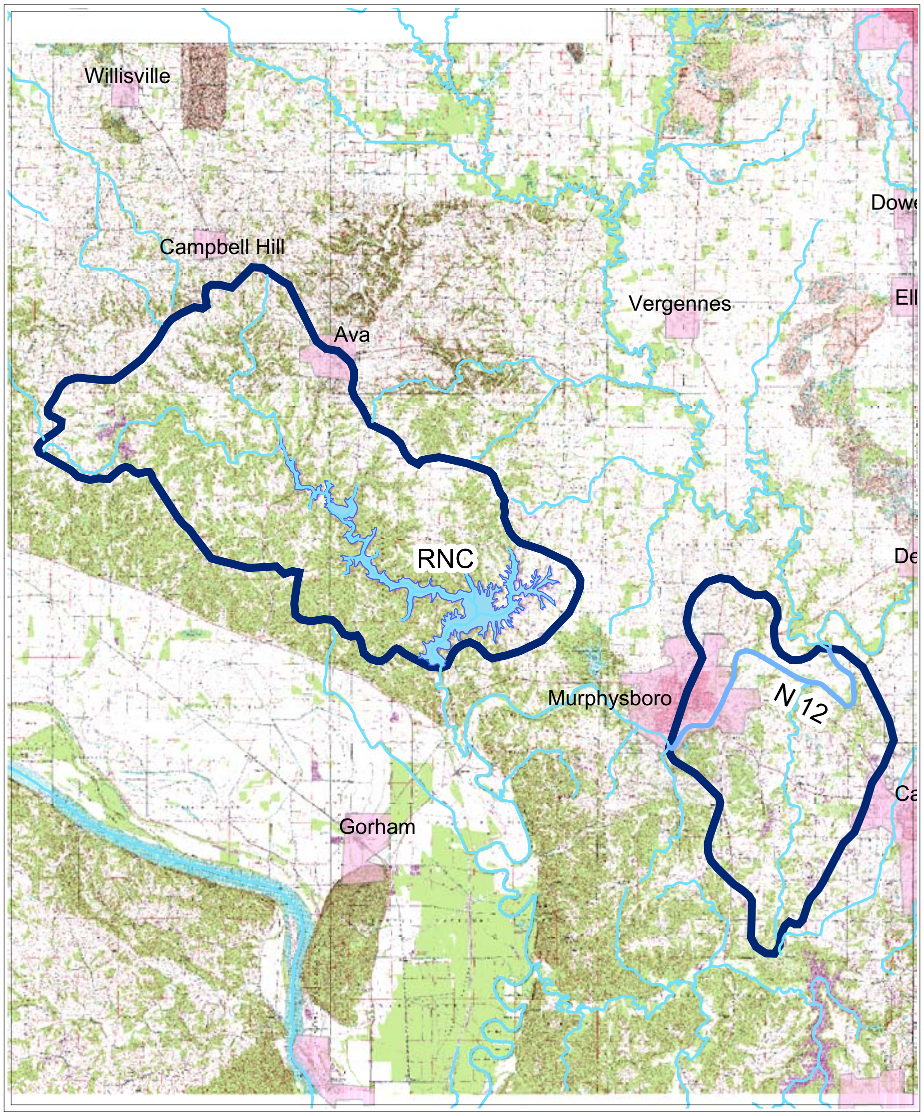
Illinois
Environmental
Protection Agency

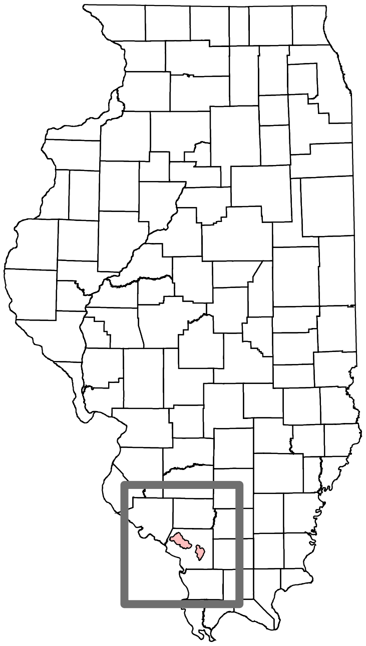
Bureau of Water
P.O. Box 19276
Springfield, IL 62794-9276

October 2004

IEPA/BOW/04-015

BIG MUDDY RIVER TMDL REPORT





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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
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REPLY TO THE ATTENTION OF:
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23 SEP 2004

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

Dear Ms. Willhite:

The United States Environmental Protection Agency (U.S. EPA) has conducted a complete review of the final Total Maximum Daily Loads (TMDLs) for phosphorus, manganese, and sulfate, including supporting documentation, for the Big Muddy River watershed, located in Jackson County, Illinois. Based on this review, U.S. EPA has determined that Illinois's TMDLs for these waterbodies meets the requirements of Section 303(d) of the Clean Water Act (CWA) and U.S. EPA's implementing regulations at 40 C.F.R. Part 130. Therefore, by this letter, U.S. EPA hereby approves three TMDLs for the Big Muddy River watershed as listed below:

Waterbody	Pollutant
Kinkaid Lake (RNC)	phosphorus
Big Muddy River (N12)	manganese, sulfate

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 these submitted TMDLs, and look forward to future quality TMDL submissions by the State of Illinois. If you have any questions, please contact Mr. Kevin Pierard, Chief of the Wetlands and Watersheds Branch at 312-886-4448.

Sincerely yours,

Jo Lynn Traub
Director, Water Division

Enclosure

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Parameter changes for developing TMDLs

In May 2001, Illinois EPA entered into a contract with Camp Dresser & McKee to develop Total Maximum Daily Loads (TMDL) for Big Muddy River (N12) and Kinkaid Lake. In the 1998 Section 303(d) List, Big Muddy River (N12) was listed as impaired for the following parameters: Manganese, cyanide, sulfates, nitrogen, pH, siltation, low dissolved oxygen (DO), total dissolved solids (TDS), and total suspended solids (TSS). Kinkaid Lake was initially listed as impaired for: Manganese, mercury, phosphorus, nitrogen, siltation, low DO, TSS, excessive algal growth, and chlorophyll-a.

Since then, new data assessed in 2002 showed that Big Muddy River (N12) is now impaired for manganese, sulfates, pH, low DO, and TSS. The listing of cyanide as a cause of impairment for Big Muddy River (N12) was done so in error and should not have been listed as such. New data assessed in 2002 for Kinkaid Lake showed it is now impaired only for pH, mercury, and siltation.

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, the TMDL for Big Muddy River (N12) will only focus on the parameters of manganese, sulfates, pH, and low DO, for which numeric water quality standards exist. Likewise, the TMDL for Kinkaid Lake will only focus on the parameter of pH. While the impairment caused by mercury is acknowledged, a TMDL will not be developed for it at this time, as mercury contamination is considered to be an interstate and international issue caused primarily by air deposition.

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

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Contents

Executive Summary

Section 1 Goals and Objectives for Big Muddy River Watershed (ILN12)

1.1 Total Maximum Daily Load (TMDL) Overview 1-1
1.2 TMDL Goals and Objectives for Big Muddy River Watershed 1-2
1.3 Report Overview 1-3

Section 2 Big Muddy River Watershed Description

2.1 Big Muddy River Watershed Overview 2-1
2.2 Stream Segment Site Reconnaissance of Big Muddy River Watershed 2-2
2.3 Lake Segment Site Reconnaissance of Big Muddy River Watershed 2-2

Section 3 Public Participation and Involvement

3.1 Big Muddy River Watershed Public Participation and Involvement 3-1

Section 4 Big Muddy River Watershed Water Quality Standards

4.1 Illinois Water Quality Standards 4-1
4.2 Designated Uses 4-1
4.3 Illinois Water Quality Standards 4-1
  4.3.1 pH 4-2
  4.3.2 Dissolved Oxygen 4-2
  4.3.3 Mercury 4-2
  4.3.4 Manganese 4-3
  4.3.5 Sulfates 4-3
  4.3.6 Parameters without Water Quality Standards 4-3
4.4 Pollution Sources 4-4
  4.4.1 Municipal Point Sources 4-4
  4.4.2 Agriculture 4-4
  4.4.3 Resource Extraction 4-5
  4.4.4 Contaminated Sediments 4-5
  4.4.5 Urban Runoff/Storm Sewers 4-6

Section 5 Big Muddy River 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 5-3
  5.1.5 Water Quality Data 5-3
    5.1.5.1 Kinkaid Lake Water Quality Data 5-5
      5.1.5.1.1 pH 5-6

- 5.1.5.1.2 Total Phosphorus 5-7
- 5.1.5.1.3 Chlorophyll "a" 5-8
- 5.1.5.1.4 Tributary Data 5-8
- 5.1.5.2 Big Muddy River Water Quality Data 5-8
  - 5.1.5.2.1 Manganese and Sulfates 5-8
  - 5.1.5.2.2 DO and TOC 5-9
  - 5.1.5.2.3 pH and TDS 5-10
- 5.1.6 Land Use 5-10
- 5.1.7 Point Sources and Animal Confinement Operations 5-12
  - 5.1.7.1 Coal Mines and Oil and Gas Fields 5-12
  - 5.1.7.2 Animal Confinement Operations 5-13
  - 5.1.7.3 Wastewater Treatment Plants 5-14
- 5.1.8 Soil Data 5-14
- 5.1.9 Cropping Practices 5-14
- 5.1.10 Reservoir Characteristics 5-15
- 5.1.11 Septic Systems 5-15
- 5.1.12 Aerial Photography 5-16

Section 6 Methodologies and Models to Complete TMDLs for the Big Muddy River

- 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 Kinkaid Lake TMDL 6-7
  - 6.2.4 Stream TMDLs for the Big Muddy River Watershed 6-7
  - 6.2.5 Calibration and Validation of Models 6-7
  - 6.2.6 Seasonal Variation 6-8
  - 6.2.7 Allocation 6-8
  - 6.2.8 Implementation and Monitoring 6-9

Section 7 Model Development for Kinkaid Lake

- 7.1 Basis for pH TMDL 7-1
- 7.2 Model Overview 7-1
- 7.3 Model Development and Inputs 7-2
  - 7.3.1 Watershed Delineation 7-2
  - 7.3.2 GWLF Inputs 7-3
    - 7.3.2.1 Transport Data File 7-3
      - 7.3.2.1.1 Land Use 7-3
      - 7.3.2.1.2 Land Use Area 7-4
      - 7.3.2.1.3 Curve Number 7-4

7.3.2.1.4 KLSCP 7-5
7.3.2.1.5 Erosivity Coefficient 7-7
7.3.2.1.6 Evapotranspiration (ET) Cover Coefficient 7-7
7.3.2.1.7 Recession Constant 7-7
7.3.2.1.8 Seepage Constant 7-7
7.3.2.1.9 Sediment Delivery Ratio 7-7
7.3.2.2 Nutrient Data File 7-8
7.3.2.3 Weather Data File 7-9
7.3.3 BATHTUB Inputs 7-9
7.3.3.1 Global Inputs 7-10
7.3.3.2 Reservoir Segment Inputs 7-10
7.3.3.3 Tributary Inputs 7-11
7.4 Model Calibration and Verification 7-11
7.4.1 GWLF Calibration 7-11
7.4.2 BATHTUB Comparison with Observed Data 7-13

Section 8 Total Maximum Daily Load for Kinkaid Lake Watershed

8.1 TMDL Endpoints for Kinkaid Lake 8-1
8.2 Pollutant Sources and Linkages 8-1
8.3 Allocation 8-2
8.3.1 Loading Capacity 8-3
8.3.2 Seasonal Variation 8-4
8.3.3 Margin of Safety 8-4
8.3.4 Waste Load Allocation 8-5
8.3.5 Load Allocation and TMDL Summary 8-5

Section 9 Implementation Plan for Kinkaid Lake

9.1 Implementation Actions and Management Measures 9-1
9.1.1 Nonpoint Source Phosphorus and pH Management 9-2
9.1.1.1 Conservation Tillage Practices 9-2
9.1.1.2 Wetlands 9-3
9.1.1.3 Filter Strips 9-4
9.1.1.4 Nutrient Management 9-5
9.1.2 Implementation Actions and Management Measures Summary 9-5
9.1.2.1 Kinkaid Lake Watershed 9-5
9.2 Reasonable Assurance 9-6
9.2.1 Available Programs 9-6
9.2.1.1 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project 9-7
9.2.1.2 Conservation Reserve Program (CRP) 9-7
9.2.1.3 Wetlands Reserve Program (WRP) 9-8

9.2.1.4 Environmental Quality Incentive Program (EQIP) 9-8
9.2.1.5 Conservation Practices Program 9-9
9.2.1.6 Wildlife Habitat Incentives Program (WHIP) 9-9
9.2.2 Cost Estimates of BMPs 9-10
9.2.2.1 Wetland 9-10
9.2.2.2 Filter Strips and Riparian Buffers 9-10
9.2.2.3 Nutrient Management Plan – NRCS 9-10
9.2.2.4 Nutrient Management Plan – IDA and Illinois EPA 9-10
9.2.2.5 Conservation Tillage 9-11
9.2.2.6 Planning Level Cost Estimates for Implementation Measures 9-11
9.3 Monitoring Plan 9-12
9.4 Implementation Time Line 9-13

Section 10 Methodology Development for the Big Muddy River Watershed

10.1 Methodology Overview 10-1
10.2 Watershed Delineation 10-2
10.3 Methodology Development and Results 10-2
10.3.1 Monte Carlo Analysis Development and Results 10-2
10.3.1.1 Monte Carlo Results for Big Muddy River Segment N12 10-3
10.3.2 DO Analysis Development and Results 10-3
10.3.3 pH Analysis Development and Results 10-9

Section 11 Total Maximum Daily Load for Big Muddy River Watershed

11.1 TMDL Endpoints for the Big Muddy River 11-1
11.2 Pollutant Source and Linkages 11-1
11.3 Allocation 11-1
11.3.1 Manganese and Sulfates TMDL 11-2
11.3.1.1 Loading Capacity 11-2
11.3.1.2 Seasonal Variation 11-2
11.3.1.3 Margin of Safety 11-2
11.3.1.4 Waste Load Allocation 11-3
11.3.1.5 Load Allocation and Summary TMDLs 11-3
11.3.2 DO TMDL 11-4
11.3.2.1 Loading Capacity 11-4
11.3.3 pH TMDL 11-4

Section 12 Implementation Plan for Big Muddy River Watershed

12.1 Implementation Actions and Management Measures for Manganese and Sulfates 12-1
12.1.1 Source Identification for Manganese and Sulfates 12-1

12.1.2 Manganese and Sulfates Management Measures 12-2
12.1.2.1 Aerobic Wetland 12-3
12.1.2.2 Compost or Anaerobic Wetland 12-3
12.1.2.3 Open Limestone Channels 12-3
12.1.2.4 Diversion Wells 12-3
12.1.2.5 Anoxic Limestone Drains 12-4
12.1.2.6 Vertical Flow Reactors 12-4
12.1.2.7 Pyrolusite Process 12-4
12.2 Implementation Actions and Management Measures for Dissolved Oxygen 12-4
12.2.1 DO Concentration Management 12-5
12.2.1.1 Filter Strips 12-5
12.2.1.2 Wetlands 12-7
12.2.1.3 Reaeration 12-8
12.3 Reasonable Assurance 12-8
12.3.1 Available Programs for Manganese and Sulfates TMDL 12-8
12.3.2 Available Programs for DO TMDL 12-9
12.3.2.1 Clean Water Act Section 319 Grants 12-9
12.3.2.2 Streambank Stabilization and Restoration Practice 12-9
12.3.2.3 Conservation Reserve Program 12-10
12.3.2.4 Wetlands Reserve Program 12-11
12.3.2.5 Environmental Quality Incentive Program 12-11
12.3.2.6 Wildlife Habitat Incentives Program 12-12
12.3.2.7 Illinois Department of Agriculture and Illinois EPA Nutrient Management Plan Project 12-13
12.3.3 Cost Estimates for BMPs 12-13
12.3.3.1 Streambank Stabilization 12-13
12.3.3.2 Filter Strips and Riparian Buffers 12-13
12.3.3.3 Planning Level Cost Estimates for Implementation Measures 12-13
12.4 Monitoring Plan 12-14
12.5 Implementation Time Line 12-15

Section 13 References

Appendices

Appendix A Historic Water Quality Data
Appendix B Directory of Coal Mines for Jackson County, Illinois May 4, 2002
Appendix C GWLF and BATHTUB Input and Output Files
Appendix D GWLF Manual
Appendix E Calculation Details
Appendix F Crop Management "C" Factor Values for Rainfall E.I. Distribution Curve #19
Appendix G Metalimnion Charts
Appendix H Sensitivity Analysis – BATHTUB Output Files
Appendix I Reduction Analyses – BATHTUB Output Files
Appendix J Monte Carlo Analyses
Appendix K Rating Curve for Depth
Appendix L Streeter-Phelps Analyses
Appendix M Error Analyses
Appendix N Chart of Activity Coefficients versus Ionic Strength
Appendix O pH Analyses
Appendix P Responsiveness Summary

Figures

1-1 Big Muddy River #1 Watershed (ILN12) Impaired Water Bodies 1-5
5-1 Big Muddy River #1 Watershed Historic Flow and Water Quality Gages 5-17
5-2 Estimated Streamflow Upstream of Kinkaid Lake Calculated from Gage 05595820 5-19
5-3 Flows in the Big Muddy River Segment N12... 5-21
5-4 Manganese Concentrations and Flows in Big Muddy River Segment N12... 5-23
5-5 Sulfate Concentrations and Flows in Big Muddy River Segment N12 5-23
5-6 pH Histogram for Segment N12 in the Big Muddy River 5-25
5-7 Coal Mines in the Big Muddy River #1 Watershed...................................... 5-27
5-8 Animal Management Facilities in the Kinkaid Lake Watershed 5-29
5-9 Animal Management Facilities in the Big Muddy River #1 Watershed........ 5-31
7-1 Relationship between pH and Chlorophyll "a" at Kinkaid Lake Station RNC-1 7-15
7-2 Relationship between pH and Chlorophyll "a" at Kinkaid Lake Station RNC-3 7-17
7-3 Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" at Kinkaid Lake Station RNC-1 7-19
7-4 Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" at Kinkaid Lake Station RNC-3 7-21
7-5 Kinkaid Lake Watershed, Historic Sampling Locations, and Modeling Divisions 7-23
7-6 Kinkaid Lake Inflows Subbasin 1 Monthly Flow Comparison 7-25
7-7 Dissolved and Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Kinkaid Lake........ 7-27
10-1 Big Muddy River #1 Watershed and Historic Sampling Locations 10-11
10-2 Flow versus Maximum H+ Ion Loading at a Constant pH of 6.5 10-13
11-1 Flow versus Maximum H+ Ion Loading for Segment N12 of the Big Muddy River 11-7

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Tables

2-1 Impaired Water Bodies in Big Muddy River Watershed 2-1
4-1 Summary of General Use Water Quality Standards for Big Muddy River Watershed 4-2
4-2 Summary of Potential Sources of Pollutants 4-4
5-1 Historical Precipitation Data for the Big Muddy River Watershed (NDCD 2002) 5-3
5-2 Average Monthly Precipitation in Jackson County from 1985 to 2001 5-3
5-3 Historic Water Quality Stations in the Big Muddy River Watershed 5-4
5-4 Summary of Constituents Associated with Potential Impairments for Big Muddy River Segments N12 and RNC (USEPA 2002b and Illinois EPA 2002) 5-5
5-5 Average pH (s.u.) Values in Kinkaid Lake 5-6
5-6 Average Total Phosphorus Concentrations (mg/L) in Kinkaid Lake at One-Foot Depth (USEPA 2002b and Illinois EPA 2002) 5-7
5-7 Average Chlorophyll "a" Concentrations (µg/L) in Kinkaid Lake (USEPA 2002b and Illinois EPA 2002) 5-8
5-8 Summary of Constituents Associated with Potential Impairments for the Big Muddy River Segment N12 5-9
5-9 Existing DO and TOC Water Quality Data and TMDL Endpoints 5-9
5-10 DO Sampling Events and Associated Flow Values 5-10
5-11 Existing pH and TDS Water Quality Data and TMDL Endpoints 5-10
5-12 Critical Trends Assessment Land Uses in Kinkaid Lake (IDNR 1996) 5-11
5-13 Land Use for Segment N12 Watershed 5-11
5-14 Comparison of Land Use Classes in the Kinkaid Lake Watershed 5-12
5-15 Wastewater Treatment Plants within N12 Watershed 5-14
5-16 Tillage Practices in the Kinkaid Lake Watershed (NRCS 2002a) 5-15
5-17 Average Depths in Feet for Kinkaid Lake 5-15
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 7-6
7-3 Critical Trends Land Assessment Land Uses and C Factors 7-6
7-4 Sediment Delivery Ratios in Kinkaid Lake Watershed 7-7
7-5 Dissolved Phosphorus Concentrations in Runoff from the Kinkaid Lake Watershed 7-8

7-6 Percentage of Agricultural and Forest Lands and Groundwater Phosphorus Concentrations in the Kinkaid Lake Watershed (Haith et al. 1996) 7-9
7-7 Annual Precipitation in Jackson County 7-9
7-8 Average Total Phosphorus Concentrations in Kinkaid Lake (mg/L) over All Depths 7-10
7-9 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Kinkaid Lake Watershed 7-12
7-10 Kinkaid Lake Calibration Sensitivity Analysis 7-13
8-1 Modeled Total Phosphorus Load by Source 8-2
8-2 Allowable Total Phosphorus Load by Model Year for Kinkaid Lake 8-3
8-3 Predicted Total Phosphorus, Chlorophyll "a," and pH Values in Kinkaid Lake 8-3
8-4 TMDL Summary for Total Phosphorus in Kinkaid Lake 8-5
8-5 Sources for Total Phosphorus Reductions 8-5
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 9-8
9-4 Local NRCS and FSA Contact Information 9-10
9-5 Cost Estimate of Various BMP Measures in Jackson County 9-11
9-6 Cost Estimate of Implementation Measures for Kinkaid Lake Watershed 9-11
10-1 LTA Manganese and Sulfates Concentrations Required to Meet Water Quality Standards in Big Muddy River Segment N12 10-3
10-2 Data Availability from 1990 to 2000 10-4
10-3 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations 10-8
11-1 TMDL Endpoints and Average Observed Concentrations for Impaired Constituents in the Big Muddy River Watershed 11-1
11-2 Average Loads Based on LTA for Manganese and Sulfates 11-2
11-3 TMDL Summary for Manganese and Sulfates 11-3
11-4 LTAs Required Based on TMDL MOS 11-3
11-5 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO 11-4
11-6 Calculated BOD_5 Loads and Required Loads in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO 11-4
12-1 Filter Strip Flow Lengths Based on Land Slope 12-6
12-2 Costs for Enrollment Options of WRP Program 12-11
12-3 Local NRCS and FSA Contact Information 12-13

12-4 Cost Estimate of Various BMP Measures in the Big Muddy River Watershed 12-14
12-5 Cost Estimate of Implementation Measures for the Big Muddy Watershed 12-14

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Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
μg/L	micrograms per liter
ALMP	Ambient Lake Monitoring Program
AMLRD	Abandoned Mined Lands Reclamation Division
AS	acute standard
AWQMN	Ambient Water Quality Monitoring Network
BMP	best management practice
BOD	biochemical oxygen demand
BOD$_5$	5-day biochemical oxygen demand
CBOD$_{20}$	20-day carbonaceous biochemical oxygen demand
CBOD$_5$	5-day carbonaceous biochemical oxygen demand
CCC	Commodity Credit Corporation
cfs	cubic feet per second
CO$_2$	carbon dioxide
CRP	Conservation Reserve Program
CS	chronic standard
CWA	Clean Water Act
DEM	Digital Elevation Model
DO	dissolved oxygen
EQIP	Environmental Quality Incentive Program
ET	evapotranspiration
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
KAWP	Kinkaid Area Watershed Project, Inc.
KDEP	Kentucky Department of Environmental Protection
kg/km^2-yr	kilograms per kilometer squared per year

LA	Load Allocation
LC	Loading Capacity
LTA	long-term average
MBI	Macroinvertebrate Biotic Index
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MOS	Margin of Safety
NASS	National Agricultural Statistics Service
NCSU	North Carolina State University
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resource Conservation Service
NWIS	National Water Inventory System
PBT	persistent, bioaccumulative toxic (chemical)
PDEP	Pennsylvania Department of Environmental Protection
ppm	parts per million
SOD	sediment oxygen demand
SSRP	Streambank Stabilization and restoration Practice
STATSGO	State Soil Geographic (database)
STORET	Storage and Retrieval (USEPA database)
TDS	total dissolved solids
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geographical Survey
WERF	Water Environment Research Foundation
WHIP	Wildlife Habitat Incentives Program
WLA	Waste Load Allocation
WRP	Wetlands Reserve Program
WWTP	wastewater treatment plants

Executive Summary
Big Muddy River Watershed

TMDL Fact Sheet

Watershed Name:	Kinkaid Lake	Big Muddy River
Impaired Segments:	RNC	N12
Location:	Jackson County, Illinois	Jackson County, Illinois
Size:	2,350 acres at normal storage	8.0 miles
Primary Watershed Land Uses:	Forest, grassland, and agriculture	Forest, grassland, and agriculture
Criteria of Concern:	pH and Mercury	Manganese, sulfates, pH, and DO
Designated Uses Affected:	General use	General use
Environmental Indicators: ***General use and public and food processing water supply***	pH monitoring	Manganese, sulfates, pH and DO monitoring
Major Sources:	Nonpoint from agriculture	Potentially contaminated groundwater, stagnant stream conditions, elevated instream temperatures, and nonpoint source loading from agriculture
Loading Capacity:	13,983 pounds/year total phosphorus	Mn = 2,244 lbs/day Sulfate = 1,163,422 lbs/day pH = No Allocation DO = No allocation
Waste Load Allocation:	Zero; No point sources	No Allocation
Margin of Safety:	Implicit through conservative modeling; additional explicit of 10 percent	Implicit through data selected for development of TMDL; additional explicit of 10 percent

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

A correlation between pH and total phosphorus was established for Kinkaid Lake, and modeling demonstrates a reduction of 43 percent total phosphorus necessary so that pH water quality standards can be achieved. Primary sources of phosphorus loading to Kinkaid Lake include runoff from agricultural lands. Procedures outlined in the implementation plan to decrease phosphorus loading to the lake include measures applied to the watershed to control nutrients in surface runoff and eroded sediment. Watershed controls include filter strips and wetlands to prevent phosphorus in surface runoff from reaching the lake, conservation tillage to decrease nutrient-rich soil erosion from agricultural fields, and development of nutrient management plans to ensure that excess phosphorus is not applied to agricultural fields.

The TMDLs for manganese and sulfates in Big Muddy River segment N12 was based on analyses performed in a Monte Carlo simulation. The simulation for manganese showed a manganese reduction of 70 percent necessary to achieve water quality standards. Results of the Monte Carlo simulation for sulfates showed a 62 percent reduction for segment N12 necessary to achieve the water quality standard. The potential source of manganese and sulfates in the Big Muddy River Watershed is contaminated groundwater. The groundwater is potentially contaminated by abandoned coal mines; however, further source identification is recommended. Confirmation that abandoned mines are a source of manganese and sulfates in the watershed would require reclamation of the mines. Passive treatment for mine reclamation is recommended.

The TMDL analysis for DO in Big Muddy River segment N12 was made through investigation of the relationship between DO, total organic carbon (TOC), 5-day biochemical oxygen demand (BOD5), and reaeration in the creek. The likely source of DO impairments in the segment is primarily a lack of aeration caused by stagnant stream conditions and elevated instream temperatures. BOD loadings in runoff from nonpoint source loads may also contribute to DO impairments. However, examination of BOD in the stream segment showed that the concentrations of BOD are low and likely represent ambient conditions in the stream; therefore, reductions in BOD concentrations are not recommended at this time. Due to data limitations and technical considerations of implementation difficulties, a load allocation cannot be developed for reaeration or temperature, so allocations were not developed for segment N12. Procedures to alleviate low DO caused by slow-moving waters can be addressed with in-stream mitigation methods such as reaeration. Additionally, riparian buffer strips aid in decreasing instream temperatures, which could help to alleviate the DO impairment. Excess nutrients can cause excessive algal growth that can also deplete DO in streams; however, analytical tools were not used to assess nutrients, algae, and DO as no algal data was available for Big Muddy River segment N12. Methods to control nutrients were still included in the implementation plan, such as buffer strips along the stream banks, which are similar to filter strips in their ability to remove nutrients from surface runoff. The potential contributions to BOD from nonpoint source loads are attributed to agricultural land uses requiring mitigation methods to control nutrients in sediment erosion and surface runoff from the land contributing to segment N12. These methods include filter strips, wetlands, conservation tillage, and nutrient management plans as discussed above.

The analysis for pH was based on hydrogen ion concentrations and the three-year flow observed in Big Muddy River segment N12. Analysis showed that the existing average hydrogen ion concentration was below the allowable loading, so allocations were not developed for pH in segment N12 at this time. Although an allocation was not developed, mitigation measures for manganese, sulfates, and DO will help control pH in Big Muddy River segment N12.

Section 1
Goals and Objectives for Big Muddy River Watershed (ILN12)

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

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

1.2 TMDL Goals and Objectives for Big Muddy River Watershed

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

- Big Muddy River (N12)
- Kinkaid Lake (RNC)

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

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

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

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

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

These elements are combined into the following equation:

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

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

1.3 Report Overview

The remaining sections of this report contain:

- **Section 2 Big Muddy River Watershed Description** provides a description of the impaired water bodies and general watershed characteristics.
- **Section 3 Public Participation and Involvement** discusses public participation activities that occurred throughout the TMDL development.
- **Section 4 Big Muddy River Watershed Water Quality Standards** defines the water quality standards for the impaired water bodies. Pollution sources will also be discussed in this section.
- **Section 5 Big Muddy River Watershed Data Review** provides an overview of available data for the Big Muddy River Watershed.
- **Section 6 Methodologies to Complete TMDLs for the Big Muddy River Watershed** discusses the models and analyses needed for TMDL development.
- **Section 7 Model Development for Kinkaid Lake** provides an explanation of model development for Kinkaid Lake.
- **Section 8 Total Maximum Daily Load for the Kinkaid Lake Watershed** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 9 Implementation Plan for Kinkaid Lake** provides methods to reduce loadings to impaired water bodies.
- **Section 10 Methodology Development for Big Muddy River** describes the analytical procedures used to examine Big Muddy River.
- **Section 11 Total Maximum Daily Load for Big Muddy River** discusses the allowable loadings to water bodies to meet water quality standards and the reduction in existing loadings needed to meet allowable loads.
- **Section 12 Implementation Plan for Big Muddy River** provides methods to reduce loadings to impaired water bodies.
- **Section 13 References** lists references used in this report.

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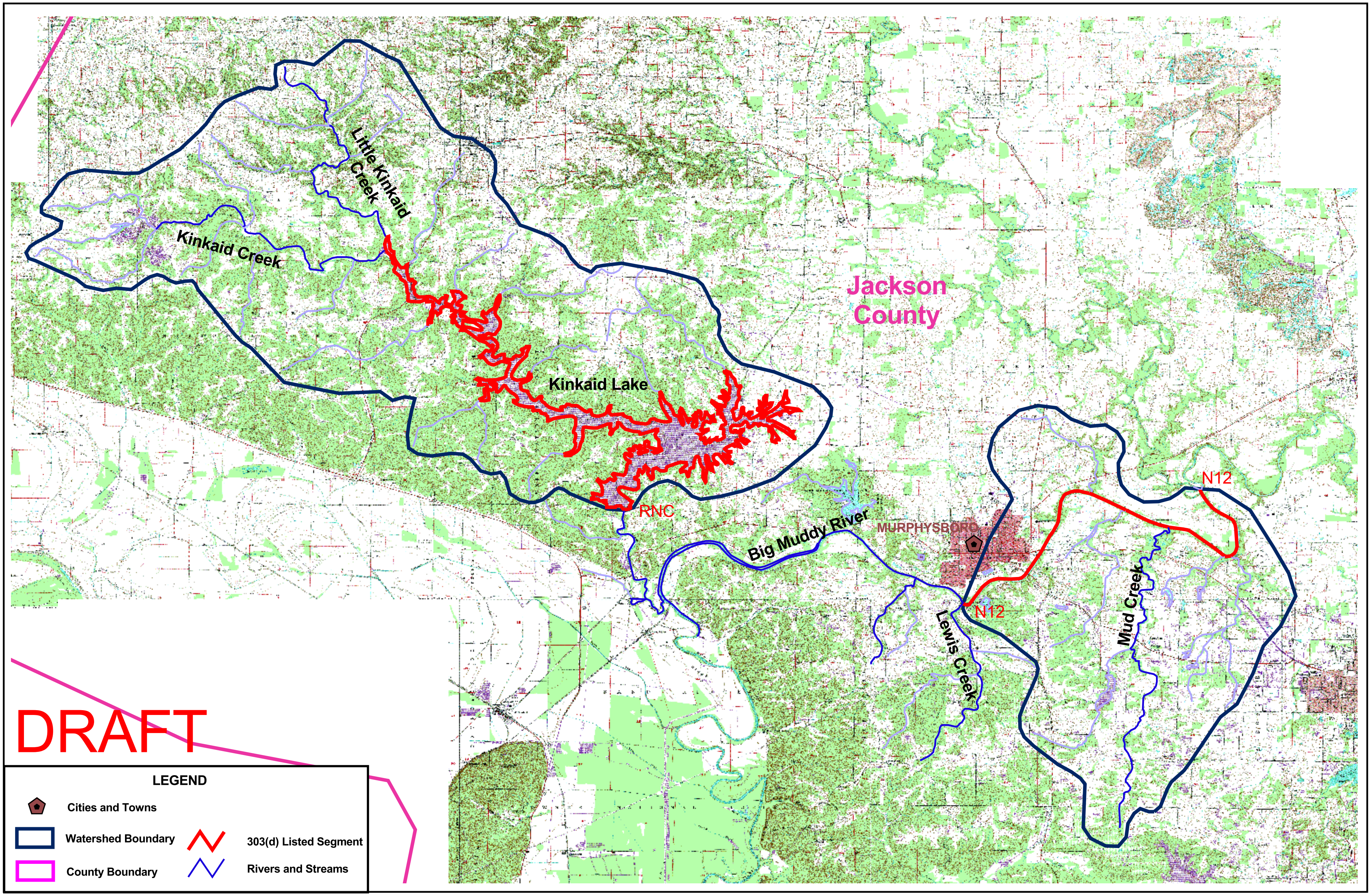

Figure 1-1
Big Muddy River #1 Watershed (ILN12)
Impaired Water Bodies

CDM

iepa/gis_data/apr/bigmuddy1.apr 032903

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Section 2
Big Muddy River Watershed Description

2.1 Big Muddy River Watershed Overview

The Big Muddy River originates in Jefferson County and flows southward. It then flows west towards Kinkaid Lake in Jackson County. Kinkaid Lake is located in Jackson County where the flow moves east towards the Big Muddy River. Big Muddy River segment N12 is located entirely in Jackson County. The entire Big Muddy River watershed, including Kinkaid Lake and all tributaries to Big Muddy River, encompasses an area of approximately 200 square miles and is located in the U.S. Geological Survey (USGS) Big Muddy Basin (Hydrologic Unit Code [HUC] 07140106). Figure 1-1 shows the impaired river and lake segments within the watershed. Impaired segments are shown in red. Table 2-1 lists the water body segments, water body size, and potential causes of impairment for each water body.

Table 2-1 Impaired Water Bodies in Big Muddy River Watershed

Water Body Segment ID	Water Body Name	Size	Potential Causes of Impairment
N12	Big Muddy River	8 miles	Manganese, sulfates, pH, dissolved oxygen (DO)
RNC	Kinkaid Lake	3,475 acres	pH, mercury

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 forested followed by rural grassland and agricultural land uses. Farmers in the area primarily raise cash crops, such as corn and soybeans.

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

The climate in Big Muddy River Watershed is cold in the winter and warm in the summer. In the winter, October through March, the average temperature is 43 degrees Fahrenheit (°F) and the average daily minimum temperature is 32°F, according to data collected at DuQuoin, Illinois. Summer temperatures are typically 70°F with an average daily maximum of 82°F. Annual precipitation is 46 inches, of which 25 inches, approximately 54 percent, usually falls in April through September (NCDC 2002).

2.2 Stream Segment Site Reconnaissance of Big Muddy River Watershed

The project team conducted a site reconnaissance of the Big Muddy River Watershed on June 19, 2001. This section briefly describes the stream segment and the site reconnaissance.

Table 2-1 lists the impaired stream segments in the Big Muddy River Watershed. Based on the 1998 303(d) list, Illinois EPA determined that one segment of Big Muddy River was impaired, Segment N12. This segment is shown in Figure 1-1. Segment N12 flows from roughly east to west, and includes a large bend to the south. The segment is located entirely in Jackson County, Illinois.

2.3 Lake Segment Site Reconnaissance of Big Muddy River Watershed

The project team visited one site on Kinkaid Lake during the site reconnaissance of the Big Muddy River Watershed on June 19, 2001. This section briefly describes a lake segment and the site reconnaissance.


Kinkaid Lake at Illinois Rt. 151 crossing.

Illinois EPA has listed one lake segment as impaired based on 1998 303(d) list data in the Big Muddy River Watershed. Kinkaid Lake, Segment RNC, is located on Kinkaid Creek in eastern Jackson County as shown in Figure 1-1. Crissenberry Dam was constructed on Kinkaid Creek in 1972. The dam is owned by the IDNR. The dam structure is 980 feet in length and 96 feet tall enabling it to store a maximum of 153,000 acre-feet, although the normal storage volume is 78,500 acre-feet. The lake is used for both recreation and a water supply (U.S. Army Corps of Engineers [USACE] 1999). The drainage area of Kinkaid Lake is approximately 62 square miles and is fed by Kinkaid, Little Kinkaid, Spring and Johnson Creeks.

Kinkaid Lake was observed from the Boat Access at Marina Road. The spillway was also observed, although the lake was not visible from the bottom of the spillway. Kinkaid Lake is a recreational area with both boating and swimming. A marina houses several boats at the lake. The spillway from Kinkaid Lake is a natural rock formation with a few enhancements, and was busy with swimmers and anglers at the time of observation.


Kinkaid Lake spillway.

Section 3
Public Participation and Involvement

3.1 Big Muddy River Watershed Public Participation and Involvement

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

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Section 4
Big Muddy River Watershed Water Quality Standards

4.1 Illinois Water Quality Standards

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

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

4.2 Designated Uses

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

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

4.3 Illinois Water Quality Standards

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

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

Parameter	**General Use Water Quality Standard**
pH	6.5 to 9.0
DO	Greater than 5.0 milligrams per liter (mg/L) Greater than 6.0 mg/L (16 hours of any 24-hour period)
Phosphorus	0.05 mg/L Lakes/reservoirs >20 acres and streams entering lakes or reservoirs
Mercury	AS = 2.6 micrograms per liter (µg/L) CS = 1.3 µg/L
Manganese	1.0 mg/L
Sulfates	500 mg/L

4.3.1 pH

The parameter pH is listed as a cause of impairment for the Big Muddy River segment N12. The General Use water quality standard for pH is a range with a minimum of 6.5 and maximum of 9.0. This is with the exception of pH levels outside this range due to natural causes.

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

4.3.2 Dissolved Oxygen

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

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

4.3.3 Mercury

Mercury is listed as a cause of impairment for Kinkaid Lake. The General Use water quality standard for mercury is based on an acute standard (AS) and chronic standard (CS). The AS for mercury is 2.6 µg/L and the CS is 1.3 µg/L.

Mercury is listed as a cause of less than full support use attainment in lakes and reservoirs if there is at least one General Use water quality violation based on ALMP or ICLP data. Mercury is also listed as a cause of less than full support if the sediment concentration is 0.701 milligrams per kilogram (mg/kg) or higher based on dry weight, or if there have been fish advisory reports due to mercury.

4.3.4 Manganese

Manganese is listed as a cause of impairment for Big Muddy River segment N12. The General Use water quality standard for manganese is 1.0 mg/L and is based on total manganese. Manganese is listed as a cause of less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data, or at least one violation determined from the most recent basin survey or facility survey data. Manganese is also listed as a cause of less than full support if there have been fish advisory reports due to manganese or the manganese concentration in the sediment is 2,800 mg/kg or higher (Illinois EPA 2000).

Manganese is listed as a cause of less than full support use attainment in lakes or reservoirs if there is at least one General Use water quality violation based on ICLP, or if the sediment concentration exceeds 2,800 mg/kg (M.B. Short 1997).

4.3.5 Sulfates

Sulfates are listed as a cause of impairment for the Big Muddy River. The General Use water quality standard for sulfates is 500 mg/L and the public and food processing water supplies standard is 250 mg/L. Sulfate is listed as a cause of a less than full support use attainment in streams if there is at least one General Use water quality violation based on the last three years of AWQMN data, or at least one violation from the most recent basin survey or facility survey data.

4.3.6 Parameters without Water Quality Standards

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

4.4 Pollution Sources

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

Table 4-2 Summary of Potential Sources of Pollutants

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

4.4.1 Municipal Point Sources

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

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

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

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

There are a total of 186 NPDES permits issued to dischargers in the Big Muddy River basin. A total of nine WWTPs discharge to the Big Muddy River mainstem, all downstream of Rend Lake. Four of these dischargers are considered major municipal dischargers (design average flow greater than one million gallons per day) (Muir et al. 1997). The point sources specific to the Big Muddy River N12 and Kinkaid Lake watersheds are discussed in Section 5.

4.4.2 Agriculture

The southern Illinois area is largely agriculture land use. Row crop agriculture is the largest single category land use in the basin. Agricultural land uses potentially contribute sediment, TSS, nutrients, and BOD loads to the water resource loading. The amount that is contributed is a function of the soil type, slope, crop management, precipitation, total amount of cropland, and the distance to the water resource (D.B. Muir, R.L. Hite, M.M. King, and M.R. Matson 1995).

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

4.4.3 Resource Extraction

Resource extraction consists of both active mining and abandoned mine lands. Runoff and discharges from mines can contain sulfates, salinity/total dissolved solids (TDS)/ chlorides, metals, TSS, and can affect the pH of the stream or lake. There are currently 47 permitted coal mines with 169 authorized discharges in the Big Muddy River basin. In addition, 1,177 inactive or abandoned mines have been identified. There are 4 pre-law inactive coal mines located in the Big Muddy River segment N12 Watershed and no permitted mines within the Kinkaid Lake Watershed. Mining is most concentrated in Beaucoup Creek, Galum Creek, Little Muddy River, Pond Creek, Hurricane Creek, and Rend Lake watersheds (Muir et al. 1997).

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

4.4.4 Contaminated Sediments

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

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

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

4.4.5 Urban Runoff/Storm Sewers

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

Section 5
Big Muddy River Watershed Data Review

5.1 Existing Data Review

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

- mapping data
- topography data
- flow data
- precipitation data
- temperature data
- 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 Kinkaid Lake and Big Muddy River impaired segment N12. A DEM is a digital representation of the landscape as a GIS-compatible grid in which each grid cell is assigned an elevation. DEMs of 90-meter resolution were downloaded from the *BASINS* database (USEPA 2002a) for watershed delineation. GIS watershed delineation defines the boundaries of a watershed by computing flow directions from elevations and locating elevation peaks on the DEM. The GIS-delineated watershed was checked against USGS 7.5-minute topographic maps to ensure agreement between the watershed boundaries and natural topographic boundaries. Figure 5-1 at the end of this section shows the location of historic flow and water quality gages for the Kinkaid Lake segment RNC and Big Muddy River segment N12 Watersheds and the boundaries for each watershed. The watershed boundaries define the area investigated for causes of impairments in each segment. Purple areas in Figure 5-1 represent features of the topographic maps that have been updated through aerial photography but have not been field verified.

The watershed for segment N12 only represents the area that drains directly to segment N12. Beaucoup Creek converges with the main stem of the Big Muddy River directly upstream of segment N12. The Big Muddy River segment directly downstream of segment N12 is also listed as full support. Sources of impaired constituents in Beaucoup Creek segment NC07 (upstream of segment N12) will be addressed separately. Therefore, the sources of impairments in segment N12 will focus on areas draining directly to the segment.

5.1.3 Flow Data

Analyses of the Kinkaid Lake and Big Muddy River Watersheds require an understanding of flow into Kinkaid Lake and through the Big Muddy River segment N12. A gage is located in segment N12; however, no gage for the tributaries to Kinkaid Lake exists. Therefore, the drainage area ratio method, represented by the following equation, was used to estimate flows into the lake.

$$\mathbf{Q}_{\mathbf{gaged}}\left(\frac{\mathbf{Area}_{\mathbf{ungaged}}}{\mathbf{Area}_{\mathbf{gaged}}}\right)=\mathbf{Q}_{\mathbf{ungaged}}$$

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 Mt. Vernon, Illinois) was chosen as an appropriate gage from which to compute flow into Kinkaid Lake. Gage 05595820 captures flow from a drainage area of 77 square miles in an upstream section of the Casey Fork Watershed, which is about 50 miles northeast of the Kinkaid Lake Watershed. Daily streamflow data for the gage were downloaded from the USGS National Water Inventory System (NWIS) for the entire period of record from October 1, 1985 to September 30, 2000 (USGS 2002a). Figure 5-2 at the end of this section shows the average monthly flows over the period of record into Kinkaid Lake calculated from the drainage area ratio method using gage 05595820.

USGS gage 05599500 (Big Muddy River at Murphysboro, Illinois) is located at the downstream end of segment N12 as shown in Figure 5-1. Gage 05599500 captures flow from a drainage area of approximately 2,169 square miles. Daily streamflow data for the gage were downloaded from the USGS NWIS for the entire period of record from January 1, 1972 to September 30, 2000 (USGS 2002a). Figure 5-3 at the end of this section shows the seasonal patterns of streamflow through segment N12 over the period of record. Flows are higher in the spring months of March through May. For Big Muddy River segment N12, average monthly flows range from 403 to 4,180 cubic feet per second (cfs) with a mean annual flow of 2,080 cfs. The 7Q10 flow (lowest average 7 consecutive day low flow with an average recurrence frequency of once in 10 years) is typically utilized as the critical low flow for NPDES permitting and is estimated to 55 cfs for segment N12 (ISWS 2000).

5.1.4 Precipitation, Temperature, and Evaporation Data

Two sites with historical temperature and precipitation data were identified in Jackson County through the NCDC database. The data from gage 1265 were used for analysis because the recent dataset was more complete than the data set from gage 5983. Fifteen months of data were missing from gage 1265 over the period from 1985 to 2001. Missing data were supplemented with data from the gage in neighboring Williamson County. Table 5-1 lists the station details for the Jackson County and Williamson County gages (NCDC 2002).

Table 5-1 Historical Precipitation Data for the Big Muddy River Watershed (NCDC 2002)

NCDC Gage Number	Station Location (Name)	Period of Record
5983	Jackson County (Murphysboro 2SW)	1948 to present
1265	Jackson County (Carbondale Sewage Plant)	1970 to present
5342	Williamson County (Marion 4NNE)	1948 to present

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

Month	Average Precipitation (inches)
January	3.2
February	3.2
March	3.6
April	4.5
May	4.9
June	5.3
July	3.0
August	3.5
September	3.5
October	3.1
November	4.8
December	3.5
Total	**46**

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

Pan evaporation data is available through the Illinois State Water Survey (ISWS) 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 60 miles northeast of the Kinkaid Lake and Big Muddy River Watersheds. 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

Twelve historic water quality stations exist within the Kinkaid Lake and Big Muddy River segment N12 watersheds and are presented in Table 5-3. This table provides the location, station identification number, and the agency that collected the water quality data. Location and station identification number are also shown in Figure 5-1.

Table 5-3 Historic Water Quality Stations in the Big Muddy River Watershed

Location	Station Identification Number	Data Collection Agency
Big Muddy River	N12	Illinois EPA Division of Water Pollution Control
Big Muddy River	05599500	USGS
Kinkaid Lake	05599540 RNC-1	USGS Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-2	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-3	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-4	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-5	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-6	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-7	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-8	Illinois EPA Division of Water Pollution Control Illinois EPA Volunteer Lake Monitoring
Kinkaid Lake	RNC-9	USEPA Region 5 Data

The impaired water body segments in the Big Muddy River Watershed were presented in Section 2. For Kinkaid Lake, segment RNC, there are 10 historic water quality stations. For Big Muddy River segment N12 there are two historic water quality stations listed in Table 5-3 and shown in Figure 5-1. The Kinkaid Lake stations beginning with "RN" have a concurrent period of record. Stations RN-A08-C-1 and 05590540 are positioned in the same place in Kinkaid Lake and have overlapping periods of record. The two stations in segment N12 are also located in the same place, but have different sampling periods. Table 5-4 summarizes available historic water quality data since 1990 from the USEPA S*torage and Retrieval (STORET*) database associated with impairments discussed in Section 2 for segments RNC and N12. Stations RNC-5 through RNC-9 are not included in Table 5-4 because their periods of record ended prior to 1990. Illinois volunteer lake monitoring data was not utilized in modeling efforts.

Table 5-4 Summary of Constituents Associated with Potential Impairments for Big Muddy River Segments N12 and RNC (USEPA 2002b and Illinois EPA 2002)

Sample Location and Parameter	Period of Record Examined for Samples	Number of Samples
Big Muddy River Segment N12; Sample Location 05599500		
Manganese	1/9/90-4/24/97	51
Sulfates	1/9/90-4/24/97	65
pH	1/9/90-4/24/97	102
DO	1/9/90-4/24/97	102
Big Muddy River Segment N12; Sample Location N12		
Manganese	10/27/97-9/6/00	27
Sulfates	11/20/97-9/6/00	25
pH	10/27/97-9/6/00	27
DO	10/27/97-9/6/00	27
Kinkaid Lake Segment RNC; Sample Location 05599540, RNC-1, RNC-2, RNC-3, RNC-4		
05599540		
pH	1/08/90-8/28/97	70
RNC-1		
pH	4/30/90-10/11/01	52
RNC-2		
pH	4/30/90-10/11/01	25
RNC-3		
pH	4/30/90-10/11/01	25
RNC-4		
PH	4/30/90-10/11/01	25

5.1.5.1 Kinkaid Lake Water Quality Data

There are four active water quality stations in Kinkaid Lake as shown in Figure 5-1 and listed in Table 5-4. The water quality station data for Kinkaid Lake were downloaded from the *STORET* online database for the years of 1977 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in Kinkaid Lake as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

The constituents of concern in Kinkaid Lake are pH and mercury. The mercury TMDL will be addressed in a regional TMDL by USEPA and will not be addressed at the state level. The regional TMDL will focus on air deposition of mercury. USEPA's strategy for addressing persistent, bioaccumulative toxic chemicals (PBT) is a two-track approach. The "fast track" involves actions that can be implemented immediately, including pollution prevention and the "virtual elimination" project. The "science track" includes the study and assessment of the problems and solutions through modeling, monitoring, and emission inventories. The "virtual elimination" project, a cooperative Canadian – U.S. strategy to virtually eliminate persistent toxic substances in the Great Lakes Basin (the Bi-national Strategy), seeks to achieve quantifiable reduction goals between now and 2005 for specific toxic substances, including mercury (USEPA 2003). Mercury is addressed by USEPA with these strategies; therefore, Illinois EPA does not address it as part of this TMDL.

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

5.1.5.1.1 pH

The average pH measurements at one-foot depth for each year of available data after 1990 at each monitoring site in Kinkaid Lake are presented in Table 5-5. At station RNC-1, samples were taken at one-foot depth from the lake surface and at the lake bottom. Samples at stations RNC-2, RNC-3, and RNC-4 were only taken at a one-foot depth from the lake surface. The TMDL endpoints for pH are a minimum of 6.5 and a maximum of 9.0. The annual averages at all three stations and the annual lake averages are all within the endpoint limits, but individual measurements in 1991, 1994, and 2000 exceeded the upper limit. Specifically, the pH value at station RNC-3 on July 9, 1991 was 9.1, and on July 12, 1994, the pH value was 9.1 at RNC-1. On June 5, 2000 and August 2, 2000, the pH value measured was 9.2 at RNC-1 and RNC-3, respectively. At gage 05599540, three values were below the lower limit for pH. On September 25, 1991 and January 11, 1996, the pH was recorded as 6.3, and on December 14, 1995, the pH was recorded as 6.2.

Table 5-5 Average pH (s.u.) Values in Kinkaid Lake

Year	RNC-1 and 05599540	RNC-2	RNC-3	RNC-4	Lake Average
1990	7.7	8.2	8.1	7.5	7.9
1991	7.7	8.1	8.2	7.6	7.9
1992	7.4				7.4
1993	8.0				8.0
1994	8.2	8.3	8.4	8.1	8.2
1995	7.2				7.2
1996	7.1				7.1
1997	7.7	7.9	7.9	7.4	7.7
2000	8.3	8.3	8.5	8.2	8.3

Fluctuations in pH can be correlated to photosynthesis from algae. Plants and algae use carbon dioxide (CO_2) during photosynthesis, which causes pH levels to rise. The photosynthetic rate progressively decreases as the residual CO_2 concentration declines and ceases completely with the extinction of light. During the night, reaeration and respiration replenish CO_2 causing the pH levels to decrease overnight (Welch 1980). Chlorophyll "a" indicates presence of excessive algal or aquatic plant growth. Reducing total phosphorus is likely to reduce algal growth thus resulting in attainment of the pH standard. Therefore, the relationship between pH, chlorophyll "a," and total phosphorus in Kinkaid Lake was investigated. The correlation between pH and chlorophyll "a" is expected to indicate a direct relationship between the two constituents. Likewise, the correlation between chlorophyll "a" and total phosphorus is expected to indicate a direct relationship. These relationships would suggest that controlling phosphorus will decrease chlorophyll "a" concentrations, which will in turn control the pH. This hypothesis is supported by Wetzel who asserts that photosynthesis and respiration are major influences on pH (1983).

5.1.5.1.2 Total Phosphorus

The average total phosphorus concentrations at one-foot depth for each year of available data from 1990 to 2000 at each monitoring site in Kinkaid Lake are presented in Table 5-6. At station RNC-1, samples were taken at a one-foot depth from the lake surface and at the lake bottom. Samples at stations RNC-2 and RNC-3 were only taken at a one-foot depth from the lake surface. The water quality standard for total phosphorus is less than or equal to 0.05 mg/L at one-foot depth. Additionally, multiple samples taken at one-foot depth since 1990 do violate the TMDL endpoint for phosphorus. It is apparent from Table 5-6 that concentrations at Station RNC-4 repeatedly violate the phosphorus standard. The raw data for all sample depths are contained in Appendix A.

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

Year	RNC-1 and 05599540	RNC-2	RNC-3	RNC-4	Lake Average
1990	0.06	0.01	0.02	0.09	0.05
1991	0.02	0.02	0.03	0.10	0.04
1992	0.02				0.02
1993	0.02		0.03		0.02
1994	0.03	0.02	0.04	0.14	0.06
1995	0.02				0.02
1996	0.03				0.03
1997	0.02	0.03	0.04	0.13	0.06
1998	0.03				0.03
2000	0.01	0.01	0.02	0.05	0.03

Phosphorus exists in water in either a particulate phase or a dissolved phase. Particulate matter includes living and dead plankton, precipitates of phosphorus, phosphorus adsorbed to particulates, and amorphous phosphorus. The dissolved phase includes inorganic phosphorus and organic phosphorus. Phosphorus in natural waters is usually found in the form of phosphates (PO_4 and PO_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.

5.1.5.1.3 Chlorophyll "a"

The average chlorophyll "a" concentrations for each year of available data from 1990 to 2001 at each active monitoring site in Kinkaid Lake are presented in Table 5-7. There was no chlorophyll "a" data available at station 05599540. The raw data for all sample depths are contained in Appendix A.

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

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1990	9.8	13.6	14.5	32.7	17.6
1991	9.0	10.5	17.1	43.1	19.9
1994	19.1	23.4	24.3	52.1	29.7
1997	13.2	19.4	27.5	48.9	27.3
1998	21.9				21.9
2000	18.4	12.7	16.4	38.0	21.4

5.1.5.1.4 Tributary Data

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

5.1.5.2 Big Muddy River Water Quality Data

There is one active and one historic water quality station in Big Muddy River segment N12 as shown in Figure 5-1. The water quality station data for segment N12 were downloaded from the *STORET* online database for the years of 1990 to 1998 (USEPA 2002b). Data collected after 1998 were available from the Illinois EPA and were incorporated into the electronic database. The data summarized in this section include water quality data for impaired constituents in the Big Muddy River segment N12 as well as constituents used in modeling efforts. The raw data are contained in Appendix A.

5.1.5.2.1 Manganese and Sulfates

Table 5-8 summarizes historical manganese and sulfates data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for impaired segments in the Big Muddy River Watershed. The raw historical water quality data are contained in Appendix A. For impairments on segment N12, the average of the data sets do not exceed the water quality standard for either manganese and sulfates. The historical water quality samples were also taken during months with historically varying flow conditions.

Table 5-8 Summary of Constituents Associated with Potential Impairments for the Big Muddy River Segment N12

Sample Location and Parameter	Endpoint (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum
Big Muddy River Segment N12; Sample Location 05599500					
Manganese	1.0	1/9/90-4/24/97; 51	0.6	2.5	0.1
Sulfates	500	1/9/90-4/24/97; 65	237	660	59
Big Muddy River Segment N12; Sample Location N12					
Manganese	1.0	10/27/97-9/6/00; 27	0.6	1.9	0.2
Sulfates	500	11/20/97-9/6/00; 24	285	653	68

Figures 5-4 and 5-5 (at the end of this section) show concentrations of manganese and sulfates, respectively, with corresponding flows in segment N12. Figures 5-4 and 5-5 exclude samples taken between October 1993 and September 1995 because flow data was unavailable for those months. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this analysis, about 75 percent of manganese samples and 88 percent of sulfates samples were taken at below average flow conditions. This suggests that most historical samples were taken under low flow conditions in segment N12 of the Big Muddy River Watershed. Analysis of impaired sample dates showed that more than half of the impaired samples were taken at below average flows.

5.1.5.2.2 DO and TOC

Table 5-9 summarizes the available historic DO and total organic carbon (TOC) data since 1990 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Big Muddy River segment N12 (raw data contained in Appendix A). TOC data are presented here because they are used in the DO analysis. The average DO concentration for segment N12 is above the water quality standard of 6.0 mg/L (16 hours of any 24-hour period), but the minimum values observed are less than the water quality standard of 6.0 mg/L.

Table 5-9 Existing DO and TOC Water Quality Data and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record Examined and Number of Data Points	Mean (mg/L)	Maximum (mg/L)	Minimum (mg/L)
Big Muddy River Segment N12; Sample Location 05599500					
DO	6.0 (16 hours of any 24-hour period)	1/9/90-4/24/97; 102	8.7	20.8	3.7
Big Muddy River Segment N12; Sample Location N12					
DO	6.0 (16 hours of any 24-hour period)	10/27/97-9/6/00; 25	7.7	12.4	4.7
TOC	–	10/27/97-9/6/00; 2	5.6	5.6	5.5

Historical flow data were presented in Section 5.1.3. The flow values during the historical sampling events for DO that had corresponding TOC measurements are presented in Table 5-10. The flow for each sample date was compared to the monthly average flow shown in Figure 5-3 for the month the sample was taken. Based on this comparison, the September 6, 2000 sample was taken at below average flows, and the

July 24, 2000 sample was taken at above average flows. Low flow values within the stream segment result in slow-moving waters, which could decrease the amount of aeration occurring in the stream. In addition, the day with DO impairment (September 6, 2000) occurred in a typically warm weather month. Elevated stream temperatures affect the aquatic environment by limiting the concentration of DO in the water column. For example, the DO concentration for 100 percent air saturated water at sea level is 14.6 mg O_2/L at 0 degrees Celsius (°C) (32°F) and decreases to 8.6 mg O_2/L at 25°C (77°F) (Brown and Brazier 1972).

Table 5-10 DO Sampling Events and Associated Flow Values

Sample Location	Date	Flow (cfs)	DO (mg/L)
Big Muddy River (N12)	7/24/00	2,060	7.9
Big Muddy River (N12)	9/6/00	400	4.7

5.1.5.2.3 pH and TDS

Table 5-11 summarizes the available historic pH data from 1990 to 2001 from the USEPA *STORET* database and recent data not yet entered into the *STORET* database for Big Muddy River segment N12 (raw data contained in Appendix A). Although the segment is not impaired for TDS, the data are used in the pH calculations. The average pH concentration for the segment is within the water quality boundaries of 6.5 and 9.0, but the minimum value observed is less than the water quality standard of 6.5.

Table 5-11 Existing pH and TDS Water Quality Data and TMDL Endpoints

Sample Location and Parameter	Endpoint (mg/L)	Period of Record and Number of Data Points	Mean	Maximum	Minimum
Big Muddy River Segment N12; Sample Location 05599500					
pH	6.5 - 9	1/9/90-4/24/97; 102	7.4	8.8	6.4
TDS	1,000	1/9/90-2/29/96; 16	620	2,010	197
Big Muddy River Segment N12; Sample Location N12					
pH	6.5 - 9	10/27/97-9/6/00; 25	7.1	8.1	6.4
TDS	1,000	7/24/00-9/6/00; 2	356	487	225

Figure 5-6 shows a histogram of pH values in Segment N12 of the Big Muddy River. This histogram illustrates that, based on historic data, three percent of the measured pH values in segment N12 violated the pH standard. The last violation occurred in August of 1998.

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 Kinkaid Lake and Big Muddy River segment N12 were used to obtain the land use from the Critical Trends Assessment Land Cover grid. Tables 5-12 and 5-13 list the land uses contributing to the Kinkaid Lake Watershed and the segment N12 watershed, as well as each land use area and percent of total area.

Table 5-12 Critical Trends Assessment Land Uses in Kinkaid Lake (IDNR 1996)

Land Use	Acres	Percent of Area
Deciduous Forest	21,597	56%
Rural Grassland (pastureland, grassland, waterways, buffer strips, CRP land, etc.)		
Pasture	2,977	8%
Grassland	5,953	16%
Row Crop (corn, soybeans, and other tilled crops)	3,576	9%
Open Water	2,703	7%
Small Grains (wheat, oats, etc.)	751	2%
Coniferous Forest	461	1%
Forested Wetlands	368	1%
Urban (high and medium density)	101	0%
Shallow Water Wetlands	61	0%
Shallow Marsh/Wetlands	27	0%
Urban Grassland	17	0%
Deep Marsh	7	0%
Barren Land	5	0%
Cattle Feedlot	6	0%
Total	38,610	100%

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

Table 5-13 Land Use for Segment N12 Watershed

Land Use	Area (Acres)	Percent of Total
Deciduous	7,164	39%
Rural Grassland	5,175	28%
Row Crop	1,989	11%
Urban Grassland	1,241	7%
Forested Wetland	813	4%
Medium Density	529	2.5%
Small Grains	491	2.5%
Orchard/Nurseries	297	2%
Open Water	292	2%
High Density	200	1%
Shallow Water/Wetlands	159	1%
Coniferous	27	0%
Shallow Marsh/Wetlands	16	0%
Low Density	11	0%
Swamp	3	0%
Deep Marsh	1	0%
Total	18,408	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 5-14 shows the cropland use classes of the

Cropland Data Layer and the Critical Trends Assessment classes to which they were applied.

Table 5-14 Comparison of Land Use Classes in the Kinkaid Lake Watershed

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

5.1.7 Point Sources and Animal Confinement Operations

5.1.7.1 Coal Mines and Oil and Gas Fields

Acid mine drainage from coal mines could contribute to manganese and sulfates concentrations in a watershed. Data from the Illinois Natural Resources Geospatial Data Clearinghouse was reviewed for coal mines, oil fields, and non-coal mines within the Big Muddy River Watershed from the following references (full citation provided in Section 13):

- Chenoweth, Cheri, 1998, Areas Mined for the Springfield (No. 5) Coal in Illinois
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 1
- Stiff, Barbara J., 1997, Areas Mined for Coal in Illinois - Part 2
- Coal Section, Illinois State Geological Survey, 1991, Point Locations of Active and Abandoned Coal Mines in Illinois
- Illinois Office of Mines and Minerals, 1998, Coal Mine Permits Boundaries in Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois
- Staff, ISGS, 1996, Non-coal Underground Mines of Illinois - Points
- Illinois State Geological Survey, not published, Oil and Gas Fields in Illinois

Figure 5-7 presents the findings from these databases for extraction operations in the Big Muddy River Watershed. Multiple coal mines were identified within the watershed and labeled on Figure 5-7. The mine names and dates of operation are listed in Appendix B. There are no permitted mines in this watershed, and a comparison of the existing and permitted mine databases suggests that non-permitted mines are likely abandoned or closed. No oil or gas fields or non-coal mines were located in the segment N12 Watershed; however, the non-coal mine database contains only 20 percent of the non-coal mines in Illinois due to the lack of a legal filing requirement.

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

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

As mentioned previously, the sampling data for manganese and sulfates, shown in Figures 5-4 and 5-5, were taken primarily under low-flow conditions. The figures show a decrease in concentrations with increases in flow indicating that groundwater is the potential source of these constituents. If the source of manganese and sulfates were due to surface runoff, an increase in concentrations would be expected with increased flows. The absence of exceedences of the water quality standards for manganese or sulfates at higher flows in the figures supports the conclusion that manganese and sulfates could have leached into the groundwater from pools within the mine sites and be the source of manganese and sulfates concentrations in segment N12. In addition, no data are available to assess the natural background of manganese and sulfates in the watershed. Natural background concentrations typically are attributed to what occurs naturally in groundwater due to mineral conditions of the soils (Water Environment Research Foundation [WERF] 1997).

5.1.7.2 Animal Confinement Operations

The Illinois EPA provided a GIS shapefile illustrating the location of livestock facilities in the Big Muddy River Basin, which contains Kinkaid Lake and Big Muddy River segment N12. The Illinois EPA assessed the potential impact of each facility on water quality with regard to the size of the facility, the site condition and management, pollutant transport efficiency, and water resources vulnerability. Two livestock facilities (cattle feedlots) were identified in the Kinkaid Lake watershed as shown in Figure 5-8. One of the feedlots was determined to have no impact on the receiving waters, and the other was determined to have a slight impact on receiving waters. Three animal management operations were located in the segment N12 watershed; two are designated as having no impact on receiving waters, and the third was not assessed. Figure 5-9 shows the animal management operations within the segment N12 Watershed.

5.1.7.3 Wastewater Treatment Plants

Table 5-15 lists the wastewater treatment facilities within the N12 watershed. No point sources were located within the Kinkaid Lake Watershed. Table 5-15 also provides information on whether there is potential for the facility to impact DO concentrations in Segment N12. With exception of the Carbondale Northwest Wastewater Treatment Plan, none of the facilities has the potential to impact DO concentrations in Segment N12. The facilities are either no discharge or discharge such little effluent that it is unlikely that they impact the Big Muddy River. The Carbondale Northwest Plant will be further discussed in Section 10.

Table 5-15 Wastewater Treatment Plants within N12 Watershed

Facility Name	NPDES Number	Potential to Impact DO Concentrations in N12
Lake Chautauqua Home	IL0045705	No
Fairway Motor Home Park	IL0045306	No
New Thompson Lake Fishing Club	IL0048569	No
Jackson Country Club	IL0038521	No
Fairway Vista Group	IL0061786	No
Paul Parrish Apartments	IL0048089	No
Green Tree Mobile Home Park	IL0036935	No
Happy Ours Mobile Home Park	IL0046299	No
Carbondale Northwest Wastewater Treatment Plant	IL0027871	Yes

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 by county are generated by the Illinois Department of Agriculture from County Transect Surveys. Data specific to the Kinkaid Lake Watershed were not available; however, the Jackson County NRCS office recommended percentages of each tillage practice for application to the Kinkaid Lake Watershed as shown in Table 5-16 (NRCS 2002a).

Table 5-16 Tillage Practices in the Kinkaid Lake Watershed (NRCS 2002a)

Tillage Practice	Corn	Soybeans	Small Grains
Conventional Till	20%	0%	20%
Reduced Till	15%	10%	50%
Mulch-Till	15%	5%	10%
No-Till	50%	85%	20%

5.1.10 Reservoir Characteristics

Reservoir characteristics were obtained from GIS analysis, the Illinois EPA, the Kinkaid Lake watershed plan, and USEPA water quality data. The watershed plan for Kinkaid Lake lists a normal pool of 2,350 acres (Kinkaid Area Watershed Project, Inc. [KAWP] 2000). Illinois EPA originally estimated the surface area of Kinkaid Lake as 3,475 acres, resulting in a large discrepancy between this value and those obtained from the watershed plan and GIS. Based on recent studies in the watershed, the surface area of 2,350 acres from the watershed plan was used to validate the surface area of 2,402 acres obtained from GIS analysis. For modeling analyses, the area obtained through GIS analysis was scaled to equal the area from the resource plan.

The water quality dataset described in Section 5.1.5.1 was used to determine the average depth of Kinkaid Lake. On each date sampled for water quality constituents, the total depth at the site was measured. Table 5-17 lists the average depth calculated for each water quality site in Kinkaid Lake for each year of available data after 1990.

Table 5-17 Average Depths in Feet for Kinkaid Lake

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1990	55.9	42.3	6.5	6.5	27.8
1991	63.0	40.3	22.0	3.4	32.2
1992	80.4	15.2	13.8	4.3	28.4
1993	73.0	22.4	15.6	6.5	29.4
1994	60.0	35.7	24.7	4.0	31.1
1996	60.0	41.1	9.2	9.2	29.9
1997	57.9	40.2	27.4	9.4	33.7
1998	57.9	39.5	29.0	10.5	34.2
2000	51.3	39.4	26.8	10.2	31.9

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

5.1.11 Septic Systems

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

5.1.12 Aerial Photography

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

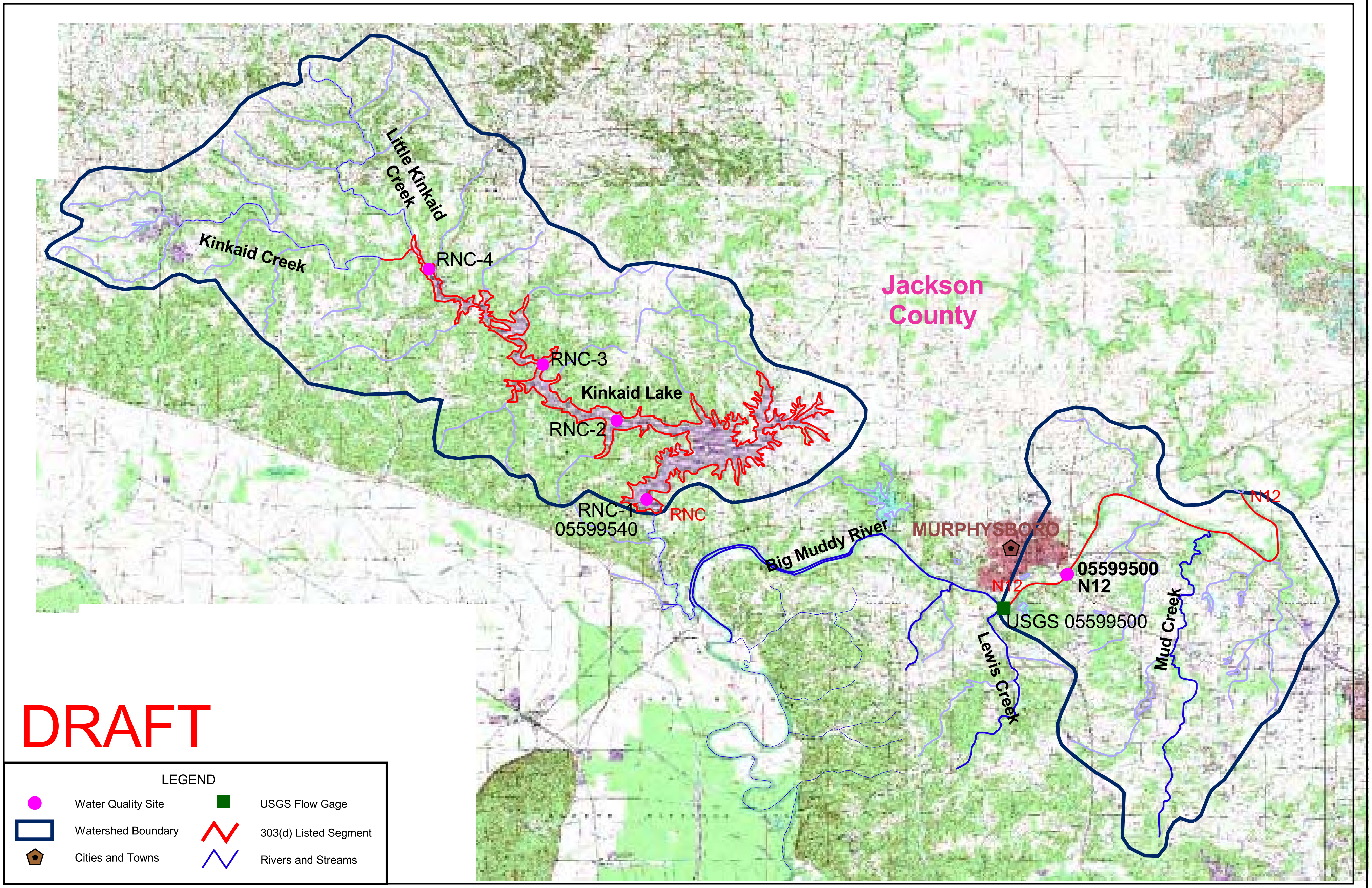

Figure 5-1
Big Muddy River #1 Watershed
Historic Flow and Water Quality Gages

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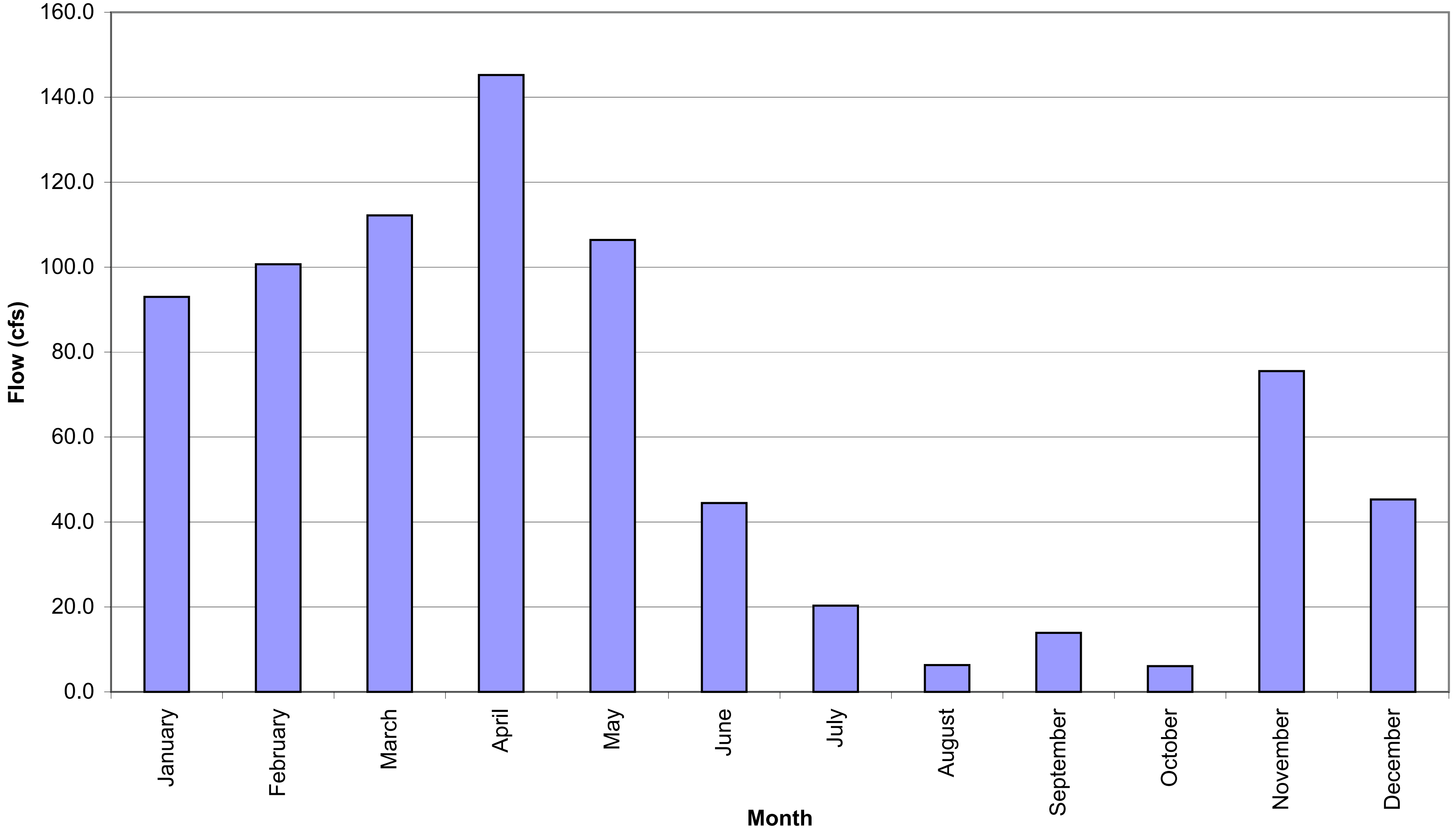
Figure 5-2: Estimated Streamflow Upstream of
Kinkaid Lake Calculated from Gage 05595820



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

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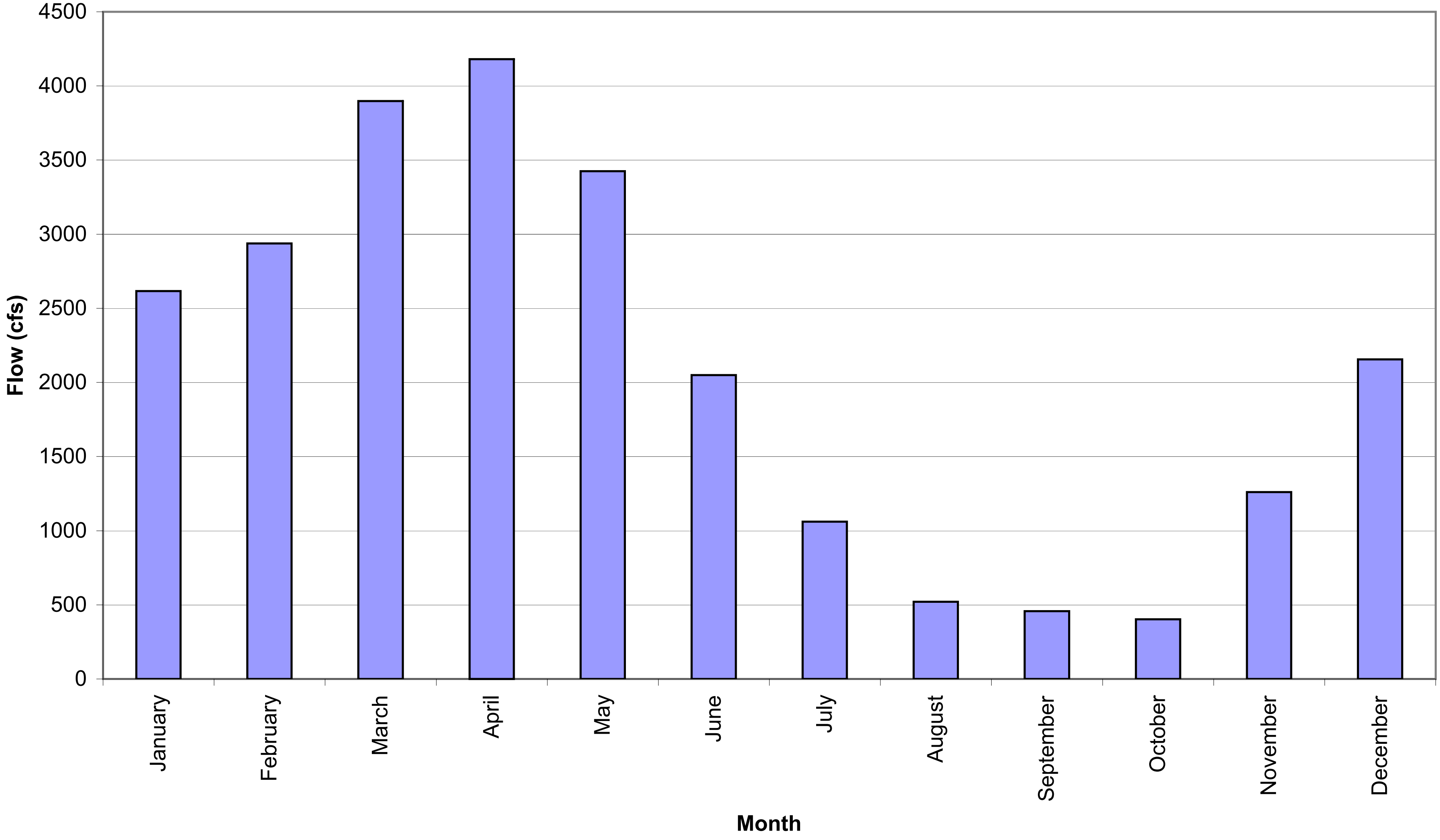
Figure 5-3: Flows in the Big Muddy River Segment N12
Gage 05599500



Period of Record
January 1, 1972 to September 30, 2000

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Figure 5-4 Manganese Concentrations and Flows in Big Muddy River Segment N12

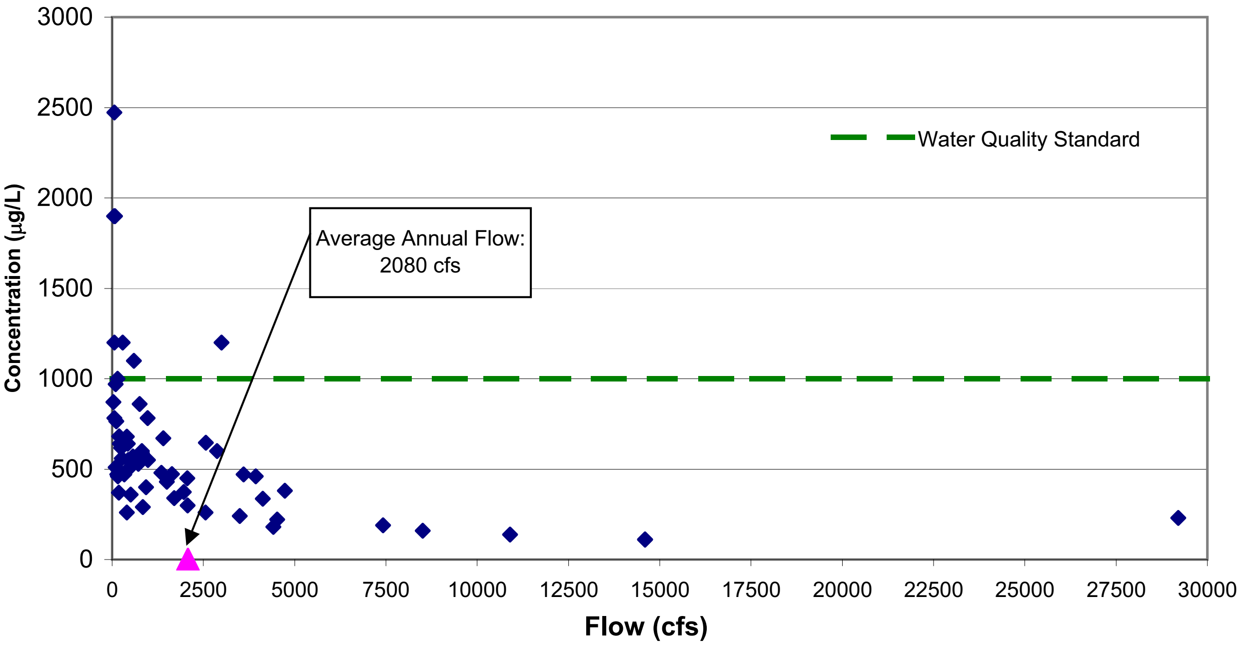

Figure 5-5: Sulfate Concentrations and Flows in Big Muddy River Segment N12

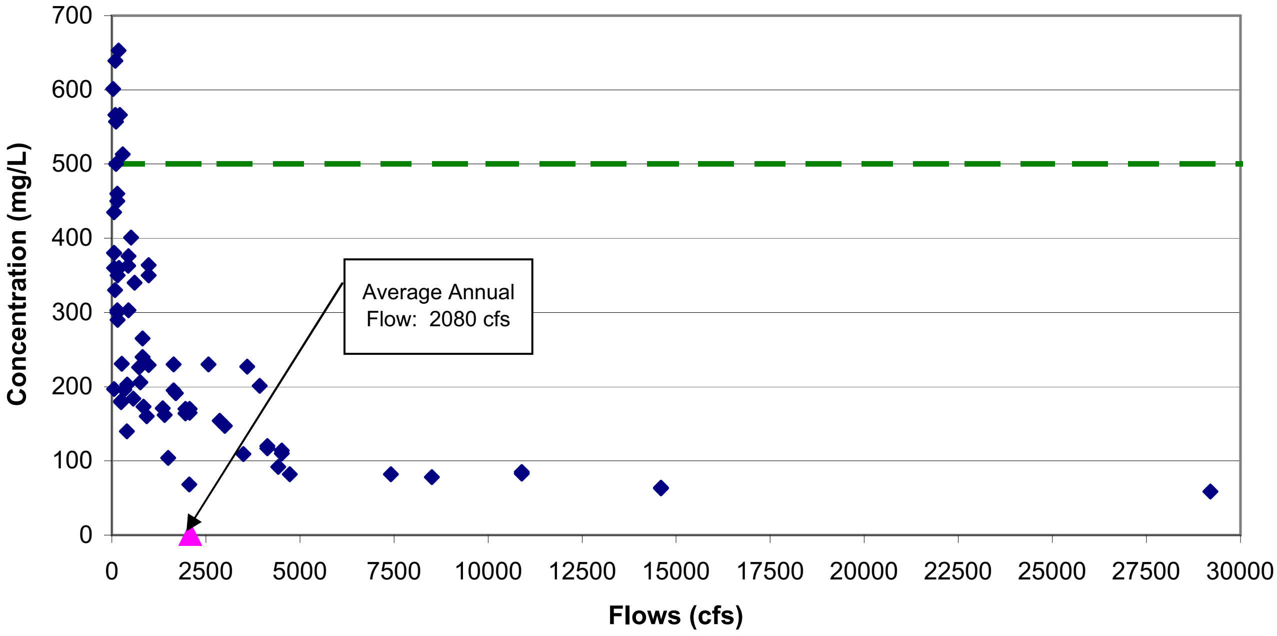

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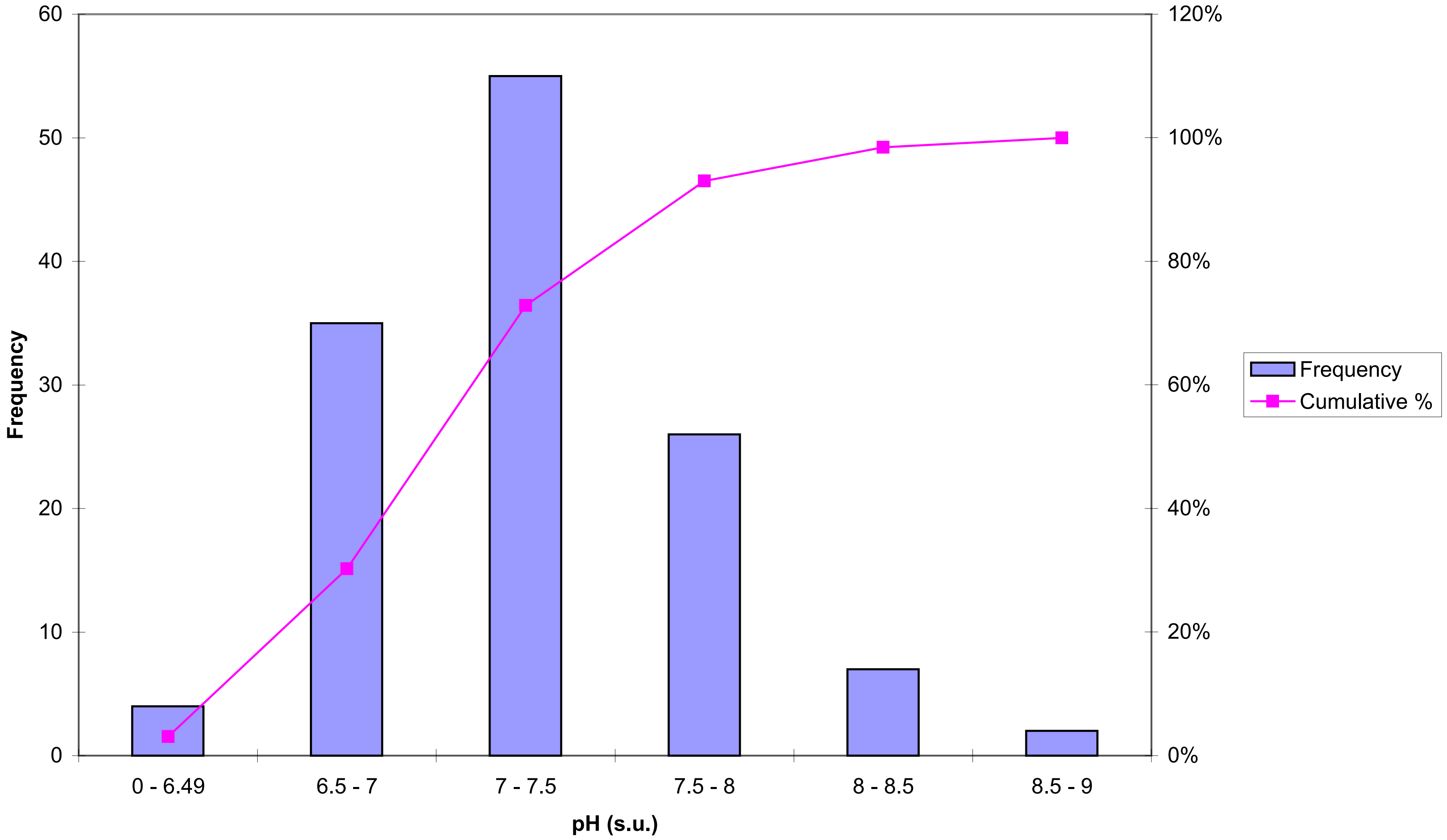
**Figure 5-6: pH Histogram for Segment N12
in the Big Muddy River**



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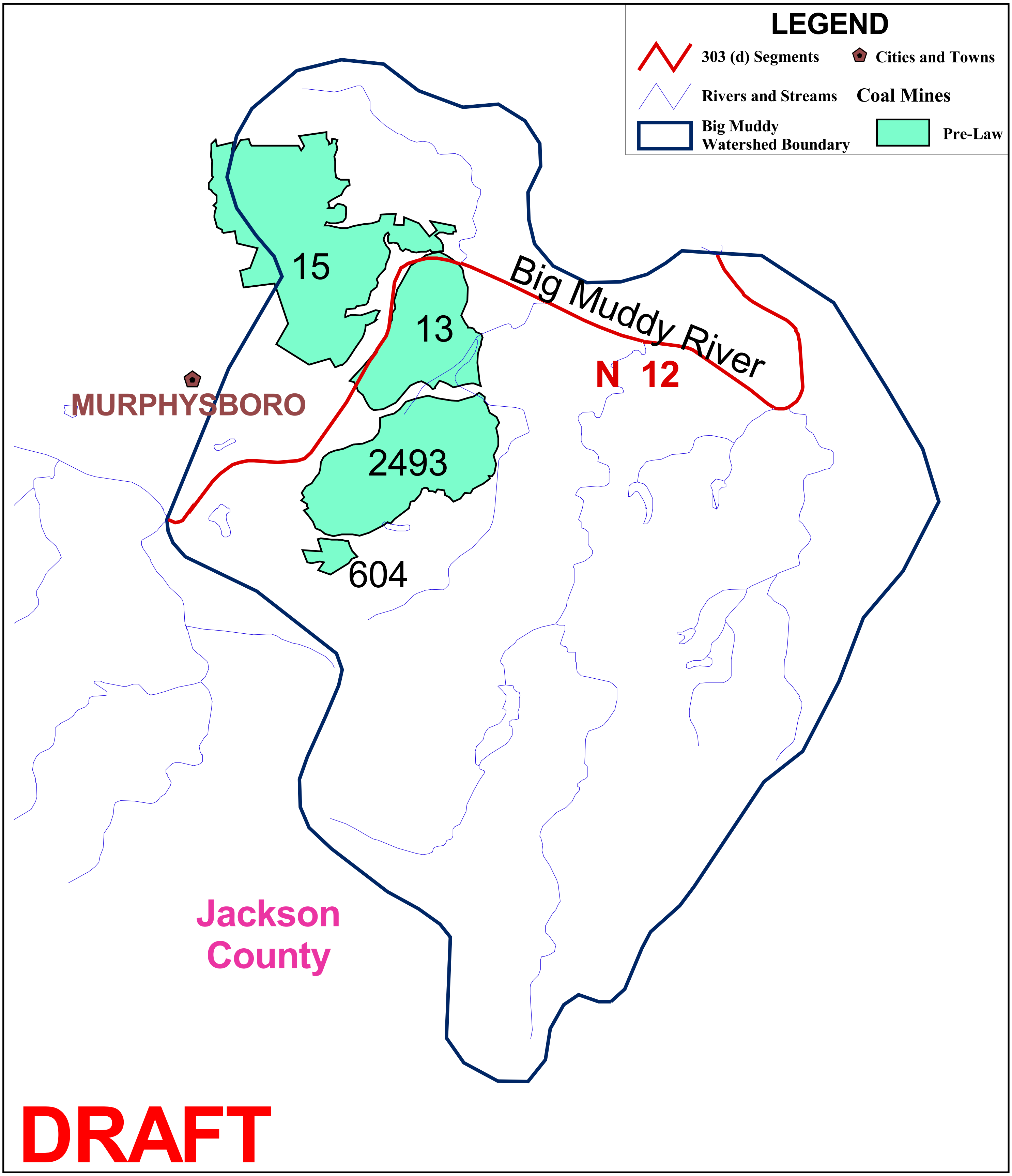

Figure 5-7
Coal Mines in the
Big Muddy River #1 Watershed

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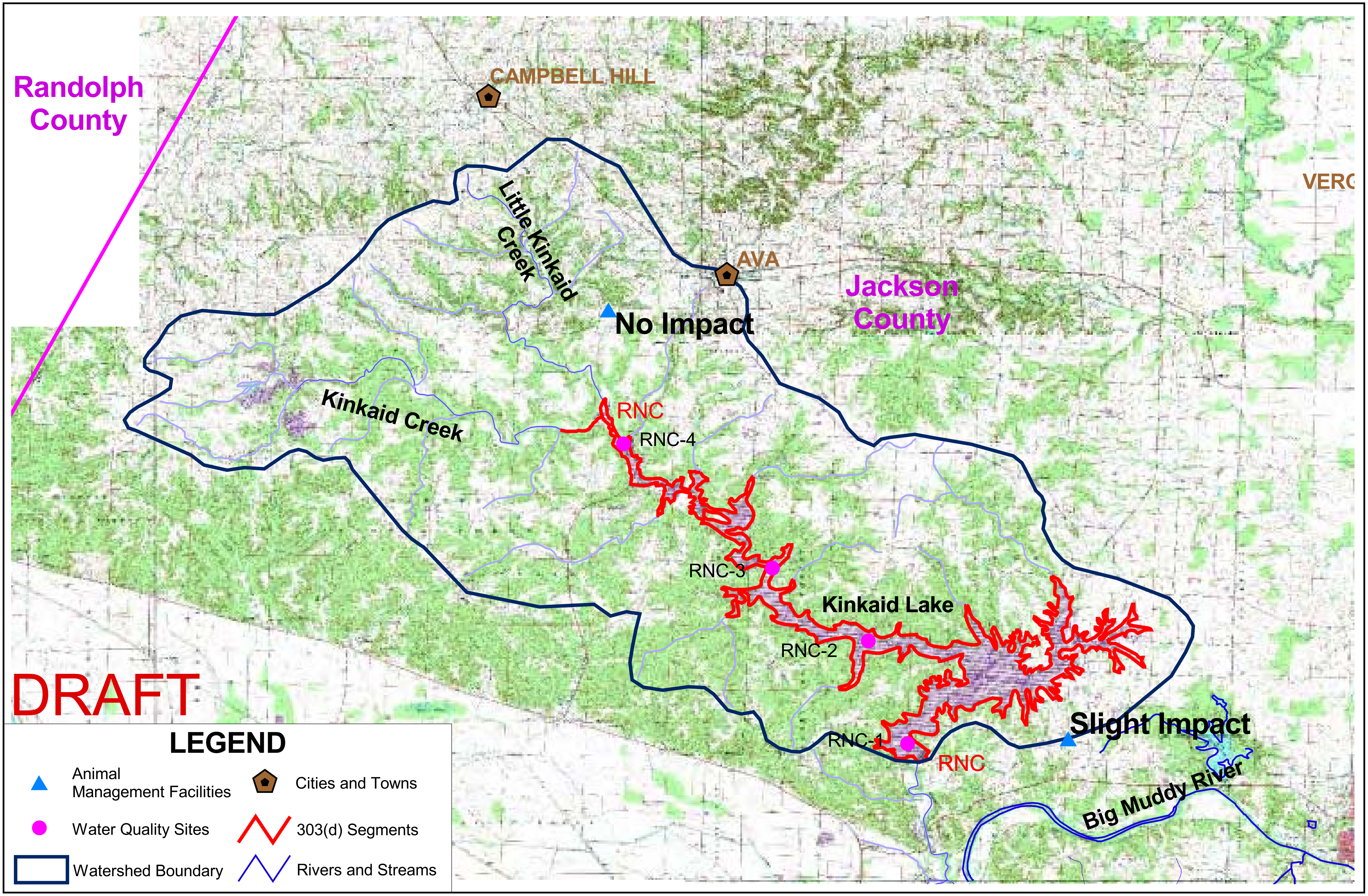

Figure 5-8
Animal Management Facilities in the
Kinkaid Lake Watershed

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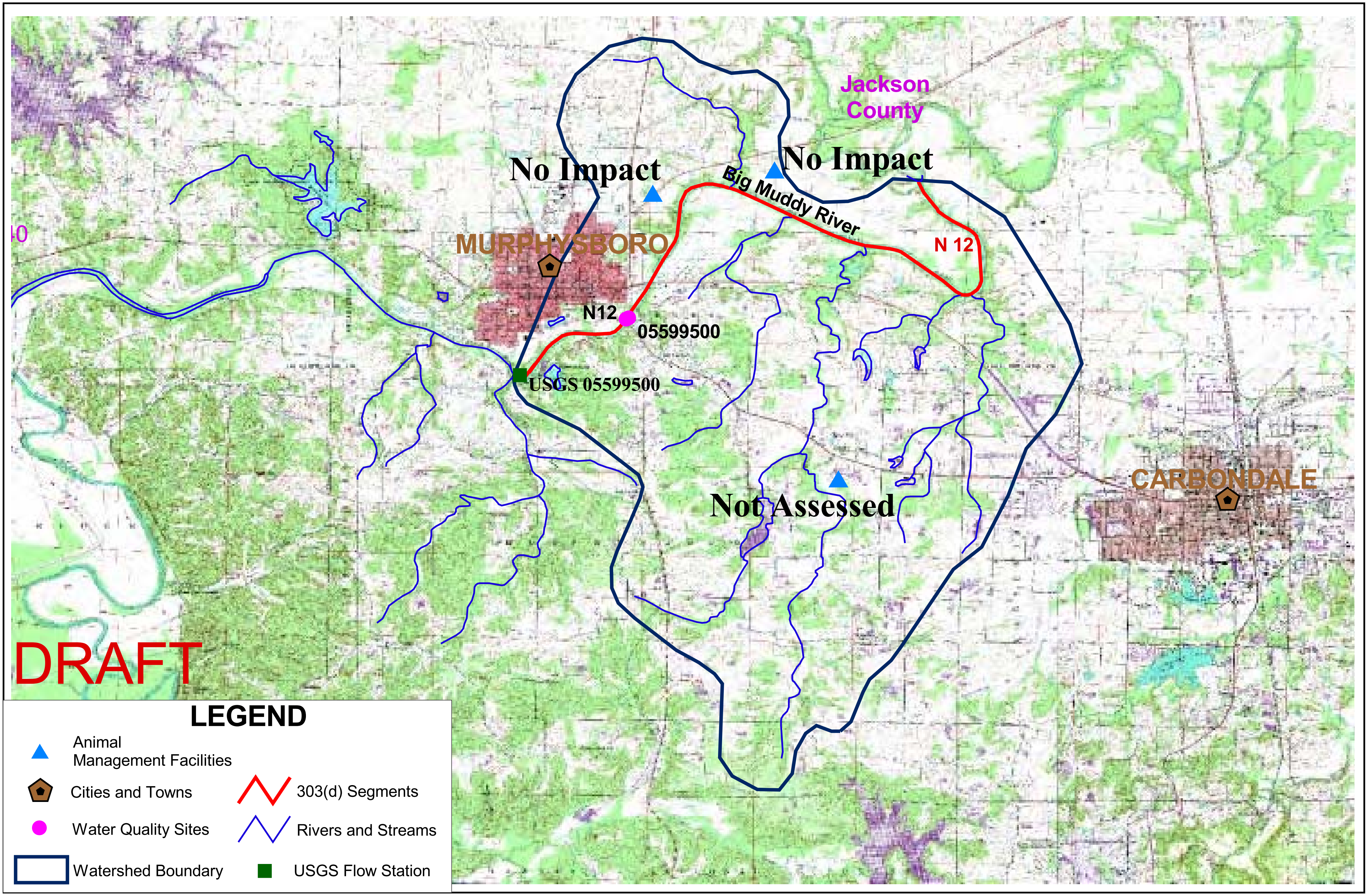

Figure 5-9
Animal Management Facilities in the
Big Muddy River #1 Watershed

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Section 6
Methodologies and Models to Complete TMDLs for the Big Muddy River

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 Big Muddy River Watershed. The endpoints presented in Section 4, which are chemical and physical endpoints of the following constituents, were targeted:

- stream segments: sulfates, pH, DO, manganese;
- lake segment: pH.

6.2 Methodologies and Models to Assess TMDL Endpoints

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

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

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

6.2.1 Watershed Models

Watershed or loading models can be divided into categories based on complexity, operation, time step, and simulation technique. USEPA has grouped existing watershed-scale models for TMDL development into three categories based on the number of processes they incorporate and the level of detail they provide (USEPA 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 Big Muddy River Watershed, a detailed model could not be constructed, calibrated, and verified with certainty and the watershed model selection should focus on the simple or mid-range models.

6.2.1.1 Watershed Model Recommendation

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

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

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

6.2.2 Receiving Water Quality Models

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

Table 6-3 General Receiving Water Quality Model Characteristics

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

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

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

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

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

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

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

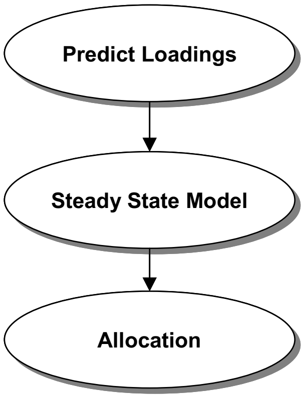
6.2.2.1 Receiving Water Model Recommendation

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

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

6.2.3 Kinkaid Lake TMDL

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



Schematic 1
Strategy for Lake TMDL Modeling

6.2.4 Stream TMDLs for the Big Muddy River Watershed

Because of limited data available for watershed and receiving water model development for the Big Muddy River Watershed, TMDLs for the following constituents will be completed using methodologies: sulfates, pH, DO, and manganese. For DO, a Streeter-Phelps analysis based on the USEPA Screening Procedures was developed. This analysis is described in Section 8. For sulfates and manganese, a Monte Carlo simulation was conducted, and the description of this analysis is also contained in Section 8. For pH, an analysis based on recurrence interval and pH was created, and this discussion is also included in Section 8.

6.2.5 Calibration and Validation of Models

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

The GWLF and BATHTUB models were calibrated based on existing data. As will be outlined in Section 7, the GWLF model was calibrated based on historical flow records. The calibration factors taken into account for the GWLF model were the recession constant and seepage constant. Water quality data on the tributaries to Kinkaid Lake were not available so the GWLF model could not be calibrated to tributary nutrient loads. Nutrient loads were based on literature values for Southern Illinois. GWLF model validation was not conducted, as the hydrology was calibrated based on 16 years of observed flow. Data collection activities needed to calibrate nutrient loads are outlined in Section 9 Implementation Plan. The calibration process for the BATHTUB model is also outlined in Section 7. For Kinkaid Lake, loads from a below normal, above normal, and dry precipitation year were taken from GWLF and entered into the BATHTUB model, which predicted average in-lake concentrations that were in turn compared to observed lake concentrations as the basis for calibration.

6.2.6 Seasonal Variation

Consideration of seasonal variation, such that water quality standards for the allocated pollutant will be met during all seasons of the year, is a requirement of a TMDL submittal. TMDLs must maintain or attain water quality standards throughout the year and consider variations in the water body's assimilative capacity caused by seasonal changes in temperature and flow (USEPA 1999). Seasonal variation for the Kinkaid Lake Watershed is discussed in Section 8 and for the Big Muddy River Watershed discussed in Section 11.

6.2.7 Allocation

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

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

6.2.8 Implementation and Monitoring

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

The implementation plan delineates a recommended list of the sources of stressors that are contributing to the water quality impairments. The amount of the reduction needed from various sources to achieve the water quality limiting parameter was then delineated. For nonpoint sources, the use of BMPs is one way to proceed to get the desired reduction in loading. The effectiveness of various BMPs was factored into the modeling and methodologies to develop the range of options of BMPs to use. Associated with those BMPs is cost information, as available. Reductions from point services through waste stream management, pretreatment controls, and other structural and nonstructural programs were also identified as applicable. The implementation plan for the Big Muddy River Watershed is presented in Section 12.

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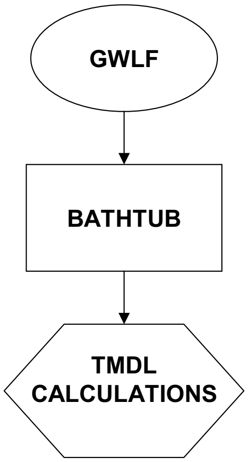
Section 7
Model Development for Kinkaid Lake

7.1 Basis for pH TMDL

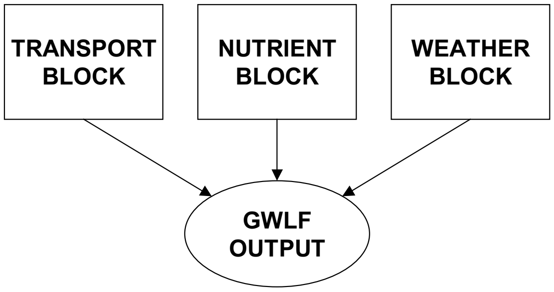
The relationships between pH, chlorophyll "a," and phosphorus were discussed in Section 5.1.5.1.1. Figures 7-1 and 7-2 show the relationship between chlorophyll "a" and pH at Kinkaid Lake stations RNC-1 and RNC-3, respectively. The relationships are only provided at these two locations because samples at stations RNC-2 and RNC-4 did not show exceedences of the pH standard. As explained in Section 5.1.5.1.1, the figures are expected to show an increase with pH as chlorophyll "a" increases. Increased chlorophyll "a" concentrations may also lead to low pH values as the CO_2 decreases during respiration. The relationship between chlorophyll "a" and phosphorus at stations RNC-1 and RNC-3 are shown in Figures 7-3 and 7-4, respectively. Likewise, these figures are expected to show a direct relationship between the constituents. The relationships presented in Figures 7-1 through 7-4 provide general trends between model constituents and represent the data available from sampling. The general relationships shown in Figures 7-1 through 7-4 suggest that controlling total phosphorus will decrease chlorophyll "a" concentrations, which will in turn bring pH into the range required for compliance with water quality standards. The TMDL will be based on the existing relationships with the knowledge that a larger data set would result in a more robust TMDL. It is therefore recommended that a TMDL endpoint of 0.05 mg/L for total phosphorus for Kinkaid Lake be utilized so that the pH standard is achieved.

7.2 Model Overview

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



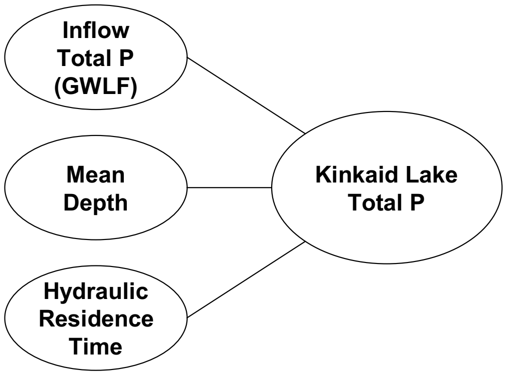
*Schematic 1
Models used for
Kinkaid Lake
TMDL calculation.*



*Schematic 2
GWLF Model.*

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



Schematic 3
BATHTUB Model Schematic.

7.3 Model Development and Inputs

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

Due to the size of the Kinkaid Lake Watershed and the multiple tributaries contributing to the lake, the watershed area was divided into four subwatersheds for accurate representation in the GWLF model. Flows within each of the subbasins were calculated from gage 05595820 with the drainage area ratio method presented in Section 5.1.3. To model Kinkaid Lake accurately in BATHTUB, the lake was divided in four sections surrounding each of the three monitoring stations.

7.3.1 Watershed Delineation

Prior to developing input parameters for the GWLF or BATHTUB models, a watershed for Kinkaid Lake was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation indicates that Kinkaid Lake captures flows from a watershed of approximately 60.3 square miles, which is consistent with the drainage area of 60.5 square miles reported in the watershed plan (KAWP 2000). The flow through the lake is primarily from northeast to southwest. Figure 7-5 at the end of this section shows the location of each water quality station in Kinkaid Lake, the boundary of the GIS-delineated watershed contributing to Kinkaid Lake, the four subbasins used in GWLF modeling, and the division of the lake for BATHTUB modeling purposes.

7.3.2 GWLF Inputs

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

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

7.3.2.1 Transport Data File

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

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

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

7.3.2.1.1 Land Use

Land use for the Kinkaid Lake Watershed was extracted from the Critical Trends Assessment Database grid for Jackson 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 5-12.

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

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

To provide accurate modeling in GWLF, the rural grassland land use class, presented in Table 5-12, was separated into two subclasses of pasture and grassland based on the recommendation of the Jackson County NRCS (2002a). The GWLF model requires nutrient runoff concentrations for each land use, and the two subclasses of rural grassland have varying concentrations. The area of each subclass was estimated from the GIS-derived rural grassland area and suggested percentages of each subclass by the Jackson County NRCS (2002a).

Due to the detailing of crops, the Cropland Data Layer land use classes, presented in Table 5-14, were used to generate evapotranspiration cover coefficients, cropping management factors, and to verify the land use obtained from the Critical Trends Assessment. Land uses used in GWLF correspond to land uses in the Critical Trends Assessment, so calculations based on the Cropland Data Layer land use classes were typically weighted by area to match the Critical Trends Assessment classes. Details of the calculations are presented in later sections and Appendix E.

7.3.2.1.2 Land Use Area

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

7.3.2.1.3 Curve Number

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

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

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

7.3.2.1.4 KLSCP

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

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

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

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

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

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

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

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

Land Use	Area (acres)	C factor
Corn	1,590	0.21
Sorghum	0	–
Soybeans	1,702	0.08
Winter Wheat	271	0.13
Other Small Grains & Hay	1,315	0.13
Double-Cropped WW/SB	1,038	0.12
Idle Cropland/CRP	20	0.02
Fallow/Idle Cropland	2,310	0.02
Pasture/Grassland/Nonag	7,937	0.02
Woods	19,220	0.003
Clouds	87	–
Urban	322	–
Water	1,962	–
Buildings/Homes/Subdivisions	438	–
Wetlands	388	–

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 E.

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

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4	
Land Use	Area (ac)	C-factor	Area (ac)	C-factor	Area (ac)	C-factor	Area (ac)	C-factor
High Density	12	–	0	–	0	–	0	–
Medium Density	89	–	0	–	0	–	0	–
Row Crop	2,618	0.14	217	0.11	35	0.12	705	0.14
Small Grains	573	0.13	21	0.13	1	0.13	156	0.13
Urban Grassland	17	0.02	0	–	0	–	0	–
Rural Grassland	6,080	0.02	984	0.02	142	0.020	1,724	0.02
Deciduous1	11,850	0.003	4,330	0.003	1,916	0.003	3,402	0.003
Deciduous2	54	0.003	7	0.003	3	0.003	34	–
Coniferous	304	0.003	113	0.003	44	0.003	0	–
Open Water	240	–	489	–	405	–	1,569	–
Shallow Marsh/ Wetland	23	–	2.7	–	0	–	1	–
Deep Marsh	5	–	0	–	0	–	2	–
Forested Wetland	308	–	2	–	9	–	49	–
Shallow Water Wetland	34	–	7	–	2	–	18	–
Barren Land	5	–	0	–	0	–	0	–

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

7.3.2.1.5 Erosivity Coefficient

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

7.3.2.1.6 Evapotranspiration (ET) Cover Coefficient

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

7.3.2.1.7 Recession Constant

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

7.3.2.1.8 Seepage Constant

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

7.3.2.1.9 Sediment Delivery Ratio

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

Table 7-4 Sediment Delivery Ratios in Kinkaid Lake Watershed

Subbasin	Area (ac)	Sediment Delivery Ratio
1	22,210	0.13
2	6,175	0.18
3	2,557	0.22
4	7,661	0.17

7.3.2.2 Nutrient Data File

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

All solid-phase nutrient concentrations from runoff for Kinkaid Lake were obtained from the GWLF manual. Figure B-4 (page 39 of Appendix D) was utilized for determining solid-phase phosphorus concentrations in the soil. A mid-range value of 0.07 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 grassland under the rural grassland land use and concentrations from animal management facilities. The grassland dissolved phosphorus concentration was estimated from the dissolved phosphorus concentration for pasture. Grassland is assured to have less animals, and therefore less animal waste, than pasture land, so the concentration was reduced for hayland. The selection of dissolved phosphorus concentrations will be confirmed in Section 7.4.1. The runoff phosphorus concentration from the feedlots and animal management areas were obtained from Novotny and Olem with a range of 4 to 15 mg/L (1994). The concentrations used to model the animal management areas were dependent on the impact each facility had on the receiving waters as recorded in the GIS file discussed in Section 5.1.7. One feedlot was identified in the Kinkaid Lake Watershed as potentially having a slight impact on water quality and one facility was identified as potentially having no impact on water quality in the receiving stream. The animal management facilities in the Kinkaid Lake Watershed were assigned dissolved phosphorus concentrations of 4 and 5.5 mg/L for the no impact and slight impact facilities, respectively, because these are at the lower end of the literature range.

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

Land Use	Dissolved Phosphorus (mg/L)
Row Crop	0.26
Small Grains	0.30
Rural Grasslands	
Pasture	0.25
Grassland	0.15
Deciduous Forest	0.009
Coniferous Forest	0.009
Animal Management Facility	4.5 - 15
Barren Land	0.008
Urban-High Density	0.01

Table 7-5 lists the land uses in the Kinkaid Lake Watershed and associated runoff phosphorus concentrations used in the GWLF model. It should be noted that although the majority of dissolved phosphorus concentrations in Table 7-5 exceed the endpoint of 0.05 mg/L of total phosphorus, once the surface runoff reaches Kinkaid Lake or its tributaries, it mixes with water already in the stream or lake and the concentration decreases. Therefore, it cannot be concluded without analysis that constituents with dissolved concentrations above the endpoint for total phosphorus are responsible for water quality impairments.

The GWLF manual suggests nutrient concentrations in groundwater based on the percentage of agricultural versus forestlands. These percentages were calculated from the land use areas in the watershed, and the appropriate groundwater concentrations were selected from the GWLF manual, page 41. The percentage of agricultural lands in each subbasin and their corresponding groundwater dissolved phosphorus concentrations are provided in Table 7-6.

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

Subbasin	Agriculture	Forest	Dissolved Phosphorus (mg/L)
1	42%	55%	0.015
2	20%	72%	0.012
3	7%	77%	0.012
4	34%	45%	0.015

7.3.2.3 Weather Data File

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

7.3.3 BATHTUB Inputs

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

Multiple simulations of the BATHTUB model were run to investigate variations in total phosphorus concentrations in a wet, normal, and dry year of precipitation to bracket conditions for calibration. The first step in choosing the wet, normal, and dry years was to calculate average annual precipitation. BATHTUB models lake concentrations based on a water year (October to September), so the precipitation data presented in Section 5.1.4 were averaged to coincide with the water year. Table 7-7 shows these annual and average annual precipitation values in Jackson County. Each water year was then

Table 7-7 Annual Precipitation in Jackson County

Model Year	Precipitation (inches)
1986	52
1987	35
1988	43
1989	47
1990	48
1991	41
1992	43
1993	54
1994	44
1995	46
1996	57
1997	49
1998	45
1999	40
2000	51
Average	**46**

classified as wet, dry, or normal based on a comparison to the average water year precipitation of 46 inches. Another consideration in selecting the years for simulation was determining which years coincided with the collection dates of in-lake total phosphorus concentrations at the water quality stations within recent years. With these criteria, the only years available for modeling Kinkaid Lake are 1994, 1997, and 2000. Based on Table 7-7, 1994 is designated as the normal year and 1997 and 2000 are both designated as wet years.

7.3.3.1 Global Inputs

Global inputs represent atmospheric contributions of precipitation, evaporation, and atmospheric phosphorus. Precipitation was discussed in the previous section and is shown in Table 7-7 for the model years 1994, 1997, and 2000. 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 kilograms per kilometer squared per year (kg/km^2-yr) (USACE 1999b).

7.3.3.2 Reservoir Segment Inputs

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

Kinkaid Lake was modeled as four segments in BATHTUB to represent the lake characteristics around each water quality station, so an average annual value of total phosphorus was calculated for each site for input of observed data. The lake segments are shown in Figure 7-5 at the end of this section. The averages of total phosphorus sampled at one-foot depth were presented in Table 5-6; however, the BATHTUB model calculates an average lake concentration. Therefore, total phosphorus samples at all depths were averaged to provide targets for the BATHTUB model. Table 7-8 shows the average annual total phosphorus concentrations for all sample depths at each station in Kinkaid Lake for the years modeled. As mentioned in Section 5.1.5.1.2, station RNC-1 had samples taken at one-foot depth from the surface and at the lake bottom, whereas stations RNC-2, RNC-3, and RNC-4 were only sampled at one-foot depth. The raw data for all sample depths are contained in Appendix A.

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

Year	RNC-1	RNC-2	RNC-3	RNC-4	Lake Average
1994	0.03	0.02	0.04	0.14	0.05
1997	0.04	0.03	0.04	0.13	0.06
2000	0.03	0.01	0.02	0.05	0.03

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 5-16. The lake length was determined in GIS, and the depth to the metalimnion was estimated from a chart of temperature versus depth. The charts are presented in Appendix G.

7.3.3.3 Tributary Inputs

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

7.4 Model Calibration and Verification

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

7.4.1 GWLF Calibration

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

Instream nutrient data was not available for model calibration, so GWLF was only calibrated to flow. The monthly average flow output from GWLF was compared to the monthly average streamflow calculated from USGS gage 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 7-6 (at the end of this section) shows the comparison between the two flows for subbasin 1 of Kinkaid Lake. The GWLF model for Kinkaid Lake was visually calibrated with a resulting recession constant of 0.15 and a seepage constant of 0.15 in each subbasin. Once calibrated, the model output data could properly be included as BATHTUB inputs. The GWLF model was not validated as flow was calibrated by visually comparing 16 years of observed flow. The summary output from GWLF for each subbasin is included in Appendix C.

Although instream nutrient concentrations are not available for the tributaries to Kinkaid Lake, Clean Lakes Studies have been conducted by the Illinois EPA on various Illinois lake watersheds, which do provide instream nutrient data for lake tributaries including dissolved and total phosphorus. A Clean Lake Study was conducted on Kinkaid Lake during the summer of 2003. The dissolved and total phosphorus concentrations predicted by GWLF for tributaries to the Kinkaid Lake subbasins were compared to the measured dissolved and total phosphorus concentrations from tributaries to lakes observed in the Clean Lakes studies as shown in Figure 7-7.

Table 7-9 shows the comparison between dissolved and total phosphorus in watersheds from Clean Lakes Studies and in the Kinkaid Lake Watershed. The dissolved phosphorus concentration in Subbasin 3 in the Kinkaid Lake Watershed was too low to be calculated by GWLF, so it is assumed to be negligible and presented as zero concentration.

Table 7-9 Percentage of Dissolved Phosphorus to Total Phosphorus Concentrations in Clean Lake Study Watersheds and the Kinkaid Lake Watershed

Watershed	Site	Mean Dissolved Phosphorus (mg/L)	Mean Total Phosphorus (mg/L)	Dissolved / Total Phosphorus
Nashville City	ROO 02	0.68	0.89	0.76
Paradise	RCG 02	0.06	0.07	0.87
Raccoon	RA 02	0.30	0.46	0.66
	RA 03	0.21	0.29	0.71
	RA 04	0.46	0.63	0.73
	RA 05	0.07	0.22	0.30
Lake Lou Yeager	A	0.06	0.13	0.46
	B	0.15	0.16	0.92
	C	0.05	0.25	0.20
	D	0.13	0.17	0.78
	E	0.06	0.12	0.46
	F	0.17	0.20	0.87
	G	0.33	0.41	0.79
	H	0.33	0.35	0.93
	I	0.13	0.14	0.96
Kinkaid	1	0.06	0.18	0.31
	2	0.01	0.10	0.12
	3	0.0	0.07	–
	4	0.03	0.10	0.26

The ratio of dissolved to total phosphorus in the Kinkaid Lake subbasins is within the range of ratios represented by the Clean Lakes Studies, except for Subbasin 2, which is below the low end of the range.

7.4.2 BATHTUB Comparison with Observed Data

The BATHTUB model's response to changes in the GWLF nutrient block were compared to known in-lake concentrations of total phosphorus and chlorophyll "a" for each year of simulation. These known concentrations were presented in Tables 5-6 and 5-7. The BATHTUB manual defines the limits of total phosphorus calibration factors as 0.5 and 2.0.The calibration factor accounts for sedimentation rates, and the limits were determined by error analysis calculations performed on test data sets (USACE 1999). The calibration limits for chlorophyll "a" are not defined in the BATHTUB manual.

The GWLF model was set at a total phosphorus soil concentration of 660 ppm based on comparison with observed data in the BATHTUB model. As part of the comparison process, the watershed was also modeled with a total phosphorus soil concentration of 440 ppm to perform a sensitivity analysis on soil phosphorus. Decreasing the total soil phosphorus concentration shows little impact on the estimated in-lake concentrations (Table 7-10). The calibration factor range for total phosphorus modeling in BATHTUB is 0.5 to 2 and use of the 616-ppm total phosphorus in the soil falls within this accepted range. Table 7-10 also shows what calibration factors for chlorophyll "a" would be required so that estimated concentrations would match observed concentrations. The columns labeled *target* in Table 7-10 represent the average observed in-lake concentrations. The results of the modeling sensitivity analyses are contained in Appendix H.

Table 7-10 Kinkaid Lake Calibration Sensitivity Analysis

Year	In-Lake Target Total Phosphorus (mg/L)	In-Lake Estimated Total Phosphorus (mg/L)	% of Total Loads from Internal Loading Required to Meet Target	Phosphorus Calibration Factor	In-Lake Target Chlorophyll "a" (μg/L)	In-Lake Estimated Chlorophyll "a" (μg/L)	Chlorophyll "a" Calibration Factor
Soil Total Phosphorus 440 ppm							
1994	0.04	0.04	0	1.0	23.6	14.6	1.6
1997	0.05	0.04	0	1.4	19.9	9.9	2.0
2000	0.03	0.04	0	0.6	18.9	12.4	1.5
Soil Total Phosphorus 616 ppm							
1994	0.04	0.03	0	1.2	23.6	13.1	1.8
1997	0.05	0.03	0	1.6	19.9	9	2.2
2000	0.03	0.04	0	0.7	18.9	11.2	1.7

A robust calibration and validation of Kinkaid Lake could not be completed because the following information was not available: observed nutrient concentrations in tributaries to the lake, site-specific data on internal cycling rates, reservoir outflow rates, and nutrient concentrations in reservoir releases. The analysis presented in Table 7-10 is therefore considered a preliminary calibration. However, BATHTUB modeling results indicate a fair estimate between predicted and observed values for the years modeled based on error statistics calculated by the BATHTUB model and should be sufficient for estimating load reductions required in the watershed. 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 Kinkaid Lake will be possible if data collection activities outlined in the future monitoring in Section 9 Implementation are implemented.

Based on modeling results, it appears that internal cycling is not occurring in Kinkaid Lake. 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 5-17 notes a depth of approximately 62 feet for Kinkaid Lake, which places it outside of the category of shallow reservoir making it appropriate that internal cycling is not occurring in modeled results. 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).

Because the modeling of the Kinkaid Lake changes based on annual loadings and climatic conditions, a validation of the model could not be completed. The model was calibrated for three climatic conditions, which will be the basis for the TMDL analysis presented in Section 8. The preliminary calibrated model was used to estimate the amount of load reductions needed from the watershed to meet water quality standards.

Figure 7-1: Relationship between pH and Chlorophyll "a" at Kinkaid Lake Station RNC-1

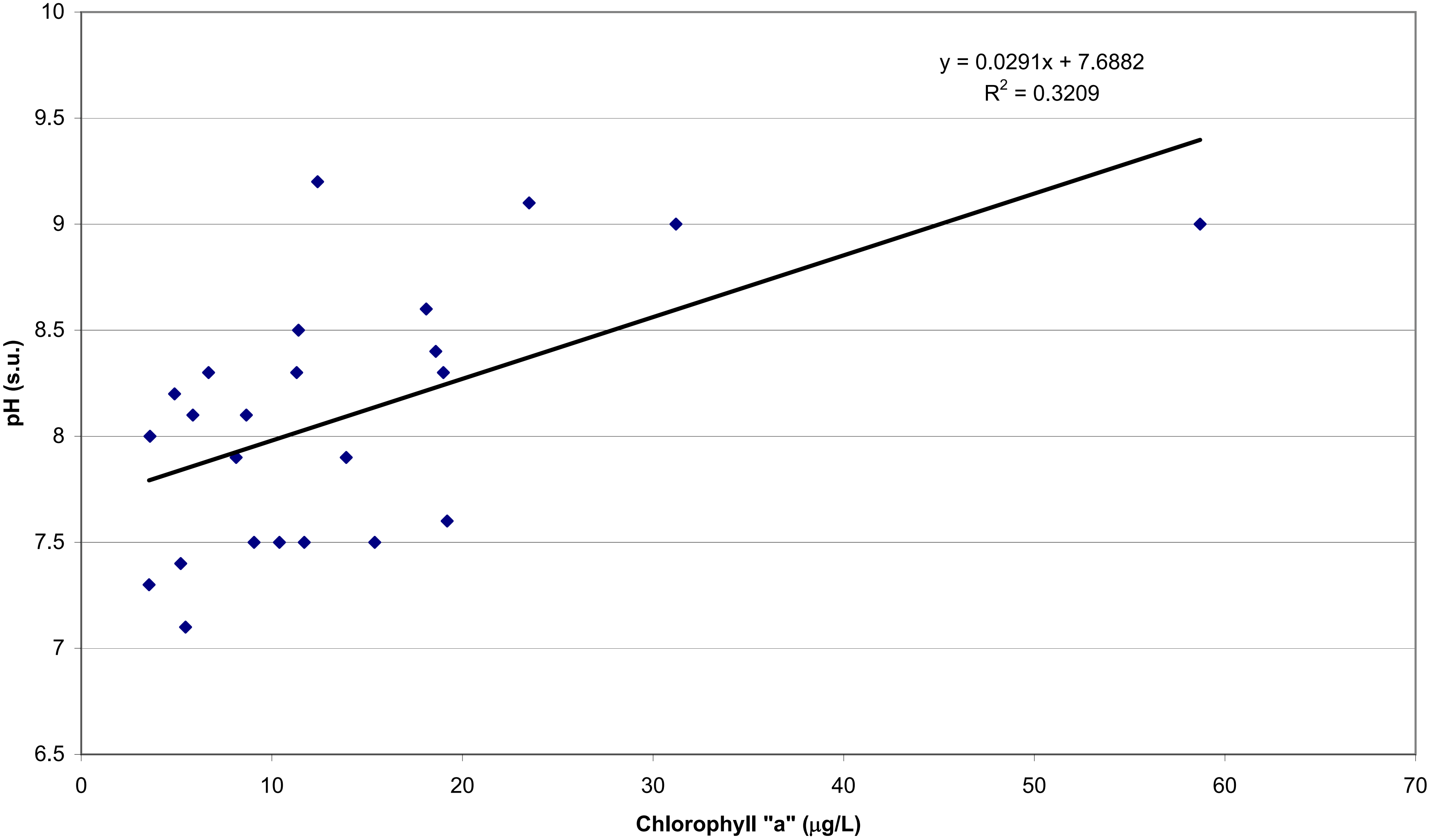


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Figure 7-2: Relationship between pH and
Chlorophyll "a" at Kinkaid Lake Station RNC-3

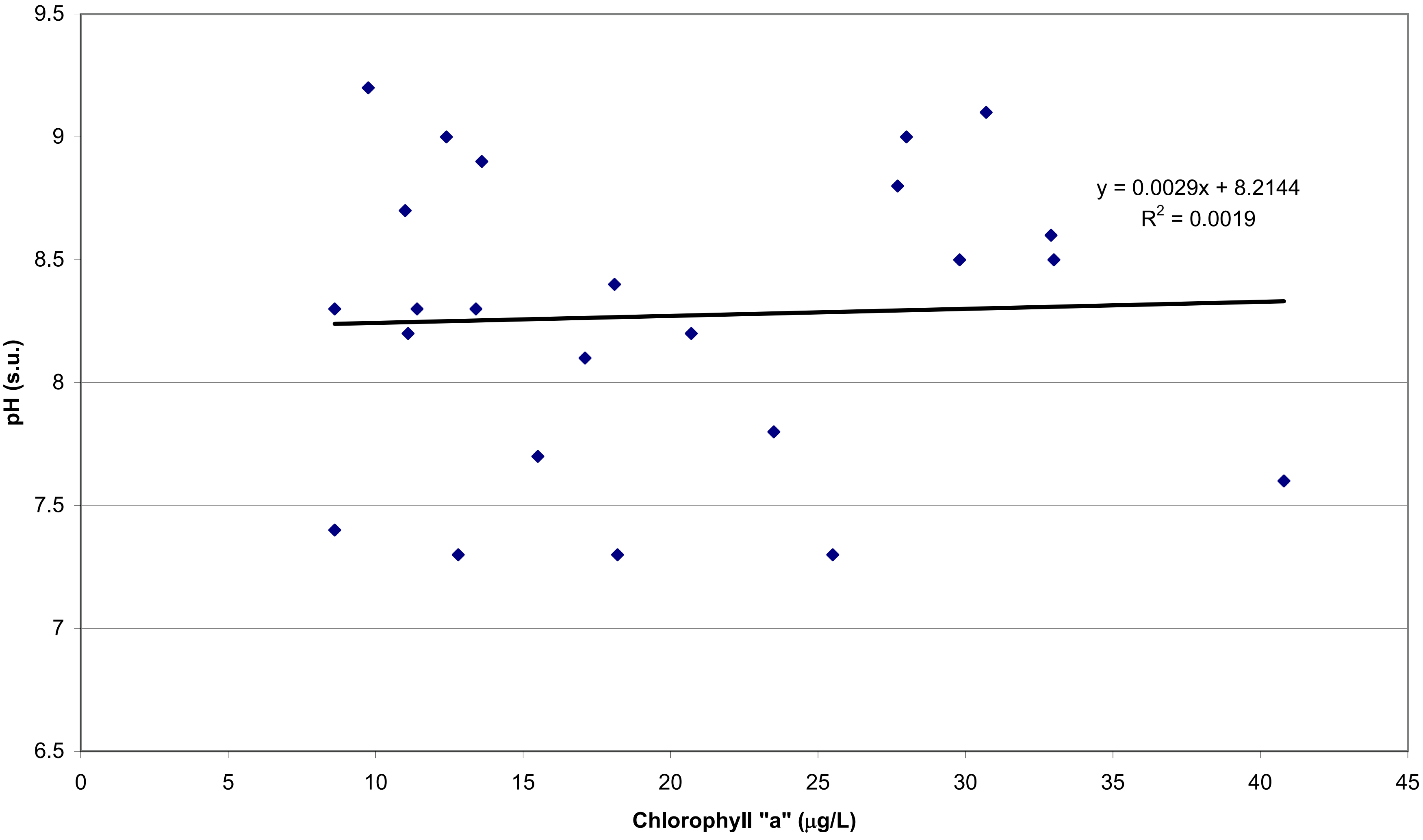

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Figure 7-3: Relationship between Total Phosphorus at One-Foot Depth and Chlorophyll "a" at Kinkaid Lake Station RNC-1

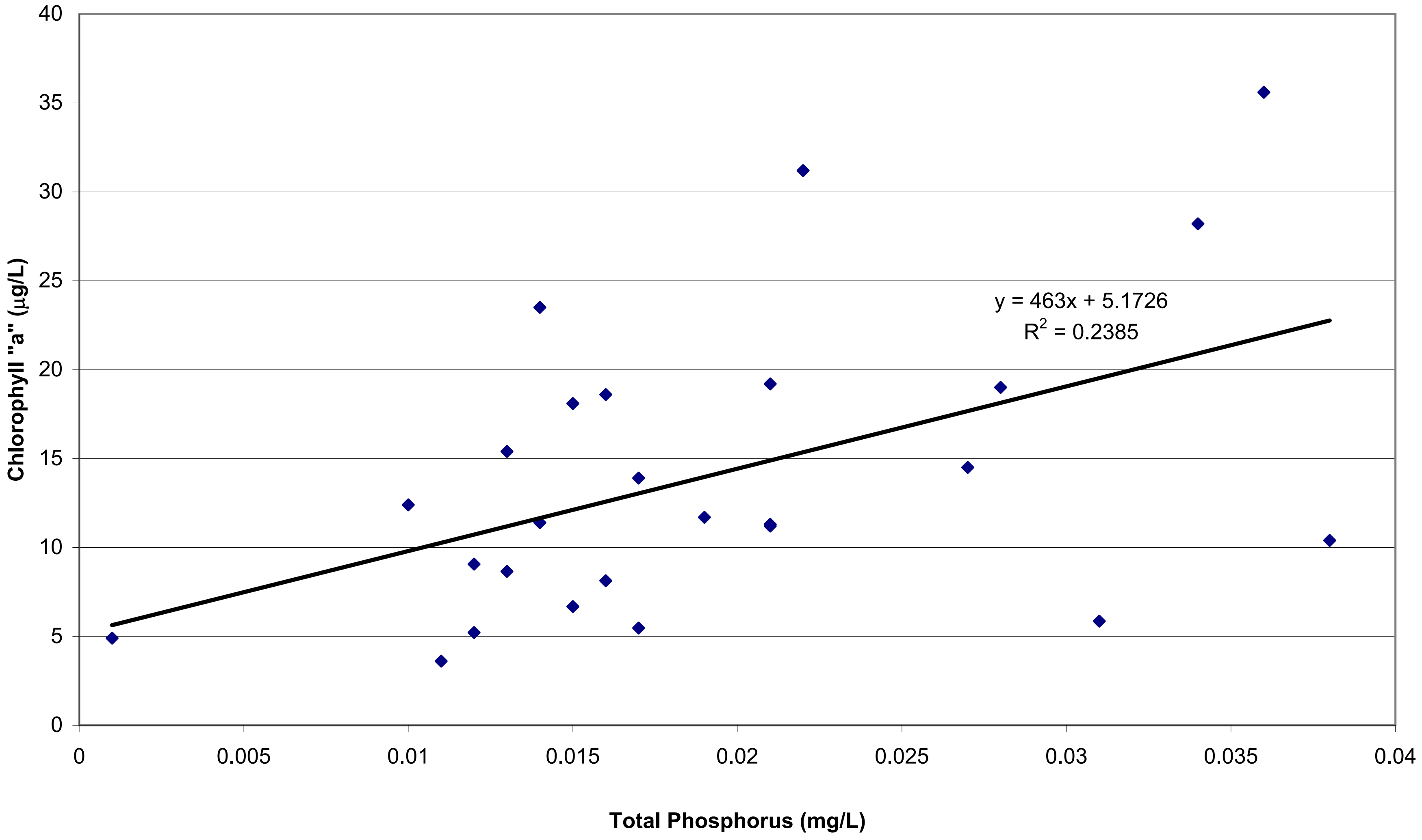

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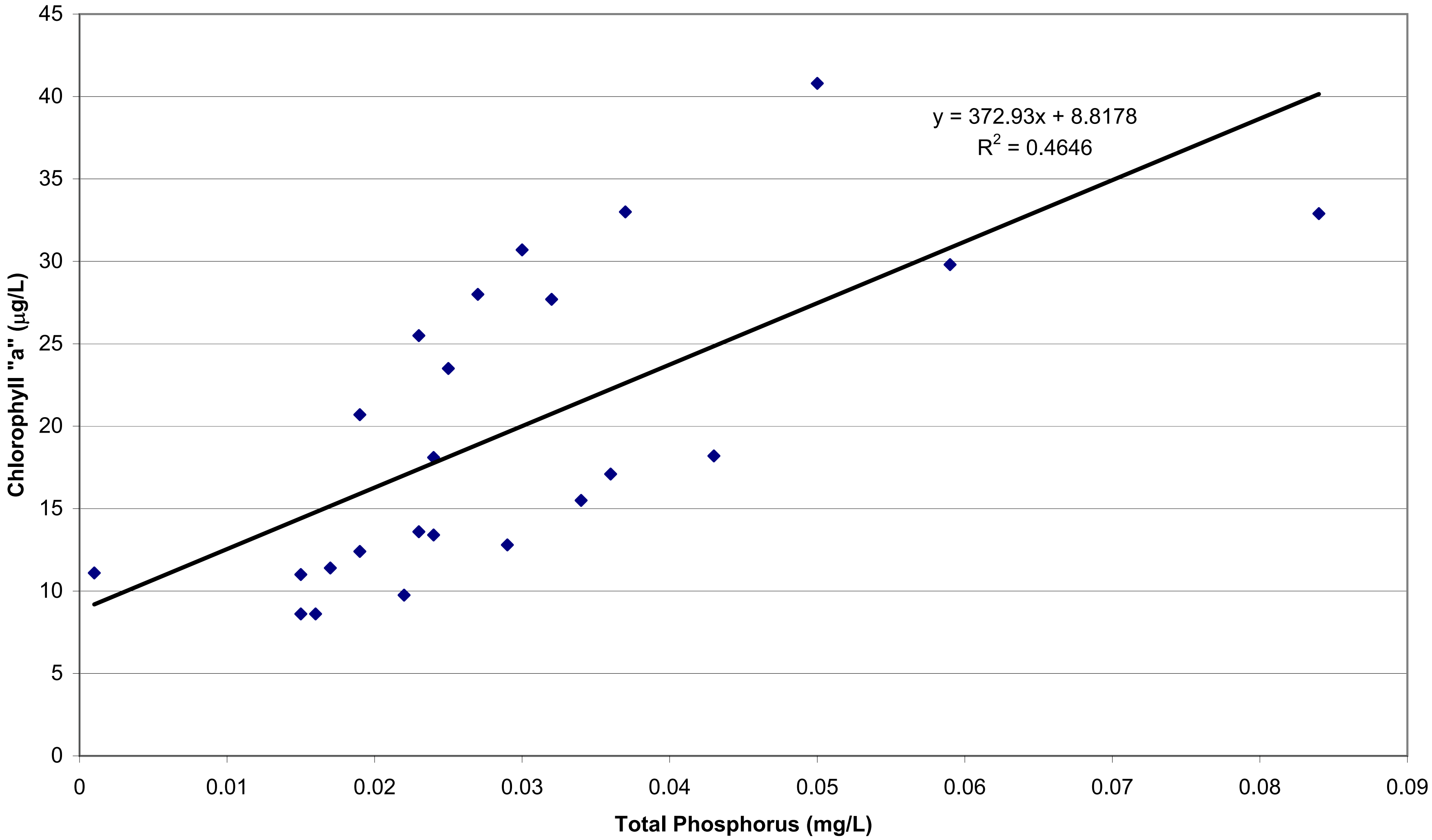
Figure 7-4: Relationship between Total Phosphorus at One-Foot Depth andChlorophyll "a" at Kinkaid Lake Station RNC-3



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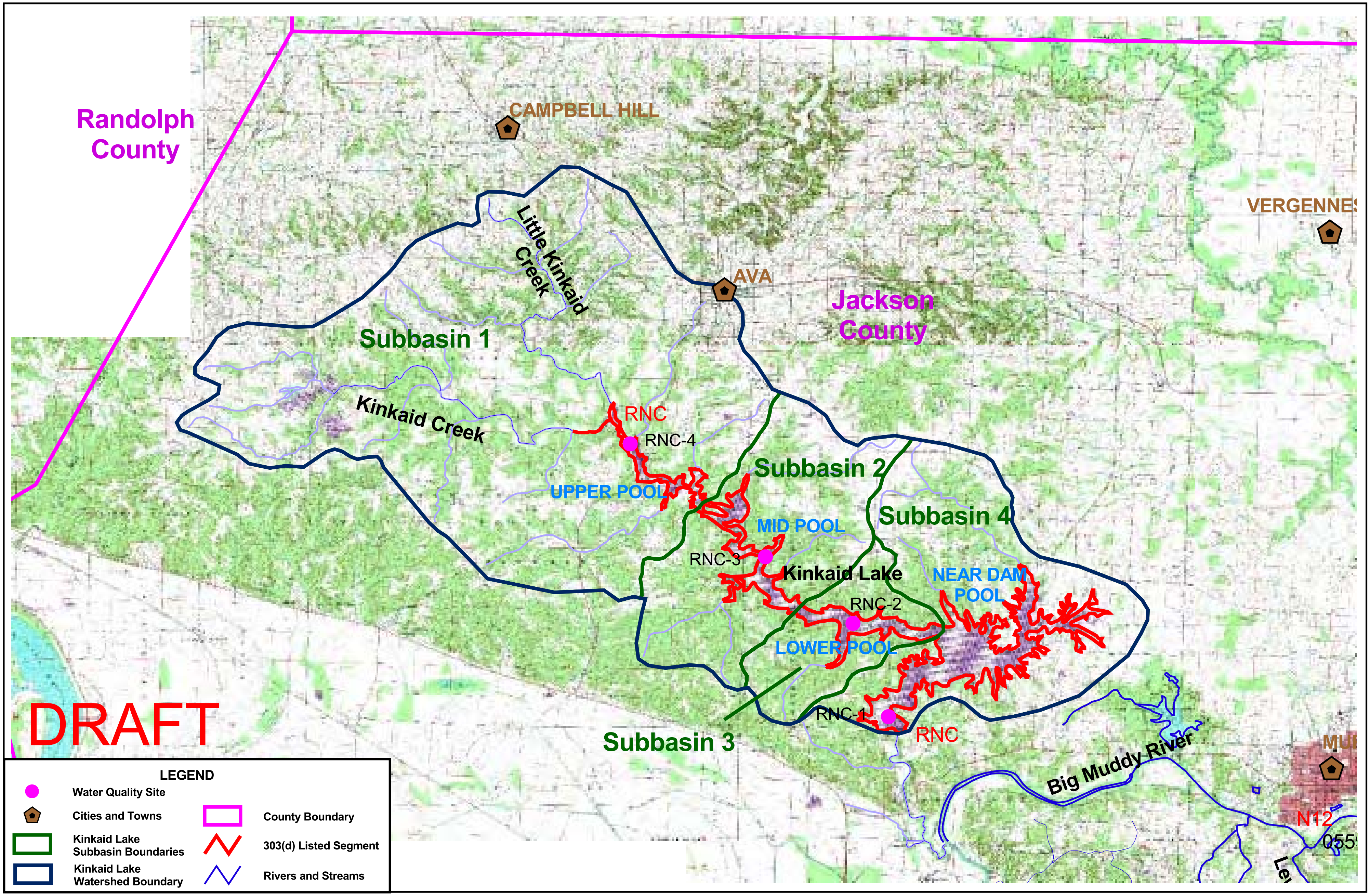

Figure 7-5
Kinkaid Lake Watershed, Historic Sampling Locations, and Modeling Divisions

CDM

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Figure 7-6: Kinkaid Lake Inflows
Subbasin 1 Monthly Flow Comparison

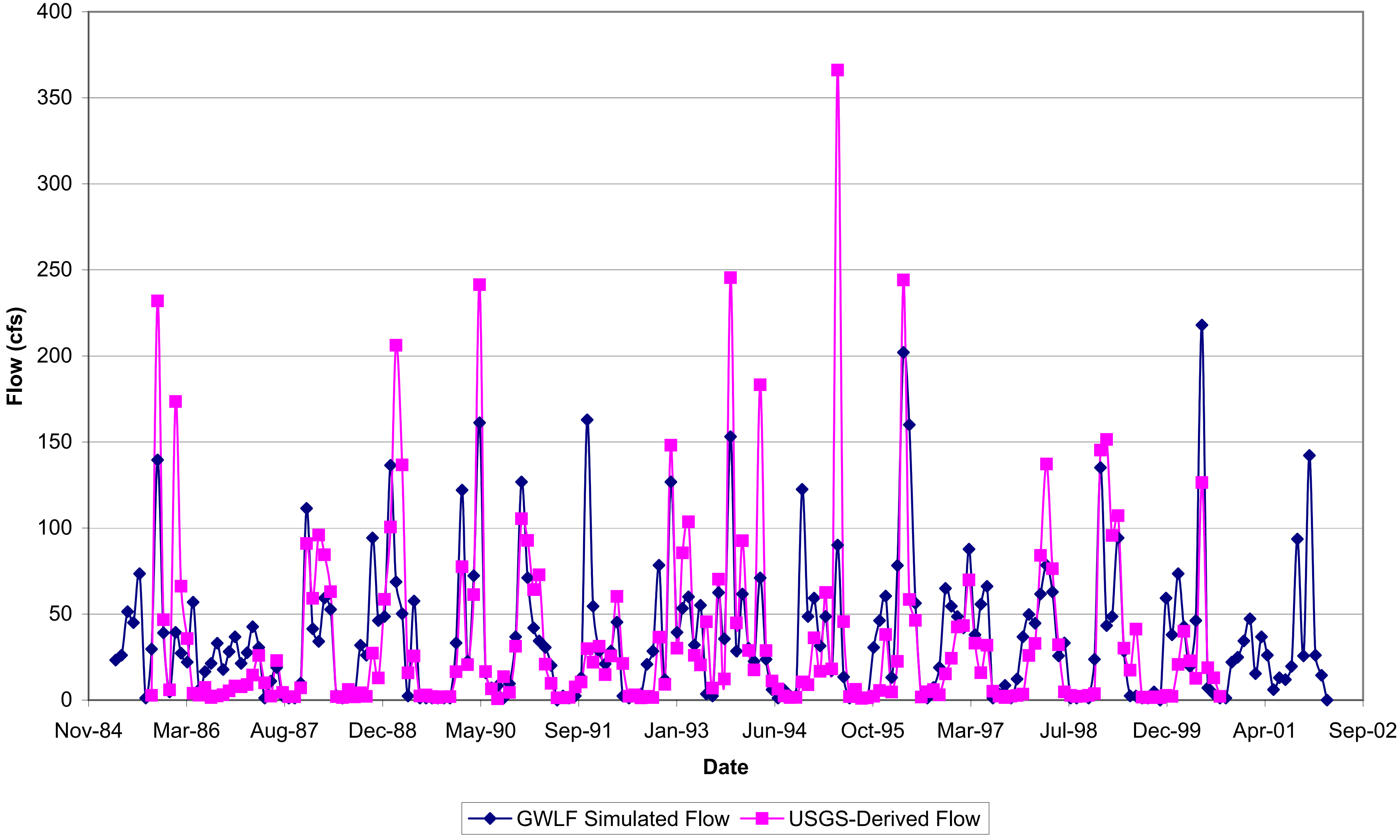

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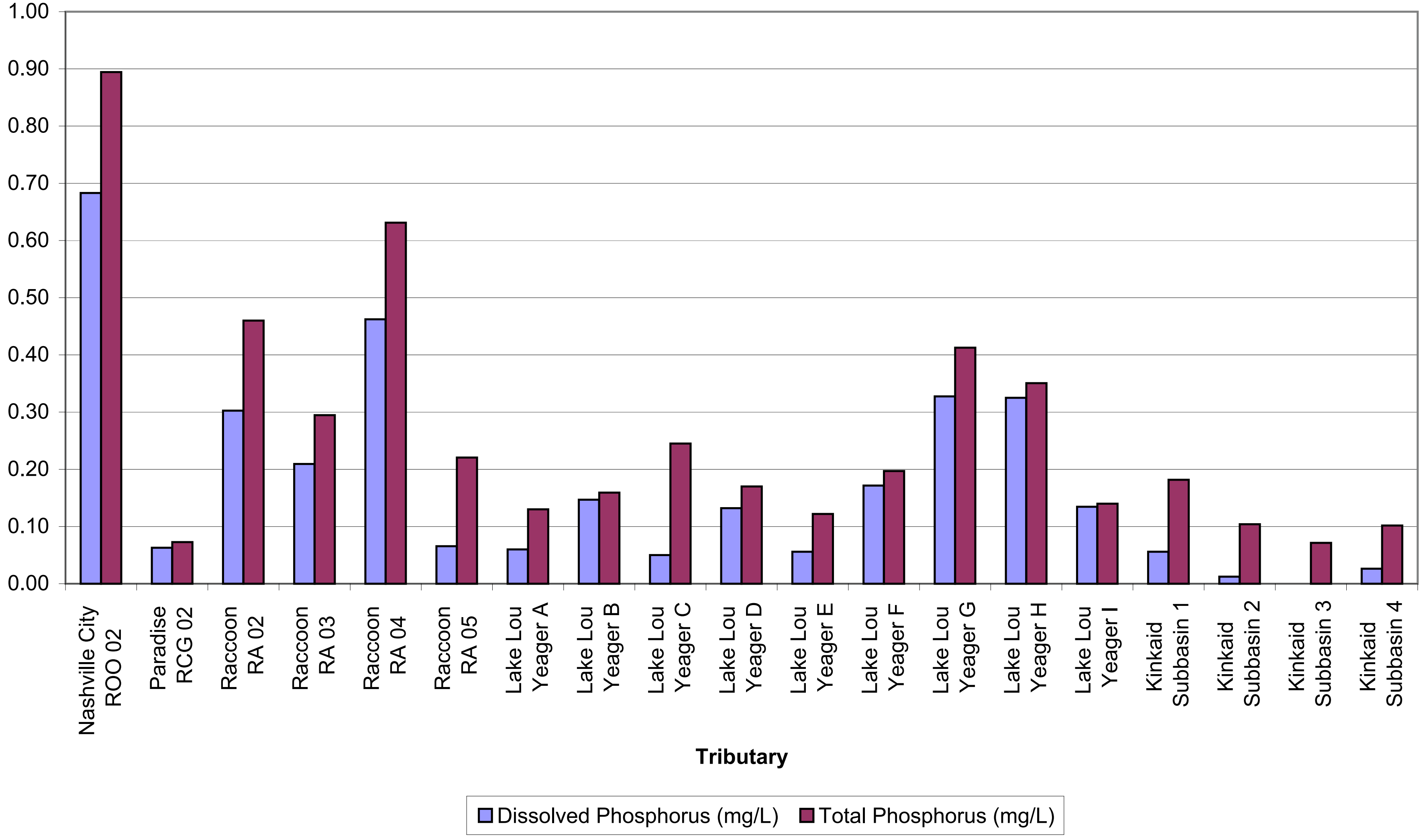
Figure 7-7: Dissolved and Total Phosphorus Concentrations Measured in Clean Lake Study Tributaries and Estimated for Tributaries to Kinkaid Lake



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Section 8
Total Maximum Daily Load for Kinkaid Lake Watershed

8.1 TMDL Endpoints for Kinkaid Lake

The desired in-lake water quality standard for pH is between 6.5 and 9 and less than or equal to 0.05 mg/L for total phosphorus. Tables 5-5, 5-6, ad 5-7 summarized the average pH, total phosphorus, and chlorophyll "a" concentrations sampled in the Kinkaid Lake Watershed. As noted in Section 5.1.5.1.1, all observed in-lake averages meet these targets, but individual samples violate the TMDL endpoints. The range of pH values is set to prevent eutrophic conditions in Kinkaid Lake and maintain aquatic life. Phosphorus is a concern as nuisance plant growth and algal concentrations in many freshwater lakes are enhanced by the availability of phosphorus.

8.2 Pollutant Sources and Linkages

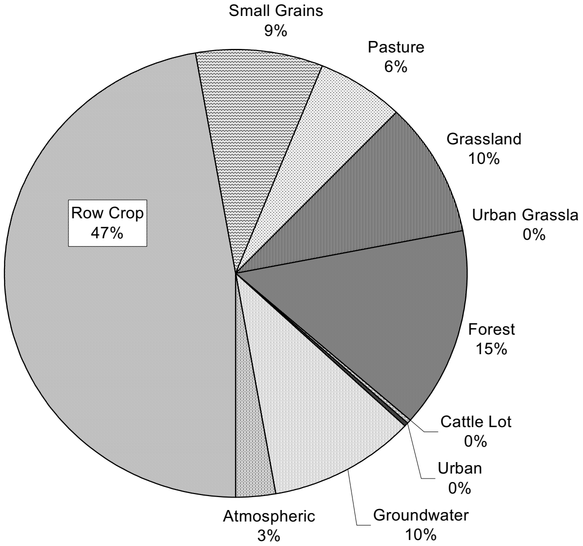
The TMDL for pH in Kinkaid Lake is dependent on a relationship between pH, chlorophyll "a," and phosphorus as explained in Sections 5.1.5.1.1 and 7.1. Relationships between phosphorus, chlorophyll "a," and pH were determined, but it is recognized that they only represent general trends.

Although Kinkaid Lake is not listed for phosphorus, sample concentrations do exceed the endpoint of 0.05 mg/L for total phosphorus in the most upstream pool. This TMDL is based on the assumption that trends in Kinkaid Lake will follow those observed in literature where the control of phosphorus results in acceptable pH values. The remainder of this section focuses on reductions in phosphorus to control pH.

Pollutant sources and their linkages to Kinkaid Lake were established through the GWLF and BATHTUB modeling techniques described in Section 7. Pollutant sources of phosphorus include nonpoint source runoff from agriculture. Atmospheric deposition is another potential source of loads. The predicted phosphorus loads from GWLF and BATHTUB 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 Kinkaid Lake Watershed.

Table 8-1 Modeled Total Phosphorus Load by Source

Land Use	1994 (normal)		1997 (wet)		2000 (wet)		Mean	
	lb/yr	**Percent**	**lb/yr**	**Percent**	**Lb/yr**	**Percent**	**lb/yr**	**Percent**
Row Crop	6,949	45%	9,276	47%	15,215	49%	10,480	47%
Small Grains	1,306	8%	1,707	9%	2,813	9%	1,942	9%
Rural Grassland								
Pasture	933	6%	1,101	6%	2,036	7%	1,357	6%
Grassland	1,446	9%	1,817	9%	3,241	10%	2,168	10%
Urban Grassland	0	0%	0	0%	27	0%	9	0%
Forest	2,006	13%	2,835	14%	4,795	16%	3,212	15%
Cattle Feedlot	23	0%	28	0%	54	0%	35	0%
Urban	70	0%	28	0%	27	0%	41	0%
Groundwater	2,262	15%	2,395	12%	2,223	7%	2,293	10%
Atmospheric	628	4%	628	3%	628	2%	628	3%
Total	**15,623**	**100%**	**19,815**	**100%**	**31,059**	**100%**	**22,165**	**100%**



The majority of the predicted phosphorus load is from 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 at the most upstream water quality site. The TMDL explained throughout the remainder of this section will examine how much the external loads need to be reduced in order to meet the total phosphorus water quality standard of 0.05 mg/L in Kinkaid Lake.

8.3 Allocation

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

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

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

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

8.3.1 Loading Capacity

The loading capacity of Kinkaid Lake is the pounds per year of total phosphorus that can be allowed as input to the lake and still meet the water quality standard of 0.05 mg/L total phosphorus. The allowable phosphorus loads that can be generated in the watershed and still maintain water quality standards was determined with the models that were set up and calibrated as discussed in Section 7. To accomplish this, the loads presented in Table 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 Kinkaid Lake. Only loads modeled from Subbasin 1 were reduced because this subbasin has the most impact on water quality at site RNC-4, which had observed phosphorus concentrations greater than 0.05 mg/L. Table 8-2 shows the allowable phosphorus loading determined for 1994, 1997, and 2000 by reducing modeled inputs to Kinkaid Lake through GWLF and BATHTUB. The output files to BATHTUB showing the results of the load reductions for 1994, 1997, and 2000 are contained in Appendix I.

Table 8-2 Allowable Total Phosphorus Load by Model Year for Kinkaid Lake

Model Year	Phosphorus (lb/yr)
1994	8,109
1997	10,697
2000	23,145
Mean	13,983

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.

The modeled total phosphorus and chlorophyll "a" concentrations resulting from the allowable loads are presented in Table 8-3. The pH values associated with the phosphorus and chlorophyll "a" concentrations shown in Table 8-3 were determined from the relationships provided in Figures 7-1 through 7-4. Only results at stations RNC-1 and RNC-3 are shown because, as mentioned previously, these are the only stations with samples that exceeded the pH standard. This analysis shows that violations of the pH water quality standard should be avoided. Therefore, the TMDL for Kinkaid Lake will focus on phosphorus as explained throughout the remainder of this section.

Table 8-3 Predicted Total Phosphorus, Chlorophyll "a," and pH Values in Kinkaid Lake

Year	Total Phosphorus (mg/L)	Chlorophyll "a" (µg/L)	pH (s.u.)
1994 (RNC-1)	0.02	16.6	8.2
1994 (RNC-3	0.02	13.1	8.3
1997 (RNC-1)	0.03	11.9	8.0
1997 (RNC-3	0.03	18.2	8.3
2000 (RNC-1)	0.02	19.1	8.2
2000 (RNC-3)	0.03	15.5	8.3

As discussed previously, modeled loads to the most upstream segment of Kinkaid Lake were reduced to attain a total phosphorus concentration of 0.05 mg/L, which in turn reduced modeled concentrations in downstream segments of the lake. Therefore, the values in Table 8-3 are much lower than the water quality standard, although the modeled concentrations in the most upstream segment are just below the phosphorus standard of 0.05 mg/L.

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

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

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

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

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

8.3.4 Waste Load Allocation

There are no point sources in the watershed; therefore, no WLA is recommended at this time.

8.3.5 Load Allocation and TMDL Summary

Table 8-4 shows a summary of the TMDL for Kinkaid Lake. On average, a total reduction of 43 percent of total phosphorus loads to Kinkaid Lake would result in compliance with the water quality standard of pH values between 6.5 and 9 based on modeling efforts.

Table 8-4 TMDL Summary for Total Phosphorus in Kinkaid Lake

LC (lb/yr)	WLA (lb/yr)	LA (lb/yr)	MOS (lb/yr)	Reduction Needed (lb/yr)	Reduction Needed (percent)
13,983	0	13,283	700	8,882	40%

Table 8-5 shows the respective reductions needed from 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. An approximate 41 percent reduction of nonpoint sources from the watershed would be necessary to meet the load allocation presented in Table 8-4. Methods to meet these targets will be outlined in Section 9.

Table 8-5 Sources for Total Phosphorus Reductions

Source	Current Load (lb/yr)	Load Reduction (lb/yr)	Percent Reduction
Atmospheric	628	0	0%
Nonpoint Sources	21,537	8,882	41%

Section 9
Implementation Plan for Kinkaid Lake

9.1 Implementation Actions and Management Measures

As discussed in Sections 7.1 and 8.2, the TMDL for Kinkaid Lake is based on relationships between pH, chlorophyll "a," and phosphorus. The remainder of this section focuses on reductions in phosphorus to control pH. It was determined that reductions in phosphorus to the TMDL endpoint of 0.05 mg/L will result in pH concentrations that meet the water quality standard. Therefore, this implementation plan focuses on measures that will reduce phosphorus.

Phosphorus loads in the Kinkaid Lake Watershed originate from external sources, such as croplands. The annual averages of data collected during sampling of Kinkaid Lake indicate that only the upstream portion of Kinkaid Lake is impaired for phosphorus (detailed in Section 7). Land use for the entire watershed illustrates that 70 percent of the agricultural practices occur in the portion of the watershed upstream of Kinkaid Lake, which supports the data. Hence, implementation measures focus on the watershed area located upstream of Kinkaid Lake (subbasin 1 in Figure 7-5). However, the TMDL endpoints and load reductions apply to the entire Kinkaid Lake Watershed.

From modeling estimates, external loads from nonpoint source runoff from agricultural crops potentially account for 56 percent of the loading to Kinkaid Lake, and forest land, both deciduous and coniferous, accounts for approximately 15 percent of the nonpoint source phosphorus loaded to the lake. Grassland and pasture land account for approximately 16 percent of the modeled load, and the remaining 14 percent are contributed by atmospheric and groundwater loads. To achieve the 41 percent reduction for the load allocations established in Section 8 (Table 8-4), management measures must address nonpoint source loading through sediment and surface runoff controls. Phosphorus sorbs readily to soil particles and controlling sediment load into the reservoir helps control phosphorus loadings.

The pH level in lakes is tied to the plant, animal, and nutrient cycles of the lake. Plants and algae use CO_2 during photosynthesis, which causes pH levels to rise. The photosynthetic rate progressively decreases as the residual CO_2 concentration declines and ceases completely with the extinction of light. During the night, reaeration and respiration replenish CO_2 causing the pH levels to decrease overnight (Welch 1980). Plant and algae growth tend to increase significantly with the addition of phosphorus to the lake; therefore, the success of controlling pH levels in Kinkaid Lake is linked to the control of nonpoint source phosphorus loads.

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 phosphorus source located in the upper Kinkaid Lake Watershed. Nonpoint sources include agricultural practices, such as cropland and a cattle feedlot.

9.1.1 Nonpoint Source Phosphorus and pH Management

The sources of nonpoint source pollution in subbasin 1 of the Kinkaid Lake Watershed consist of agricultural cropland and a cattle feedlot, although the feedlot in the upper watershed was designated as having no impact on the receiving waters. BMPs evaluated for treatment of these nonpoint sources are:

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

Total phosphorus originating from cropland is most efficiently treated with a combination of no-till or conservation tillage practices and grass filter strips. Wetlands located upstream of the reservoir potentially provide further reductions in total and dissolved phosphorus in runoff from croplands and cattle operations. Nutrient management focuses on source control of nonpoint source contributions to Kinkaid Lake.

9.1.1.1 Conservation Tillage Practices

For the Kinkaid Lake Watershed, conservation tillage practices could help reduce nutrient loads in the lake. Nonpoint source runoff from 3,200 acres of row crops and small grain agriculture in subbasin 1 were estimated to contribute 27 percent of the phosphorus load to Kinkaid Lake. Total phosphorus loading from cropland is controlled through management BMPs, such as conservation tillage. Conservation tillage maintains at least 30 percent of the soil surface covered by residue after planting. Crop residuals or living vegetation cover on the soil surface protect against soil detachment from water and wind erosion. Conservation tillage practices can remove up to 45 percent of the dissolved and total phosphorus from runoff and approximately 75 percent of the sediment. Additionally, studies have found around 93 percent less erosion occurred from no-till acreage compared to acreage subject to moldboard plowing (North Carolina State University [NCSU] 2000). It is estimated that conventional till currently accounts for 20 percent of corn, 0 percent of soybean, and 20 percent of small grain tillage practices in Jackson County, and these percentages were assumed to apply to the Kinkaid Lake Watershed as well. 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 average 10.5 tons/acre/year. To achieve a 19 percent reduction in phosphorus load, the erosion rate for the watershed would need to be reduced to 8.5 tons/acre/year. Similarly, the C-factors for corn, soybeans, and small grains would need to be reduced from 0.21, 0.08, and 0.13 to 0.17, 0.06, and 0.10, respectively.

9.1.1.2 Wetlands

The use of wetlands as a structural control is most applicable to nutrient reduction from agricultural lands in subbasin 1 of Kinkaid Lake. Therefore this section only focuses on the subbasin 1 watershed. Wetlands are an effective BMP for sediment and phosphorus control 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 agricultural runoff from subbasin 1, which is estimated to contribute approximately 27 percent of the current total phosphorus load to Kinkaid Lake, a wetland system could be constructed on the upstream end of the reservoir. Treatment of sediment and phosphorus from agricultural runoff could be accomplished through a combination of no-till practices, wetlands, and filter strips.

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. Since a wetland to treat agricultural runoff from the 22,275-acre upper Kinkaid Lake Watershed would need to be approximately 134 acres based on these recommendations, it is recommended to build a wetland system composed of a series of wetlands on different tributaries around the basin to achieve the 134 acres of wetlands for treatment (Denison and Tilton 1993).

9.1.1.3 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to Kinkaid Lake 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 subbasin 1 of the Kinkaid Lake 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 Kinkaid Lake will reduce the amount of algal growth in the lake system, which can cause more significant diurnal pH fluctuations from photosynthesis. Filter strips reduce nutrient and sediment loads to lakes by establishing ground depressions and roughness that settles sediment out of runoff and providing vegetation to filter nutrients out of overland flow. As much as 75 percent of sediment and 45 percent of total phosphorus can be removed from runoff by a grass filter strip (NCSU 2000). 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 Kincaid Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 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.

Filter strip widths for the Kinkaid Lake TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 9-1 outlines the guidance for filter strip flow length by slope (NRCS 1999).). Based on slope estimates near tributaries within the watershed, filter strips widths of 90 to 234 feet could be incorporated in locations throughout the watershed. The total acreage examined was 107 acres.

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

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

The filter strip lengths and widths presented above are used to calculate an approximation of BMP costs in Section 9.2.2.6 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.

9.1.1.4 Nutrient Management

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

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

- Plan summary
- Manure summary, including annual manure generation, use, and export
- Nutrient application rates by field and crop
- Summary of excess manure utilization procedures
- Implementation schedule
- Manure management and stormwater BMPs

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

9.1.2 Implementation Actions and Management Measures Summary

9.1.2.1 Kinkaid Lake Watershed

To meet the reductions outlined in Section 8 for Kinkaid Lake, 41 percent of phosphorus loaded from nonpoint source pollution would need to be reduced 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:

- Conservation tillage
- Nutrient management (reduction of total phosphorus in sediment by 20 percent)
- Filter strips

These practices were only applied to subbasin 1 because reductions are only required in the upper pool of Kinkaid Lake. The modeling effort showed that filter strips do not provide much total phosphorus reduction, most likely due to routing constraints of the GWLF model as discussed in Section 7.3.2.1.1 and the small magnitude of area available for filter strip development.

Table 9-2 Summary of Total Phosphorus Load Reductions

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

* Literature Value

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 was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible.

A combination of implementing these external load reduction practices would allow the Kinkaid Lake Watershed to meet its total goal of reducing phosphorus loads by 44 percent. 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 programs available to assist with funding of implementing practices and also an estimate of costs to the watershed for implementing these practices.

9.2.1 Available Programs

Approximately 24 percent of the Kinkaid Lake Watershed is classified as rural grassland (pasture land, Conservation Reserve Program [CRP], waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill, which encourage landowners to implement resource conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following 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, 4,327 acres of cropland have been targeted in the Kinkaid Lake Watershed. This voluntary project will supply incentive payments to producers to have Nutrient Management Plans developed and implemented. Additionally, if sediments or phosphorus have 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 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 one of the following:

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

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

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

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

- Riparian buffers
- Filter strips

- Grass waterways
- Shelter belts
- Field windbreaks
- Living snow fences
- Contour grass strips
- Salt tolerant vegetation
- Shallow water areas for wildlife
- Eligible acreage within an USEPA-designated wellhead protection area (FSA 1997)

9.2.1.3 Wetlands Reserve Program (WRP)

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. 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

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

9.2.1.4 Environmental Quality Incentive Program (EQIP)

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 2002d,e).

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.

9.2.1.5 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.

9.2.1.6 Wildlife Habitat Incentives Program (WHIP)

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

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

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

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

Table 9-4 Local NRCS and FSA Contact Information

Contact	Address	Phone
Local NRCS Office		
W. Scott Martin	1213 N. 14th Street, Murphysboro, Illinois 62966	618-684-3064 x3
Local FSA Office		
Murphysboro Service Center	1213 N. 14th Street, Murphysboro, Illinois 62966	618-684-3471

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 Kinkaid Lake Watershed are presented in Section 9.2.2.6 and Table 9-6.

9.2.2.1 Wetland

The price to establish a wetland is site specific. In general, the cost to construct a wetland includes creation of wetland hydrology, site preparation for planting, shrub or tree planting, and labor costs. The average project cost to establish a wetland in Jackson County is $1,280/acre. It should be noted that the larger the wetland acreage to be established the more cost-effective the project.

9.2.2.2 Filter Strips and Riparian Buffers

Jackson County NRCS estimates an average cost per acre to install and maintain a grass filter strip with a 10-year life span at $90/acre. This price quote accounts for seeding and mowing every other year to remove woody sprouts. A riparian buffer strip established with bare root stock has a life span of 10-years and an installation cost of $384/acre.

9.2.2.3 Nutrient Management Plan – NRCS

Generally, agricultural land in Jackson County is comprised of cropland; therefore, nutrient management concentrates on nitrogen, phosphorus, potassium, lyme, and pest management residuals. The Nutrient Management Program in Jackson County consists of soil testing every three years using University of Illinois Guidelines and site specific recommendations for 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 is estimated as $5/acre paid to the producer and

$2/acre for a third party vendor who develops the plans. The total plan development cost is estimated at $7/acre.

9.2.2.5 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. 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 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 and the CRP.

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

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	WRP	Wetland	10	$1,280	$128.00
	CRP	Grass Filter Strips	10	$90	$9.00
	CRP	Riparian Buffer	10	$384	$38.40
	NRCS	Nutrient Management Plan		$10	
	IDA and Illinois EPA	Nutrient Management Plan		$7	
	CRP	Conservation Tillage	1	$17	$17.35

A total order of magnitude cost for implementation measures in the watershed was estimated to be $266,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 9-6 summarizes the number of acres each measure 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 costs of operating the measure over its life cycle. The IDA and Illinois EPA sponsored nutrient management plan is applied to all cropland acres in the Kinkaid Lake Watershed, whereas the costs for conservation tillage were only developed for Subbasin 1.

Table 9-6 Cost Estimate of Implementation Measures for Kinkaid Lake Watershed

		Capital Costs		Maintenance Costs	
BMP	Treated Acres	Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Wetland on River	134	$1,280	$172,000	$128.00	$17,000
Grass Filter Strips	107	$90	$10,000	$9.00	$1,000
Nutrient Management Plan	4,327	$7	$30,000		
Conservation Tillage	3,200	$17	$54,000	$17.35	$56,000
Total			**$266,000**		**$74,000**

9.3 Monitoring Plan

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

- Track implementation of management measures in the watershed
- Estimate effectiveness of management measures
- Continue ambient monitoring of Kinkaid Lake
- Tributary monitoring

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

- Determine the extent to which management measures and practices have been implemented compared to action needed to meet TMDL endpoints

- Establish a baseline from which decisions can be made regarding the need for additional incentives for implementation efforts

- Measure the extent of voluntary implementation efforts

- Support workload and 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.

Illinois EPA monitors Kinkaid Lake 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. Additionally, Illinois EPA conducted a Clean Lakes Study on Kinkaid Lake, which would provide instream nutrient data for Kinkaid Lake tributaries including dissolved and total phosphorus, during the summer of 2003.

Tributary monitoring is needed to better assess the contribution of internal loading to Kinkaid Lake. 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.

9.4 Implementation Time Line

Implementing the actions outlined in this section for the Kinkaid Lake Watershed should occur in phases and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. Once improvements are implemented, it may take Kinkaid Lake 10 years or more to reach the water quality standard target of 0.05 g/L for total phosphorus and associated targets between 6.5 and 9 for pH (Wetzel 1983). In summary, to meet water quality standards in Kinkaid Lake may take up to 20 years to complete.

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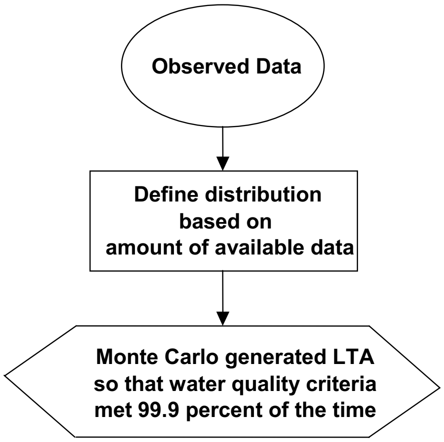
Section 10
Methodology Development for the Big Muddy River Watershed

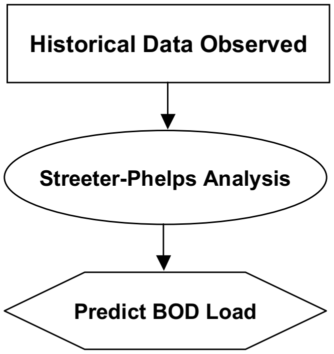
10.1 Methodology Overview

Methodologies were utilized in the TMDL analysis of the Big Muddy River segment N12. For manganese and sulfates, a Monte Carlo simulation was utilized to estimate a long-term average instream concentration needed to meet water quality standards. Investigation of DO required a Streeter-Phelps analysis.



Schematic 1

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



Schematic 2

The Streeter-Phelps analysis was conducted as illustrated in the schematic to the right. Observed data were utilized to set up a Streeter-Phelps analysis to predict stream coefficients that would be required to result in observed DO concentrations. This Streeter-Phelps analysis was based on USEPA's Screening Procedures (Mills et al. 1985). The 5-day biochemical oxygen demand (BOD_5) load and reaeration coefficient (k_a) utilized in the Streeter-Phelps analysis were examined in the TMDL for DO for segment N12.

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

10.2 Watershed Delineation

A watershed for the area contributing directly to Big Muddy River segment N12 was delineated with GIS analyses through use of the DEM as discussed in Section 5.1.2. The delineation suggests that segment N12 captures flows from a directly contributing watershed of approximately 28 square miles. Figure 10-1 at the end of this section shows the location of the water quality stations in the Big Muddy River segment N12 and the boundary of the GIS-delineated watershed contributing to the segment N12.

10.3 Methodology Development and Results

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

10.3.1 Monte Carlo Analysis Development and Results

For each constituent exceeding water quality standards, the available data was analyzed and an appropriate distribution was chosen to represent the data. A lognormal distribution, defined as a distribution of a random variables whose logarithm is normally distributed, was chosen to analyze segment N12 since sufficient data for this site was available to utilize this distribution.

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

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

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

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

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

LTA = Mean * (1 - PR99.9)

10.3.1.1 Monte Carlo Results for Big Muddy River Segment N12

Manganese values in Segment N12 ranged from 0.1 to 2.5 mg/L and sulfates values ranged from 59 to 660 mg/L as shown in Table 5-8. Two of the output model concentrations are significant to the TMDL analysis of segment N12. The first is the average concentration calculated from the triangular distribution of the observed data. The second concentration is the LTA, which represents the average concentration that should be observed over the long term to ensure that the water quality standard is exceeded fewer than once every three years. Table 10-1 shows the average concentration calculated from the distribution utilized in the Monte Carlo analysis and the LTA concentration needed so that water quality standards will be achieved in Big Muddy River segment N12. Calculation details are presented in Appendix E.

Table 10-1 LTA Manganese and Sulfates Concentrations Required to Meet Water Quality Standards in Big Muddy River Segment N12

Constituent	Average Concentration Calculated from Distribution (mg/L)	LTA Concentration (mg/L)
Manganese	0.6	0.2
Sulfates	247	104

Table 10-1 shows that the concentration required to meet water quality reductions, the LTA, is lower than the observed average concentration for manganese and sulfates; therefore, the TMDL for segment N12 requires that a load reduction be made for manganese and sulfates based upon the available data. The TMDL will be discussed in Section 11.

10.3.2 DO Analysis Development and Results

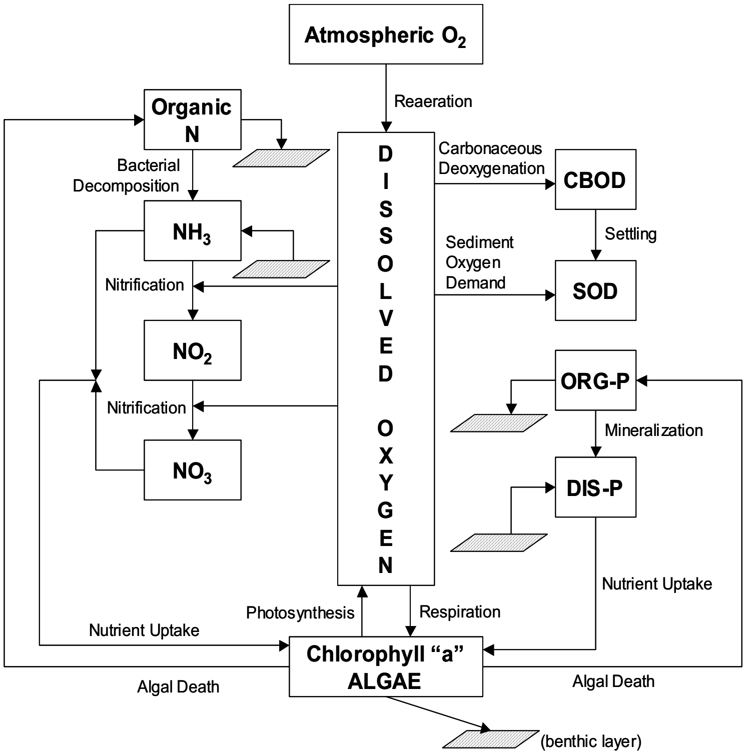
A Streeter-Phelps analysis was utilized for investigation of DO in the Big Muddy River segment N12 Watershed. Data availability useful for analyzing DO for this watershed is described in Table 10-2. The historic water quality data were investigated from 1990 to 2000.

Table 10-2 Data Availability from 1990 to 2000

Model Parameter	Historic data available (yes/no)
Flow	Yes
Stream Temperature	Yes
DO	Yes
5-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)	No
BOD_5	No
Total Nitrogen	No
Total Organic Carbon	Yes
Ammonia	Yes
Nitrate + Nitrite	Yes
Total Kjeldahl Nitrogen	Yes
Total Phosphorus	Yes
Dissolved Phosphorus	Yes
Orthophosphate	Yes
pH	Yes
20-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_{20}$)	No
Daily Minimum And Maximum DO	No
Chlorophyll "a"	No
Stream Depth	Yes

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

- Deoxygenation of biodegradable organics whereby bacteria and fungi (decomposers) utilize oxygen in the bioxidation-decomposition process
- Sediment oxygen demand (SOD), where oxygen is utilized by organisms inhabiting the upper layers of the bottom sediment deposits
- Nitrification, in which oxygen is utilized during oxidation of ammonia and organic nitrogen to nitrates
- Respiration by algae and aquatic vascular plants that use oxygen during night and early morning hours to sustain their living processes

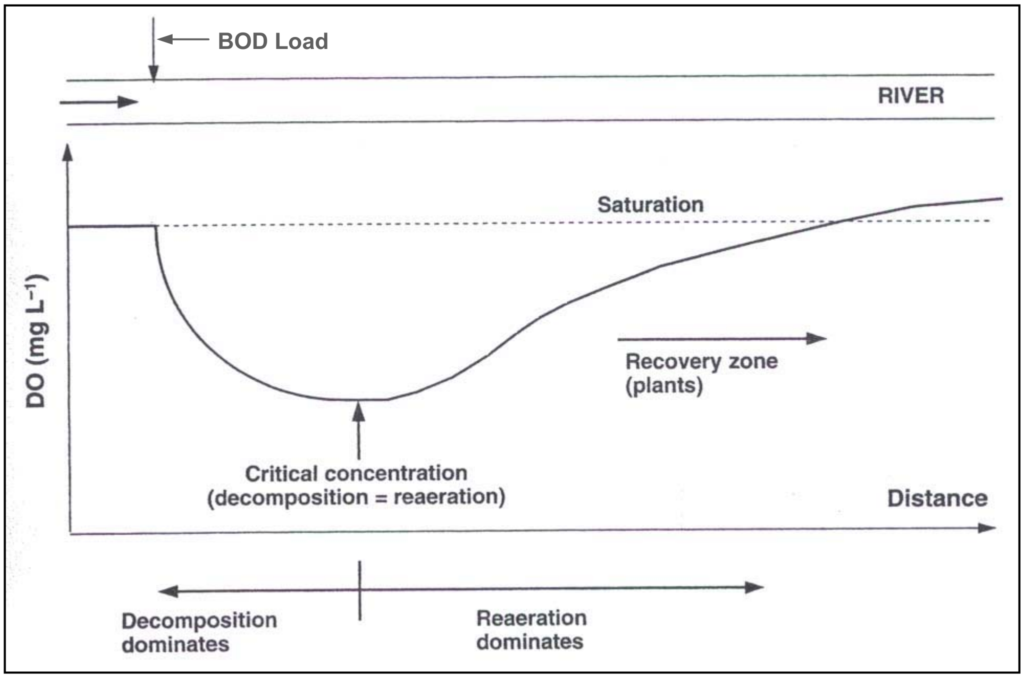


Major oxygen sources are:

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

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

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



Water quality models have built upon the Streeter-Phelps equation to evaluate the DO balance in streams. The analysis for segment N12 is based on BOD_5 and reaeration only. There is not enough coincident nutrient and algal historical data from this site to assess impacts of nutrient loads on algal growth that also impact DO levels. Free floating and attached algae as well as aquatic plants are of concern. The extent to which algae impact the DO resources of a river is dependent on many factors, such as turbidity, which can decrease light transmittance through the water column. Additionally, the photosynthetic rate constantly changes in response to variations in sunlight intensity and is not constant. This results in diurnal fluctuations in DO levels (Mills et al. 1985). In addition, there is not enough data available to estimate the impacts of SOD at these sites.

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

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

The initial BOD_5 concentration (L_o) was calculated from observed TOC data. Literature states that the ratio of BOD_5 to TOC is typically between 1.0 and 1.6

(Metcalf and Eddy, Inc. 1991). For analysis, a ratio of 1.3 was used to calculate BOD_5 for each sample date.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 10-3 shows the observed TOC data and the BOD_5 concentrations (L_0) calculated from observed TOC data. It also shows the k_a and k_d coefficients calculated with the above equations. In addition, the estimated BOD_5 load was calculated based on the calculated BOD_5 concentration and average daily flow on the day the sample was taken. Revised k_a and k_d values are also shown in Table 10-3. These values were utilized in the Streeter-Phelps equation described above and the resulting calculated DO was compared to observed DO readings. If there was not a match between the calculated DO and observed DO, k_a and k_d were revised within their accepted ranges so that calculated DO more closely matched observed DO. If possible, only k_a was revised as it was calculated based on estimated depth and flow while k_d was based on estimated depth. As shown in Table 10-3, the reaeration coefficient was much lower for the impaired sample date than for the non-impaired date. Additionally, the flow for the impaired date was below average as discussed in Section 5.1.5.2.2. Analysis details are contained in Appendix L. In addition to lower flow condtions, there are many factors that may contribute to depressed DO in the Big Muddy River including nutrients stimulating algal activity and other organic loads which could exert an oxygen demand within the system.

Table 10-3 Streeter-Phelps Calculated BOD_5 Concentrations (L_0) and Loads Associated with DO Concentrations

Sample Location and Date	**N12** **7/24/2000**	**N12** **9/6/2000**
Measured DO (mg/L)	7.9	4.7
Measured TOC (mg/L)	5.6	5.5
Calculated BOD_5 Concentration (mg/L)	7.3	7.2
Calculated BOD_5 Load (lb/day)	81,071	15,526
Calculated k_a (1/day)	0.6	1.2
Revised k_a (1/day)	45.4	3.2
Calculated k_d (1/day)	0.36	0.46
Revised k_d (1/day)	0.36	0.46
Flow (cfs)	2,060	400

In addition to the analysis described above, analyses were conducted examining the Big Muddy River during 7Q10 flows or critical low flows with the Carbondale WWTP at its average design flow and BOD limit of 30 mg/L BOD. During these critical conditions, the discharge of the WWTP should not cause DO levels to fall below the 6.0 mg/L standard within segment N12. This was determined by assessing what BOD concentration would need to discharged from the facility to depress DO concentrations below 6 mg/L. It was estimated that a BOD concentration of over 450 mg/L would have to be discharged in order for DO concentrations to fall below 6.0 mg/L. Therefore, no wasteload allocation will be recommended for this facility in Section 11. Analyses details are also contained in Appendix L.

An error analysis was run on the literature ranges of values for k_a and k_d for each sample date to validate their use for the Streeter-Phelps analysis. This analysis is contained in Appendix M.

10.3.3 pH Analysis Development and Results

An analytical method was used to analyze pH in segment N12 of the Big Muddy River. The method incorporates TDS concentrations, ionic strength, an activity coefficient, and flows to calculate a maximum hydrogen ion loading that will maintain a pH value between 6.5 and 9.0 within segment N12.

The ionic strength is calculated with the following equation:

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

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

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

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

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

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

This equation can be used to develop the maximum allowable hydrogen ion concentration for a specific pH and varying flow regimes. Figure 10-2 shows the maximum allowable H^+ ion loading at a pH of 6.5 for various flows. Using a pH of 6.5 and the three-year peak flow in the above equation will result in the maximum hydrogen ion concentration allowed to maintain a pH of at least 6.5. The three-year peak flow is utilized because pH is considered a potential cause of use impairment if the water quality standard is at least once in the most recent three-year period (Illinois EPA 2000) allowable excursion.

The 95th percentile of the TDS concentrations in segment N12 is 1,194 mg/L resulting in an ionic strength of 0.02. An activity coefficient of 0.9 was determined from literature for segment N12. The chart used to determine the activity coefficient is provided in Appendix N. As mentioned in Section 5.1.3, flows for segment N12 were obtained from USGS gage 05599500. A lognormal distribution was used to develop the three-year peak flow through segment N12 of 16,426 cfs. Using this flow in the above equation, a maximum allowable hydrogen ion concentration of 14,200 g/day or 31 lb/day was calculated. Analysis details are contained in Appendix O.

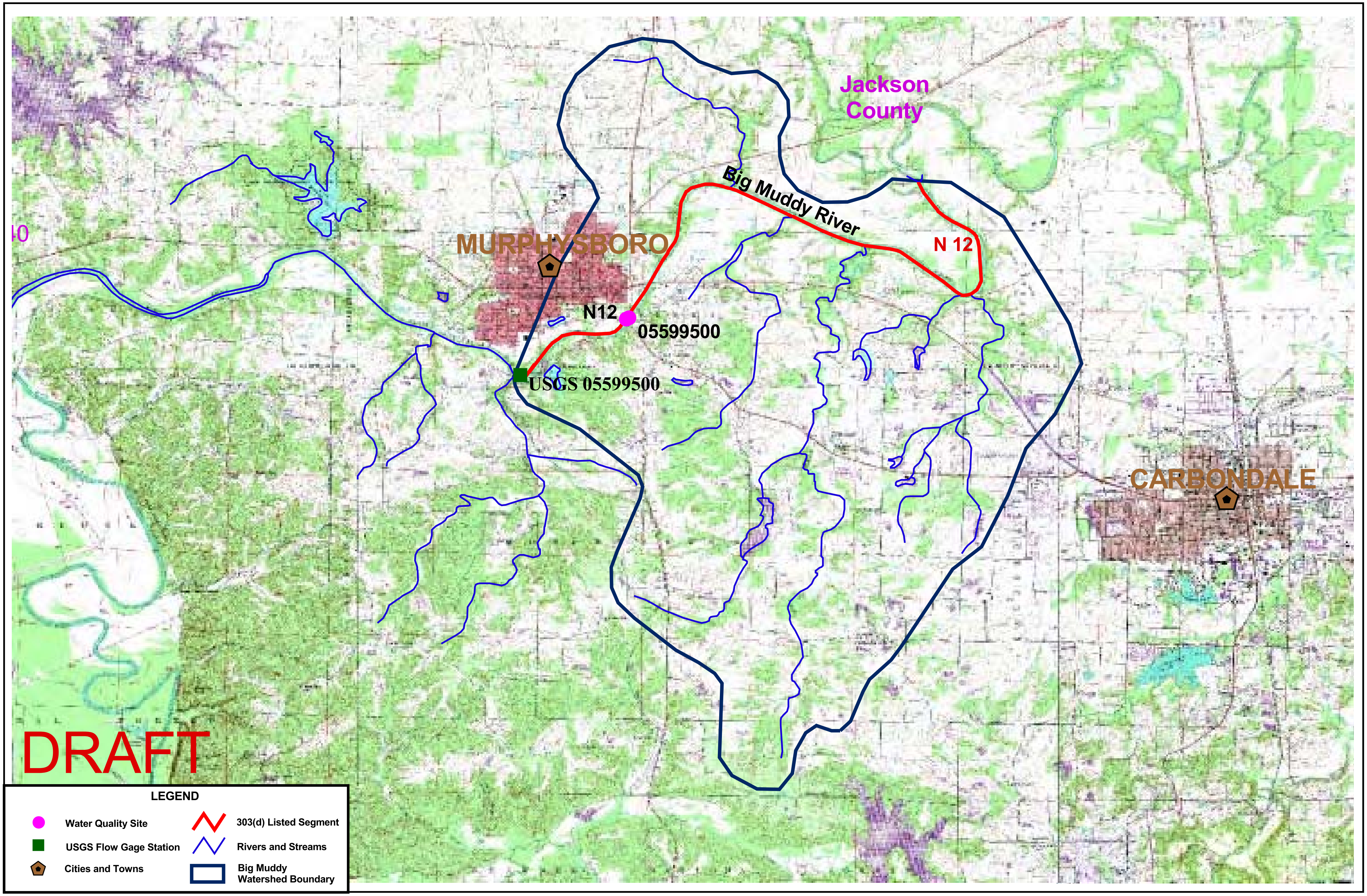


Figure 10-1
Big Muddy River #1 Watershed &
Historic Sampling Locations

CDM

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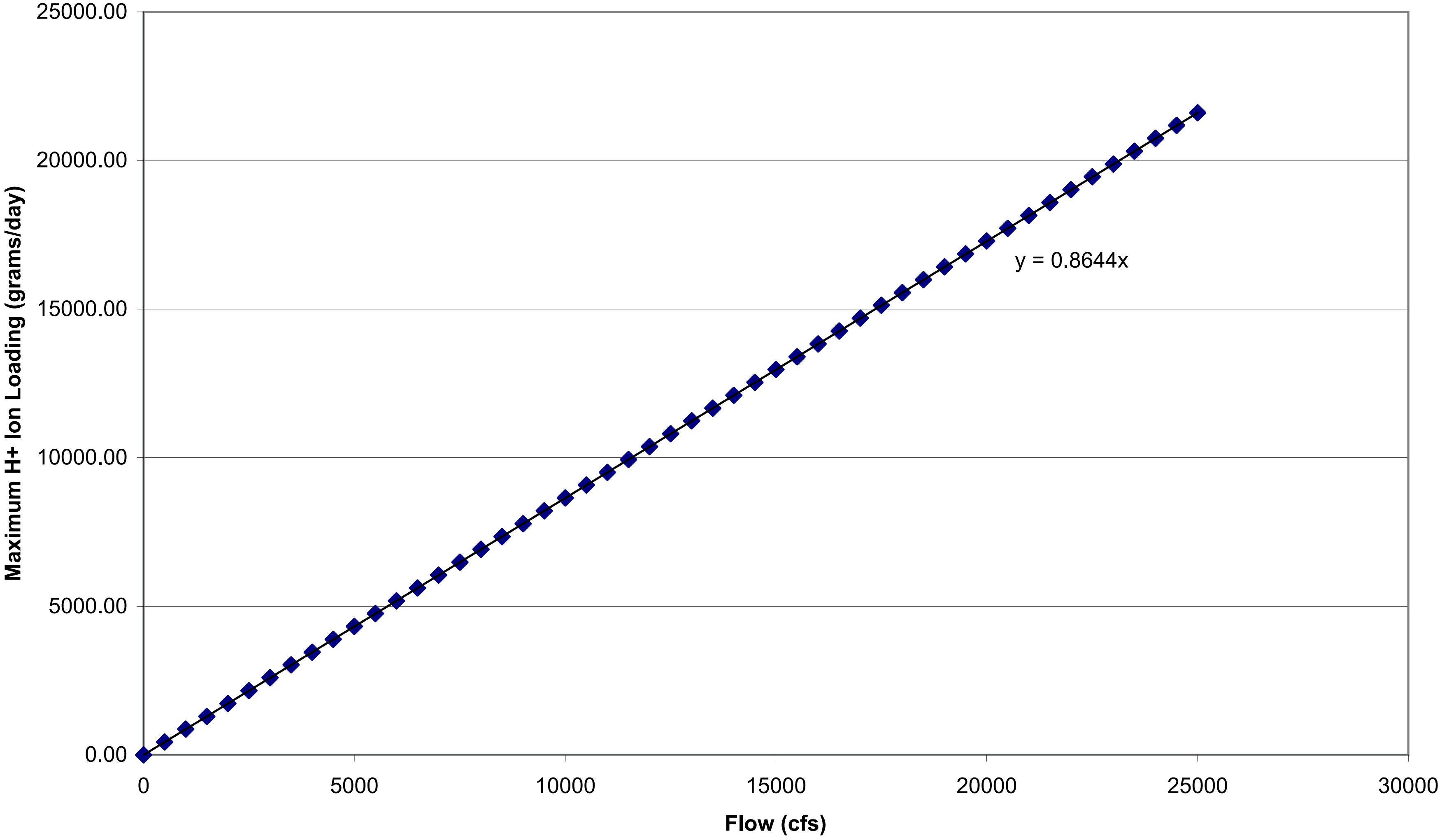
Figure 10-2: Flow versus Maximum H^+ Ion Loading at a Constant pH of 6.5



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Section 11
Total Maximum Daily Load for Big Muddy River Watershed

11.1 TMDL Endpoints for the Big Muddy River

The TMDL endpoints for manganese, sulfates, pH, and DO in a stream segment are summarized in Table 11-1. For manganese and sulfates, the concentrations must be below the TMDL endpoint. For DO, concentrations must be greater than 6.0 mg/L for 16 hours of any 24-hour period. For pH, the desired measurement is between the endpoint limits. These endpoints are based on protection of aquatic life in the Big Muddy River and its tributaries. Some of the average concentrations, which are based on a limited data set, meet the desired endpoints. However, the data set has maximum or minimum values, presented in Section 5.1.5.2.4, that do not meet the desired endpoints and this was the basis for TMDL analysis. Further monitoring as outlined in the monitoring plan presented in Section 12, will help further define when impairments are occurring in the watershed and support the TMDL allocations outlined in the remainder of this section.

Table 11-1 TMDL Endpoints and Average Observed Concentrations for Impaired Constituents in the Big Muddy River Watershed

Constituent	TMDL Endpoint	Average Observed Value for N12
Manganese	1.0 mg/L	0.6 mg/L
Sulfates	500 mg/L	250 mg/L
DO	6.0 mg/L (16 hours of any 24-hour period)	8.5 mg/L
pH	6.5 - 9 s.u.	7.3 s.u.

11.2 Pollutant Source and Linkages

Pollutant sources for the Big Muddy River were identified through the existing data review described in Section 5. Based on the data review, the source of manganese and sulfates in the Big Muddy River segment N12 is groundwater potentially contaminated by abandoned coal mines. The likely source of oxygen demanding constituents is primarily factors occurring during low flow conditions, such as slow-moving waters and increased water temperatures promoting algal growth. Nonpoint source loads in the watershed may also contribute to low DO in the stream. Sources of low pH include acid mine drainage and fluctuations due to algal growth in aquatic systems.

11.3 Allocation

As explained in Section 1, the TMDL for Big Muddy River segment N12 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.

11.3.1 Manganese and Sulfates TMDL

11.3.1.1 Loading Capacity

The loading capacity for manganese and sulfates for impaired segment N12 was based on the Monte Carlo analysis described in Section 10. The LTA, determined by analysis to meet water quality standards generated from the Monte Carlo analysis, is the basis for loading capacity for segment N12. This LTA was multiplied by average flow in each segment to determine an average load. These average loads are shown in Table 11-2.

Table 11-2 Average Loads Based on LTA for Manganese and Sulfates

Constituent	LTA (mg/L)	Allowable Load (lb/day)
Manganese	0.2	2,244
Sulfates	103.7	1,163,422

11.3.1.2 Seasonal Variation

A season is represented by changes in weather; for example, a season can be classified as warm or cold as well as wet or dry. Seasonal variation is represented in the Big Muddy River segment N12 TMDL as conditions were investigated during all seasons of the year. Section 5.1.3 discusses the flow data available for Segment NC12 and Section 5.1.5 and Appendix A contain the water quality data available for manganese and sulfate. A review of the flow data and water quality data (Figures 5-4 and 5-5) show that the water quality data were gathered at various times during the year, thus capturing seasonal variations in loadings into the river. Since the various pollutant sources are expected to contribute loadings in different quantities during different time periods (e.g., spring run-off loads), the loadings for this TMDL will focus on a LTA loading rather than specifying different loadings by season. As more data are gathered, further refinement of the seasonal variation may be possible.

11.3.1.3 Margin of Safety

The MOS can be implicit (incorporated into the TMDL analysis through conservative assumptions) or explicit (expressed in the TMDL as a portion of the loadings) or a combination of both. An explicit MOS of 10 percent is recommended for manganese and sulfates in the Big Muddy River segment N12 Watershed because of the limited data set available for analysis and because Monte Carlo analysis incorporates uncertainty to some degree into the LTA.

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

11.3.1.4 Waste Load Allocation

TMDLs completed in upstream watersheds that relate to mining activity will help reduce pollutant loads to segment N12. This also applies to the next section discussing Load Allocation.

11.3.1.5 Load Allocation and Summary TMDLs

Table 11-3 shows a summary of the TMDL for manganese and sulfates in the Big Muddy River segment N12 watershed. The calculated allowable loads (LC) necessary to maintain the water quality standard are reduced by the MOS, representing the uncertainty in the data analysis, to determine the allowable loading from the watershed, the LA. The LC was calculated from the LTA presented in Section 10.3.1. Reductions of 70 percent for manganese and 62 percent for sulfates were estimated as the required decreases in loadings so that water quality standards will be met in the stream segments.

Table 11-3 TMDL Summary for Manganese and Sulfates

Constituent	LC (lb/day)	WLA (lb/day)	LA (lb/day)	MOS (lb/day)	Reduction Needed (lb/day)	Reduction Needed (percent)
Manganese	2,244	0	2,020	224	4,662	70%
Sulfates	1,163,422	0	1,047,080	116,342	1,722,615	62%

Table 11-4 LTAs Required Based on TMDL MOS

Constituent	Monte Carlo LTA (mg/L)	Recalculated LTA (mg/L)
Manganese	0.20	0.18
Sulfates	103.7	93

The required LTAs presented in Section 10 and in Table 11-2 were reduced because of the applied MOS and are presented in Table 11-4. The recalculated LTA represents the LA in Table 11-3. Methods to meet these LTAs will be outlined in Section 12.

11.3.2 DO TMDL

11.3.2.1 Loading Capacity

As discussed in Section 10.3.2, the analysis suggests that the principle cause of DO impairments in segment N12 is a lack of aeration caused by low flows. Table 11-5 shows the aeration coefficient calculated from the observed DO in Section 10.3 for sample dates that did not meet the TMDL endpoint and the coefficient that would be required to meet the TMDL endpoint of 6.0 mg/L DO (16 hours of any 24-hour period) for sampling events that had DO measurements less than 6.0 mg/L. Increasing aeration in the stream is not a parameter for which a TMDL can be developed. Therefore, no loading capacity will be developed at this time. Methods to achieve elevated reaeration coefficients will be outlined in Section 10.

Table 11-5 Calculated Reaeration Coefficients and Required Reaeration Coefficients in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Modeled k_a (1/day)	Required k_a (1/day)
N12	9/6/00	4.7	3.2	11.5

Based on the data analysis, increases of aeration would be required in summer months but not during winter conditions. Monitoring data to make the analysis more robust will be discussed in Section 12 as well as management measures to increase aeration and reduce nonpoint source loads contributing to non-attainment of the DO water quality standard.

To confirm that reductions in BOD_5 loads to meet the water quality standard are not an appropriate measure for controlling DO in this watershed, the Streeter-Phelps equations presented in Section 10.3.2 were used to estimate the BOD_5 loading required to meet the water quality standard on each sample date impaired for DO.

Table 11-6 shows the BOD_5 loads estimated from TOC as discussed in Section 10.3.2 and the BOD_5 loading that would be necessary to meet water quality standards.

Table 11-6 Calculated BOD_5 Loads and Required Loads in the Big Muddy River Segment N12 Watershed Based on TMDL Endpoint for DO

Segment	Date	Measured DO Concentration (mg/L)	Calculated BOD_5 (lb/d)	Required BOD_5 (lb/d)
N12	9/6/00	4.7	7.2	0

Table 11-6 shows that the reductions in BOD_5 loads necessary for compliance with the DO loads are not a feasible option for increasing DO in the Big Muddy River Watershed.

11.3.3 pH TMDL

Figure 11-1 shows the existing maximum hydrogen ion concentration versus flow using hydrogen concentrations calculated from the pH sample data for segment N12 and the equation presented in Section 10.3.3. From this figure, the maximum hydrogen ion concentration for the three-year peak flow of 16,426 cfs was determined as 10.5 lb/day. The allowable maximum hydrogen ion concentration calculated in Section 10 is 31 lb/day. The existing concentration is below the allowable concentration indicating that no allocations are necessary at this time to meet the TMDL endpoint for pH in Big Muddy River segment N12. Because the relationship between hydrogen ion concentration and pH is an inverse log-arithmetic function, since the maximum load is greater than the allowable load no allocations are needed to increase the pH within the watershed.

Since current pH loadings are less than the allowable loading predicted from analysis, no TMDL for pH is recommended at this time. Although no TMDL is recommended, the implementation strategies outlined in Section 12 will also help control pH in the Big Muddy River segment N12 Watershed.

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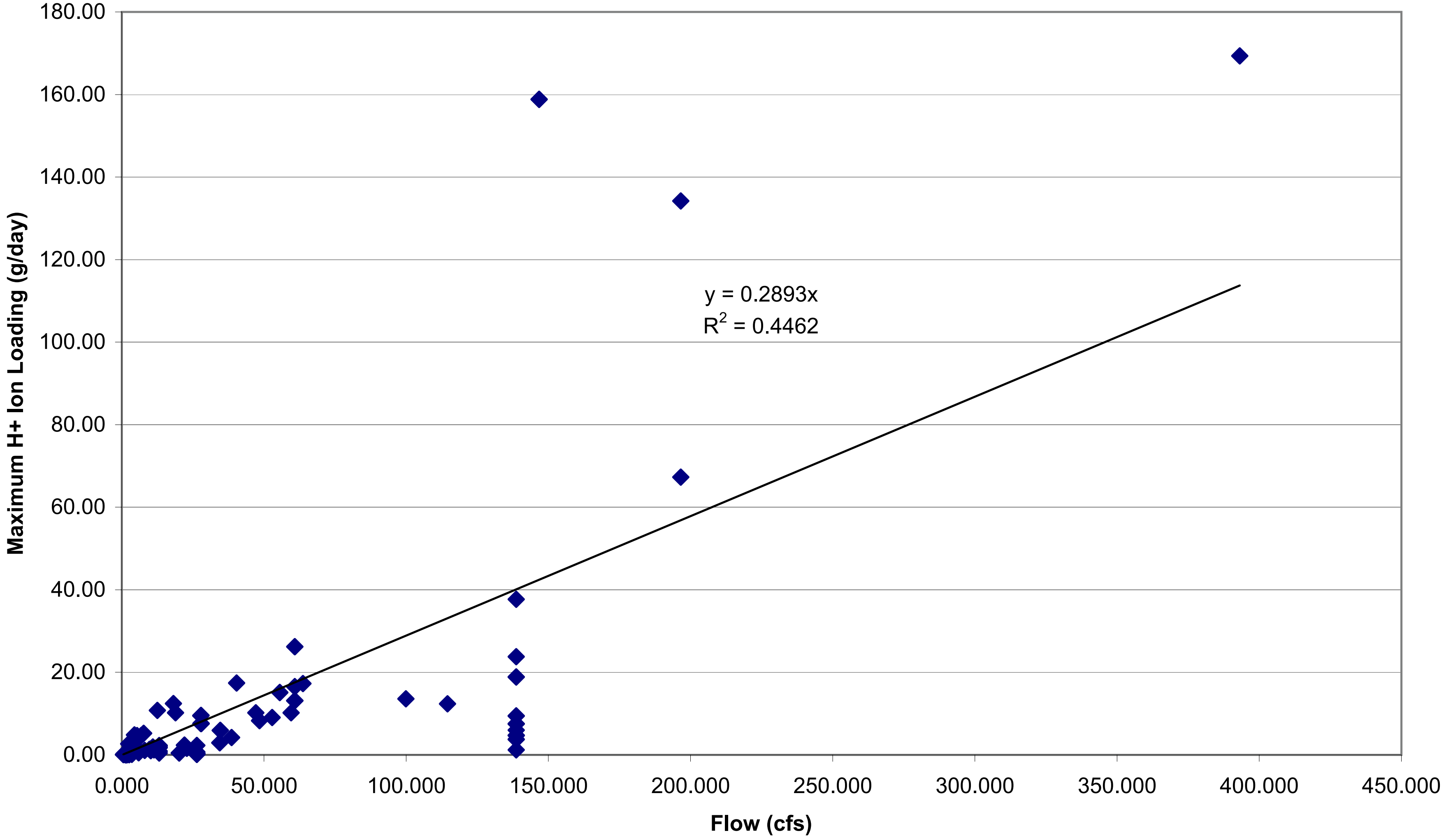
Figure 11-1: Flow versus Maximum H^+ Ion Loading
for Segment N12 of the Big Muddy River



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Section 12

Implementation Plan for Big Muddy River Watershed

12.1 Implementation Actions and Management Measures for Manganese and Sulfates

An adaptive management or phased approach is recommended for the manganese and sulfates TMDL for this watershed, because of the limited amount of longitudinal data available for the TMDL analysis of segment N12 in the Big Muddy River Watershed. Longitudinal data would be represented by multiple sampling locations in segment N12. Adaptive management is a systematic process for continually improving management policies and practices through learning from the outcomes of operational programs. Some of the differentiating characteristics of adaptive management are:

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

Based on existing data review, presented in Section 10, the likely sources of manganese and sulfates in the Big Muddy River segment N12 watershed are from abandoned mines. Further source identification is required as outlined in the next section. Acid mine drainage and excessive algal growth could cause pH impairments, but as explained in Section 11, no TMDL for pH is recommended at this time. BMPs recommended for DO, manganese, and sulfates should also help mitigate pH impairments.

12.1.1 Source Identification for Manganese and Sulfates

It is recommended that further source identification activities take place within the watershed because the current data regarding sources of manganese and sulfates in the segment N12 watershed is limited. The GIS data and mapping provided in Section 5 (Figure 5-1) should be the basis for the start of the source investigation. Collection of data during various flow conditions may also be beneficial in determining the source of these constituents. For the segment N12 watershed, the location of the potential discharge from the abandoned coal mines should be identified in addition to other mining activity, which could contribute manganese and sulfate concentrations in the receiving waters. Once potential sources are identified and located, sampling stations should be placed in appropriate locations to assess water quality downstream of these sources. The potential source identification and station sampling placement should be the result of field investigations.

Although the watershed delineation through mined areas may not be exact, the implementation actions and management measures remain applicable to the entire Big Muddy River Watershed.

12.1.2 Manganese and Sulfates Management Measures

It is likely that the main contributors to impairments within the watershed are abandoned mine sites. If the major source of manganese and sulfates in the segment N12 watershed is attributed to abandoned mining, active chemical treatment methods, passive treatment methods, and mine reclamation are available. Active chemical treatment typically involves the addition of alkaline chemicals, such as calcium carbonate, sodium hydroxide, sodium bicarbonate, and anhydrous ammonia to acid mine drainage. These chemicals raise the pH to acceptable levels and decrease the solubility of dissolved metals. Metal precipitates form and settle out of the solution. Active chemical treatment is not a viable option for the segment N12 watershed because the chemicals are expensive, and the treatment system requires additional costs associated with operation and maintenance as well as the disposal of metal-laden sludge.

Reclamation of abandoned mines is another method of controlling pollutants. Reclamation of abandoned mine land involves clearing site vegetation, removing contaminated topsoil and coal, and restoring functionality of the site for recreational, agricultural, or wildlife habitat purposes. The environmental benefits realized from abandoned mine reclamation projects are numerous and significant, including restoring land for future use and improving water quality. Restoration of the land can result in increased and enhanced pasture land, recreational areas, or wildlife habitat (Pennsylvania Department of Environmental Protection [PDEP] 2002). However, reclamation projects tend to be costly and resource intensive and may not be appropriate for abandoned mine sites in segment N12 watershed.

Passive methods could be utilized until full reclamation of a mine occurs. Chemical addition and energy consuming treatment processes are virtually eliminated with passive treatment systems. The operation and maintenance requirements of passive systems are considerably less than active treatment systems (PDEP 2002). Therefore, passive treatment systems would be the best solution for controlling manganese and sulfates from abandoned coal mines in segment N12 of the Big Muddy River Watershed.

Following are examples of the passive treatment technologies:

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

The remainder of this section discusses these technologies.

12.1.2.1 Aerobic Wetland

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

12.1.2.2 Compost or Anaerobic Wetland

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

12.1.2.3 Open Limestone Channels

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

12.1.2.4 Diversion Wells

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

12.1.2.5 Anoxic Limestone Drains

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

12.1.2.6 Vertical Flow Reactors

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

12.1.2.7 Pyrolusite Process

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

12.2 Implementation Actions and Management Measures for Dissolved Oxygen

DO impairments are addressed by focusing on organic loads that consume oxygen through decomposition and nutrient loads that can cause algal growth, which can also deplete DO. Analysis provided in Section 10 established a relationship between reaeration, BOD_5, and DO concentrations in Big Muddy River segment N12, so management measures for segment N12 will focus on increasing reaeration decreasing BOD_5 loads to increase DO concentrations.

DO impairments in Big Muddy River segment N12 are mostly attributed to low flow or stagnant conditions within the creek. Runoff from nonpoint sources may also contribute a BOD_5 load in Big Muddy River segment N12. An additional contributor to low DO is increased water temperatures. Therefore, management measures for the segment N12 watershed will focus on reducing nonpoint source loading through sediment and surface runoff controls, reducing stream temperatures, and reducing stagnant conditions through reaeration.

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

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

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

12.2.1 DO Concentration Management

The sources of nonpoint source pollution in the Big Muddy River TMDL are divided between agricultural cropland and rural grasslands. There are three animal management facilities in the watershed. Although, two have been classified as no impact facilities, the third has not been assessed. BMPs evaluated for treatment of these nonpoint sources are:

- Filter strips
- Wetlands
- Reaeration

Organic and nutrient loads originating from cropland is most efficiently treated with a combination of riparian buffer or grass filter strips. Wetlands can be used to treat pollutant loads originating from animal management operations. Instream management measures for DO focus on reaeration techniques. The Streeter-Phelps equations presented in Section 10 utilizes a reaeration coefficient. Increasing the reaeration coefficient by physical means will increase DO in Big Muddy River segment N12.

12.2.1.1 Filter Strips

Filter strips can be used as a structural control to reduce pollutant loads, including nutrients and sediment, to the Big Muddy River segment N12. Filter strips implemented along stream segments slow and filter nutrients and sediment out of runoff, help reduce stream water temperatures thereby increasing the water body DO saturation level, and provide bank stabilization decreasing erosion and deposition. The following paragraphs focus on the implementation of filter strips in Big Muddy River segment N12 watershed. Finally, design criteria and size selection of filter strips are detailed.

Organic debris in topsoil contributes to the BOD_5 load to water bodies (USEPA 1997). Increasing the length of stream bordered by grass and riparian buffer strips will decrease the amount of BOD_5 and nutrient load associated with sediment loads to Big Muddy River segment N12. Nutrient criteria, currently being developed and expected to be adopted around 2007 by the Illinois EPA, will assess the instream nutrient concentrations required for the watershed. As stated previously, excess nutrients in streams can cause excessive algal growth, which can deplete DO in streams. Adoption of nutrient criteria will potentially affect this DO TMDL and help control exceedences of DO water quality criteria in Big Muddy River segment N12.

Filter strips will help control BOD_5 levels by removing organic loads associated with sediment from runoff; however, no studies were identified as providing an estimate of removal efficiency. Grass filter strips can remove as much as 75 percent of sediment and 45 percent of total phosphorus from runoff, so it is assumed that the removal of BOD_5 falls within this range (NCSU 2000). Riparian buffer strips also help reduce water temperatures increasing the water body DO saturation level as explained in Section 10.

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

Filter strip widths for the Big Muddy River TMDL were estimated based on the slope. According to the NRCS Planning and Design Manual, the majority of sediment is removed in the first 25 percent of the width (NRCS 1994). Table 12-1 outlines the guidance for filter strip flow length by slope (NRCS 1999). Based on slope estimates near tributaries within the watershed, filter strips widths of 72 to 144 feet could be incorporated in locations throughout the watershed. The total acreage examined was 112 acres.

Table 12-1 Filter Strip Flow Lengths Based on Land Slope

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

The acreages provided above are used to calculate an approximation of BMP cost in Section 12.3 and should only be used as a guideline for watershed planning. It is recommended that landowners evaluate their land near streams and lakes and create or extend filter strips, where applicable, according to the NRCS guidance presented in

Table 12-1. Programs available to fund the construction of these buffer strips are discussed in Section 9.3.

12.2.1.2 Wetlands

Wetlands can be used as a structural control to treat loads from animal management operations located in the segment N12 watershed. Two of the three animal management facilities in the watershed have been designated as having no impact on receiving waters and the third has not been assessed. In the event that the third facility is found to have a negative impact on water quality, a constructed wetland could be used to treat organic, nutrient, and sediment loads from the animal management operations between the operation and the creek. Wetlands are an effective BMP for sediment, nutrient, and organic load control because they:

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

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

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

It is recommended that further investigation take place within the watershed to confirm the impact of animal management facilities on Big Muddy River segment N12. Due to data illustrating the lack of impacts of nonpoint source runoff from these facilities, wetlands were not analyzed as a treatment for this TMDL. However, it is recommended that animal control facility managers consider wetlands to treat nonpoint source runoff from control facilities.

12.2.1.3 Reaeration

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

12.3 Reasonable Assurance

Reasonable assurance means that a demonstration is given that the pollutant reductions in this watershed will be implemented. It should be noted that all programs discussed in this section are voluntary. The discussion in Sections 12.1 and 12.2 provided a means for obtaining the reductions necessary. The remainder of this section discusses the programs available to assist with funding and an estimate of costs to the watershed for implementing these practices.

12.3.1 Available Programs for Manganese and Sulfates TMDL

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

Abandoned mine sites are reclaimed through the ALMRD according to a priority list as monies become available. Because the federally designated first priority for ALMRD projects is safety, most of the early reclamation projects were not environmentally oriented. Even so, the AMLRD has completed a large number of environmentally oriented reclamation projects (Muir et al. 1997). Due to the uncertainty of sources of manganese and sulfates in the Big Muddy River segment N12 Watershed, no cost estimates were developed for mitigation of the potential sources provided in this report. If the abandoned mines in the segment N12 watershed are shown to contribute to impairment of segments within the watershed, funds from the ALMRD focused on environmental projects should be directed towards water bodies with TMDLs.

12.3.2 Available Programs for DO TMDL

Approximately 42 percent of the Big Muddy River segment N12 watershed is classified as rural grassland (pasture land, CRP, waterways, buffer strips, etc.), row crop, and small grains land. There are several voluntary conservation programs established through the 2002 U.S. Farm Bill that encourage landowners to implement resource-conserving practices for water quality and erosion control purposes. These programs would apply to crop fields and rural grasslands that are presently used as pasture land. Each program is discussed separately in the following sections.

12.3.2.1 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).

12.3.2.2 Streambank Stabilization and Restoration Practice

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

12.3.2.3 Conservation Reserve Program

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

Eligible land must be one of the following:

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

2. Certain marginal pasture land enrolled in the Water Bank Program.

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

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

- Riparian buffers
- Filter strips
- Grass waterways
- Shelter belts
- Field windbreaks
- Living snow fences
- Contour grass strips
- Salt tolerant vegetation
- Shallow water areas for wildlife
- Eligible acreage within an USEPA-designated wellhead protection area (FSA 1997)

12.3.2.4 Wetlands Reserve Program

The 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 options follow in Table 12-2 (USDA 1996).

Table 12-2 Costs for Enrollment Options of WRP Program

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

12.3.2.5 Environmental Quality Incentive Program

The 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 2002d,e).

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

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

12.3.2.6 Wildlife Habitat Incentives Program

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

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

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

As discussed in Section 9.2.1.1, the IDA and Illinois EPA are co-sponsoring a Cropland Nutrient Management Plan project in watersheds that have or are developing a TMDL. Under this project, 2,480 acres of cropland have been targeted in the Big Muddy River segment N12 watershed.

The FSA administers the CRP. NRCS administers the EQIP, WRP, and WHIP. Local NRCS and FSA contact information in Jackson County are listed in Table 12-3 below.

Table 12-3 Local NRCS and FSA Contact Information

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

12.3.3 Cost Estimates for BMPs

Cost estimates for different BMPs and individual practice prices such as filter strip installation are detailed in the following sections. Table 12-4 outlines the cost of implementation measures per acre. Finally, an estimate of the total order of magnitude costs for implementation measures in the Big Muddy River segment N12 Watershed are presented in Section 12.3.3.3 and Table 12-5.

12.3.3.1 Streambank Stabilization

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

12.3.3.2 Filter Strips and Riparian Buffers

The Jackson County NRCS estimates an average cost per acre to install a grass filter strip with a 10-year life span at $90/acre. A riparian buffer strip established with bare root stock has a life span of 10 years and an installation cost of $384/acre. Based on this preliminary estimate, it appears that grass filter strips would be a more cost-effective way to control BOD and nutrient loads in the watershed.

12.3.3.3 Planning Level Cost Estimates for Implementation Measures

Cost estimates for different implementation actions are presented in Table 12-4. The column labeled *Program* lists the financial assistance program available for various BMPs. The programs represented in the table are the WRP and the CRP.

Table 12-4 Cost Estimate of Various BMP Measures in the Big Muddy River Watershed

Source	Program or Sponsor	BMP	Life Span	Installation Mean $/acre	Maintenance $/ac/yr
Nonpoint	CRP	Grass Filter Strips	10	$90.00	$9.00
	CRP	Riparian Buffer	10	$384.00	$40.00
	319 or SSRP	Streambank Stabilization *	10	$40.00	$4.00

* Streambank stabilization cost calculated on linear foot basis.

The total order of magnitude capital costs for implementation measures in the watershed were estimated to be $1,700,000. The total cost is calculated as the number of acres over which a BMP or structural measure is applied by the cost per acre. Table 12-5 summarizes the number of acres each measure is applied to in the basin and the corresponding cost. The acreages reported in Table 12-5 are a preliminary estimate in order to provide an overall understanding of cost of implementation in the watershed. The total only represents capital costs and annual maintenance costs. These do not represent the total costs of operating the measure over its life cycle.

Table 12-5 Cost Estimate of Implementation Measures for the Big Muddy Watershed

BMP	Treated Acres	Capital Costs		Maintenance Costs	
		Mean $/acre	Watershed $	$/ac/yr	Watershed $/yr
Grass Filter Strips	112	$90.00	$10,080.00	$9.00	$1,000.00
Streambank Stabilization *	42,240	$40.00	$1,689,600.00	$4.00	$168,960.00
Total			**$1,699,680.00**		**$169,960.00**

* Streambank stabilization cost calculated on linear foot basis.

12.4 Monitoring Plan

The purpose of the monitoring plan for the Big Muddy River segment N12 Watershed 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 and in upstream contributing watersheds,
- estimate effectiveness of management measures,
- continued ambient monitoring.

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

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

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

Illinois EPA monitors segment N12 yearly through the Ambient Water Quality Monitoring Network program and conducts Intensive Basin Surveys every 5 years. Continuation of this monitoring will assess instream water quality as improvements in the watershed are completed. This data will also be used to assess whether water quality standards in the watershed are being attained. To further support DO modeling and to plan for future nutrient criteria in the watershed, the following parameters should be added to the monitoring list:

- BOD_5
- BOD_{20}
- Chlorophyll "a" or algae monitoring

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

12.5 Implementation Time Line

Implementing the actions outlined in this section for the Big Muddy River segment N12 Watershed should occur in phases and the effectiveness of the management actions should be assessed as improvements are made. It is assumed that it may take up to one to two years for further source identification in the watershed. It is also assumed that it may take up to five years to secure funding for actions needed in the watershed and five to seven years after funding to implement the measures. The length of time required to meet water quality standards will be based on the types of BMPs implemented in the watershed. In summary, meeting water quality standards in the segment N12 watershed may take 15 to 20 years to complete.

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Section 13
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Appendix A
Historic Water Quality Data

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	MANGANESE, TOTAL (UG/L AS MN)	470
5599500	2/8/1990	MANGANESE, TOTAL (UG/L AS MN)	373
5599500	4/16/1990	MANGANESE, TOTAL (UG/L AS MN)	337
5599500	5/22/1990	MANGANESE, TOTAL (UG/L AS MN)	112
5599500	5/22/1990	MANGANESE, TOTAL (UG/L AS MN)	109
5599500	7/9/1990	MANGANESE, TOTAL (UG/L AS MN)	783
5599500	8/21/1990	MANGANESE, TOTAL (UG/L AS MN)	617
5599500	9/24/1990	MANGANESE, TOTAL (UG/L AS MN)	560
5599500	11/13/1990	MANGANESE, TOTAL (UG/L AS MN)	765
5599500	1/8/1991	MANGANESE, TOTAL (UG/L AS MN)	138
5599500	2/12/1991	MANGANESE, TOTAL (UG/L AS MN)	222
5599500	4/9/1991	MANGANESE, TOTAL (UG/L AS MN)	472
5599500	6/4/1991	MANGANESE, TOTAL (UG/L AS MN)	590
5599500	6/4/1991	MANGANESE, TOTAL (UG/L AS MN)	600
5599500	7/16/1991	MANGANESE, TOTAL (UG/L AS MN)	682
5599500	8/20/1991	MANGANESE, TOTAL (UG/L AS MN)	2473
5599500	10/15/1991	MANGANESE, TOTAL (UG/L AS MN)	782
5599500	11/12/1991	MANGANESE, TOTAL (UG/L AS MN)	460
5599500	1/7/1992	MANGANESE, TOTAL (UG/L AS MN)	300
5599500	2/20/1992	MANGANESE, TOTAL (UG/L AS MN)	646
5599500	4/14/1992	MANGANESE, TOTAL (UG/L AS MN)	860
5599500	5/18/1992	MANGANESE, TOTAL (UG/L AS MN)	680
5599500	7/13/1992	MANGANESE, TOTAL (UG/L AS MN)	1000
5599500	8/17/1992	MANGANESE, TOTAL (UG/L AS MN)	1900
5599500	1/12/1993	MANGANESE, TOTAL (UG/L AS MN)	160
5599500	2/16/1993	MANGANESE, TOTAL (UG/L AS MN)	340
5599500	1/6/1994	MANGANESE, TOTAL (UG/L AS MN)	470
5599500	3/2/1994	MANGANESE, TOTAL (UG/L AS MN)	280
5599500	4/6/1994	MANGANESE, TOTAL (UG/L AS MN)	820
5599500	5/23/1994	MANGANESE, TOTAL (UG/L AS MN)	860
5599500	7/6/1994	MANGANESE, TOTAL (UG/L AS MN)	350
5599500	8/4/1994	MANGANESE, TOTAL (UG/L AS MN)	400
5599500	9/19/1994	MANGANESE, TOTAL (UG/L AS MN)	890
5599500	11/1/1994	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	12/7/1994	MANGANESE, TOTAL (UG/L AS MN)	590
5599500	1/30/1995	MANGANESE, TOTAL (UG/L AS MN)	360
5599500	2/21/1995	MANGANESE, TOTAL (UG/L AS MN)	310
5599500	4/12/1995	MANGANESE, TOTAL (UG/L AS MN)	710
5599500	5/10/1995	MANGANESE, TOTAL (UG/L AS MN)	282
5599500	6/15/1995	MANGANESE, TOTAL (UG/L AS MN)	540
5599500	7/20/1995	MANGANESE, TOTAL (UG/L AS MN)	820
5599500	8/22/1995	MANGANESE, TOTAL (UG/L AS MN)	380
5599500	10/31/1995	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	12/18/1995	MANGANESE, TOTAL (UG/L AS MN)	550
5599500	1/31/1996	MANGANESE, TOTAL (UG/L AS MN)	290
5599500	2/29/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	3/25/1996	MANGANESE, TOTAL (UG/L AS MN)	480
5599500	5/1/1996	MANGANESE, TOTAL (UG/L AS MN)	230
5599500	6/25/1996	MANGANESE, TOTAL (UG/L AS MN)	1200
5599500	7/31/1996	MANGANESE, TOTAL (UG/L AS MN)	530

5599500	4/24/1997	MANGANESE, TOTAL (UG/L AS MN)	470
N12	10/27/1997	MANGANESE, TOTAL (UG/L AS MN)	640
N12	11/20/1997	MANGANESE, TOTAL (UG/L AS MN)	370
N12	2/3/1998	MANGANESE, TOTAL (UG/L AS MN)	500
N12	3/5/1998	MANGANESE, TOTAL (UG/L AS MN)	260
N12	4/16/1998	MANGANESE, TOTAL (UG/L AS MN)	460
N12	5/14/1998	MANGANESE, TOTAL (UG/L AS MN)	380
N12	6/17/1998	MANGANESE, TOTAL (UG/L AS MN)	240
N12	7/21/1998	MANGANESE, TOTAL (UG/L AS MN)	670
N12	8/27/1998	MANGANESE, TOTAL (UG/L AS MN)	470
N12	10/8/1998	MANGANESE, TOTAL (UG/L AS MN)	1100
N12	12/1/1998	MANGANESE, TOTAL (UG/L AS MN)	970
N12	1/4/1999	MANGANESE, TOTAL (UG/L AS MN)	430
N12	2/8/1999	MANGANESE, TOTAL (UG/L AS MN)	190
N12	3/22/1999	MANGANESE, TOTAL (UG/L AS MN)	180
N12	4/27/1999	MANGANESE, TOTAL (UG/L AS MN)	600
N12	6/10/1999	MANGANESE, TOTAL (UG/L AS MN)	400
N12	9/16/1999	MANGANESE, TOTAL (UG/L AS MN)	1900
N12	11/1/1999	MANGANESE, TOTAL (UG/L AS MN)	870
N12	12/6/1999	MANGANESE, TOTAL (UG/L AS MN)	510
N12	1/3/2000	MANGANESE, TOTAL (UG/L AS MN)	360
N12	3/8/2000	MANGANESE, TOTAL (UG/L AS MN)	570
N12	4/12/2000	MANGANESE, TOTAL (UG/L AS MN)	640
N12	5/1/2000	MANGANESE, TOTAL (UG/L AS MN)	550
N12	7/24/2000	MANGANESE, TOTAL (UG/L AS MN)	450
N12	9/6/2000	MANGANESE, TOTAL (UG/L AS MN)	260

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	SULFATE, TOTAL (MG/L AS SO4)	450
5599500	1/9/1990	SULFATE, TOTAL (MG/L AS SO4)	460
5599500	2/8/1990	SULFATE, TOTAL (MG/L AS SO4)	164
5599500	2/8/1990	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	4/16/1990	SULFATE, TOTAL (MG/L AS SO4)	120
5599500	4/16/1990	SULFATE, TOTAL (MG/L AS SO4)	117
5599500	5/22/1990	SULFATE, TOTAL (MG/L AS SO4)	64
5599500	5/22/1990	SULFATE, TOTAL (MG/L AS SO4)	63
5599500	7/9/1990	SULFATE, TOTAL (MG/L AS SO4)	350
5599500	7/9/1990	SULFATE, TOTAL (MG/L AS SO4)	364
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	181
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	179
5599500	8/21/1990	SULFATE, TOTAL (MG/L AS SO4)	180
5599500	9/24/1990	SULFATE, TOTAL (MG/L AS SO4)	231
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	500
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	557
5599500	1/8/1991	SULFATE, TOTAL (MG/L AS SO4)	83
5599500	1/8/1991	SULFATE, TOTAL (MG/L AS SO4)	85
5599500	2/12/1991	SULFATE, TOTAL (MG/L AS SO4)	110
5599500	2/12/1991	SULFATE, TOTAL (MG/L AS SO4)	114
5599500	4/9/1991	SULFATE, TOTAL (MG/L AS SO4)	230
5599500	4/9/1991	SULFATE, TOTAL (MG/L AS SO4)	195
5599500	6/4/1991	SULFATE, TOTAL (MG/L AS SO4)	265
5599500	6/4/1991	SULFATE, TOTAL (MG/L AS SO4)	240
5599500	7/16/1991	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	7/16/1991	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	8/20/1991	SULFATE, TOTAL (MG/L AS SO4)	380
5599500	8/20/1991	SULFATE, TOTAL (MG/L AS SO4)	380
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	360
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	290
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	350
5599500	1/7/1992	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	1/7/1992	SULFATE, TOTAL (MG/L AS SO4)	165
5599500	2/20/1992	SULFATE, TOTAL (MG/L AS SO4)	230
5599500	4/14/1992	SULFATE, TOTAL (MG/L AS SO4)	206
5599500	5/18/1992	SULFATE, TOTAL (MG/L AS SO4)	203
5599500	7/13/1992	SULFATE, TOTAL (MG/L AS SO4)	300
5599500	7/13/1992	SULFATE, TOTAL (MG/L AS SO4)	303
5599500	8/17/1992	SULFATE, TOTAL (MG/L AS SO4)	330
5599500	1/12/1993	SULFATE, TOTAL (MG/L AS SO4)	78
5599500	2/16/1993	SULFATE, TOTAL (MG/L AS SO4)	191
5599500	1/6/1994	SULFATE, TOTAL (MG/L AS SO4)	270
5599500	3/2/1994	SULFATE, TOTAL (MG/L AS SO4)	168
5599500	4/6/1994	SULFATE, TOTAL (MG/L AS SO4)	240
5599500	5/23/1994	SULFATE, TOTAL (MG/L AS SO4)	170
5599500	7/6/1994	SULFATE, TOTAL (MG/L AS SO4)	163
5599500	8/4/1994	SULFATE, TOTAL (MG/L AS SO4)	260
5599500	9/19/1994	SULFATE, TOTAL (MG/L AS SO4)	440
5599500	11/1/1994	SULFATE, TOTAL (MG/L AS SO4)	660
5599500	12/7/1994	SULFATE, TOTAL (MG/L AS SO4)	172

5599500	1/30/1995	SULFATE, TOTAL (MG/L AS SO4)	162
5599500	2/21/1995	SULFATE, TOTAL (MG/L AS SO4)	164
5599500	4/12/1995	SULFATE, TOTAL (MG/L AS SO4)	210
5599500	5/10/1995	SULFATE, TOTAL (MG/L AS SO4)	186
5599500	6/15/1995	SULFATE, TOTAL (MG/L AS SO4)	91
5599500	7/20/1995	SULFATE, TOTAL (MG/L AS SO4)	162
5599500	8/22/1995	SULFATE, TOTAL (MG/L AS SO4)	146
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	197
5599500	########	SULFATE, TOTAL (MG/L AS SO4)	376
5599500	1/31/1996	SULFATE, TOTAL (MG/L AS SO4)	173
5599500	2/29/1996	SULFATE, TOTAL (MG/L AS SO4)	513
5599500	3/25/1996	SULFATE, TOTAL (MG/L AS SO4)	171
5599500	5/1/1996	SULFATE, TOTAL (MG/L AS SO4)	58.7
5599500	6/25/1996	SULFATE, TOTAL (MG/L AS SO4)	147
5599500	7/31/1996	SULFATE, TOTAL (MG/L AS SO4)	226
5599500	4/24/1997	SULFATE, TOTAL (MG/L AS SO4)	227
N12	########	SULFATE, TOTAL (MG/L AS SO4)	566
N12	########	SULFATE, TOTAL (MG/L AS SO4)	653
N12	2/3/1998	SULFATE, TOTAL (MG/L AS SO4)	303
N12	4/16/1998	SULFATE, TOTAL (MG/L AS SO4)	201
N12	5/14/1998	SULFATE, TOTAL (MG/L AS SO4)	82
N12	6/17/1998	SULFATE, TOTAL (MG/L AS SO4)	109
N12	7/21/1998	SULFATE, TOTAL (MG/L AS SO4)	162
N12	8/27/1998	SULFATE, TOTAL (MG/L AS SO4)	196
N12	10/8/1998	SULFATE, TOTAL (MG/L AS SO4)	340
N12	12/1/1998	SULFATE, TOTAL (MG/L AS SO4)	566
N12	1/4/1999	SULFATE, TOTAL (MG/L AS SO4)	104
N12	2/8/1999	SULFATE, TOTAL (MG/L AS SO4)	81.8
N12	3/22/1999	SULFATE, TOTAL (MG/L AS SO4)	91.9
N12	4/27/1999	SULFATE, TOTAL (MG/L AS SO4)	154
N12	6/10/1999	SULFATE, TOTAL (MG/L AS SO4)	160
N12	9/16/1999	SULFATE, TOTAL (MG/L AS SO4)	435
N12	11/1/1999	SULFATE, TOTAL (MG/L AS SO4)	601
N12	12/6/1999	SULFATE, TOTAL (MG/L AS SO4)	639
N12	1/3/2000	SULFATE, TOTAL (MG/L AS SO4)	401
N12	3/8/2000	SULFATE, TOTAL (MG/L AS SO4)	184
N12	4/12/2000	SULFATE, TOTAL (MG/L AS SO4)	363
N12	5/1/2000	SULFATE, TOTAL (MG/L AS SO4)	229
N12	7/24/2000	SULFATE, TOTAL (MG/L AS SO4)	68
N12	9/6/2000	SULFATE, TOTAL (MG/L AS SO4)	140

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	PH (STANDARD UNITS)	7.8
5599500	1/9/1990	PH (STANDARD UNITS)	7.8
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	7.5
5599500	2/8/1990	PH (STANDARD UNITS)	8.3
5599500	2/8/1990	PH (STANDARD UNITS)	8.8
5599500	2/8/1990	PH (STANDARD UNITS)	8.8
5599500	2/8/1990	PH (STANDARD UNITS)	8
5599500	4/16/1990	PH (STANDARD UNITS)	7
5599500	4/16/1990	PH (STANDARD UNITS)	7
5599500	5/22/1990	PH (STANDARD UNITS)	6.9
5599500	5/22/1990	PH (STANDARD UNITS)	6.6
5599500	7/9/1990	PH (STANDARD UNITS)	7.9
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.2
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	7/9/1990	PH (STANDARD UNITS)	7.3
5599500	8/21/1990	PH (STANDARD UNITS)	7.5
5599500	8/21/1990	PH (STANDARD UNITS)	7.2
5599500	8/21/1990	PH (STANDARD UNITS)	7.2
5599500	9/24/1990	PH (STANDARD UNITS)	7.8
5599500	11/13/1990	PH (STANDARD UNITS)	8.2
5599500	11/13/1990	PH (STANDARD UNITS)	8.2
5599500	1/8/1991	PH (STANDARD UNITS)	6.4
5599500	1/8/1991	PH (STANDARD UNITS)	6.4
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	7.1
5599500	2/12/1991	PH (STANDARD UNITS)	6.8
5599500	2/12/1991	PH (STANDARD UNITS)	6.8
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	2/12/1991	PH (STANDARD UNITS)	7
5599500	4/9/1991	PH (STANDARD UNITS)	7.4
5599500	4/9/1991	PH (STANDARD UNITS)	7.4
5599500	6/4/1991	PH (STANDARD UNITS)	7.3
5599500	6/4/1991	PH (STANDARD UNITS)	7.2
5599500	7/16/1991	PH (STANDARD UNITS)	7.9
5599500	7/16/1991	PH (STANDARD UNITS)	7.7
5599500	7/16/1991	PH (STANDARD UNITS)	7.9
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8
5599500	7/16/1991	PH (STANDARD UNITS)	7.8

5599500	8/20/1991	PH (STANDARD UNITS)	6.9
5599500	8/20/1991	PH (STANDARD UNITS)	6.9
5599500	10/15/1991	PH (STANDARD UNITS)	7.05
5599500	11/12/1991	PH (STANDARD UNITS)	7
5599500	11/12/1991	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	6.9
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	1/7/1992	PH (STANDARD UNITS)	7
5599500	2/20/1992	PH (STANDARD UNITS)	7.2
5599500	2/20/1992	PH (STANDARD UNITS)	7.2
5599500	4/14/1992	PH (STANDARD UNITS)	7.3
5599500	4/14/1992	PH (STANDARD UNITS)	7.3
5599500	4/14/1992	PH (STANDARD UNITS)	7.44
5599500	4/14/1992	PH (STANDARD UNITS)	7.33
5599500	4/14/1992	PH (STANDARD UNITS)	7.29
5599500	4/14/1992	PH (STANDARD UNITS)	7.29
5599500	5/18/1992	PH (STANDARD UNITS)	7.1
5599500	7/13/1992	PH (STANDARD UNITS)	7.1
5599500	7/13/1992	PH (STANDARD UNITS)	7.1
5599500	8/17/1992	PH (STANDARD UNITS)	7.7
5599500	1/12/1993	PH (STANDARD UNITS)	7.4
5599500	2/16/1993	PH (STANDARD UNITS)	7.6
5599500	1/6/1994	PH (STANDARD UNITS)	7.7
5599500	3/2/1994	PH (STANDARD UNITS)	8
5599500	4/6/1994	PH (STANDARD UNITS)	7.8
5599500	5/23/1994	PH (STANDARD UNITS)	7.7
5599500	7/6/1994	PH (STANDARD UNITS)	7.6
5599500	8/4/1994	PH (STANDARD UNITS)	7.7
5599500	9/19/1994	PH (STANDARD UNITS)	8.5
5599500	11/1/1994	PH (STANDARD UNITS)	8
5599500	12/7/1994	PH (STANDARD UNITS)	7.9
5599500	1/30/1995	PH (STANDARD UNITS)	7.6
5599500	2/21/1995	PH (STANDARD UNITS)	7.9
5599500	4/12/1995	PH (STANDARD UNITS)	7.2
5599500	5/10/1995	PH (STANDARD UNITS)	7
5599500	6/15/1995	PH (STANDARD UNITS)	7.3
5599500	7/20/1995	PH (STANDARD UNITS)	7.9
5599500	8/22/1995	PH (STANDARD UNITS)	7.3
5599500	10/31/1995	PH (STANDARD UNITS)	7.1
5599500	12/18/1995	PH (STANDARD UNITS)	7.2
5599500	1/31/1996	PH (STANDARD UNITS)	7.4
5599500	2/29/1996	PH (STANDARD UNITS)	7.4
5599500	3/25/1996	PH (STANDARD UNITS)	6.6
5599500	5/1/1996	PH (STANDARD UNITS)	6.8
5599500	6/25/1996	PH (STANDARD UNITS)	6.8
5599500	7/31/1996	PH (STANDARD UNITS)	7.3

5599500	4/24/1997	PH (STANDARD UNITS)	7.2
N12	10/27/1997	PH (STANDARD UNITS)	7.2
N12	11/20/1997	PH (STANDARD UNITS)	6.4
N12	2/3/1998	PH (STANDARD UNITS)	7.5
N12	3/5/1998	PH (STANDARD UNITS)	7.5
N12	4/16/1998	PH (STANDARD UNITS)	7.2
N12	5/14/1998	PH (STANDARD UNITS)	7
N12	6/17/1998	PH (STANDARD UNITS)	7.1
N12	7/21/1998	PH (STANDARD UNITS)	6.7
N12	8/27/1998	PH (STANDARD UNITS)	6.4
N12	10/8/1998	PH (STANDARD UNITS)	7.3
N12	12/1/1998	PH (STANDARD UNITS)	7.3
N12	1/4/1999	PH (STANDARD UNITS)	8.1
N12	2/8/1999	PH (STANDARD UNITS)	7.3
N12	3/22/1999	PH (STANDARD UNITS)	7.2
N12	4/27/1999	PH (STANDARD UNITS)	7.4
N12	6/10/1999	PH (STANDARD UNITS)	6.5
N12	9/16/1999	PH (STANDARD UNITS)	7.3
N12	11/1/1999	PH (STANDARD UNITS)	7.4
N12	12/6/1999	PH (STANDARD UNITS)	7
N12	1/3/2000	PH (STANDARD UNITS)	6.6
N12	3/8/2000	PH (STANDARD UNITS)	6.6
N12	4/12/2000	PH (STANDARD UNITS)	7.1
N12	5/1/2000	PH (STANDARD UNITS)	7.6
N12	7/24/2000	PH (STANDARD UNITS)	6.9
N12	9/6/2000	PH (STANDARD UNITS)	6.5

Primary Station ID	Start Date	Parameter Long Name	Result Value
5599500	1/9/1990	OXYGEN, DISSOLVED MG/L	20.8
5599500	1/9/1990	OXYGEN, DISSOLVED MG/L	20.8
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12.5
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12.3
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	11.6
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	12
5599500	2/8/1990	OXYGEN, DISSOLVED MG/L	11.4
5599500	4/16/1990	OXYGEN, DISSOLVED MG/L	8.5
5599500	4/16/1990	OXYGEN, DISSOLVED MG/L	8.5
5599500	5/22/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	5/22/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	3.7
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.5
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/9/1990	OXYGEN, DISSOLVED MG/L	4.3
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	5.6
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	8/21/1990	OXYGEN, DISSOLVED MG/L	4.4
5599500	9/24/1990	OXYGEN, DISSOLVED MG/L	7.1
5599500	11/13/1990	OXYGEN, DISSOLVED MG/L	9.1
5599500	11/13/1990	OXYGEN, DISSOLVED MG/L	9.1
5599500	1/8/1991	OXYGEN, DISSOLVED MG/L	12.9
5599500	1/8/1991	OXYGEN, DISSOLVED MG/L	12.9
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.1
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	13
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.2
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.4
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	13.3
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	12
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.8
5599500	2/12/1991	OXYGEN, DISSOLVED MG/L	11.8
5599500	4/9/1991	OXYGEN, DISSOLVED MG/L	7.6
5599500	4/9/1991	OXYGEN, DISSOLVED MG/L	7.6
5599500	6/4/1991	OXYGEN, DISSOLVED MG/L	4.8
5599500	6/4/1991	OXYGEN, DISSOLVED MG/L	4.7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.67
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.6
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	7
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	7.2
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.8
5599500	7/16/1991	OXYGEN, DISSOLVED MG/L	6.8

5599500	8/20/1991	OXYGEN, DISSOLVED MG/L	9.2
5599500	8/20/1991	OXYGEN, DISSOLVED MG/L	9.2
5599500	10/15/1991	OXYGEN, DISSOLVED MG/L	9.45
5599500	11/12/1991	OXYGEN, DISSOLVED MG/L	10.8
5599500	11/12/1991	OXYGEN, DISSOLVED MG/L	10.8
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.6
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.6
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	1/7/1992	OXYGEN, DISSOLVED MG/L	10.7
5599500	2/20/1992	OXYGEN, DISSOLVED MG/L	10.1
5599500	2/20/1992	OXYGEN, DISSOLVED MG/L	10.1
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.8
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.8
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	9
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.7
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.73
5599500	4/14/1992	OXYGEN, DISSOLVED MG/L	8.69
5599500	5/18/1992	OXYGEN, DISSOLVED MG/L	6.9
5599500	7/13/1992	OXYGEN, DISSOLVED MG/L	4.3
5599500	7/13/1992	OXYGEN, DISSOLVED MG/L	4.3
5599500	8/17/1992	OXYGEN, DISSOLVED MG/L	9.6
5599500	1/12/1993	OXYGEN, DISSOLVED MG/L	10.4
5599500	2/16/1993	OXYGEN, DISSOLVED MG/L	11.3
5599500	1/6/1994	OXYGEN, DISSOLVED MG/L	11.6
5599500	3/2/1994	OXYGEN, DISSOLVED MG/L	11.6
5599500	4/6/1994	OXYGEN, DISSOLVED MG/L	9.3
5599500	5/23/1994	OXYGEN, DISSOLVED MG/L	5.4
5599500	7/6/1994	OXYGEN, DISSOLVED MG/L	5.5
5599500	8/4/1994	OXYGEN, DISSOLVED MG/L	5.8
5599500	9/19/1994	OXYGEN, DISSOLVED MG/L	5.6
5599500	11/1/1994	OXYGEN, DISSOLVED MG/L	10.5
5599500	12/7/1994	OXYGEN, DISSOLVED MG/L	7.9
5599500	1/30/1995	OXYGEN, DISSOLVED MG/L	12
5599500	2/21/1995	OXYGEN, DISSOLVED MG/L	11.7
5599500	4/12/1995	OXYGEN, DISSOLVED MG/L	8.6
5599500	5/10/1995	OXYGEN, DISSOLVED MG/L	5.9
5599500	6/15/1995	OXYGEN, DISSOLVED MG/L	3.9
5599500	7/20/1995	OXYGEN, DISSOLVED MG/L	4.7
5599500	8/22/1995	OXYGEN, DISSOLVED MG/L	4.1
5599500	10/31/1995	OXYGEN, DISSOLVED MG/L	7.3
5599500	12/18/1995	OXYGEN, DISSOLVED MG/L	10.8
5599500	1/31/1996	OXYGEN, DISSOLVED MG/L	12.2
5599500	2/29/1996	OXYGEN, DISSOLVED MG/L	10.7
5599500	3/25/1996	OXYGEN, DISSOLVED MG/L	11
5599500	5/1/1996	OXYGEN, DISSOLVED MG/L	6.9
5599500	6/25/1996	OXYGEN, DISSOLVED MG/L	6.2
5599500	7/31/1996	OXYGEN, DISSOLVED MG/L	6.8

5599500	4/24/1997	OXYGEN, DISSOLVED MG/L	8.3
N12	10/27/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.2
N12	11/20/1997	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8
N12	2/3/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.3
N12	3/5/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.6
N12	4/16/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.8
N12	5/14/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.7
N12	6/17/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.8
N12	7/21/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	5.2
N12	8/27/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.3
N12	10/8/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.1
N12	12/1/1998	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.2
N12	1/4/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	12.4
N12	2/8/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.3
N12	3/22/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.5
N12	4/27/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
N12	6/10/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.8
N12	9/16/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	6.6
N12	11/1/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.7
N12	12/6/1999	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	9.2
N12	1/3/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	10.5
N12	3/8/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.8
N12	4/12/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	8.5
N12	5/1/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.2
N12	7/24/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	7.9
N12	9/6/2000	OXYGEN ,DISSOLVED, ANALYSIS BY PROBE MG/L	4.7

Secondary ID .1	Start Date	Parameter Long Name	Result Value
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	54
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	52
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-1	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	76
RNC-1	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	59
RNC-1	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	88
RNC-1	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	64
RNC-1	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	80
RNC-1	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	78
RNC-1	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	78
RNC-1	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	84
RNC-1	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	81
RNC-1	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	81
RNC-1	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	72

RNC-1	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	73
RNC-1	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	74
RNC-1	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	71
RNC-1	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	75
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	85
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	70
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	72
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	63
RNC-1	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	66
RNC-1	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	65
RNC-1	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	50
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	59.5
RNC-1	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	59
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	71
RNC-1	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	56.5
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	56
RNC-1	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	57.5
RNC-1	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	55

RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	54.5
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	55.2
RNC-1	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	54
RNC-1	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	56.6
RNC-1	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	62
RNC-1	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	60
RNC-1	########	DEPTH OF POND OR RESERVOIR IN FEET	58.5
RNC-1	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	4/28/2000	DEPTH OF POND OR RESERVOIR IN FEET	24
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-1	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	58
RNC-1	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	55
RNC-1	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-1	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	57
RNC-2	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	47
RNC-2	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	49
RNC-2	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	51
RNC-2	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	39

RNC-2	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	38.5
RNC-2	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-2	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-2	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-2	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	18
RNC-2	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-2	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-2	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-2	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	23
RNC-2	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	24
RNC-2	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	40.5
RNC-2	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	40.5
RNC-2	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-2	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	23
RNC-2	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-2	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-2	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	44
RNC-2	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	41.5
RNC-2	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	37.5
RNC-2	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	41.5
RNC-2	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	43
RNC-2	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	46
RNC-2	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	39

RNC-2	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-2	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-2	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	35.5
RNC-2	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	41.2
RNC-2	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-2	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	33
RNC-2	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	########	DEPTH OF POND OR RESERVOIR IN FEET	42
RNC-2	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	39
RNC-2	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-2	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-2	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	40
RNC-3	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	20
RNC-3	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	21
RNC-3	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	25.5
RNC-3	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	25.5
RNC-3	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	18
RNC-3	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-3	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-3	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-3	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	15

RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-3	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-3	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	16
RNC-3	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	15
RNC-3	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	14
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	6/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	38
RNC-3	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	36
RNC-3	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-3	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	44
RNC-3	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	41
RNC-3	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	39.5
RNC-3	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	37
RNC-3	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	32.5
RNC-3	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	31.5
RNC-3	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	28.5
RNC-3	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	31
RNC-3	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	26.5
RNC-3	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	25
RNC-3	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	29.5
RNC-3	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	26

RNC-3	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	22
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	24.5
RNC-3	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	33.3
RNC-3	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	33
RNC-3	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	19
RNC-3	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	30
RNC-3	########	DEPTH OF POND OR RESERVOIR IN FEET	29
RNC-3	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-3	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	28
RNC-3	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	26
RNC-3	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	27
RNC-4	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/30/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	5/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	12
RNC-4	6/6/1990	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RNC-4	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	6/14/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	6/27/1990	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/13/1990	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/23/1990	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RNC-4	8/7/1990	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	8/17/1990	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	9/26/1990	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/22/1991	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/24/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	5/21/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	6/4/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/5/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/11/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	6/19/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/9/1991	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/23/1991	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	8/13/1991	DEPTH OF POND OR RESERVOIR IN FEET	2.5
RNC-4	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	8/15/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	9/16/1991	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	5/24/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	5/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	4

RNC-4	6/13/1992	DEPTH OF POND OR RESERVOIR IN FEET	4
RNC-4	7/11/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/30/1992	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	8/9/1992	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	5/18/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	5/31/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	6/14/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	6/29/1993	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	7/26/1993	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	2.5
RNC-4	4/13/1994	DEPTH OF POND OR RESERVOIR IN FEET	2
RNC-4	5/11/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	6/6/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	7/12/1994	DEPTH OF POND OR RESERVOIR IN FEET	3
RNC-4	8/3/1994	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	8/16/1994	DEPTH OF POND OR RESERVOIR IN FEET	3.5
RNC-4	8/27/1994	DEPTH OF POND OR RESERVOIR IN FEET	5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	6/16/1996	DEPTH OF POND OR RESERVOIR IN FEET	17
RNC-4	7/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	7/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	8/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	8/15/1996	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	9/3/1996	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	9/18/1996	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	10/1/1996	DEPTH OF POND OR RESERVOIR IN FEET	7.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RNC-4	4/11/1997	DEPTH OF POND OR RESERVOIR IN FEET	12.5
RNC-4	5/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	8.5
RNC-4	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	6/19/1997	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	6/20/1997	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	7/10/1997	DEPTH OF POND OR RESERVOIR IN FEET	20
RNC-4	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	7/23/1997	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	8/5/1997	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	8/21/1997	DEPTH OF POND OR RESERVOIR IN FEET	5.5
RNC-4	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	8/22/1997	DEPTH OF POND OR RESERVOIR IN FEET	8
RNC-4	9/15/1997	DEPTH OF POND OR RESERVOIR IN FEET	6
RNC-4	9/29/1997	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	10/9/1997	DEPTH OF POND OR RESERVOIR IN FEET	6.5
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	4.5
RNC-4	6/3/1998	DEPTH OF POND OR RESERVOIR IN FEET	11.2
RNC-4	6/18/1998	DEPTH OF POND OR RESERVOIR IN FEET	10

RNC-4	7/7/1998	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-4	7/31/1998	DEPTH OF POND OR RESERVOIR IN FEET	11.5
RNC-4	8/14/1998	DEPTH OF POND OR RESERVOIR IN FEET	13
RNC-4	9/4/1998	DEPTH OF POND OR RESERVOIR IN FEET	7
RNC-4	9/22/1998	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	########	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	1/11/2000	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	4/26/2000	DEPTH OF POND OR RESERVOIR IN FEET	10
RNC-4	6/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	9
RNC-4	7/5/2000	DEPTH OF POND OR RESERVOIR IN FEET	11
RNC-4	8/2/2000	DEPTH OF POND OR RESERVOIR IN FEET	11

Secondary ID .1	Start Date	Parameter Long Name	Result Value	ample Depth (ft)
5599540	1/8/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/5/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	
5599540	4/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	5/16/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/28/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	7/31/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	9/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	
5599540	12/4/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/29/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/28/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.032	
5599540	3/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	5/23/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	8/7/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/25/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
5599540	2/3/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	3/10/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/15/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	5/7/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	7/1/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	8/12/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/23/1992	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	1/27/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	3/3/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.060	
5599540	4/21/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	5/19/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	7/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	9/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	11/7/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	12/8/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
5599540	1/9/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	2/8/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	3/23/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	5/3/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/29/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	8/2/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	9/7/1995	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	
5599540	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	
5599540	1/11/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	
5599540	2/28/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	
5599540	3/19/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/25/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	6/20/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	
5599540	8/13/1996	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	

5599540	3/24/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
5599540	4/29/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	
RNC-1	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-1	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	Lake Bottom
RNC-1	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	1
RNC-1	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	Lake Bottom
RNC-1	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-1	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.075	Lake Bottom
RNC-1	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-1	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.584	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.083	Lake Bottom
RNC-1	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	1
RNC-1	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	Lake Bottom
RNC-1	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-1	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	Lake Bottom
RNC-1	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-1	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.067	Lake Bottom
RNC-1	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	Lake Bottom
RNC-1	5/18/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	
RNC-1	6/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	
RNC-1	7/28/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	
RNC-1	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	1
RNC-1	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.037	Lake Bottom
RNC-1	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	1
RNC-1	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	Lake Bottom
RNC-1	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.014	1
RNC-1	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	Lake Bottom
RNC-1	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	1
RNC-1	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.031	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	Lake Bottom
RNC-1	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-1	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	Lake Bottom
RNC-1	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.028	1
RNC-1	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.035	Lake Bottom
RNC-1	7/10/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	
RNC-1	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-1	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.117	Lake Bottom
RNC-1	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	1
RNC-1	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	Lake Bottom
RNC-1	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-1	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.174	Lake Bottom
RNC-1	11/3/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.021	
RNC-1	8/25/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	
RNC-1	9/21/1998	PHOSPHORUS, TOTAL (MG/L AS P)	0.034	
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	
RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	1

RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	12
RNC-1	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	Lake Bottom
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	1
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	13
RNC-1	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.008	Lake Bottom
RNC-1	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-1	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.100	Lake Bottom
RNC-1	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.009	1
RNC-1	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.038	Lake Bottom
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-1	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.095	Lake Bottom
RNC-2	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-2	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-2	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.010	1
RNC-2	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-2	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1
RNC-2	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.018	1
RNC-2	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.040	1
RNC-2	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-2	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-2	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-2	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	1
RNC-2	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.039	1
RNC-2	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-2	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.026	1
RNC-2	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.020	1
RNC-2	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.011	1
RNC-2	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-2	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-2	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-2	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.013	1
RNC-3	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.001	1
RNC-3	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
RNC-3	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	1
RNC-3	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.024	1
RNC-3	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.030	1
RNC-3	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.017	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.029	1
RNC-3	5/18/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.015	1
RNC-3	6/29/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.069	1
RNC-3	7/28/1993	PHOSPHORUS, TOTAL (MG/L AS P)	0.012	1
RNC-3	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.084	1
RNC-3	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.016	1

RNC-3	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.027	1
RNC-3	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.032	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.025	1
RNC-3	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.043	1
RNC-3	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.059	1
RNC-3	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.037	1
RNC-3	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.050	1
RNC-3	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.034	1
RNC-3	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-3	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	1
RNC-3	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.019	1
RNC-3	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.022	1
RNC-3	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.023	1
RNC-4	4/30/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.046	1
RNC-4	6/14/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.152	1
RNC-4	7/13/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.109	1
RNC-4	8/17/1990	PHOSPHORUS, TOTAL (MG/L AS P)	0.116	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.036	1
RNC-4	4/22/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.097	1
RNC-4	6/11/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.106	1
RNC-4	7/9/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.130	1
RNC-4	8/15/1991	PHOSPHORUS, TOTAL (MG/L AS P)	0.090	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	1
RNC-4	4/13/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.185	1
RNC-4	6/6/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.136	1
RNC-4	7/12/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.123	1
RNC-4	8/16/1994	PHOSPHORUS, TOTAL (MG/L AS P)	0.155	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.078	1
RNC-4	4/11/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.121	1
RNC-4	6/19/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.072	1
RNC-4	7/23/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.063	1
RNC-4	8/22/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.245	1
RNC-4	10/9/1997	PHOSPHORUS, TOTAL (MG/L AS P)	0.147	1
RNC-4	4/26/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
RNC-4	6/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.070	1
RNC-4	7/5/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.077	1
RNC-4	8/2/2000	PHOSPHORUS, TOTAL (MG/L AS P)	0.047	1
RNC-4	########	PHOSPHORUS, TOTAL (MG/L AS P)	0.033	1

Secondary ID .1	Start Date	Parameter Long Name	Result Value
RNC-1	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.9
RNC-1	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.3
RNC-1	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.9
RNC-1	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.4
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.56
RNC-1	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.86
RNC-1	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	6.68
RNC-1	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.66
RNC-1	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.6
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.22
RNC-1	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10.4
RNC-1	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.4
RNC-1	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.5
RNC-1	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.2
RNC-1	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.7
RNC-1	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19
RNC-1	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.1
RNC-1	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	19.2
RNC-1	9/15/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.35
RNC-1	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	5.47
RNC-1	11/3/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.21
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.63
RNC-1	6/9/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.41
RNC-1	6/23/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.55
RNC-1	8/25/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.6
RNC-1	9/21/1998	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28.2
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.5
RNC-1	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.61
RNC-1	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.4
RNC-1	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.13
RNC-1	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	58.7
RNC-1	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.07
RNC-2	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.84
RNC-2	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16
RNC-2	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	22.3
RNC-2	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.1
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	4.79
RNC-2	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.64
RNC-2	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	6.68
RNC-2	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.6
RNC-2	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	14.1
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	7.7
RNC-2	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.5
RNC-2	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	10
RNC-2	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.6
RNC-2	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.5
RNC-2	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.2
RNC-2	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	25.1
RNC-2	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29
RNC-2	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	22.4
RNC-2	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.41
RNC-2	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.64
RNC-2	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.6

RNC-2	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.01
RNC-2	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.5
RNC-2	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.5
RNC-3	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.1
RNC-3	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11
RNC-3	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	23.5
RNC-3	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.1
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.61
RNC-3	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	17.1
RNC-3	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.4
RNC-3	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.7
RNC-3	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.4
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.8
RNC-3	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	32.9
RNC-3	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	8.61
RNC-3	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	28
RNC-3	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.7
RNC-3	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	18.2
RNC-3	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.8
RNC-3	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	33
RNC-3	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	40.8
RNC-3	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	15.5
RNC-3	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	20.7
RNC-3	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	13.6
RNC-3	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	12.4
RNC-3	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	9.75
RNC-3	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	25.5
RNC-4	4/30/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	27.62
RNC-4	6/14/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	38.84
RNC-4	7/13/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	30.92
RNC-4	8/17/1990	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	35.04
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	31.15
RNC-4	4/22/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	26.7
RNC-4	6/11/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	74.17
RNC-4	7/9/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	50.73
RNC-4	8/15/1991	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	47.12
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.69
RNC-4	4/13/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	11.31
RNC-4	6/6/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	51.62
RNC-4	7/12/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	69.83
RNC-4	8/16/1994	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	75.65
RNC-4	4/11/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	3.98
RNC-4	6/19/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	46.44
RNC-4	7/23/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	79.63
RNC-4	8/22/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	58.99
RNC-4	10/9/1997	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	55.63
RNC-4	4/26/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	29.1
RNC-4	6/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	49.9
RNC-4	7/5/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	41.5
RNC-4	8/2/2000	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	53.1
RNC-4	########	CHLOROPHYLL-A UG/L SPECTROPHOTOMETRIC ACID. METH.	16.4

Secondary ID .1	Start Date	Parameter Long Name		Result Value	Sample Depth (ft)
5599540	01/08/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	02/05/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	04/16/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	05/16/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	06/28/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	07/31/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	09/17/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
5599540	10/24/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	12/04/90	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	01/29/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	02/28/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	03/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
5599540	05/23/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	08/07/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	
5599540	09/25/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.3	
5599540	11/14/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	12/16/91	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	02/03/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	03/10/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	
5599540	04/15/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	
5599540	05/07/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	07/01/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	08/12/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	09/23/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	11/16/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	12/21/92	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
5599540	01/27/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	03/01/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	04/12/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
5599540	05/11/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
5599540	06/29/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	08/18/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	09/29/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	11/10/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	12/08/93	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	01/13/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	03/03/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	04/21/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	05/19/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
5599540	07/06/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	08/03/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	
5599540	09/06/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	11/07/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
5599540	12/08/94	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	
5599540	01/09/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	02/08/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
5599540	03/23/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
5599540	05/03/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/29/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
5599540	08/02/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
5599540	09/07/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
5599540	10/18/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.5	
5599540	12/14/95	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.2	
5599540	01/11/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.3	
5599540	02/28/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	03/19/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	04/25/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	06/20/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	08/13/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
5599540	09/03/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
5599540	11/12/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
5599540	12/11/96	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
5599540	01/14/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.5	
5599540	02/18/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
5599540	03/24/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
5599540	04/29/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
5599540	06/09/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	

5599540	07/16/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
5599540	08/28/97	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-1	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
RNC-1	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
RNC-1	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3	
RNC-1	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-1	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-1	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
RNC-1	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7	
RNC-1	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5	
RNC-1	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.1	
RNC-1	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	
RNC-1	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9	
RNC-1	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
RNC-1	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-1	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9	
RNC-1	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-1	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7	
RNC-1	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3	
RNC-1	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.7	
RNC-1	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
RNC-1	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8	
RNC-1	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6	
RNC-1	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
RNC-1	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	
RNC-1	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.6	
RNC-1	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8	1
RNC-1	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8	12
RNC-1	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7	56
RNC-1	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.2	1
RNC-1	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	13
RNC-1	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2	56
RNC-1	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	1
RNC-1	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	53
RNC-1	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9	1
RNC-1	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1	55
RNC-1	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	1
RNC-1	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.99	53
RNC-2	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4	
RNC-2	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6	
RNC-2	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1	
RNC-2	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-2	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5	
RNC-2	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-2	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9	
RNC-2	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.7	
RNC-2	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2	
RNC-2	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	
RNC-2	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7	
RNC-2	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5	
RNC-2	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9	
RNC-2	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.8	
RNC-2	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4	

RNC-2	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
RNC-2	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-2	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6
RNC-2	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-2	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
RNC-2	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-2	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9
RNC-2	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-2	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9
RNC-2	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-3	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-3	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.7
RNC-3	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8
RNC-3	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-3	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.4
RNC-3	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-3	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-3	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.1
RNC-3	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-3	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-3	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6
RNC-3	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-3	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9
RNC-3	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.8
RNC-3	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-3	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-3	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5
RNC-3	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.5
RNC-3	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
RNC-3	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
RNC-3	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-3	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.9
RNC-3	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9
RNC-3	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	9.2
RNC-3	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-4	4/30/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.8
RNC-4	6/14/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
RNC-4	7/13/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
RNC-4	8/17/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.9
RNC-4	10/22/1990	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.7
RNC-4	4/22/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.6
RNC-4	6/11/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8
RNC-4	7/9/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-4	8/15/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-4	10/16/1991	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
RNC-4	4/13/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.5
RNC-4	6/6/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-4	7/12/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-4	8/16/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-4	10/11/1994	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.3
RNC-4	4/11/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	6.8
RNC-4	6/19/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.6
RNC-4	7/23/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.1
RNC-4	8/22/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.3
RNC-4	10/9/1997	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.2
RNC-4	4/26/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.1
RNC-4	6/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	7.9
RNC-4	7/5/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2
RNC-4	8/2/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.4
RNC-4	10/11/2000	PH (STANDARD UNITS)	(standard: 6.5-9.0)	8.2

Appendix B

Directory of Coal Mines for Jackson County, Illinois May 4, 2002

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)

MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC
13	BIG MUDDY COAL & IRON C	BIG MUDDY	9	SHAFT	MRP	1906-21	MURPHYSBORO	JACKSON	8S	2W	34
13	CONSOLIDATED C C OF ST LOUIS	C C C	9	SHAFT		1921-26	MURPHYSBORO	JACKSON	8S	2W	34
15	CARBONDALE C C EARLIER 78?	HARRISON		SHAFT		1878-91	MURPHYSBORO	JACKSON	8S	2W	33
15	ST LOUIS ORE & STEEL	HARRISON		SHAFT	RPP	1891-94	MURPHYSBORO	JACKSON	8S	2W	33
15	BIG MUDDY COAL & IRON C	HARRISON		SHAFT		1894-16	MURPHYSBORO	JACKSON	8S	2W	33
604	TEMPLETON C C	TEMPLETON	1	SLOPE	MRP	1927-44	MURPHYSBORO	JACKSON	9S	2W	16
2493	BIG MUDDY COAL & IRON C	BIG MUDDY	6	SHAFT		1898-09	MURPHYSBORO	JACKSON	9S	2W	10

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC

APPENDIX B

DIRECTORY OF SELECTED COAL MINES FOR JACKSON COUNTY, ILLINOIS (IDNR 2000)
MAY 3, 2000

ISGS INDEX	COMPANY NAME	MINE NAME	MINE NO.	MINE TYPE	METHOD	YEARS OPERATED	SEAM MINED	COUNTY	LOCATION		
									TWP	RGE	SEC

Appendix C
GWLF and BATHTUB Input and Output Files

GWLF Input Data Files

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Transprt.dat

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"Small-Grains",232.1,80.1,0.04431
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"Grassland",1640.2,68.7,0.00294
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"Deciduous",4795.7,59.4,0.00215
"Deciduous",21.8,66.2,0.00108
"Coniferous",122.9,61.1,0.00198
"Cattle-Lot",0.2,74.2,0.00036
"Open-Water",97,99.8,0
"Shall-Marsh",9.2,99.6,0
"Deep-Marsh",1.9,100,0
"Forest-Wet",124.7,100,0
"Shall-Water",13.7,100,0
"Barren-Land",1.9,100,0
"High-Density",4.7,90.1,0
"Med-Density",36,81.2,0
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Nutrient.dat

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2.9,0.26
1.8,0.3
3,0.25
3,0.15
3,0.25
0.06,0.009
0.06,0.009
0.06,0.009
0,4
0,0
0,0
0,0
0,0
0,0
0.0743,0.00841
0.0756,0.010112
0.0424,0.00609
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subbasin 2

Transprt.dat

```
7,4
0.15,0.15,10,0,0,0.18,10
0
0
0
0
0
"APR",0.5,13,0,0.27
"MAY",0.94,14,1,0.27
"JUNE",0.95,14.5,1,0.27
"JULY",0.94,14.3,1,0.27
"AUG",0.93,13.4,1,0.27
"SEPT",0.94,12.2,1,0.27
"OCT",0.92,11,1,0.14
"NOV",0.45,10,0,0.14
"DEC",0.42,9.4,0,0.14
"JAN",0.52,9.7,0,0.14
"FEB",0.53,10.6,0,0.14
"MAR",0.52,11.8,0,0.14
"Row-Crop",88,81.9,0.0515
"Small-Grains",8.4,77.7,0.0385
"Pasture",132.8,68.6,0.0064
"Grassland",265.5,68.6,0.0064
"Deciduous",1752.4,62.2,0.0029
"Deciduous",3,82.2,0.0014
"Coniferous",45.8,63.6,0.0021
"Open-Water",198,100,0
"Shall-Marsh",1.1,89.5,0
"Forest-Wet",1,100,0
"Shall-Water",3,94.6,0
```

Nutrient.dat

```
3000,616,0.1,0.012
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
0.06,0.009
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subbasin 3

Transprt.dat

```
7,3
0.15,0.15,10,0,0,0.22,10
0
0
0
0
0
"APR",0.44,13,0,0.27
"MAY",0.95,14,1,0.27
"JUNE",0.95,14.5,1,0.27
"JULY",0.95,14.3,1,0.27
"AUG",0.94,13.4,1,0.27
"SEPT",0.95,12.2,1,0.27
"OCT",0.95,11,1,0.14
"NOV",0.42,10,0,0.14
"DEC",0.4,9.4,0,0.14
"JAN",0.45,9.7,0,0.14
"FEB",0.46,10.6,0,0.14
"MAR",0.45,11.8,0,0.14
"Row-Crop",14.3,77.5,0.09219
"Small-Grains",0.4,75.2,0.02781
"Pasture",19.2,61.7,0.00919
"Grassland",38.3,61.7,0.00919
"Deciduous",775.5,65.5,0.00321
"Deciduous",1.1,89.4,0.00256
"Coniferous",17.9,60.3,0.00265
"Open-Water",163.8,99.9,0
"Forest-Wet",3.4,100,0
"Shall-Water",0.7,100,0
```

Nutrient.dat

```
3000,616,0.1,0.012
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
0.06,0.009
0.06,0.009
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Subbasin 4

Transprt.dat

```
7,5
0.15,0.15,10,0,0,0.17,10
0
0
0
0
0
"APR",0.63,13,0,0.27
"MAY",0.88,14,1,0.27
"JUNE",0.9,14.5,1,0.27
"JULY",0.89,14.3,1,0.27
"AUG",0.89,13.4,1,0.27
"SEPT",0.89,12.2,1,0.27
"OCT",0.85,11,1,0.14
"NOV",0.56,10,0,0.14
"DEC",0.52,9.4,0,0.14
"JAN",0.66,9.7,0,0.14
"FEB",0.68,10.6,0,0.14
"MAR",0.66,11.8,0,0.14
"Row-Crop",285.4,83.1,0.03306
"Small-Grains",63,79.8,0.03064
"Pasture",232.6,72.5,0.00620
"Grassland",465.1,72.5,0.00620
"Deciduous",1376.8,65,0.00234
"Deciduous",13.7,62.1,0.00177
"Cattle-Lot",2.1,73.9,0.00622
"Open-Water",635.1,100,0
"Shall-Marsh",0.5,100,0
"Deep-Marsh",0.8,100,0
"Forest-Wet",19.9,99.7,0
"Shall-Water",7.3,98.8,0
```

Nutrient.dat

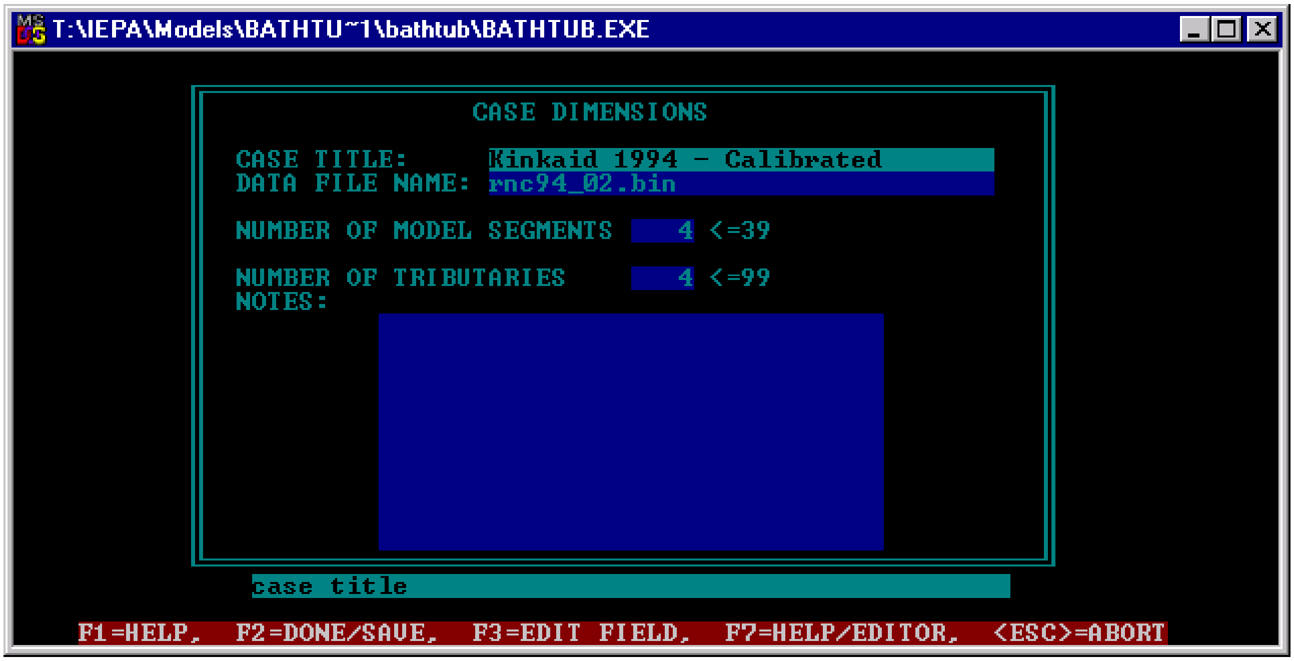
```
3000,616,0.25,0.015
0,0,0
2.9,0.26
1.8,0.3
3,0.25
3,0.15
0.06,0.009
0.06,0.009
0,219
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0,0
0
```

Weather.dat (excerpt)

```
30
6.39,0.00
5.00,0.00
8.61,0.00
16.94,0.00
19.44,0.00
11.11,2.31
9.44,0.00
5.00,0.00
3.06,0.00
5.83,0.00
9.44,0.13
13.89,0.00
16.11,0.00
17.78,0.94
12.22,1.55
13.61,0.03
15.28,0.00
18.33,0.00
19.44,0.00
19.44,0.00
20.28,0.00
20.83,0.00
21.67,0.00
18.61,1.09
14.17,0.00
17.22,0.00
20.28,0.53
20.00,0.48
15.83,0.00
18.33,0.00
31
20.00,1.52
17.22,0.25
12.50,0.30
13.61,0.00
16.67,0.00
20.28,0.00
20.83,0.00
13.89,0.00
16.39,0.00
18.89,0.00
19.17,0.00
21.11,0.10
22.78,0.53
21.67,3.35
21.11,0.10
18.89,0.13
16.39,0.00
10.28,0.23
15.00,0.00
19.17,0.00
20.83,0.00
20.00,1.75
11.94,2.29
16.11,0.00
```

```
18.06,0.00
20.00,0.00
24.72,0.00
21.94,0.03
17.22,0.00
21.94,0.00
25.56,0.00
30
21.39,0.00
22.22,0.00
23.89,0.18
22.50,2.26
24.17,1.57
20.56,0.79
19.72,0.71
19.17,0.00
22.50,0.00
23.89,2.59
23.06,1.02
18.33,1.27
12.78,0.13
13.61,0.00
17.22,0.05
21.39,0.00
23.33,2.06
18.06,1.57
18.33,0.00
17.22,0.00
20.56,0.00
23.06,0.91
21.94,0.00
25.28,1.70
24.72,0.15
25.28,0.00
25.83,0.00
24.44,4.42
18.89,0.30
21.67,0.00
```

BATHTUB Model Input Screens for 1994 Simulation



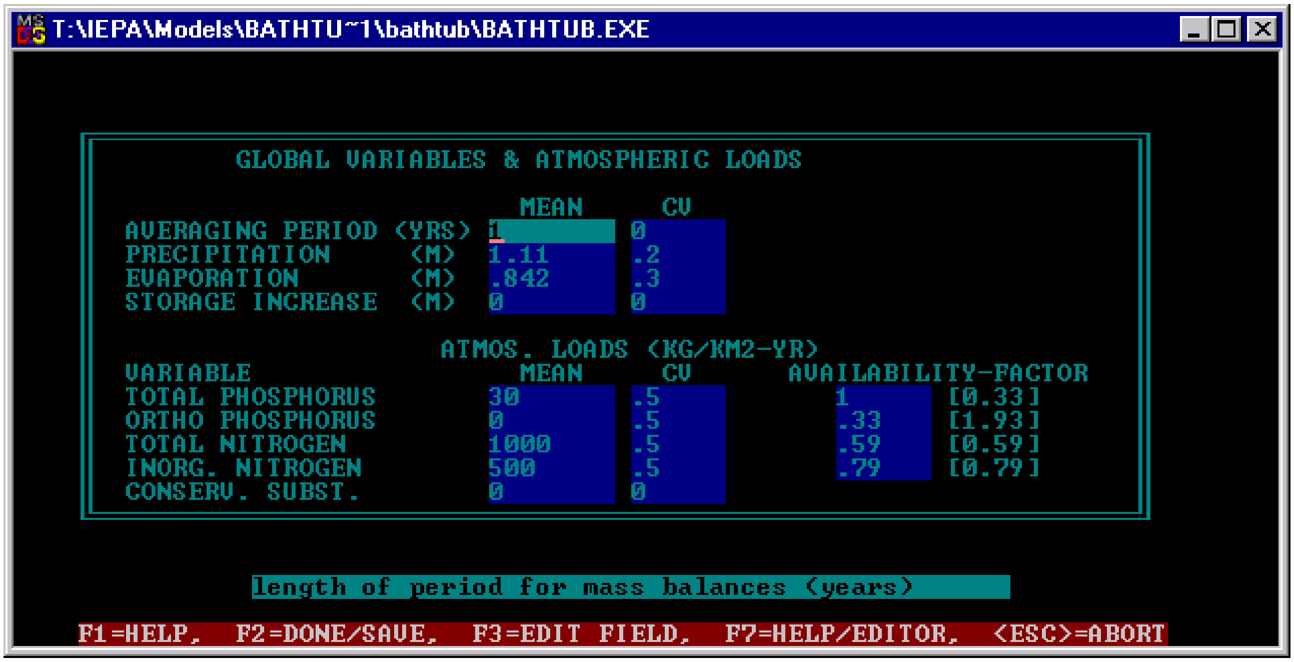
```
                CASE DIMENSIONS

CASE TITLE:       Kinkaid 1994 - Calibrated
DATA FILE NAME:   rnc94_02.bin

NUMBER OF MODEL SEGMENTS      4 <=39

NUMBER OF TRIBUTARIES         4 <=99
NOTES:

      case title
```

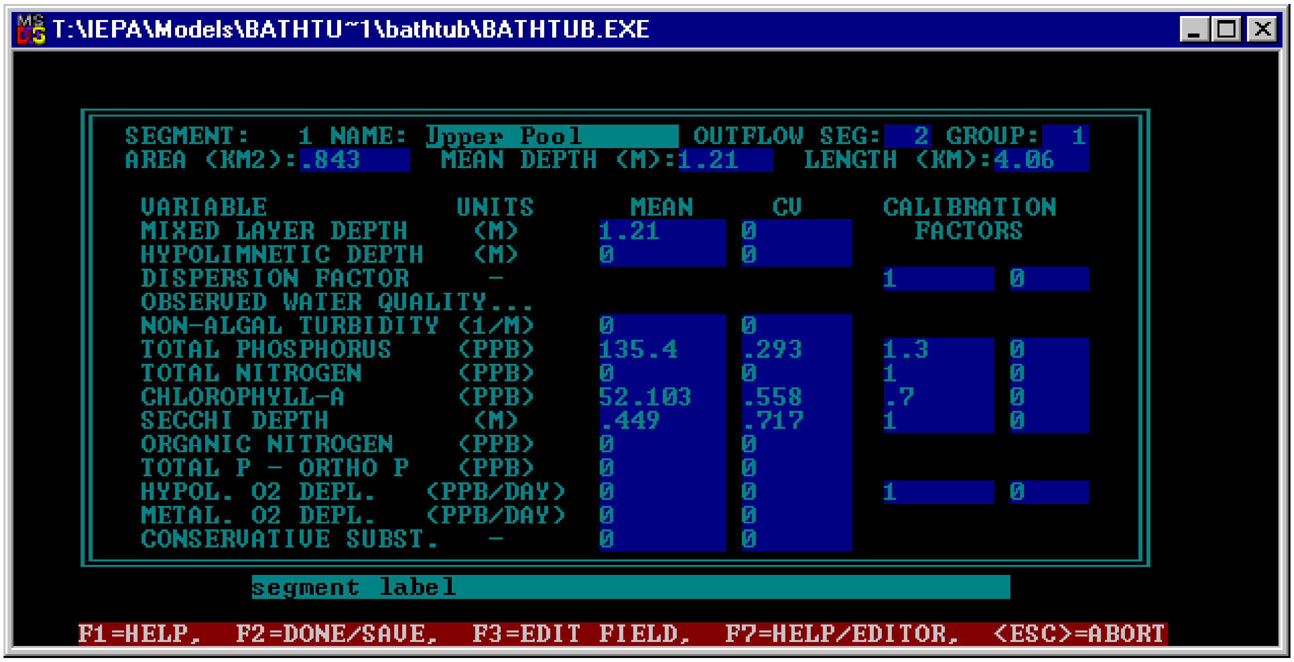


```
         GLOBAL VARIABLES & ATMOSPHERIC LOADS

                                MEAN     CV
AVERAGING PERIOD (YRS)      1        0
PRECIPITATION       (M)     1.11     .2
EVAPORATION         (M)     .842     .3
STORAGE INCREASE    (M)     0        0

                       ATMOS. LOADS (KG/KM2-YR)
VARIABLE                        MEAN     CV          AVAILABILITY-FACTOR
TOTAL PHOSPHORUS            30       .5              1       [0.33]
ORTHO PHOSPHORUS            0        .5              .33     [1.93]
TOTAL NITROGEN              1000     .5              .59     [0.59]
INORG. NITROGEN             500      .5              .79     [0.79]
CONSERV. SUBST.             0        0

      length of period for mass balances (years)
```

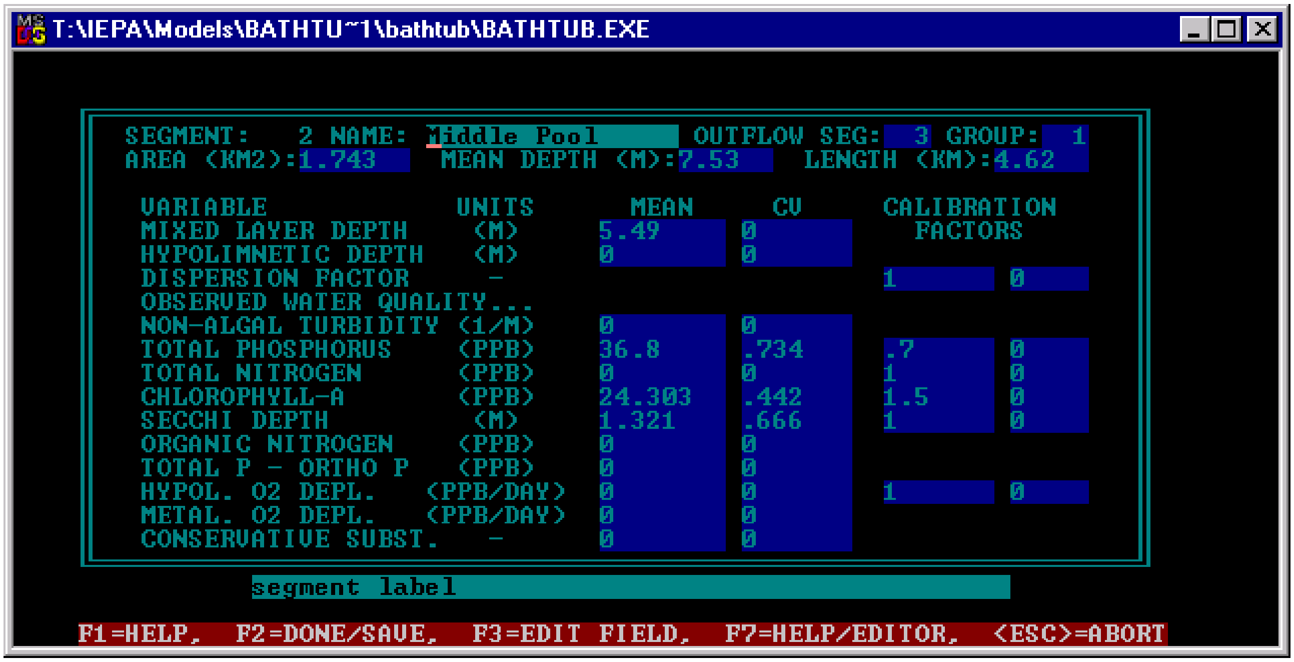


```
SEGMENT:    1 NAME: Upper Pool       OUTFLOW SEG:  2 GROUP:  1
AREA (KM2):.843        MEAN DEPTH (M):1.21     LENGTH (KM):4.06

 VARIABLE             UNITS       MEAN      CV       CALIBRATION
 MIXED LAYER DEPTH     (M)       1.21      0           FACTORS
 HYPOLIMNETIC DEPTH    (M)       0         0
 DISPERSION FACTOR      -                            1       0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)       0         0
 TOTAL PHOSPHORUS     (PPB)      135.4     .293      1.3     0
 TOTAL NITROGEN       (PPB)      0         0         1       0
 CHLOROPHYLL-A        (PPB)      52.103    .558      .7      0
 SECCHI DEPTH          (M)       .449      .717      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
```

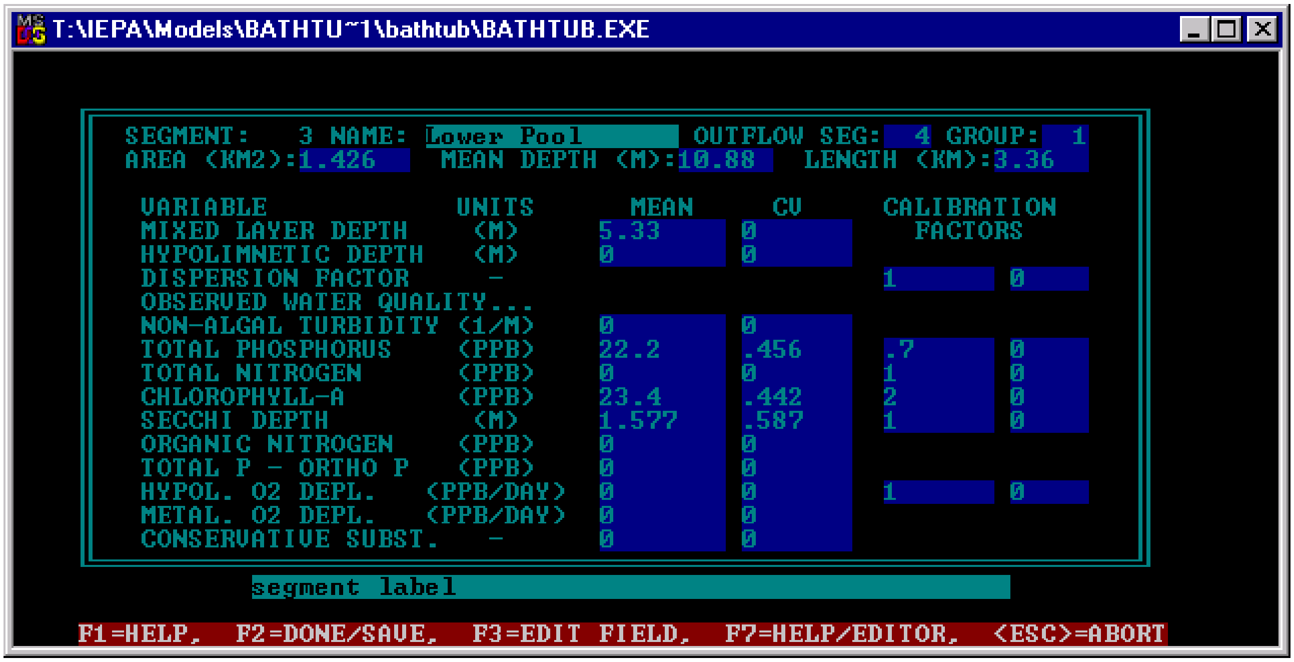


```
SEGMENT:    2 NAME: Middle Pool      OUTFLOW SEG:  3 GROUP:  1
AREA (KM2):1.743       MEAN DEPTH (M):7.53     LENGTH (KM):4.62

 VARIABLE             UNITS       MEAN      CV       CALIBRATION
 MIXED LAYER DEPTH     (M)       5.49      0           FACTORS
 HYPOLIMNETIC DEPTH    (M)       0         0
 DISPERSION FACTOR      -                            1       0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)       0         0
 TOTAL PHOSPHORUS     (PPB)      36.8      .734      .7      0
 TOTAL NITROGEN       (PPB)      0         0         1       0
 CHLOROPHYLL-A        (PPB)      24.303    .442      1.5     0
 SECCHI DEPTH          (M)       1.321     .666      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
```

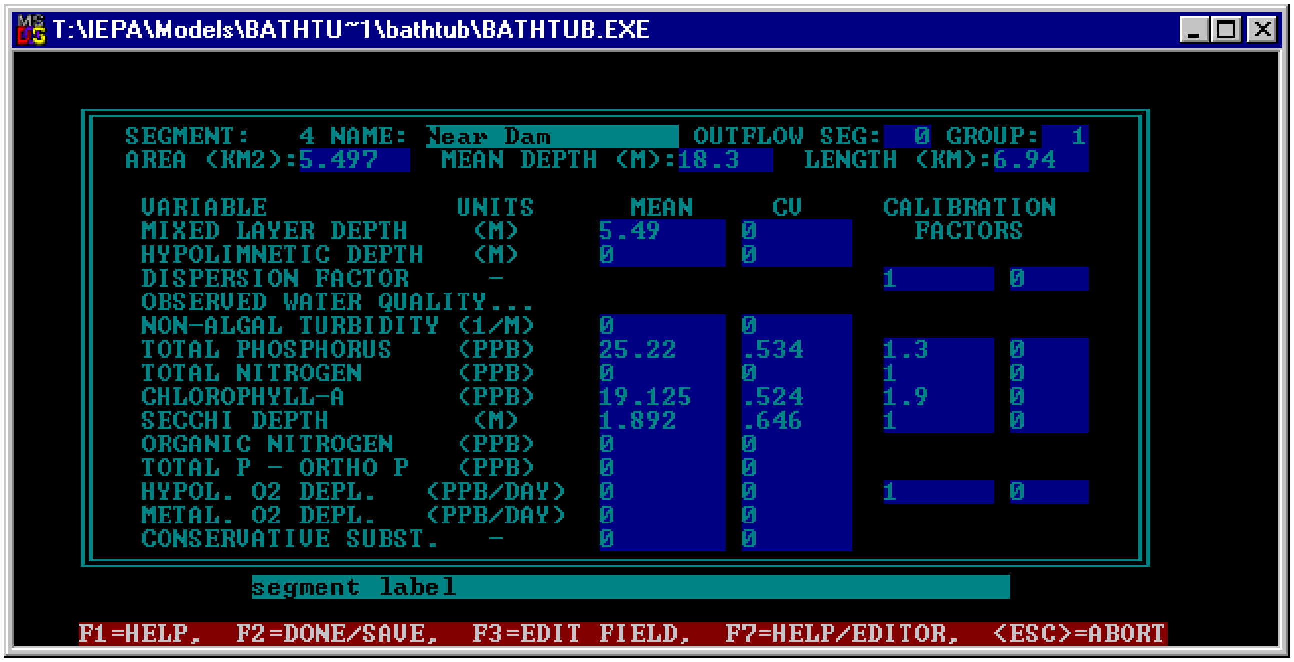


```
 SEGMENT:    3 NAME: Lower Pool       OUTFLOW SEG:   4 GROUP:   1
 AREA (KM2):1.426      MEAN DEPTH (M):10.88     LENGTH (KM):3.36

  VARIABLE                  UNITS       MEAN      CV       CALIBRATION
  MIXED LAYER DEPTH          (M)       5.33      0           FACTORS
  HYPOLIMNETIC DEPTH         (M)       0         0
  DISPERSION FACTOR           -                            1        0
  OBSERVED WATER QUALITY...
  NON-ALGAL TURBIDITY (1/M)            0         0
  TOTAL PHOSPHORUS          (PPB)      22.2      .456      .7       0
  TOTAL NITROGEN            (PPB)      0         0         1        0
  CHLOROPHYLL-A             (PPB)      23.4      .442      2        0
  SECCHI DEPTH               (M)       1.577     .587      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
```

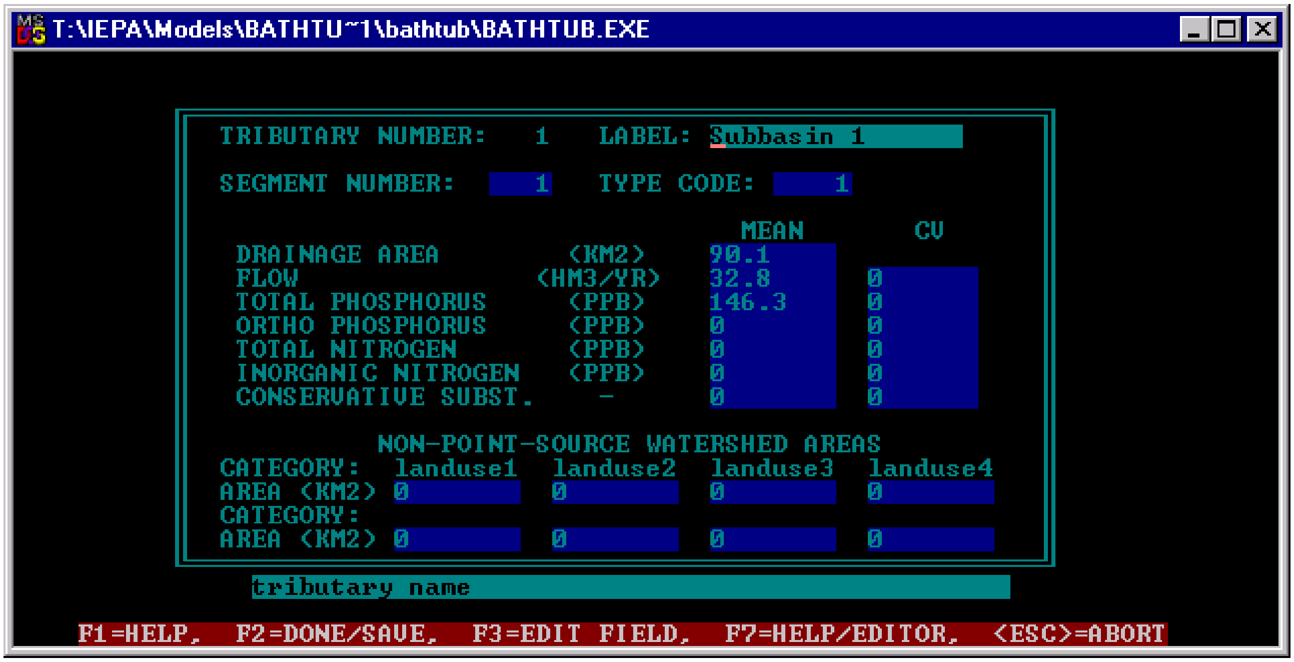


```
 SEGMENT:    4 NAME: Near Dam         OUTFLOW SEG:   0 GROUP:   1
 AREA (KM2):5.497      MEAN DEPTH (M):18.3      LENGTH (KM):6.94

  VARIABLE                  UNITS       MEAN      CV       CALIBRATION
  MIXED LAYER DEPTH          (M)       5.49      0           FACTORS
  HYPOLIMNETIC DEPTH         (M)       0         0
  DISPERSION FACTOR           -                            1        0
  OBSERVED WATER QUALITY...
  NON-ALGAL TURBIDITY (1/M)            0         0
  TOTAL PHOSPHORUS          (PPB)      25.22     .534      1.3      0
  TOTAL NITROGEN            (PPB)      0         0         1        0
  CHLOROPHYLL-A             (PPB)      19.125    .524      1.9      0
  SECCHI DEPTH               (M)       1.892     .646      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
```



```
TRIBUTARY NUMBER:    1    LABEL: Subbasin 1

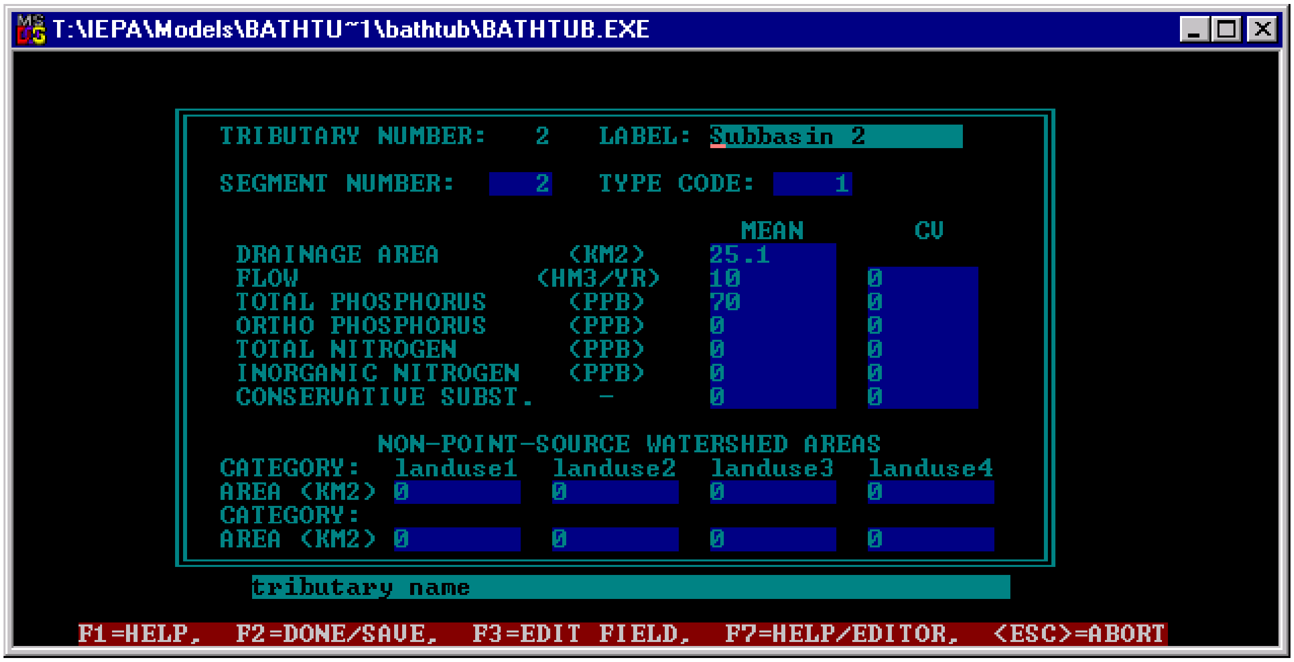
SEGMENT NUMBER:      1    TYPE CODE:     1

                                      MEAN        CV
 DRAINAGE AREA          (KM2)      90.1
 FLOW                 (HM3/YR)     32.8        0
 TOTAL PHOSPHORUS       (PPB)      146.3       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
```



```
TRIBUTARY NUMBER:    2    LABEL: Subbasin 2

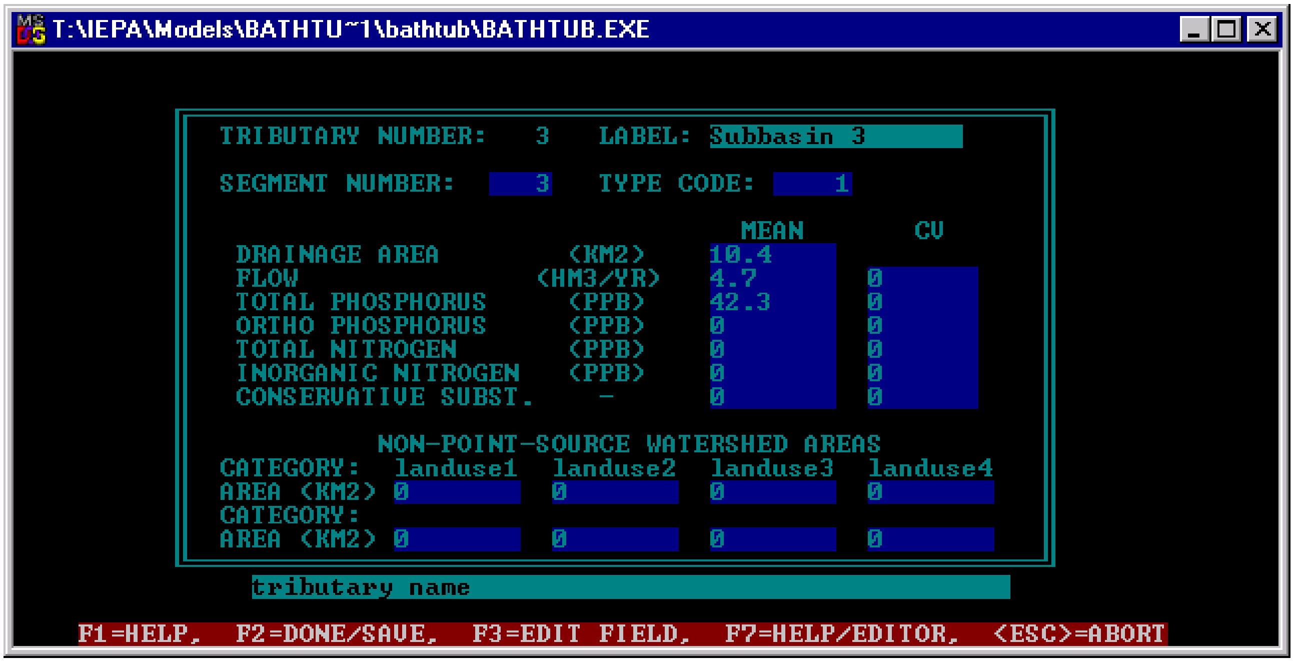
SEGMENT NUMBER:      2    TYPE CODE:     1

                                      MEAN        CV
 DRAINAGE AREA          (KM2)      25.1
 FLOW                 (HM3/YR)     10          0
 TOTAL PHOSPHORUS       (PPB)      70          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
```



```
TRIBUTARY NUMBER:   3   LABEL: Subbasin 3

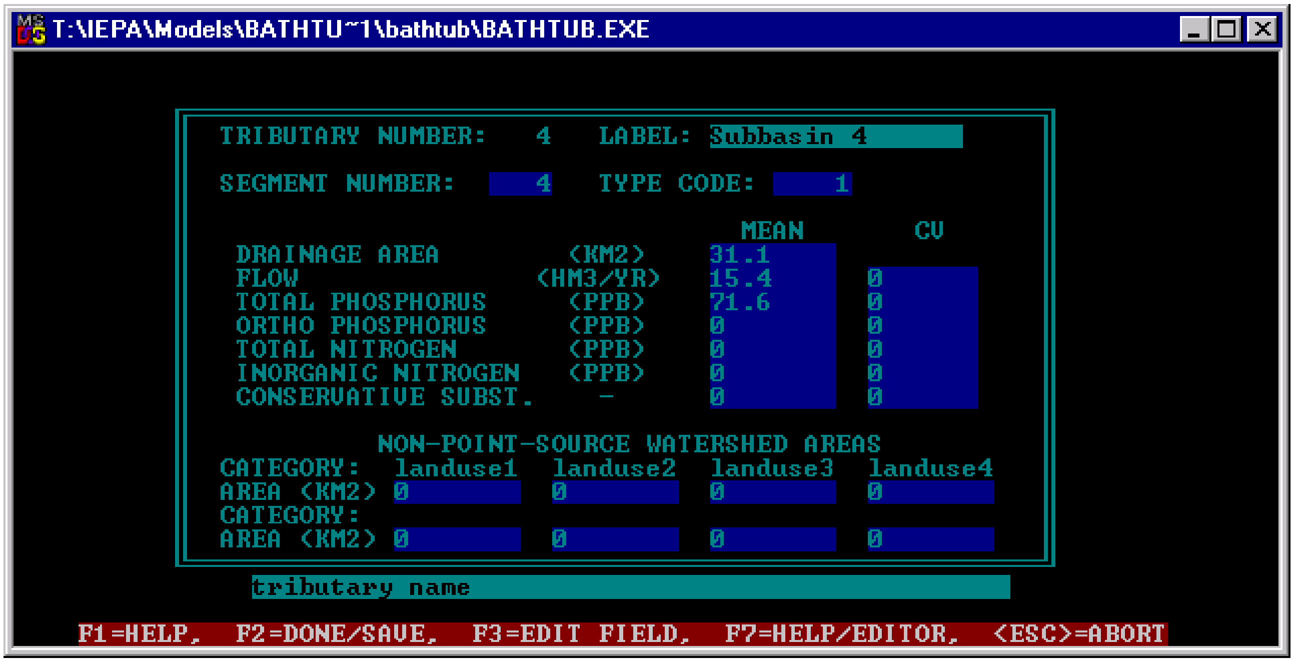
SEGMENT NUMBER:     3   TYPE CODE:     1

                                    MEAN        CU
 DRAINAGE AREA          (KM2)      10.4
 FLOW                 (HM3/YR)     4.7         0
 TOTAL PHOSPHORUS       (PPB)      42.3        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
```



```
TRIBUTARY NUMBER:   4   LABEL: Subbasin 4

SEGMENT NUMBER:     4   TYPE CODE:     1

                                    MEAN        CU
 DRAINAGE AREA          (KM2)      31.1
 FLOW                 (HM3/YR)     15.4        0
 TOTAL PHOSPHORUS       (PPB)      71.6        0
 ORTHO PHOSPHORUS       (PPB)      0           0
 TOTAL NITROGEN         (PPB)      0           0
 INORGANIC NITROGEN     (PPB)      0           0
 CONSERVATIVE SUBST.      -        0           0

          NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1   landuse2   landuse3   landuse4
AREA (KM2) 0          0          0          0
CATEGORY:
AREA (KM2) 0          0          0          0

  tributary name

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

BATHTUB Model Output for 1994 Simulation

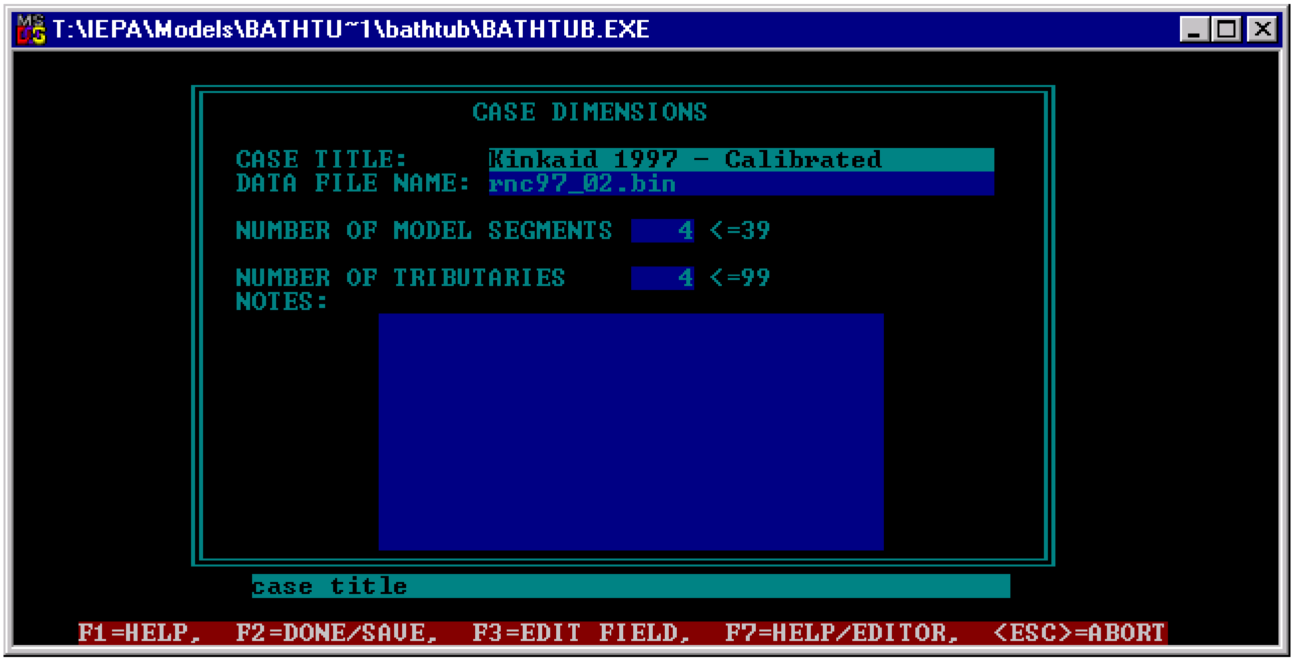
```
CASE: Kinkaid 1994 - Calibrated
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3   135.4   .29   137.6   .48     .98   -.06   -.06   -.03
 CHL-A      MG/M3    52.1   .56    49.9   .53    1.04    .08    .12    .06
 SECCHI         M      .4   .72      .5   .66     .98   -.03   -.09   -.03
 ORGANIC N  MG/M3      .0   .00  1364.6   .41     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00   106.7   .39     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    36.8   .73    39.3   .45     .94   -.09   -.25   -.08
 CHL-A      MG/M3    24.3   .44    22.2   .67    1.09    .20    .26    .11
 SECCHI         M     1.3   .67     1.4   .53     .93   -.11   -.25   -.08
 ORGANIC N  MG/M3      .0   .00   675.5   .47     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    39.0   .49     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    22.2   .46    23.1   .45     .96   -.09   -.15   -.06
 CHL-A      MG/M3    23.4   .44    20.2   .67    1.16    .33    .43    .18
 SECCHI         M     1.6   .59     1.7   .60     .92   -.14   -.29   -.10
 ORGANIC N  MG/M3      .0   .00   623.3   .48     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    33.7   .58     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    25.2   .53    23.3   .46    1.08    .15    .30    .12
 CHL-A      MG/M3    19.1   .52    19.1   .66    1.00    .01    .01    .00
 SECCHI         M     1.9   .65     1.8   .60    1.05    .08    .19    .06
 ORGANIC N  MG/M3      .0   .00   597.8   .46     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    31.7   .58     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    36.7   .48    36.3   .45    1.01    .02    .03    .01
 CHL-A      MG/M3    23.6   .50    22.6   .53    1.05    .09    .14    .06
 SECCHI         M     1.6   .64     1.6   .50    1.01    .02    .04    .01
 ORGANIC N  MG/M3      .0   .00   683.9   .40     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    40.0   .50     .00    .00    .00    .00
```

```
CASE: Kinkaid 1994 - Calibrated
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       32.800  .000E+00  .000        .364
 2  1 Subbasin 2             25.100       10.000  .000E+00  .000        .398
 3  1 Subbasin 3             10.400        4.700  .000E+00  .000        .452
 4  1 Subbasin 4             31.100       15.400  .000E+00  .000        .495
----------------------------------------------------------------------------
PRECIPITATION                 9.509       10.555  .446E+01  .200       1.110
TRIBUTARY INFLOW            156.700       62.900  .000E+00  .000        .401
***TOTAL INFLOW             166.209       73.455  .446E+01  .029        .442
ADVECTIVE OUTFLOW           166.209       65.448  .102E+02  .049        .394
***TOTAL OUTFLOW            166.209       65.448  .102E+02  .049        .394
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---         CONC  EXPORT
ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV  MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            4798.6   67.7  .000E+00     .0  .000  146.3    53.3
 2 1 Subbasin 2             700.0    9.9  .000E+00     .0  .000   70.0    27.9
 3 1 Subbasin 3             198.8    2.8  .000E+00     .0  .000   42.3    19.1
 4 1 Subbasin 4            1102.6   15.6  .000E+00     .0  .000   71.6    35.5
-------------------------------------------------------------------------------
PRECIPITATION               285.3    4.0  .203E+05  100.0  .500   27.0    30.0
TRIBUTARY INFLOW           6800.1   96.0  .000E+00     .0  .000  108.1    43.4
***TOTAL INFLOW            7085.4  100.0  .203E+05  100.0  .020   96.5    42.6
ADVECTIVE OUTFLOW          1521.9   21.5  .483E+06 2375.1  .457   23.3     9.2
***TOTAL OUTFLOW           1521.9   21.5  .483E+06 2375.1  .457   23.3     9.2
***RETENTION               5563.5   78.5  .495E+06 2432.9  .126     .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P  --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME     RATIO      COEF
     M/YR       YRS     MG/M3       YRS        -         -
     6.88    1.9902      36.7     .6739    1.4839     .7852
```

BATHTUB Model Input Screens for 1997 Simulation



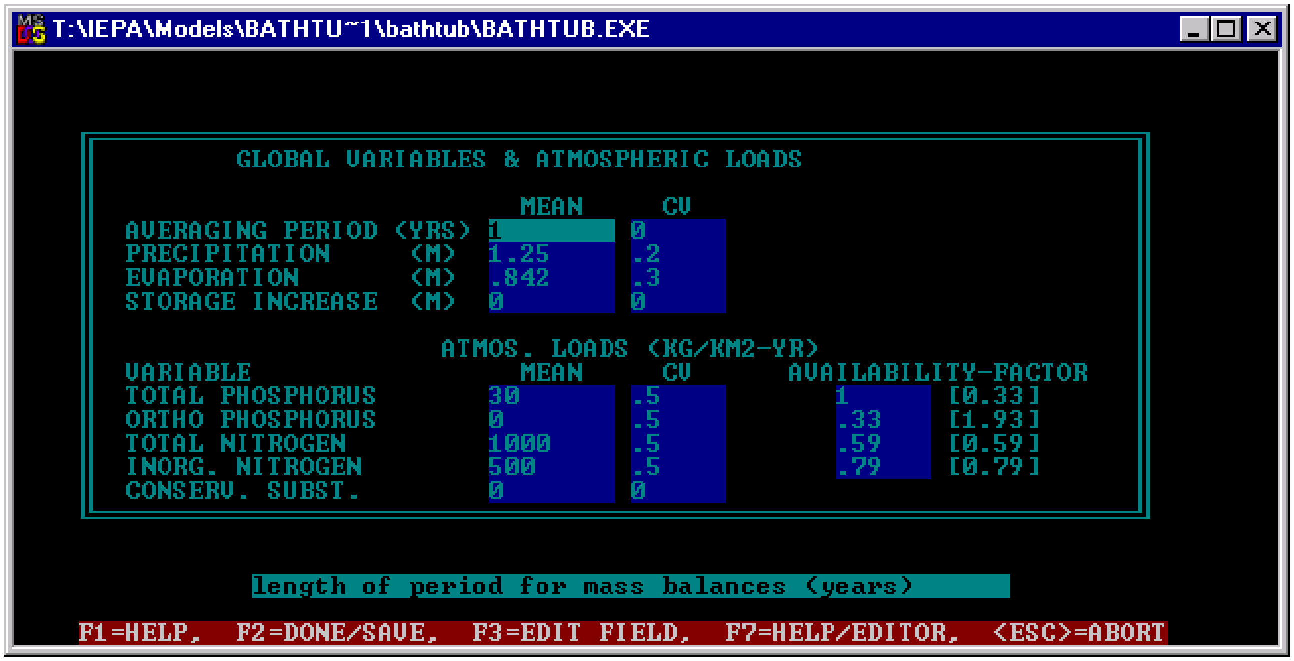
```
                CASE DIMENSIONS

CASE TITLE:       Kinkaid 1997 - Calibrated
DATA FILE NAME:   rnc97_02.bin

NUMBER OF MODEL SEGMENTS      4 <=39

NUMBER OF TRIBUTARIES         4 <=99
NOTES:

      case title
```

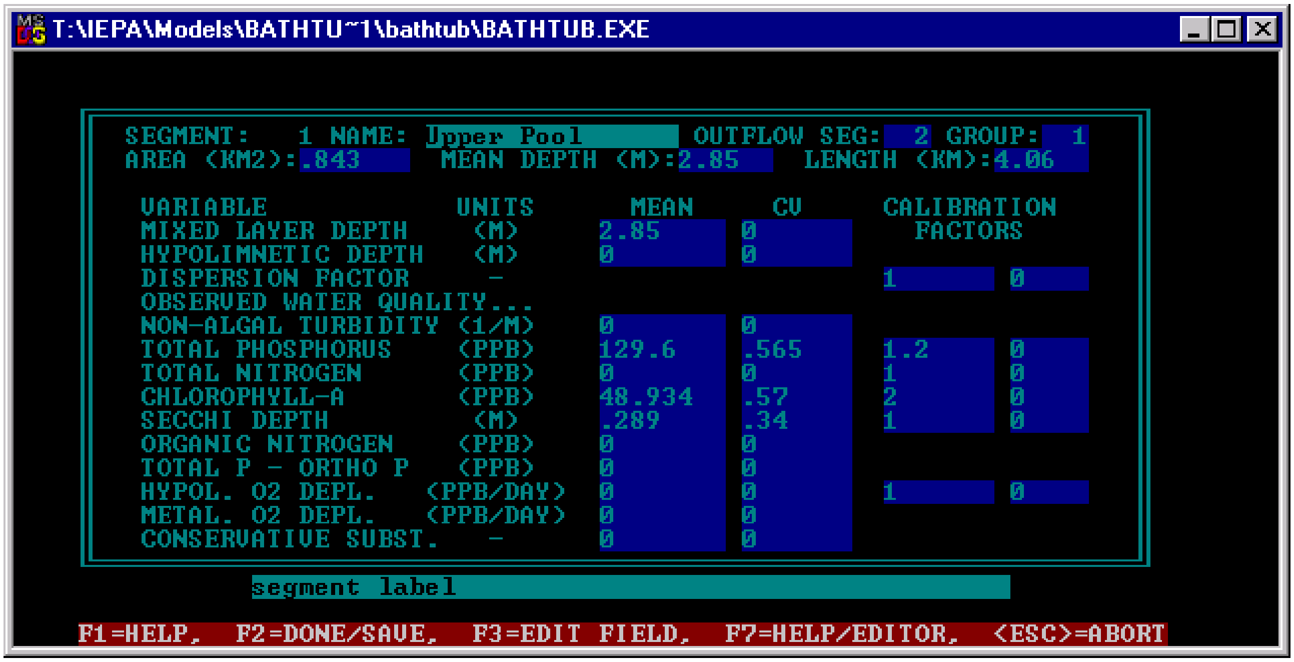


```
         GLOBAL VARIABLES & ATMOSPHERIC LOADS

                             MEAN      CV
AVERAGING PERIOD (YRS)    1         0
PRECIPITATION      (M)    1.25      .2
EVAPORATION        (M)    .842      .3
STORAGE INCREASE   (M)    0         0

                       ATMOS. LOADS (KG/KM2-YR)
VARIABLE                     MEAN      CV       AVAILABILITY-FACTOR
TOTAL PHOSPHORUS          30        .5            1       [0.33]
ORTHO PHOSPHORUS          0         .5            .33     [1.93]
TOTAL NITROGEN            1000      .5            .59     [0.59]
INORG. NITROGEN           500       .5            .79     [0.79]
CONSERV. SUBST.           0         0

      length of period for mass balances (years)
```

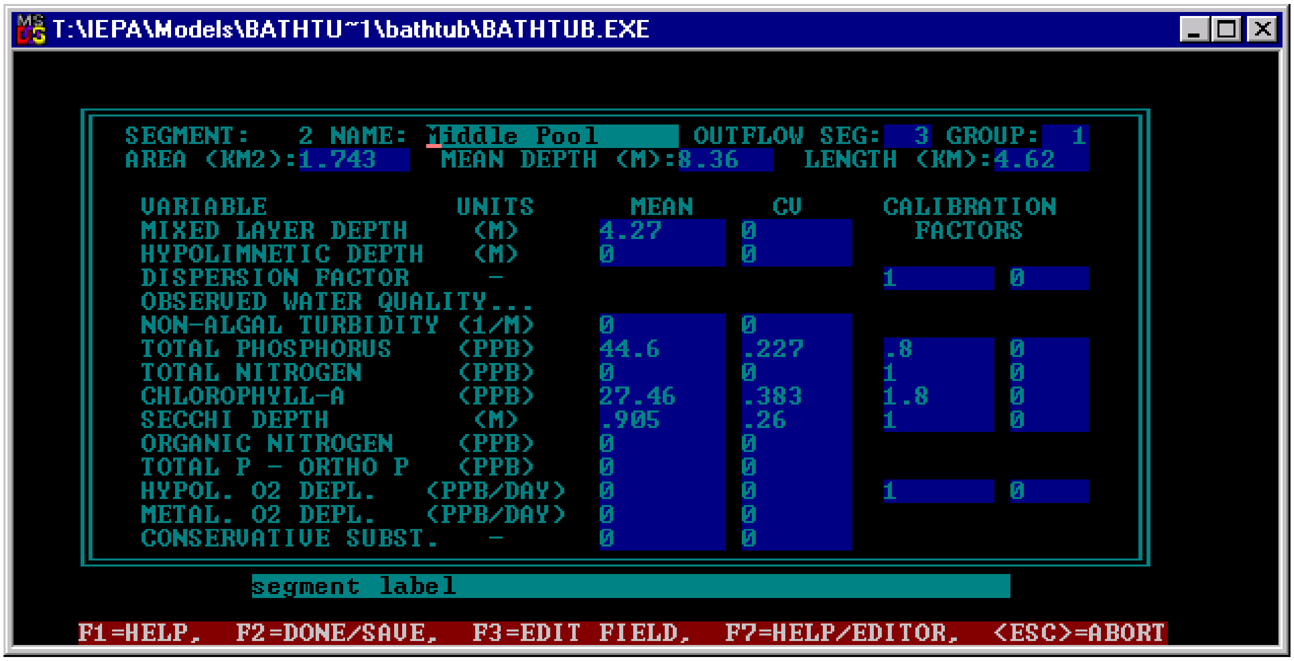


```
SEGMENT:    1 NAME: Upper Pool       OUTFLOW SEG:  2 GROUP:   1
AREA (KM2):.843       MEAN DEPTH (M):2.85     LENGTH (KM):4.06

 VARIABLE                UNITS        MEAN      CV       CALIBRATION
 MIXED LAYER DEPTH        (M)        2.85      0          FACTORS
 HYPOLIMNETIC DEPTH       (M)        0         0
 DISPERSION FACTOR         -                            1        0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)           0         0
 TOTAL PHOSPHORUS        (PPB)       129.6     .565     1.2      0
 TOTAL NITROGEN          (PPB)       0         0        1        0
 CHLOROPHYLL-A           (PPB)       48.934    .57      2        0
 SECCHI DEPTH             (M)        .289      .34      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
```

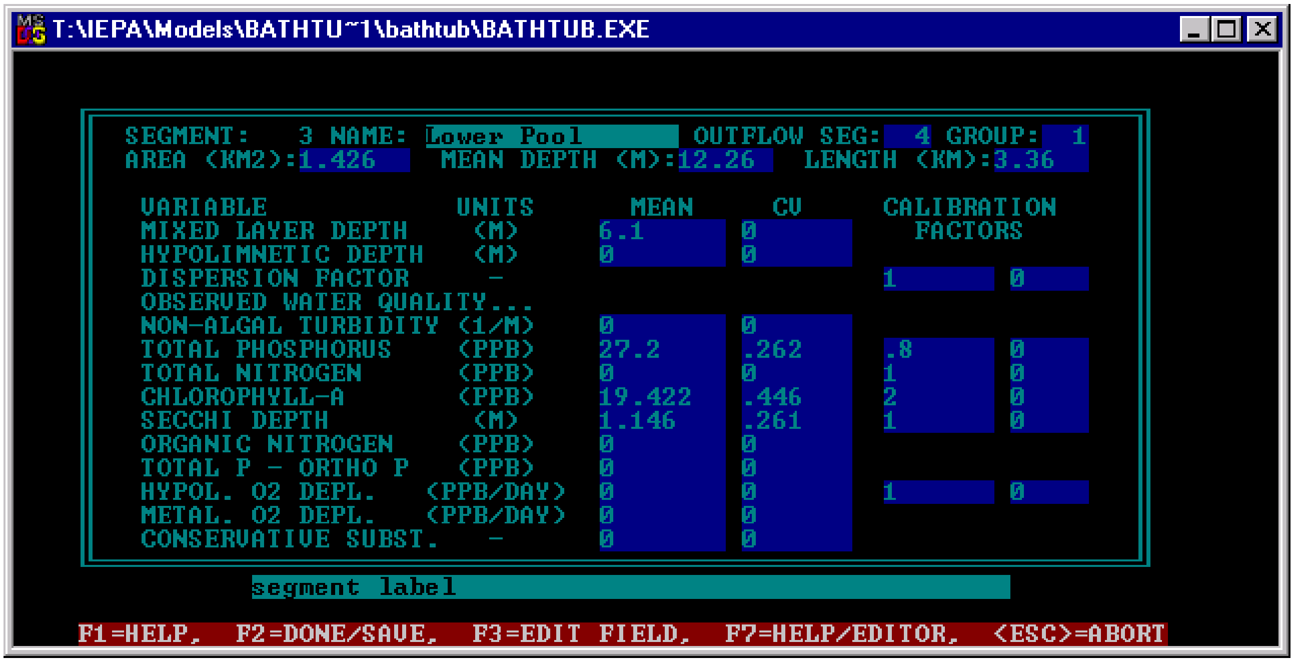


```
SEGMENT:    2 NAME: Middle Pool      OUTFLOW SEG:  3 GROUP:   1
AREA (KM2):1.743      MEAN DEPTH (M):8.36     LENGTH (KM):4.62

 VARIABLE                UNITS        MEAN      CV       CALIBRATION
 MIXED LAYER DEPTH        (M)        4.27      0          FACTORS
 HYPOLIMNETIC DEPTH       (M)        0         0
 DISPERSION FACTOR         -                            1        0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)           0         0
 TOTAL PHOSPHORUS        (PPB)       44.6      .227     .8       0
 TOTAL NITROGEN          (PPB)       0         0        1        0
 CHLOROPHYLL-A           (PPB)       27.46     .383     1.8      0
 SECCHI DEPTH             (M)        .905      .26      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
```

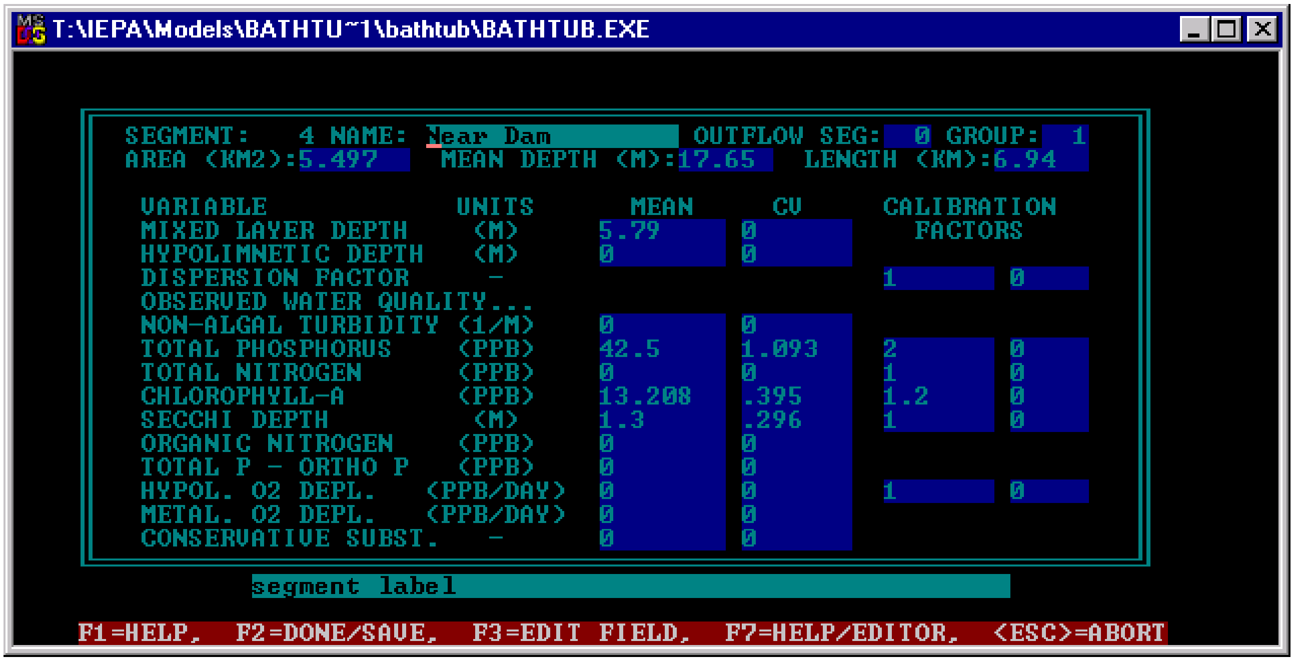


```
SEGMENT:    3 NAME: Lower Pool       OUTFLOW SEG:   4 GROUP:   1
AREA (KM2):1.426     MEAN DEPTH (M):12.26    LENGTH (KM):3.36

 VARIABLE              UNITS       MEAN      CV       CALIBRATION
 MIXED LAYER DEPTH      (M)      6.1       0            FACTORS
 HYPOLIMNETIC DEPTH     (M)      0         0
 DISPERSION FACTOR       -                          1         0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)       0         0
 TOTAL PHOSPHORUS      (PPB)     27.2      .262     .8        0
 TOTAL NITROGEN        (PPB)     0         0        1         0
 CHLOROPHYLL-A         (PPB)     19.422    .446     2         0
 SECCHI DEPTH           (M)      1.146     .261     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
```

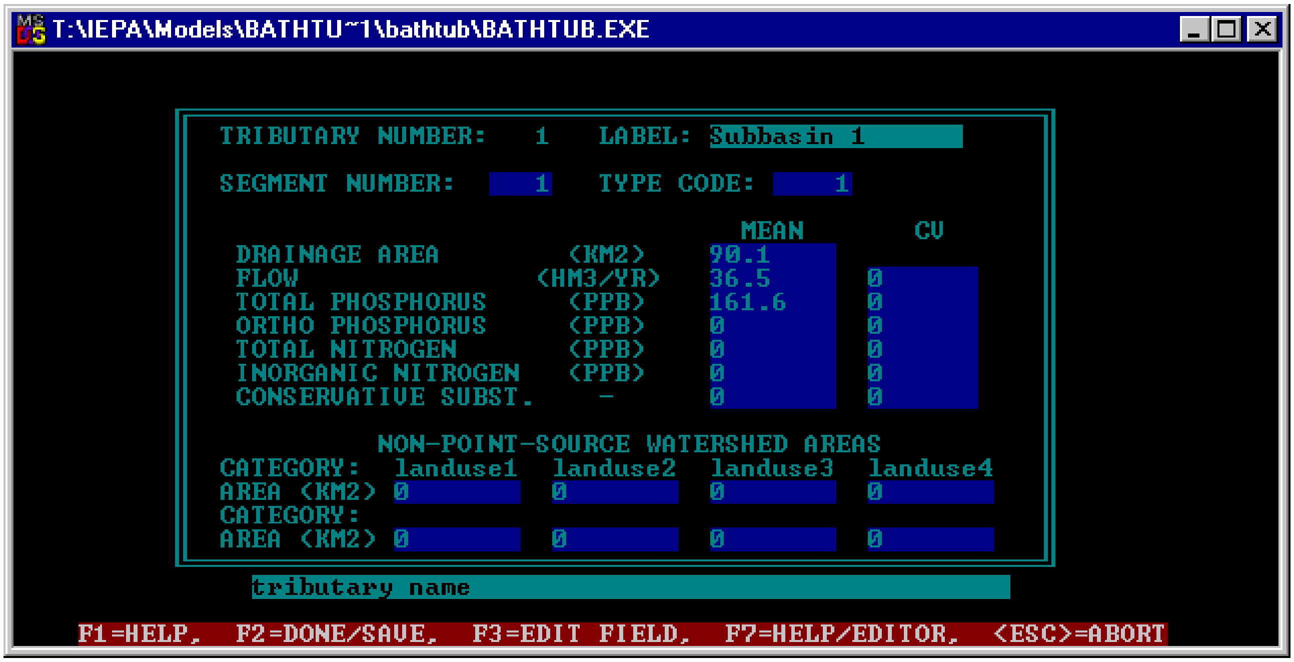


```
SEGMENT:    4 NAME: Near Dam         OUTFLOW SEG:   0 GROUP:   1
AREA (KM2):5.497     MEAN DEPTH (M):17.65    LENGTH (KM):6.94

 VARIABLE              UNITS       MEAN      CV       CALIBRATION
 MIXED LAYER DEPTH      (M)      5.79      0            FACTORS
 HYPOLIMNETIC DEPTH     (M)      0         0
 DISPERSION FACTOR       -                          1         0
 OBSERVED WATER QUALITY...
 NON-ALGAL TURBIDITY (1/M)       0         0
 TOTAL PHOSPHORUS      (PPB)     42.5      1.093    2         0
 TOTAL NITROGEN        (PPB)     0         0        1         0
 CHLOROPHYLL-A         (PPB)     13.208    .395     1.2       0
 SECCHI DEPTH           (M)      1.3       .296     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
```



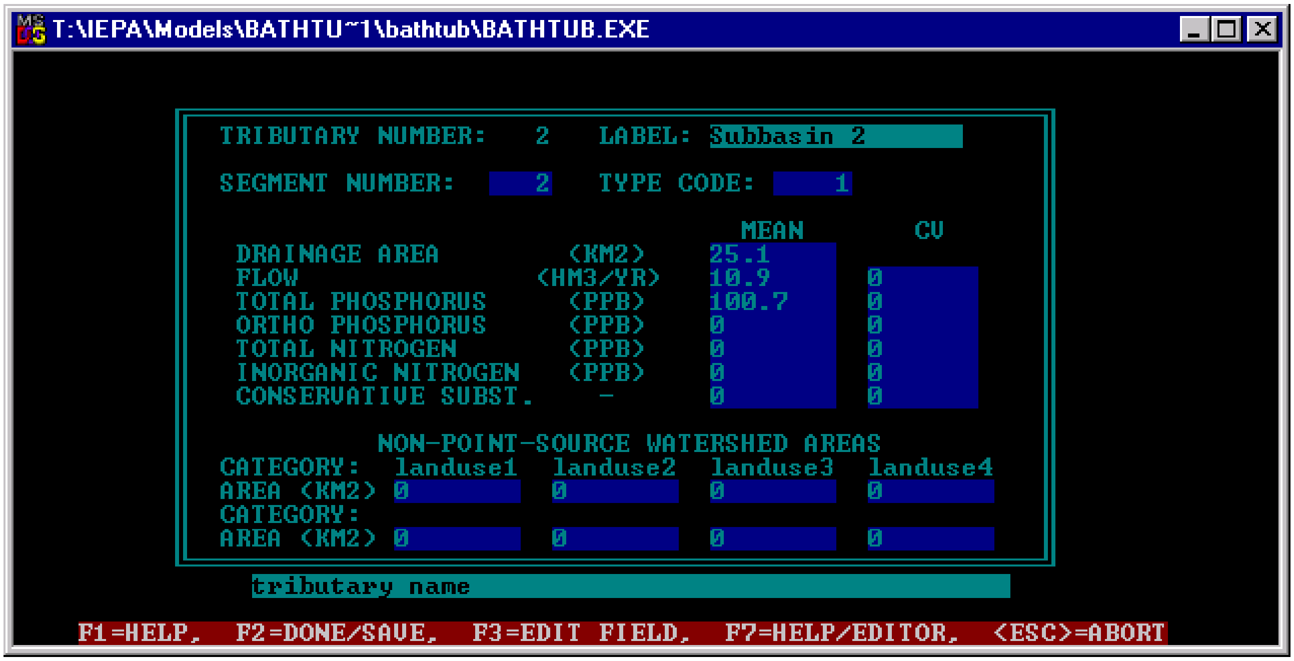
```
TRIBUTARY NUMBER:    1    LABEL: Subbasin 1

SEGMENT NUMBER:      1    TYPE CODE:     1

                                    MEAN       CV
 DRAINAGE AREA          (KM2)     90.1
 FLOW                 (HM3/YR)    36.5       0
 TOTAL PHOSPHORUS       (PPB)     161.6      0
 ORTHO PHOSPHORUS       (PPB)     0          0
 TOTAL NITROGEN         (PPB)     0          0
 INORGANIC NITROGEN     (PPB)     0          0
 CONSERVATIVE SUBST.      -       0          0

         NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:   landuse1   landuse2   landuse3   landuse4
AREA (KM2)  0          0          0          0
CATEGORY:
AREA (KM2)  0          0          0          0

    tributary name
```



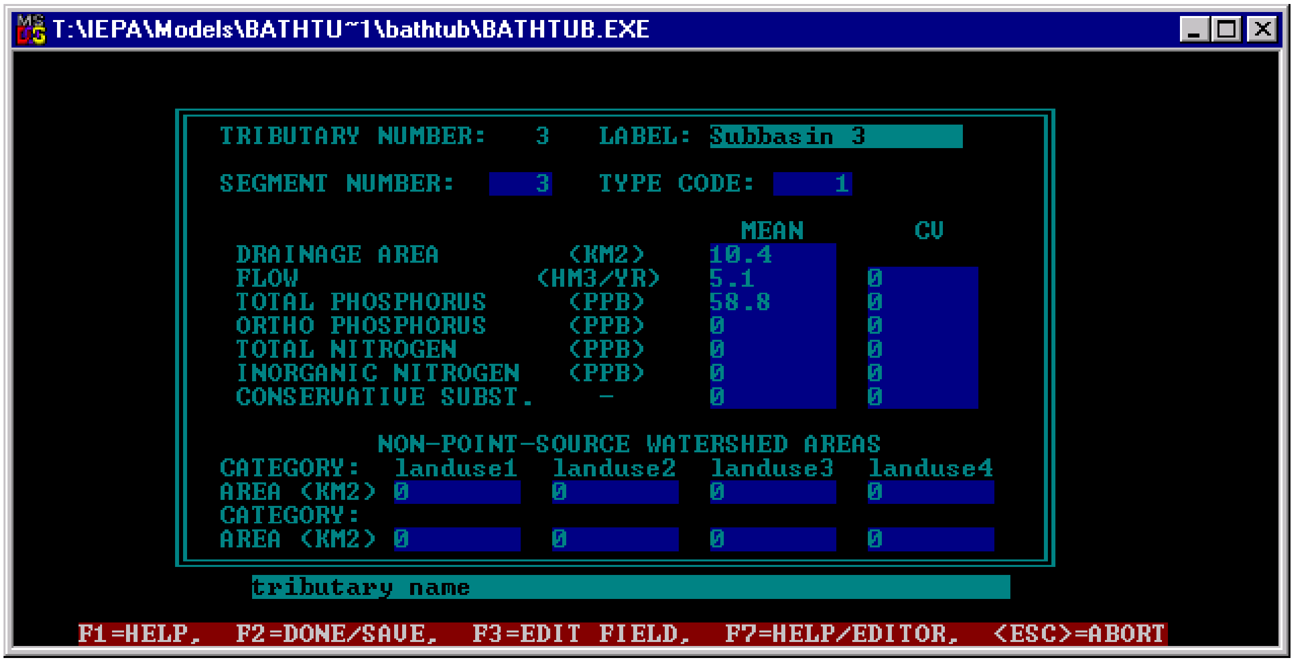
```
TRIBUTARY NUMBER:    2    LABEL: Subbasin 2

SEGMENT NUMBER:      2    TYPE CODE:     1

                                    MEAN       CV
 DRAINAGE AREA          (KM2)     25.1
 FLOW                 (HM3/YR)    10.9       0
 TOTAL PHOSPHORUS       (PPB)     100.7      0
 ORTHO PHOSPHORUS       (PPB)     0          0
 TOTAL NITROGEN         (PPB)     0          0
 INORGANIC NITROGEN     (PPB)     0          0
 CONSERVATIVE SUBST.      -       0          0

         NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:   landuse1   landuse2   landuse3   landuse4
AREA (KM2)  0          0          0          0
CATEGORY:
AREA (KM2)  0          0          0          0

    tributary name
```



```
 TRIBUTARY NUMBER:    3    LABEL: Subbasin 3

 SEGMENT NUMBER:      3    TYPE CODE:     1

                                       MEAN        CV
  DRAINAGE AREA          (KM2)      10.4
  FLOW                 (HM3/YR)     5.1         0
  TOTAL PHOSPHORUS       (PPB)      58.8        0
  ORTHO PHOSPHORUS       (PPB)      0           0
  TOTAL NITROGEN         (PPB)      0           0
  INORGANIC NITROGEN     (PPB)      0           0
  CONSERVATIVE SUBST.      -        0           0

           NON-POINT-SOURCE WATERSHED AREAS
 CATEGORY:  landuse1   landuse2   landuse3   landuse4
 AREA (KM2) 0          0          0          0
 CATEGORY:
 AREA (KM2) 0          0          0          0

   tributary name

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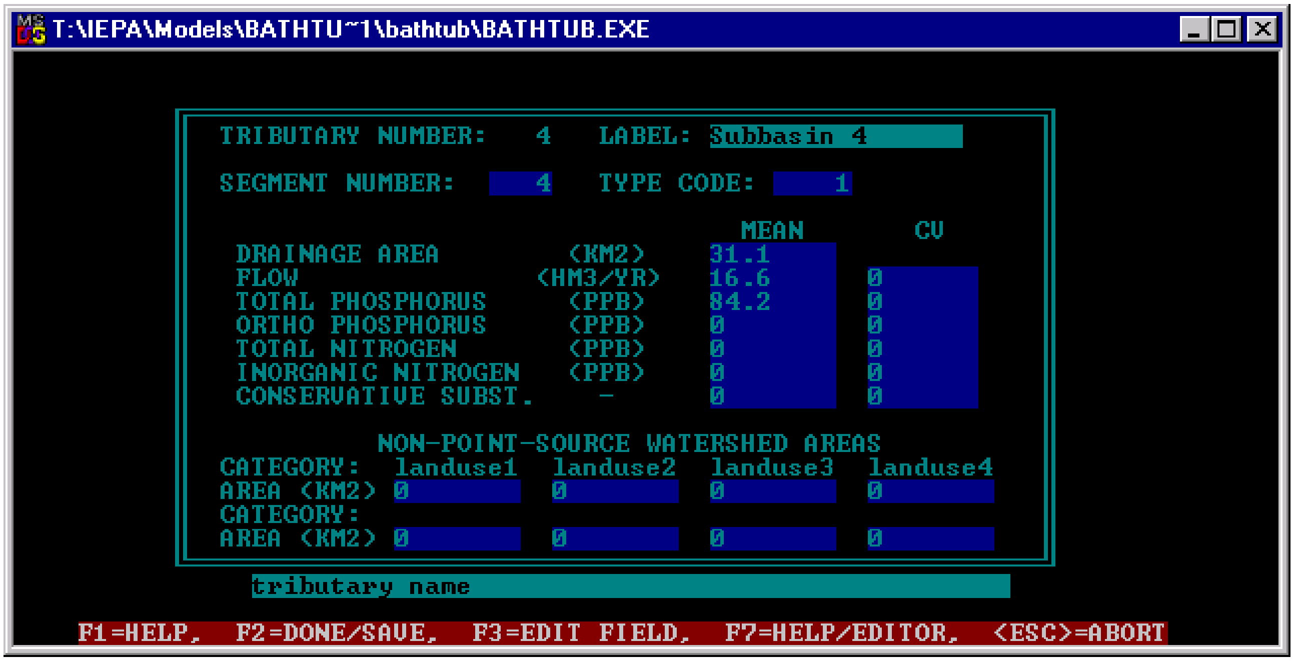


```
 TRIBUTARY NUMBER:    4    LABEL: Subbasin 4

 SEGMENT NUMBER:      4    TYPE CODE:     1

                                       MEAN        CV
  DRAINAGE AREA          (KM2)      31.1
  FLOW                 (HM3/YR)     16.6        0
  TOTAL PHOSPHORUS       (PPB)      84.2        0
  ORTHO PHOSPHORUS       (PPB)      0           0
  TOTAL NITROGEN         (PPB)      0           0
  INORGANIC NITROGEN     (PPB)      0           0
  CONSERVATIVE SUBST.      -        0           0

           NON-POINT-SOURCE WATERSHED AREAS
 CATEGORY:  landuse1   landuse2   landuse3   landuse4
 AREA (KM2) 0          0          0          0
 CATEGORY:
 AREA (KM2) 0          0          0          0

   tributary name

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

BATHTUB Model Output for 1997 Simulation

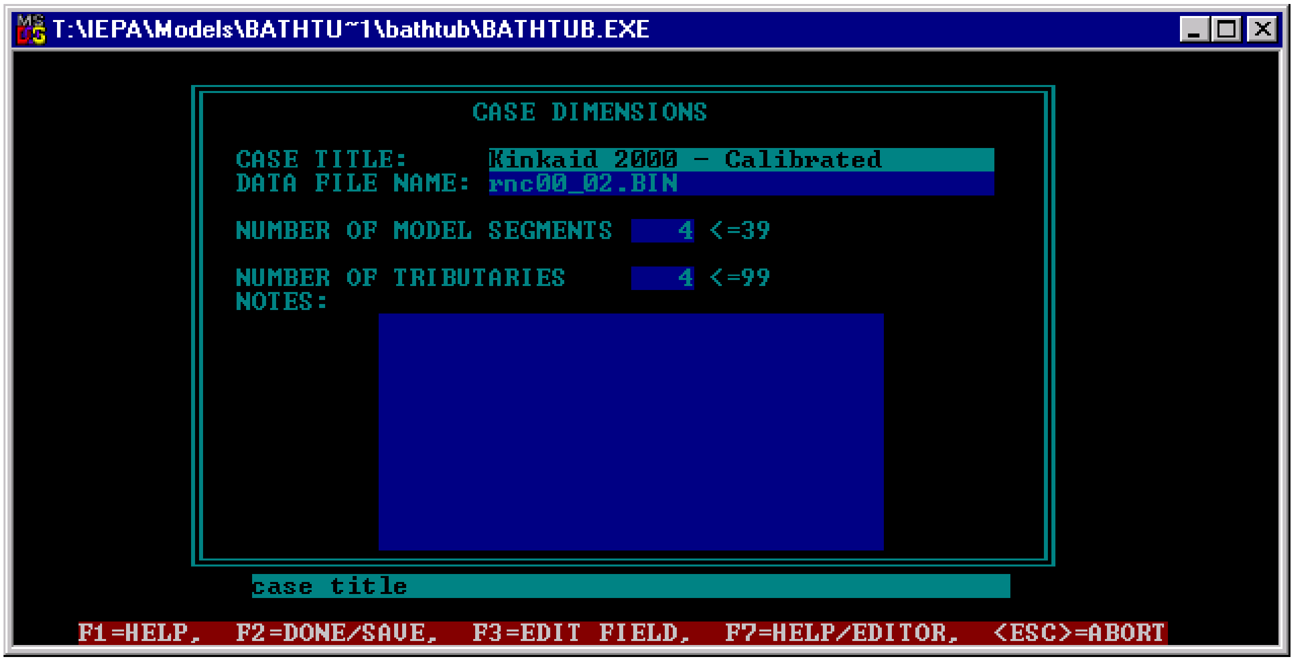
```
CASE: Kinkaid 1997 - Calibrated
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3   129.6   .56   133.1   .45     .97   -.05   -.10   -.04
 CHL-A      MG/M3    48.9   .57    45.6   .46    1.07    .12    .20    .10
 SECCHI         M      .3   .34      .3   .32     .98   -.07   -.09   -.05
 ORGANIC N  MG/M3      .0   .00  1364.9   .32     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00   130.1   .25     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    44.6   .23    43.0   .45    1.04    .16    .14    .07
 CHL-A      MG/M3    27.5   .38    27.5   .50    1.00    .00    .00    .00
 SECCHI         M      .9   .26      .9   .35    1.00    .00    .00    .00
 ORGANIC N  MG/M3      .0   .00   814.6   .39     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    54.7   .42     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    27.2   .26    25.6   .45    1.06    .23    .22    .11
 CHL-A      MG/M3    19.4   .45    15.9   .54    1.22    .45    .58    .29
 SECCHI         M     1.1   .26     1.3   .38     .90   -.41   -.38   -.23
 ORGANIC N  MG/M3      .0   .00   548.0   .36     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    33.3   .43     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    42.5  1.09    37.0   .45    1.15    .13    .52    .12
 CHL-A      MG/M3    13.2   .40    12.9   .47    1.03    .06    .07    .04
 SECCHI         M     1.3   .30     1.3   .33     .99   -.04   -.04   -.02
 ORGANIC N  MG/M3      .0   .00   483.8   .30     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    29.2   .37     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    48.3   .75    44.9   .45    1.08    .10    .27    .08
 CHL-A      MG/M3    19.9   .44    18.9   .43    1.05    .12    .15    .09
 SECCHI         M     1.1   .29     1.1   .29     .98   -.09   -.09   -.06
 ORGANIC N  MG/M3      .0   .00   632.2   .31     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    43.5   .35     .00    .00    .00    .00
```

```
CASE: Kinkaid 1997 - Calibrated
 GROSS WATER BALANCE:
                       DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
 ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
 ----------------------------------------------------------------------------
  1  1 Subbasin 1             90.100       36.500  .000E+00  .000        .405
  2  1 Subbasin 2             25.100       10.900  .000E+00  .000        .434
  3  1 Subbasin 3             10.400        5.100  .000E+00  .000        .490
  4  1 Subbasin 4             31.100       16.600  .000E+00  .000        .534
 ----------------------------------------------------------------------------
 PRECIPITATION                 9.509       11.886  .565E+01  .200       1.250
 TRIBUTARY INFLOW            156.700       69.100  .000E+00  .000        .441
 ***TOTAL INFLOW             166.209       80.986  .565E+01  .029        .487
 ADVECTIVE OUTFLOW           166.209       72.980  .114E+02  .046        .439
 ***TOTAL OUTFLOW            166.209       72.980  .114E+02  .046        .439
 ***EVAPORATION                 .000        8.007  .577E+01  .300        .000
 ----------------------------------------------------------------------------

 GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
 COMPONENT: TOTAL P
                       ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
 ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
 -------------------------------------------------------------------------------
  1 1 Subbasin 1            5898.4   65.7  .000E+00     .0  .000   161.6    65.5
  2 1 Subbasin 2            1097.6   12.2  .000E+00     .0  .000   100.7    43.7
  3 1 Subbasin 3             299.9    3.3  .000E+00     .0  .000    58.8    28.8
  4 1 Subbasin 4            1397.7   15.6  .000E+00     .0  .000    84.2    44.9
 -------------------------------------------------------------------------------
 PRECIPITATION               285.3    3.2  .203E+05  100.0  .500    24.0    30.0
 TRIBUTARY INFLOW           8693.6   96.8  .000E+00     .0  .000   125.8    55.5
 ***TOTAL INFLOW            8978.9  100.0  .203E+05  100.0  .016   110.9    54.0
 ADVECTIVE OUTFLOW          2697.3   30.0  .150E+07 7379.0  .454    37.0    16.2
 ***TOTAL OUTFLOW           2697.3   30.0  .150E+07 7379.0  .454    37.0    16.2
 ***RETENTION               6281.6   70.0  .151E+07 7412.4  .195      .0      .0
 -------------------------------------------------------------------------------

           HYDRAULIC    -------------- TOTAL P --------------
  OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
      RATE      TIME      CONC      TIME     RATIO      COEF
      M/YR       YRS     MG/M3       YRS        -         -
      7.67    1.8016      48.3     .7074    1.4135     .6996
```

BATHTUB Model Input Screens for 2000 Simulation



```
T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

                      CASE DIMENSIONS

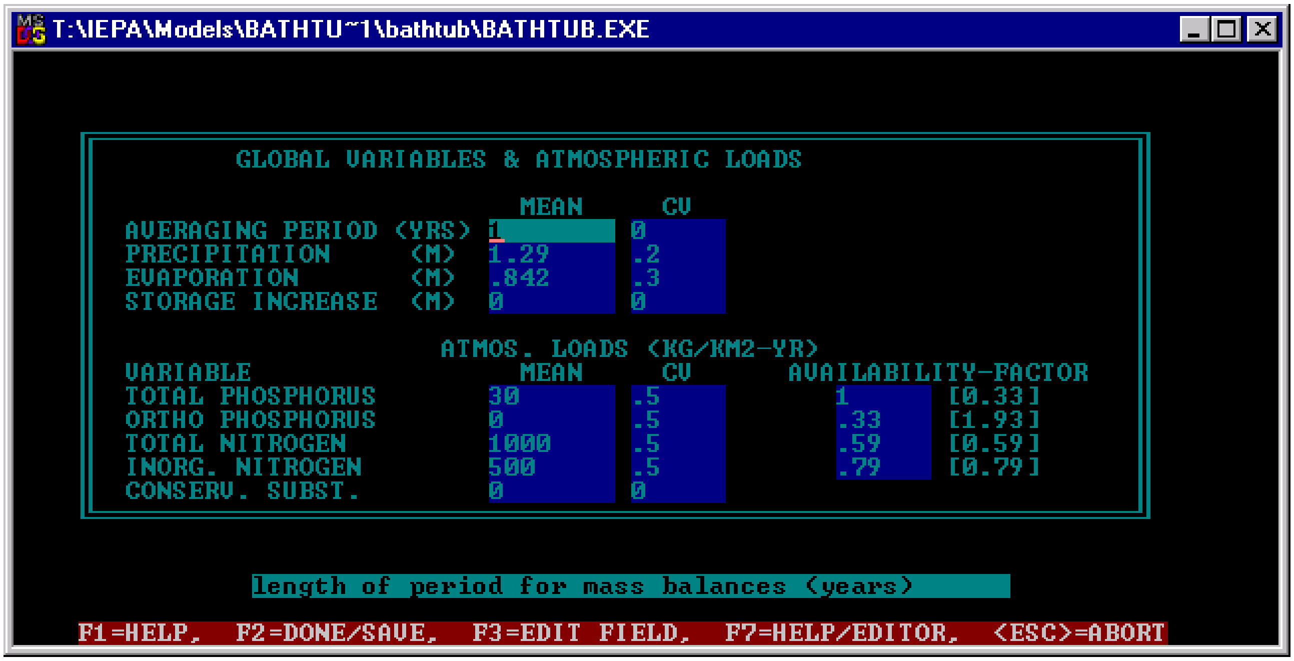
    CASE TITLE:          Kinkaid 2000 - Calibrated
    DATA FILE NAME:      rnc00_02.BIN

    NUMBER OF MODEL SEGMENTS       4 <=39

    NUMBER OF TRIBUTARIES          4 <=99
    NOTES:

       case title

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



```
T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

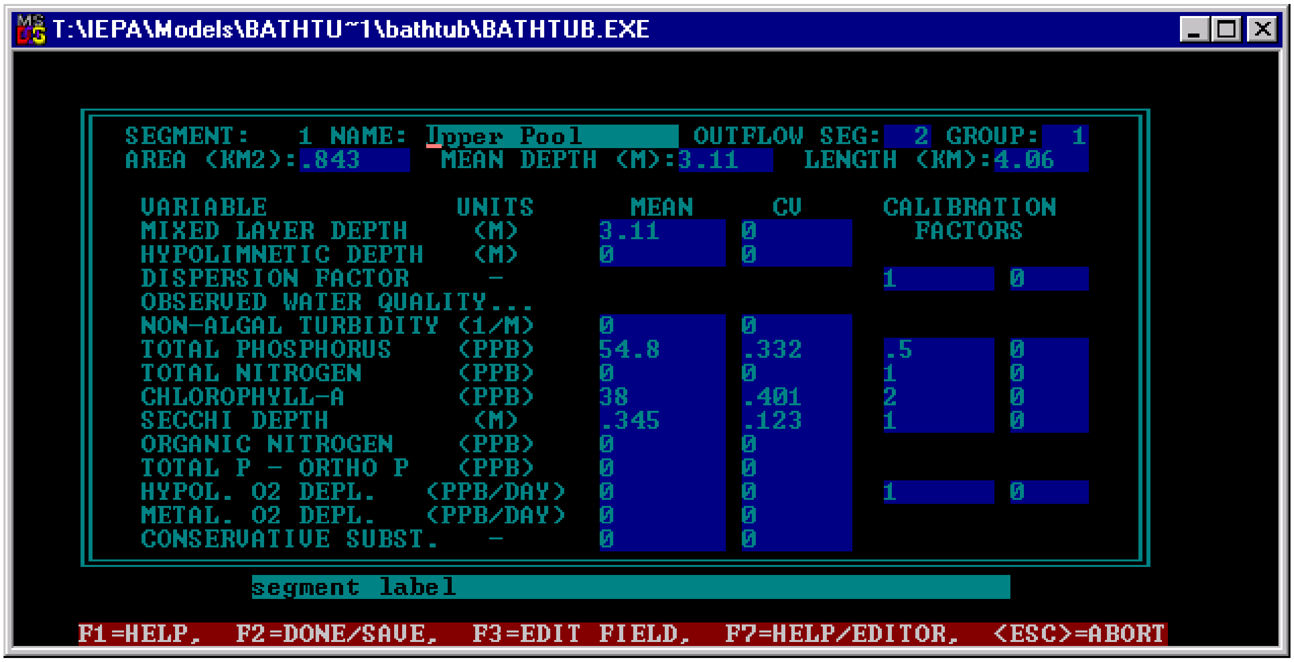
           GLOBAL VARIABLES & ATMOSPHERIC LOADS

                                 MEAN      CV
    AVERAGING PERIOD (YRS)   1         0
    PRECIPITATION      (M)   1.29      .2
    EVAPORATION        (M)   .842      .3
    STORAGE INCREASE   (M)   0         0

                        ATMOS. LOADS (KG/KM2-YR)
    VARIABLE                     MEAN      CV        AVAILABILITY-FACTOR
    TOTAL PHOSPHORUS         30        .5             1       [0.33]
    ORTHO PHOSPHORUS         0         .5             .33     [1.93]
    TOTAL NITROGEN           1000      .5             .59     [0.59]
    INORG. NITROGEN          500       .5             .79     [0.79]
    CONSERV. SUBST.          0         0

       length of period for mass balances (years)

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

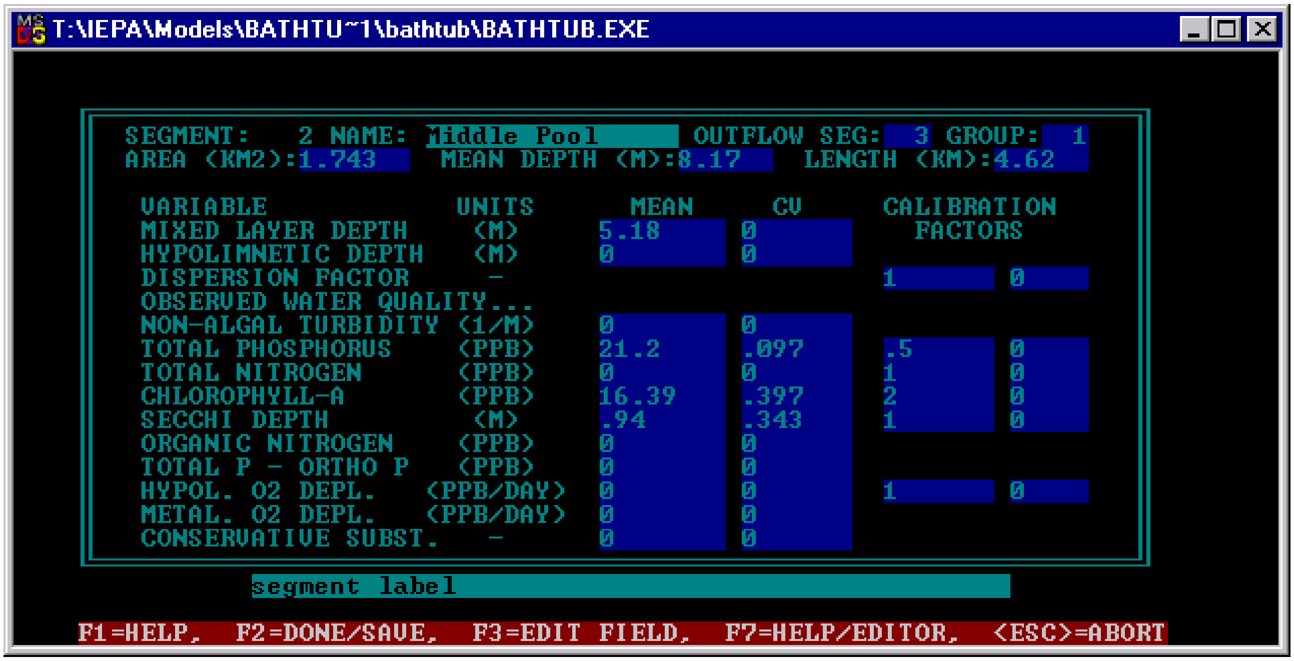


```
  SEGMENT:    1 NAME: Upper Pool        OUTFLOW SEG:  2 GROUP:  1
  AREA (KM2):.843      MEAN DEPTH (M):3.11      LENGTH (KM):4.06

   VARIABLE                UNITS       MEAN      CV        CALIBRATION
   MIXED LAYER DEPTH        (M)       3.11      0            FACTORS
   HYPOLIMNETIC DEPTH       (M)       0         0
   DISPERSION FACTOR         -                          1          0
   OBSERVED WATER QUALITY...
   NON-ALGAL TURBIDITY (1/M)          0         0
   TOTAL PHOSPHORUS        (PPB)      54.8      .332    .5         0
   TOTAL NITROGEN          (PPB)      0         0       1          0
   CHLOROPHYLL-A           (PPB)      38        .401    2          0
   SECCHI DEPTH             (M)       .345      .123    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
```

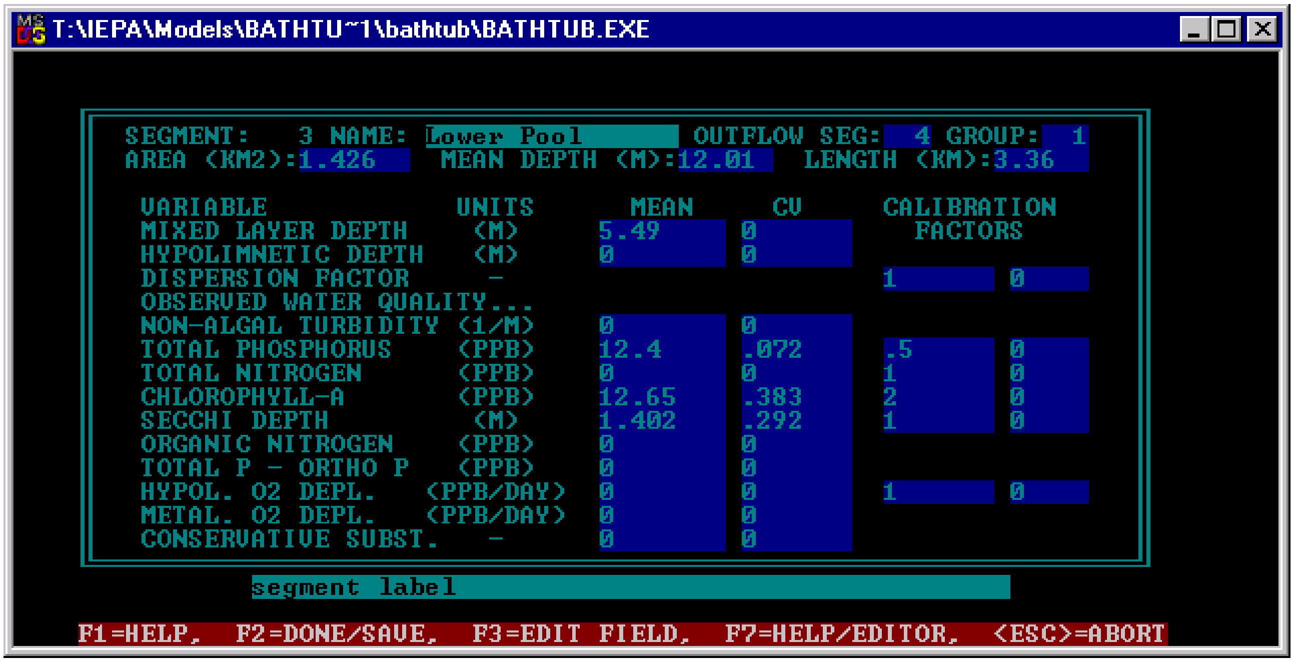


```
  SEGMENT:    2 NAME: Middle Pool       OUTFLOW SEG:  3 GROUP:  1
  AREA (KM2):1.743     MEAN DEPTH (M):8.17      LENGTH (KM):4.62

   VARIABLE                UNITS       MEAN      CV        CALIBRATION
   MIXED LAYER DEPTH        (M)       5.18      0            FACTORS
   HYPOLIMNETIC DEPTH       (M)       0         0
   DISPERSION FACTOR         -                          1          0
   OBSERVED WATER QUALITY...
   NON-ALGAL TURBIDITY (1/M)          0         0
   TOTAL PHOSPHORUS        (PPB)      21.2      .097    .5         0
   TOTAL NITROGEN          (PPB)      0         0       1          0
   CHLOROPHYLL-A           (PPB)      16.39     .397    2          0
   SECCHI DEPTH             (M)       .94       .343    1          0
   ORGANIC NITROGEN        (PPB)      0         0
   TOTAL P - ORTHO P       (PPB)      0         0
   HYPOL. O2 DEPL.       (PPB/DAY)    0         0       1          0
   METAL. O2 DEPL.       (PPB/DAY)    0         0
   CONSERVATIVE SUBST.       -        0         0

                 segment label

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



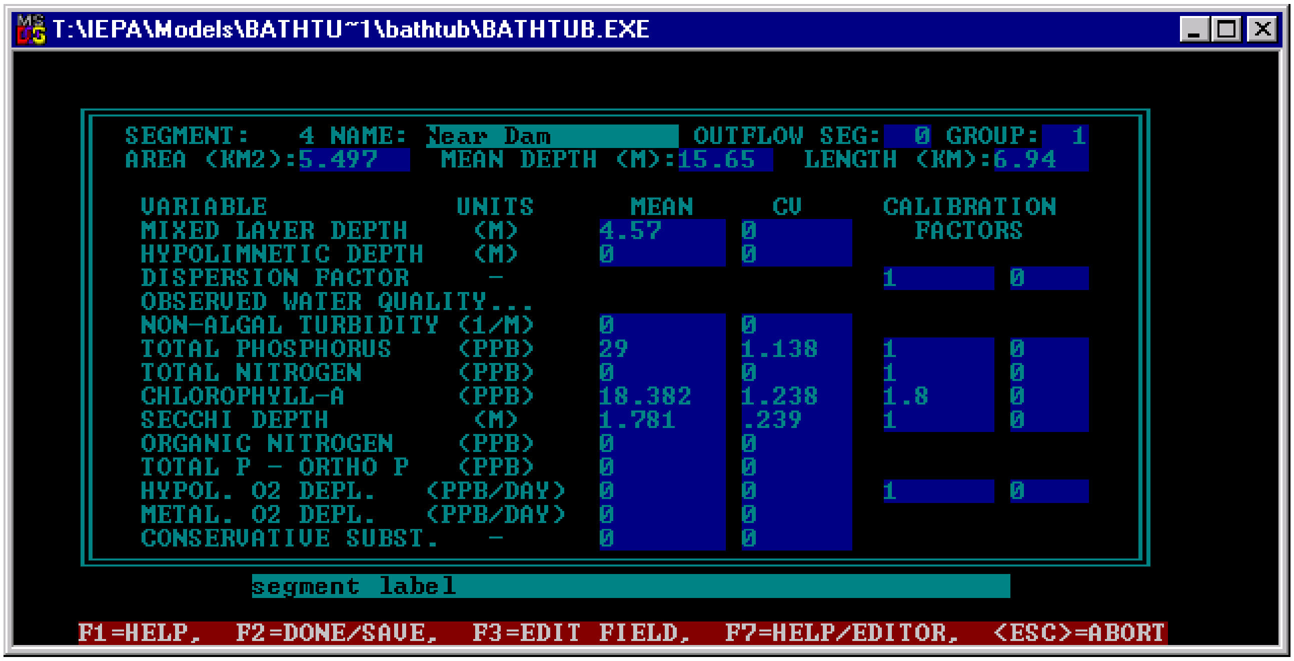
```
T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

  SEGMENT:    3 NAME: Lower Pool       OUTFLOW SEG:  4 GROUP:  1
  AREA (KM2):1.426     MEAN DEPTH (M):12.01    LENGTH (KM):3.36

   VARIABLE              UNITS       MEAN     CV      CALIBRATION
   MIXED LAYER DEPTH      (M)       5.49     0          FACTORS
   HYPOLIMNETIC DEPTH     (M)       0        0
   DISPERSION FACTOR       -                          1        0
   OBSERVED WATER QUALITY...
   NON-ALGAL TURBIDITY (1/M)        0        0
   TOTAL PHOSPHORUS      (PPB)      12.4     .072     .5       0
   TOTAL NITROGEN        (PPB)      0        0        1        0
   CHLOROPHYLL-A         (PPB)      12.65    .383     2        0
   SECCHI DEPTH           (M)       1.402    .292     1        0
   ORGANIC NITROGEN      (PPB)      0        0
   TOTAL P - ORTHO P     (PPB)      0        0
   HYPOL. O2 DEPL.     (PPB/DAY)    0        0        1        0
   METAL. O2 DEPL.     (PPB/DAY)    0        0
   CONSERVATIVE SUBST.     -        0        0

           segment label

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



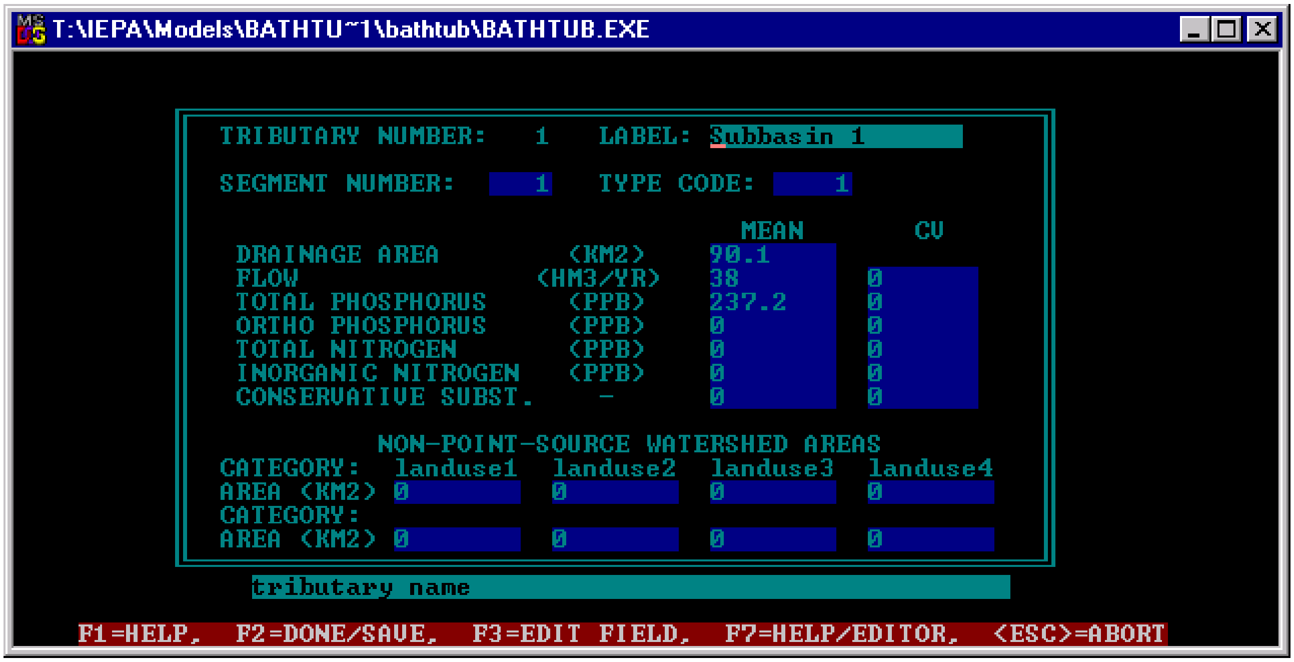
```
T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

  SEGMENT:    4 NAME: Near Dam         OUTFLOW SEG:  0 GROUP:  1
  AREA (KM2):5.497     MEAN DEPTH (M):15.65    LENGTH (KM):6.94

   VARIABLE              UNITS       MEAN     CV      CALIBRATION
   MIXED LAYER DEPTH      (M)       4.57     0          FACTORS
   HYPOLIMNETIC DEPTH     (M)       0        0
   DISPERSION FACTOR       -                          1        0
   OBSERVED WATER QUALITY...
   NON-ALGAL TURBIDITY (1/M)        0        0
   TOTAL PHOSPHORUS      (PPB)      29       1.138    1        0
   TOTAL NITROGEN        (PPB)      0        0        1        0
   CHLOROPHYLL-A         (PPB)      18.382   1.238    1.8      0
   SECCHI DEPTH           (M)       1.781    .239     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
```

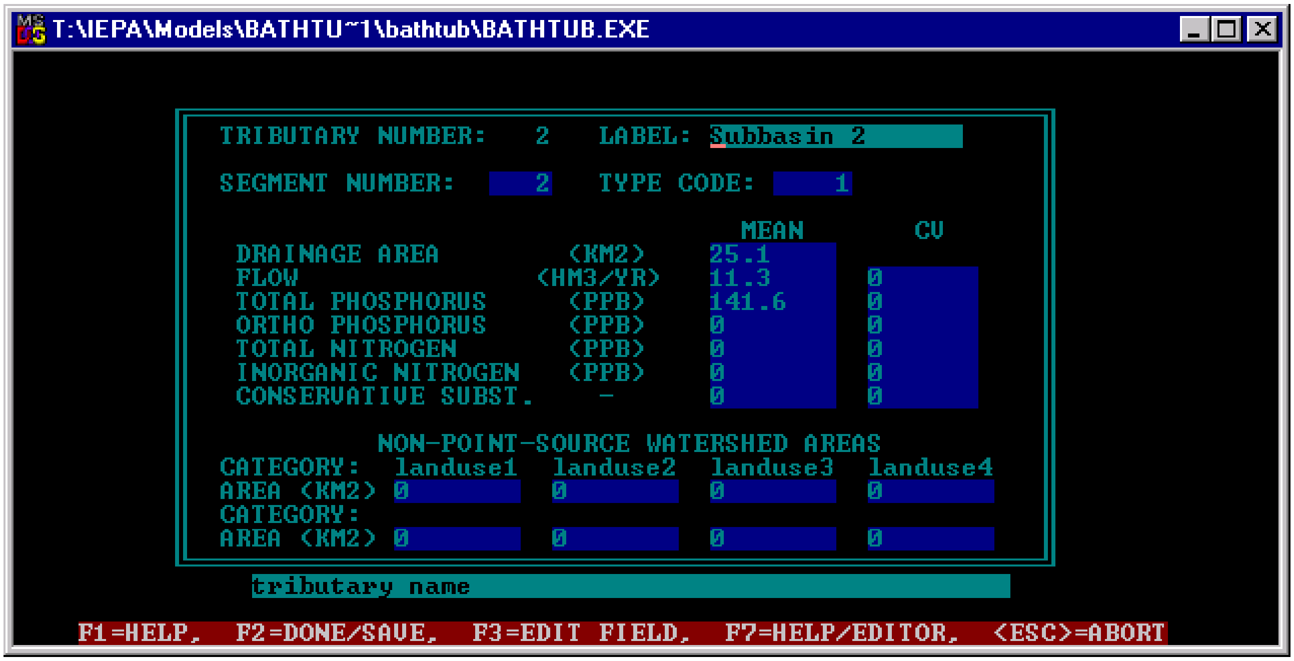


```
TRIBUTARY NUMBER:    1    LABEL: Subbasin 1

SEGMENT NUMBER:       1    TYPE CODE:     1

                                    MEAN       CV
 DRAINAGE AREA         (KM2)      90.1
 FLOW                (HM3/YR)     38         0
 TOTAL PHOSPHORUS      (PPB)      237.2      0
 ORTHO PHOSPHORUS      (PPB)      0          0
 TOTAL NITROGEN        (PPB)      0          0
 INORGANIC NITROGEN    (PPB)      0          0
 CONSERVATIVE SUBST.     -        0          0

         NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0
    tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT
```

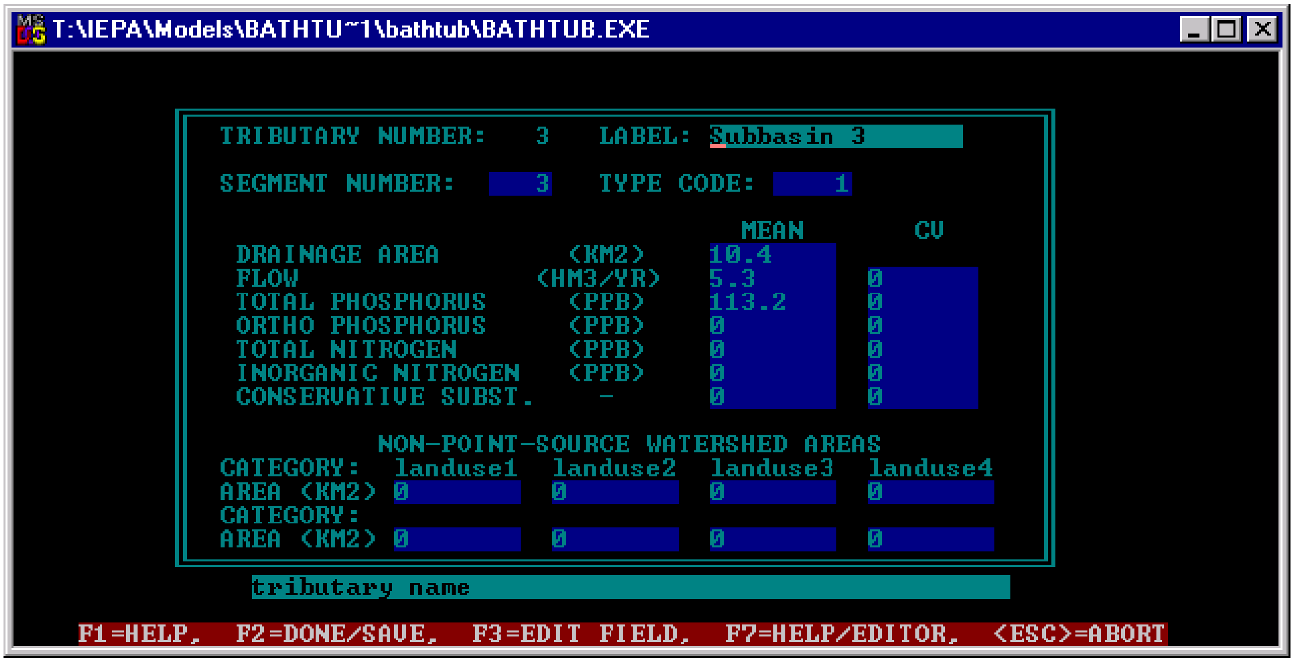


```
TRIBUTARY NUMBER:    2    LABEL: Subbasin 2

SEGMENT NUMBER:       2    TYPE CODE:     1

                                    MEAN       CV
 DRAINAGE AREA         (KM2)      25.1
 FLOW                (HM3/YR)     11.3       0
 TOTAL PHOSPHORUS      (PPB)      141.6      0
 ORTHO PHOSPHORUS      (PPB)      0          0
 TOTAL NITROGEN        (PPB)      0          0
 INORGANIC NITROGEN    (PPB)      0          0
 CONSERVATIVE SUBST.     -        0          0

         NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0
    tributary name
F1=HELP, F2=DONE/SAVE, F3=EDIT FIELD, F7=HELP/EDITOR, <ESC>=ABORT
```



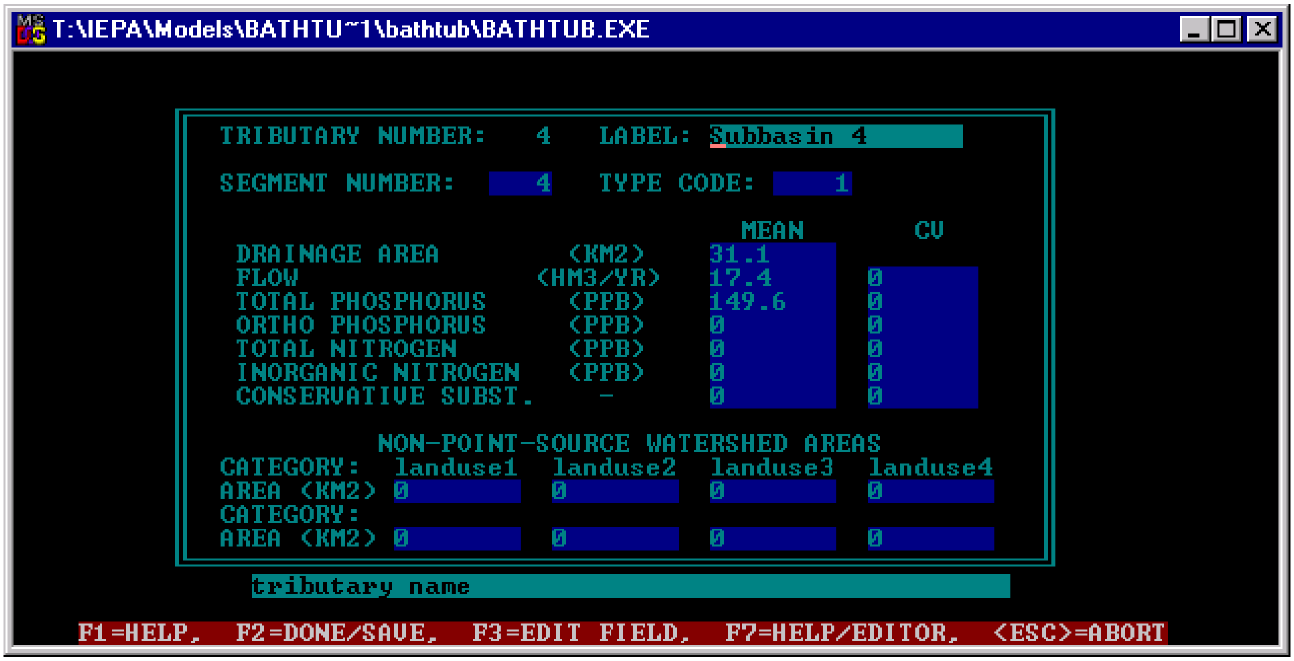
```
T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

TRIBUTARY NUMBER:   3   LABEL: Subbasin 3

SEGMENT NUMBER:    3    TYPE CODE:    1

                                   MEAN       CV
 DRAINAGE AREA          (KM2)     10.4
 FLOW                 (HM3/YR)    5.3        0
 TOTAL PHOSPHORUS       (PPB)     113.2      0
 ORTHO PHOSPHORUS       (PPB)     0          0
 TOTAL NITROGEN         (PPB)     0          0
 INORGANIC NITROGEN     (PPB)     0          0
 CONSERVATIVE SUBST.     -        0          0

         NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0
    tributary name
F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```



```
T:\IEPA\Models\BATHTU~1\bathtub\BATHTUB.EXE

TRIBUTARY NUMBER:   4   LABEL: Subbasin 4

SEGMENT NUMBER:    4    TYPE CODE:    1

                                   MEAN       CV
 DRAINAGE AREA          (KM2)     31.1
 FLOW                 (HM3/YR)    17.4       0
 TOTAL PHOSPHORUS       (PPB)     149.6      0
 ORTHO PHOSPHORUS       (PPB)     0          0
 TOTAL NITROGEN         (PPB)     0          0
 INORGANIC NITROGEN     (PPB)     0          0
 CONSERVATIVE SUBST.     -        0          0

         NON-POINT-SOURCE WATERSHED AREAS
CATEGORY:  landuse1  landuse2  landuse3  landuse4
AREA (KM2) 0         0         0         0
CATEGORY:
AREA (KM2) 0         0         0         0
    tributary name
F1=HELP,  F2=DONE/SAVE,  F3=EDIT FIELD,  F7=HELP/EDITOR,  <ESC>=ABORT
```

BATHTUB Model Output for 2000 Simulation

```
CASE: Kinkaid 2000 - Calibrated
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    54.8   .33    72.2   .45     .76   -.83  -1.03   -.49
 CHL-A      MG/M3    38.0   .40    32.0   .42    1.19    .43    .50    .30
 SECCHI         M      .3   .12      .4   .21     .95   -.43   -.19   -.22
 ORGANIC N  MG/M3      .0   .00  1032.9   .31     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    99.0   .27     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    21.2   .10    32.6   .45     .65  -4.43  -1.60   -.93
 CHL-A      MG/M3    16.4   .40    18.3   .52     .90   -.27   -.31   -.17
 SECCHI         M      .9   .34      .9   .33    1.04    .13    .15    .09
 ORGANIC N  MG/M3      .0   .00   623.0   .35     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    43.9   .38     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    12.4   .07    19.4   .45     .64  -6.21  -1.66   -.98
 CHL-A      MG/M3    12.6   .38    12.7   .56     .99   -.02   -.02   -.01
 SECCHI         M     1.4   .29     1.4   .36    1.00    .01    .01    .01
 ORGANIC N  MG/M3      .0   .00   477.6   .35     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    28.0   .46     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    29.0  1.14    24.3   .45    1.20    .16    .66    .15
 CHL-A      MG/M3    18.4  1.24    19.7   .70     .93   -.06   -.20   -.05
 SECCHI         M     1.8   .24     1.7   .73    1.06    .24    .20    .07
 ORGANIC N  MG/M3      .0   .00   614.0   .49     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    33.4   .58     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    27.4   .77    29.3   .45     .93   -.09   -.25   -.08
 CHL-A      MG/M3    18.9   .87    19.5   .57     .97   -.04   -.09   -.03
 SECCHI         M     1.4   .26     1.4   .56    1.05    .18    .16    .07
 ORGANIC N  MG/M3      .0   .00   632.3   .40     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    40.3   .45     .00    .00    .00    .00
```

```
CASE: Kinkaid 2000 - Calibrated
 GROSS WATER BALANCE:
                       DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
 ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
 ----------------------------------------------------------------------------
  1  1 Subbasin 1             90.100       38.000  .000E+00  .000        .422
  2  1 Subbasin 2             25.100       11.300  .000E+00  .000        .450
  3  1 Subbasin 3             10.400        5.300  .000E+00  .000        .510
  4  1 Subbasin 4             31.100       17.400  .000E+00  .000        .559
 ----------------------------------------------------------------------------
 PRECIPITATION                 9.509       12.267  .602E+01  .200       1.290
 TRIBUTARY INFLOW            156.700       72.000  .000E+00  .000        .459
 ***TOTAL INFLOW             166.209       84.267  .602E+01  .029        .507
 ADVECTIVE OUTFLOW           166.209       76.260  .118E+02  .045        .459
 ***TOTAL OUTFLOW            166.209       76.260  .118E+02  .045        .459
 ***EVAPORATION                 .000        8.007  .577E+01  .300        .000
 ----------------------------------------------------------------------------

 GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
 COMPONENT: TOTAL P
                       ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
 ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
 -------------------------------------------------------------------------------
  1 1 Subbasin 1            9013.6   63.9  .000E+00     .0  .000   237.2   100.0
  2 1 Subbasin 2            1600.1   11.3  .000E+00     .0  .000   141.6    63.7
  3 1 Subbasin 3             600.0    4.3  .000E+00     .0  .000   113.2    57.7
  4 1 Subbasin 4            2603.0   18.5  .000E+00     .0  .000   149.6    83.7
 -------------------------------------------------------------------------------
 PRECIPITATION               285.3    2.0  .203E+05  100.0  .500    23.3    30.0
 TRIBUTARY INFLOW          13816.7   98.0  .000E+00     .0  .000   191.9    88.2
 ***TOTAL INFLOW           14101.9  100.0  .203E+05  100.0  .010   167.3    84.8
 ADVECTIVE OUTFLOW          1850.4   13.1  .702E+06 3452.5  .453    24.3    11.1
 ***TOTAL OUTFLOW           1850.4   13.1  .702E+06 3452.5  .453    24.3    11.1
 ***RETENTION              12251.5   86.9  .717E+06 3523.1  .069      .0      .0
 -------------------------------------------------------------------------------

           HYDRAULIC    -------------- TOTAL P  --------------
  OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
      RATE      TIME      CONC      TIME     RATIO      COEF
      M/YR       YRS     MG/M3       YRS         -         -
      8.02    1.5738      27.4     .2329    4.2933     .8688
```

Appendix D
GWLF Manual

G W L F

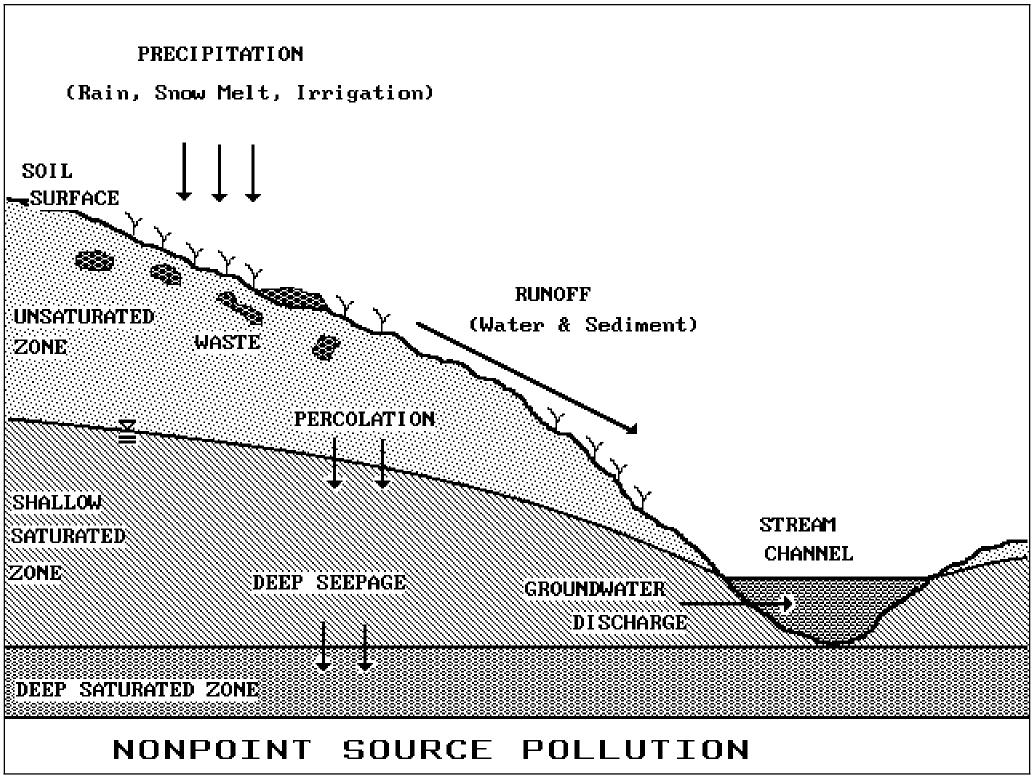
GENERALIZED WATERSHED LOADING FUNCTIONS

VERSION 2.0

USER'S MANUAL

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

Douglas A. Haith, Ross Mandel & Ray Shyan Wu



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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**, underline and *italic*, respectively.

MODEL DESCRIPTION

Model Structure

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

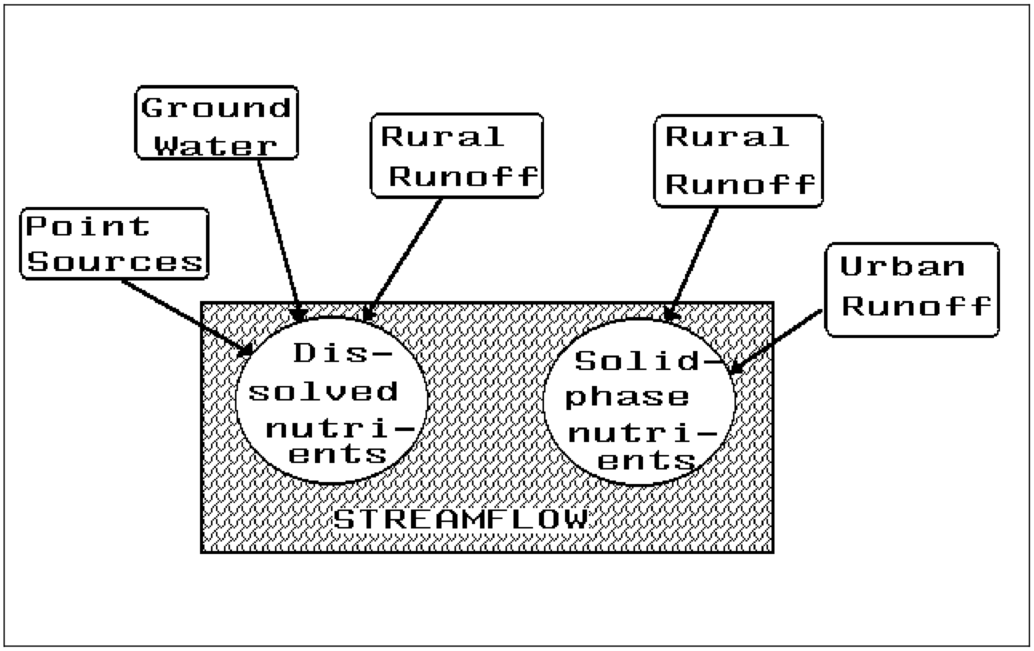


Figure 1. Nutrient Sources in GWLF.

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

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

Input Data

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

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

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

Model Output

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

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

The program also provides

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

GWLF PROGRAM

Required Files

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

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

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

Program Structure

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

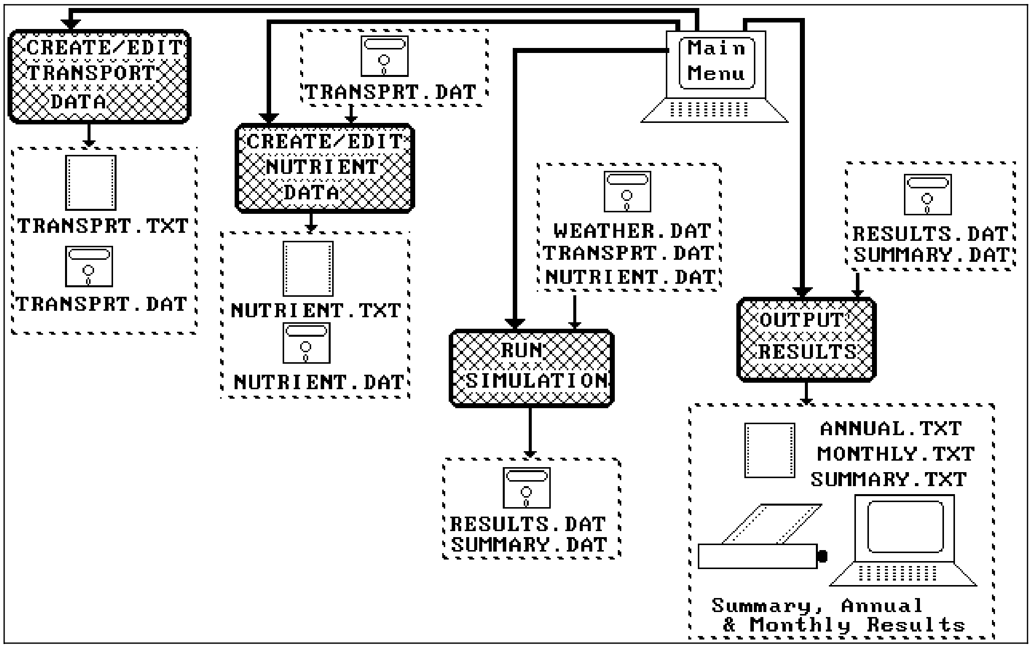
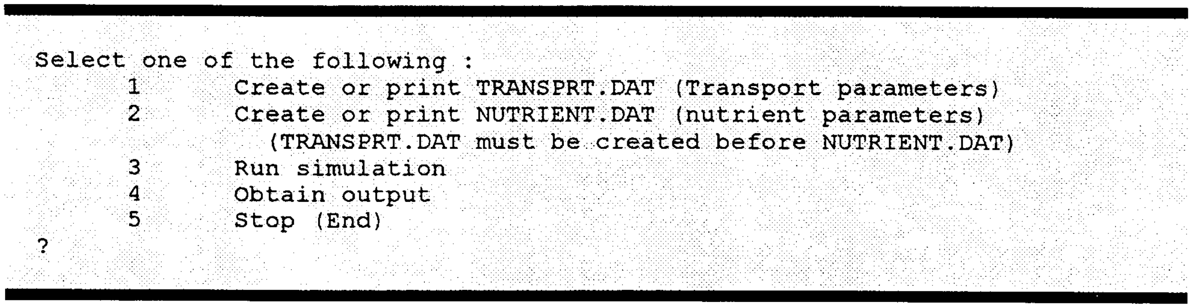


Figure 2. Structure of the GWLF Program.

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



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

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

Transport Data Manipulation

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

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

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

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

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

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

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

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

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

Nutrient Data Manipulation

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

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

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

Simulation

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

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

DISPLAY 4. The Menu Page for Simulation Options.

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

Results Output

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

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

DISPLAY 5. The Menu Page for Output Generation.

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

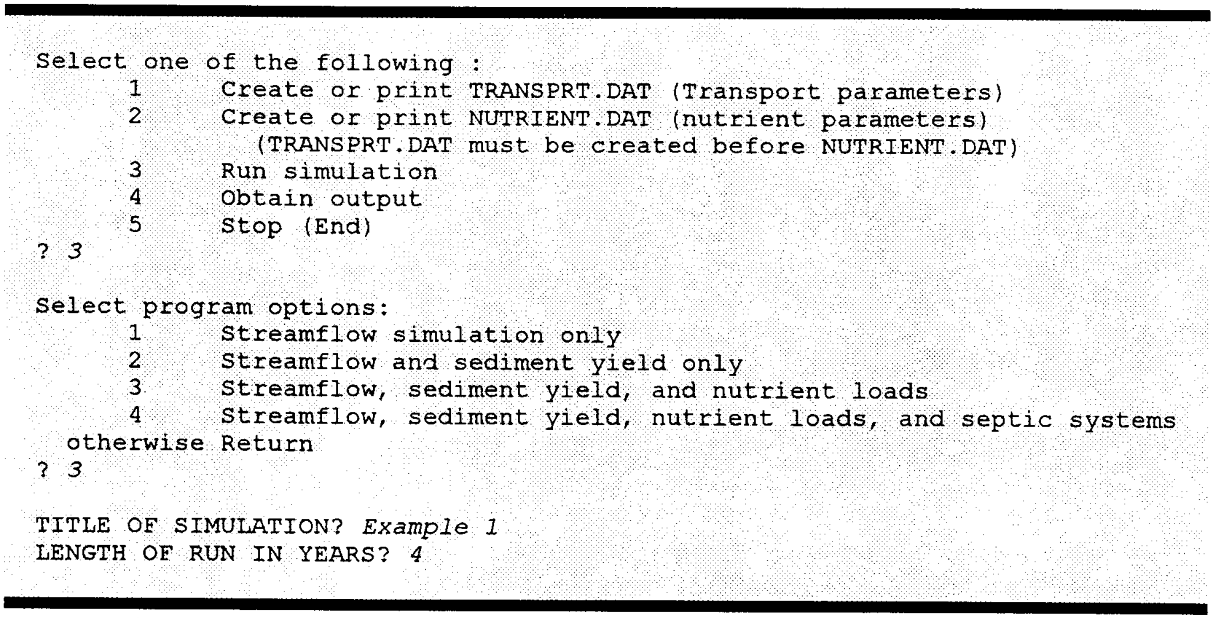
This example is designed to allow the user to become familiar with the operation of the program and the way results are presented. The data set and results are those described in Appendix C for the GWLF validation for the West Branch Delaware River Watershed in New York.

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

Simulation

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

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



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

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

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

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

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

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

Results Generation

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

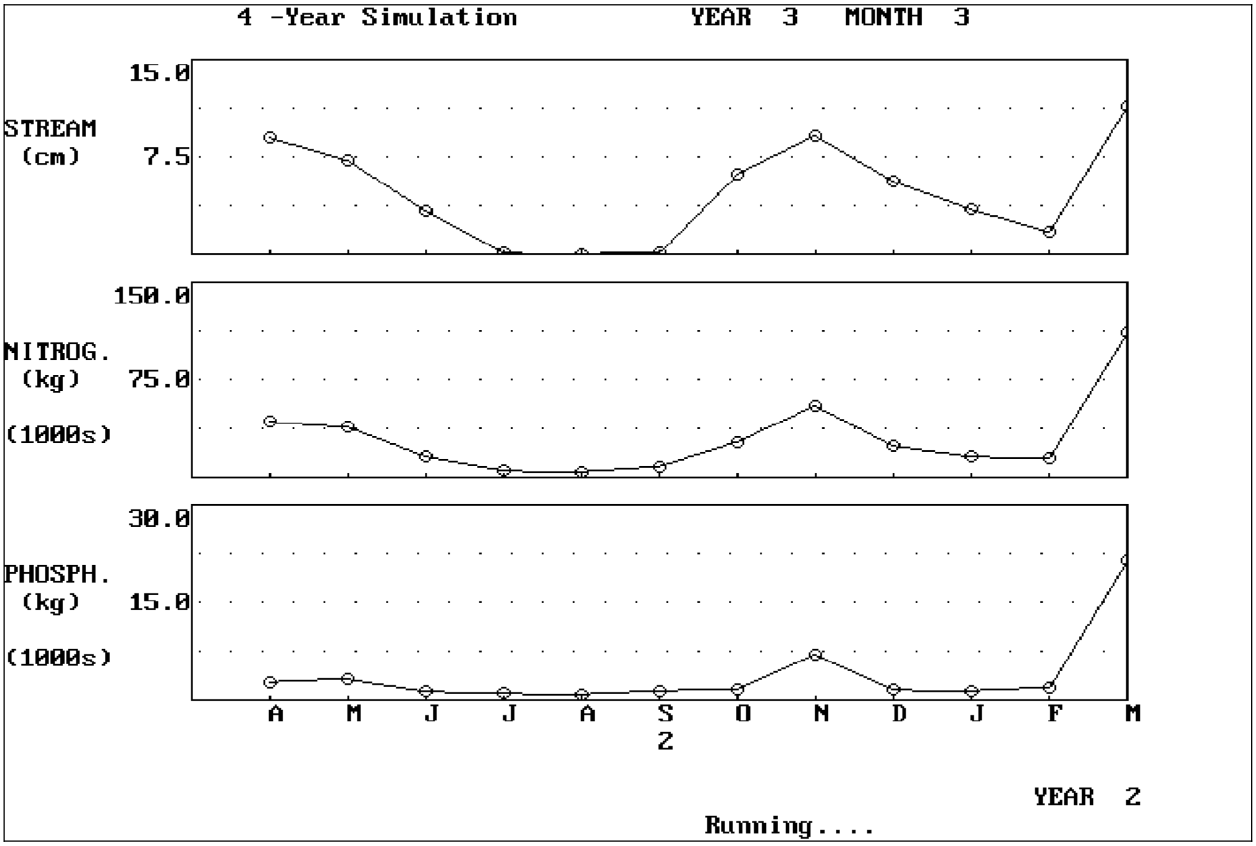


Figure 3. Screen Display during Simulation.

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

EXAMPLE 2: EFFECTS OF ELIMINATION OF WINTER MANURE SPREADING

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

Nutrient Parameters Modification

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

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

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

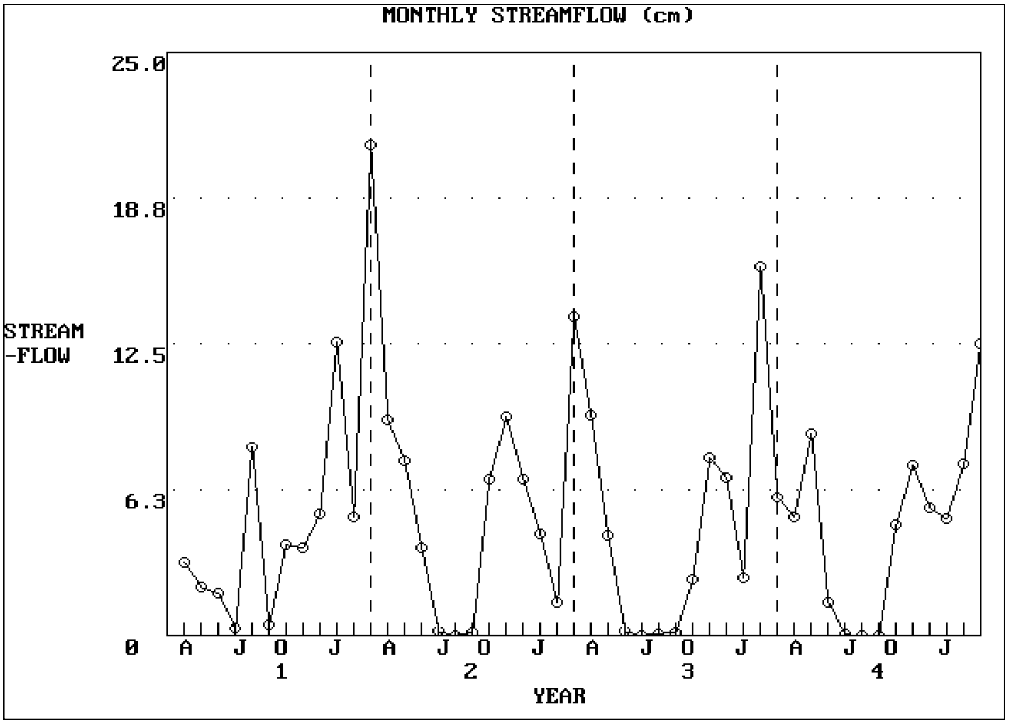


Figure 4. Monthly Streamflows for Example 1.

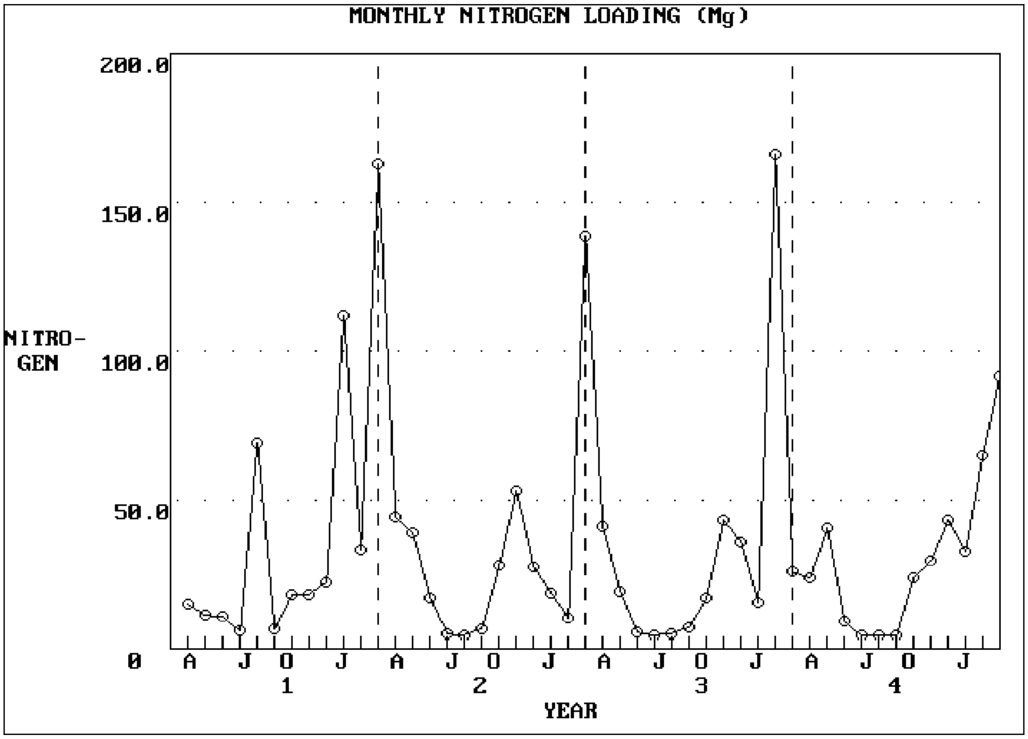


Figure 5. Monthly Nitrogen Loads for Example 1.

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

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

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

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

DISPLAY 7. Result Generating Menu in Example 1.

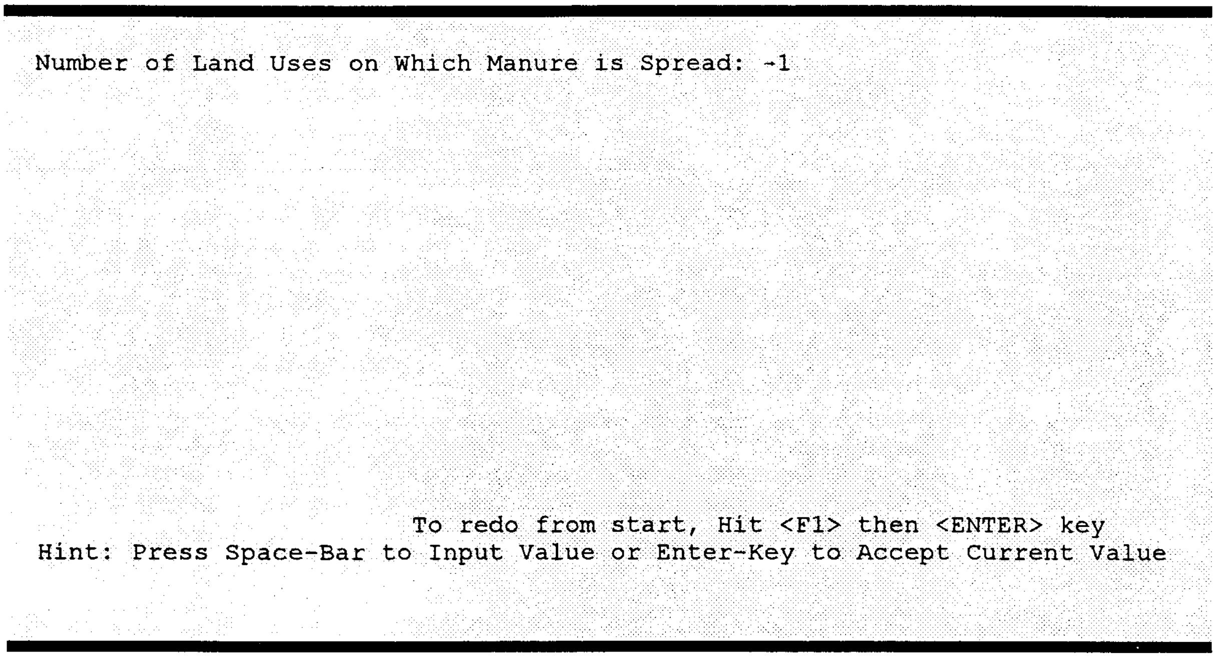
```
Select one of the following :
      1      Create or print TRANSPRT.DAT (Transport parameters)
      2      Create or print NUTRIENT.DAT (nutrient parameters)
               (TRANSPRT.DAT must be created before NUTRIENT.DAT)
      3      Run simulation
      4      Obtain output
      5      Stop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

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

DISPLAY 8. Modification of Nutrient Parameters.

Simulation and Results Generation

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



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




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

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

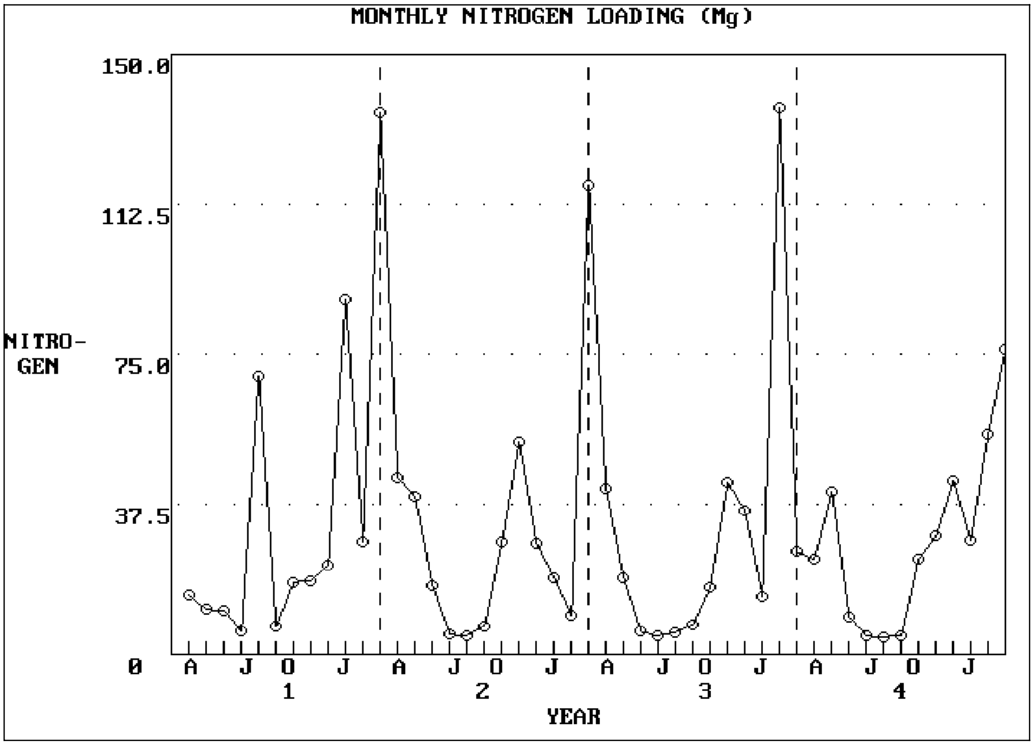


Figure 6. Monthly Nitrogen Loads with no Manure Spreading .

EXAMPLE 3: A 30-YEAR SIMULATION STUDY

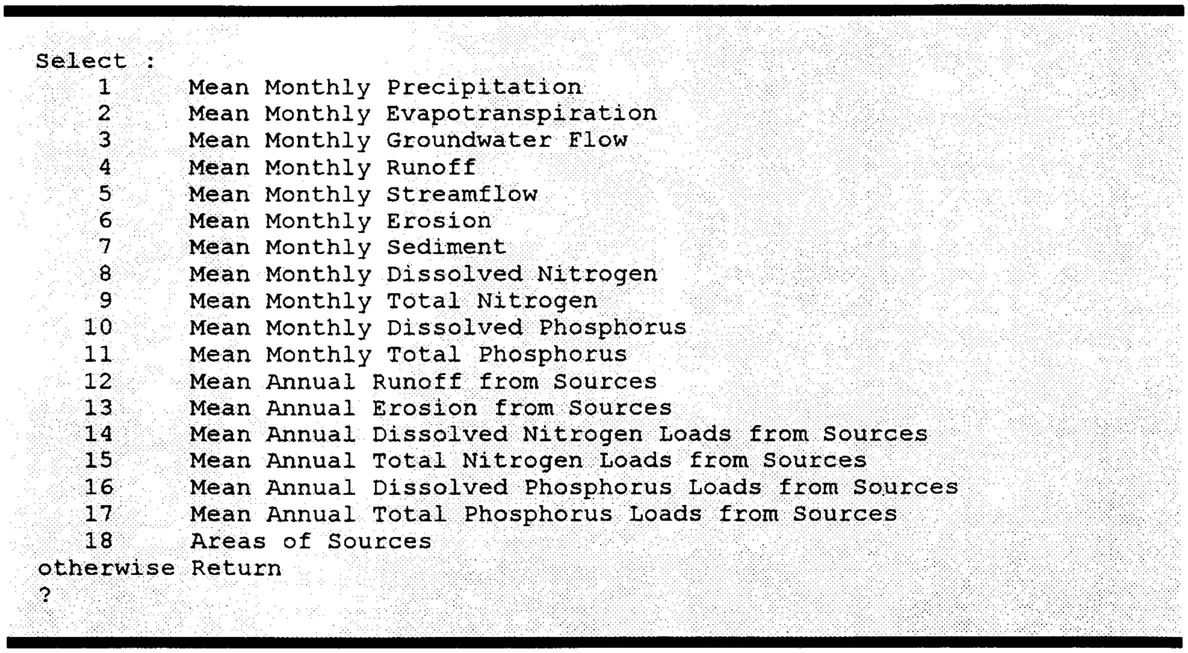
In Example 3, a simulation of the West Branch Delaware River Basin is based on a 30-yr (4/62-3/92) weather record given in the file **WALT462.392**.

Simulation and Results Generation

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

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

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



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

DISPLAY 10. The Options for Plotting Summary

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

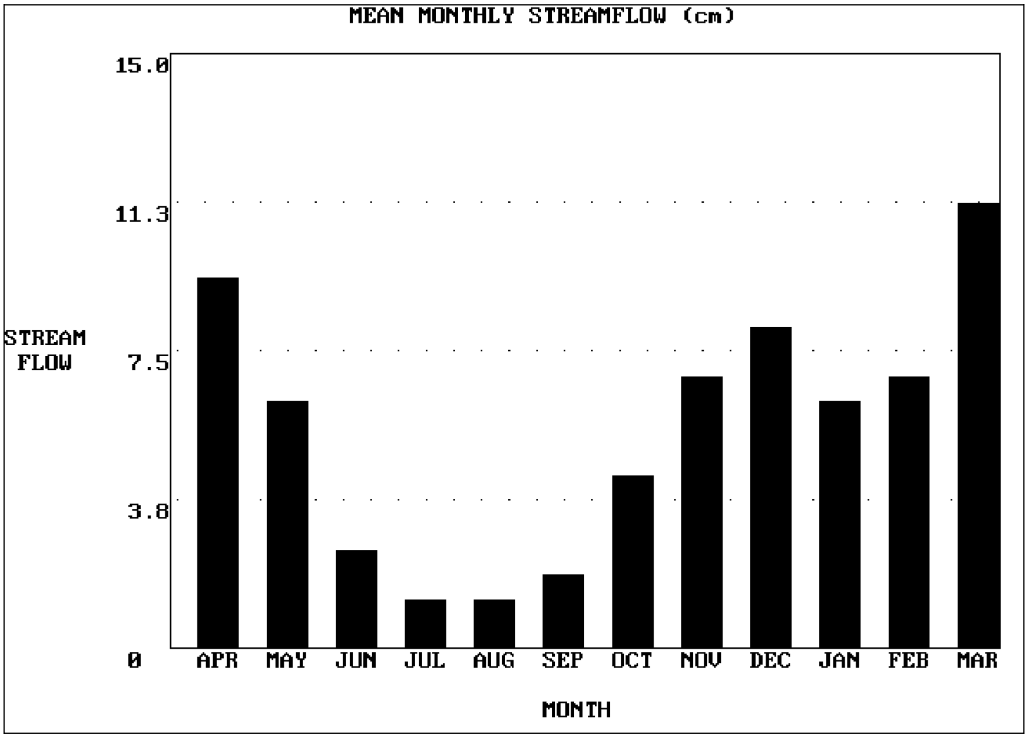


Figure 7. Mean Monthly Streamflows for 30-yr Simulation.

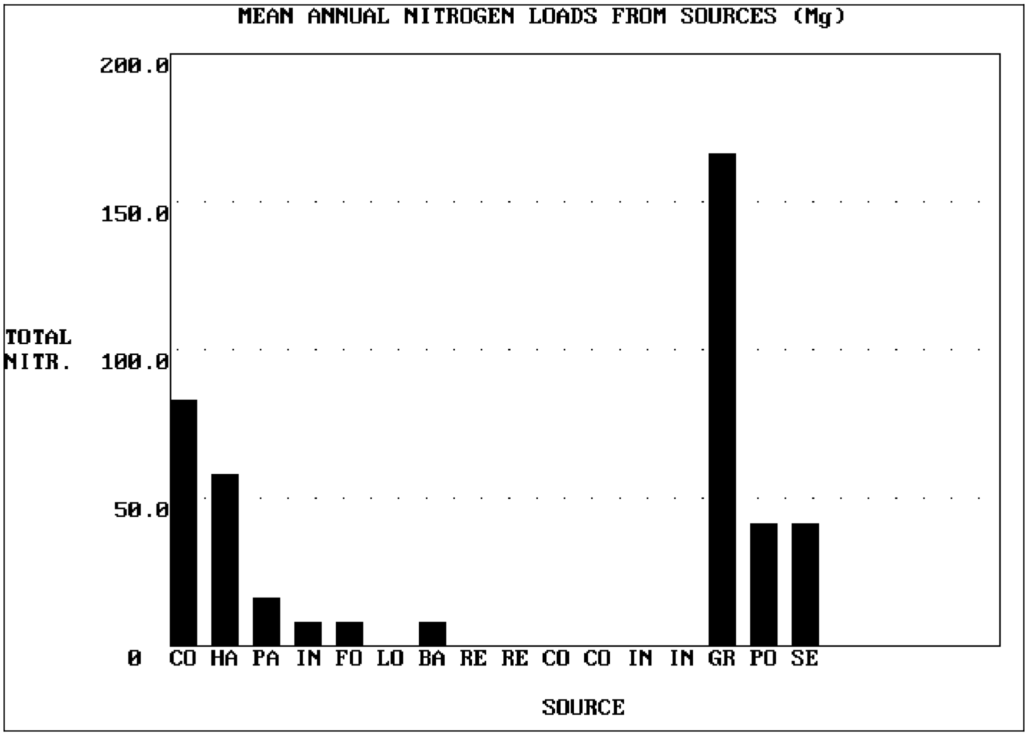


Figure 8. Mean Annual Nitrogen Load from Sources for 30-yr Simulation.

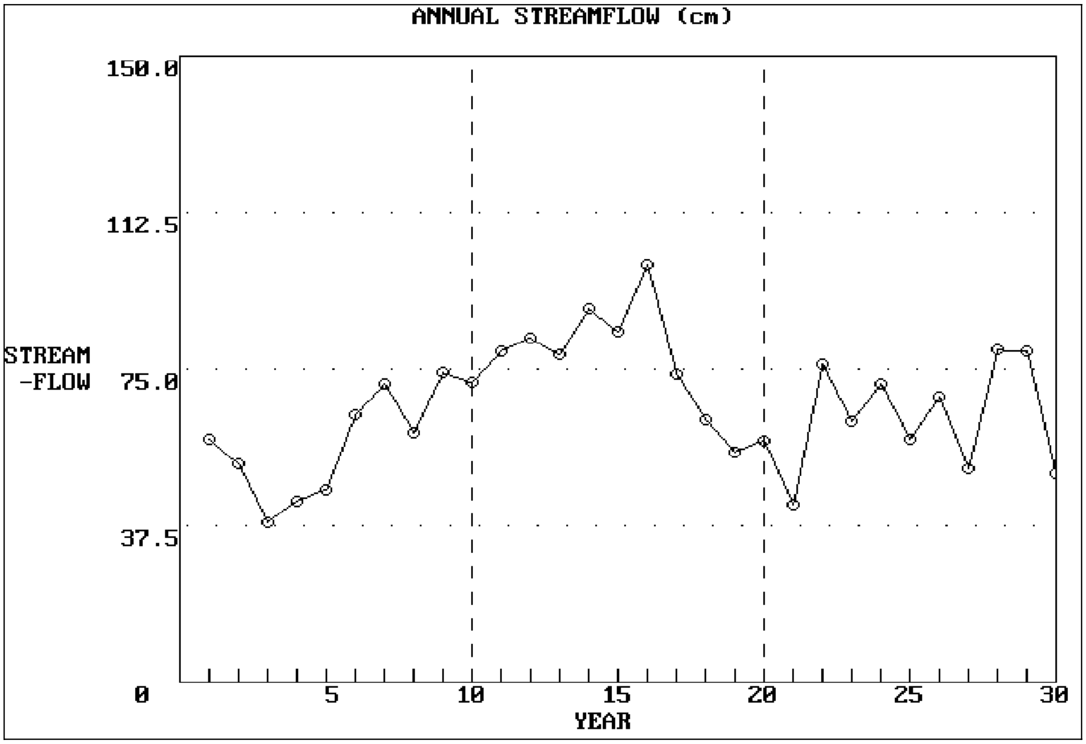


Figure 9. Annual Streamflows for 30-yr Simulation.

APPENDIX A: MATHEMATICAL DESCRIPTION OF GWLF

General Structure

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

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

$$LD_m = DP_m + DR_m + DG_m + DS_m \tag{A-1}$$

$$LS_m = SP_m + SR_m + SU_m \tag{A-2}$$

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:

$$LD_m = 0.1 \sum_{k} \sum_{t=1}^{d_m} Cd_k \, Q_{kt} \, AR_k \tag{A-3}$$

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):

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

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):

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

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

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

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

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

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

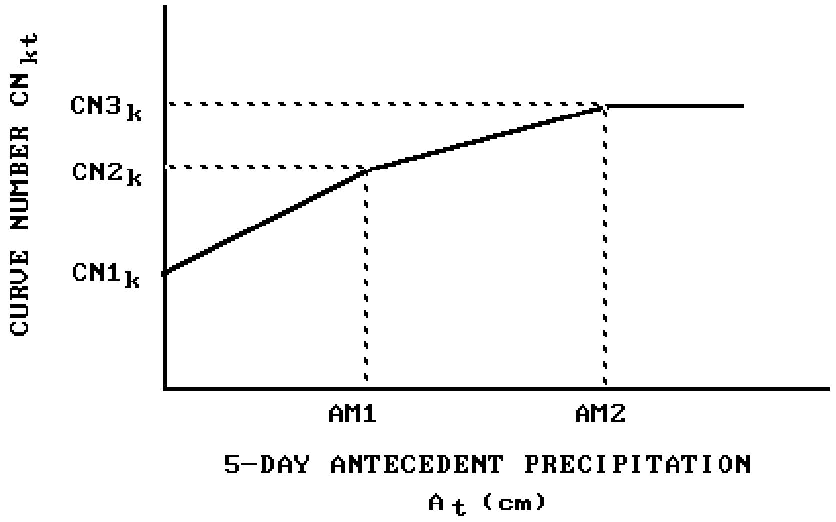


Figure A-1. Curve Number as Function of Antecedent Moisture.

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

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

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

$$0.4036 + 0.0059\ CN2_k$$

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

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

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

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

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):

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

where the coefficient a_t varies with season and geographical location.

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

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

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

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

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

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

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:

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

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 $N_{k,max}$:

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

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

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

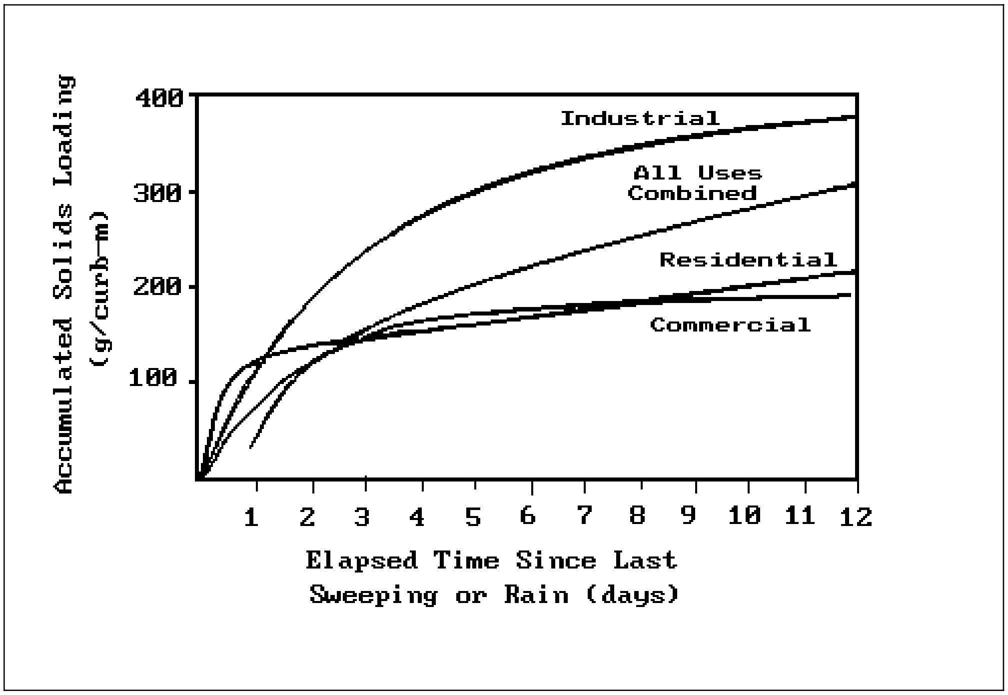


Figure A-2. Accumulation of Pollutants on Urban Surfaces (Sartor & Boyd, 1972; redrawn in Novotny & Chesters, 1981).

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).

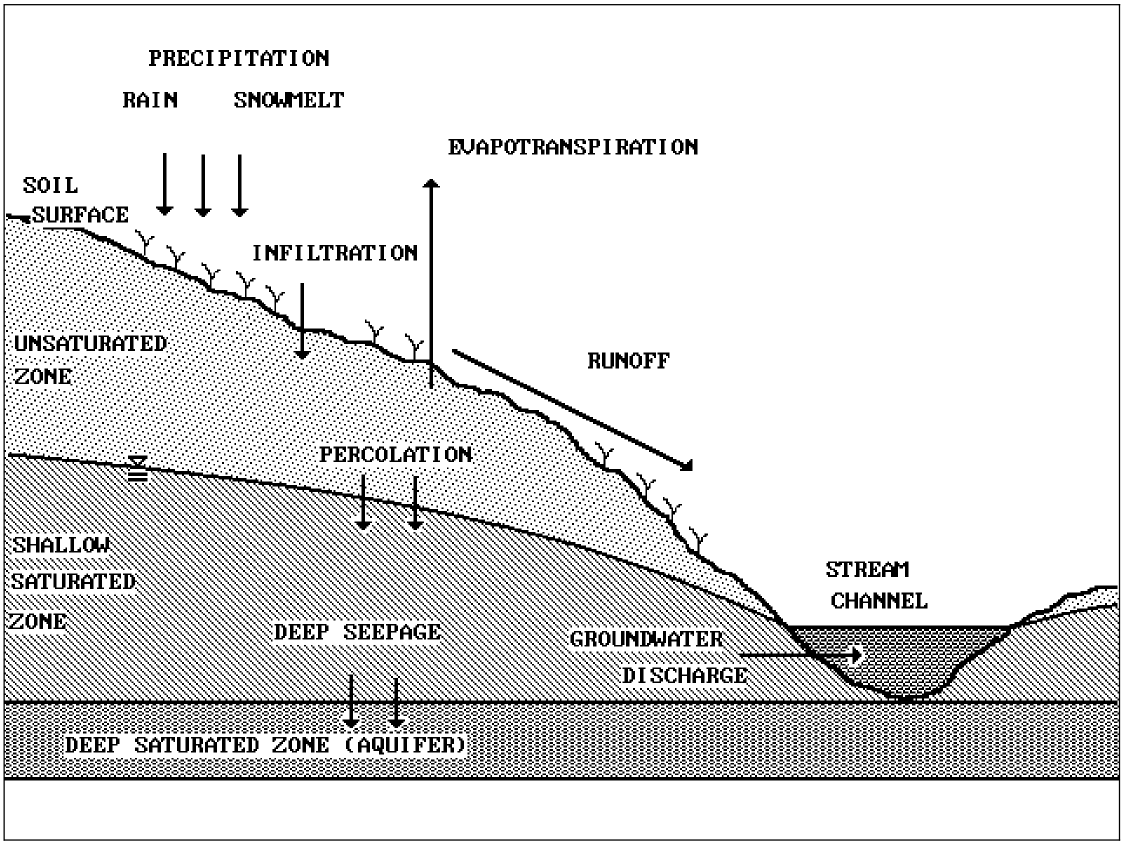


Figure A-3. Lumped Parameter Model for Groundwater Discharge.

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 for can be given the value 0.3 when foliage is absent and 1.0 otherwise. Perennial crops, such as grass, hay, meadow, and pasture, crops grown in flooded soil, such as rice, and conifers can be given a cover coefficient of 1.0 year round.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$\frac{dS}{dt} = -r\,S \tag{B-1}$$

or,

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

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

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

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

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

The recession constant is thus given by

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

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):

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

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

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

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

Figure B-2.

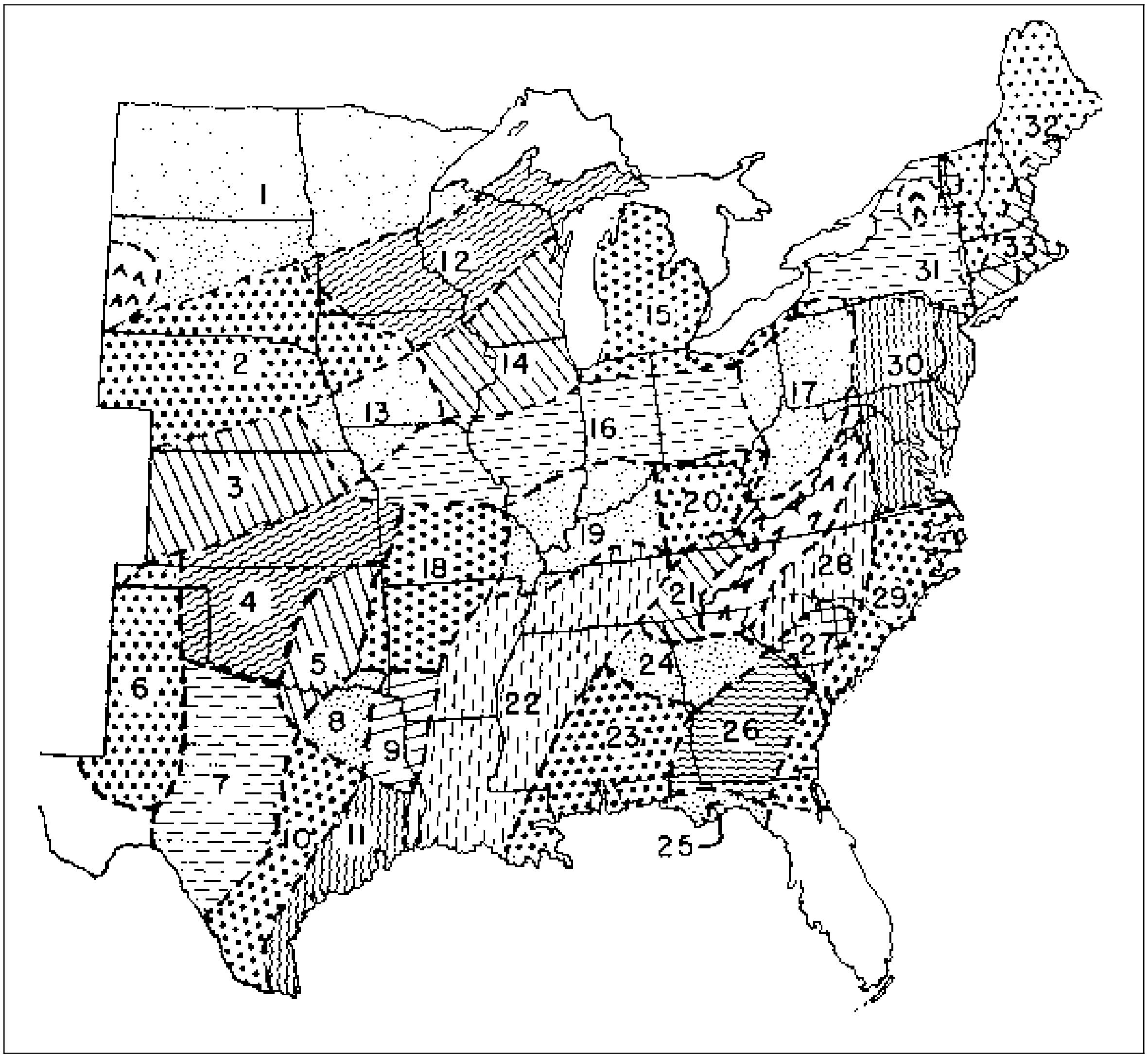


Figure B-1. Rainfall Erosivity Zones in Eastern U.S. (Wischmeier & Smith, 1978).

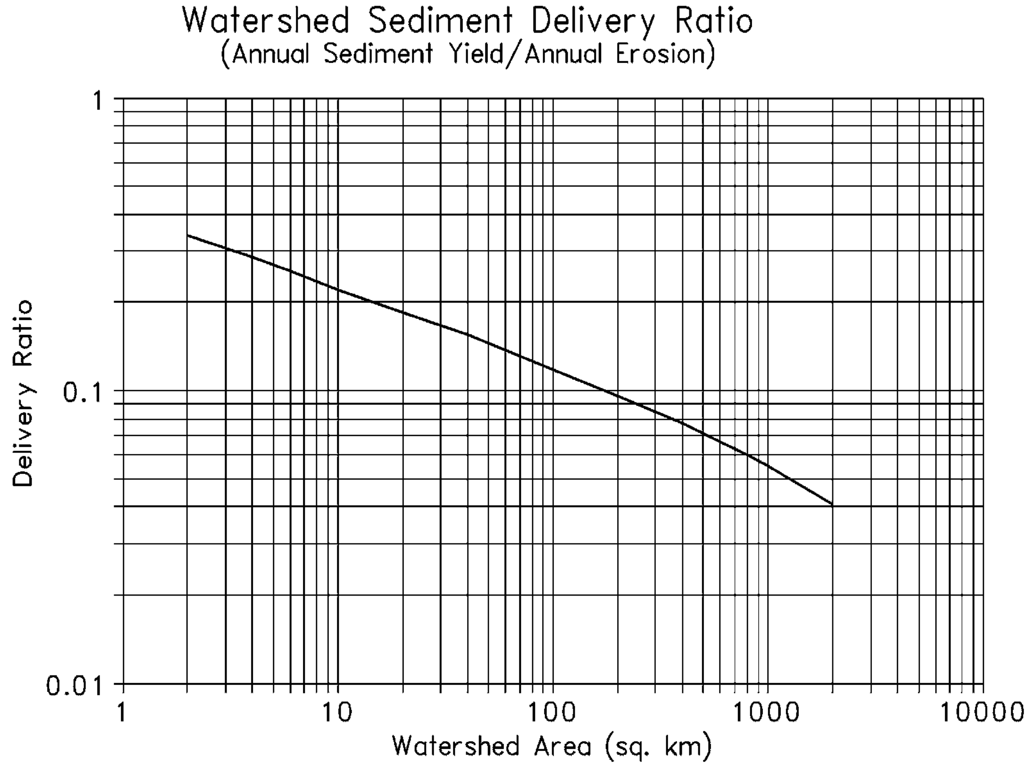


Figure B-2. Watershed Sediment Delivery Ratios (Vanoni, 1975).

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).

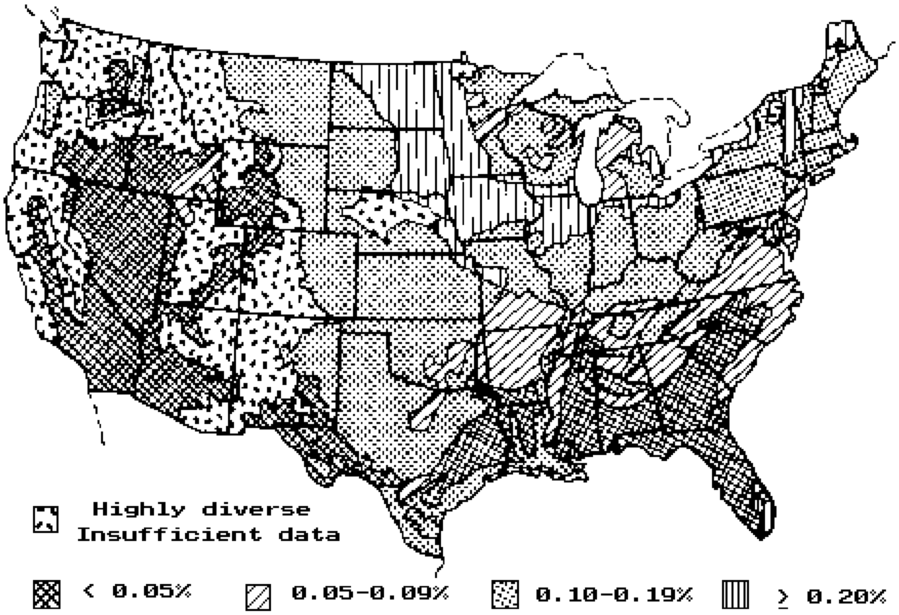


Figure B-3. Nitrogen in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

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.

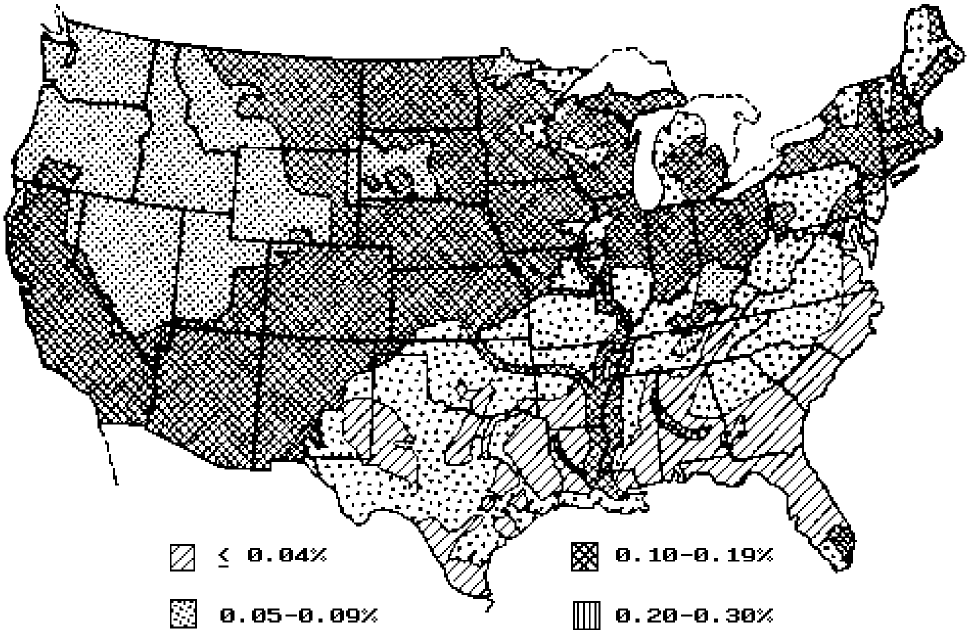


Figure B-4. P_2O_5 (44% phosphorus) in Surface 30 cm of Soils (Parker, *et al.*, 1946; Mills, *et al.*, 1985).

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	Suspended Solids	BOD	Total Nitrogen	Total Phosphorus
	(------------------------------	kg/ha-day	---------------------------	)
<u>Impervious Surfaces</u>				
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
<u>Pervious Surfaces</u>				
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, <u>et al</u>., 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.

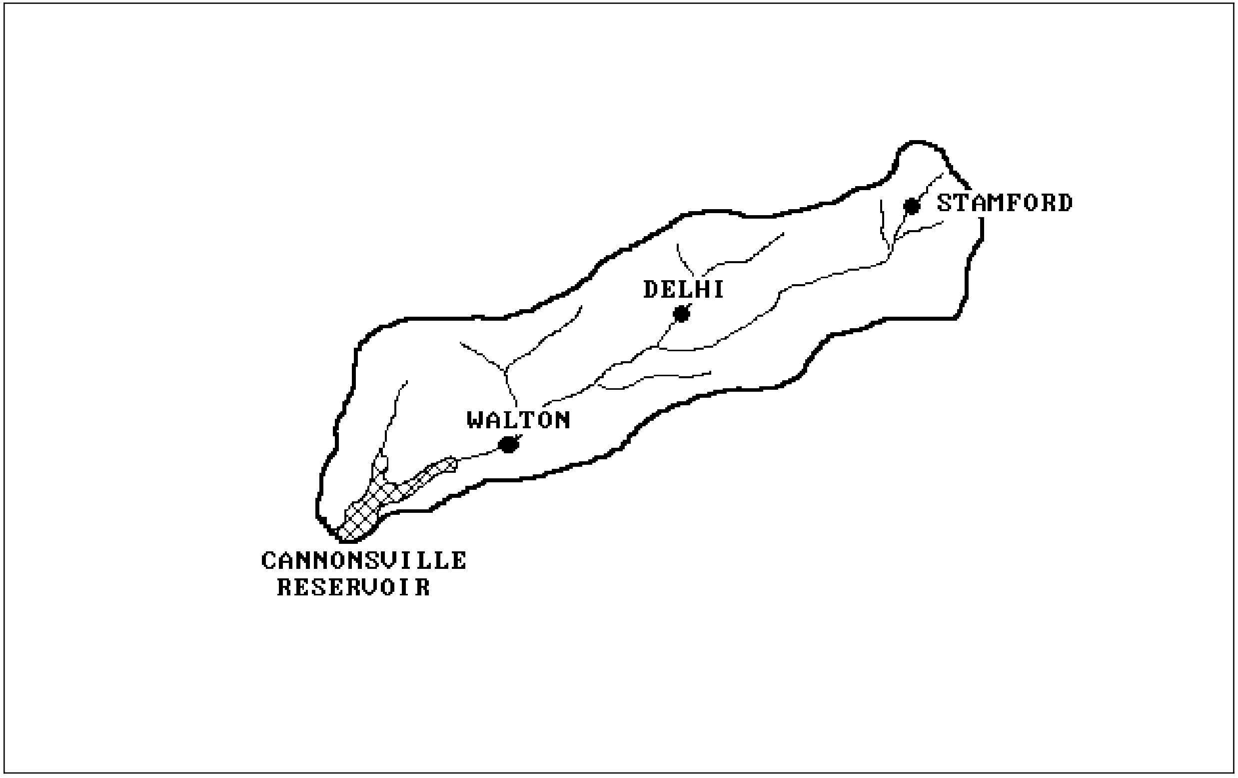


Figure C-1. West Branch Delaware River Watershed.

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.

<u>*Other Transport Parameters*</u>. 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^*.

<u>*Nutrient Concentrations and Accumulation Rates*</u>. 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.

<u>*Septic System Parameters*</u>. 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	Population Served 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).

<u>*Point Sources*</u>. 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.

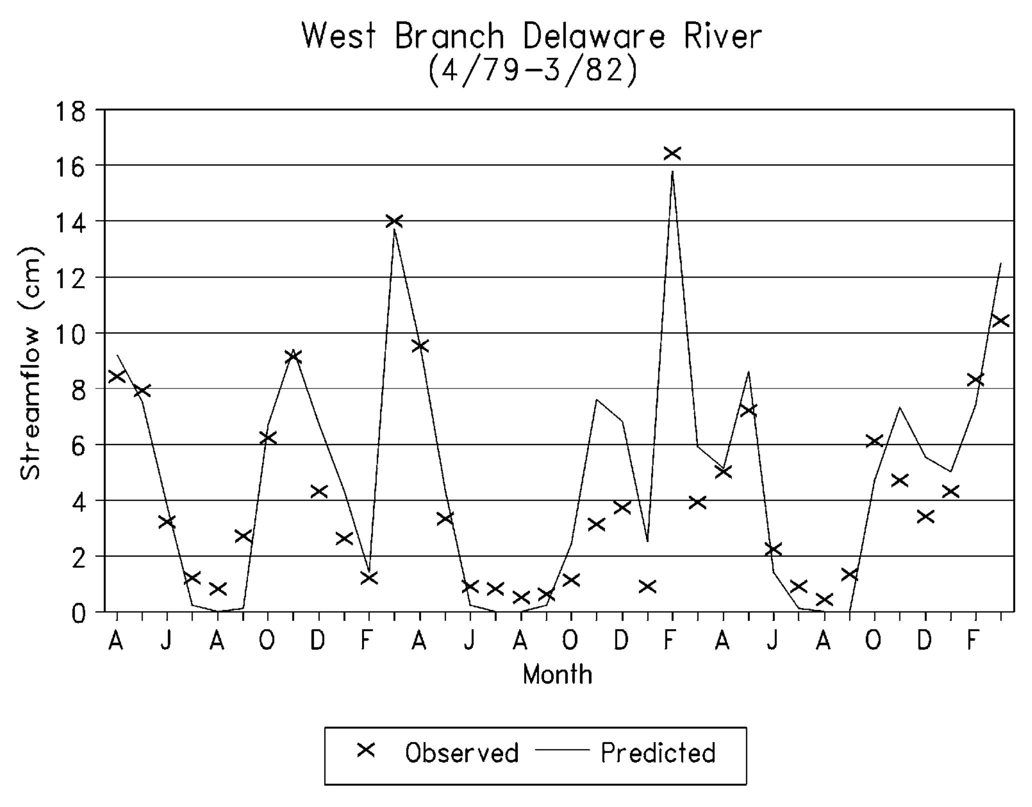


Figure C-2. Observed and Predicted Monthly Streamflow.

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.

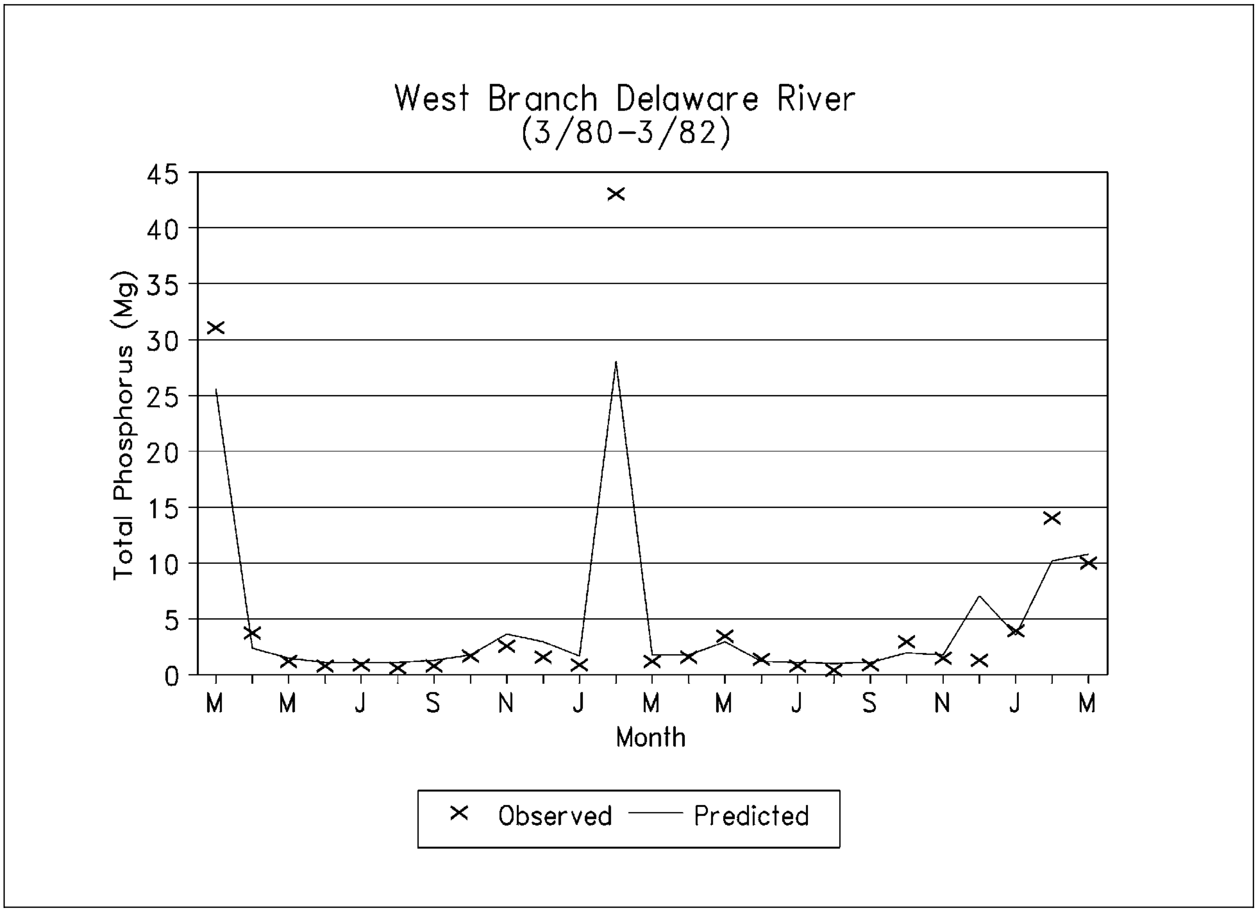


Figure C-3. Observed and Predicted Total Phosphorus in Streamflow.

Constituent	Validation Period	Monthly Means		Coefficient of Determination (R^2)
		Predicted	Observed	
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.

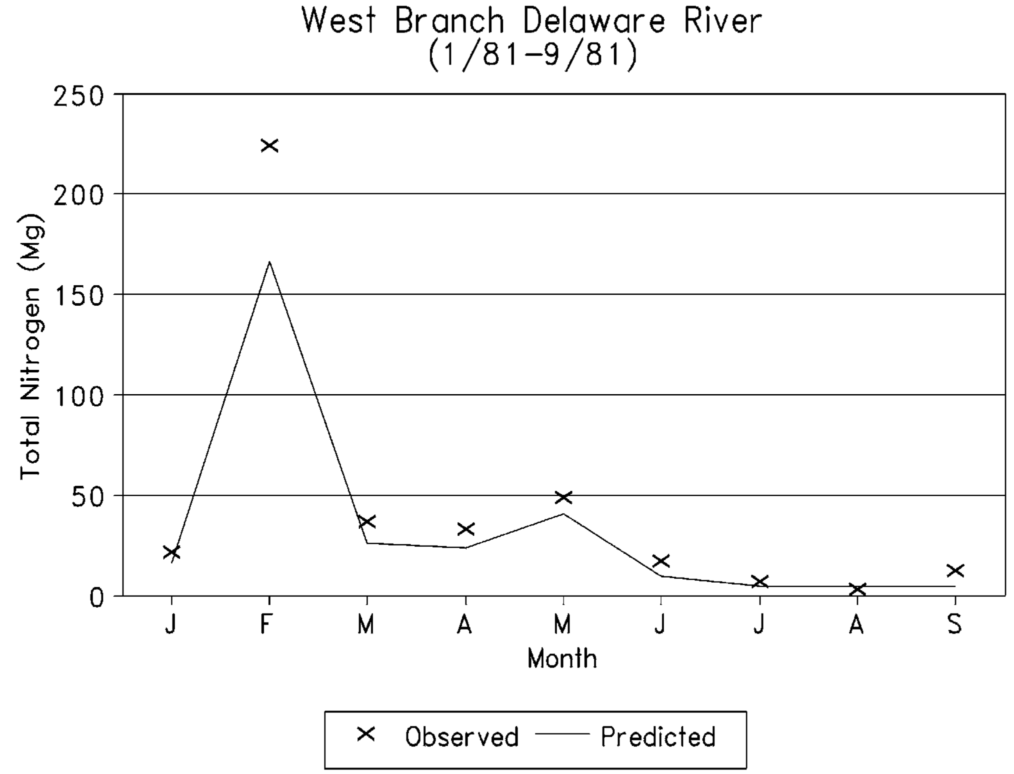


Figure C-4. Observed and Predicted Total Nitrogen in Streamflow.

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
               NORMAL         PONDING      SHORT-CIRCUIT    DISCHARGE
MONTH          SYSTEMS        SYSTEMS      SYSTEMS          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
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W. Branch Delaware River 4/78-3/82   YEAR  1

       PRECIP       EVAPOTRANS   GR.WAT.FLOW  RUNOFF       STREAMFLOW
          -----------------(cm)----------------------------------
APR      5.2          1.7          3.1          0.0          3.1
MAY      7.9          7.4          2.1          0.0          2.1
JUNE    10.5          9.7          1.8          0.0          1.8
JULY    10.8         10.9          0.3          0.0          0.4
AUG     17.0         10.4          4.6          3.4          8.1
SEPT     7.6          5.5          0.4          0.1          0.4
OCT     11.6          3.1          3.9          0.0          3.9
NOV      4.7          0.7          3.7          0.1          3.8
DEC     12.6          0.2          5.2          0.0          5.2
JAN     19.1          0.2          8.7          3.8         12.6
FEB      4.0          0.1          4.6          0.5          5.1
MAR     10.9          1.1         16.5          4.6         21.0
---------------------------------------------------------------
YEAR   121.9         50.9         54.9         12.6         67.4

       EROSION   SEDIMENT  DIS.NITR  TOT.NITR  DIS.PHOS  TOT.PHOS
        ----(1000 Mg)----       ------------(Mg)------------------
APR       8.3       0.0      14.9      15.0       1.3       1.3
MAY      13.3       0.0      11.3      11.5       1.1       1.2
JUNE     29.3       0.0      10.8      11.0       1.2       1.2
JULY     39.4       0.0       5.8       6.1       1.0       1.0
AUG     109.6       4.7      54.9      69.5       3.8      10.0
SEPT     35.4       0.0       6.8       6.9       1.1       1.1
OCT      10.3       0.0      17.8      18.1       1.4       1.4
NOV       1.4       0.0      18.2      18.4       1.4       1.4
DEC       1.8       0.0      22.1      22.3       1.5       1.5
JAN       0.0       3.8     100.4     112.2       8.9      13.9
FEB       0.0       0.2      32.7      33.5       2.8       3.1
MAR       5.0       7.7     139.6     163.2      11.2      21.3
----------------------------------------------------------------
YEAR    253.8      16.5     435.3     487.5      36.6      58.3

SOURCE       AREA   RUNOFF   EROSION  DIS.NITR TOT.NITR DIS.PHOS TOT.PHOS
             (ha)    (cm)    (Mg/ha)    --------------(Mg)------------
CORN           3430.   24.70    52.26    81.18   116.13    12.18    27.33
HAY           13085.   19.27     2.93    70.59    78.06     3.78     7.02
PASTURE        5093.   13.86     3.91    21.18    25.06     1.76     3.45
INACTIVE       3681.   13.86     4.15     8.16    11.14     0.66     1.95
FOREST        56682.    9.81     0.00    10.57    10.57     0.33     0.33
LOGGING          20.    0.00    52.99     0.00     0.21     0.00     0.09
BARN YARDS       41.   44.22     0.00     5.31     5.31     0.92     0.92
RES-imperv      104.   82.95     0.00     0.00     0.86     0.00     0.09
RES-perv        546.   14.52     0.00     0.00     0.30     0.00     0.04
COMM-imperv      49.   82.95     0.00     0.00     0.90     0.00     0.10
COMM-perv        41.   14.52     0.00     0.00     0.02     0.00     0.00
INDUS-imperv     34.   82.95     0.00     0.00     0.63     0.00     0.07
INDUS-perv       67.   14.52     0.00     0.00     0.04     0.00     0.01
GROUNDWATER                             154.61   154.61     5.91     5.91
POINT SOURCE                             45.60    45.60     9.90     9.90
SEPTIC SYSTEMS                           38.10    38.10     1.11     1.11
---------------------------------------------------------------------------
TOTAL                                   435.30   487.55    36.58    58.33
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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   RUNOFF   EROSION  DIS.NITR TOT.NITR DIS.PHOS TOT.PHOS
             (ha)    (cm)    (Mg/ha)    ---------------(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
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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
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W. Branch Delaware River 4/78-3/82   YEAR  4

       PRECIP       EVAPOTRANS   GR.WAT.FLOW  RUNOFF       STREAMFLOW
          -----------------(cm)-----------------------------------

APR     10.3          2.1          5.0          0.1          5.1
MAY     13.0          7.4          8.1          0.5          8.6
JUNE     8.1         10.4          1.4          0.0          1.4
JULY     7.0         11.4          0.1          0.0          0.1
AUG      5.4          8.7          0.0          0.0          0.0
SEPT    13.7          5.4          0.0          0.0          0.0
OCT     13.1          2.9          4.6          0.2          4.7
NOV      5.9          0.7          7.3          0.0          7.3
DEC      8.2          0.1          4.3          1.1          5.5
JAN      6.6          0.1          4.6          0.4          5.0
FEB      9.1          0.1          5.9          1.5          7.4
MAR      9.0          0.7         10.7          1.8         12.5
---------------------------------------------------------------
YEAR   109.4         50.0         52.0          5.7         57.7

       EROSION   SEDIMENT  DIS.NITR  TOT.NITR  DIS.PHOS  TOT.PHOS
        ----(1000 Mg)----       ------------(Mg)-------------------

APR      28.0       0.0      23.5      23.9       1.6       1.7
MAY      55.8       0.4      39.3      40.8       2.3       2.9
JUNE     15.4       0.0       9.3       9.4       1.1       1.1
JULY     20.1       0.0       4.6       4.8       0.9       1.0
AUG      12.7       0.0       4.3       4.5       0.9       0.9
SEPT     43.2       0.0       4.6       4.9       1.0       1.0
OCT      10.5       0.2      23.0      23.8       1.6       1.9
NOV       2.4       0.0      29.5      29.7       1.7       1.7
DEC       0.5       3.6      32.0      43.2       2.2       7.0
JAN       0.0       0.7      30.6      32.9       2.6       3.5
FEB       0.0       4.3      51.9      65.1       4.5      10.1
MAR       0.7       3.1      82.0      91.6       6.7      10.7
----------------------------------------------------------------
YEAR    189.3      12.3     334.7     374.4      27.2      43.5

SOURCE       AREA   RUNOFF   EROSION  DIS.NITR TOT.NITR DIS.PHOS TOT.PHOS
             (ha)    (cm)    (Mg/ha)    --------------(Mg)-------------
CORN           3430.   14.66    38.98    44.57    70.64     6.60    17.89
HAY           13085.   10.52     2.19    38.54    44.12     2.06     4.48
PASTURE        5093.    6.48     2.91     9.90    12.79     0.82     2.08
INACTIVE       3681.    6.48     3.10     3.81     6.04     0.31     1.27
FOREST        56682.    3.67     0.00     3.95     3.95     0.12     0.12
LOGGING          20.    0.00    39.52     0.00     0.15     0.00     0.07
BARN YARDS       41.   31.05     0.00     3.73     3.73     0.65     0.65
RES-imperv      104.   68.27     0.00     0.00     0.87     0.00     0.09
RES-perv        546.    6.96     0.00     0.00     0.30     0.00     0.04
COMM-imperv      49.   68.27     0.00     0.00     0.92     0.00     0.10
COMM-perv        41.    6.96     0.00     0.00     0.02     0.00     0.00
INDUS-imperv     34.   68.27     0.00     0.00     0.64     0.00     0.07
INDUS-perv       67.    6.96     0.00     0.00     0.04     0.00     0.01
GROUNDWATER                               146.50   146.50     5.60     5.60
POINT SOURCE                               45.60    45.60     9.90     9.90
SEPTIC SYSTEMS                             38.10    38.10     1.11     1.11
---------------------------------------------------------------------------
TOTAL                                     334.70   374.40    27.18    43.49
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Appendix E
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 E-1 lists the curve numbers for each landuse in the Kinkaid Lake Watershed.

Table E-1 Curve Numbers in Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row-Crop	82.1	81.9	77.5	83.1
Small Grains	80.1	77.7	75.2	79.8
Rural Grassland	68.7	68.6	61.7	72.5
Urban Grassland	74.2	---	---	---
Deciduous1	59.4	62.2	65.5	65
Deciduous2	66.2	82.2	89.4	62.1
Coniferous	61.1	63.6	60.3	---

Cattle Feedlot	74.2	---	---	73.9
Open Water	99.8	100	99.9	100
Shallow Marsh	99.6	89.5	---	100
Deep Marsh	100	---	---	100
Forested Wetland	100	100	100	99.7
Shallow Water Wetland	100	94.6	100	98.8
Barren Land	100	---	---	---
High Density	90.1	---	---	---
Medium Density	81.2	---	---	---

Soil Erodibility Factor (K)

The K factor is developed in ArcView and Excel.

1. In ArcView, add the attribute tables statsgoc.dbf and statsgol.dbf to the Table list. Join the statsgoc.dbf table to the statsgol.dbf table by field *muidsegnum*. This appends the percentage of each soil type to the soils in each layer. Export the joined table as a .dbf named statsgo_kf.dbf.
    1. Open the table statsgo_kf.dbf in Excel. Remove all fields except *muid, layernum, kffact, kfact,* and *comppct*.
    2. Sort the entire table by *layernum* then by *muid*. This promotes all soils in layer 1 to the top of the spreadsheet.
    3. Remove all records for soils below layer 1.
    4. Ensure the sum of the *comppct* field for each muid is equal to 100.
    5. In a new column labeled *product*, multiply *kffact* by *comppct* and divide by 100 for each record. If the value in the *kffact* field is zero, use the value in the *kfact* field
    6. In a new column labeled *kffact_r* (revised), sum *product* over each muid to obtain the revised K factor for each muid.
    7. Copy the *kffact_r* column and use the "Paste Special/Values" option to paste the column into the *layernum* column. This is done so that the *kffact_r* values will be retained when the statsgo_kf.dbf table is saved and used again in ArcView.
    8. Delete all columns except for *muid* and *kffact_r.* Delete any rows without a value in the *kffact_r* field.
    9. Save the table.
    10. In ArcView, add the table statsgo_kf.dbf, the STATSGO shapefile in UTM 16 projection, and the landuse grid. Join the statsgo_kf.dbf table to the statsgo.dbf table by *muid*. This attaches the average K factor to each muid in statsgo.dbf.
    11. Set the analysis extent and cell size to the landuse grid.
    12. Convert the SATSGO shapefile to a grid using the *kffact_r* field as the grid value.
    13. To average the K factor grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

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

Table E-2 Weighted K factors for the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4

Row Crop	0.39	0.39	0.37	0.40
Small Grains	0.39	0.38	0.37	0.39
Urban Grassland	0.41	---	---	---
Rural Grassland	0.39	0.39	0.37	0.39
Deciduous1	0.38	0.37	0.37	0.37
Deciduous2	0.39	0.37	0.37	0.38

Topographic Factor (LS)

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

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

$m = B/(1+B)$

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

$\Theta = \arctan(\text{slope}/100)$

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

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

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

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

Map Calc. 7: ([Map Calculation 3] + [Map Calculation 6])
Output: Correct S-value in each cell
Save Map Calculation 7 as a permanent grid named *S_grid*.

8. Compute the Beta grid with the map calculator.
   Map Calc. 1: ((([theta_grid].Sin) / 0.0896) / ((([theta_grid].Sin).Pow(0.8)) * 3.0 + 0.56)
   Save Map Calculation 1 as a permanent grid named *Beta_grid*.
9. Compute the M grid with the map calculator.
   Map Calc. 1: ([beta_grid] / ([beta_grid] + 1))
   Save Map Calculation 1 as permanent grid named *M_grid*.
10. Compute the flow length (Lambda) grid with the map calculator and a succession of calculations
    Map Calc. 1: ([fdr] = 1 OR [fdr] = 4 OR [fdr] = 16 OF [fdr] = 64)
    Output: 1 in cells flowing in cardinal direction and 0 in other cells
    Map Calc. 2: ([Map Calculation 1] * 30.8875)
    {30.885 = cell length}
    Output: 30.885 in cells flowing in cardinal direction and 0 in others.
    Map Calc. 3: ([Map Calculation 2] = 0)
    Output: 0 in cells flowing in cardinal direction and 1 in others
    Map Calc. 4: ([Map Calculation 3] * 43.682)
    {43.682= length across cell diagonal}
    Output: 43.682 in cells flowing in non-cardinal direction, 0 in others.
    Map Calc. 5: ([Map Calculation 4] + [Map Calculation 2])
    Output: correct flow lengths in each cell – 30.885 in cardinal, 43.682 in others
    Map Calc. 6: ([Map Calculation 5] * 100 / 2.54 / 12
    Output: flow length grid in feet
    Save Map Calculation 6 as a permanent grid named *Lambda_grid*
11. Compute the L with the map calculator.
    Map Calc. Statement: ([lambda_grid] / 72.6).Pow([m_grid])
    Save Map Calculation 1 as a permanent grid named *L_grid*.
12. Compute the LS grid with the map calculator.
    Map Calc. Statement: ([L-grid] * [S_grid])
    Save Map Calculation 1 as a permanent grid named *LS_grid*.
13. To average the LS grid over the landuse shapefile polygons, select "Average grid value on polygon" from the CRWR-Raster menu.

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

Table E-3 Weighted LS factors for the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.891	1.163	2.105	0.597
Small Grains	0.879	0.793	0.584	0.614
Urban Grassland	0.358	---	---	---

Rural Grassland	1.023	0.819	1.242	0.797
Deciduous1	1.886	2.554	2.890	2.086
Deciduous2	0.931	1.297	2.311	1.571

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 Jackson County NRCS office included as Appendix F. The Jackson County NRCS office also provided an estimate of the percentage of each crop rotation across the Kinkaid Lake Watershed. The spreadsheet used to calculate a weighted c-factor for corn, soybeans, and small grains is shown at the end of this appendix. The values in 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 Kinkaid Lake Watershed. The values in the Table 1 are then weighted by the percentage of each tillage practice in Table 2 to determine a single c-factor for corn, soybeans, and small grains.

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

Table E-4 Cropland Data Layer C factors for Kinkaid Lake Watershed

Landuse	Subbasin 1 C-factor	Subbasin 2 C-factor	Subbasin 3 C-factor	Subbasin 4 C-factor
High Density	---	---	---	---
Medium Density	---	---	---	---
Row Crop	0.14	0.11	0.12	0.14
Small Grains	0.13	0.13	0.13	0.13
Urban Grassland	0.02	---	---	---
Rural Grassland	0.02	0.02	0.02	0.02
Deciduous	0.003	0.003	0.003	0.003
Deciduous	0.003	0.003	0.003	0.003
Coniferous	0.003	0.003	0.003	---

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

Table E-5 C Factors by Critical Trends Assessment Landuse Classes in the Kinkaid Lake Watershed

Landuse	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
Row Crop	0.14	0.11	0.12	0.14
Small Grains	0.13	0.13	0.13	0.13
Urban Grassland	0.02	---	---	---
Rural Grassland	0.02	0.02	0.02	0.02
Deciduous	0.003	0.003	0.003	0.003
Coniferous	0.003	0.003	0.003	---

Evapotranspiration (ET) Cover Coefficient

The ET cover coefficient was calculated in an Excel spreadsheet. The cover coefficients for crops available in the GWLF Manual and the crops listed in the Cropland Data Layer landuse file differ. Therefore, crops in the Cropland Data Layer file were summed into classes matching the available crop cover coefficients. Table E-6 shows the original and adjusted areas for Kinkaid Lake. The adjusted sorghum area is the sum of sorghum and other small grains and hay, and the adjusted soybean area represents soybeans plus half of the double-cropped WW/SB area. Adjusted area from winter wheat represents winter wheat plus half the double-cropped WW/SB area.

Table E-6 Cropland Data Layer Landuses, Areas and Adjusted Areas

	Subbasin 1		Subbasin 2		Subbasin 3		Subbasin 4	
Landuse	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)	Area (m2)	Adjusted Area (m2)
Corn	4802400	4802400	316800	316800	36000	36000	1279800	1279800
Sorghum	---	4111200	---	295200	---	53100	---	860400
Soybeans	4550400	6004800	897300	1093500	86400	96750	1354500	1793700
Winter Wheat	864900	2319300	96300	292500	19800	30150	117000	556200
Other Small Grains & Hay	4111200		295200		53100		860400	
Double-Cropped WW/SB	2908800		392400		20700		878400	
Idle Cropland/ CRP	61200	61200	1800	1800	900	900	16200	16200
Fallow/ Idle Cropland	5445900	5445900	1684800	1684800	151200	151200	2065500	2065500
Pasture/Grassland/ Nonagricultural	20782800	20782800	3417300	3417300	912600	912600	7005600	7005600
Woods	42413400	42413400	16074900	16074900	7675200	7675200	11617200	11617200
Clouds	203400	203400	63900	63900	8100	8100	78300	78300
Urban	965700	965700	47700	47700	11700	11700	277200	277200
Water	607500	607500	1380600	1380600	1232100	1232100	4717800	4717800
Buildings/Homes/ Subdivisions	1317600	1317600	92700	92700	37800	37800	325800	325800
Wetlands	834300	834300	225000	225000	99900	99900	411300	411300
Total	89869500	89869500	24986700	24986700	10345500	10345500	31005000	31005000

Table E-7 shows the calculation of a single crop coefficient for each 10% of the growing season and for each calendar month. The ET cover coefficients for each crop were obtained from page 29 of the GWLF Manual. To create the coefficient for each 10% of the growing season, each crop coefficient in columns B-E was weighted by its corresponding area in Table A-8. An average monthly ET coefficient (column G) was calculated from the coefficients in Column F, and then each growing season was assigned to a calendar month (Column H).

Table E-7 Calculation of the Monthly Crop Evapotranspiration Cover Coefficients for Subbasin 1 of the Kinkaid Lake Watershed

A	B	C	D	E	**F**	**G**	H
% of Growing Season	Field Corn	Grain Sorghum	Winter Wheat	Soybeans	**Weighted Average ET Coefficient**	**Average Monthly ET Coefficient**	Month
0	0.45	0.3	1.08	0.3	**0.45**	**0.45**	Nov - Apr
10	0.51	0.4	1.19	0.35	**0.52**		
20	0.58	0.65	1.29	0.58	**0.69**	**0.61**	May
30	0.66	0.9	1.35	1.05	**0.95**		
40	0.75	1.1	1.4	1.07	**1.03**	**0.99**	June
50	0.85	1.2	1.38	0.94	**1.04**	**1.04**	July
60	0.96	1.1	1.36	0.8	**0.99**		
70	1.08	0.95	1.23	0.66	**0.92**	**0.96**	August
80	1.2	0.8	1.1	0.53	**0.86**		
90	1.08	0.65	0.75	0.43	**0.71**	**0.78**	September
100	0.7	0.5	0.4	0.36	**0.49**		
					0.45	**0.47**	October

Table E-8 shows the calculation of a single area-weighted crop coefficient for each month. First, the crop coefficients from Table E-7 were entered into Column B of Table E-8. The monthly ET values in Columns C, D, E, F, and G 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 H) from the adjusted areas in Table E-6 and the monthly ET cover coefficients in Table E-8.

Table E-8 Calculation of a Monthly ET Cover Coefficient in Subbasin 1 of the Kinkaid Lake Watershed

A	B	C	D	E	F	G	**H**
	Crop	Pasture	Forest	68% Urban	30% Urban	Water/ Wetland	**Weighted Average ET**
April	0.45	1.09	0.3	0.32	0.7	0.75	**0.58**
May	0.61	0.95	1	0.32	0.7	0.75	**0.90**
June	0.99	0.83	1	0.32	0.7	0.75	**0.94**
July	1.04	0.79	1	0.32	0.7	0.75	**0.93**
August	0.96	0.8	1	0.32	0.7	0.75	**0.92**
September	0.78	0.91	1	0.32	0.7	0.75	**0.92**
October	0.47	0.91	1	0.32	0.7	0.75	**0.86**
November	0.45	0.83	0.3	0.32	0.7	0.75	**0.50**
December	0.45	0.69	0.3	0.32	0.7	0.75	**0.46**
January	0.45	1.16	0.3	0.32	0.7	0.75	**0.60**
February	0.45	1.23	0.3	0.32	0.7	0.75	**0.62**
March	0.45	1.19	0.3	0.32	0.7	0.75	**0.61**

Table E-9 shows the calculated ET cover coefficients for each subbasin in the Kinkaid Lake Watershed.

Table E-9 ET Cover Coefficients in the Kinkaid Lake Watershed

Month	Subbasin 1	Subbasin 2	Subbasin 3	Subbasin 4
April	0.58	0.50	0.44	0.63
May	0.90	0.94	0.95	0.88
June	0.94	0.95	0.95	0.90
July	0.93	0.94	0.95	0.89
August	0.92	0.93	0.94	0.89
September	0.92	0.94	0.95	0.89
October	0.86	0.92	0.95	0.85
November	0.50	0.45	0.42	0.56
December	0.46	0.42	0.40	0.52
January	0.60	0.52	0.45	0.66
February	0.62	0.53	0.46	0.68
March	0.61	0.52	0.45	0.66

A B C D E F G H I J

Corn-Soybean Rotation
75% of watershed

Conventional Till (Spring Plow)	
Corn after Soybean	0.3
Soybean after Corn*	0.25
Reduced-Till (20% Cover)	
Corn after Soybean	0.35
Soybean after Corn*	0.17
Mulch-Till (30% cover)	
Corn after Soybean	0.32
Soybean after Corn*	0.15
No-Till (70%/30% Cover)	
Corn after Soybean	0.16
Soybean after Corn*	0.06

*Assumed Drilled

Corn-Soybean-Wheat Rotation
25% of watershed

Conventional Till (Spring Plow)	
Corn after Wheat**	0.25
Soybean after Corn*	0.25
Wheat after Soybean$^{\#}$	0.15
Reduced-Till (20% Cover)	
Corn after Wheat**	0.21
Soybean after Corn*	0.17
Wheat after Soybean$^{\#}$	0.13
Mulch-Till (30% cover)	
Corn after Wheat**	0.18
Soybean after Corn*	0.15
Wheat after Soybean$^{\#}$	0.12
No-Till (70%/30% Cover)	
Corn after Wheat**	0.05
Soybean after Corn*	0.06
Wheat after Soybean$^{\#}$	0.09

*Assumed Drilled
**Used Corn after Small Grain
$^{\#}$Used Small Grain after Soybean

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

Tillage Practice	**Corn**	**Soybeans**	**Small Grains**
Conventional Till	0.29	0.25	0.15
Reduced Till	0.32	0.17	0.13
Mulch-Till	0.29	0.15	0.12
No-Till	0.13	0.06	0.09

Table 2 - Tillage Practice Percentages in Kinkaid Lake Watershed

Tillage Practice	**Corn**	**Soybeans**	**Small Grains**
Conventional Till	20%	0%	20%
Reduced Till	15%	10%	50%
Mulch-Till	15%	5%	10%
No-Till	50%	85%	20%

C-factors Weighted by Percent of Each Tillage Practice

Corn	**Soybeans**	**Small Grains**
0.21	0.08	0.13

Appendix F

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

.126
.11 .06
.13
.316

TABLE 3 - CROP MANAGEMENT "C" FACTOR VALUES FOR RAINFALL "E.I." DISTRIBUTION CURVE # 19 1/

CROP SEQUENCE		FALL PLOW	SPRING PLOW	CHISEL - DISK - RIDGE 2/ % Cover After Plant				No-Till % Cover After Plant			
				20%	30%	40%	50%	60%	70%	80%	90%
CORN after Soybeans		.43	.30	.35	.32	.27	---	20% .20	30% .16	40% * .12	3/
CORN after Corn		.38	.25	.20	.18	.15	.13	.07	.05	.04	.03
CORN after Small Grain		.39	.25	.21	.18	.16	.14	.07	.05	.04	.03
CORN after Meadow 4/		.17	.11	.11	.09	.08	.07	.03	.02	o .01	.01
CORN 2nd yr. after Meadow 4/		.33	.21	.18	.16	.14	.12	.06	.05	.04	.03
SOYBEANS after Soybeans 5/	Wide Row	.48	.37	.37	.36	---	---	20% .22	30% .17	40% .13	3/
	Drill	.42	.29	.34	.33	---	---	.19	.14	.10	
SOYBEANS after Corn 5/	Wide Row	.40	.31	.19	o .16	.14	.12	.08	.06	* .04	.03
	Drill	.34	.25	.17	.15	.13	.11	.07	.06	.04	.03
SOYBEANS after Sm. Grain 5/	Wide Row	.45	.27	.22	.19	.17	.15	.08	.07	.04	.03
	Drill	.38	.22	.18	.16	.14	.12	.08	.07	.04	.03
SOYBEANS after Meadow 4, 5/	Wide Row	.19	.14	.09	.07	.06	.05	.03	.02	.01	.01
	Drill	.16	.11	.08	.07	.06	.05	.03	.02	.01	.01
SOYBEANS after Corn 2nd year after meadow 5/	Wide Row	.35	.26	.16	.14	.12	.11	.08	.06	.04	.03
	Drill	.30	.21	.15	.13	.11	.10	.07	.06	.04	.03
SMALL GRAIN after Corn (Grain) 6/		.15	.14	.11	.10	.09	.08	.06	.05	.04	.03
SMALL GRAIN after Corn (Silage) 7/		.22	---	.22	---	---	---	.16	---	---	---
SMALL GRAIN after Soybeans 6/		.17	.15	.13	o .12	---	---	20% .10	30% .09	40% .08	3/

WHEAT/SOYBEANS (Double Crop)

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

.11
.25
.08
44
6

Meadow (Full year-Established)

Grass-Legume	.004
Legume only	.02 ←

USDA-SCS-Illinois
February, 1982 *

Footnotes for "C" Factor Tables

1. Values in this table are based on high level management with yields equal to or exceeding the following: corn - 100 bu/ac; soybeans - 40 bu/ac; wheat - 45 bu/ac; oats - 60 bu/ac; meadow - 3 tons/ac. For medium level management multiply factors by 1.2.

2. Values for chisel and disk systems are for fall primary tillage and two secondary tillage operations prior to planting. For primary tillage in the spring and ridge planting up and down hill multiply values by the appropriate factor: E.I. Curve 14-.9; E.I. Curve 16-.8; E.I. Curve 19-.7. For ridge planting on the contour, multiply values by the appropriate factor: E.I. Curve 14-.7; E.I. Curve 16-.6; E.I. Curve 19-.5. (These factors are in addition to the appropriate "P" factor.) Ridge planting is applicable only for row crops following row crops.

3. Percentages apply only to crops following soybeans.

4. Values are based on sod or a grass-legume mixture consisting of at least 50% grass and has been established at least one full growing season. If meadow stand is primarily legume, multiply factor by 1.2.

5. Use wide row factors for row widths greater than 20 inches and drill factors for 20 inches and less.

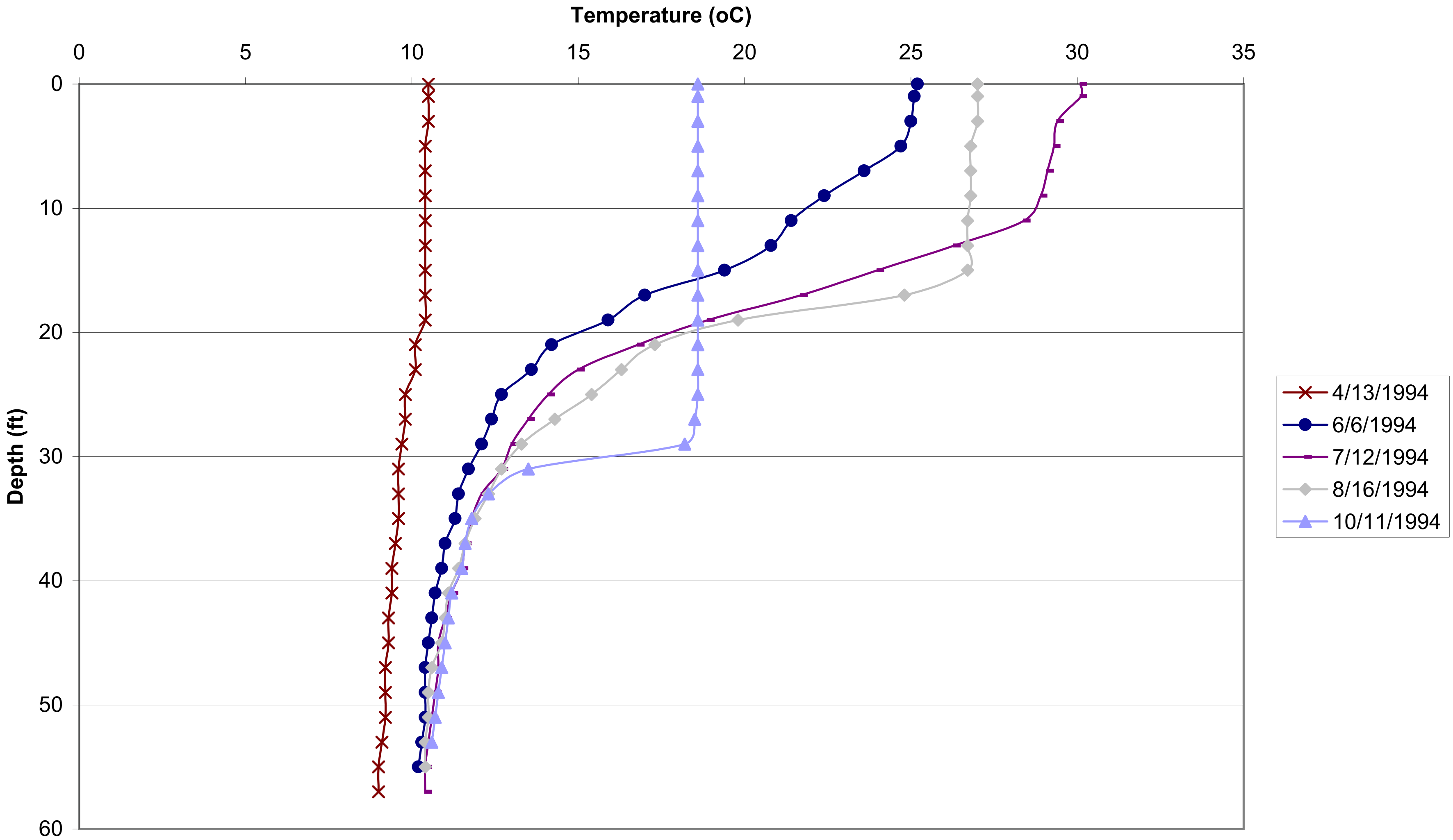
6. The same factors are applicable for both small grain with and without meadow seedings.

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

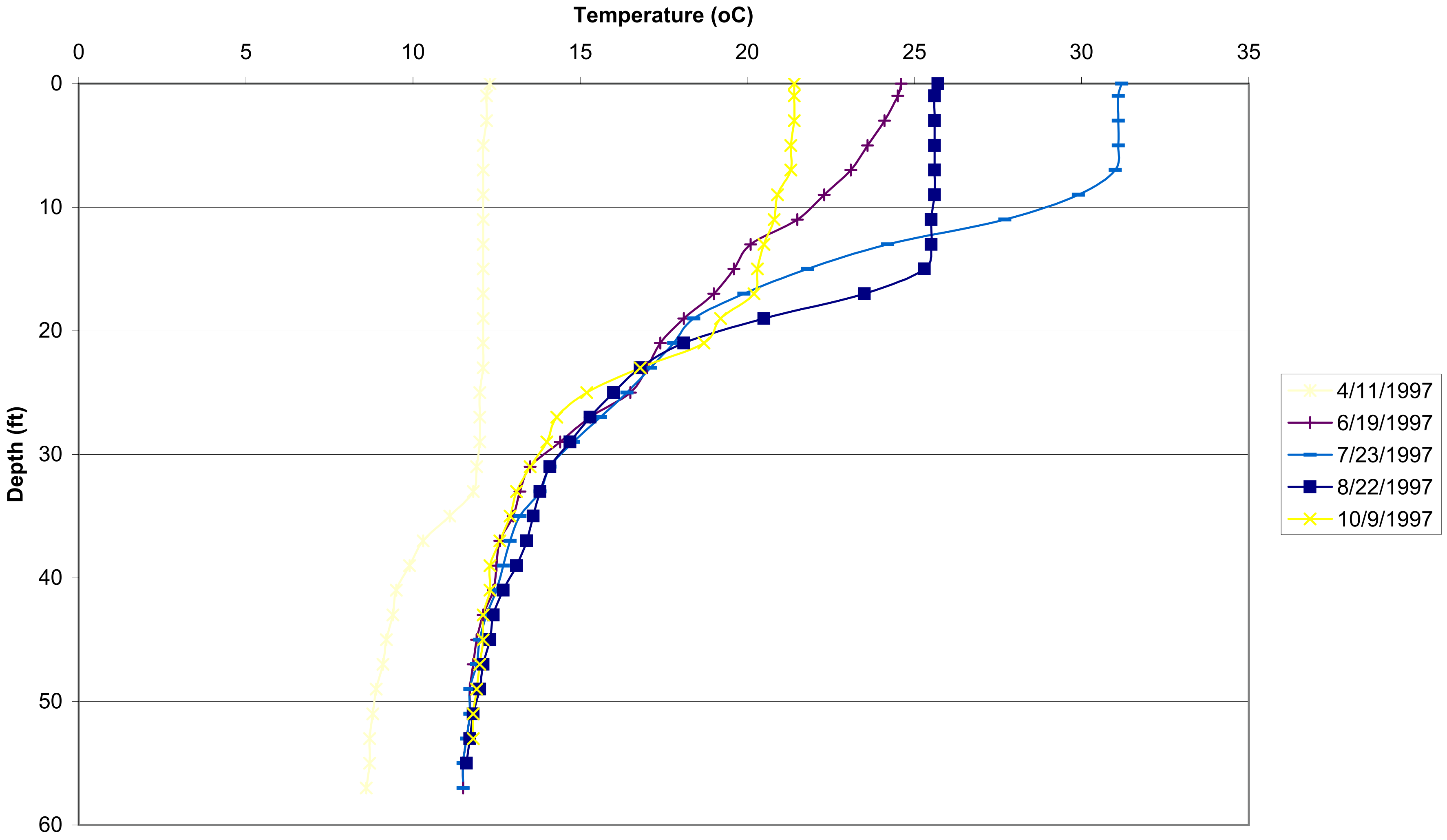
RLD:tm:6/7

Appendix G
Metalimnion Charts

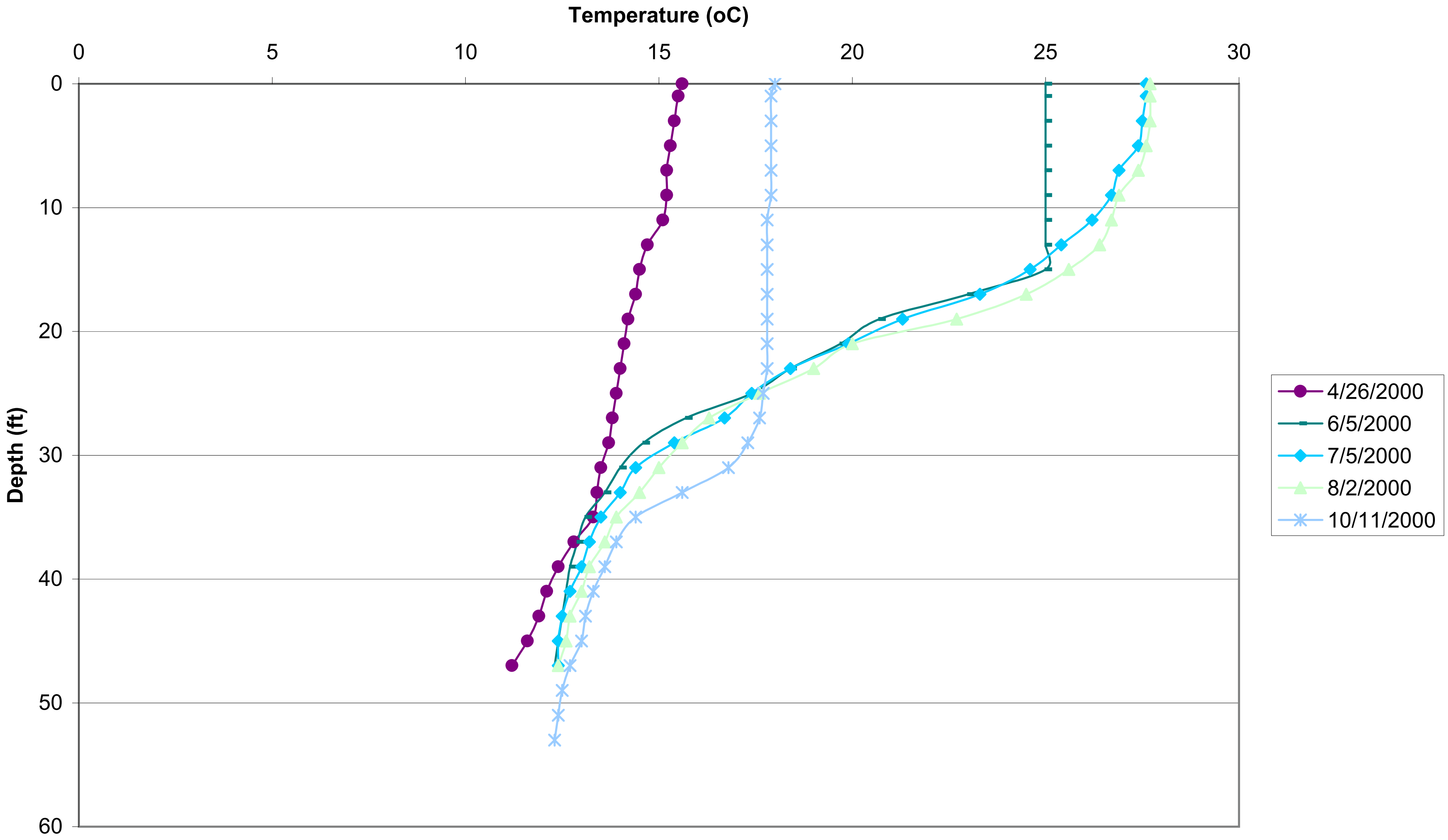
1994 Temperature Profile
Kinkaid Lake (RNC-1)



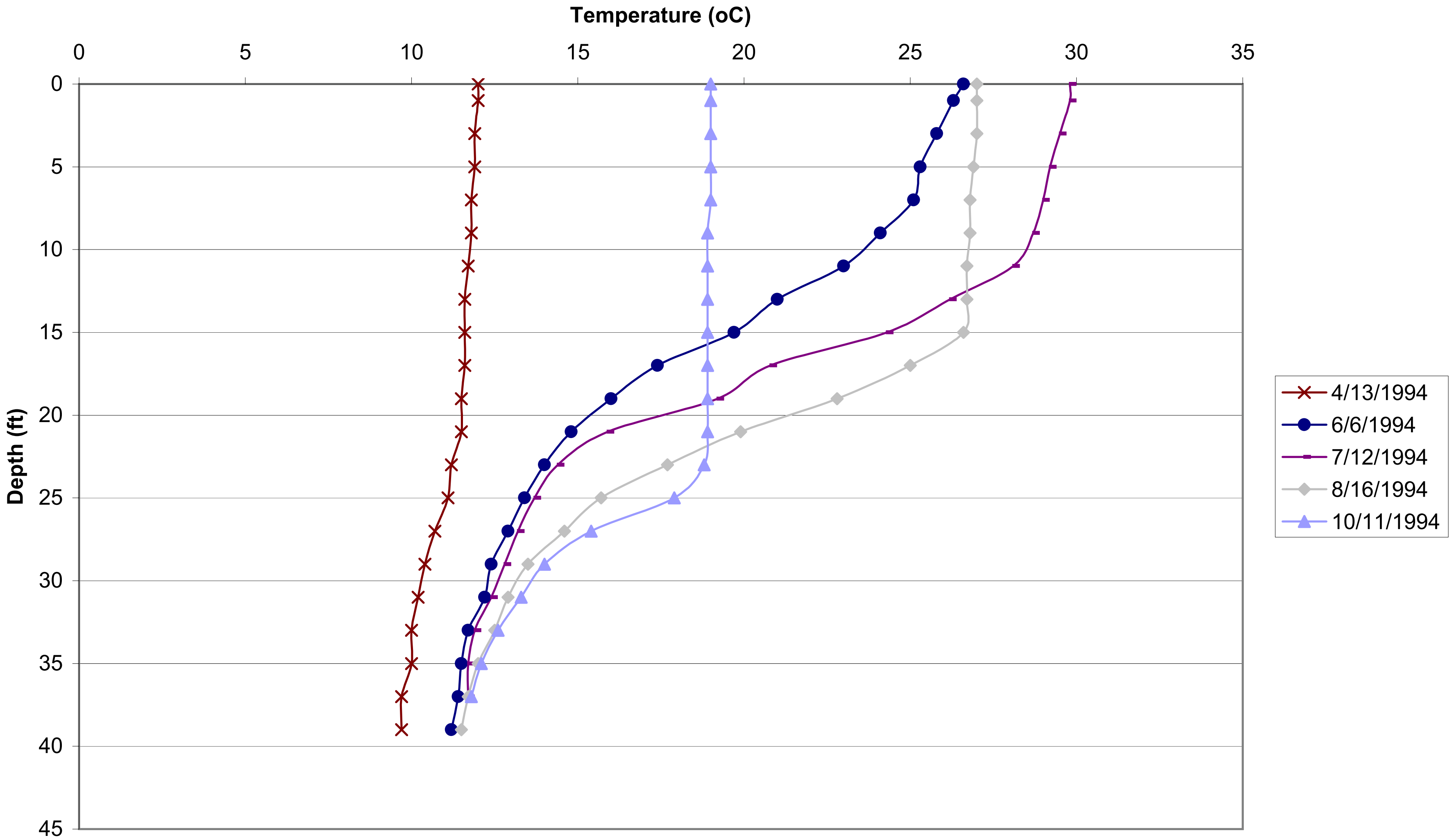
1997 Temperature Profile
Kinkaid Lake (RNC-1)



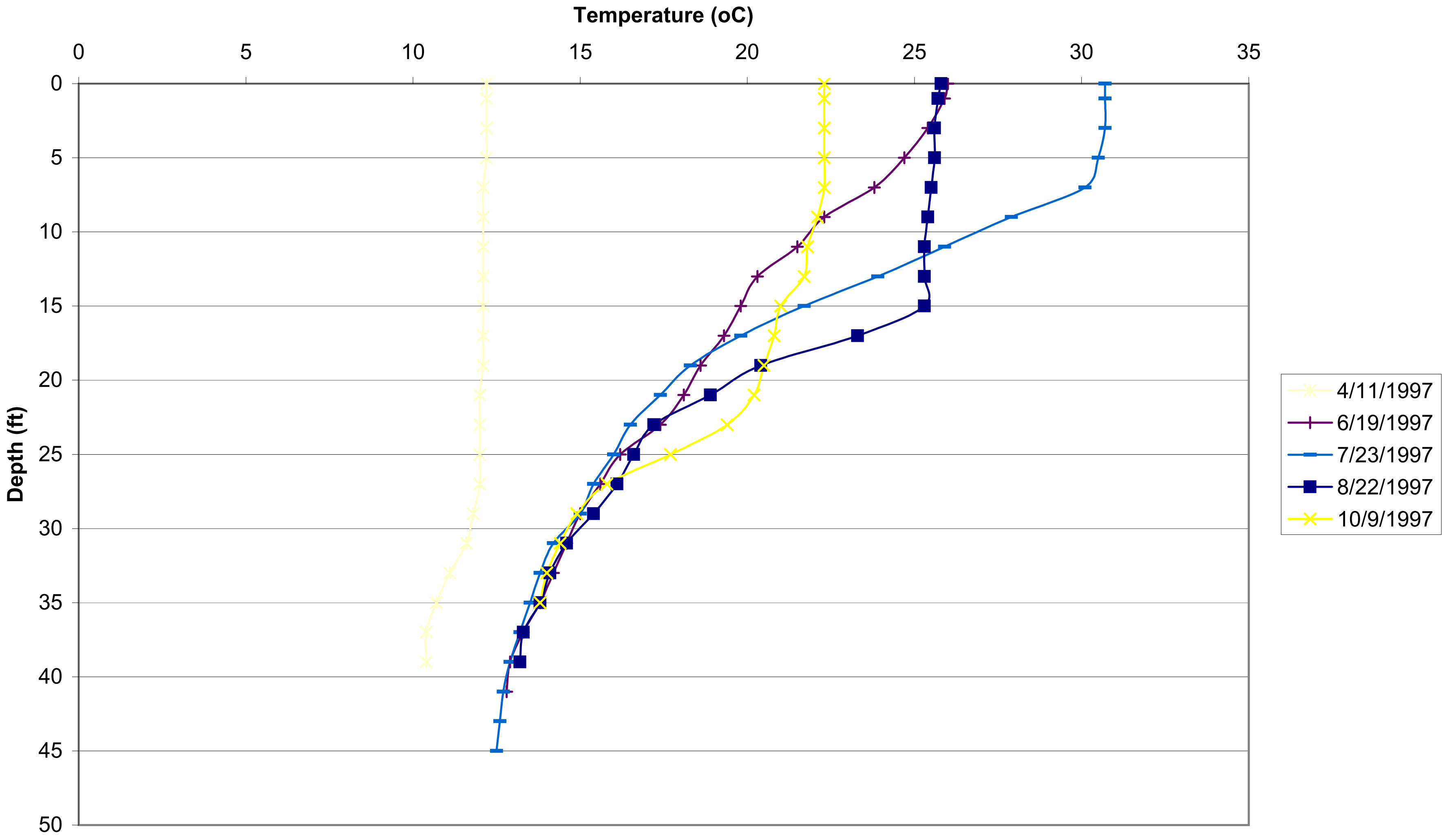
2000 Temperature Profile
Kinkaid Lake (RNC-1)



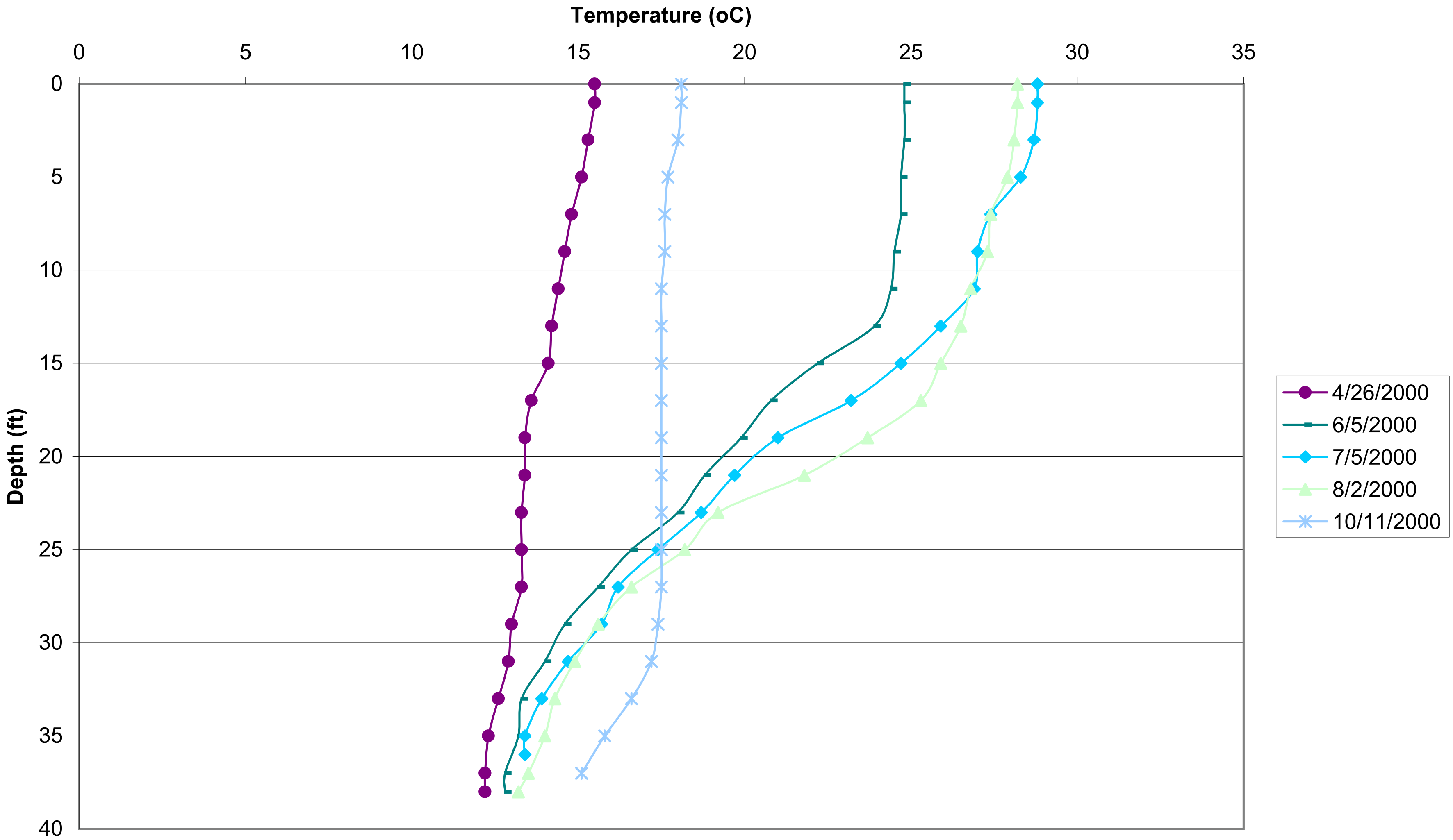
1994 Temperature Profile
Kincaid Lake (RNC-2)



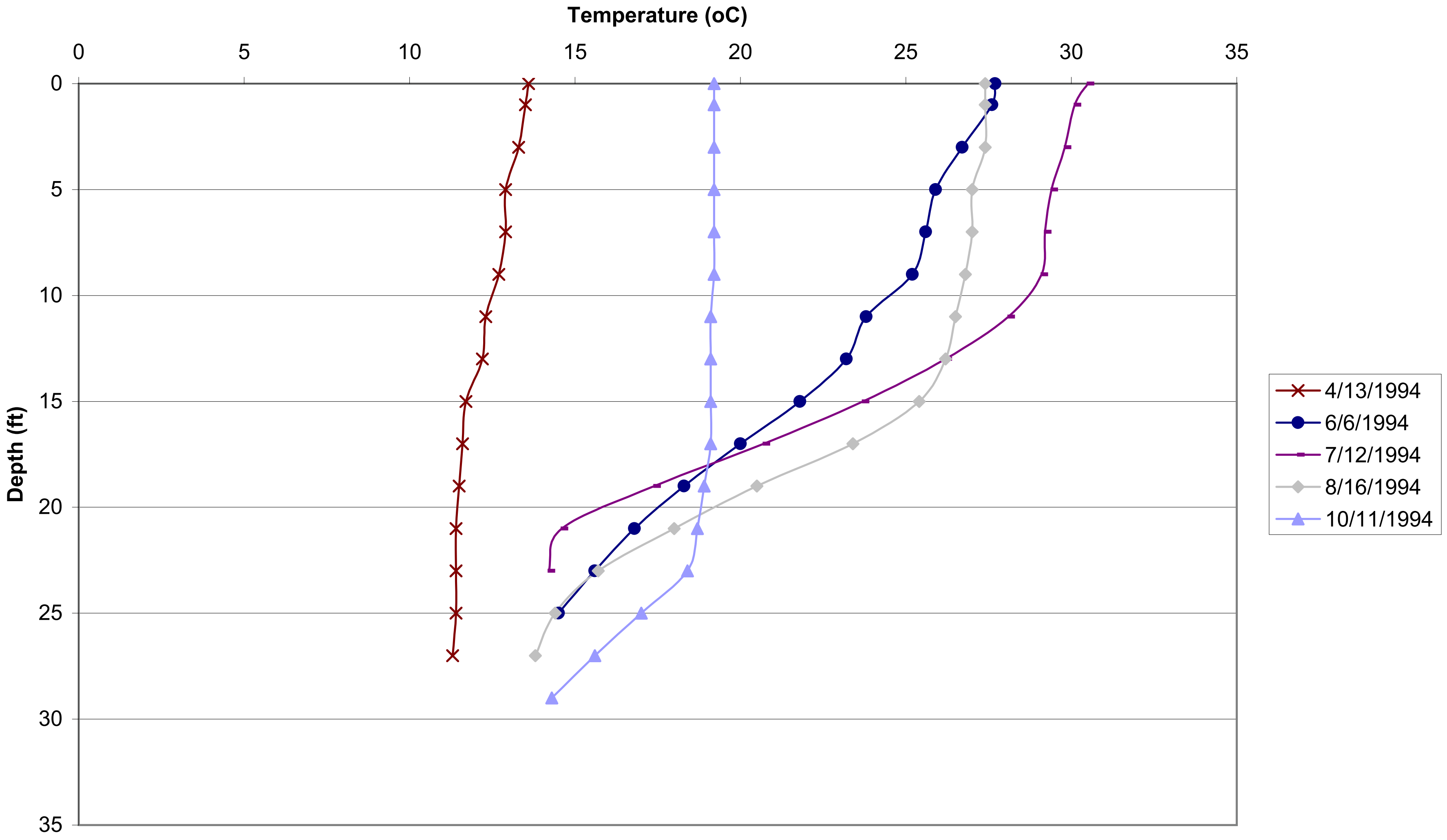
1997 Temperature Profile
Kincaid Lake (RNC-2)



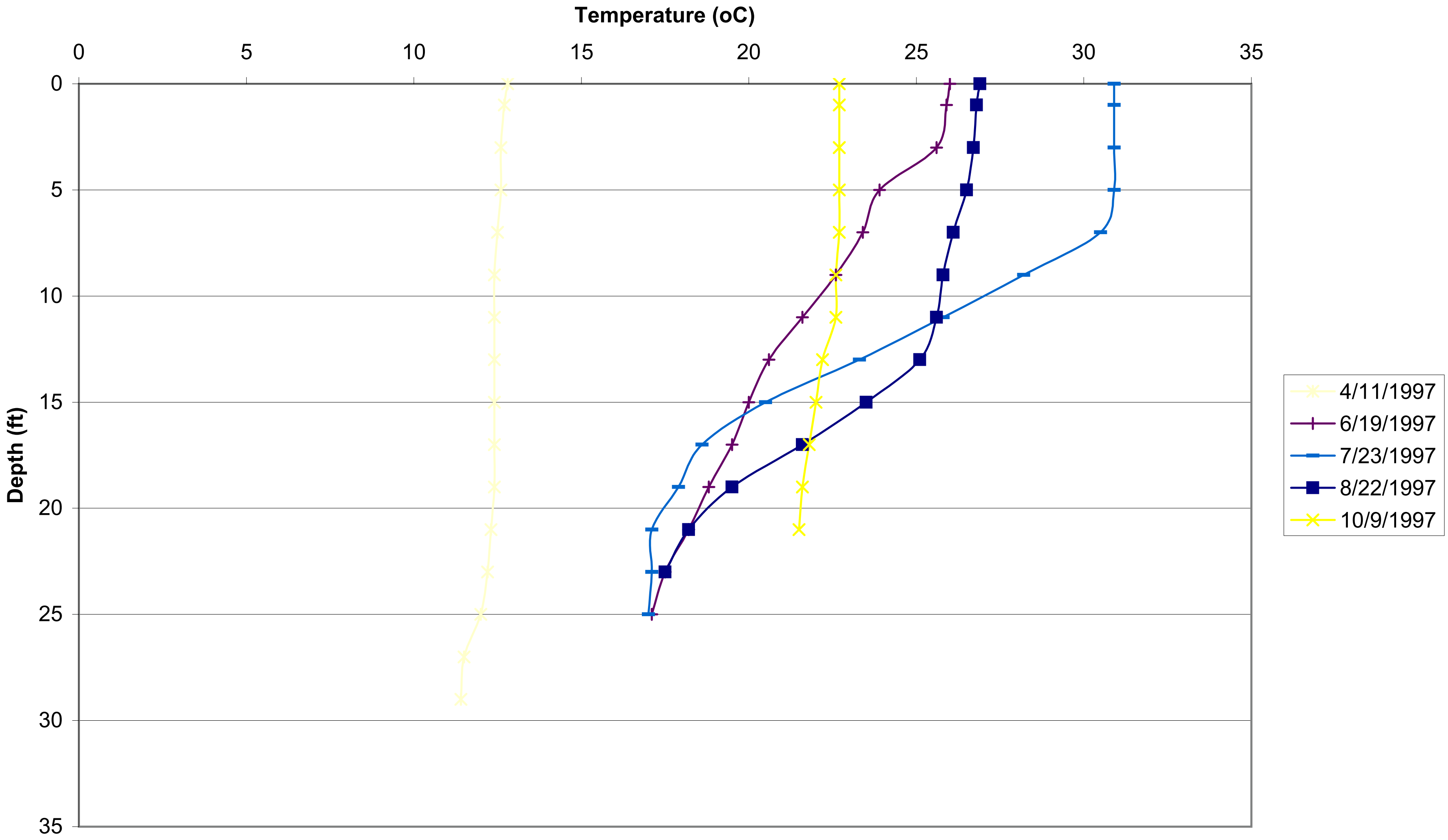
2000 Temperature Profile
Kincaid Lake (RNC-2)



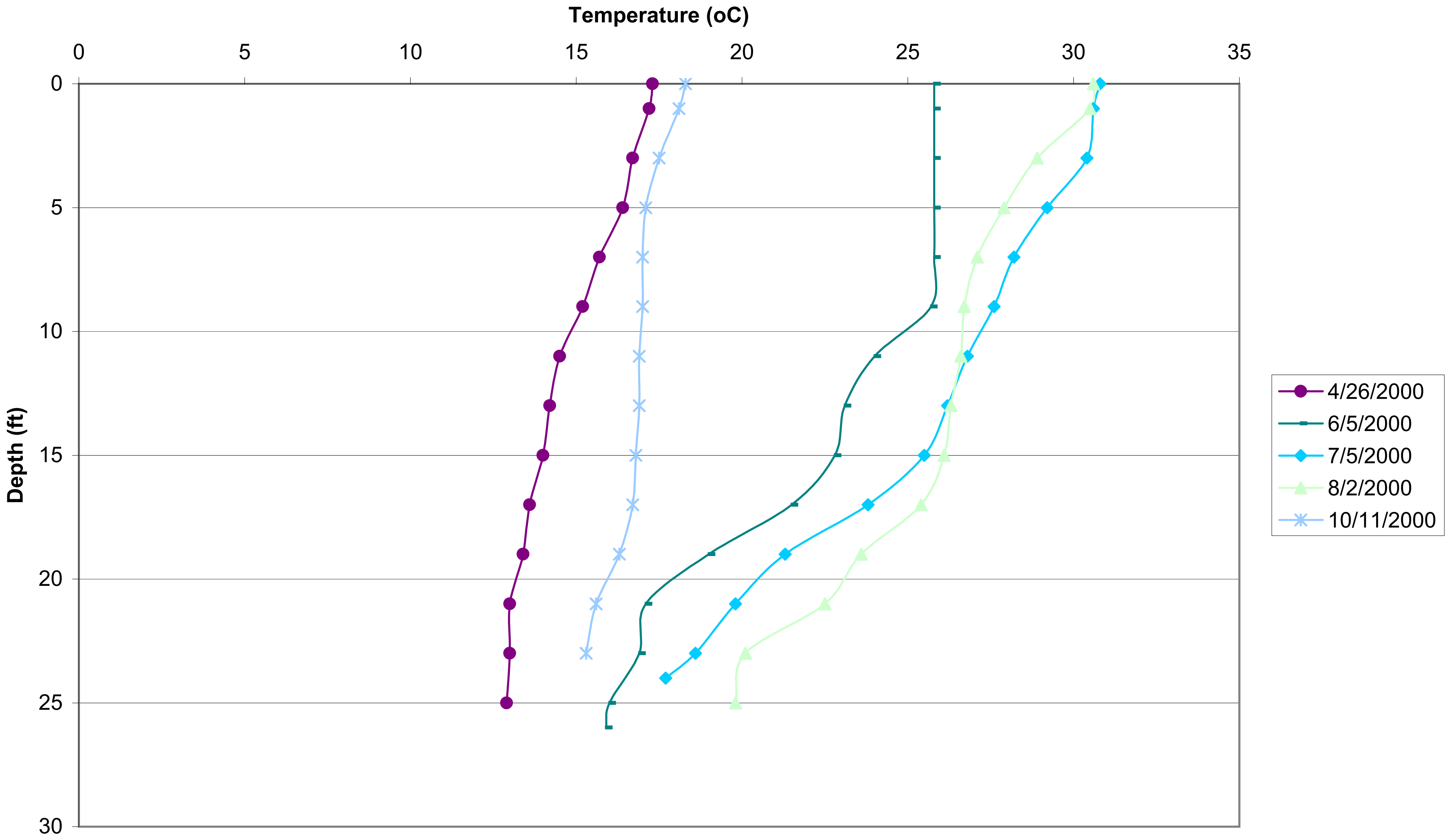
1994 Temperature Profile
Kincaid Lake (RNC-3)



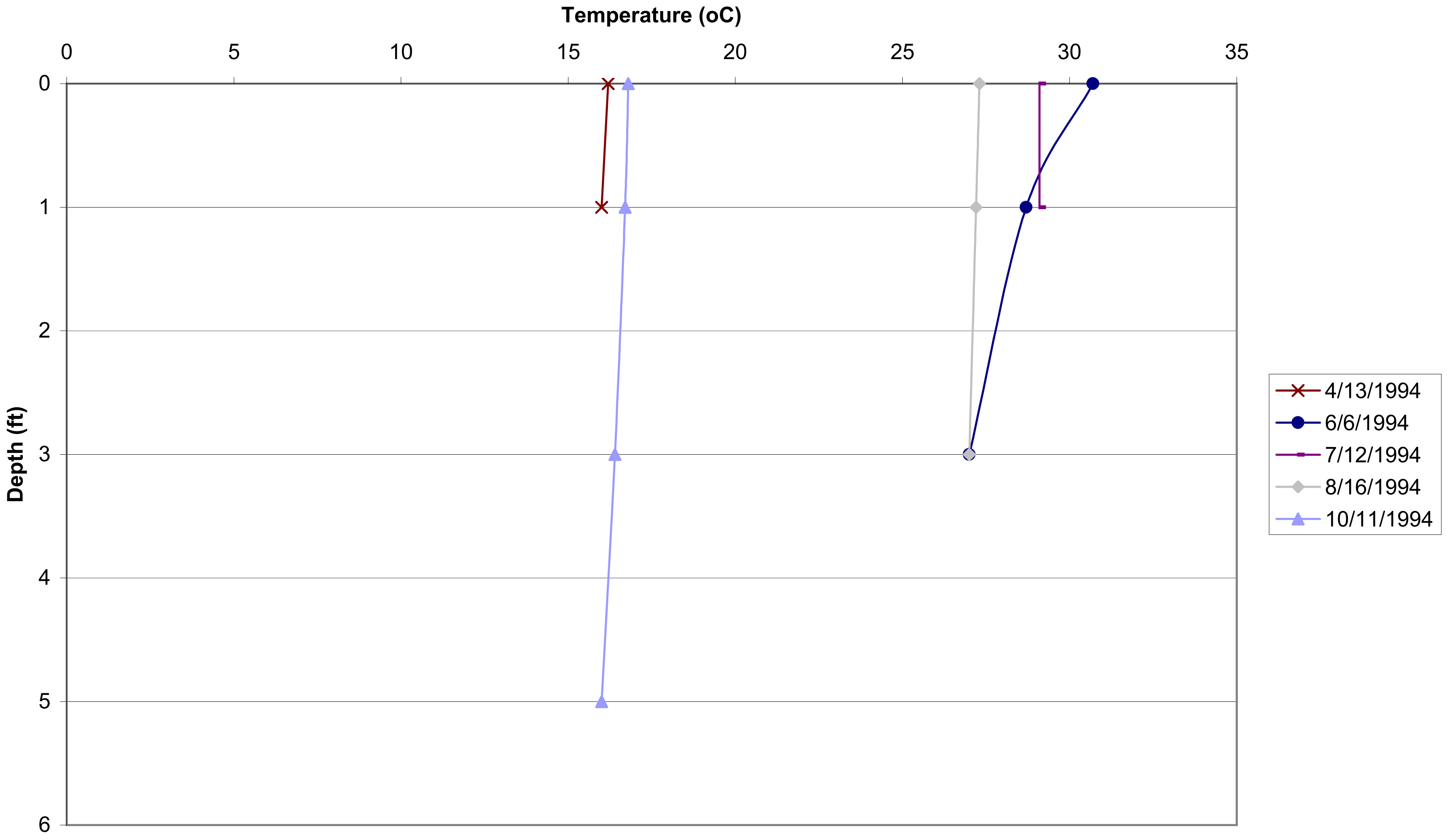
1997 Temperature Profile
Kincaid Lake (RNC-3)



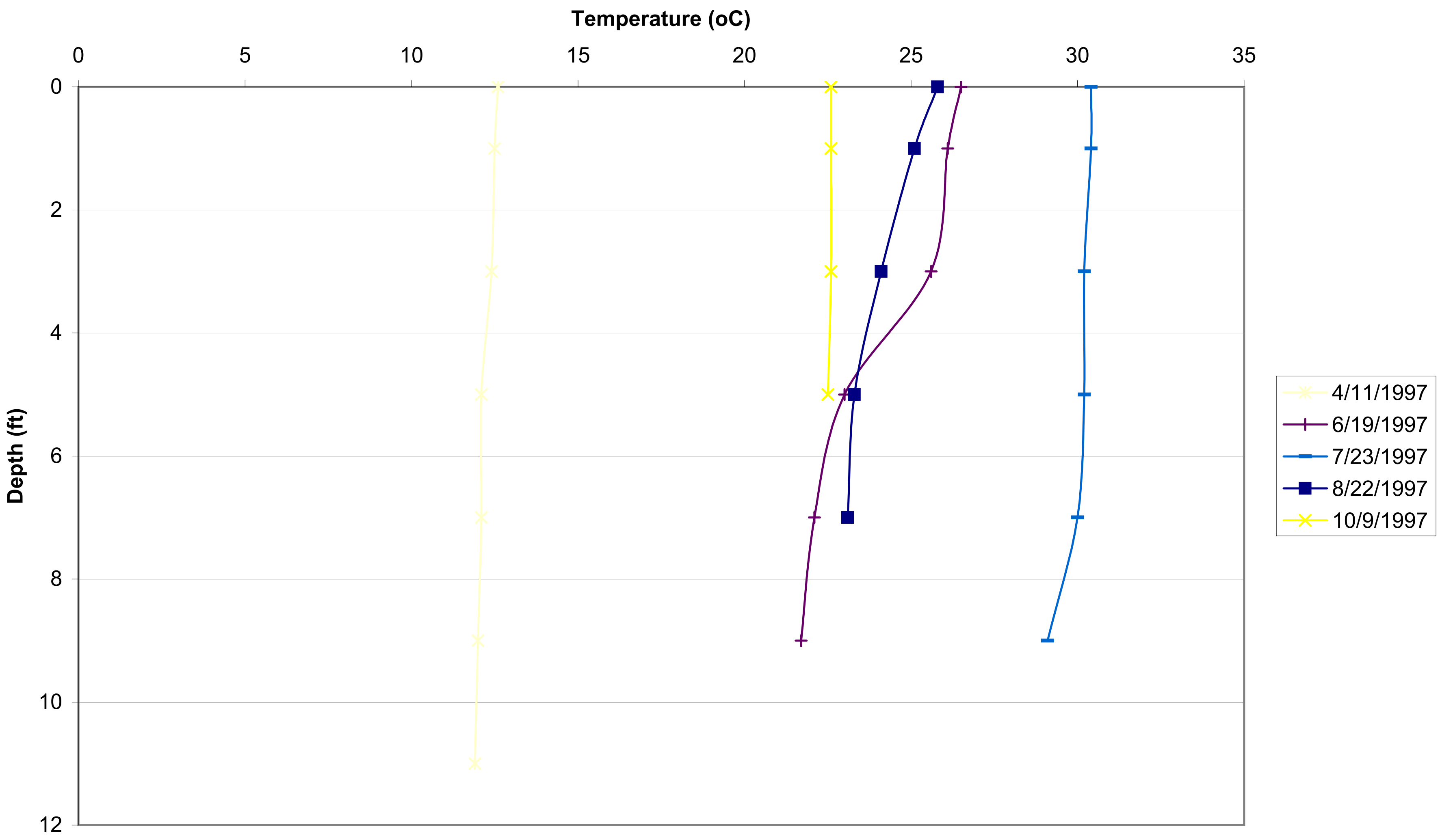
2000 Temperature Profile
Kincaid Lake (RNC-3)



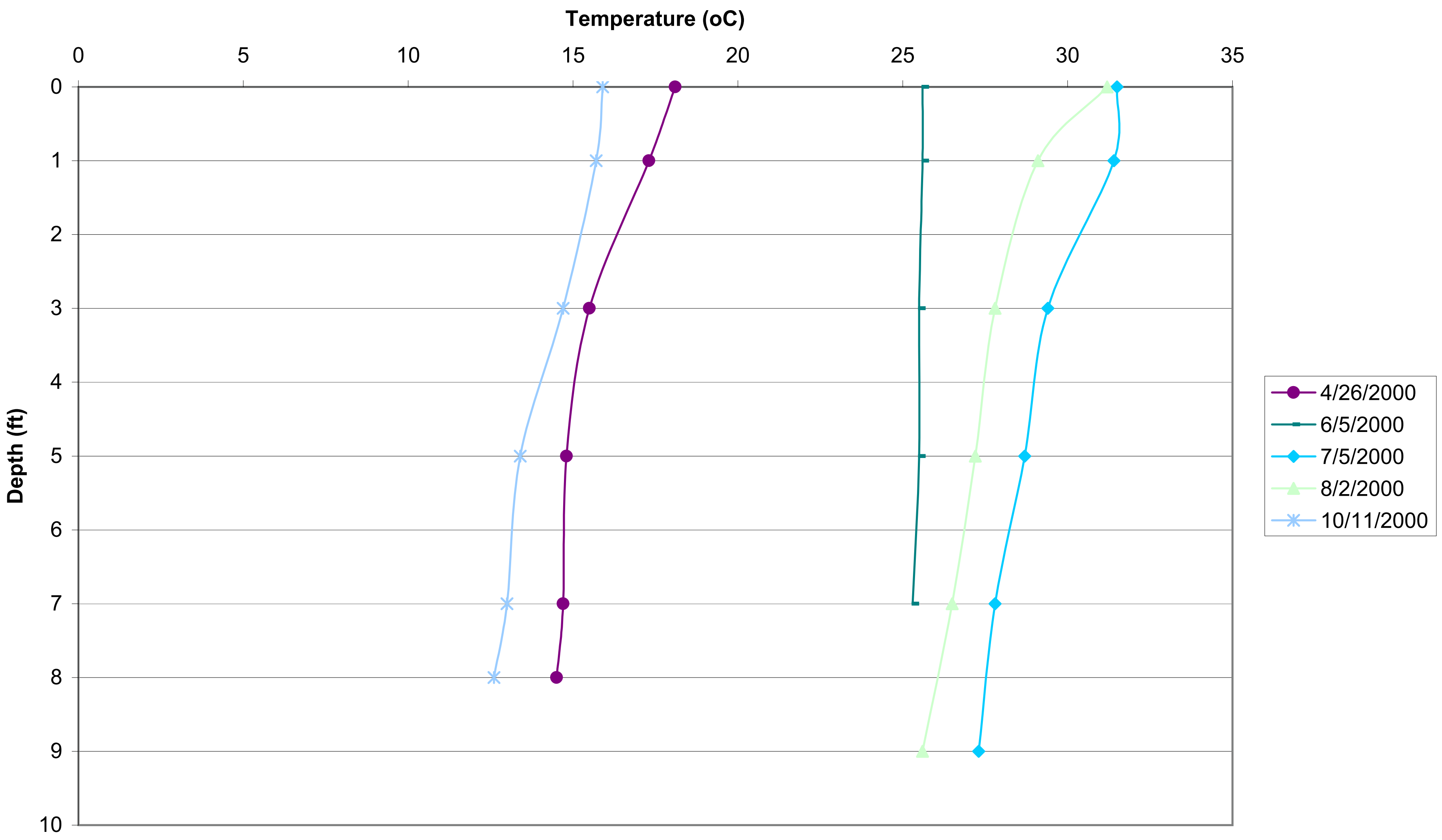
1994 Temperature Profile
Kincaid Lake (RNC-4)



1997 Temperature Profile
Kincaid Lake (RNC-4)



2000 Temperature Profile
Kincaid Lake (RNC-4)



Appendix H
Sensitivity Analysis - BATHTUB Output Files

H.1 BATHTUB Sensitivity

This appendix provides the BATHTUB output files for the soil phosphorus sensitivity analysis. For each modeled year, the BATHTUB model was run with soil phosphorus values of 440 ppm and 660 ppm. The output concentrations from BATHTUB were not calibrated so that the raw model results could be compared.

BATHTUB Output for 1994 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

```
CASE: Kinkaid 1994 - Sed 440
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3   135.4   .29    88.9   .48    1.52   1.44   1.56    .75
 CHL-A      MG/M3    52.1   .56    50.7   .59    1.03    .05    .08    .03
 SECCHI         M      .4   .72      .5   .67     .98   -.02   -.06   -.02
 ORGANIC N  MG/M3      .0   .00  1381.7   .47     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00   108.0   .45     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    36.8   .73    49.8   .45     .74   -.41  -1.13   -.35
 CHL-A      MG/M3    24.3   .44    17.5   .65    1.39    .75    .95    .42
 SECCHI         M     1.3   .67     1.7   .66     .77   -.38   -.91   -.27
 ORGANIC N  MG/M3      .0   .00   566.7   .41     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    30.5   .43     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    22.2   .46    30.4   .45     .73   -.69  -1.17   -.49
 CHL-A      MG/M3    23.4   .44    13.0   .64    1.80   1.32   1.69    .76
 SECCHI         M     1.6   .59     2.5   .86     .64   -.76  -1.59   -.43
 ORGANIC N  MG/M3      .0   .00   460.1   .38     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    21.0   .54     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    25.2   .53    16.2   .46    1.55    .83   1.64    .63
 CHL-A      MG/M3    19.1   .52     5.9   .72    3.24   2.24   3.39   1.32
 SECCHI         M     1.9   .65     4.4  1.98     .43  -1.30  -3.01   -.40
 ORGANIC N  MG/M3      .0   .00   297.7   .38     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00     8.3  1.65     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    36.7   .48    31.0   .45    1.18    .35    .63    .26
 CHL-A      MG/M3    23.6   .50    13.1   .54    1.81   1.18   1.71    .80
 SECCHI         M     1.6   .64     3.3  1.56     .49  -1.10  -2.52   -.42
 ORGANIC N  MG/M3      .0   .00   467.5   .36     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    23.1   .61     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 1994 - Sed 440
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       32.800  .000E+00  .000        .364
 2  1 Subbasin 2             25.100       10.000  .000E+00  .000        .398
 3  1 Subbasin 3             10.400        4.700  .000E+00  .000        .452
 4  1 Subbasin 4             31.100       15.400  .000E+00  .000        .495
----------------------------------------------------------------------------
PRECIPITATION                 9.509       10.555  .446E+01  .200       1.110
TRIBUTARY INFLOW            156.700       62.900  .000E+00  .000        .401
***TOTAL INFLOW             166.209       73.455  .446E+01  .029        .442
ADVECTIVE OUTFLOW           166.209       65.448  .102E+02  .049        .394
***TOTAL OUTFLOW            166.209       65.448  .102E+02  .049        .394
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---         CONC  EXPORT
ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            3899.9   67.4  .000E+00     .0  .000   118.9    43.3
 2 1 Subbasin 2             600.0   10.4  .000E+00     .0  .000    60.0    23.9
 3 1 Subbasin 3             198.8    3.4  .000E+00     .0  .000    42.3    19.1
 4 1 Subbasin 4             802.3   13.9  .000E+00     .0  .000    52.1    25.8
-------------------------------------------------------------------------------
PRECIPITATION               285.3    4.9  .203E+05  100.0  .500    27.0    30.0
TRIBUTARY INFLOW           5501.1   95.1  .000E+00     .0  .000    87.5    35.1
***TOTAL INFLOW            5786.3  100.0  .203E+05  100.0  .025    78.8    34.8
ADVECTIVE OUTFLOW          1062.1   18.4  .236E+06 1158.9  .457    16.2     6.4
***TOTAL OUTFLOW           1062.1   18.4  .236E+06 1158.9  .457    16.2     6.4
***RETENTION               4724.2   81.6  .249E+06 1223.5  .106      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P  --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME      RATIO      COEF
     M/YR       YRS     MG/M3       YRS        -         -
     6.88    1.9902      36.7     .8252    1.2118     .8164
```

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

```
CASE: Kinkaid 1994 - No Calibration
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------

 TOTAL P    MG/M3   135.4   .29   105.9   .48    1.28    .84    .91    .44
 CHL-A      MG/M3    52.1   .56    58.7   .57     .89   -.21   -.34   -.15
 SECCHI         M      .4   .72      .4   .60    1.07    .10    .26    .08
 ORGANIC N  MG/M3      .0   .00  1564.9   .46     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00   122.3   .43     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------

 TOTAL P    MG/M3    36.8   .73    56.2   .45     .65   -.58  -1.57   -.49
 CHL-A      MG/M3    24.3   .44    18.8   .63    1.29    .58    .74    .33
 SECCHI         M     1.3   .67     1.6   .60     .82   -.30   -.71   -.22
 ORGANIC N  MG/M3      .0   .00   597.1   .42     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    32.9   .42     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------

 TOTAL P    MG/M3    22.2   .46    33.1   .45     .67   -.87  -1.48   -.62
 CHL-A      MG/M3    23.4   .44    14.0   .63    1.67   1.16   1.49    .67
 SECCHI         M     1.6   .59     2.3   .80     .68   -.66  -1.39   -.39
 ORGANIC N  MG/M3      .0   .00   482.0   .39     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    22.7   .52     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------

 TOTAL P    MG/M3    25.2   .53    17.9   .46    1.41    .64   1.28    .49
 CHL-A      MG/M3    19.1   .52     6.7   .72    2.84   1.99   3.02   1.17
 SECCHI         M     1.9   .65     4.0  1.84     .47  -1.17  -2.70   -.39
 ORGANIC N  MG/M3      .0   .00   316.4   .40     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00     9.8  1.47     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------

 TOTAL P    MG/M3    36.7   .48    35.0   .45    1.05    .10    .17    .07
 CHL-A      MG/M3    23.6   .50    14.6   .53    1.61    .95   1.39    .66
 SECCHI         M     1.6   .64     3.0  1.44     .54   -.97  -2.23   -.40
 ORGANIC N  MG/M3      .0   .00   503.4   .36     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    25.9   .58     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 1994 - No Calibration
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----       RUNOFF
ID  T LOCATION                  KM2          MEAN  VARIANCE    CV         M/YR
-----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100        32.800  .000E+00  .000         .364
 2  1 Subbasin 2             25.100        10.000  .000E+00  .000         .398
 3  1 Subbasin 3             10.400         4.700  .000E+00  .000         .452
 4  1 Subbasin 4             31.100        15.400  .000E+00  .000         .495
-----------------------------------------------------------------------------
PRECIPITATION                 9.509        10.555  .446E+01  .200        1.110
TRIBUTARY INFLOW            156.700        62.900  .000E+00  .000         .401
***TOTAL INFLOW             166.209        73.455  .446E+01  .029         .442
ADVECTIVE OUTFLOW           166.209        65.448  .102E+02  .049         .394
***TOTAL OUTFLOW            166.209        65.448  .102E+02  .049         .394
***EVAPORATION                 .000         8.007  .577E+01  .300         .000
-----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---         CONC  EXPORT
ID T LOCATION                 KG/YR   %(I)  KG/YR**2   %(I)    CV  MG/M3  KG/KM2
--------------------------------------------------------------------------------
 1 1 Subbasin 1              4798.6   67.7  .000E+00     .0  .000  146.3    53.3
 2 1 Subbasin 2               700.0    9.9  .000E+00     .0  .000   70.0    27.9
 3 1 Subbasin 3               198.8    2.8  .000E+00     .0  .000   42.3    19.1
 4 1 Subbasin 4              1102.6   15.6  .000E+00     .0  .000   71.6    35.5
--------------------------------------------------------------------------------
PRECIPITATION                 285.3    4.0  .203E+05  100.0  .500   27.0    30.0
TRIBUTARY INFLOW             6800.1   96.0  .000E+00     .0  .000  108.1    43.4
***TOTAL INFLOW              7085.4  100.0  .203E+05  100.0  .020   96.5    42.6
ADVECTIVE OUTFLOW            1170.7   16.5  .286E+06 1405.4  .457   17.9     7.0
***TOTAL OUTFLOW             1170.7   16.5  .286E+06 1405.4  .457   17.9     7.0
***RETENTION                 5914.7   83.5  .300E+06 1472.9  .093     .0      .0
--------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P  --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME     RATIO      COEF
     M/YR       YRS     MG/M3       YRS         -         -
     6.88    1.9902      36.7     .6739    1.4839     .8348
```

BATHTUB Output for 1997 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

```
CASE: Kinkaid 1997 - Sed 400
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3   129.6   .56    96.1   .45    1.35    .53   1.11    .41
 CHL-A      MG/M3    48.9   .57    19.5   .49    2.51   1.62   2.66   1.23
 SECCHI         M      .3   .34      .4   .45     .79   -.70   -.85   -.42
 ORGANIC N  MG/M3      .0   .00   769.3   .25     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    83.6   .33     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    44.6   .23    47.0   .45     .95   -.23   -.19   -.10
 CHL-A      MG/M3    27.5   .38    16.3   .49    1.68   1.35   1.50    .84
 SECCHI         M      .9   .26     1.2   .42     .75  -1.11  -1.03   -.59
 ORGANIC N  MG/M3      .0   .00   561.2   .32     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    34.9   .39     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    27.2   .26    28.6   .45     .95   -.19   -.19   -.10
 CHL-A      MG/M3    19.4   .45     8.7   .53    2.22   1.79   2.31   1.16
 SECCHI         M     1.1   .26     1.7   .46     .69  -1.40  -1.30   -.69
 ORGANIC N  MG/M3      .0   .00   385.4   .28     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    20.6   .42     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    42.5  1.09    16.7   .45    2.54    .85   3.47    .79
 CHL-A      MG/M3    13.2   .40     5.1   .59    2.57   2.39   2.73   1.34
 SECCHI         M     1.3   .30     1.8   .44     .74  -1.03  -1.09   -.57
 ORGANIC N  MG/M3      .0   .00   307.2   .24     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    15.4   .46     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    48.3   .75    31.1   .45    1.55    .59   1.64    .50
 CHL-A      MG/M3    19.9   .44     9.0   .47    2.21   1.82   2.30   1.23
 SECCHI         M     1.1   .29     1.5   .34     .73  -1.08  -1.11   -.70
 ORGANIC N  MG/M3      .0   .00   406.4   .26     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    25.8   .34     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 1997 - Sed 400
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       36.500  .000E+00  .000        .405
 2  1 Subbasin 2             25.100       10.900  .000E+00  .000        .434
 3  1 Subbasin 3             10.400        5.100  .000E+00  .000        .490
 4  1 Subbasin 4             31.100       16.600  .000E+00  .000        .534
----------------------------------------------------------------------------
PRECIPITATION                 9.509       11.886  .565E+01  .200       1.250
TRIBUTARY INFLOW            156.700       69.100  .000E+00  .000        .441
***TOTAL INFLOW             166.209       80.986  .565E+01  .029        .487
ADVECTIVE OUTFLOW           166.209       72.980  .114E+02  .046        .439
***TOTAL OUTFLOW            166.209       72.980  .114E+02  .046        .439
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
ID T LOCATION                KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1             4898.3   68.2  .000E+00     .0  .000   134.2    54.4
 2 1 Subbasin 2              698.7    9.7  .000E+00     .0  .000    64.1    27.8
 3 1 Subbasin 3              199.9    2.8  .000E+00     .0  .000    39.2    19.2
 4 1 Subbasin 4             1097.3   15.3  .000E+00     .0  .000    66.1    35.3
-------------------------------------------------------------------------------
PRECIPITATION                285.3    4.0  .203E+05  100.0  .500    24.0    30.0
TRIBUTARY INFLOW            6894.2   96.0  .000E+00     .0  .000    99.8    44.0
***TOTAL INFLOW             7179.4  100.0  .203E+05  100.0  .020    88.7    43.2
ADVECTIVE OUTFLOW           1220.4   17.0  .307E+06 1511.3  .454    16.7     7.3
***TOTAL OUTFLOW            1220.4   17.0  .307E+06 1511.3  .454    16.7     7.3
***RETENTION                5959.0   83.0  .320E+06 1575.0  .095      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME     RATIO      COEF
     M/YR       YRS     MG/M3       YRS        -         -
     7.67    1.8016      48.3     .8848    1.1303     .8300
```

1997 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

```
CASE: Kinkaid 1997 - No Calibration
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3   129.6   .56   110.9   .45    1.17    .28    .58    .22
 CHL-A      MG/M3    48.9   .57    21.0   .47    2.33   1.49   2.45   1.14
 SECCHI         M      .3   .34      .4   .44     .80   -.66   -.81   -.41
 ORGANIC N  MG/M3      .0   .00   803.8   .24     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    86.3   .31     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    44.6   .23    53.7   .45     .83   -.82   -.69   -.37
 CHL-A      MG/M3    27.5   .38    18.0   .47    1.53   1.10   1.22    .70
 SECCHI         M      .9   .26     1.2   .40     .79   -.93   -.86   -.51
 ORGANIC N  MG/M3      .0   .00   599.0   .32     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    37.9   .38     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    27.2   .26    32.0   .45     .85   -.63   -.61   -.31
 CHL-A      MG/M3    19.4   .45     9.6   .51    2.02   1.58   2.03   1.04
 SECCHI         M     1.1   .26     1.6   .44     .72  -1.26  -1.18   -.64
 ORGANIC N  MG/M3      .0   .00   405.3   .28     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    22.2   .40     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    42.5  1.09    18.5   .45    2.30    .76   3.10    .70
 CHL-A      MG/M3    13.2   .40     5.7   .57    2.31   2.12   2.42   1.20
 SECCHI         M     1.3   .30     1.7   .43     .76   -.94  -1.00   -.54
 ORGANIC N  MG/M3      .0   .00   320.3   .25     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    16.5   .45     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    48.3   .75    35.2   .45    1.37    .42   1.18    .36
 CHL-A      MG/M3    19.9   .44     9.9   .45    2.01   1.60   2.02   1.11
 SECCHI         M     1.1   .29     1.5   .33     .76   -.98  -1.00   -.64
 ORGANIC N  MG/M3      .0   .00   427.0   .26     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    27.4   .34     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 1997 - No Calibration
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       36.500  .000E+00  .000        .405
 2  1 Subbasin 2             25.100       10.900  .000E+00  .000        .434
 3  1 Subbasin 3             10.400        5.100  .000E+00  .000        .490
 4  1 Subbasin 4             31.100       16.600  .000E+00  .000        .534
----------------------------------------------------------------------------
PRECIPITATION                 9.509       11.886  .565E+01  .200       1.250
TRIBUTARY INFLOW            156.700       69.100  .000E+00  .000        .441
***TOTAL INFLOW             166.209       80.986  .565E+01  .029        .487
ADVECTIVE OUTFLOW           166.209       72.980  .114E+02  .046        .439
***TOTAL OUTFLOW            166.209       72.980  .114E+02  .046        .439
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
ID T LOCATION                   KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            5898.4   65.7  .000E+00     .0  .000   161.6    65.5
 2 1 Subbasin 2            1097.6   12.2  .000E+00     .0  .000   100.7    43.7
 3 1 Subbasin 3             299.9    3.3  .000E+00     .0  .000    58.8    28.8
 4 1 Subbasin 4            1397.7   15.6  .000E+00     .0  .000    84.2    44.9
-------------------------------------------------------------------------------
PRECIPITATION               285.3    3.2  .203E+05  100.0  .500    24.0    30.0
TRIBUTARY INFLOW           8693.6   96.8  .000E+00     .0  .000   125.8    55.5
***TOTAL INFLOW            8978.9  100.0  .203E+05  100.0  .016   110.9    54.0
ADVECTIVE OUTFLOW          1348.7   15.0  .375E+06 1844.8  .454    18.5     8.1
***TOTAL OUTFLOW           1348.7   15.0  .375E+06 1844.8  .454    18.5     8.1
***RETENTION               7630.2   85.0  .389E+06 1911.5  .082      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME     RATIO      COEF
     M/YR       YRS     MG/M3       YRS        -         -
     7.67    1.8016      48.3     .7074    1.4135     .8498
```

BATHTUB Output for 2000 Sensitivity Analysis

Constant Sediment Phosphorus Concentration of 440 mg/kg

```
CASE: Kinkaid 2000 - Sed 440
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN     CV    MEAN     CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    54.8   .33   124.0   .45     .44  -2.46  -3.04  -1.46
 CHL-A      MG/M3    38.0   .40    21.4   .35    1.78   1.44   1.66   1.08
 SECCHI         M      .3   .12      .4   .21     .86  -1.26   -.55   -.63
 ORGANIC N  MG/M3      .0   .00   790.8   .23     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    80.1   .23     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN     CV    MEAN     CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    21.2   .10    57.9   .45     .37 -10.36  -3.74  -2.17
 CHL-A      MG/M3    16.4   .40    13.8   .44    1.18    .43    .49    .29
 SECCHI         M      .9   .34     1.0   .35     .94   -.18   -.22   -.13
 ORGANIC N  MG/M3      .0   .00   521.9   .27     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    36.0   .31     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN     CV    MEAN     CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    12.4   .07    35.4   .45     .35 -14.58  -3.90  -2.30
 CHL-A      MG/M3    12.6   .38    11.1   .47    1.14    .33    .37    .21
 SECCHI         M     1.4   .29     1.5   .35     .95   -.19   -.20   -.12
 ORGANIC N  MG/M3      .0   .00   440.7   .29     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    25.1   .39     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN     CV    MEAN     CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    29.0  1.14    21.8   .45    1.33    .25   1.05    .23
 CHL-A      MG/M3    18.4  1.24     8.8   .72    2.08    .59   2.12    .51
 SECCHI         M     1.8   .24     3.1  1.94     .57  -2.32  -1.98   -.28
 ORGANIC N  MG/M3      .0   .00   365.7   .45     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    14.0  1.39     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN     CV    MEAN     CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    27.4   .77    39.6   .45     .69   -.48  -1.37   -.41
 CHL-A      MG/M3    18.9   .87    11.2   .53    1.69    .60   1.51    .52
 SECCHI         M     1.4   .26     2.2  1.57     .65  -1.70  -1.56   -.28
 ORGANIC N  MG/M3      .0   .00   443.3   .33     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    25.6   .56     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 2000 - Sed 440
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       38.000  .000E+00  .000        .422
 2  1 Subbasin 2             25.100       11.300  .000E+00  .000        .450
 3  1 Subbasin 3             10.400        5.300  .000E+00  .000        .510
 4  1 Subbasin 4             31.100       17.400  .000E+00  .000        .559
----------------------------------------------------------------------------
PRECIPITATION                 9.509       12.267  .602E+01  .200       1.290
TRIBUTARY INFLOW            156.700       72.000  .000E+00  .000        .459
***TOTAL INFLOW             166.209       84.267  .602E+01  .029        .507
ADVECTIVE OUTFLOW           166.209       76.260  .118E+02  .045        .459
***TOTAL OUTFLOW            166.209       76.260  .118E+02  .045        .459
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            7311.2   64.7  .000E+00     .0  .000   192.4    81.1
 2 1 Subbasin 2            1200.1   10.6  .000E+00     .0  .000   106.2    47.8
 3 1 Subbasin 3             499.8    4.4  .000E+00     .0  .000    94.3    48.1
 4 1 Subbasin 4            2002.7   17.7  .000E+00     .0  .000   115.1    64.4
-------------------------------------------------------------------------------
PRECIPITATION               285.3    2.5  .203E+05  100.0  .500    23.3    30.0
TRIBUTARY INFLOW          11013.8   97.5  .000E+00     .0  .000   153.0    70.3
***TOTAL INFLOW           11299.1  100.0  .203E+05  100.0  .013   134.1    68.0
ADVECTIVE OUTFLOW          1665.9   14.7  .570E+06 2802.5  .453    21.8    10.0
***TOTAL OUTFLOW           1665.9   14.7  .570E+06 2802.5  .453    21.8    10.0
***RETENTION               9633.2   85.3  .584E+06 2870.2  .079      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P  --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC       TIME     RATIO      COEF
     M/YR       YRS     MG/M3        YRS        -         -
     8.02    1.5738      27.4      .2907    3.4400     .8526
```

2000 - *Constant Sediment Phosphorus Concentration of 616 mg/kg*

```
CASE: Kinkaid 2000 - No Calibration
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    54.8   .33   144.4   .45     .38  -2.92  -3.60  -1.73
 CHL-A      MG/M3    38.0   .40    22.7   .34    1.68   1.29   1.49     .99
 SECCHI         M      .3   .12      .4   .21     .87  -1.15   -.51   -.58
 ORGANIC N  MG/M3      .0   .00   820.7   .23     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    82.4   .23     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    21.2   .10    65.2   .45     .33 -11.58  -4.18  -2.43
 CHL-A      MG/M3    16.4   .40    14.8   .43    1.11    .26    .30    .18
 SECCHI         M      .9   .34     1.0   .34     .96   -.11   -.14   -.08
 ORGANIC N  MG/M3      .0   .00   543.4   .27     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    37.7   .30     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    12.4   .07    38.8   .45     .32 -15.84  -4.24  -2.50
 CHL-A      MG/M3    12.6   .38    11.9   .46    1.06    .15    .17    .10
 SECCHI         M     1.4   .29     1.4   .34     .98   -.09   -.09   -.06
 ORGANIC N  MG/M3      .0   .00   459.3   .29     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    26.6   .38     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    29.0  1.14    24.3   .45    1.20    .16    .66    .15
 CHL-A      MG/M3    18.4  1.24    10.1   .74    1.81    .48   1.72    .41
 SECCHI         M     1.8   .24     2.8  1.79     .63  -1.91  -1.63   -.25
 ORGANIC N  MG/M3      .0   .00   395.9   .48     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    16.4  1.27     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1       2       3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    27.4   .77    44.6   .45     .61   -.63  -1.81   -.54
 CHL-A      MG/M3    18.9   .87    12.4   .53    1.53    .49   1.22    .42
 SECCHI         M     1.4   .26     2.1  1.42     .70  -1.38  -1.27   -.24
 ORGANIC N  MG/M3      .0   .00   470.1   .35     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    27.7   .56     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 2000 - No Calibration
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       38.000  .000E+00  .000        .422
 2  1 Subbasin 2             25.100       11.300  .000E+00  .000        .450
 3  1 Subbasin 3             10.400        5.300  .000E+00  .000        .510
 4  1 Subbasin 4             31.100       17.400  .000E+00  .000        .559
----------------------------------------------------------------------------
PRECIPITATION                 9.509       12.267  .602E+01  .200       1.290
TRIBUTARY INFLOW            156.700       72.000  .000E+00  .000        .459
***TOTAL INFLOW             166.209       84.267  .602E+01  .029        .507
ADVECTIVE OUTFLOW           166.209       76.260  .118E+02  .045        .459
***TOTAL OUTFLOW            166.209       76.260  .118E+02  .045        .459
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            9013.6   63.9  .000E+00     .0  .000   237.2   100.0
 2 1 Subbasin 2            1600.1   11.3  .000E+00     .0  .000   141.6    63.7
 3 1 Subbasin 3             600.0    4.3  .000E+00     .0  .000   113.2    57.7
 4 1 Subbasin 4            2603.0   18.5  .000E+00     .0  .000   149.6    83.7
-------------------------------------------------------------------------------
PRECIPITATION               285.3    2.0  .203E+05  100.0  .500    23.3    30.0
TRIBUTARY INFLOW          13816.7   98.0  .000E+00     .0  .000   191.9    88.2
***TOTAL INFLOW           14101.9  100.0  .203E+05  100.0  .010   167.3    84.8
ADVECTIVE OUTFLOW          1850.4   13.1  .702E+06 3452.5  .453    24.3    11.1
***TOTAL OUTFLOW           1850.4   13.1  .702E+06 3452.5  .453    24.3    11.1
***RETENTION              12251.5   86.9  .717E+06 3523.1  .069      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME     RATIO      COEF
     M/YR       YRS     MG/M3       YRS        -         -
     8.02    1.5738      27.4     .2329    4.2933     .8688
```

Appendix I
Reduction Analyses - BATHTUB Output Files

BATHTUB Output for 1994 Reduction Analysis

```
CASE: Kinkaid 1994 - Reduced
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3   135.4   .29    48.9   .46    2.77   3.48   3.79   1.87
 CHL-A      MG/M3    52.1   .56    18.2   .67    2.86   1.89   3.04   1.21
 SECCHI         M      .4   .72      .7  1.32     .62   -.67  -1.71   -.32
 ORGANIC N  MG/M3      .0   .00   641.3   .54     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    50.2  1.04     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    36.8   .73    21.6   .45    1.71    .73   1.99    .62
 CHL-A      MG/M3    24.3   .44    13.1   .74    1.86   1.40   1.79    .72
 SECCHI         M     1.3   .67     2.1   .91     .63   -.70  -1.65   -.41
 ORGANIC N  MG/M3      .0   .00   466.5   .43     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    22.7   .56     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    22.2   .46    15.6   .45    1.42    .77   1.31    .55
 CHL-A      MG/M3    23.4   .44    13.3   .71    1.75   1.27   1.62    .67
 SECCHI         M     1.6   .59     2.4   .88     .65   -.73  -1.53   -.41
 ORGANIC N  MG/M3      .0   .00   467.1   .44     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    21.5   .64     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    25.2   .53    20.2   .45    1.25    .42    .83    .32
 CHL-A      MG/M3    19.1   .52    16.6   .67    1.16    .28    .42    .17
 SECCHI         M     1.9   .65     2.0   .68     .93   -.10   -.24   -.07
 ORGANIC N  MG/M3      .0   .00   540.5   .45     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    27.3   .60     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    36.7   .48    22.3   .45    1.64   1.03   1.85    .75
 CHL-A      MG/M3    23.6   .50    15.6   .61    1.52    .83   1.20    .53
 SECCHI         M     1.6   .64     2.0   .56     .81   -.32   -.74   -.24
 ORGANIC N  MG/M3      .0   .00   524.9   .41     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    27.6   .59     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 1994 - Reduced
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       32.800  .000E+00  .000        .364
 2  1 Subbasin 2             25.100       10.000  .000E+00  .000        .398
 3  1 Subbasin 3             10.400        4.700  .000E+00  .000        .452
 4  1 Subbasin 4             31.100       15.400  .000E+00  .000        .495
----------------------------------------------------------------------------
PRECIPITATION                 9.509       10.555  .446E+01  .200       1.110
TRIBUTARY INFLOW            156.700       62.900  .000E+00  .000        .401
***TOTAL INFLOW             166.209       73.455  .446E+01  .029        .442
ADVECTIVE OUTFLOW           166.209       65.448  .102E+02  .049        .394
***TOTAL OUTFLOW            166.209       65.448  .102E+02  .049        .394
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---         CONC  EXPORT
ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            1390.7   37.8  .000E+00     .0  .000    42.4    15.4
 2 1 Subbasin 2             700.0   19.0  .000E+00     .0  .000    70.0    27.9
 3 1 Subbasin 3             198.8    5.4  .000E+00     .0  .000    42.3    19.1
 4 1 Subbasin 4            1102.6   30.0  .000E+00     .0  .000    71.6    35.5
-------------------------------------------------------------------------------
PRECIPITATION               285.3    7.8  .203E+05  100.0  .500    27.0    30.0
TRIBUTARY INFLOW           3392.2   92.2  .000E+00     .0  .000    53.9    21.6
***TOTAL INFLOW            3677.4  100.0  .203E+05  100.0  .039    50.1    22.1
ADVECTIVE OUTFLOW          1321.9   35.9  .358E+06 1758.8  .453    20.2     8.0
***TOTAL OUTFLOW           1321.9   35.9  .358E+06 1758.8  .453    20.2     8.0
***RETENTION               2355.6   64.1  .368E+06 1808.5  .258      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P  --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME     RATIO      COEF
     M/YR       YRS     MG/M3       YRS        -         -
     6.88    1.9902      36.7    1.2984     .7702     .6405
```

BATHTUB Output for 1997 Reduction Analysis

```
CASE: Kinkaid 1997 - Reduced
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN    CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3    129.6   .56    50.0   .45    2.59   1.68    3.54    1.32
 CHL-A      MG/M3     48.9   .57    24.5   .57    2.00   1.21    2.00     .86
 SECCHI         M       .3   .34      .4   .42     .82   -.57    -.69    -.36
 ORGANIC N  MG/M3       .0   .00   884.5   .33     .00    .00     .00     .00
 TP-ORTHO-P MG/M3       .0   .00    92.6   .33     .00    .00     .00     .00
 --------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN    CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3     44.6   .23    27.1   .45    1.65   2.20    1.86     .99
 CHL-A      MG/M3     27.5   .38    18.2   .57    1.51   1.08    1.19     .60
 SECCHI         M       .9   .26     1.1   .43     .79   -.91    -.84    -.47
 ORGANIC N  MG/M3       .0   .00   602.8   .39     .00    .00     .00     .00
 TP-ORTHO-P MG/M3       .0   .00    38.2   .46     .00    .00     .00     .00
 --------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN    CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3     27.2   .26    19.2   .45    1.41   1.32    1.29     .66
 CHL-A      MG/M3     19.4   .45    12.0   .58    1.61   1.07    1.38     .65
 SECCHI         M      1.1   .26     1.5   .42     .79   -.91    -.85    -.48
 ORGANIC N  MG/M3       .0   .00   460.5   .35     .00    .00     .00     .00
 TP-ORTHO-P MG/M3       .0   .00    26.5   .46     .00    .00     .00     .00
 --------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN    CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3     42.5  1.09    33.6   .45    1.27    .22     .88     .20
 CHL-A      MG/M3     13.2   .40    11.9   .48    1.11    .25     .29     .16
 SECCHI         M      1.3   .30     1.4   .34     .96   -.14    -.15    -.09
 ORGANIC N  MG/M3       .0   .00   462.4   .30     .00    .00     .00     .00
 TP-ORTHO-P MG/M3       .0   .00    27.6   .38     .00    .00     .00     .00
 --------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                      OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE             MEAN    CV    MEAN    CV   RATIO      1       2       3
 --------------------------------------------------------------------------
 TOTAL P    MG/M3     48.3   .75    31.7   .45    1.52    .56    1.57     .48
 CHL-A      MG/M3     19.9   .44    14.2   .49    1.40    .77     .98     .51
 SECCHI         M      1.1   .29     1.2   .29     .90   -.38    -.39    -.27
 ORGANIC N  MG/M3       .0   .00   525.3   .32     .00    .00     .00     .00
 TP-ORTHO-P MG/M3       .0   .00    35.1   .38     .00    .00     .00     .00
 --------------------------------------------------------------------------
```

```
CASE: Kinkaid 1997 - Reduced
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       36.500  .000E+00  .000        .405
 2  1 Subbasin 2             25.100       10.900  .000E+00  .000        .434
 3  1 Subbasin 3             10.400        5.100  .000E+00  .000        .490
 4  1 Subbasin 4             31.100       16.600  .000E+00  .000        .534
----------------------------------------------------------------------------
PRECIPITATION                 9.509       11.886  .565E+01  .200       1.250
TRIBUTARY INFLOW            156.700       69.100  .000E+00  .000        .441
***TOTAL INFLOW             166.209       80.986  .565E+01  .029        .487
ADVECTIVE OUTFLOW           166.209       72.980  .114E+02  .046        .439
***TOTAL OUTFLOW            166.209       72.980  .114E+02  .046        .439
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ---- --- VARIANCE ---          CONC  EXPORT
ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            1770.3   36.5  .000E+00     .0  .000    48.5    19.6
 2 1 Subbasin 2            1097.6   22.6  .000E+00     .0  .000   100.7    43.7
 3 1 Subbasin 3             299.9    6.2  .000E+00     .0  .000    58.8    28.8
 4 1 Subbasin 4            1397.7   28.8  .000E+00     .0  .000    84.2    44.9
-------------------------------------------------------------------------------
PRECIPITATION               285.3    5.9  .203E+05  100.0  .500    24.0    30.0
TRIBUTARY INFLOW           4565.5   94.1  .000E+00     .0  .000    66.1    29.1
***TOTAL INFLOW            4850.8  100.0  .203E+05  100.0  .029    59.9    29.2
ADVECTIVE OUTFLOW          2449.5   50.5  .123E+07 6028.8  .452    33.6    14.7
***TOTAL OUTFLOW           2449.5   50.5  .123E+07 6028.8  .452    33.6    14.7
***RETENTION               2401.2   49.5  .123E+07 6053.7  .462      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P  --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE       TIME      CONC       TIME     RATIO      COEF
     M/YR        YRS     MG/M3        YRS        -         -
     7.67     1.8016      48.3     1.3095     .7637     .4950
```

BATHTUB Output for 2000 Reduction Analysis

```
CASE: Kinkaid 2000 - Reduced
 T STATISTICS COMPARE OBSERVED AND PREDICTED MEANS
 USING THE FOLLOWING ERROR TERMS:
  1 = OBSERVED WATER QUALITY ERROR ONLY
  2 = ERROR TYPICAL OF MODEL DEVELOPMENT DATA SET
  3 = OBSERVED AND PREDICTED ERROR
 SEGMENT:  1 Upper Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    54.8   .33    49.4   .45    1.11    .31    .38    .18
 CHL-A      MG/M3    38.0   .40    24.1   .48    1.58   1.14   1.32    .73
 SECCHI         M      .3   .12      .4   .22     .88  -1.04   -.46   -.50
 ORGANIC N  MG/M3      .0   .00   853.1   .32     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    85.0   .28     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  2 Middle Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    21.2   .10    27.1   .45     .78  -2.54   -.92   -.53
 CHL-A      MG/M3    16.4   .40    15.5   .55    1.06    .14    .16    .08
 SECCHI         M      .9   .34     1.0   .36     .98   -.06   -.07   -.04
 ORGANIC N  MG/M3      .0   .00   560.0   .35     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    39.0   .39     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  3 Lower Pool
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    12.4   .07    17.5   .45     .71  -4.75  -1.27   -.75
 CHL-A      MG/M3    12.6   .38    11.4   .58    1.11    .27    .30    .15
 SECCHI         M     1.4   .29     1.5   .37     .96   -.15   -.16   -.09
 ORGANIC N  MG/M3      .0   .00   446.9   .35     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    25.6   .47     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  4 Near Dam
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    29.0  1.14    23.5   .45    1.23    .18    .78    .17
 CHL-A      MG/M3    18.4  1.24    19.1   .71     .96   -.03   -.11   -.03
 SECCHI         M     1.8   .24     1.7   .76    1.03    .13    .11    .04
 ORGANIC N  MG/M3      .0   .00   600.3   .48     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    32.3   .58     .00    .00    .00    .00
 -------------------------------------------------------------------------
 SEGMENT:  5 AREA-WTD MEAN
                       OBSERVED     ESTIMATED               T STATISTICS
 VARIABLE            MEAN    CV    MEAN    CV   RATIO      1      2      3
 -------------------------------------------------------------------------
 TOTAL P    MG/M3    27.4   .77    25.6   .45    1.07    .09    .25    .08
 CHL-A      MG/M3    18.9   .87    17.7   .59    1.07    .07    .18    .06
 SECCHI         M     1.4   .26     1.4   .57    1.01    .04    .04    .02
 ORGANIC N  MG/M3      .0   .00   592.3   .40     .00    .00    .00    .00
 TP-ORTHO-P MG/M3      .0   .00    37.2   .46     .00    .00    .00    .00
 -------------------------------------------------------------------------
```

```
CASE: Kinkaid 2000 - Reduced
GROSS WATER BALANCE:
                      DRAINAGE AREA      ---- FLOW (HM3/YR) ----      RUNOFF
ID  T LOCATION                  KM2         MEAN  VARIANCE    CV        M/YR
----------------------------------------------------------------------------
 1  1 Subbasin 1             90.100       38.000  .000E+00  .000        .422
 2  1 Subbasin 2             25.100       11.300  .000E+00  .000        .450
 3  1 Subbasin 3             10.400        5.300  .000E+00  .000        .510
 4  1 Subbasin 4             31.100       17.400  .000E+00  .000        .559
----------------------------------------------------------------------------
PRECIPITATION                 9.509       12.267  .602E+01  .200       1.290
TRIBUTARY INFLOW            156.700       72.000  .000E+00  .000        .459
***TOTAL INFLOW             166.209       84.267  .602E+01  .029        .507
ADVECTIVE OUTFLOW           166.209       76.260  .118E+02  .045        .459
***TOTAL OUTFLOW            166.209       76.260  .118E+02  .045        .459
***EVAPORATION                 .000        8.007  .577E+01  .300        .000
----------------------------------------------------------------------------

GROSS MASS BALANCE BASED UPON ESTIMATED CONCENTRATIONS
COMPONENT: TOTAL P
                      ----- LOADING ----  --- VARIANCE ---         CONC  EXPORT
ID T LOCATION               KG/YR   %(I)  KG/YR**2   %(I)    CV   MG/M3  KG/KM2
-------------------------------------------------------------------------------
 1 1 Subbasin 1            5407.4   51.5  .000E+00     .0  .000   142.3    60.0
 2 1 Subbasin 2            1600.1   15.2  .000E+00     .0  .000   141.6    63.7
 3 1 Subbasin 3             600.0    5.7  .000E+00     .0  .000   113.2    57.7
 4 1 Subbasin 4            2603.0   24.8  .000E+00     .0  .000   149.6    83.7
-------------------------------------------------------------------------------
PRECIPITATION               285.3    2.7  .203E+05  100.0  .500    23.3    30.0
TRIBUTARY INFLOW          10210.5   97.3  .000E+00     .0  .000   141.8    65.2
***TOTAL INFLOW           10495.8  100.0  .203E+05  100.0  .014   124.6    63.1
ADVECTIVE OUTFLOW          1794.7   17.1  .659E+06 3236.4  .452    23.5    10.8
***TOTAL OUTFLOW           1794.7   17.1  .659E+06 3236.4  .452    23.5    10.8
***RETENTION               8701.0   82.9  .673E+06 3305.8  .094      .0      .0
-------------------------------------------------------------------------------

          HYDRAULIC    -------------- TOTAL P --------------
 OVERFLOW RESIDENCE      POOL RESIDENCE  TURNOVER RETENTION
     RATE      TIME      CONC      TIME     RATIO      COEF
     M/YR       YRS     MG/M3       YRS        -         -
     8.02    1.5738      27.4     .3129    3.1954     .8290
```

Appendix J
Monte Carlo Analyses

J.1 Monte Carlo Analyses

This appendix contains results of the Monte Carlo analyses for manganese and sulfates in the Big Muddy River #1 Watershed. Each analysis generates 10,000 random numbers which can be obtained electronically.

IEPA
Watershed Load Reductions
7/15/2002

Monte Carlo Simulations using @RISK 3.5

Watershed : N12 Big Muddy River #1

Manganese

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

Percent Reduction

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

PR (Mn) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Mn) 51.1% percent

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

mean 0.6 mg/L

LTA = mean * (1 - PR99)

LTA (Mn) 0.291 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Mn) 66.8% percent

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

mean 0.6 mg/L

LTA = mean * (1 - PR99.9)

LTA (Mn) 0.198 mg/L

Monte Carlo Simulations using @RISK 3.5

Watershed : N12 Big Muddy River #1

Sulfate

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

Percent Reduction

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

PR (Sulfate) #NAME?

After Monte-Carlo Simulation:

Percent reduction at the 99th percentile

PR99 (Sulfate) 36.2% percent

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

mean 246.9 mg/L

LTA = mean * (1 - PR99)

LTA (Sulfate) 157.576 mg/L

Percent reduction at the 99.9th percentile

PR99.9 (Sulfate) 58.0% percent

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

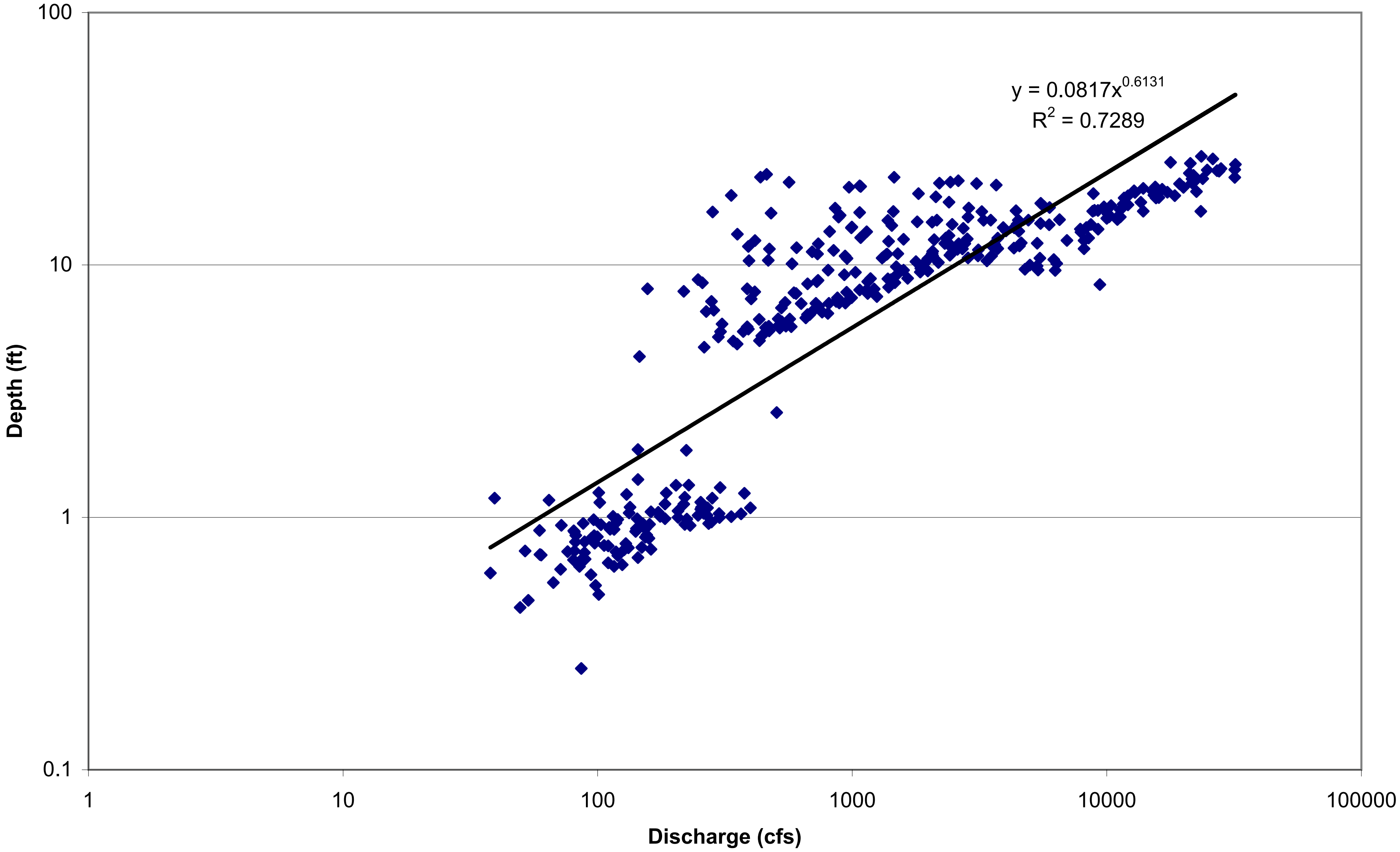
mean 246.9 mg/L

LTA = mean * (1 - PR99.9)

LTA (Sulfate) 103.660 mg/L

Appendix K
Rating Curve for Depth

Depth Rating Curve for the Big Muddy River



Appendix L
Streeter-Phelps Analyses

Big Muddy Segment N12 Watershed
Aeration Coefficient Summary

Location	Date	DO observed	BOD @ DO Observed	Ka @ DO observed	Ka at DO = 6 mg/L
N12	7/24/2000	7.9	7.3	45.4	11.05
N12	9/6/2000	4.7	7.2	3.2	11.53

Definitions

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

DONE Used Q from USGS Derived Flows and H calculated from Q. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C	@ T	k_d	x	U	L_o	C_s	C	H	T	Q
		k_a	k_a									
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
0.376206	4	0.519612	45.4	0.364011	5280	1.1	7.3	8.3	7.9	8.8	25.1	2060
0.375403												

x	y	m	b	
25	8.4	-0.16	12.4	
30	7.6			

DO @ Temp 8.4

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	360	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.3	mg/L

DONE Used Q from USGS Derived Flows and H calculated from Q. Used Ka and Kd from N12 9/6/00.

		20 °C	@ T									
D	D_o	k_a	k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.276206	4	0.519612	11.04779	0.364011	5280	1.1	7.3	8.3	6	8.8	25.1	2060
2.276206												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.4

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	360	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.3	mg/L

DONE Using Depth and Q Determined from Habitat Survey. Kd is temp corrected and Ka is calibrated.

		20 °C	@ T									
D mg/L	D_o mg/L	k_a 1/day	k_a 1/day	k_d 1/day	x ft	U ft/s	L_o mg/L	C_s mg/L	C mg/L	H ft	T °C	Q cfs
3.513029	4	1.065987	3.2	0.458047	5280	1.1	7.2	8.2	4.7	5.4	25.5	400
3.503937												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp 8.3

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	360 feet
DO @ Elev.	8.3 mg/L
DO Elev Factor	0.99
DO @ Temp/Elev	8.2 mg/L

DONE Using Depth and Q Determined from Habitat Survey. Kd is temp corrected and Ka is calibrated.

D	D_o	20 °C k_a	@ T k_a	k_d	x	U	L_o	C_s	C	H	T	Q
mg/L	mg/L	1/day	1/day	1/day	ft	ft/s	mg/L	mg/L	mg/L	ft	°C	cfs
2.213029	4	1.065987	11.52703	0.458047	5280	1.1	7.2	8.2	6	5.4	25.5	400
2.213029												

x	y	m	b
25	8.4	-0.16	12.4
30	7.6		

DO @ Temp	8.3

x	y	m	b
0	8.4	-0.0003	8.4
2000	7.8		

Elevation	360	feet
DO @ Elev.	8.3	mg/L
DO Elev Factor	0.99	
DO @ Temp/Elev	8.2	mg/L

Appendix M
Error Analyses

M.1 Monte Carlo Analysis Development and Results

This appendix provides the results of the Monte-Carlo DO error analysis. The analysis was run on the range of possible values for the BOD_5 decay rate coefficient (k_d) and the reaeration rate coefficient (k_a). The Monte-Carlo program requires a distribution of k_a and k_d values. For each DO sample date, a triangle distribution was chosen to analyze the Big Muddy River segment N12 since data for this site was extremely limited.

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

A triangular distribution assumes that the values of a given data set are most often at or near the mode and linearly distributed to the minimum and maximum values. The minimum is the smallest concentration of the sample data set. The maximum value is the largest sample in the sample data set. The mode is the value that is most likely to be observed in a long time series of sample data. Water quality data were not available to determine the actual k_a and k_d, so the estimated values discussed in Section 10.3 and shown in Table 10-3 were used as the mode for each sample date.

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

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

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

	Column A D mg/L	Column B D_o mg/L	Column C x ft	Column D U ft/s	Column E L_o mg/L	Column F D_s mg/L	Column G DO_{obs} mg/L	Column H Q cfs	Column I Ka	Column J Kd
Row 3	=F3-G3	4	5280	1.1	7.3	8.3	7.9	2060	`=RiskTriang(0.01,45.4,100`	`=RiskTriang(0.02,0.364,3.4)`

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

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	3.7	0.7	0.0
Maximum =	8.2	99.0	3.4
Mean =	7.6	48.7	1.3
Std Deviation =	0.6	20.6	0.8
Variance =	0.4	422.6	0.6
Skewness =	-2.2	0.1	0.6
Kurtosis =	8.4	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	7.4	39.2	2.0

95th Percent Confidence Interval

6.3 8.9

99.9th Percent Confidence Interval

5.5 9.7

	Column A **D** **mg/L**	**Column B** **D_o** **mg/L**	**Column C** **x** **ft**	**Column D** **U** **ft/s**	**Column E** **L_o** **mg/L**	**Column F** **D_s** **mg/L**	**Column G** **DO_{obs}** **mg/L**	**Column H** **Q** **cfs**	**Column I** **Ka**	**Column J** **Kd**
Row 3	=F3-G3	4	5280	1.0	7.2	8.2	4.7	5.38	=RiskTriang(0.01,3,100)	=RiskTriang(0.02,0.458,3.4)

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

Summary of Monte Carlo Results

	DO	Ka	Kd
Minimum =	3.3	0.2	0.0
Maximum =	8.2	99.7	3.4
Mean =	6.9	34.4	1.3
Std Deviation =	1.1	23.3	0.7
Variance =	1.3	542.5	0.6
Skewness =	-0.9	0.6	0.5
Kurtosis =	2.7	2.4	2.4
Errors Calculated =	0.0	0.0	0.0
Mode =	6.4	44.1	0.7

95th Percent Confidence Interval

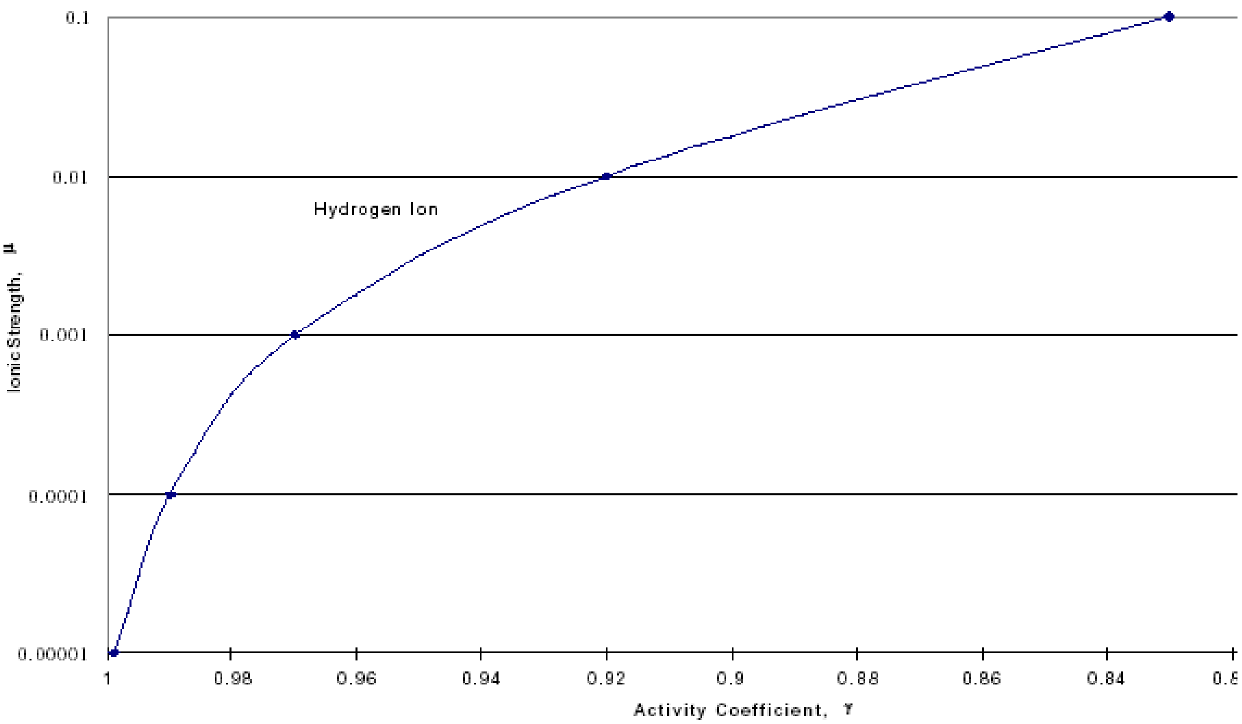
4.7 9.1

99.9th Percent Confidence Interval

3.1 10.6

Appendix N
Chart of Activity Coefficients versus Ionic Strength

Ionic Strength versus Activity Coefficient (Snoeyink 1980)



Appendix O
pH Analyses

IEPA
pH TMDL
9/12/2002

Watershed	Segment	TDS 95 percentile (mg/L)	Ionic Strength (μ)	Activity CorrectionFactor
Big Muddy River	N12	1194	0.02985	0.9

Additional Notes:
- Activity Correction factor computed from Figure 5 (KDEP 2001)
- TDS 95 percentile is computed from observed data

Watershed	**Segment**	**Area (miles^2)**	**3 yr-Flow (cfs)**	**Max H+ Ion Loading @ pH of 6.5 (g/day)**	**Max H+ Ion Loading @ pH of 6.5 (lbs/day)**	**Actual H+ Ion Loading (g/day)**	**Actual H+ Ion Loading (lbs/day)**	**Reduction in H+ Ion Loading (lbs/day)**
Big Muddy River	N12	2169	16,425.55	14,198.25	31.30	4,751.91	10.48	(20.83)

Additional Notes:
1) 3-yr flow calculated by the Log Normal Distribution
2) Max H+ concentration @ pH of 6.5 is determined by relationship in QvsLoading_g (6.5)
3) Actual H+ concentration for Big Muddy @ 3 yr flow is determined by relationship in QvsLoading_g (N12)

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9/12/2002

Water Quality pH Standard = 6.5
Activity CorrectionFactor (N12) = 0.9 * based upon the TDS concentrations observed in the watershed

	N12	
Flow (cfs)	**Max Ion Loading (g/day)**	**Max Ion Loading (lbs/day)**
0	0.00	0.000
500	432.22	0.953
1000	864.45	1.906
1500	1296.67	2.859
2000	1728.89	3.811
2500	2161.12	4.764
3000	2593.34	5.717
3500	3025.56	6.670
4000	3457.78	7.623
4500	3890.01	8.576
5000	4322.23	9.529
5500	4754.45	10.482
6000	5186.68	11.434
6500	5618.90	12.387
7000	6051.12	13.340
7500	6483.35	14.293
8000	6915.57	15.246
8500	7347.79	16.199
9000	7780.02	17.152
9500	8212.24	18.105
10000	8644.46	19.057
10500	9076.68	20.010
11000	9508.91	20.963
11500	9941.13	21.916
12000	10373.35	22.869
12500	10805.58	23.822
13000	11237.80	24.775
13500	11670.02	25.728
14000	12102.25	26.680
14500	12534.47	27.633
15000	12966.69	28.586
15500	13398.92	29.539
16000	13831.14	30.492
16500	14263.36	31.445
17000	14695.58	32.398
17500	15127.81	33.351
18000	15560.03	34.303
18500	15992.25	35.256
19000	16424.48	36.209
19500	16856.70	37.162
20000	17288.92	38.115
20500	17721.15	39.068
21000	18153.37	40.021
21500	18585.59	40.974
22000	19017.82	41.926
22500	19450.04	42.879
23000	19882.26	43.832
23500	20314.48	44.785
24000	20746.71	45.738
24500	21178.93	46.691
25000	21611.15	47.644

IEPA
pH TMDL
9/12/2002

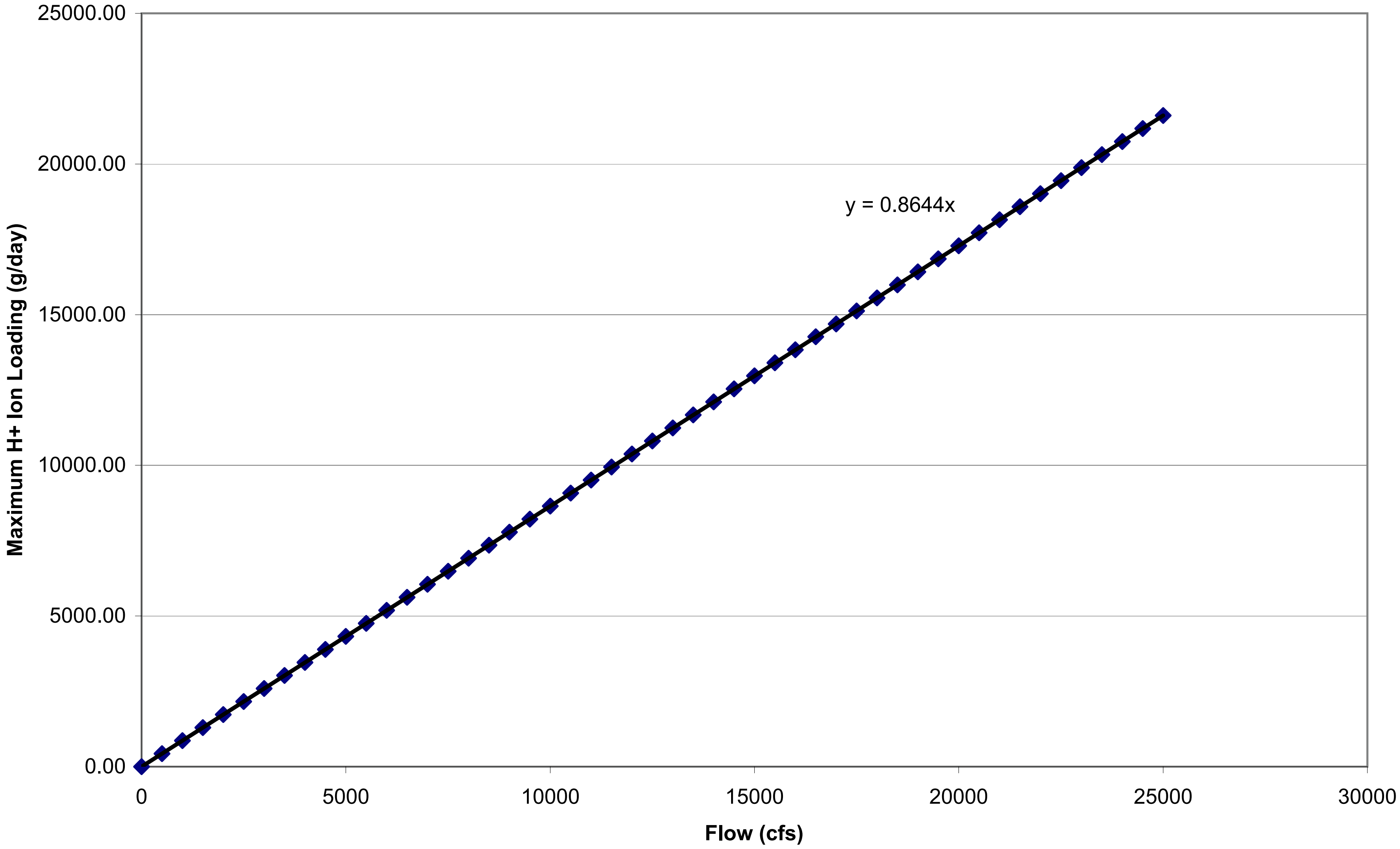
Big Muddy River (N12)

Water Quality pH Standard = 6.5
Activity CorrectionFactor = 0.9

Max Ion Loading (g/day)	Max Ion Loading (lbs/day)	pH (measured)	Flow (cfs)
0.08	0.000	7.800	1.898
0.08	0.000	7.800	1.898
0.36	0.001	8.300	26.386
0.36	0.001	8.300	26.386
2.27	0.005	7.500	26.386
0.36	0.001	8.300	26.386
0.11	0.000	8.800	26.386
0.11	0.000	8.800	26.386
0.72	0.002	8.000	26.386
15.11	0.033	7.000	55.600
15.11	0.033	7.000	55.600
67.27	0.148	6.900	196.551
134.21	0.296	6.600	196.551
0.45	0.001	7.900	13.112
1.79	0.004	7.300	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
2.25	0.005	7.200	13.112
1.79	0.004	7.300	13.112
1.79	0.004	7.300	13.112
0.28	0.001	7.500	3.285
0.56	0.001	7.200	3.285
0.56	0.001	7.200	3.285
0.15	0.000	7.800	3.541
0.03	0.000	8.200	1.508
0.03	0.000	8.200	1.508
158.81	0.350	6.400	146.740
158.81	0.350	6.400	146.740
13.14	0.029	7.100	60.850
13.14	0.029	7.1	60.850
16.54	0.036	7	60.850
13.14	0.029	7.1	60.850
13.14	0.029	7.1	60.850
26.22	0.058	6.8	60.850
26.22	0.058	6.8	60.850
16.54	0.036	7	60.850
16.54	0.036	7	60.850
2.39	0.005	7.4	22.078
2.39	0.005	7.4	22.078
1.49	0.003	7.3	10.972
1.88	0.004	7.2	10.972
0.09	0.000	7.9	2.571
0.14	0.000	7.7	2.571
0.09	0.000	7.9	2.571
0.11	0.000	7.8	2.571
0.11	0.000	7.8	2.571
0.11	0.000	7.8	2.571
0.11	0.000	7.8	2.571
0.28	0.001	6.9	0.808
0.28	0.001	6.9	0.808
0.19	0.000	7.05	0.781
0.57	0.001	7	2.087
0.57	0.001	7	2.087
9.54	0.021	6.9	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
7.58	0.017	7	27.867
5.93	0.013	7.2	34.598
5.93	0.013	7.2	34.598
1.38	0.003	7.3	10.164
1.38	0.003	7.3	10.164
1.00	0.002	7.44	10.164
1.29	0.003	7.33	10.164
1.42	0.003	7.29	10.164
1.42	0.003	7.29	10.164
1.18	0.003	7.1	5.479
0.43	0.001	7.1	1.979
0.43	0.001	7.1	1.979
0.06	0.000	7.7	1.104
12.40	0.027	7.4	114.565
1.56	0.003	7.6	22.886
7.52	0.017	7.7	138.663
3.77	0.008	8	138.663
5.97	0.013	7.8	138.663
7.52	0.017	7.7	138.663
9.47	0.021	7.6	138.663
7.52	0.017	7.7	138.663
1.19	0.003	8.5	138.663
3.77	0.008	8	138.663
4.75	0.010	7.9	138.663
9.47	0.021	7.6	138.663
4.75	0.010	7.9	138.663
23.78	0.052	7.2	138.663
37.69	0.083	7	138.663
18.89	0.042	7.3	138.663
4.75	0.010	7.9	138.663
18.89	0.042	7.3	138.663
0.17	0.000	7.1	0.794
1.02	0.002	7.2	5.937
1.23	0.003	7.4	11.335
0.42	0.001	7.4	3.891
12.41	0.027	6.6	18.174
169.37	0.373	6.8	393.103
17.40	0.038	6.8	40.387
1.32	0.003	7.3	9.693
8.31	0.018	7.2	48.465
9.49	0.021	6.9	27.733
4.63	0.010	6.5	5.385
0.49	0.001	7.2	2.881
2.65	0.006	6.4	2.450
0.51	0.001	7.5	5.950
2.96	0.007	7.5	34.464
9.07	0.020	7.2	52.907
17.31	0.038	7	63.677
10.17	0.022	7.1	47.118
10.22	0.023	6.7	18.847
4.82	0.011	6.4	4.456
1.10	0.002	7.3	8.077
0.18	0.000	7.3	1.306
0.44	0.001	8.1	20.194
13.61	0.030	7.3	99.891
10.21	0.023	7.2	59.504
4.18	0.009	7.4	38.637
10.76	0.024	6.5	12.520
0.10	0.000	7.3	0.754
0.06	0.000	7.4	0.512
0.35	0.001	7	1.306
4.70	0.010	6.6	6.879
5.23	0.012	6.6	7.660
1.26	0.003	7.1	5.829
0.90	0.002	7.6	13.153
9.49	0.021	6.9	27.733
4.63	0.010	6.5	5.385

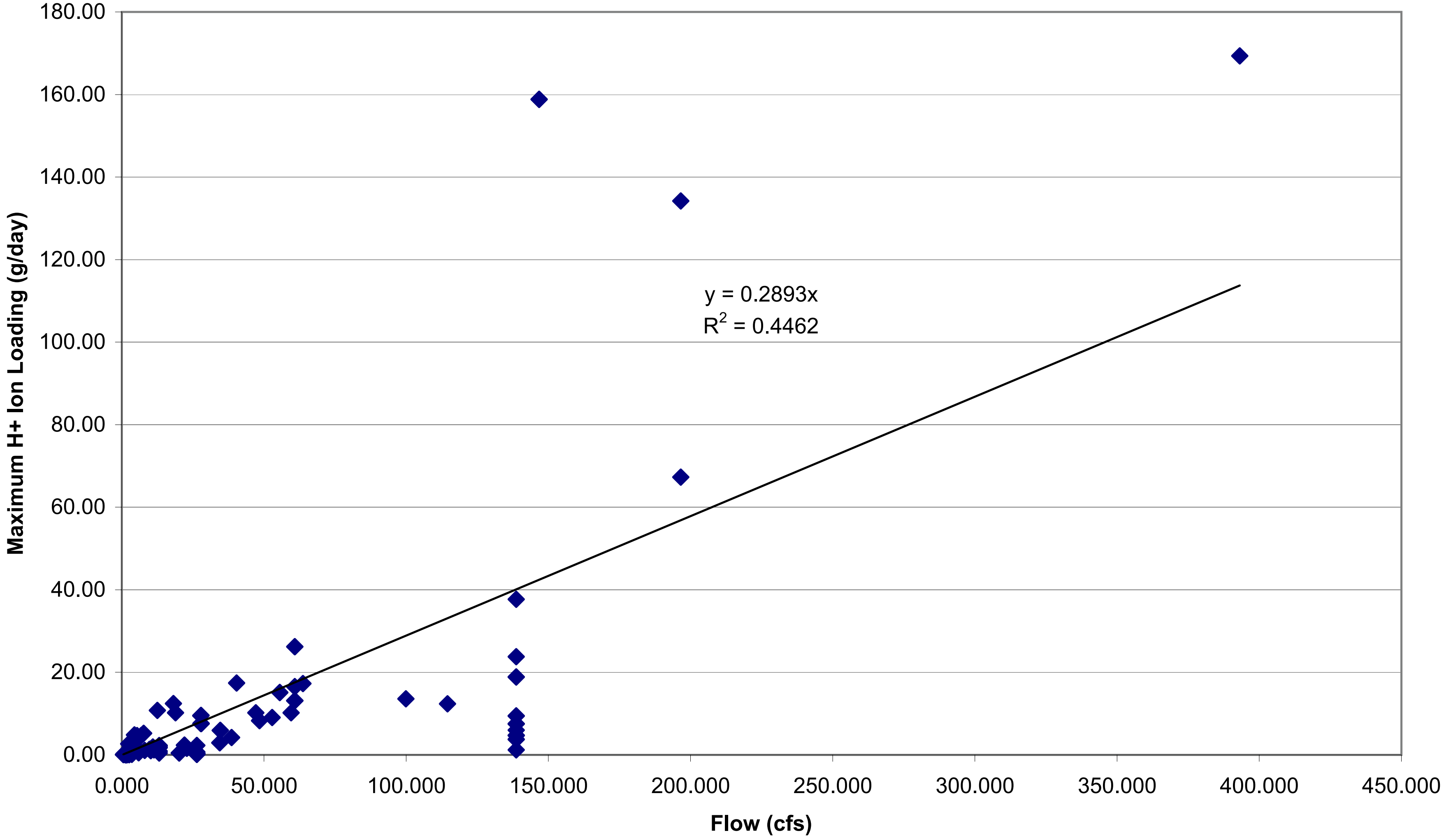
Gage	Date	Time of pH Sample	pH (S.U.)	Flow (cfs)
5599500	1/9/1990	10:30	7.8	1.898
5599500	1/9/1990	10:45	7.8	1.898
5599500	2/8/1990	13:00	8.3	26.386
5599500	2/8/1990	13:30	8.3	26.386
5599500	2/8/1990	13:32	7.5	26.386
5599500	2/8/1990	13:35	8.3	26.386
5599500	2/8/1990	13:37	8.8	26.386
5599500	2/8/1990	13:38	8.8	26.386
5599500	2/8/1990	13:40	8	26.386
5599500	4/16/1990	15:00	7	55.600
5599500	4/16/1990	15:15	7	55.600
5599500	5/22/1990	10:00	6.9	196.551
5599500	5/22/1990	10:30	6.6	196.551
5599500	7/9/1990	14:00	7.9	13.112
5599500	7/9/1990	14:02	7.3	13.112
5599500	7/9/1990	14:05	7.2	13.112
5599500	7/9/1990	14:07	7.2	13.112
5599500	7/9/1990	14:10	7.2	13.112
5599500	7/9/1990	14:13	7.2	13.112
5599500	7/9/1990	14:15	7.2	13.112
5599500	7/9/1990	14:45	7.3	13.112
5599500	7/9/1990	15:00	7.3	13.112
5599500	8/21/1990	9:30	7.5	3.285
5599500	8/21/1990	9:45	7.2	3.285
5599500	8/21/1990	10:00	7.2	3.285
5599500	9/24/1990	13:30	7.8	3.541
5599500	11/13/1990	13:00	8.2	1.508
5599500	11/13/1990	13:30	8.2	1.508
5599500	1/8/1991	11:30	6.4	146.740
5599500	1/8/1991	12:00	6.4	146.740
5599500	2/12/1991	12:00	7.1	60.850
5599500	2/12/1991	12:10	7.1	60.850
5599500	2/12/1991	12:20	7	60.850
5599500	2/12/1991	12:30	7.1	60.850
5599500	2/12/1991	12:40	7.1	60.850
5599500	2/12/1991	12:50	6.8	60.850
5599500	2/12/1991	13:00	6.8	60.850
5599500	2/12/1991	13:30	7	60.850
5599500	2/12/1991	14:00	7	60.850
5599500	4/9/1991	13:00	7.4	22.078
5599500	4/9/1991	13:30	7.4	22.078
5599500	6/4/1991	10:00	7.3	10.972
5599500	6/4/1991	10:30	7.2	10.972
5599500	7/16/1991	12:30	7.9	2.571
5599500	7/16/1991	12:35	7.7	2.571
5599500	7/16/1991	12:40	7.9	2.571
5599500	7/16/1991	12:45	7.8	2.571
5599500	7/16/1991	12:50	7.8	2.571
5599500	7/16/1991	13:00	7.8	2.571
5599500	7/16/1991	13:30	7.8	2.571
5599500	8/20/1991	12:30	6.9	0.808
5599500	8/20/1991	13:00	6.9	0.808
5599500	10/15/1991	12:00	7.05	0.781
5599500	11/12/1991	12:00	7	2.087
5599500	11/12/1991	12:30	7	2.087
5599500	1/7/1992	10:15	6.9	27.867
5599500	1/7/1992	10:20	7	27.867
5599500	1/7/1992	10:25	7	27.867
5599500	1/7/1992	10:30	7	27.867
5599500	1/7/1992	10:35	7	27.867
5599500	1/7/1992	10:40	7	27.867
5599500	1/7/1992	11:00	7	27.867
5599500	1/7/1992	11:30	7	27.867
5599500	2/20/1992	11:30	7.2	34.598
5599500	2/20/1992	12:00	7.2	34.598
5599500	4/14/1992	10:30	7.3	10.164
5599500	4/14/1992	11:00	7.3	10.164
5599500	4/14/1992	11:05	7.44	10.164
5599500	4/14/1992	11:10	7.33	10.164
5599500	4/14/1992	11:15	7.29	10.164
5599500	4/14/1992	11:25	7.29	10.164
5599500	5/18/1992	11:00	7.1	5.479
5599500	7/13/1992	12:30	7.1	1.979
5599500	7/13/1992	13:00	7.1	1.979
5599500	8/17/1992	12:00	7.7	1.104
5599500	1/12/1993	7:00	7.4	114.565
5599500	2/16/1993	9:00	7.6	22.886
5599500	1/6/1994	7:00	7.7	138.663
5599500	3/2/1994	7:00	8	138.663
5599500	4/6/1994	8:00	7.8	138.663
5599500	5/23/1994	8:00	7.7	138.663
5599500	7/6/1994	12:00	7.6	138.663
5599500	8/4/1994	8:00	7.7	138.663
5599500	9/19/1994	11:00	8.5	138.663
5599500	11/1/1994	8:00	8	138.663
5599500	12/7/1994	8:00	7.9	138.663
5599500	1/30/1995	8:00	7.6	138.663
5599500	2/21/1995	8:00	7.9	138.663
5599500	4/12/1995	7:00	7.2	138.663
5599500	5/10/1995	8:00	7	138.663
5599500	6/15/1995	8:00	7.3	138.663
5599500	7/20/1995	8:00	7.9	138.663
5599500	8/22/1995	8:00	7.3	138.663
5599500	10/31/1995	8:00	7.1	0.794
5599500	12/18/1995	7:00	7.2	5.937
5599500	1/31/1996	9:00	7.4	11.335
5599500	2/29/1996	8:00	7.4	3.891
5599500	3/25/1996	8:00	6.6	18.174
5599500	5/1/1996	8:00	6.8	393.103
5599500	6/25/1996	8:00	6.8	40.387
5599500	7/31/1996	8:00	7.3	9.693
5599500	4/24/1997	8:00	7.2	48.465
N12	7/24/2000		6.9	27.733
N12	9/6/2000		6.5	5.385
N12	10/27/1997		7.2	2.881
N12	11/20/1997		6.4	2.450
N12	2/3/1998		7.5	5.950
N12	3/5/1998		7.5	34.464
N12	4/16/1998		7.2	52.907
N12	5/14/1998		7	63.677
N12	6/17/1998		7.1	47.118
N12	7/21/1998		6.7	18.847
N12	8/27/1998		6.4	4.456
N12	10/8/1998		7.3	8.077
N12	12/1/1998		7.3	1.306
N12	1/4/1999		8.1	20.194
N12	2/8/1999		7.3	99.891
N12	3/22/1999		7.2	59.504
N12	4/27/1999		7.4	38.637
N12	6/10/1999		6.5	12.520
N12	9/16/1999		7.3	0.754
N12	11/1/1999		7.4	0.512
N12	12/6/1999		7	1.306
N12	1/3/2000		6.6	6.879
N12	3/8/2000		6.6	7.660
N12	4/12/2000		7.1	5.829
N12	5/1/2000		7.6	13.153
N12	7/24/2000		6.9	27.733
N12	9/6/2000		6.5	5.385

Calculated Flow vs. Maximum H^+ Ion Loading



AppendixO-pHAnalyses.xls, 'QvsLoading_g (6.5)_N12'

Existing Flow vs. Maximum H^+ Ion Loading in Segment N12 of the Big Muddy River



CDM

AppendixO-pHAnalyses.xls, 'QvsLoading_g (N12)'

Appendix P
Responsiveness Summary

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Responsiveness Summary

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

What is a TMDL?

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

Background

The watershed targeted for TMDL development is Big Muddy River (ILN12), which originates in Jefferson County, Illinois. The watershed encompasses an area of approximately 200 square miles. Land use in the watershed is predominately forestland followed by rural grassland and agricultural land uses. TMDLs developed for impaired water bodies in the Big Muddy River watershed include Big Muddy River segment N12 and Kinkaid Lake (RNC). In the 2002 Section 303(d) List, Big Muddy River (N12) was listed as impaired for manganese, sulfates, pH, low dissolved oxygen (DO), and total suspended solids (TSS). Kinkaid Lake was listed as impaired for pH, mercury, and siltation. The Clean Water Act and USEPA regulations require that states develop TMDLs for waters on the Section 303(d) List. Illinois EPA is currently developing TMDLs for pollutants that have numeric water quality standards. Therefore, TMDLs were only developed for the following: Big Muddy River (N12): manganese, sulfates, pH, and DO; Kinkaid Lake (RNC): pH. While the impairment caused by mercury is acknowledged, a TMDL will not be developed for it at this time. The Illinois EPA contracted with Camp Dresser & McKee (CDM) to prepare a TMDL report for the Big Muddy River watershed.

Public Meetings

Public meetings were held in the city of Springfield on June 5, 2001 and in the city of Murphysboro on December 12, 2001 and February 26, 2004. The Illinois EPA provided public notice for the February 26, 2004 meeting by placing display ads in the Southern Illinoisan on January 27, 2004, and the Carbondale Times and The Spokesman on January 25, 2004. This notice gave the date, time, location, and purpose of the meeting. The notice also provided references to obtain additional information about this specific site, the TMDL Program and other related issues. Approximately 50 individuals and organizations were also sent the public notice by first class mail. The draft TMDL

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

The final public meeting started at 6:00 p.m. on Thursday, February 26, 2004. It was attended by approximately 36 people and concluded at 7:25 p.m. with the meeting record remaining open until midnight, March 29, 2004.

Questions and Comments

1. If Kinkaid Lake was listed only for sediment, why were nutrients addressed in the TMDL?

Response: The 2002 303(d) List shows Kinkaid Lake being impaired for pH, mercury, and siltation. As discussed in the report, mercury was not addressed in this TMDL report. Since siltation does not have a numeric water quality standard, a TMDL was not developed for it. A TMDL was developed for pH since it has a numeric water quality standard. During the analysis, an attempt was made to link pH swings to algal blooms that occur in the lake. These algal blooms are a result of increased phosphorus levels within the lake. Therefore, a reduction in phosphorus loading to the lake should help control algal blooms, which in turn should help stabilize pH levels.

2. Only three samples for pH violated the standards. Was this TMDL done just to address these few excursions?

Response: Yes. Any violation of the water quality standard can place that water body on the 303(d) List, for which TMDLs must be developed. Since numeric water quality standards exist for pH, a TMDL was developed for Kinkaid Lake.

3. Why was station RNC-4 high in phosphorus but didn't violate the pH standard? Did the phosphorus from RNC-4 get distributed throughout the rest of the lake?

Response: Phosphorus entering a lake is transported throughout the lake. RNC-4 is at the upper reaches of the reservoir. The phosphorus that was transported to other areas of the reservoir from RNC-4 could cause algal blooms and associated pH violations.

4. When will TMDLs be developed for the listed causes without standards?

Response: TMDLs are currently only conducted for listed causes for which a water quality standard exists. Pending development of appropriate water quality standards, as may be proposed by the Agency or others and adopted by the Illinois Pollution Control Board, we will continue to work with watershed planning groups and others to identify causes and treat potential sources of impairment.

5. The GWLF model assumes that all row crop runoff directly enters the lake. That assumption is not correct.

Response: GWLF does not route flow and data were not available for the tributaries to Kinkaid Lake. Therefore, calibration in these areas could not be completed. The calibration exercise was used to estimate what runoff and associated phosphorus concentrations were entering the lake. The GWLF model was selected based on the amount of data available for calibration.

6. Using the Casey Fork flow gauge for this watershed was not representative for the tributary that runs into the lake. A gauge used to be in the upper tributary years ago. That data could be used to calculate flow in Kinkaid Lake.
Response: It is best to utilize more recent flow data that occurred during the time of data collection for calibration. Use of the Casey Fork gauge was considered conservative because it has a less steep slope than the Kinkaid Lake tributaries.

7. An NRCS study performed by Roger Windhorn looked at erosion and sedimentation rates occurring in Kinkaid Lake watershed. Was that looked at during TMDL development?

Response: Yes this study was part of the Kinkaid Lake Management Plan and was evaluated during TMDL development.

8. Was runoff and erosion from the forestland within the lake watershed considered in the model?

Response: Yes, the contribution of forestland to the phosphorus load was analyzed through the GWLF model. According to the analysis, forestland contributes approximately 3,212 lbs per year, or 15 percent of the total phosphorus load entering the lake.

9. Assuming that no-till, filter strips, and dry dams are already in place, what else can a farmer do to prevent phosphorus loads in the watershed?

Response: Producers in the watershed are encouraged to use soil testing and nutrient management plans to ensure that they are not over-applying fertilizers to their fields. The Agency recommends that producers follow fertilizer recommendations found in the University of Illinois Agronomy Handbook and NRCS 590 Standard. Information pertaining to nutrient management planning and programs that provide financial incentives to develop such plans can be found in the Implementation Plan of the TMDL report.

10. A lot of highly erodable land in the watershed has been enrolled in conservation programs. About one-third of row crops currently in conservation programs have very low P tests. I don’t believe the 18 percent reduction in phosphorus through nutrient management planning is achievable for this watershed. There has been a lot of conservation tillage done in the watershed in the last 20 years, so there may not be as much saving in additional conservation tillage practices.

Response: The consultants did not have access to soil test results from individual landowners. The GWLF model was set at a total phosphorus soil concentration of 660 ppm based on comparison with observed data in the BATHTUB model, as well as a sensitivity analysis to confirm that this was within the correct range. The report recognizes the high percentage of no-till being practiced in the watershed,

and encourages those not currently practicing conventional tillage to consider practicing a form of conservation tillage. In the report, the 19 percent reduction in phosphorus from conservation tillage practices is based on an average, so that reduction may or may not be reached. Likewise, the 20 percent reduction in total phosphorus from nutrient management plans is also based on an estimate. The report suggests that stakeholders use an adaptive management approach, in that the effectiveness of a BMP is estimated after it is incorporated into the watershed.

11. Why weren't any reductions recommended for internal cycling in the lake?

Response: Kinkaid Lake is very deep and is less likely to experience internal cycling than other shallower lakes in Illinois. The calibration did not indicate that phosphorus enriched sediment and cycling were causing impairments.

12. Is there a correlation between high phosphorus and low DO in the stream?

Response: There can be, although that correlation was not proved through the analysis in this report. High phosphorus loading to the stream can cause algal blooms. As the algae dies and decay, the consuming bacteria use oxygen in the water, reducing the amount of dissolved oxygen in the stream. For segment N12, we believe that low flow and stagnant conditions, as well as possible BOD loads, are causing low DO to occur in the stream. As stated in the Implementation Plan, further monitoring is required to properly identify these sources.

13. How often are samples taken for stream segment N12?

Response: The station on Segment N12 is part of the Agency's Ambient Water Quality Monitoring Network. Water chemistry samples are taken on approximately a nine-week rotating schedule, year round. This segment is also sampled by the agency every five years through the Intensive Basin Survey, in which water chemistry as well as habitat and biological parameters are assessed.

14. The report doesn't mention that county SWCDs administer the CPP program through the Illinois Department of Agriculture. Some of the practices recommended in the Implementation Plan could be funded through the CPP program as well.

Response: Thank you for your comment. This will be incorporated into the final version of this report.

15. The animal management facility mentioned in the report for Kinkaid Lake is being closed, with the land being seeded to grass, so the erosion and potential phosphorus load contribution from that site won't occur in the future.

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

16. At what point will the lake be delisted, or the study be completely finalized?

Response: The lake can be delisted by: 1) having a new assessment show that it is no longer impaired, 2) having an approved TMDL developed for the causes for which it is listed. The study will be finalized after it is approved by USEPA. Once approved, a final version will be printed and made available to the public.

17. At what point will a determination be made that the voluntary measures listed in the Implementation Plan become involuntary?

Response: At this time, the Agency does not foresee any of the recommended actions in the Implementation Plan becoming mandatory for the pollutants addressed in this TMDL report.

18. Would future industry or sewage plant expansion be affected by this TMDL?

Response: Any new wastewater discharge for the causes identified in this TMDL will be affected by the allocations in this report. Appropriate discharge limits for those causes will be established prior to permitting. New data will be reviewed at that time to confirm the impairment continues.

19. Has a study been done about dredging the river?

Response: To the Agency's knowledge, no study has been done for dredging this segment of the Big Muddy River.

20. Who is the contact person at the Agency for lake and stream monitoring?

Response: Mike Bundren (lake monitoring) and Dave Muir (stream monitoring) can be contacted at the Illinois EPA regional office in Marion by calling (618) 993-7200.

21. We are confused by the discussion in Section 7.1 of the basis for requiring a reduction in phosphorus to achieve the pH TMDL. Only data from stations RNC-1 and RNC-3 are presented to support the expected relationship between total phosphorus, chlorophyll-a and pH. [Note: we were not able to replicate the consultant's correlation between total phosphorus and chlorophyll-a at station RNC1. The data set for RNC-1 included in Appendix A includes two values that are not shown in figure 8-3: a chlorophyll-a value of 58.7 on 8/2/2000 (for which there is a corresponding total phosphorus value of 0.009) and a total phosphorus value of 0.654 on 10/22/90. Using those values, we calculated an r^2 of 0.03; substituting the total phosphorus median value of 0.16, results in an r^2 of 0.029. We also note that the chlorophyll-a value of 58.7 on 8/2/2000 appears to have been used in Figure 7.1 to demonstrate the expected relationship between chlorophyll-a and pH. If that value is eliminated from that analysis, the r^2 becomes 0.04.]

For most stations in the lake and for the lake as a whole (considering data from all four stations), there is no correlation (r^2,0.15) between total phosphorus and pH, chlorophyll-a and pH or total phosphorus and chlorophyll-a. Moderate correlations exist between total phosphorus and chlorophyll-a at station RNC-3 (r^2=0.46) and for the entire lake (r^2=0.37), and between chlorophyll-a and pH at station RNC-1 (r^2=0.37). For station RNC-4, which has the highest total phosphorus concentrations, but no exceedences of the pH standard, there is no correlation between any of the variables (r^2 </=0.10).

Response: The relationships presented in Section 7 were intended to confirm that there is a relationship between pH and chlorophyll-a in addition to chlorophyll-a and phosphorus. These general relationships have been established in literature, which suggest that reducing algae (chlorophyll-a) maintains pH and reducing phosphorus concentrations reduce algae (chlorophyll-a). Additional data collection for Kinkaid Lake may establish the same relationships found in literature. All the r^2 values are low, and the figures were intended to show general trends and provide examples of what has been established through literature. The relationships established in literature were used as the basis for the focus of this TMDL – control of phosphorus and thereby control of algae (chlorophyll-a) and pH.

22. We also find the discussion of loading capacity confusing. The section states that load reductions were modeled for RNC-4 because it violates the phosphorus standard (but not the pH standard), but then says that the effects of the modeled reductions are only shown for stations RNC-1 and RNC-3 because they are the only stations that violated the pH standard (RNC-1 never violates the phosphorus standard and at RNC-3 only one sample since 1994 has exceeded the standard. At both stations, the mean total phosphorus concentration is well below the standard).

Response: Phosphorus loadings in sub-basins 2, 3 and 4 were less than sub-basin 1. Therefore sub-basin 1 and its contributions to station RNC-4 were targeted for reductions. Phosphorus flows through the lake as well as settles and can cause algae growth in various parts of the lake. Since the largest loads were generated from sub-basin 1, it was the focus of the reductions to maintain pH throughout the lake.

23. The relationships provided in Figures 7-1 through 7-4 are weak, at best. At RNC-1, there is no relationship between total phosphorus and chlorophyll-a and only a moderate correlation between chlorophyll-a and pH. There is also no direct correlation between total phosphorus and pH (r^2=0.04). At RNC-3, there is only a moderate correlation between total phosphorus and chlorophyll-a and no correlation between chlorophyll-a and pH. There is also no direct correlation between total phosphorus and pH (r^2=0.0007). We also note that the predicted mean total phosphorus values after a 40 percent reduction in phosphorus loadings shown in Table 8-3 exceed the mean of the observed values at RNC-1 in 1997 and 2000 and at RNC-3 in 2000.

Response: See response to question 21.

24. In Section 9.1.2 Implementation Actions and Management Measures Summary, it is not apparent how the "Potential Percent Reductions" values in Table 9-2 were derived. For example, what is the basis for the statement in the preceding paragraph, 3rd bullet: "Nutrient management (reductions of total phosphorus in sediment by 20 percent)"? No citations to the scientific literature are provided, and no data or analysis are presented to support this statement.

Response: This was estimated 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.

25. We were not able to find any results of modeling BMP effectiveness in Appendix C, GWLF and BATHTUB input and output files. Table 9-2 shows a potential reduction of 19% 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 increased losses of dissolved phosphorus (McIssac et al, J. Soil and Water Conservation: 50 (4) 383-397 (1995)).

Response: The tillage practices category listed in Table 10.2 refer to conservation tillage practices, and the report has been changed to reflect that. Table 10.6 in the report suggests that it would be beneficial for all of the cropland in the watershed to have some form of conservation tillage implemented. Section 9.1.1.1 on page 9-2 of the report states "Conservation tillage is assumed to include tillage practices that preserve at least 30 percent residue cover of the soil after crops are planted." The GWLF model took into account those cropland acres in which conservation tillage practices, including no-till, have already been implemented. 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. McIssaac et al. conclude that "[T]he fate of the dissolved P in runoff from agricultural fields is likely to depend upon the hydrologic context of each particular field in question. Dissolved P may be absorbed by vegetation or soils in buffer strips, wetlands, riparian zones, or stream banks. Whether elevated levels of dissolved P in runoff represents a problem in a watershed depends upon these processes. " If we proceed with an iterative approach to BMP installation and monitor the results, dissolved and total phosphorus loads can be better understood and treated.

26. 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.

In 2003, Kinkaid Lake began a Phase I Clean Lakes Study funded through Illinois EPA. A component of this Study is to collect tributary data. Once taken and verified, these data can be analyzed to see how it can compliment or enhance the TMDL analysis.

27. We believe that 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. Presenting reductions in terms of soil erosion being reduced by tons per acre and targeted C factors 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.

28. 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 9.1.1.2, on page 9-3 of the report states: "To maintain removal efficiency, sheet flow should be maintainted and substrate should be monitored to assess whether the wetland is operating optimally." It is true that sheet flow should be maintained in order for filter strips to properly filter pollutants. This will be reflected in the final version of the report.

29. We noted a significant disagreement between the Agency's contractors on the effectiveness of buffer strips and wetlands in removing phosphorus, and even by CDM in its discussion of BMP for nutrients in different TMDLs. The TMDL for the Charleston Side Channel Reservoir (Section 9.1.4, page 39) used the following values in its discussion of measures to achieve the necessary load reductions:

The combination of the following BMPs result in a reduction of 94.6 percent of the total phosphorus load to the lake

- 33.5 percent reduction through aeration, sediment sealing, or system flushing (90 percent of internal load)
- 20 percent reductions of external load due to cultural practices (primarily through CRP, tillage, and nutrient management practices)
- 70 percent reduction of external load due to buffer strips
- 65 percent reduction of external load due to ponds or wetlands

These values differ greatly from the values used by CDM in their discussions of implementation of the Washington County Lake TMDL (Section 10.2.3, page 10-12) and the Altamont New Reservoir TMDL (Section 9.1.3, page 9.6):

Management Measure	Altamont New Reservoir TMDL (Table 9-2)	Washington County Lake TMDL (Table 10-4)	Kinkaid Lake TMDL (Table 9-2)
Nutrient Management	17%	11%	14%
Tillage Practices	38%	30%	19%
Filter Strips*	22%	22%	14%
Wetland*	5%	40%	25%

*Literature value utilized for estimation

We note particularly the great difference in the estimates for the potential reductions from wetlands both in the two TMDLs prepared by CDM and the Charleston Side Channel Reservoir TMDL. But CDM also has taken contradictory positions on the effectiveness of wetlands in the two TMDLs we have reviewed. In the Altamont New Reservoir TMDL (Section 9.1, page 9-6), CDM states: "The lower bound of the literature value for wetlands (i.e. 5%) was used due to studies that have shown the long-term effectiveness of phosphorus removal in wetlands is negligible." But in the Washington County Lake TMDL, CDM has used a value of 40%. As quoted by CDM (Altamont New Reservoir TMDL, Section 9.1.1, page 9.2 and Washington County Lake TMDL Section 10.2.1.2, page 10.9), "Over the long term, it is generally thought that wetlands are neither sources nor sinks of phosphorus (Kovasic et al. 2000)". We believe that most of the scientific literature supports Dr. Kovacic's statement.

Response: The inconsistencies for potential percent reduction of management measures in each report prepared by CDM was done in error and will be corrected in the final published reports. The correct values for each management measure are shown below. This change does not impact the degree of implementation recommended for each watershed.

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**

30. The only site in the watershed actually visited by the project team was the Mt. Joy boat ramp, which is in no way representative of the 38,535-acre watershed.

Response: This was the only area shown in pictures in the report. The team visited other areas of the watershed not shown in the report. The extent of the TMDL scope for the study did include field investigations.

31. The TMDL and the implementation plan are derived from a computer model and not from hands-on data collection from the watershed. While this is saving of time and money, it may not realistically reflect conditions in the watershed and may not lead to practical solutions for the impairments which exist.

Response: This TMDL was developed based on readily available data. The water quality data used in the modeling were based on data collected by Illinois EPA from Kinkaid Lake. While the amount of and types of data were lacking in some areas, the Implementation Plan suggests practices that are known to control pollutant loadings that lead to pH impairment. As the report suggests, an adaptive management approach to implementation should be taken, and future monitoring will provide more data, which local stakeholders can use for implementation decision making.

32. The Kinkaid watershed is arguably the steepest watershed in Illinois. One-third of the watershed is in excess of 15% slope and 25,000 acres are in excess of 5% slope. The highest point in the watershed is more than 400 feet above the base of the dam. The headwaters of the original creek are 254 feet higher than the base of the dam.

Response: The slope of this watershed was taken into account during the analysis. Slope length and slope steepness are factors used in the USLE equation, which is a component of the GWLF model that was used during TMDL development.

33. Stream flow into the lake was not measured, but was estimated from stream flow at Casey Fork (Mt. Vernon). One can question the similarity of the two watersheds. (p. 5-2)

Response: Flow data from the Casey Fork watershed were used in the absence of a gauge in the Kinkaid Lake watershed. The drainage area ratio method was used to estimate flows entering the lake. An explanation of this method can be found in Section 5.1.3 of the report.

34. Average monthly rainfall data were used in the model. While these data are probably accurate, there is no accounting for the rate of precipitation. In a steeply sloping watershed, three inches of rain falling over three days is entirely different from three inches over 2 hours (a heavy rain in the Kinkaid watershed is comparable to flushing a toilet).

Response: TMDLs are supposed to account for all seasonal conditions within a watershed, not specific events. Use of monthly precipitation takes into account that requirement of TMDL development.

35. How was water volume calculated for segment RNC4 (upper lake)? This appears to have a major bearing on total phosphorus entering the lake if total Phosphorus = mg Phos./L. x water volume. IEPA has not established specific boundaries for the lake segment represented by each sampling site, but has assigned a surface area to the lake segments. When these areas were added together, it resulted in their estimate of total lake surface area being approximately 50% more than it actually is. (p. 5-15)

Response: The entire volume of the lake was calculated based on historic depth and surface area. Specific segment volumes were not calculated separately.

36. On p.5-6 and 5-7, it is stated that the correlation between pH and chlorophyll a is expected to indicate a direct relationship between the two constituents. In fact Table 5-5 (p.6) shows that segment RNC4 has some of the lowest pH values for the lake and the text indicates no individual samples with a pH impairment. Yet Table 5-7 shows segment RNC4 with chlorophyll a levels more than double those of any other portion of the lake. The actual data contradicts the hypothesis.

Response: TMDLs are supposed to account for all seasonal conditions within a watershed, not specific events. Use of monthly precipitation takes into account that requirement of TMDL development.

37. On page 5-7, it is stated that these relationships would suggest that controlling phosphorus will in turn control pH. Table 5-6 (page 5-7) shows RNC4 with by far the highest phosphorus levels for the lake, but Table 5-5 shows that segment to be in compliance for pH. In fact it is the sampling segments which are well within the standards for Phosphorus that have shown a few individual violations for pH. The actual data again disproves the hypothesis.

Response: See response to question 21.

38. The computer model assumes that all cropland is immediately adjacent to streams. That is definitely not the case in the Kinkaid watershed.

Response: See response to question 5.

39. The TMDL report states that there are no terraces in the Kinkaid Watershed. KAWP 2000 (page 11) reports more than 24,000 linear feet of terraces in the watershed (source – Jackson County Soil and Water Conservation District).

Response: This statement has been deleted from the report.

40. In 1991, 1995, and 1996, the text (page 5-6) reports a total of three individual samples slightly below the lower pH limit in the discharge below the spillway. Table 5-4 (page 5-5) reports a total of 70 samples from this location over a seven year period. In 1991, 1994, and 2000 the text reports a total of 4 individual samples testing slightly above the upper limit for pH in segments RNC1 and RNC3. Table 5-4 reports a total of 77 samples taken from these locations over an 11 year period. Do these data indicate any consistent trend toward pH violations? Is it possible to question the accuracy of the instrumentation or readings for pH?

Response: The data indicate that pH impairments are infrequent, however IEPA has determined that 1 violation in a 3 period indicates impairment. All data are shown in Appendix A

41. What is the location of the gauge at which the discharge from the lake was sampled? If it is, as we surmise, located at the Highway 149 bridge, that location is approximately one mile downstream from the spillway. That portion of the creek has it's own watershed and is, at times, actually supplied by the Big Muddy River.

Resonse: Downstream discharge was not analyzed for the Kinkaid Lake TMDL. Water quality data used for TMDL development were taken from the four water quality stations located within the lake.

42. Why does passing over the spillway cause a pH drop of 3 (9.1 in RNC 1 to 6.1 in the "discharge")?

Response: The only water quality data analyzed for Kinkaid Lake were from stations sampled within the lake. No water quality data were analyzed from water that passed over the spillway for this TMDL.

43. A 1983 erosion study of the Kinkaid watershed determined that there was almost 5 times the amount of sheet and rill erosion from cropland as was determined by the 2000 study (KAWP 2000, page 40). Some of the decrease in erosion is attributed to conversion to conservation tillage on cropland. In addition, land use changes have resulted in 1,100 acres of cropland being converted to hay or pasture lands and 2,200 acres of cropland have been enrolled into CRP and seeded to permanent grass cover.

Response: The land use coverage used in the modeling was obtained from Illinois Department of Natural Resource's Critical Trends Assessment database, and was supplemented by the National Agricultural Statistics Service's Cropland Data Layer. Cropland taken out of production would be reflected in these data. Current tillage practices were obtained from the most recent Soil Transect Survey conducted by the Illinois Department of Agriculture. These data were reviewed and verified to be applicable to the Kinkaid Lake watershed by local NRCS staff.

44. The KAWP 2000 erosion study (page 43) reports that sheet and rill erosion from cropland accounts for approximately 25% of the sediment delivered annually into Kinkaid Lake. Sheet and rill erosion from woodlands and grasslands account for 45% of the sediment delivered annually. The remaining sediment delivered annually comes from gully, stream bank and shoreline erosion.

Response: Although gully, stream bank and shoreline erosion are not accounted for in GWLF, they do contain as much phosphorus as the other sources. The source of phosphorus they do contain is accounted for in the Margin of Safety for the TMDL.

45. Sediment from woodlands, grasslands, stream banks and shoreline is not devoid of phosphorus even though none has been applied.

Response: Sediment loading and associated phosphorus loading from woodlands and grasslands was accounted for in the model. Loadings from stream banks and shoreline erosion would be accounted for in the margin of safety.

46. On page 4-5, it is stated that phosphorus is commonly released from sediment into the water when anoxic conditions exist. There is good potential in the upper lake (RNC4) for anoxic conditions to exist, especially during the warm season and especially west of Highway 151. Anoxic conditions occur all over the lake below the thermocline. How much of the soluble phosphorus in the lake comes from sediment deposited over the past 30 years?

Response: The data do not show that this portion of the lake stratifies so as to cause anoxic conditions. Further study would need to occur to determine the amount of phosphorus entering the lake via sediment.

47. The text on page 7-14 states that the model assumes internal cycling is not occurring in Kinkaid Lake. The shallow upper end, especially since significant siltation has occurred, does indeed qualify as a shallow reservoir.

Response: See response to 46.

48. Conservation tillage practices should be continued and encouraged as stated on page 9-2. Voluntary conversion of cropland into conservation programs should be continued and encouraged. Nutrient management is an economical and sensible practice and is already probably followed by most farmers.

Response: The Agency concurs with this statement, and these practices are discussed in the report's Implementation Plan.

49. KAWP 2000 page 30 reports that only 5% of the land adjacent to streams is in cropland. This refutes the assumption in the model that all cropland in the watershed is immediately adjacent to streams. 81% of land adjacent to streams is forested for a width of at least 200 feet from the stream and 14% is in grassland for a width of at least 200 feet.

Response: The model does not assume all cropland is adjacent to streams. It groups all land use within a sub-basin together and predicts loading from a given area. A detailed model which would require more extensive data than is available for the watershed would be needed to account for the spatially varying land use.

50. The implementation plan appears to assume that storm water runoff would flow slowly and evenly across the length of the filter strips. In a watershed as steep as Kinkaid, this will not be the case.

Response: Design of filter strips would have to take into account local conditions.

51. A map showing the intended location of the filter strips would be helpful. Further study may well indicate it would not be possible to filter strip 1900 feet of the two streams mentioned without tearing out existing riparian corridor (trees) or existing grasslands (some on steeply sloping land). Political considerations have been ignored. Much of those two streams are on U.S. Forest Service land. In the past they have not been eager to allow such alterations on their lands.

Response: The total potential length of filter strip installation was based on land use coverage used in the GIS analysis. Only land that is farmed to the edge of streams were considered as potential locations for filter strips. Land use currently in grassland or woodland was not considered, and the agency in no way is condoning such land being replaced by filter strips. The installation of filter strips is strictly voluntary. We encourage local stakeholders to further study filter strip placement in the watershed.

52. The text states that over the long term wetlands are not thought to have an effect on phosphorus entering the lake (page 9.3). Why then is it recommended to construct 134 acres of wetlands?

Response: The text states that there are varying results from wetlands. Consideration of wetlands would need to take this into account as well as site-specific design considerations.

53. Hedging statements such as those at the bottom of page 7-13, pointing out deficiencies in data plus lack of on-the-ground experience in the watershed, lead one to question the validity of both the TMDL and implementation procedures. There is a reasonable possibility that if the implementation plan is completely carried out, the TMDL will still not be in compliance.

Response: This TMDL was developed based on readily available data. We noted in the report where data gaps exist, and suggest additional data that could be collected to strengthen the correlations attempted in the report. The purpose of the Implementation Plan is to suggest practices that may help reduce phosphorus loads to the lake, which should help control pH. We recommend using an adaptive management approach in concert with future monitoring. Data from future monitoring-collected after some BMPs are installed-will determine whether or not the lake is fully supporting its designated uses and if and where additional BMPs are needed.

54. Since 1983 many improvements have been made in the watershed and efforts are on-going to do more. There is also a reasonable probability that if nothing is done to carry out the implementation plan, the lake will show compliance (unless, of course, we continue to use data from the last century).

Response: Land use data, cropping and tillage practices in the watershed were based on the most recent data and verified by county NRCS staff, which would reflect improvements made since 1983. Future assessments of Lake Kinkaid will be based on future data taken through the Ambient Lake Monitoring Program. These monitoring data will be assessed according to methodologies explained in the state's 305(b) Report. The lake will only show compliance when future data show that it is fully supporting all of it's designated uses.

55. On the basis of the TMDL report, it is difficult to see justification for expenditure of public and private funds to create the wetlands and filter strips recommended in the implementation plan.

Response: The report's Implementation Plan recommends that an adaptive management approach be taken. Not all of the recommended practices need to be installed all at once, but rather interested landowners can voluntarily enroll land in programs that provide financial assistance for implementing these practices. Landowners are free to install these practices regardless of whether or not a TMDL has been developed in their watershed. Filter strips and wetlands are recommended based on their ability to reduce the amount of nutrient-laden sediments from entering waterways.

56. Most local citizens perceive sedimentation and siltation to be the major problems at Kinkaid Lake. If we continue existing efforts to prevent sedimentation through erosion control and to manage siltation, the TMDL as perceived by the EPA will come into compliance.

Response: The goal of the TMDL is for Kinkaid Lake to fully support all of its designated uses. Future data assessments will be based on samples taken through the Clean Lake Study and the Ambient Lake Monitoring Program. The target for this TMDL is based on the numeric standard for pH, which can be achieved by reducing phosphorus loads to the lake. Much of this phosphorus enters the lake through sediment. By decreasing the amount of sediment entering the lake through implementation of the recommended BMPs, the phosphorus loads should decrease as well.

57. The only impairment the contractor addressed in the TMDL was pH due to four minor excursions over a ten-year period. The hypothesis used by the consultant is based on a hypothesis by Wetzel who asserts that photosynthesis and respiration are major influences on pH. That hypothesis would not work in RNC-4 because the light column is too short for chlorophyll-a due to the sediment in suspension. I would prefer data from Kinkaid Lake be applied to prove their hypothesis before making an assumption based on a previous study from another situation and location to suggest a relationship between phosphorus and chlorophyll-a to pH in Kinkaid Lake

Response: The TMDL takes into account the entire lake column not just segment RNC-4. It is likely that the algae activity that could be associated with pH impairments occur in different portions of the lake. . In fact, none of the pH excursions were measured in RNC-4-there were two each in RNC-1 and RNC-3.

58. Why did CDM not conclude the paucity of infractions from as large a number of samples should remove the impairment concern from Kinakid Lake? Is it a federal mandate that once a resource is placed on an impaired list, it cannot be found to be an insignificant impairment to warrant removal from the 303(d) List?

Response: pH is listed as a cause of impairment in lakes when at least one violation of the applicable standard for pH (<6.5 or >9.0) occurs during the monitoring year. The Clean Water Act mandates that TMDLs should be developed for waters listed on the State's 303(d) List. The only way a cause of impairment can be de-listed is if: 1. a TMDL is developed for that cause; 2. new data show the water body is no longer impaired for that cause; or 3. the cause is found to be "pollution" (e.g., flow reduction or habitat modification) and not a "pollutant" (e.g., pH).

59. During the final public meeting, the consultant was provided with a copy of "Kinkaid Lake Watershed Investigation" conducted July 11, 2000, by R. D. Windhorn, which arrived at figures for deposition of materials from the watershed to Kinkaid Lake. The BATHTUB model used the wrong assumption that all materials from crop fields and the watershed were deposited directly into Kinkaid Lake. That assumption is not scientifically sound and taints the model's findings. Perhaps Mr. Windhorn's data could be inserted into the model and the load form the watershed to the lake recalculated for a more accurate assessment.

Response: See response to 49.

60. Presently, the Kinkaid-Reed's Creek Conservancy District is in the middle of a Phase I Clean Lakes Study that should provide fresh data for a review on the validity and the necessity of this impairment at Kinkaid Lake. The new data should be reviewed to ascertain if the present condition of Kinkaid Lake warrants the Illinois EPA impairment concern.

Response: We concur with this statement. As new data are taken from the lake, through the Clean Lakes Study as well as the Agency's Ambient Lake Monitoring Program, the data will be used in future assessments to determine if the lake is supporting all of it's designated uses. If not, the most recent data will be assessed to determine causes of impairment. The Implementation Plan for this report includes a continued monitoring plan and an adaptive management approach for monitoring BMP effectiveness.

DISTRIBUTION OF RESPONSIVENESS SUMMARY

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

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