mg/L, Sediment at 616 mg/kg, No Internal Cycling
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Watershed	2.720	1.004	.000E+00	.000	.369
		PRECIPITATION	.231	.213	.181E-02	.200	.920
		TRIBUTARY INFLOW	2.720	1.004	.000E+00	.000	.369
		***TOTAL INFLOW	2.951	1.217	.181E-02	.035	.412
		ADVECTIVE OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***TOTAL OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	300.2	97.7	.000E+00	.0	.000	299.0	110.4
		PRECIPITATION	6.9	2.3	.120E+02	100.0	.500	32.6	30.0
		TRIBUTARY INFLOW	300.2	97.7	.000E+00	.0	.000	299.0	110.4
		***TOTAL INFLOW	307.1	100.0	.120E+02	100.0	.011	252.5	104.1
		ADVECTIVE OUTFLOW	69.1	22.5	.974E+03	8115.2	.452	67.6	23.4
		***TOTAL OUTFLOW	69.1	22.5	.974E+03	8115.2	.452	67.6	23.4
		***RETENTION	238.0	77.5	.983E+03	8189.8	.132	.0	.0

	HYDRAULIC	--------------	TOTAL P	--------------	
OVERFLOW RATE M/YR	RESIDENCE TIME YRS	POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
4.42	1.2002	121.3	.4845	2.0640	.7750

2001 – *Varying Dairy Phosphorus Concentrations; Constant Sediment Phosphorus Concentration of 792 mg/kg*

```
CASE: 2001 Dairy at 5mg/L; Sediment at 792 mg/kg; No Internal Cycling
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 Reservoir
                      OBSERVED     ESTIMATED              T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 ---------------------------------------------------------------------------
 TOTAL P     MG/M3   121.3   .13    36.6   .45    3.32    9.15    4.46    2.55
 CHL-A       MG/M3    21.9   .19    10.4   .45    2.11    3.83    2.16    1.53
 SECCHI          M      .9   .05     1.2   .21     .74   -5.97   -1.07   -1.40
 ORGANIC N  MG/M3       .0   .00   436.1   .27     .00     .00     .00     .00
 TP-ORTHO-P MG/M3       .0   .00    27.8   .33     .00     .00     .00     .00
 ---------------------------------------------------------------------------
CASE: 2001 Dairy at 5mg/L; Sediment at 792 mg/kg; No Internal Cycling
 GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
 ID  T LOCATION                KM2         MEAN  VARIANCE    CV         M/YR
 ------------------------------------------------------------------------------
  1  1 Watershed             2.720        1.004  .000E+00  .000         .369
 ------------------------------------------------------------------------------
 PRECIPITATION                .231         .213  .181E-02  .200         .920
 TRIBUTARY INFLOW            2.720        1.004  .000E+00  .000         .369
 ***TOTAL INFLOW             2.951        1.217  .181E-02  .035         .412
 ADVECTIVE OUTFLOW           2.951        1.022  .521E-02  .071         .346
 ***TOTAL OUTFLOW            2.951        1.022  .521E-02  .071         .346
 ***EVAPORATION               .000         .195  .340E-02  .300         .000
 ------------------------------------------------------------------------------

 GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
 COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
 ID T LOCATION             KG/YR   %(I)  KG/YR**2   %(I)     CV   MG/M3  KG/KM2
 ---------------------------------------------------------------------------------
  1 1 Watershed            100.1   93.5  .000E+00     .0   .000    99.7    36.8
 ---------------------------------------------------------------------------------
 PRECIPITATION               6.9    6.5  .120E+02  100.0   .500    32.6    30.0
 TRIBUTARY INFLOW          100.1   93.5  .000E+00     .0   .000    99.7    36.8
 ***TOTAL INFLOW           107.0  100.0  .120E+02  100.0   .032    88.0    36.3
 ADVECTIVE OUTFLOW          37.4   34.9  .285E+03 2375.7   .452    36.6    12.7
 ***TOTAL OUTFLOW           37.4   34.9  .285E+03 2375.7   .452    36.6    12.7
 ***RETENTION               69.6   65.1  .292E+03 2433.4   .245      .0      .0
 ---------------------------------------------------------------------------------

          HYDRAULIC     -------------- TOTAL P  --------------
  OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
      RATE      TIME      CONC      TIME     RATIO      COEF
      M/YR       YRS     MG/M3       YRS         -         -
      4.42    1.2002     121.3    1.3903     .7193     .6507
```

CASE: 2001 – Dairy at 82.5mg/L; Sediment at 792mg/kg; No Internal Cycling

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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	121.3	.13	54.0	.45	2.25	6.18	3.01	1.72
CHL-A	MG/M3	21.9	.19	13.6	.38	1.60	2.43	1.37	1.10
SECCHI	M	.9	.05	1.1	.20	.82	-4.09	-.73	-.99
ORGANIC N	MG/M3	.0	.00	510.5	.26	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.6	.31	.00	.00	.00	.00

CASE: 2001 – Dairy at 82.5mg/L; Sediment at 792mg/kg; No Internal Cycling
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	Watershed	2.720	1.004	.000E+00	.000	.369
		PRECIPITATION	.231	.213	.181E-02	.200	.920
		TRIBUTARY INFLOW	2.720	1.004	.000E+00	.000	.369
		***TOTAL INFLOW	2.951	1.217	.181E-02	.035	.412
		ADVECTIVE OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***TOTAL OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	200.1	96.7	.000E+00	.0	.000	199.3	73.6
		PRECIPITATION	6.9	3.3	.120E+02	100.0	.500	32.6	30.0
		TRIBUTARY INFLOW	200.1	96.7	.000E+00	.0	.000	199.3	73.6
		***TOTAL INFLOW	207.0	100.0	.120E+02	100.0	.017	170.2	70.2
		ADVECTIVE OUTFLOW	55.2	26.7	.622E+03	5176.5	.452	54.0	18.7
		***TOTAL OUTFLOW	55.2	26.7	.622E+03	5176.5	.452	54.0	18.7
		***RETENTION	151.8	73.3	.630E+03	5245.7	.165	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
4.42	1.2002	121.3	.7187	1.3913	.7334

CASE: 2001 - Dairy at 123.75mg/L; Sediment at 792mg/kg; No Internal Cycling

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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	121.3	.13	54.0	.19	2.25	6.18	3.01	3.51
CHL-A	MG/M3	21.9	.19	13.6	.30	1.60	2.43	1.37	1.34
SECCHI	M	.9	.05	1.1	.18	.82	-4.09	-.73	-1.11
ORGANIC N	MG/M3	.0	.00	510.5	.21	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	33.6	.26	.00	.00	.00	.00

CASE: 2001 - Dairy at 123.75mg/L; Sediment at 792mg/kg; No Internal Cycling

GROSS WATER BALANCE:

	DRAINAGE AREA	---- FLOW (HM3/YR) ----			RUNOFF
ID T LOCATION	KM2	MEAN	VARIANCE	CV	M/YR
1 1 Watershed	2.720	1.004	.000E+00	.000	.369
PRECIPITATION	.231	.213	.181E-02	.200	.920
TRIBUTARY INFLOW	2.720	1.004	.000E+00	.000	.369
***TOTAL INFLOW	2.951	1.217	.181E-02	.035	.412
ADVECTIVE OUTFLOW	2.951	1.022	.521E-02	.071	.346
***TOTAL OUTFLOW	2.951	1.022	.521E-02	.071	.346
***EVAPORATION	.000	.195	.340E-02	.300	.000

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P

	----- LOADING ----		--- VARIANCE ---			CONC	EXPORT
ID T LOCATION	KG/YR	%(I)	KG/YR**2	%(I)	CV	MG/M3	KG/KM2
1 1 Watershed	200.1	96.7	.000E+00	.0	.000	199.3	73.6
PRECIPITATION	6.9	3.3	.120E+02	100.0	.500	32.6	30.0
TRIBUTARY INFLOW	200.1	96.7	.000E+00	.0	.000	199.3	73.6
***TOTAL INFLOW	207.0	100.0	.120E+02	100.0	.017	170.2	70.2
ADVECTIVE OUTFLOW	55.2	26.7	.111E+03	922.0	.191	54.0	18.7
***TOTAL OUTFLOW	55.2	26.7	.111E+03	922.0	.191	54.0	18.7
***RETENTION	151.8	73.3	.119E+03	991.2	.072	.0	.0

	HYDRAULIC	-------------- TOTAL P	--------------		
OVERFLOW RATE	RESIDENCE TIME	POOL CONC	RESIDENCE TIME	TURNOVER RATIO	RETENTION COEF
M/YR	YRS	MG/M3	YRS	-	-
4.42	1.2002	121.3	.7187	1.3913	.7334

CASE: 2001 - Dairy at 247.5mg/L; Sediment at 792mg/kg; No Internal Cycling

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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	121.3	.13	89.4	.45	1.36	2.33	1.14	.65
CHL-A	MG/M3	21.9	.19	17.5	.32	1.25	1.14	.64	.59
SECCHI	M	.9	.05	1.0	.19	.90	-2.05	-.37	-.53
ORGANIC N	MG/M3	.0	.00	599.2	.24	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	40.5	.28	.00	.00	.00	.00

CASE: 2001 - Dairy at 247.5mg/L; Sediment at 792mg/kg; No Internal Cycling
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Watershed	2.720	1.004	.000E+00	.000	.369
		PRECIPITATION	.231	.213	.181E-02	.200	.920
		TRIBUTARY INFLOW	2.720	1.004	.000E+00	.000	.369
		***TOTAL INFLOW	2.951	1.217	.181E-02	.035	.412
		ADVECTIVE OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***TOTAL OUTFLOW	2.951	1.022	.521E-02	.071	.346
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	500.3	98.6	.000E+00	.0	.000	498.3	183.9
		PRECIPITATION	6.9	1.4	.120E+02	100.0	.500	32.6	30.0
		TRIBUTARY INFLOW	500.3	98.6	.000E+00	.0	.000	498.3	183.9
		***TOTAL INFLOW	507.2	100.0	.120E+02	100.0	.007	416.9	171.9
		ADVECTIVE OUTFLOW	91.4	18.0	.170E+04	14184.1	.452	89.4	31.0
		***TOTAL OUTFLOW	91.4	18.0	.170E+04	14184.1	.452	89.4	31.0
		***RETENTION	415.9	82.0	.171E+04	14264.3	.100	.0	.0

	HYDRAULIC	-------------- TOTAL P	--------------		
OVERFLOW RATE	RESIDENCE TIME	POOL CONC	RESIDENCE TIME	TURNOVER RATIO	RETENTION COEF
M/YR	YRS	MG/M3	YRS	-	-
4.42	1.2002	121.3	.2934	3.4088	.8199

Appendix H
Phosphorus Reductions - BATHTUB Output Files

BATHTUB Output for 1993 Reduction Analysis

CASE: Altamont 1993 - 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 Reservoir

		OBSERVED		ESTIMATED			T STATISTICS		
VARIABLE		MEAN	CV	MEAN	CV	RATIO	1	2	3
TOTAL P	MG/M3	124.3	.10	49.6	.45	2.51	8.92	3.42	1.99
CHL-A	MG/M3	61.0	1.00	36.1	1.60	1.69	.53	1.52	.28
SECCHI	M	.9	.04	1.0	.38	.88	-3.13	-.47	-.34
ORGANIC N	MG/M3	.0	.00	985.6	1.22	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	62.0	1.10	.00	.00	.00	.00

CASE: Altamont 1993 - Reduced
GROSS WATER BALANCE:

ID	T	LOCATION	DRAINAGE AREA KM2	---- FLOW (HM3/YR) ---- MEAN	VARIANCE	CV	RUNOFF M/YR
1	1	Watershed	2.720	1.855	.000E+00	.000	.682
		PRECIPITATION	.231	.349	.487E-02	.200	1.510
		TRIBUTARY INFLOW	2.720	1.855	.000E+00	.000	.682
		***TOTAL INFLOW	2.951	2.204	.487E-02	.032	.747
		ADVECTIVE OUTFLOW	2.951	2.009	.827E-02	.045	.681
		***TOTAL OUTFLOW	2.951	2.009	.827E-02	.045	.681
		***EVAPORATION	.000	.195	.340E-02	.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	Watershed	232.0	73.7	.000E+00	.0	.000	125.1	85.3
		PRECIPITATION	6.9	2.2	.120E+02	100.0	.500	19.9	30.0
		INTERNAL LOAD	75.9	24.1	.000E+00	.0	.000	.0	.0
		TRIBUTARY INFLOW	232.0	73.7	.000E+00	.0	.000	125.1	85.3
		***TOTAL INFLOW	314.9	100.0	.120E+02	100.0	.011	142.9	106.7
		ADVECTIVE OUTFLOW	99.6	31.6	.202E+04	16794.6	.451	49.6	33.8
		***TOTAL OUTFLOW	99.6	31.6	.202E+04	16794.6	.451	49.6	33.8
		***RETENTION	215.3	68.4	.202E+04	16857.0	.209	.0	.0

	HYDRAULIC	-------------- TOTAL P	--------------		
OVERFLOW RATE M/YR	RESIDENCE TIME YRS	POOL CONC MG/M3	RESIDENCE TIME YRS	TURNOVER RATIO -	RETENTION COEF -
8.70	.6484	124.3	.5140	1.9453	.6836

BATHTUB Output for 1998 Reduction Analysis

CASE: Altamont 1998 - 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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	153.8	.13	49.6	.45	3.10	8.84	4.21	2.41
CHL-A	MG/M3	61.3	1.00	36.4	1.58	1.68	.52	1.50	.28
SECCHI	M	.9	.03	1.0	.38	.88	-4.81	-.45	-.33
ORGANIC N	MG/M3	.0	.00	993.2	1.22	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	62.6	1.09	.00	.00	.00	.00

CASE: Altamont 1998 - Reduced
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	Watershed	2.720	1.243	.000E+00	.000	.457
PRECIPITATION			.231	.282	.318E-02	.200	1.220
TRIBUTARY INFLOW			2.720	1.243	.000E+00	.000	.457
***TOTAL INFLOW			2.951	1.525	.318E-02	.037	.517
ADVECTIVE OUTFLOW			2.951	1.330	.658E-02	.061	.451
***TOTAL OUTFLOW			2.951	1.330	.658E-02	.061	.451
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	88.0	38.3	.000E+00	.0	.000	70.8	32.4
PRECIPITATION			6.9	3.0	.120E+02	100.0	.500	24.6	30.0
INTERNAL LOAD			135.0	58.7	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			88.0	38.3	.000E+00	.0	.000	70.8	32.4
***TOTAL INFLOW			229.9	100.0	.120E+02	100.0	.015	150.8	77.9
ADVECTIVE OUTFLOW			66.0	28.7	.886E+03	7383.0	.451	49.6	22.4
***TOTAL OUTFLOW			66.0	28.7	.886E+03	7383.0	.451	49.6	22.4
***RETENTION			164.0	71.3	.894E+03	7449.5	.182	.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 -
5.76	.9759	153.8	.8684	1.1515	.7131

BATHTUB Output for 2001 Reduction Analysis

CASE: Altamont 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 Reservoir

VARIABLE		OBSERVED MEAN	OBSERVED CV	ESTIMATED MEAN	ESTIMATED CV	RATIO	T STATISTICS 1	T STATISTICS 2	T STATISTICS 3
TOTAL P	MG/M3	121.3	.13	49.9	.45	2.43	6.78	3.30	1.89
CHL-A	MG/M3	21.9	.19	14.3	.40	1.53	2.19	1.24	.97
SECCHI	M	.9	.05	1.1	.20	.83	-3.74	-.67	-.89
ORGANIC N	MG/M3	.0	.00	524.8	.27	.00	.00	.00	.00
TP-ORTHO-P	MG/M3	.0	.00	34.7	.32	.00	.00	.00	.00

CASE: Altamont 2001 - Reduced
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	Watershed	2.720	1.004	.000E+00	.000	.369
PRECIPITATION			.231	.213	.181E-02	.200	.920
TRIBUTARY INFLOW			2.720	1.004	.000E+00	.000	.369
***TOTAL INFLOW			2.951	1.217	.181E-02	.035	.412
ADVECTIVE OUTFLOW			2.951	1.022	.521E-02	.071	.346
***TOTAL OUTFLOW			2.951	1.022	.521E-02	.071	.346
***EVAPORATION			.000	.195	.340E-02	.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	Watershed	106.1	58.8	.000E+00	.0	.000	105.6	39.0
PRECIPITATION			6.9	3.8	.120E+02	100.0	.500	32.6	30.0
INTERNAL LOAD			67.5	37.4	.000E+00	.0	.000	.0	.0
TRIBUTARY INFLOW			106.1	58.8	.000E+00	.0	.000	105.6	39.0
***TOTAL INFLOW			180.5	100.0	.120E+02	100.0	.019	148.4	61.2
ADVECTIVE OUTFLOW			51.0	28.2	.530E+03	4415.2	.452	49.9	17.3
***TOTAL OUTFLOW			51.0	28.2	.530E+03	4415.2	.452	49.9	17.3
***RETENTION			129.5	71.8	.538E+03	4482.3	.179	.0	.0

OVERFLOW RATE M/YR	HYDRAULIC RESIDENCE TIME YRS	TOTAL P POOL CONC MG/M3	TOTAL P RESIDENCE TIME YRS	TOTAL P TURNOVER RATIO -	TOTAL P RETENTION COEF -
4.42	1.2002	121.3	.8245	1.2129	.7175

Appendix I
Responsiveness Summary

THIS PAGE INTENTIONALLY LEFT BLANK

Responsiveness Summary

This responsiveness summary responds to substantive questions and comments received during the public comment period from November 17, 2003 through January 20, 2004 postmarked, including those from the December 18, 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 Altamont new Reservoir 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 Altamont New Reservoir (RCJ), which originates in southwest Effingham County. The watershed encompasses an area of approximately 1 square mile. Land use in the watershed is predominately agriculture followed by forestland. Altamont New Reservoir consists of 57 acres and is used as the drinking water source for the city of Altamont. The water body is listed on the Illinois EPA 2002 Section 303(d) List as being impaired for aldrin (sediment), copper (sediment), phosphorus, total ammonia-N, unionized ammonia, 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, a TMDL was only developed for phosphorus. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Altamont New Reservoir watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001 and in the city of Altamont on December 6, 2001 and December 18, 2003. The Illinois EPA provided public notice for the December 18, 2003 meeting by placing display ads in the "Altamont News" on November 25, 2003 and "The Altamont Independent" on November 24, 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 68 individuals and organizations were also sent the public notice by first class mail. The draft TMDL Report was available for review at the Altamont Municipal Building city 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 Thursday, December 18, 2003. It was attended by approximately 22 people and concluded at 8:00 p.m. with the meeting record remaining open until midnight, January 20, 2004.

Questions and Comments

1. The city of Altamont owns the property surrounding the reservoir, and it is already in grassland. Was that taken into consideration?

Response: Yes, the land use coverage used for the model would have taken that into account. The report calls for quite a few acres of land to be put into filter strips. We understand, however, that there really isn't much that would qualify because many acres are already in grassland. Some of the upper ends of the tributaries wouldn't qualify for filter strips because the land is so flat. Conservation tillage practices would be a good means of slowing runoff.

2. The model used generalized information based on Effingham County data and applied that to this specific watershed. Wouldn't it have behooved you to come to the watershed and take actual data or use numbers that are different from Effingham County? That may have changed the results of the modeling. Most of Effingham County consists mostly of farmland; this watershed contains very little.

Response: The factors used in modeling pollutant loads from farmland were reviewed by local NRCS employees, and verified that they were applicable to this watershed.

3. The report mentions using aeration to control the internal cycling that occurs in the reservoir. The reservoir already has one aeration device. Does the amount of oxygen in the water affect how much phosphorus is available?

Response: Yes. A lack of oxygen in the water promotes the release of phosphorus from the sediments, making it available for algal growth.

4. If the samples are taken when the phosphorus levels are high and the oxygen levels are low, this would make a big difference in the data results. When were the water samples taken in the reservoir?

Response: Water quality data for this reservoir have been taken as part of Illinois EPA's Ambient Lake Monitoring Program since 1981. The data used for the TMDL analysis were from the years 1990-2001. Data for the Ambient Lake Monitoring Program are taken during the months of April through October. This ensures that samples are taken during the growing season, representing ambient conditions during the spring, summer, and fall months, not just during times when high nutrient results are expected to occur.

5. Is the Illinois EPA suggesting that farmers cut back on their phosphate usage? What percentage should they cut back?

Response: The report suggests that individual producers enroll in a nutrient management program to ensure that they are not over-applying fertilizers. The report does not give an across-the-board reduction of phosphorus application in the watershed.

6. The consultant was provided with some phosphorus data from local landowners. Was this data incorporated into the analysis?

Response: The consultant was given Bray P1 phosphorus data, but the data could not be converted into values for total phosphorus in soil. Therefore, the data could not be used in the model.

7. This reservoir is not used for anything other than as a source for drinking water. The Illinois EPA designates it as a public body of water, although the city does not allow swimming, and very little fishing is done. There is nothing wrong with the quality of the drinking water, so what was the reason for doing this study?

Response: The designated uses applied to the reservoir are established by federal law and state statues and include drinking water use, swimming, and recreational use. Specific water quality standards are set to protect these uses. If these standards are violated, the State is required to place that water body on a list of impaired waters, known as the 303(d) List. The Clean Water Act further dictates that states develop TMDLs for water bodies which fall onto that list.

8. The phosphorus impairment is a result of actions the city has no control over, yet the report directs the city to spend half a million dollars to dredge the reservoir.

Response: <u>All of the practices recommended in the Implementation Plan are voluntary</u>. Dredging the reservoir is listed as a possible option for removing the phosphorus-laden sediment from the reservoir, and the Agency recognizes the expense involved in implementing this practice. Installing a different or additional aeration system in the reservoir could be a more cost-effective means of reducing the available phosphorus and improving water quality. In addition, the report recommends the implementation of land management practices which prevent the transport of phosphorus into the reservoir.

9. The city owns the property surrounding the reservoir, and the farmers in the watershed are very conscientious and already do an excellent job, so I don't see how any of the recommended practices will do any good.

Response: Based on the data used for the modeling, the contribution of phosphorus from cropland is small (15 percent) compared to the amount caused by internal cycling (68 percent). That is why the Implementation Plan calls for the use of an aeration system in the reservoir, in order to suppress the release of phosphorus in the reservoir's sediment. It will take a combination of in-reservoir practices as well as best management practices on the land in order to reduce phosphorus by 84

percent. Neither the city of Altamont, nor the farmers in the watershed, are legally required to participate in any program identified in the Implementation Plan. The practices and programs specifically recommended in the TMDL report are all voluntary measures that could be taken to reduce the phosphorus load in the reservoir.

10. The SWCD have funds (approximately $1,000) that have been alotted to this particular watershed, as well as some additional funds, that can be applied to this watershed for conservation tillage and nutrient management plans. However, there have been recent issues related to processing the applications for the Nutrient Management Plans Program being offered by the Illinois Department of Agriculture. The department is currently working on streamlining the application process. Therefore, Nutrient Management Plans aren't going to be put on the docket, and will not be available this year for this watershed, but will be available next year. Cost share for no-till is still available.

Response: NRCS has an EQIP program available that can cost-share for nutrient management plans or no-till practices. Farmers who are interested in signing up for this program are encouraged to visit the county NRCS.

11. What about wildlife? The presence of ducks and geese can contribute to the phosphorus problem. Was this taken into consideration?

Response: The contribution of wildlife was not considered as a direct source in the modeling effort. However, wildlife and other natural conditions are taken into account through the Margin of Safety.

12. How long has it been since this reservoir was built, that it already has so much phosphorus in it? Does anyone have any data to show how much phosphorus was coming in when it was first built?

Response: Construction of the reservoir was completed in 1971. According to USEPA's Legacy STORET database, ambient water quality data were first taken in the reservoir in 1981. Violations of the total phosphorus water quality standard of 0.05 mg/L were first reported May 1, 1985, and have been seen almost every year since.

13: According to the report, two-thirds of the phosphorus is coming from within the reservoir, leaving only about a third coming from external sources. What will happen if all of the recommended measures are applied to the land, and nothing is reduced in the reservoir?

Response: Since most of the phosphorus is a result of internal cycling, it is likely the impairment would still exist, and the level of phosphorus in the water would not meet the 0.05 mg/L standard.

14. Employees at the water treatment plant were never aware that the reservoir was exceeding it's phosphorus standard. Was the phosphate standard recently lowered? Why wasn't this brought to our attention earlier?

Response: The current total phosphorus standard, 0.05 mg/L, has been in place since the early 1970s. Illinois EPA began publishing the 303(d) List of impaired waters in 1992, and only began developing TMDLs in 2000. The TMDL for this reservoir is based on the 1998 and 2002 303(d) Lists. Phosphorus impairments are not unusual and are fairly typical in lakes and reservoirs in Illinois and throughout the Midwest.

15. In the mid-1980s, the reservoir had to be treated for algae more than it does now. The phosphorus rates vary, depending on what time of season the samples are taken, due to runoff and lake turnover. The city would like to see the phosphorus loads reduced so employees won't have to be out there treating for the algae all the time during the summer.

Response: We concur that this would be a benefit to reducing phosphorus loading to the reservoir.

16. Why was USLE used in the modeling instead of RUSLE, which is currently use by NRCS? The sedimentation results of these two methods can vary by as much as 30 or 40 percent.

Response: The model is currently set up to only use USLE instead of RUSLE. RUSLE is used for figuring erosion on a field-by-field basis, whereas USLE is more appropriate for calculating erosion on a watershed basis, which is the focus of this TMDL.

17. What happens if all of the practices recommended in the report, both in the water and on land, are implemented and the reservoir still does not meet the phosphorus standard of 0.05 mg/l?

Response: As stated earlier, all of the recommended practices for this watershed are strictly voluntary in nature. If the standard is still violated after practices are implemented, the reservoir would remain on our 303(d) list of Impaired Waters. Illinois EPA is currently developing a suite of nutrient standards which we expect to propose within the next few years. The 0.05 mg/L total phosphorus may change somewhat, at which time the TMDL may need to be reviewed and adjusted accordingly. Once a water body is determined to be impaired, or after a TMDL is established for a water body, federal law states that there cannot be additional loadings to the receiving waters from permitted facilities. For example, if an entity in the watershed (such as a sewage treatment plant) wanted to discharge wastewater containing a phosphorus load, it would be prohibited by the Agency from doing so.

18. If someone were to purchase land in the watershed and wanted to pasture 15-20 head of livestock, would the agency prevent that from happening?

Response: No. The number of animals would have to be much larger before the Agency would get involved in regulating an animal operation, which it then has the authority to do based on laws regulating a Confined Animal Feeding Operation (CAFO). In the case of cattle, there would have to be a minimum of 300 feeder cattle and be designated as a CAFO due to i) a discharge to surface waters or ii) animals having access to surface waters, before the Agency would require the operation to apply for a permit. Although the operation would be regulated, the Agency would have no authority to determine the number of animals the operation can have.
Small animal feeding operations (those with less than 300 animal units, including the 15-20 head operation suggested in the question) can be designated a CAFO, but only after the Agency has visited the facility and determined that the operation is causing a violation of the water quality standard.

19. Other TMDL reports have discussed that decaying plant matter can contribute to the phosphorus level in water. This reservoir is surrounded by grass and cropland, so unless the decaying plant matter is removed, such as from hay and cropland, it will contribute phosphorus.

Response: The data taken from the land use coverage was used by the model and took into account the contribution of phosphorus from different land uses, including grassland, hayland, and cropland. The results of the modeling show that row crops and small grains combined contribute 15 percent of the phosphorus load, whereas grassland/hayland only contribute one percent of the load.

20. Should the grassland surrounding the reservoir be baled after it is cut to remove the decaying matter so it doesn't run off into the reservoir?

Response: While the practice of baling and removing the cut grass would certainly be beneficial, the overall impact this would have on load reductions in the reservoir are probably small, since grassland contributes such a small percentage of the load. The presence of grassland surrounding the reservoir is beneficial, since it acts as a filter and removes sediments and particulate from runoff coming directly into the reservoir.

21. How does aeration remove the phosphorus from the water?

Response: An aeration system in the lake will not remove phosphorus from the lake. Aerating the lake will prevent the release of phosphorus from the sediments and into the water column, thus making the phosphorus unavailable for algal growth. The only way to remove the phosphorus would be to dredge the lake, which is much more expensive than aeration.

22. Is there a way to distinguish between different types of phosphorus, so you can tell which one is causing the problem?

Response: Illinois EPA tests the water for dissolved phosphorus and total phosphorus. The standard is based on total phosphorus, which is what was used in the modeling.

23. What was the contribution of phosphorus from the dairy that is located in this watershed?

Response: Modeling results showed that the dairy contributes approximately 15 percent of the phosphorus load, which is equal to the amount contributed by all of the cropland.

24. Some of the acres immediately surrounding the reservoir are trees. Wouldn't the leaves contribute phosphorus to the reservoir?

Response: The leaves could contain a small amount of phosphorus, but mostly are composed of nitrogen. Removing the trees would not be desirable or recommended. What little phosphorus the leaves may contribute to the reservoir would be accounted for in the Margin of Safety.

25. The city already has an aerator in the reservoir, located near the dam. Where would be a good spot to put another one? Does the Agency have a certain type they recommend us using?

Response: The model is not designed to specify the type, size, or location of an aeration system in the reservoir. The city would need to research that option if it decides to install another aeration system. The Illinois State Water Survey or companies that sell and install these systems may be able to provide that information.

26. Are there any grants available that could help the city pay for another aeration system?

Response: Section 319 of the federal Clean Water Act provides states with funds that could be used to help pay for aeration. This grant program is administered by Illinois EPA, and is based on a 60-40 match.

27. The report states that the overall phosphorus load needs to be reduced by 84 percent. Even if all of the loads coming from cropland and the dairy were reduced to zero, there will still be loading from the internal cycling, which needs to be reduced by 90 percent. In reality, that seems to be asking to achieve an unachievable standard.

Response: The total phosphorus standard is set low to prevent nutrient enrichment and excessive algal growth from occurring in a lake or reservoir. As stated

previously, Illinois EPA is reviewing its nutrient standards. Part of this review will determine whether or not the current phosphorus standard is appropriate, or whether it needs to be changed. The studies and data analyzed for this TMDL should give a clearer picture as to what may be expected from this watershed.

28. How much lower could the phosphorus standard go?

Response: The USEPA has recommended the standard be set lower than the current 0.05 mg/L. However, Illinois EPA has decided to conduct its own study. At this time, the nutrient standards are still being developed, and probably won't be finalized for another three to five years.

29. The Altamont New Reservoir is part of Illinois EPA's Volunteer Lake Monitoring Program. Every so often we are asked to gather water quality samples. Since this reservoir is on the list of impaired waters, will we be required to collect more samples?

Response: No. The program operates on limited funds, so the water chemistry data collection effort at different lakes is rotated. However, Illinois EPA will continue to monitor this reservoir through its Ambient Lake Monitoring Program.

30. The use of STATSGO and a 90-meter resolution DEM for such a small watershed is not appropriate. Much more refined data and land use could have been obtained from the soil survey for Effingham County.

Response: No SURGO electronic soils data were available for the watershed. For the Altamont New Reservoir watershed, the hard-copy soil survey was digitized and resulting USLE factors were calculated. The results of this effort were compared to USLE factors generated using the STATSGO data and there was not a significant difference in the datasets to warrant use of the digitized data. Since STATSGO data were being used for other watersheds within the southern portion of the state for TMDL development, the consultant determined it would be best to be consistent with TMDL development in other watersheds.
90-meter DEMs were used for initial watershed delineation and were then verified using USGS topographic maps. In addition, the watershed delineation was compared to Illinois EPA's delineation of the watershed. 30-meter DEMs were used for USLE factor calculation. These were the most refined data available electronically at the time of model development. Physical survey data could have been conducted to establish more refined topography. This was not in the scope of this TMDL study. The land use data for the study were 30-meter resolution.

31. A Bray P1 test of 88 lb/acre exceeds the level of 70 lbs/acre at which Illinois NRCS practice standard 590, the University of Illinois Agronomy Handbook and the Illinois Department of Agriculture's nutrient management practice guidelines indicate that no additional phosphorus should be applied until additional soil tests are completed. These results suggest that producers have an opportunity to reduce costs and potential loadings of phosphorus to the reservoir.

Response: The average Bray P1 test for the watershed was 88 lb/acre. We agree that nutrient management could result in reductions of phosphorus to the reservoir as outlined in the report implementation section. The recommendations in the University of Illinois Agronomy Handbook have since been incorporated into the report.

32. It is not apparent how the "Potential Percent Reduction" values in Table 9.2 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.

33. Table 9.2 shows a potential reduction of 38 percent for "tillage practices" without specifying what residue levels would be required to achieve that reduction. 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 increase losses of dissolved phosphorus.

Response: The tillage practices category listed in Table 9.2 refers to conservation tillage practices, and the report has since been changed to reflect that. Section 9.2.2.5 on page 9-11 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". Although conservation tillage practices, such as no-till, can result in an increase in dissolved phosphorus runoff, the benefits gained from reductions in erosion and particulate phosphorus will decrease the loads of total phosphorus as well as sedimentation in the impaired water bodies.

34. 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: We concur with this statement and have outlined this as a future data collection need within a possible monitoring program in the Implementation Plan.

35. It would be more helpful to producers and providers of technical assistance within the watershed to provide more readily understandable information on the changes needed to reduce phosphorus loadings. For example, if it is believed that most of the phosphorus is moving with sediment and the current average soil loss within the watershed is estimated to be 4 tons per acre per year. Achieving a 38 percent reduction in phosphorus losses due to erosion would require that soil losses be reduced to an average of 2.4 tons/acre/year. Similarly, if the current average C-factor value for cropland in the watershed is 0.25, a reduction of 38 percent would require that the average value be 0.15. This approach would provide producers with a specific measurable goal rather than an indefinite "tillage practices".

Response: The required reductions in soil loss and C-factor were calculated during the analysis but not specifically stated in the text of the draft final report. These data have since been inserted into the text of the report for the convenience of producers and technical service providers.

36. 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.

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."

37. In Appendix D, Table D-2 shows K factors of 0.42 for "open water" and 0.37 for "shallow water wetland". Table D-4 shows LS factors of 0.29 for "open water" and 0.13 for "shallow water wetland". These values are not correct.

Response: We concur with this comment. These values should be zero, and the report has been changed to reflect that. However, these values do not impact the results of the modeling effort since these land uses were not used in the USLE analysis.