LAKE MONROE DIAGNOSTIC AND FEASIBILITY STUDY

Prepared by:

William W. Jones
Michael Jenson
Eric Jourdain
Sherry Mitchell-Bruker
Lara Strong
Laura Bieberich
Jeffrey Helmuth
Tim Kroeker

School of Public and Environmental Affairs
Indiana University
Bloomington, Indiana 47405

Prepared for:

Monroe County Commissioners
Courthouse Room 302
Bloomington, Indiana 47404

March 1997

Acknowledgments

This project was made possible by a Section 314 grant from the U.S. Environmental Protection Agency. Matching funds were provided by the State of Indiana and local sources. The grant was administered by the Indiana Department of Environmental Management. We'd especially like to thank Sharen Janzen and Carol Newhouse of IDEM for their help and guidance.

This project required the valuable time and talents of many people. We especially wish to thank Susan Fernandes, Richard Martin, Earl Riggs, and the Monroe County Lakes Task Force for spearheading the effort to garner local financial and political support for this study.

We'd also like to thank all those who wrote letters supporting this study and to the following who contributed funds or in-kind services to make this study possible: City of Bloomington Utilities Services Board, Indiana University, City of Bloomington, Bynum Fanyo Inc., Smith Neubecker & Associates, Town of Ellettsville, Southern Monroe Water Corporation, Monroe County Realty and Development, and the Sassafras Audubon Society.

In addition to the authors listed, the following SPEA graduate students assisted with sample collection and analysis: Lisa Blazure, James Joerke, Ken McBride and Rob Price. Sherry Mitchell-Bruker analyzed the hydrology and sedimentation data and wrote those chapters. Rene Aubourg prepared the GIS analysis and maps of watershed land features. Robyn Dommel and Chana Frenkel collected and analyzed sediment samples for physical and chemical properties. Cynthia Mahigian Moorhead prepared many of the original graphics and was the final report production manager. Our thanks go out to all of these people.

This work was funded, in part, by grants from the U.S. Environmental Protection Agency (Grant No. 5995208–01–0) and the Indiana Department of Natural Resources. It was managed administratively by the Indiana Department of Environmental management (Contract No. ARN 93–395A).

Finally, this effort is dedicated to Professor David G. Frey , whose study of Lake Monroe and passion for limnology have inspired many of us to do the work that we now do.

TABLE OF CONTENTS

EXECUTIVE SUMMARY xxiii

1.0 INTRODUCTION 1

2.0 LAKE SETTING 3

- 2.1 LOCATION AND HISTORY 3
  - Geology 6
  - Soils 8
  - Highly Erodible Land 11
- 2.2 MORPHOMETRY 4
- 2.3 DRAINAGE BASIN SIZE AND CHARACTERISTICS 6
- 2.4 GEOLOGY AND SOILS 6
  - Geology 6
  - Soils 8
  - Highly Erodible Land 11
- 2.5 LAND USE 11
- 2.6 CLIMATE 15
- 2.7 DEMOGRAPHICS 15
  - Population 15
  - Economics 17
- 2.8 PUBLIC ACCESS AND RECREATIONAL USE 17
  - Public Access 17
  - Recreational Use 20
- 2.9 MAJOR LAKES WITHIN 80-KILOMETER RADIUS 24
- 2.10 DRINKING WATER USE 24
- 2.11 WILDLIFE RESOURCES 28
  - Habitat Management 28
  - Birds 29
  - Mammals, Reptiles and Amphibians 29
  - Rare and Endangered Species 29

3.0 HISTORICAL DATA 34

- 3.1 OVERVIEW OF PAST STUDIES 34
- 3.2 WATER QUALITY TRENDS SUGGESTED BY THE HISTORIC DATA 35
- 3.3 FISHERIES 39
- 3.4 FISH TISSUE STUDIES 41

4.0 HYDROLOGY 432

4.1 GROUNDWATER AND SURFACE WATER INTERACTIONS 43
4.2 HYDROLOGIC BUDGET 51

5.0 WATER QUALITY 61

5.1 METHODS 61
5.2 SAMPLING SCHEDULE 64
5.3 RESULTS 64
Temperature 64
Dissolved Oxygen 66
Alkalinity 66
pH 68
Soluble Reactive Phosphorus 68
Total Phosphorus 72
Nitrate-Nitrogen 72
Ammonia-Nitrogen 72
Organic Nitrogen 75
Total Suspended Solids 75
Transparency 75
Chlorophyll *a* *78*
Plankton 79
Macrophytes 83
5.4 TROPHIC STATE 87
Introduction 87
Trophic State Indices 87
Trophic State Reuslts 88

6.0 SEDIMENTS 93

6.1 SEDIMENT BUDGET 93
Sediment Inputs 93
Sediment Output 94
Sediment Accumulation 94
Potential Watershed Sources of Sediments 103
6.2 SEDIMENT CHARACTERISTICS 103
Methods 103
Color Analysis 105
Particle Size 105
Organic Matter 105
Nitrogen and Phosphorus 108
Toxic Compounds 118

7.0 NUTRIENT BUDGET 110

7.1 PHOSPHORUS BUDGET 110
Inputs 110
Phosphorus Outputs 112
7.2 PHOSPHORUS EXPORT MODEL 114
7.3 AGNPS MODELING 114
Methods 117
AGNPS Results 123
AGNPS Summary 128

8.0 POLLUTION SOURCES 130

8.1 OVERVIEW 130
8.2 POINT SOURCES 130
8.3 NONPOINT SOURCES 130
Agriculture 134
Silviculture 135
Urbanization 137
Septic System Failure 138
Streambank Erosion 140
Lakeshore Erosion 140
Recreation Impacts 140

9.0 MANAGEMENT ALTERNATIVES 145

9.1 INTRODUCTION 145
9.2 AGRICULTURAL BMPs 145
Conservation Tillage 146
Contour Stripcropping 146
Crop Rotation 146
Grassed Waterways 146
Filter Strips 146
Animal Waste Management 147
Water and Sediment Control Basins 147
Fertilizer Management 149
9.3 FORESTRY BMPs 149
Planning 149
Stream Buffers 149
Stream Crossings 149
Drainage 149
Site Closure 149

9.4 URBAN BMPs 150
Stormwater Management 150
Construction Sites 151
Fertilizer Management 155
Constructed Wetlands for Wastewater Treatment 156
Management of Sensitive Lands 156
9.5 SHORELINE AND STREAMBANK PROTECTION 158
Revegetation 159
Littoral Zone Revegetation 160
Beach Sloping 163
Structural Methods 164
Streambank Fencing 164
9.6 WETLANDS TREATMENT OF NPS POLLUTANTS 165
Purpose 165
Design Considerations 165
9.7 IN-LAKE TREATMENT 166
Phosphorus Precipitation/Inactivation 166
Dredging 167
Aeration 168
Rooted Macrophyte Control 169
9.8 LAKE USE MANAGEMENT 170
Lake Use Restrictions 171
Space Zoning 171
Time Zoning 172
9.9 DRINKING WATER TREATMENT 172

10.0 RECOMMENDATIONS 174

10.1 MANAGEMENT NEEDS 174
10.2 MANAGEMENT APPROACH 175
10.3 POINT SOURCE MANAGEMENT 176
10.4 NONPOINT SOURCE MANAGEMENT 176
Agricultural Areas 176
Forested Lands 177
Urbanized Lands 177
10.5 SHORELINE EROSION 180
10.6 MAINTAINING DRINKING WATER QUALITY 181
10.7 MANAGING HUMAN USE 182
Safety 182
Overuse 183
10.8 POTENTIAL PROBLEMS NOT REQUIRING ACTION AT THIS TIME 184
Aquatic Macrophytes 185
Sediment Accumulation 185

11.0 INSTITUTIONAL FRAMEWORK FOR IMPLEMENTATION 186

11.1 INTRODUCTION 186
11.2 LEGAL AUTHORITY FOR WATER MANAGEMENT 186
11.3 EXISTING JURISDICTIONS 186
11.4 WHO GAINS? 187
11.5 MANAGEMENT APPROACHES 188
11.6 CASE STUDIES 191
Mutual Consent Model 191
Enabling Legislation Model 192
Special Purpose Legislation 193
The Monroe County Lakes Task Force 195
11.7 RECOMMENDATIONS 196
The State's Role 197
LMWC'S Role 198
11.8 CONCLUSION 201

12.0 IMPLEMENTATION 202

12.1 TECHNICAL AND FINANCIAL FEASIBILITY 202
12.2 PUBLIC PARTICIPATION 202
12.3 TIMETABLE 204
12.4 OPERATION AND MAINTENANCE PLAN 205
12.5 PERMIT REQUIREMENTS 205
12.6 ENVIRONMENTAL EVALUATION 205

13.0 LITERATURE CITED 208

APPENDIX A: U.S. EPA Clean Lakes Program Guidance 221

APPENDIX B: Water Quality Data 237

APPENDIX C: Plankton Data 247

APPENDIX D: Fisheries Report 273

APPENDIX E: Current Lake Monroe Watershed Jurisdictions 299

List of Tables

Chapter 2: Lake Setting

Table 2–1. Lake Morphometry 4

Table 2–2. Watershed Land Slopes 8

Table 2–3. Lake Monroe Watershed Land Uses 11

Table 2–4. Temperature and Precipitation Data 15

Table 2–5. Population by County and Township, 1980–90 16

Table 2–6. Population Projections 17

Table 2–7. Economic Information 18

Table 2–8. Employment Data 18

Table 2–9. Recreational Activity Participants by Category at Lake Monroe 20

Table 2–10. Visitorship Data from Lake User Survey 21

Table 2–11. Lake Monroe Fishing Tournaments Registered with IDNR in 1993 22

Table 2–12. Lake Monroe Sailing Association 1993 Events 23

Table 2–13. Lake Monroe Events Sponsored by Fourwinds Marina 24

Table 2–14. Lakes over 40 Hectares within 80 Kilometers of Lake Monroe 25

Table 2–15. Recreational Activities at Nearby Lakes 25

Table 2–16. Drinking Water Sales in February and September 1993 27

Table 2–17. Nature Preserves and Natural Areas in the Monroe Watershed 28

Table 2–18. Bird Species in the Lake Monroe Watershed 30

Table 2–19. Rare and Endangered Species in the Lake Monroe Watershed 33

Chapter 3: Historical Data

Table 3–1. Historical Data—Lake Monroe Dam 36

Table 3–2. Historical Data—Lake Monroe Causeway 37

Table 3–3. Post Impoundment Northern Pike, Walleye, and Hybrid Striped Bass (HSB) Stocked at Lake Monroe 40

Table 3–4. Results of the 1992 Fisheries Survey 41

Table 3–5. Selected Results of 1985 Lake Monroe Fish Tissue and Sediment Analyses 42

Chapter 4: Hydrology

Table 4–1. Baseflow Separation Results 48

Table 4–2. Hydrologic Inputs 53

Table 4–3. Regression Results—Discharge Estimation 53

Table 4–4. Lake Monroe Hydrologic Outputs and Water Budget Results 57

Chapter 5: Water Quality

Table 5–1. Weather Conditions at Time of Sampling 63

Table 5–2. Mean Inorganic Nitrogen to Inorganic Phosphorus Ratios for Upper, Middle, and Lower Basins 84

Table 5–3. Aquatic Plant Attributes 85

Table 5–4. Aquatic Macrophyte Coverage (acres) in Lake Monroe 86

Table 5–5. The Indiana Trophic State Index 89

Chapter 6: Sediments

Table 6–1. Regression Results—Total Suspended Solids Estimation for Monroe Watershed Streams 93

Table 6–2. Modeled Sediment Inputs and Outputs 96

Table 6–3. Sedimentation Rates for Other Indiana Reservoirs 97

Table 6–4. Results of the Lake Monroe Shoreline Survey 98

Table 6–5. Monroe Reservoir Life Base on Modeled Sediment Load and Inflow Rate 101

Table 6–6. Relative Suspended Sediment Loading to Lake Monroe 102

Table 6–7. Percentage of Subwatershed Land in Various Slope Classes 105

Table 6–8. Lake Monroe Sediment Color 105

Table 6–9. Particle Size Distribution in Lake Monroe Sediments 106

Table 6–10. Settling Rates for Soil Particles of Different Sizes in Lake Monroe Sediments 108

Table 6–11. Lake Monroe Organic Carbon 108

Table 6–12. Lake Monroe Sediment Nutrient Concentrations (dry weight) 108

Table 6–13. Sediment Toxic Compound Results (units in mg/kg dry wt) 108

Chapter 7: Nutrient Budget

Table 7–1. Modeled Monthly Phosphorus Inputs and Outputs for Lake Monroe 113

Table 7–2. Phosphorus Budget 113

Table 7–3. Phosphorus Export Model Results for the Lake Monroe Watershed 115

Table 7–4. Summary of AGNPS Results 128

Chapter 8: Pollution Sources

Table 8–1. Status of Wastewater Treatment Plant—Monroe Reservoir Watershed 131, 132

Table 8–2. Ranges of Nonpoint Source Pollutant Loads by Land Use, kg/ha per Year (Source: Sonzogni et al., 1980) 133

Table 8–3. Runoff Coefficients for Various Rural Land Uses (Source: Marsh and Borton, 1976) 133

Table 8–4. Mean Nutrient Concentrations (mg/L) from Harvested and Control Watersheds in Hoosier National Forest (Source: Moss, 1989) 136

Table 8–5. Monroe County Septic System Regulations for Lake Watersheds 139

Chapter 9: Management Alternatives

Table 9–1. Maximum Permissible Design Velocities for Grassed Waterways 147

Table 9–2. Some Representative Examples of Slope-Density Requirements 159

Table 9–3. Vegetation for Lakeshore and Streambank Slopes (Adapted from: McComas, 1966) 161

Table 9–4. Some Rooted Plants to Grow in Midwestern Lakes Needing Habitat 163

Chapter 10: Recommendations

Table 10–1. An Overloaded Lake! 184

Chapter 11: Institutional Framework for Implementation

Table 11–1. Lake Monroe Jurisdictions 187

Table 11–2. Proposed Reorganization of the Lakes Task Force 196

Chapter 12: Implementation

Table 12–1. Public Use of Monroe Reservoir and Opinions of 179 Lake Users Surveyed During Summer, 1992 203

Table 12–2. Public Perception of Monroe Reservoir Problems: Opinions of 179 Lake Users Surved During Summer, 1992 203

List of Figures

Chapter 2: Lake Setting

Figure 2–1. Location of Lake Monroe 3

Figure 2–2. Lake Monroe Morphometry 5

Figure 2–3. Monroe Reservoir Watershed 7

Figure 2–4. Topographic Regions (After Burger, 1966 8

Figure 2–5. Map Showing Bedrock Geology in the Lake Monroe Area (After Burger, 1966) 9

Figure 2–6. Map of Indiana Showing Glacial Boundaries (After Burger, 1966) 11

Figure 2–7. Soil Associations in Monroe and Brown Counties 12

Figure 2–8. Monroe Reservoir Watershed Land Use/Land Cover 13

Figure 2–9. Public Lands Within the Watershed 14

Figure 2–10. Public Access to Lake Monroe 19

Figure 2–11. City of Bloomington Utilities—Water Jurisdiction and Contract Customer Meter Locations 26

Chapter 3: Historic Data

Figure 3–1. Historic Total Phosphorus Results for Lake Monroe 38

Figure 3–2. Historic Total Kjeldahl Nitrogen Results for Lake Monroe 38

Figure 3–3. Historic Secchi Disk Tansparency Results for Lake Monroe 38

Chapter 4: Hydrology

Figure 4–1. Schematic Diagram Showing Generalized Geology and Shallow Groundwater Flow in the Vicinity of Cordry Lake (Not to Scale) 44

Figure 4–2. Static Water Levels in Domestic Wells in the Lake Monroe Watershed. Dry Wells (d) Are Indicated 45

Figure 4–3. Correlation Between Ground Elevations and Water Table Elevations Indicates a Shallow Water Table 46

Figure 4–4. Elevation Profile of Dry Wells in the Lake Monroe Watershed 46

Figure 4–5. Example of Baseflow Separation Results for Stephens Creek 47

Figure 4–6. Location of Stream Monitoring Stations in the Lake Monroe Watershed 48

Figure 4–7. Groundwater Model Results 50

Figure 4–8. Cross-section of Water Table Near Lake Monroe 52

Figure 4–9. Modeled vs. Measured Daily Mean Discharge—Stephens Creek 54

Figure 4–10. Modeled vs. Measured Daily Mean Discharge—Brummetts Creek 54

Figure 4–11. Modeled vs. Measured Daily Mean Discharge—North Fork Salt Creek 55

Figure 4–12. Modeled vs. Measured Daily Mean Discharge—Middle Fork Salt Creek 55

Figure 4–13. Modeled vs. Measured Daily Mean Discharge—South Fork Salt Creek 56

Figure 4–14. Streamflow Inputs to Lake Monroe from April 15, 1992 to April 15, 1993 57

Figure 4–15. Daily Lake Monroe Stages from April 1992 to May 1993 58

Figure 4–16. Comparison of Lake Monroe Water Budget Surplus to Inflow, Outflow and Storage 60

Chapter 5: Water Quality

Figure 5–1. Location of Lake and Stream Sampling Sites 61

Figure 5–2. Temperature Isopleth for the Upper Basin, Lake Monroe 64

Figure 5–3. Temperature Isopleth for the Middle Basin, Lake Monroe 65

Figure 5–4. Temperature Isopleth for the Lower Basin, Lake Monroe 65

Figure 5–5. Stream Temperatures at Sampling Sites 66

Figure 5–6. Dissolved Oxygen Isopleth for the Upper Basin, Lake Monroe 67

Figure 5–7. Dissolved Oxygen Isopleth for the Middle Basin, Lake Monroe 67

Figure 5–8. Dissolved Oxygen Isopleth for the Lower Basin , Lake Monroe 68

Figure 5–9. Relationship Between Temperature and Dissolved Oxygen in Lake Monroe 69

Figure 5–10. Dissolved Oxygen Concentrations in the Lake Monroe Watershed Streams 69

Figure 5–11. Alkalinities—Lake Monroe Sites 69

Figure 5–12. Alkalinities—Monroe Watershed Streams 70

Figure 5–13. Relationship Between Alkalinity and Discharge in the Monroe Watershed Streams 70

Figure 5–14. pH—Lake Monroe Sites (Epilimnion) 70

Figure 5–15. pH—Monroe Watershed Streams 70

Figure 5–16. Soluble Reactive Phosphorus—Lake Monroe Sites 71

Figure 5–17. Soluble Reactive Phosphorus—Lake Basin Means 71

Figure 5–18. Soluble Reactive Phosphorus—Monroe Watershed Streams 71

Figure 5–19. Total Phosphorus—Lake Monroe Sites 73

Figure 5–20. Total Phosphorus—Lake Basin Means 73

Figure 5–21. Total Phosphorus—Monroe Watershed Streams 73

Figure 5–22. Nitrate—Lake Monroe Sites 74

Figure 5–23. Nitrate—Monroe Watershed Streams 74

Figure 5–24. Ammonia—Lake Monroe Sites 76

Figure 5–25. Ammonia—Monroe Watershed Streams 76

Figure 5–26. Organic Nitrogen—Lake Monroe Sites 77

Figure 5–27. Organic Nitrogen—Lake Basin Means 77

Figure 5–28. Organic Nitrogen—Monroe Watershed Streams 77

Figure 5–29. Suspended solids—Lake Monroe Basin Means 78

Figure 5–30. Suspended Solids—Monroe Watershed Streams 78

Figure 5–31. Secchi Disk Transparency—Monroe Lake Sites 79

Figure 5–32. Location of 1% Light Levels—Monroe Lake Sites 79

Figure 5–33. Chlorophyll *a*—Lake Basin Means 79

Figure 5–34. Plankton Densities (Includes Three Graphs A, B, & C) 80, 81

Figure 5–35. Plankton Biovolumes (Includes Three Graphs A, B, & C) 82, 83

Figure 5–36. Relationship Between Epilimnetic Total Phosphorus and Secchi Disk Transparency 84

Figure 5–37. Areal Coverage of Rooted Macrophytes in Lake Monroe 86

Figure 5–38. Carlson's Trophic State Index 88

Figure 5–39. Trophic State Index Scores Using the Indiana TSI 90

Figure 5–40. Trophic State Index Scores for Lake Monroe Using Carlson's TSI 91

Chapter 6: Sediments

Figure 6–1. Comparison of Measured vs. Modeled TSS Loads, Monroe Watershed 93

Figure 6–2. Modeled Sediment Loads for 1992-933 95

Figure 6–3. Sediment Contributions to Lake Monroe 96

Figure 6–4. Shoreline Survey Segments 99

Figure 6–5. Locations of Sediment Cores and Grab Samples 100

Figure 6–6. Sediment Depth Cross-section for Transect 1 100

Figure 6–7. Sediment Depth Cross-section for Transect 2 100

Figure 6–8. Sediment Depth Cross-section for Transect 3 101

Figure 6–9. Projected Changes in Lake Monroe Storage Based on Current Stream Suspended Sediment Loads 102

Figure 6–10. Volume of Sediment Eroded from Lands in Different Uses (Source: Thurow et al., 1975) 103

Figure 6–11. Land Use Categories by Sub-Watershed 104

Figure 6–12.Suspended Sediment Pattern in Lake Monroe Following a Spring 1986 Runoff Event. Note Sediment Plumes from Watershed to the East and from Erosion of the Fairfax Peninsula to the Southwest 107

Chapter 7: Nutrient Budget

Figure 7–1. Results of Phosphorus vs. Discharge Regressions for Measured Values 111

Figure 7–2. Modeled Phosphorus Load for Stephens Creek 111

Figure 7–3. Modeled Phosphorus Load for Brummetts Creek 111

Figure 7–4 .Modeled Phosphorus Load for North Fork Salt Creek 111

Figure 7–5. Modeled Phosphorus Load for Middle Fork Salt Creek 111

Figure 7–6. Modeled Phosphorus Load for South Fork Salt Creek 111

Figure 7–7. Annual Phosphorus Loading to Lake Monroe 113

Figure 7–8. Box Plots of Phosphorus Export Coefficients from Various Land Uses (From: Reckhow et al., 1980) 116

Figure 7–9. Phosphorus Loading to Lake Monroe Estimated from Export Coefficients 117

Figure 7–10. Phosphorus Loading to Lake Monroe by Land Use 117

Figure 7–11. AGNPS Cells for the Stephens Creek Watershed 118

Figure 7–12. AGNPS cells for the Hamilton Creek Watershed 119

Figure 7–13. AGNPS cells for the Ramp Creek Watershed 120

Figure 7–14. Surface Drainage—Stephens Creek 124

Figure 7–15. AGNPS Soil Erosion—Stephens Creek 124

Figure 7–16. AGNPS Sediment Yield—Stephens Creek 124

Figure 7–17. AGNPS Sediment Phosphorus—Stephens Creek 124

Figure 7–18. Surface Drainage—Hamilton Creek 125

Figure 7–19. AGNPS Soil Erosion—Hamilton Creek 125

Figure 7–20. AGNPS Sediment Yield—Hamilton Creek 126

Figure 7–21. AGNPS Sediment Phosphorus—Hamilton Creek 126

Figure 7–22. Surface Drainage—Ramp Creek 127

Figure 7–23. AGNPS Soil Erosion—Ramp Creek 127

Figure 7–24. AGNPS Sediment Yield—Ramp Creek 127

Figure 7–25. AGNPS Sediment Phosphorus—Ramp Creek 127

Chapter 8: Pollution Sources

Figure 8–1. Agricultural Sources of NPS Pollution (Source: Humstone Squires Associates, 1990) 134

Figure 8–2. Logging Sources of NPS Pollution (Humstone Squires Associates, 1990) 135

Figure 8–3. Construction Sources of NPS Pollution (Humstone Squires Associates, 1990) 137

Figure 8–4. Depth-Area Curve for Lake Monroe 141

Figure 8–5. Depth-Volume Curve for Lake Monroe 142

Figure 8–6. Bottom Sediment Resuspension by Recreational Motorboats in Shallow Lakes (Source: Yousef et al., 1978) 143

Chapter 9: Management Alternatives

Figure 9–1. Typical Barnyard Runoff Management System (Source: Linquist et al., 1987) 148

Figure 9–2. Sediment Retention Basin Cross Section 151

Figure 9–3. The Pollutant Removal Effectiveness of Sediment Retention Basins in the Great Lakes Area (Source: Driscoll, 1986) 152

Figure 9–4. Straw Bale Dike Installation (For Drainage Area less than 0.5 Acre) (Source: U.S. EPA, 1976c) 153

Figure 9–5. Filter Fence Installation (Source: Bauman, 1988) 154

Figure 9–6. Typical Design of Artificial Wetlands for Treatment of On-site Wastewater 157

Figure 9–7. Modifications for Long Slopes (Source: Michigan Sea Grant Program, 1988) 158

Figure 9–8. Willow Post Technique for Steep Streambanks and Lakeshores 161

Figure 9–9. Reed Roll for the Rapid Population of Shoreline Vegetation (Source: Tourbier and Westmacott, 1976) 162

Figure 9–10. Cross Section of Beach Sloping (Source: McComas, 1986) 164

Figure 9–11. Cross Section of a Riprapped Shore (Source: McComas, 1986) 165

Figure 9–12. Time and Space Zoning Options for Human Use Management of Lakes 172

Chapter 10: Recommendations

Figure 10–1. Lake Monroe Phosphorus Loading Rate Plotted Against Vollenweider's Loading Curve 175

Chapter 11: Institutional Framework for Implementation

Figure 11–1. A Fragmented Watershed Management Approach According to Standard Geopolitical Divisions 189

Figure 11–2. An Integrated Watershed Management Spatial Approach 190

EXECUTIVE SUMMARY

Background

Lake Monroe, at 4,350 hectares (10,750 acres), is the largest inland water body in Indiana. Its watershed covers 440 mi^2 and includes portions of six counties. The reservoir was constructed by the U.S. Army Corps of Engineers in 1965. Built originally for flood protection and low-flow augmentation of the White River downstream, Lake Monroe's importance as a water resource has grown with each year. The lake serves as the primary drinking water supply for Bloomington and eight rural water companies. It is the major recreational resource in the southern one-half of the state. Over 1.5 million people visited the lake during 1989. Access to Lake Monroe is available through four state recreation areas, two state wildlife refuges, the Hoosier National Forest, and ten public boat ramps. Approximately one-half of the 190 mile (306 km) shoreline is publicly owned.

Purpose of Study

This diagnostic and feasibility has two primary purposes: (1) to diagnose problems with Lake Monroe and (2) identify technically feasible solutions to the problems identified. The protocol used to conduct this study is specified in guidance materials provided by the U.S. Environmental Protection Agency, which provide about 50% of the project's costs. The State of Indiana contributed about 30% and local contributions provided the remaining 20% of the total costs.

Results

As a result of conducting the Diagnostic portion of the study of Lake Monroe, we have identified the following areas that require management:

1. Water transparency is poor, particularly in the Upper Basin and somewhat less so in the Middle Basin. Fine clay particles—due to runoff, shoreline erosion and sediment resuspension by boats and wind—color the water brown. This limits the light available to algae and decreases the aesthetic appeal of the lake.

2. Phosphorus concentrations are high enough in the Upper Basin to classify that area as eutrophic. If poor transparency wasn't limiting algal growth, the Upper Basin would experience extensive algal blooms.

3. Naturally erosive alluvial soils along streambanks and valley bottoms in the watershed contribute sediment loading to the lake.

4. Shoreline erosion is a serious problem along much of the lakeshore. This erosion contributes to poor water transparency, sediment accumulation, degraded aesthetics, and property damage.

5. Sediment accumulation, while not excessive at current rates (0.03 inches per year), causes localized navigation problems in the upper ends of the lake.

6. Urbanization of the watershed is proceeding at increasing rates as Bloomington expands southward and more people desire "country living." Construction on steep slopes and shallow clay soils characteristic of much of the watershed has the potential to increase the current sedimentation rate 10- to 100-fold.

7. Sediments taken from Sugar Camp Creek Bay had elevated concentrations of arsenic, chromium, nickel, and zinc.

8. Heavy human recreational use of Lake Monroe contributes to lake degradation, interferes with human enjoyment of the resource, and causes safety problems. Lake users surveyed felt that their enjoyment of the lake was threatened more by other lake users than by degraded water quality.

9. Little is known of the presence (or absence) of algal toxins in Lake Monroe. This potential threat is becoming important to drinking water utilities nationally.

10. The scenic beauty of Lake Monroe's shoreline zone is one of its strongest assets and is a major reason people visit the lake. Aesthetics must therefore be considered in the management plan.

11. No comprehensive, coordinated program is underway to protect and manage Lake Monroe and its watershed. This complacency is, perhaps, the greatest threat to the lake.

Recommendations

Most water quality problems in Lake Monroe can be managed by applying Best Management Practices (BMPs) in the lake's watershed to help prevent the delivery of excess water, sediments, and nutrients into the lake. These practices can be applied to farmland, timbered land and to land being developed. In-lake practices are needed to correct eroding shorelines, protect the drinking water supply, and provide a safer and better recreational environment.

1. **Agricultural BMPs**
   - streambank erosion controls
   - vegetative filter strips
   - stormwater detention ponds
   - deny livestock access to streams
   - educational programs

2. **Forestry BMPs**
   - landowner education
   - stream buffer zones
   - stable stream crossings
   - drainage structures
   - proper site closure

3. **Urbanized Land BMPs**
   - Better education for developers and contractors
   - Basin-wide runoff and erosion control regulations
   - Better enforcement of existing erosion regulations
   - Maintenance of control structures
   - Special protection for sensitive lands
     —shorelands
     —steep slopes
   - Consider innovative techniques for land preservation and protection
     —transferable development rights
     —mutually restrictive covenants
     —scenic easements
     —deed restrictions
     —mitigation banks
     —aesthetic performance standards
     —scenic zoning
   - Maintain and enforce existing watershed septic system regulations

4. **Shoreline Erosion BMPs**
   - Re-grading and vegetative stabilization
   - Willow post technique
   - Riprap

5. **Maintenance of Drinking Water Quality**
   - Prevent eutrophication and the formation of THM precursors
   - Manage to prevent formation of toxin-forming blue-green algae

6. **Managing Human Use**
   - Boater safety education
   - More marker buoys to designate shoreline zones and other sensitive areas
   - More enforcement of existing boating regulations
   - Establishment of a study commission to consider: limits on boat density, boat size, horsepower size and boat speed; time zoning; space zoning; limits on fishing tournaments; limits on commercially sponsored events (such as fishing tournaments and July 4th boat parties).

Implementation

The beneficiaries of a healthy, attractive Lake Monroe include not only lake users, but also drinking water customers, local businesses, and landowners whose land values increase because of the lake. The successful implementation of this lake and watershed management plan will require the *will* to make it work, *money* to pay for the work, and a *political structure* to facilitate the work. Strong community support for this study and for protecting Lake Monroe suggests that there is sufficient will to get the job done. There are considerable financial resources available for installing BMPs through a variety of Federal and State grants. Locally, additional funds can be acquired through: user fees, a drinking water surcharge, a new construction impact fee, and/or the raw water surcharge fee currently paid by Bloomington Utilities to the State.

Finally, implementation requires an integrated, watershed-level management approach. We recommend the formation of a legislatively created Lake Monroe Watershed Commission to provide this needed structure. This commission could manage a watershed protection fund, establish management priorities, approve projects for funding, provide coordination, and recommend regulations and legislation to any of the city- or county-level jurisdictions in the watershed.

1.0 INTRODUCTION

This study was undertaken due to concerns over deteriorating water quality at Lake Monroe and increased development pressures along the lake. These concerns coalesced in the summer of 1990. Spearheaded by the Monroe County Planning Department and by the Lakes Task Force, the importance of Lake Monroe to the community was thoroughly documented. Current and potential threats to the lake were also documented. In December, the School of Public and Environmental Affairs at Indiana University pulled together these materials and prepared a proposal to the U.S. Environmental Protection Agency (U.S. EPA) for a Phase I Diagnostic Feasibility Study of Lake Monroe.

Local support for this study was tremendous. In the short space of two weeks, nearly $20,000 in local matching funds and in-kind services was raised, along with thirty-two letters of support. The letters of support came from federal, state and local politicians; local businesses; local realtors; and environmental groups. The completed proposal was submitted by the Monroe County Commissioners and the grant was awarded in September 1991 and the study officially began in April 1992.

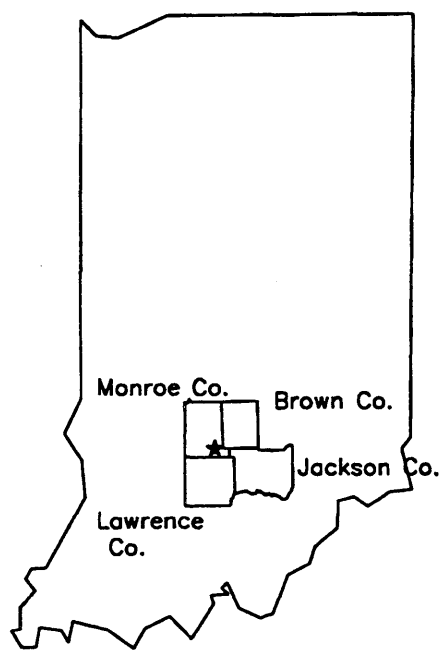
Phase I Diagnostic Feasibility studies must follow specific EPA guidelines (see Appendix A). The diagnostic study identifies problems in the lake and its watershed. The feasibility study evaluates technically feasible management options to address the problems identified. This report includes the final diagnostic and feasibility study. This report will be reviewed by the U.S. EPA, the Indiana Department of Environmental Management, the Indiana Department of Natural Resources, and by local citizens. Comments are encouraged and should be directed to the primary author at the address on the cover page.

2.0 LAKE SETTING

2.1 Location and History

Lake Monroe is situated in south-central Indiana, about ten miles south and east of Bloomington (Figure 2-1). The dam is located 41 kilometers (25.9 miles) above the mouth of Salt Creek, a tributary of the East Fork White River, about 3 km (2 mi.) east of Harrodsburg in southern Monroe County. The latitude and longitude coordinates of the dam are 86°30'40" E and 39°00'29" N. The reservoir occupies the main valley of Salt Creek and the major portion lies within Monroe County with the upper end of the reservoir extending into Brown and Jackson counties. A causeway carrying State Highway 446 divides the reservoir into two basins.

Figure 2-1. Location of Lake Monroe



Lake Monroe was designed, built, and is operated by the Louisville District of the U.S. Army Corps of Engineers. After years of study, the lake was authorized by Title II of Public Law 85-500 approved July 3, 1958. The general authority for public access to and recreational use of the project is contained in Section 4 of the Flood Control Act approved December 22, 1944 (Corps of Engineers, 1967). Construction began in November 1960 and all construction and land clearing was completed in October 1964. Partial impoundment of the reservoir pool was begun February 1, 1965 and once the last power lines crossing the pool were removed, the reservoir was placed in complete operation on February 10, 1966. Impoundment of the low flow regulation pool (elevation 538 feet above Mean Sea Level [MSL]) was completed at 2:00 a.m., April 28, 1966 (Corps of Engineers, 1966).

Lake Monroe is a unit of the general comprehensive plan for flood control for the Ohio River Basin and was constructed for the joint purposes of flood control, water supply, and low flow augmentation. According to a contract between the United States of America and the State of Indiana dated December 1, 1960, the Federal government's primary interest in the project was flood control, and the storage capacity allocated for flood control is the "sole responsibility and under the sole authority of the U.S. Government." After the regulation of flood control is accomplished, the State of Indiana has the primary interest of water supply and low flow regulation. The regulation of the release or withdrawal of water from the storage capacity allocated to water supply and low flow augmentation and the uses which such water is to serve is the "sole responsibility and under the sole authority of the State of Indiana" (Corps of Engineers, 1966). A minimum release from the reservoir of 50 cubic feet per second (cfs) is required as long as the pool is above 515 MSL.

The reservoir storage capacity allocated for future siltation consists of the volume below elevation 515 feet MSL (23,300 acre-feet). The reservoir capacity allocated for water supply and the regulation of low flows is the volume between 515 feet MSL and 538 feet MSL (159,900 acre-feet). The storage capacity allocated for flood control is that volume between elevations 538 feet MSL and 556 feet MSL (258,800 acre-feet) (Corps of Engineers, 1966). The normal recreational pool level (also referred to as the low flow regulation pool) is maintained at elevation 538 MSL.

The dam itself is earth and rock-filled with a top elevation of 574 feet MSL; crown width of 30 feet; length of 1,350 feet; and maximum height of 93 feet. A 600-foot long emergency spillway at elevation 556 feet MSL marks the upper limit of the flood control pool (Corps of Engineers, 1966; Corps of Engineers, 1967). Project lands were generally acquired to elevation 560 feet MSL. Approximately 1,445 acres of land were acquired above elevation 560 feet MSL for public access and recreational purposes.

The original estimated construction cost of Lake Monroe was $4,359,000. Of this, 54.1% ($2,358,219) was apportioned to the State of Indiana for payment. This amount was proportional to the expected benefits that local interests would derive from the project (Corps of Engineers, 1966). It was estimated that after 100 years of providing benefits, the original cost of the project would be repaid (Mike Graham, personal communication).

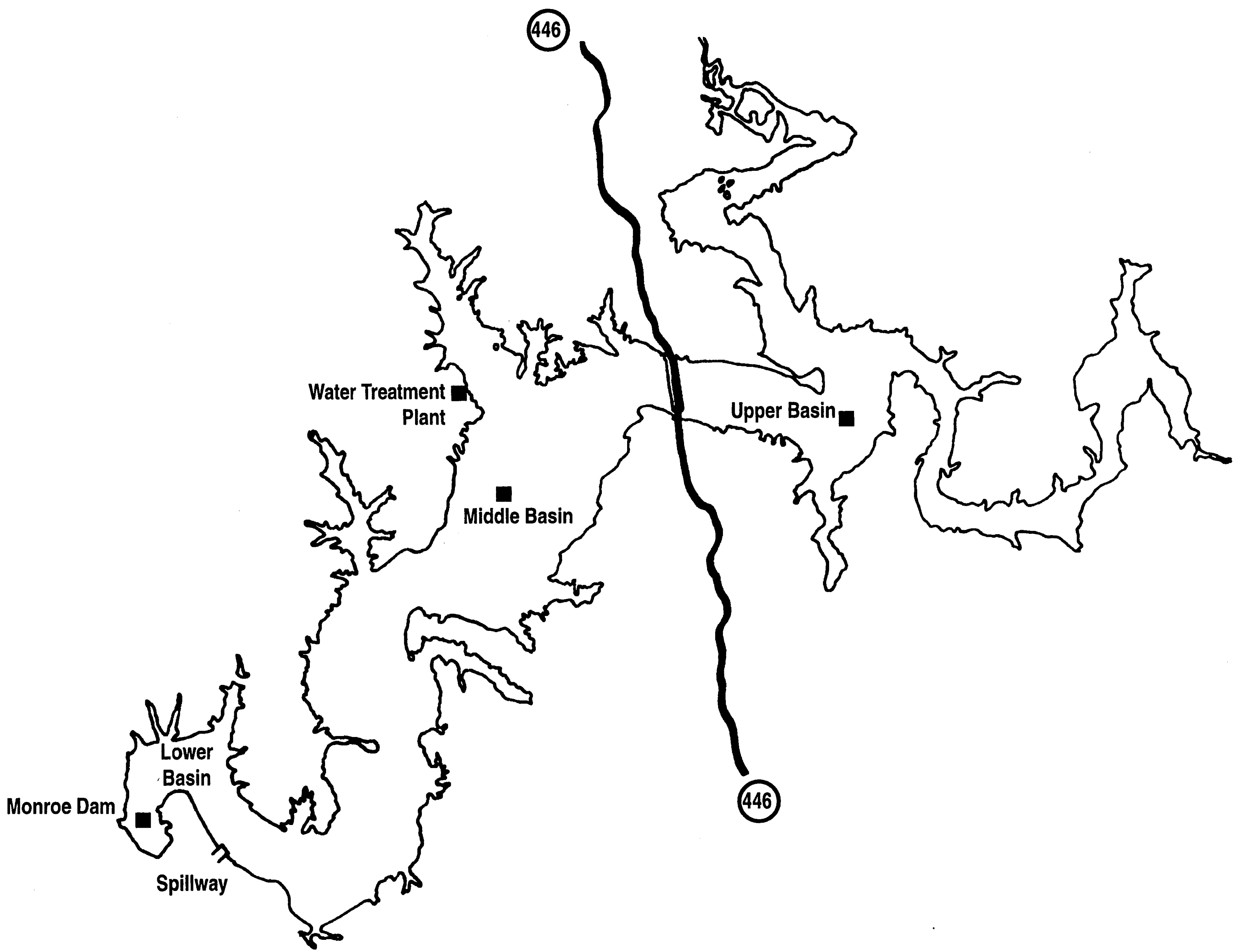
2.2 *Morphometry*

At its normal pool of 4,350 hectares (10,750 acres), Lake Monroe is the largest impoundment in Indiana and is significantly larger than 1238 ha (3,060 ac.) Lake Wawasee, the largest natural lake within Indiana (Clark, 1980). Lake Monroe has a maximum depth of 16.5 meters (54 ft) and a mean depth of 5.3 meters (17.3 ft) (Andrews, 1989). The maximum depth occurs in the original, narrow bed of Salt Creek near the dam. The maximum effective depths of the lake are 10 meters (33 feet) in the lower basin, 6 meters (20 feet) in the middle basin, and 3 meters (12 feet) in the upper basin (Table 2-1; Figure 2-2).

Table 2-1. Lake Monroe Morphometry

	Silt Pool	*Normal Pool*	*Flood Control Pool*
Elevation			
(ft MSL)	515	538	556
Area			
(hectares)	1,327	4,350	7,467
(acres)	3,280	10,750	18,450
Volume			
(meters^3)	27,506,800	197,235,000	319,227,200
(acre-feet)	22,300	159,900	258,800
Max. Depth			
(meters)	—	16.5	21.9
(feet)	—	54	72
Mean Depth			
(meters)	—	4.5	4.3
(feet)	—	14.9	14.0
Shoreline Length			
(km)	—	165	305
(mi.)	—	103	190
Pool Length			
(km)	—	35-60	60-71
(mi.)	—	22-37	37-44

Figure 2-2. Lake Monroe Morphometry



2.3 *Drainage Basin Size and Characteristics*

Lake Monroe drains a hilly and predominantly forested watershed of 1,075 km^2 (415 mi^2) in size, excluding the lake area (Figure 2-3). This results in a rather large drainage basin area to lake area of 24.7:1. The watershed includes portions of Monroe, Brown, Bartholomew, Jackson, and Lawrence counties. Of the total drainage basin, 21.0% lies in Monroe County, 56.1% in Brown County, 1.9% in Bartholomew County, 20.7% in Jackson County, and 0.3% in Lawrence County. At normal pool, 88% of the lake's surface area lies in Monroe County and 12% in Brown County.

Bloomington is the largest city in the watershed and is the county seat of Monroe County. The first permanent settlement in the Bloomington area was in 1816 (Thomas, 1981). Bloomington is the home of Indiana University, which was first established as a state seminary in 1820. Indiana University is the second-oldest major state university west of the Alleghenies. Nashville, the county seat of Brown County, is the next largest community. It was founded in 1836 (Noble, et al., 1990). Numerous small towns dot the watershed.

Salt Creek and its tributaries drain 89.1% of Lake Monroe's watershed (North Fork—45.8%; South and Middle Forks—43.3%). Smaller streams and direct runoff drain the remaining 10.9% of the watershed. The only outlet from Lake Monroe is Salt Creek and flow from the lake is controlled by the Corps of Engineers.

The highest elevation in the watershed lies at Weed Patch Hill in Brown County State Park (1,058 feet above sea level), and the lowest is on the lake at normal pool (538 feet above sea level). Land slopes range up to 50% (Table 2-2).

2.4 *Geology and Soils*

2.4.1 Geology

Lake Monroe is sited at the boundary between two distinct topographic regions (Figure 2-4). To the east, and embracing essentially all of the area that drains to the lake, is hill country that is part of the Norman Upland unit. Along the western flank of the lake, and extending for many miles in a north-south belt, is a plateau called the Mitchell Plain (Gray, et al., 1975; Hartke and Gray, 1989).

The Mitchell Plain is underlain by as much as 450 feet of middle Mississippian limestones of the Bordon Group (Figure 2-5) (Burger, et al., 1966). The region displays some of the best solutional or karst topography in the world (Hall, 1989). Broad surfaces are high, rolling, and well-drained, but most streams of moderate size cut the plain in deep valleys. Soils are, for the most part, moderately deep and moderately fertile, and the subsoil, as is characteristic of limestone areas, is red and clayey. Some parts of the Mitchell Plain are drained by extensive networks of underground streams, and in such areas, springs, caves, and sinkholes are common.

The Norman Upland, which occupies nearly the entire drainage area of Lake Monroe, is an area of steep rocky hills and narrow ridgetops. It is dissected by stream valleys of every size. Very little land is flat enough to farm, and much of the flat land is low and wet, along stream bottoms. Only the major valleys have significant floodplains. The bedrock is relatively resistant siltstone and interbedded shales of the Borden Group which yield poor, thin, stony soil (Hall, 1989; Gray, et al., 1975). The Borden Group is quite impervious to water, providing a tight basin for Lake Monroe. Its impervious nature and the compact soils derived from it also mean that the groundwater storage capacity is low and groundwater reserves are small, except perhaps in the valley fills (Frey, 1976).

The watershed is largely unglaciated (Figure 2-6). The Illinoisan glacier spilled over into the headwaters of the Middle and South Forks of Salt Creek—about as far downstream as Houston on Little Salt Creek and Kurtz on the main branch of South Fork (Frey, 1976). The relative effect of glacial tills is greatest in the South Fork and least

Figure 2-3. Monroe Reservoir Watershed

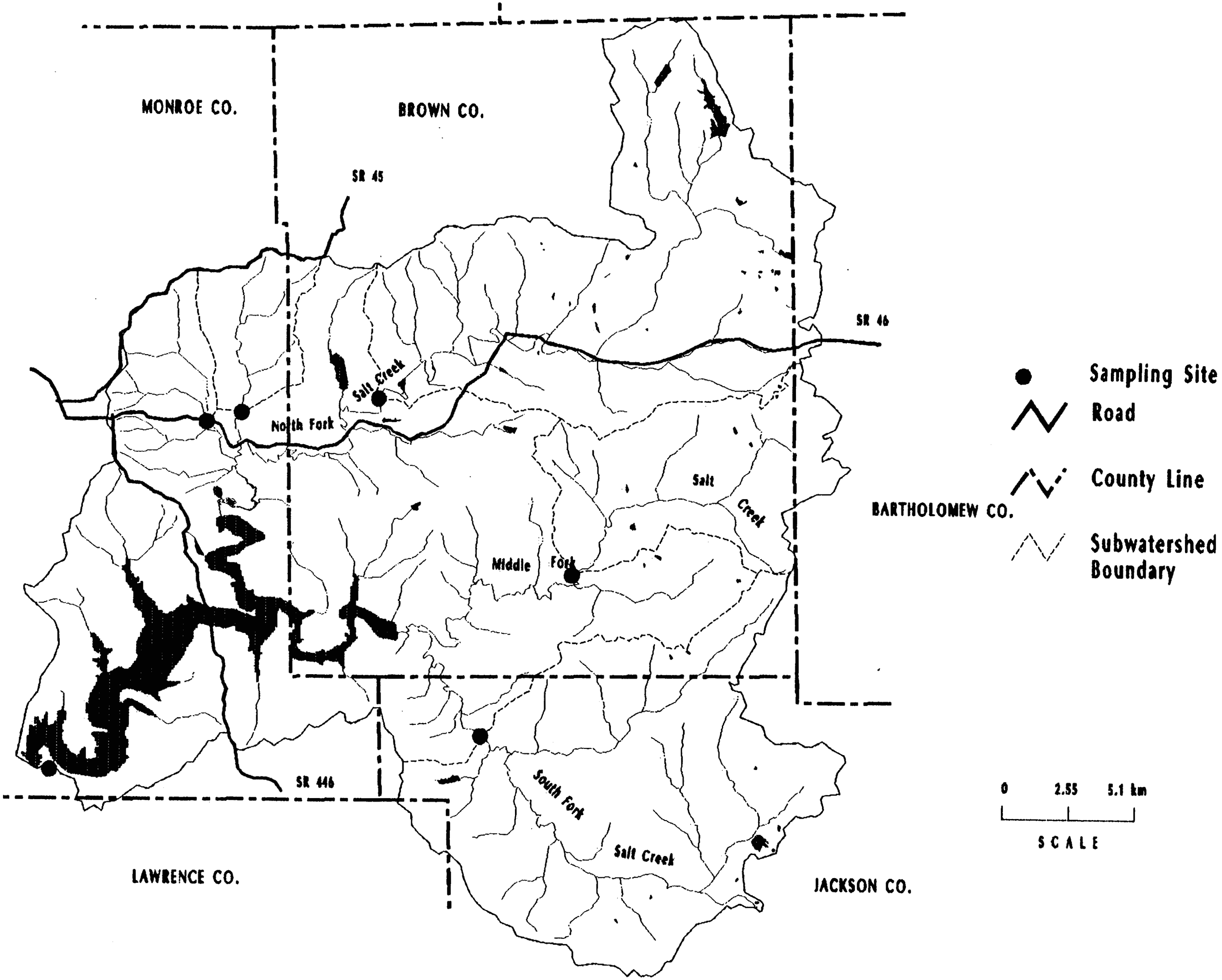


Table 2-2. Lake Monroe Watershed Land Slopes

Slope Class (% Slope)	*Land Area (ha)*	*% of Total Land*
0-5	53484	49.7
5-10	37963	35.3
10-15	12254	11.4
15-20	2920	2.7
20-25	695	0.6
>25	41	<0.1

in the North Fork. Weathering of the tills releases different concentrations of major ions than are released by weathering of native bedrock. Terraces developed along Salt Creek as far downstream as the Lake Monroe Dam are partially composed of outwash sand associated with meltwater from these older glaciers (Hartke and Gray, 1989).

2.4.2 Soils.

A condensed map of soil associations in Monroe and Brown counties appears in Figure 2-7. A description of soil characteristics, by county, is included with the map.

Monroe County. Monroe County is where the division between the Norman Upland and the Mitchell Plain occurs in the watershed. Most of the county is covered by a loess cap that is Wisconsian in age. The major stream in the Monroe County part of the watershed is the North Fork of Salt Creek, which flows through a valley 0.25-1.5 miles wide.

The majority of the watershed in Monroe County (about 55%) is of a Berks-Weikert association. These are well-drained soils formed in residuum from sandstone, siltstone, and shale. The soil is shallow to moderately deep and is found on steep to very steep upland areas.

Figure 2-4. Topographic Regions in South-Central Indiana (Source: Burger et al., 1966)

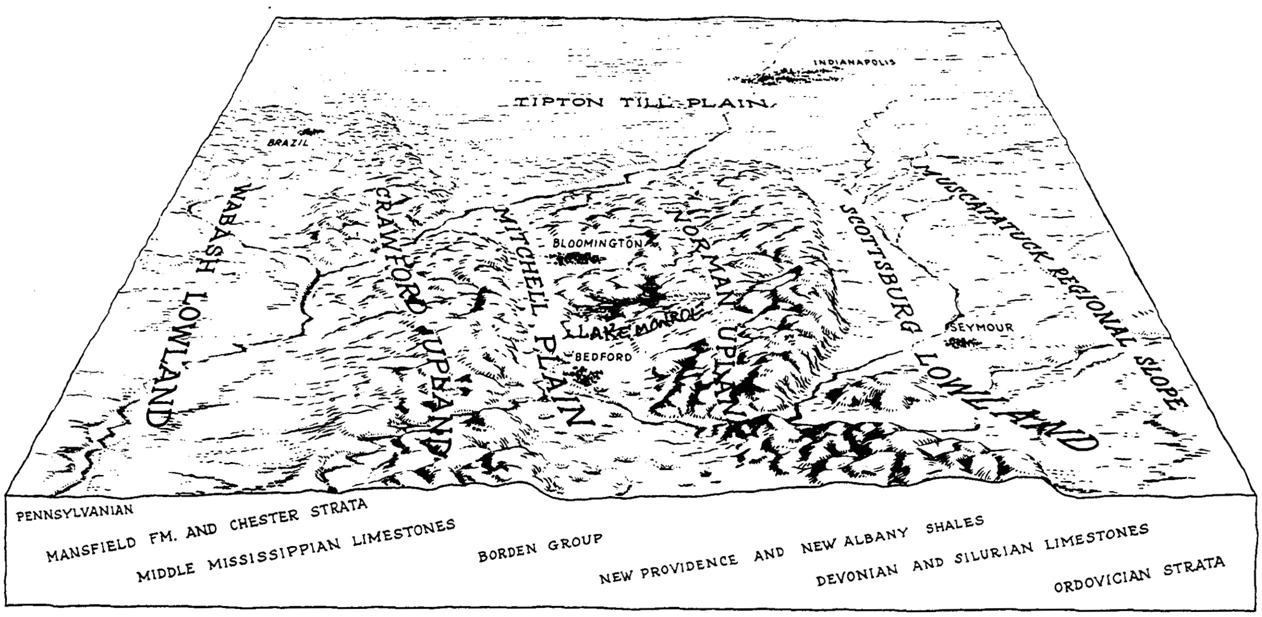
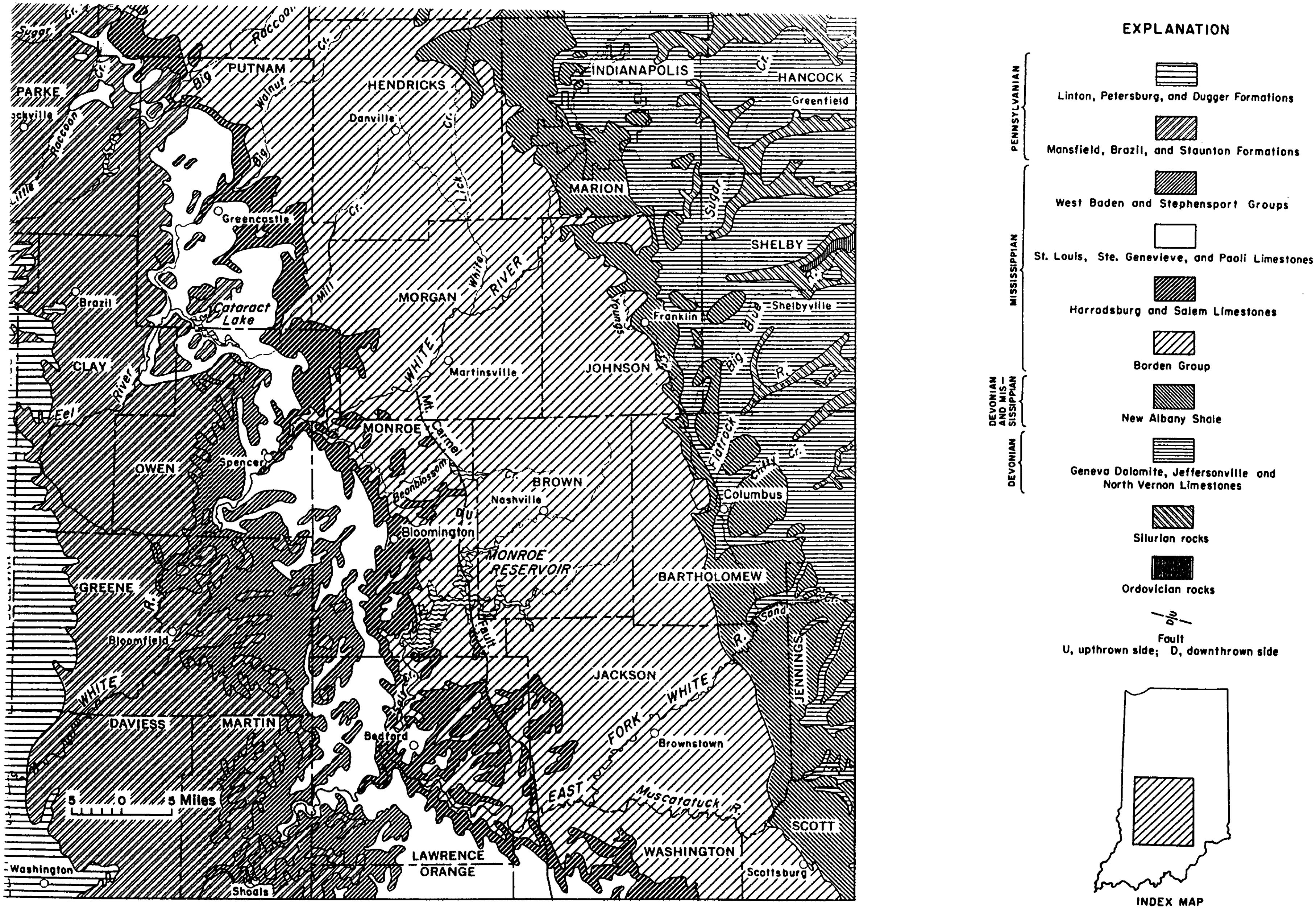


Figure 2-5. Map Showing Bedrock Geology in the Lake Monroe Area (Source: Burger et al., 1966)



Some of the North Fork valley (about 5% of the Monroe County watershed area) is of a Haymond-Stendal association. These are somewhat poorly drained to well-drained soils formed in alluvium. They are deep and found on nearly level land in the flood plain.

A large part of the watershed area (about 40%) along and north of the lower basin is of a Crider-Caneyville association. These are well-drained soils formed in loess and residuum from limestone. They are moderately deep to deep and are found in upland areas that are gently to strongly sloping. The border between this area and the Berks-Weikert association roughly marks the boundary between the Norman Upland and the Mitchell Plain (Thomas, 1981).

Brown County. Illinoian glacial till covers the sharply sloping land of north-central and southeastern Brown County, which includes most of the Lake Monroe's watershed area in the county. Meltwater from glaciers deposited stratified outwash and lacustrine material in terraces adjacent to the flood plains along the major stream valleys. Wisconsin loess covers most of the nearly level to moderately sloping uplands. The two major streams in the Brown County watershed area are the North Fork and Middle Fork of Salt Creek, which run through valleys 0.25-0.50 miles wide.

The vast majority of the Brown County area of the watershed (about 85%) is composed of a Berks-Wellston-Trevlac association of soils. These are well-drained soils formed in loess and in material weathered from shale, siltstone, and sandstone. They are moderately deep to deep and are found on moderately sloping to very steep land. This is mostly soil on ridges and side-slopes in the uplands.

A small amount of the Brown County watershed (about 10%) is in a Stendal-Haymond-Steff association of soils. These are somewhat poorly drained to well-drained soils formed in silty alluvial deposits on the flood plains along the major streams. They are deep soils which are found on nearly level land.

A minor part of the watershed (about 5%) surrounding the upper reaches of Hamilton Creek are composed of a Stonehead-Trevlac-Berks association of soils. These are moderately drained to well-drained soils formed in loess and in material weathered from shale, siltstone, and sandstone. They are moderately deep to deep and found in uplands areas that are moderately sloping to very steep (Noble, et al., 1990).

Jackson County. The Lake Monroe watershed overlaps the northwest corner of Jackson County. The terrain is a part of the Norman Upland, and thus shares its characteristics. The major stream draining the area is the South Fork of Salt Creek.

About half of the watershed area in Jackson County is of a Berks-Gilpin-Weikert association. This consists of loamy Berks and Gilpin Soils and shallow loamy Weikert soil. All are derived from weathered sandstone and shale, are well-drained and are found in steep areas.

About 25% of the watershed area in Jackson County is of a Wellston-Zanesville-Berks association. These are composed of silty Wellston and Zanesville soils with fragipans, both in wind-blown silts and weathered sandstone and shale and found in sloping areas. There is also Berks soil present, in weathered sandstone and shale, found in steep areas. All of these soils are well-drained.

The final (roughly) 25% of the Jackson County portion of the watershed is in a Wakeland-Stendal-Haymond-Bartle association. These are composed of the somewhat poorly drained, silty Wakeland and Stendal soils on nearly level sites and well-drained, silty Haywood soils in alluvial deposits. There are also somewhat poorly drained, silty Bartle soils with fragipans in acid alluvial deposits (Agricultural Experiment Station and SCS, 1971).

Bartholomew and Lawrence Counties. Bartholomew and Lawrence Counties each contain only small portions of the Lake Monroe Watershed, and each area in these counties is in a Berks-Gilpin-Weikert association. These contain well-drained, loamy Berks and Gilpin soils, and shallow, loamy Weikert soils in weathered sandstone and shale.

All are found in steep areas (Agricultural Experiment Station and SCS, 1971).

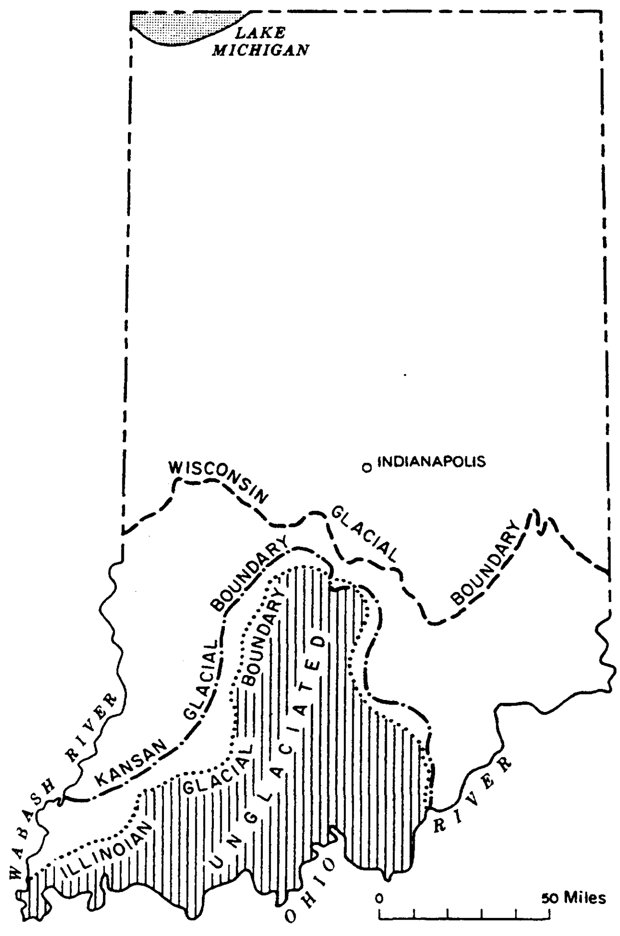
2.4.3 Highly Erodible Land

The majority of the soils in Lake Monroe's watershed are classified as highly erodible lands (HEL). This classification is given to soils, usually on steep slopes, which have a high *potential* for erosion if disturbed or used without applying best management practices. The HEL soils in the watershed include: Berks, Caneyville, Chetwynd, Ebal, Gilpin, Hickory, Weikert, and Wellston. In addition, some of the Crider, Peking, Ryker, and Tilsit soils are also classified as highly erodible.

2.5 Land Use

Land use information was compiled from land use and land cover digital data from U.S. Geological Survey 1:250,000 and 1:100,000 scale maps (USGS, 1990). More than 86% of Lake Monroe's 1,076-km^2 watershed is in forest (Figure 2-8; Table 2-3). Public lands comprise much of this forested area (Figure 2-9). A large portion of the 31,566 ha (78,000 ac.) Brown Co. Ranger District of the Hoosier National Forest lies within Lake Monroe's watershed as do 16,188 ha (40,000 ac.) of state forest land (Morgan-Monroe State Forest and Yellowwood State Forest) and all 6,300 ha (15,547 ac.) of Brown County State Park (Gray, et al., 1975).

Figure 2-6. Map of Indiana Showing Glacial Boundaries (Source: Burger et al., 1966)

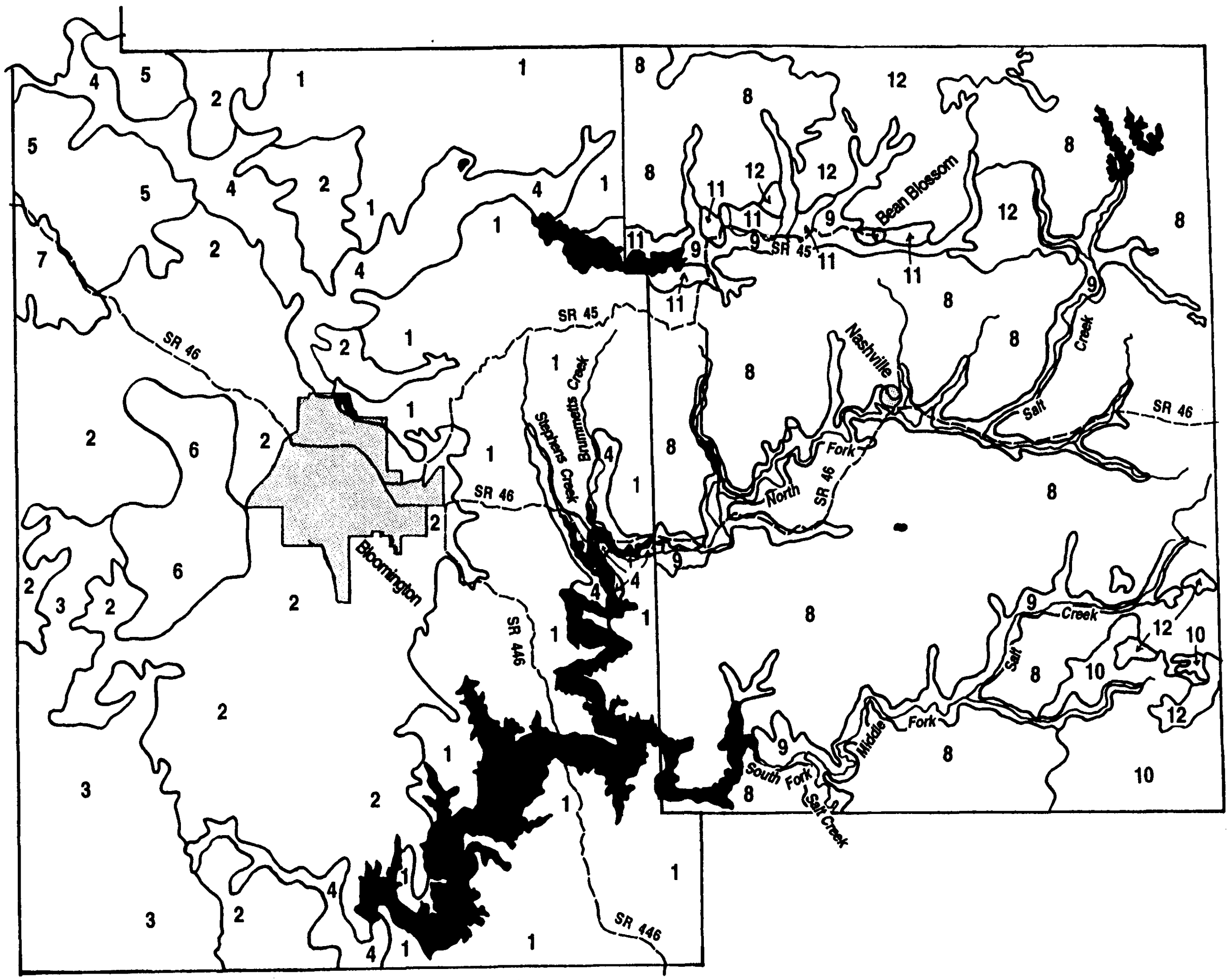


Due to the nature of the Norman Upland, agriculture is of minor importance except along ridgetops and valley bottoms. As such, agricultural lands comprise only 12.2% of the watershed. Urban or built-up lands comprise 1.4% of the watershed but this area is most likely underestimated due to the inability of the GIS system to resolve the numerous small homesites which dot the watershed.

Table 2-3. Lake Monroe Watershed Land Uses

Land Use Category	*Area (hectares)*	*Percent of Total*
Forest	92,818	86.3
Agriculture	13,087	12.2
Urban/Built-Up	1,452	1.4
Other Water	182	0.1
TOTAL	107,539	100.0

Figure 2-7. Soil Associations in Monroe and Brown Counties



1 Berks-Weikert: Moderately deep and shallow, steep and very steep, well-drained soils formed in residuum from sandstone, siltstone, and shale; on uplands.

2 Crider-Caneyville: Deep and moderately deep, gently sloping to strongly sloping, well-drained soils formed in loess and residuum from limestone; on uplands.

3 Ebal-Gilpin-Tilsit: Deep and moderately deep, nearly level to moderately steep, moderately well-drained and well-drained soils formed in loess, colluvium, and residuum from shale, sandstone, and siltstone; on uplands.

4 Haymond-Stendal: Deep, nearly level, well-drained and somewhat poorly drained soils formed in alluvium; on flood plains.

5 Ryker-Hickory: Deep, gently sloping to very steep, well-drained soils formed in loess, glacial till, and residuum from limestone; on uplands.

6 Hosmer-Crider: Deep, nearly level to moderately sloping, well-drained and moderately well-drained soils formed in loess and residuum from limestone, sandstone, siltstone, and shale; on uplands.

7 Peoga-Bartle: Deep, nearly level, poorly drained and somewhat poorly drained soils formed in loess and lakebed sediments or in old alluvium; on uplands.

8 Berks-Wellston-Trevlac association: Moderately deep and deep, moderately sloping to very steep, well-drained soils formed in loess and in material weathered from shale, siltstone, and sandstone; on uplands.

9 Stendal-Haymond-Steff association: Deep, nearly level, somewhat poorly drained to well-drained soils formed in silty alluvial deposits; on flood plains.

10 Stonehead-Trevlac-Berks association: Deep and moderately deep, moderately sloping to very steep, moderately well-drained and well-drained soils formed in loess and in material weathered from shale, siltstone, and sandstone; on uplands.

11 Pekin-Chetwynd-Bartle association: Deep, nearly level to very steep, somewhat poorly drained to well-drained soils formed in silty and loamy deposits; on terraces.

12 Hickory-Cincinnati-Rossmoyne association: Deep, gently sloping to very steep, well-drained and moderately well-drained soils formed in loess and in the underlying loamy and silty glacial drift and till; on uplands.

Figure 2-8. Monroe Reservoir Watershed Land Use/Land Cover

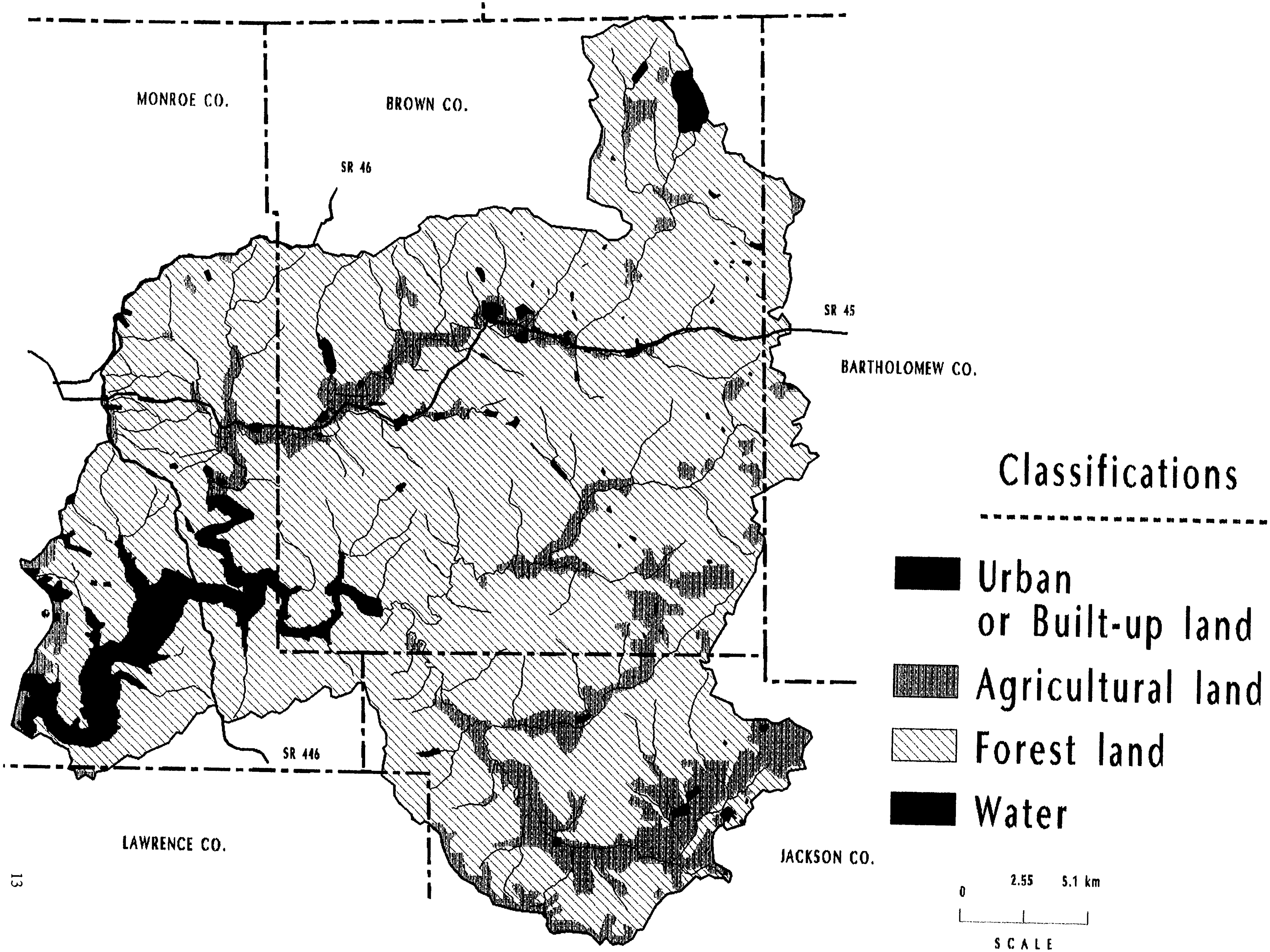
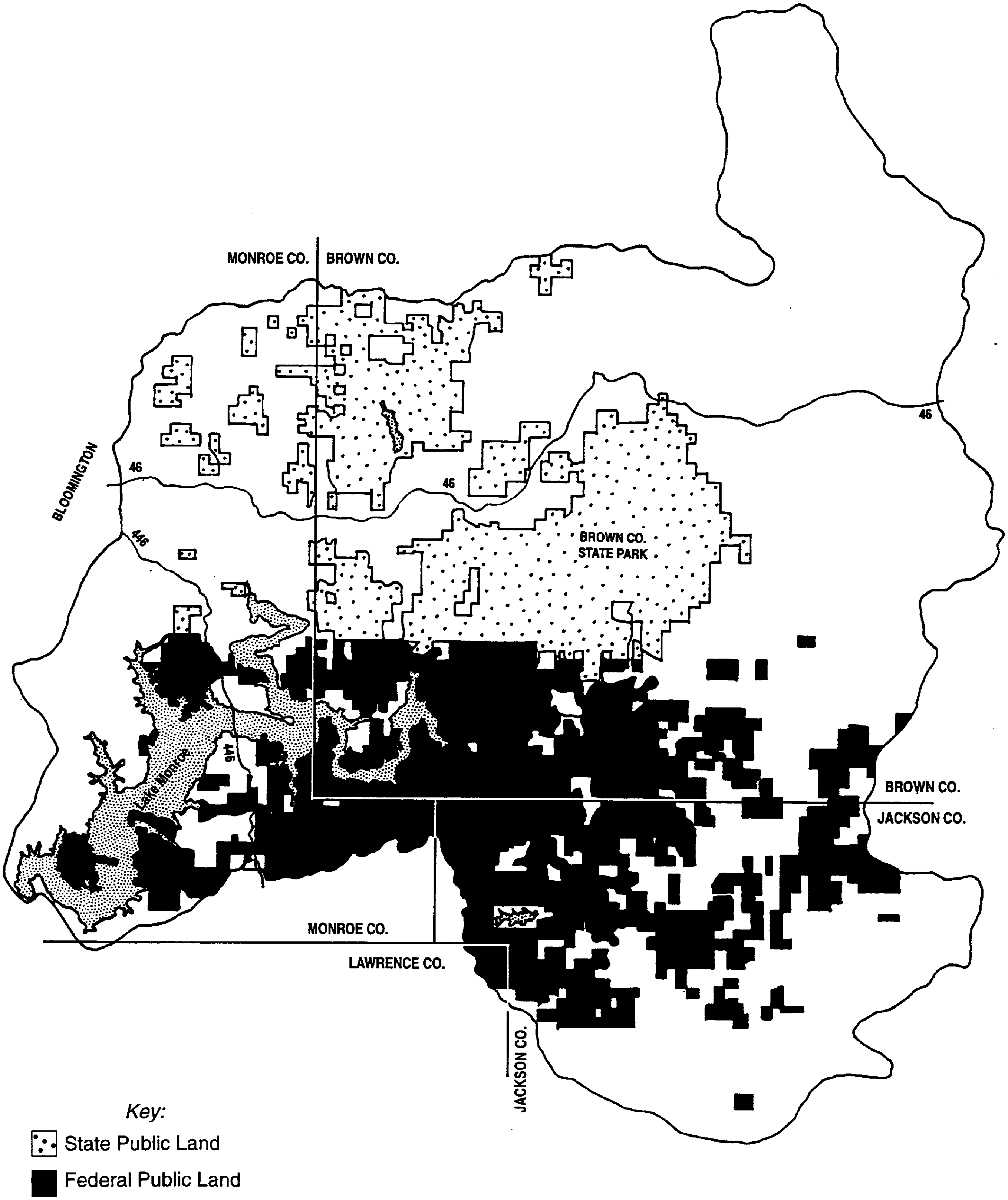


Figure 2-9. Public Lands Within Lake Monroe's Watershed



Approximately 50% of Lake Monroe's shoreland (above 560 MSL) is privately owned. Although much of this area is presently forested, significant land use changes are anticipated in the future on these private lands. The remaining 50% of the shoreline and land immediately surrounding the lake is owned by either the Indiana Department of Natural Resources, the U.S. Forest Service, or the Corps of Engineers.

2.6 Climate

The climate in the Lake Monroe watershed typically displays wide variations in temperature, experiencing cold winters and hot summers. This is typical of areas in the middle latitudes of the interior United States. In winter the average temperature is 32 degrees Fahrenheit, and the average summer temperature is 75 degrees Fahrenheit (Thomas, 1981).

Monroe County has an average annual precipitation of 42.34 inches with an average seasonal snowfall of almost 8 inches (Table 2-4). Only an average of 4 days per year have at least 1 inch of snow on the ground. Approximately 50% of the annual precipitation falls during May-September. July is usually the wettest month of the year.

The average relative humidity in midafternoon is 65%. The prevailing winds are from the southwest, although northwest winds prevail in one or two of the winter months.

2.7 Demographics

2.7.1 Population

While Lake Monroe's watershed is relatively sparsely populated at the present time, census data from 1990 indicate that many of the townships within the watershed grew at a rate faster than the state mean for the period of

Table 2-4. Average Temperature and Precipitation Data for the Period 1951–75 at Bloomington, IN

Month	*Average Daily Temperature Maximum (°F)*	*Average Daily Temperature Minimum (°F)*	*Average Daily Temperature (°F)*	*Average Precipitation (inches)*	*Average Snowfall (inches)*
January	39.3	21.2	30.3	2.87	2.4
February	43.1	23.3	33.2	2.61	2.4
March	51.7	31.7	41.6	3.92	0.1
April	66.0	43.6	54.8	3.80	0.6
May	75.6	52.7	64.4	4.40	0.0
June	83.2	61.6	72.4	4.41	0.0
July	87.0	65.3	76.2	4.47	0.0
August	85.5	63.3	74.4	3.35	0.0
September	79.8	56.8	68.3	3.42	0.0
October	69.4	45.2	57.3	2.31	0.0
November	53.5	34.9	44.2	3.38	0.7
December	42.0	25.2	33.4	3.40	1.5
YEAR	64.7	43.7	54.2	42.34	7.7

Source: Thomas, 1981.

Table 2-5. Population Changes for Townships in Lake Monroe's Watershed, 1980-90

County, Township	*1980*	*1990*	*% Change*
Brown County	12377	14080	13.8
Hamblin	3365	4032	19.8
Jackson	3774	4151	10.0
Van Buren	1207	1419	17.6
Washington	4031	4478	11.1
Monroe County	98785	108978	10.3
Benton	2892	3116	7.7
Bloomington	39877	42156	5.7
Clear Creek	3089	3883	25.7
Perry	26634	31985	20.1
Polk	373	332	–11.0
Salt Creek	1157	1316	13.7
Jackson County	36523	37730	3.3
Owen	1380	1525	10.5
Pershing	1296	1380	6.5
Salt Creek	314	309	–1.6
Lawrence County			
Pleasant Run	–	1649	–

Source: Bureau of the Census (1991)

1980-1990. From 1980 to 1990, Monroe (pop. 108,978, +10.3%) and Brown (pop. 14,080, +13.8%), were among the fastest-growing counties in the state, while Jackson County (37,730, +3.3%) also showed an increase in population. During the same time period, the State of Indiana had an increase in population of just under 1% (Table 2-5).

Five Monroe County townships include most of the county's portion of the watershed within their boundaries: Benton, Clear Creek, Perry, Polk, and Salt Creek. A small portion of a sixth township (Bloomington) also lies within the watershed. Over the decade from 1980-1990, those five townships had an increase in population of 19.0%, compared to the county-wide growth rate of 10.3%. A portion of the actual growth within these townships no doubt occurred outside of the watershed boundaries, however; the census data cannot be broken down for the watershed area exclusively. It is significant to note that the city of Bloomington, which includes about 60% of the county's population total and virtually all the county's industry, lies outside Lake Monroe's watershed.

Brown County is the fastest-growing county within Lake Monroe's watershed. Between 1980 and 1990, the population increased 13.8%. Most of this change occurred in the three townships which lie almost entirely within the watershed: Hamblin, Van Buren, and Washington. Nashville, which lies within the watershed and is the largest town in Brown County, has a permanent population of less than 2,500. There is no heavy industry in Nashville, but county-wide, there are 171 manufacturing jobs; 1,106 service-related jobs; 293 construction jobs; and 1,165 jobs in retail trade in the county. Those four industries account for 90% of employment in Brown County.

In Jackson County, there are three townships which have a significant portion of the lake's watershed within their boundary. Pershing Township (pop. 1,380, +6.5%), and Owen Township (pop. 1,525, +10.5) showed population growth in the past decade, while Salt Creek Township (pop. 309, -1.5%), decreased in population. The two largest population centers in Jackson County, the towns of Seymour and Brownstown, are both well outside the watershed.

Table 2-6. Population Projections for Watershed Townships

County, Township	*1995*	*2000*	*2005*	*2010*	*2015*	*2020*
Brown County						
Hamblin						
Van Buren	4810	5130	5380	5430	5350	5180
Washington	1370	1390	1400	1370	1340	1300
Monroe County	4500	4540	4530	4490	4440	4370
Benton						
Bloomington	3590	3840	4020	4150	4320	4600
Perry	38540	38500	39130	40290	41390	42390
Polk	29000	29770	30430	31220	32370	33850
Salt Creek	440	450	460	470	490	520
Jackson County	1410	1510	1580	1630	1700	1810
Owen						
Pershing	1450	1460	1480	1490	1500	1510
Salt Creek	1410	1440	1470	1490	1500	1500
Lawrence County	330	330	340	340	350	350
Pleasant Run						
	1560	1550	1540	1520	1510	1490

Source: Indiana Business Research Center, 1986.

Population projections for townships in the watershed are given in Table 2-6. The majority of these townships are expected to experience population growth between now and the year 2020. Polk (56.6%), Benton (47.6%), and Hamblin (28.5%) townships are projected to have the highest population growth rates during this period. Pleasant Run (-10.7%) and Van Buren (-9.1%) townships are projected to lose the most population.

2.7.1 Economics

Economic information for counties in the watershed is given in Table 2-7. Monroe County has the highest housing values, the lowest unemployment rate, but one of the lowest per capita incomes. This is most likely due to the large number of lower-paying student jobs related to Indiana University. Bartholomew County has the highest per capita income.

The manufacturing sector employs the largest number of workers in the five counties but most of the jobs occur in the cities of Bloomington, Columbus, and Bedford—which all lie outside Lake Monroe's watershed (Table 2-8). The government sector is the largest employer in Monroe County, due largely to Indiana University. Retail jobs are the largest employment sector in Brown County due to tourism (see also p. 24).

2.8 Public Access and Recreational Use

2.8.1 Public Access

Public lands included in the Monroe Reservoir project total 25,875 acres. Of this, approximately 23,953 acres (including the lake itself) are leased to the State of Indiana and managed by DNR's Division of Reservoir Management. Public management areas include:

Table 2-7. Economic Information

County	*Unemployment Rate (%)*	*Per Capita Income ($)*	*Total Personal Income ($000)*	*Median Value Owner-Occupied Home ($)*
Monroe	3.3	13,905	1,443,820	66,600
Bartholomew	5.2	15,891	1,032,540	57,200
Brown	5.3	12,828	172,192	64,900
Jackson	6.1	14,673	547,848	43,900
Lawrence	8.8	13,910	601,206	42,000

Source: Creeth, 1992

Table 2-8. Employment Data

Employment Sector	*Bartholomew County*	*Brown County*	*Jackson County*	*Lawrence County*	*Monroe County*
Ag. Services	159	17	79	116	407
Mining	42	NA	12	171	221
Construction	2,052	293	1,044	853	2,897
Manufacturing	14,326	171	5,462	5,007	10,030
Transportation	1,934	66	874	683	1,979
Wholesale Trade	1,015	35	841	349	1,439
Retail Trade	6,520	1,165	3,675	3,302	12,198
Finance, Real Estate, Insurance	2,443	147	940	811	3,444
Services	6,777	1,106	2,900	3,616	13,518
Government	4,501	618	2,195	2,423	17,191

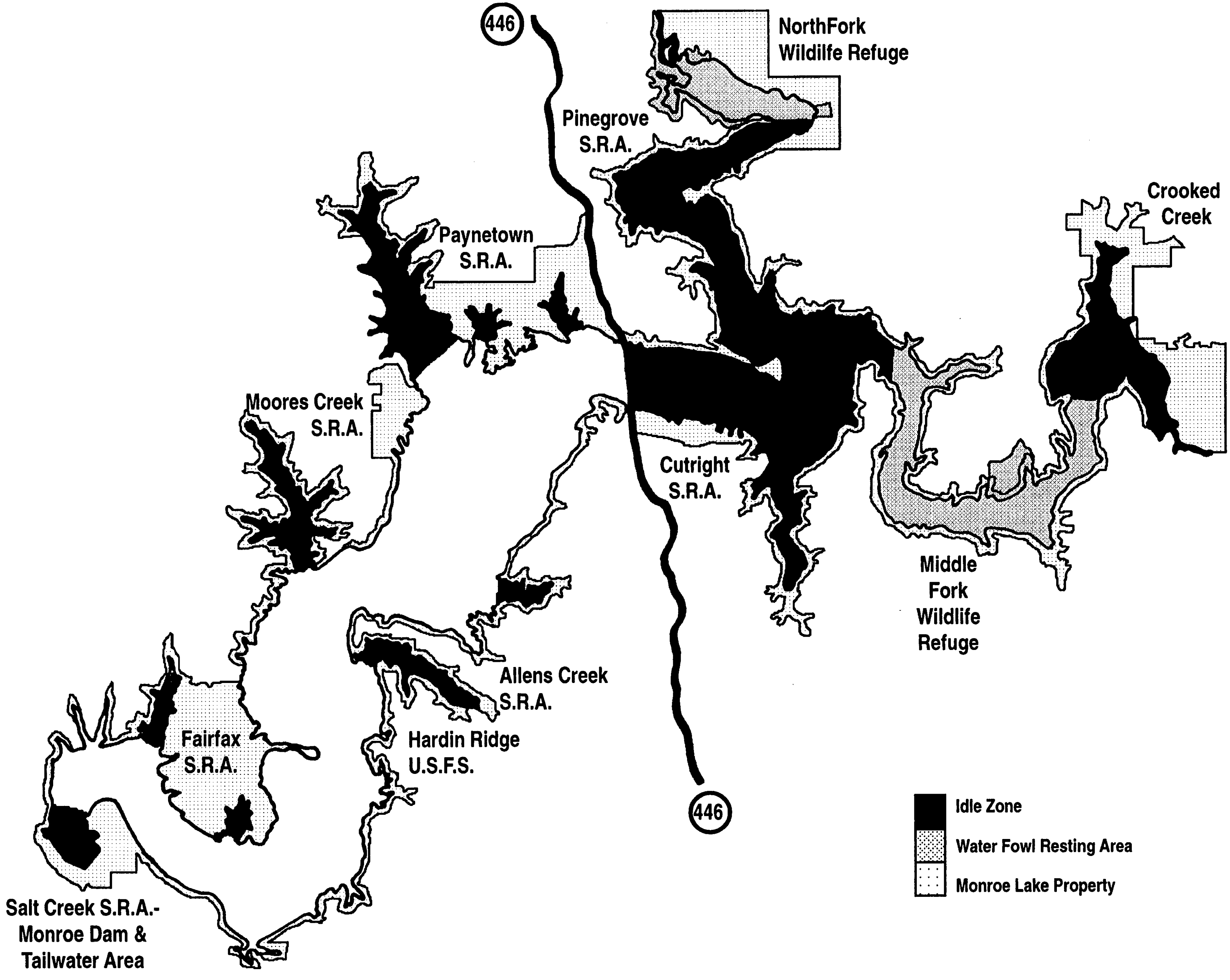
Source: Creeth, 1992

- Lake Monroe—10,750 acres
- Corps of Engineers Dam —404 acres
- U.S. Forest Service—1,518 acres
- State Recreation Areas—2,136 acres
- Fish & Wildlife Management —11,067 acres

Public recreational facilities at the lake include (Figure 2-10):

- Allen Creek State Recreational Area (Indiana DNR)
- Cutright State Recreation Area (Indiana DNR)
- Fairfax State Recreation Area (Indiana DNR)
- Moores Creek State Recreation Area (Indiana DNR)
- Paynetown State Recreation Area (Indiana DNR)
- Salt Creek State Recreation Area (Indiana DNR)
- Hardin Ridge Recreation Area (U.S. Forest Service)

Figure 2-10. Public Access to Lake Monroe



- Charles C. Deam Wilderness Area (U.S. Forest Service)
- North Fork Wildlife Refuge (Indiana DNR)
- Middle Fork Wildlife Refuge (Indiana DNR)
- Ten public boat ramps (Indiana DNR, U.S. Forest Service)

The Indiana DNR operates public beaches at the Fairfax and Paynetown SRAs and the U.S. Forest Service operates a public beach at Hardin Ridge. A $2.00 per car entrance fee is charged at each of these sites. The fees are used to help maintain the facilities.

2.8.2 Recreational Use

The U.S. Army Corps of Engineers records the total number of visitors at 11 recreational sites on Lake Monroe by use of traffic meters. These meters are operated at the Salt Creek Ramp, Dam Overlook, Fairfax Beach, Moore's Creek, Paynetown, Pinegrove, Crooked Creek, Cutright, Allen's Creek, Hardin Ridge, and Tailwater. In the early 1980s, the Corps developed a survey to determine the recreational activities of visitors to the lake. Over a period of several weeks on selected days, all visitors to the lake were stopped and asked a series of questions regarding the nature of their visit and the recreational activities in which they participated. The total number of vehicles at the lake was obtained from the traffic counters, and the number of visitors extrapolated from those data. Since many visitors to the lake participate in several activities (e.g., camping, swimming, boating), the total number of visitors to the lake is less than the sum of participants in all activities (Table 2-9). It should also be noted that there are other, unmonitored access sites to the lake for various activities, and that these numbers may therefore be only conservative estimates of the true number of lake users. The most popular activities at Lake Monroe during 1992 were (in order): sight-seeing, fishing, swimming, picnicking, boating, camping, other, skiing, and hunting.

We conducted an informal lake user survey on July 25 and August 1, 1992 (both Saturdays) at the Cutright Boat Ramp, the Moore's Creek Boat Ramp, the Fairfax State Recreation Area, and the Hardin Ridge Recreation

Table 2-9. Recreational Activity Participants by Category at Lake Monroe

Activity	*1983*	*1985*	*1987*	*1989*	*1990*	*1991*	*1992*
Camping	125525	118077	138303	154443	141554	144907	129847
Picnicking	193241	188818	243645	280990	237896	236818	217337
Boating	183840	187981	234242	263800	158260	128417	211879
Fishing	246317	232024	324044	425739	339085	335503	314352
Hunting	12814	11901	16542	12005	11999	12911	12822
Sight-Seeing	234310	233072	300857	351353	337848	254977	395410
Skiing	77617	70141	85252	91357	87391	90180	82440
Swimming	267775	270144	308295	328138	214252	223803	294322
Other	100640	128375	141283	140003	144350	122493	123568
Total*	1035688	1069469	1332017	1525239	1386415	1398798	1344843

*Many lake visitors report involvement in several recreational activities. Therefore, the sum of all activities is greater than the total visitors for each year.

Source: Corps of Engineers (1993).

Table 2-10. Visitorship Data from Lake Monroe User Survey Conducted July 25 and August 1, 1992

Home County	*No. Responding*	*Average No. Visits/Year*	*Visits/Year Range*
Monroe	81	49	2-365
Marion	24	15	1-52
Morgan	12	52	4-270
Lawrence	13	21	5-52
Brown	3	24	3-40
Johnson	6	15	1-30
Allen	4	4	2-6
Owen	3	64	20-150
Hamilton	3	6	1-10
Hendricks	3	111	12-300
Shelby	3	20	6-40
Bartholomew	2	16	12-20
Greene	2	21	15-26
Jackson	2	25	10-40
Tippecanoe	2	13	11-15
Delaware	1	4	
Grant	1	12	
Hancock	1	22	
Howard	1	5	
Jefferson	1	1	
Kosciusko	1	1	
Lake	1	1	
Perry	1	6	
Starke	1	6	
St. Joseph	1	6	
Sullivan	1	12	
Tipton	1	12	
Warren	1	1	

Other States (Ohio, Alabama, New Mexico: 1 each)

Area. The survey was conducted with the assistance of volunteers from the Monroe County Lake's Task Force and the Monroe County Planning Department. Most of the lake users surveyed were residents of Indiana and came from 28 different counties—from St. Joseph County in the north to Perry County in the south (Table 2-10). The average number of visits per year indicate that it is not uncommon for Indiana residents to visit Lake Monroe frequently and to travel long distances to do so. For example, both the St. Joseph and Perry County responses show an average of six visits per year.

In addition to these public facilities, many private entities sponsor recreational events and activities on the lake. The largest category of these lake events appears to be fishing tournaments. A maximum of 175 boats are allowed for any given fishing tournament. Table 2-11 is a list of fishing tournaments which have been registered with the Indiana DNR office. The dates and numbers of boats involved on the list appear to be very misleading. For example, the "Crappiethon," which is the largest fishing tournament held on the lake, is listed as involving 175 boats and taking place on one day, May 22. In reality, the Crappiethon is held from early April until early June, and has attracted up to 16,000 participants (1988) in past years (Randy Roberts, personal communication,

Table 2-11. Lake Monroe Fishing Tournaments Registered with IDNR in 1993

Date	*No. of Boats*	*Group*
3/20-21/93	100	Turtle Creek Bass Buster
3/28/93	100	Indiana Non-Profit Bass Association (INBA)
4/3/93	125	Bedford Optimist Club
4/4/93	175	Indiana B.A.S.S. Chapter Federation
4/9/93	176	AW Local 933
4/10/93	100	Hoosier Bass'N Gals Spring "Open"
4/17/93	150	Rawlings Enterprises Inc. Senior Bass Circuit
4/18/93	175	Raccoon Bass Anglers
4/24/93	100	Brown County Big Brothers/Big Sisters
5/1-2/93	175	Indiana B.A.S.S. Chapter Federation
5/8/93	175	United Auto Workers Community Action Program
5/9/93	175	Operation Bass - Redman Tournament
5/15-16/93	175	Bassathon U.S.A
5/22/93	175	Crappiethon U.S.A
5/23/93	175	American Scholarship Tournaments
6/5-6/93	75	Indiana B.A.S.S. Chapter Federation
6/12-13/93	175	Hoosier Bass Masters
6/19/93	100	Central Indiana Bassmasters
6/20/93	175	Indiana B.A.S.S. Chapter Federation
6/27/93	175	Indiana State AFL-CIO
7/10/93	100	Hoosier Bass'N Gals "Kid & Company"
7/11/93	175	Fort Vallonia Bassmaster (Boy Scout Tournament)
7/17/93	175	Royal Order of Moose Lodge #398
8/21/93	100	Speedway "500" Bassmasters
8/22/93	175	Indiana B.A.S.S. Chapter Federation
8/28/93	150	Teamsters Local Union 135
8/29/93	175	Operation Bass - Redman Tournament
9/11/93	100	Arvin Recreation League
9/25/93	175	Turtle Creek Bass Busters
9/26/93	175	UAW Local 933
10/2/93	100	Hoosier Bass'N Gals "Open" Team
10/3/93	100	Hoosier Bass'N Gals Fall "Open"
10/16/93	40	Indiana B.A.S.S. Chapter Federation (Classic)

1993). Although many of these participants are fishing from the bank, it does seem reasonable to infer that more than 175 boats are involved in such an event.

Fishing tournaments which are expected to draw 15 or more boats are expected to register with the Paynetown office of the Indiana DNR. A drawing is then held in October or November to assign weekends to these tournaments. The DNR keeps an eye on the tournaments to ensure that the boat limits are not exceeded, but enforcement is sometimes difficult (Randy Roberts, personal communication, 1993).

Table 2-12 is a list of races and events sponsored by the Lake Monroe Sailing Association (LMSA). Participation in these events varies. The LMSA has approximately 200 boats in its membership. The weekly races of light displacement and cruiser series boats usually involve 5-10 boats, and the regattas, overnight cruises and harbor days usually draw around 25-50 boats (Rita Flynn, personal communication, 1993).

Table 2-12. Lake Monroe Sailing Association 1993 Events

Date	*Event*
March 28	Spring Harbor Day #1
April 4	Spring Harbor Day #2
25	Race (Light Displacement/Cruiser Series)
May 1-2	Cruiser Overnighter
2	Race (Light Displacement)
9	Race (Light Displacement/Cruiser Series)
15-16	Thistle High Water Regatta
22-23	Cruiser Overnighter
23	Race (Light Displacement)
30	Spring Regatta
June 6	Race (Light Displacement/Cruiser Series)
13	Race (Light Displacement/Cruiser Series)
20	Race (Light Displacement/Cruiser Series)
July 4	Flotilla and Fireworks Raft-Up
11	Race (Light Displacement/Cruiser Series)
17-18	Cruiser Overnighter
18	Race (Light Displacement)
25	Race (Light Displacement/Cruiser Series)
31-1	Cruiser Overnighter
Aug. 28	Dessert Raft-Up and Moonlight Sail
29	Race (Light Displacement/Cruiser Series)
Sept. 5	Race (Light Displacement/Cruiser Series)
11-12	Governor's Cup Regatta
18-19	Cruiser Overnighter
19	Race (Light Displacement)
26	Race (Light Displacement/Cruiser Series)
Oct. 2-3	Point to Point Regatta
9-10	Cruiser Overnighter
10	Race (Light Displacement)
17	Race (Light Displacement/Cruiser Series)
24	Race (Light Displacement/Cruiser Series)
Nov. 7	Fall Harbor Day #1
14	Fall Harbor Day #2

Table 2-13. Lake Monroe Events Sponsored by Fourwinds Marina During 1993

Date	*Number of People*	*Event*
January 30	100	Marina Appreciation Weekend
June 5	400	Harbor Club Picnic/Treasure Hunt
July 4	3000	Fireworks
August 28	400	Harbor Club Picnic/Poker Run

Table 2-13 is a list of four events which the Fourwinds Marina hosts on Lake Monroe each year. Most of these events are closed to the public. However, the Fourth of July fireworks event, which attracts an estimated 3,000 people, is open to the public in general.

This is only a brief summary of the events held on Lake Monroe. Other than fishing tournaments, there are no requirements to register an event held on the lake, and there are, no doubt, a large number of events which are not listed.

Economic Impact of Lake Monroe. From 1982 to 1992, an average of 1.27 million people per year visited Lake Monroe. Peak visitation during this period was 1.54 million people in 1989. According to Mike Graham of the Corps of Engineers (personal communication, 1993), the number of visitors to the lake can be affected by economic factors and weather conditions. For example, in 1990, high water conditions at the lake kept all beaches closed until late June, therefore reducing the number of visitors to the lake.

The recreational activities at the lake have a significant economic impact on the City of Bloomington and Monroe County. Visitors from all over the state and beyond are attracted to the area by the various activities at the lake and contribute to the local economy through the expenditure of tourist dollars. Although no studies have been conducted to specifically determine the economic impact of the lake on the local economy, the best estimate comes from information provided by the Monroe County Convention and Visitors Bureau (Valerie Pena, personal communication, 1992). Information gathered by the Bureau indicate that in 1989, a total of $150,000,000 was spent by visitors to Bloomington and Monroe County, and that 14% of the visitors were attracted to the area by Lake Monroe. Based on that information, 14% of $150,000,000—or $21,000,000—was added to the local economy through direct and indirect expenditures by visitors to Lake Monroe.

2.9 Major Lakes within 80-Kilometer Radius

There are a number of lakes within an 80-km radius of Lake Monroe that are suitable for aquatic-based recreation. All are reservoirs rather than natural lakes. The next-largest Monroe County lake is 583 ha (1,440 acre) Lake Lemon. Access is much more limited on Lake Lemon but yet it still receives significant congestion on summer weekends.

Table 2-14 lists selected characteristics for major lakes (>40 ha) within an 80 km radius of Lake Monroe. The data represent a single set of samples from each lake collected during July and August (IDEM, 1986). Table 2-15 summarizes the recreational opportunities at these same lakes.

2.10 Drinking Water Use

Although Lake Monroe was constructed primarily as a flood control project, it also serves as the primary source of water to the city of Bloomington and nine rural water companies serving approximately 100,000 users (Figure 2-11).

Table 2-14. Lakes over 40 Hectares within 80 Kilometers of Lake Monroe

Lake (County)	*Distance (km)/ Direction From Lake Monroe*	*Size (ha)*	*Max. Depth (m)*	*Mean Depth (m)*	*Total Phos. (mg/l)*[1]	*Secchi Disk Transparency (m)*	*Indiana Eutrophication Index*
Yellowwood (Brown Co.)	11 km NNE	54	9.1	4.3	E-0.033 H-0.085	4.3	8
Griffy (Monroe Co.)	16km NNW	53	9.1	3.1	E-0.013 H-0.042	4.1	21
Lemon (Monroe Co.)	15km N	668	8.5	2.9	E-0.022 H-0.089	1.0	28
Starve Hollow (Jackson Co.)	40 km SE	59	5.2	2.1	E-0.020 H-0.039	0.8	35
Eagle Creek (Marion Co.)	78km N	607	40.0	3.8	E-0.083 H-0.817	0.6	41
West Boggs (Martin Co.)	46km SW	243	32.0	3.8	E-0.103 H-0.249	2.0	33
Brush Creek Reservoir (Jennings Co.)	72km E	68	9.8	3.1	E-0.021 H-0.497	0.4	31

[1]E=epilimnetic sample; H=hypolimnetic sample

Source: Indiana Clean Lakes Program, 1994.

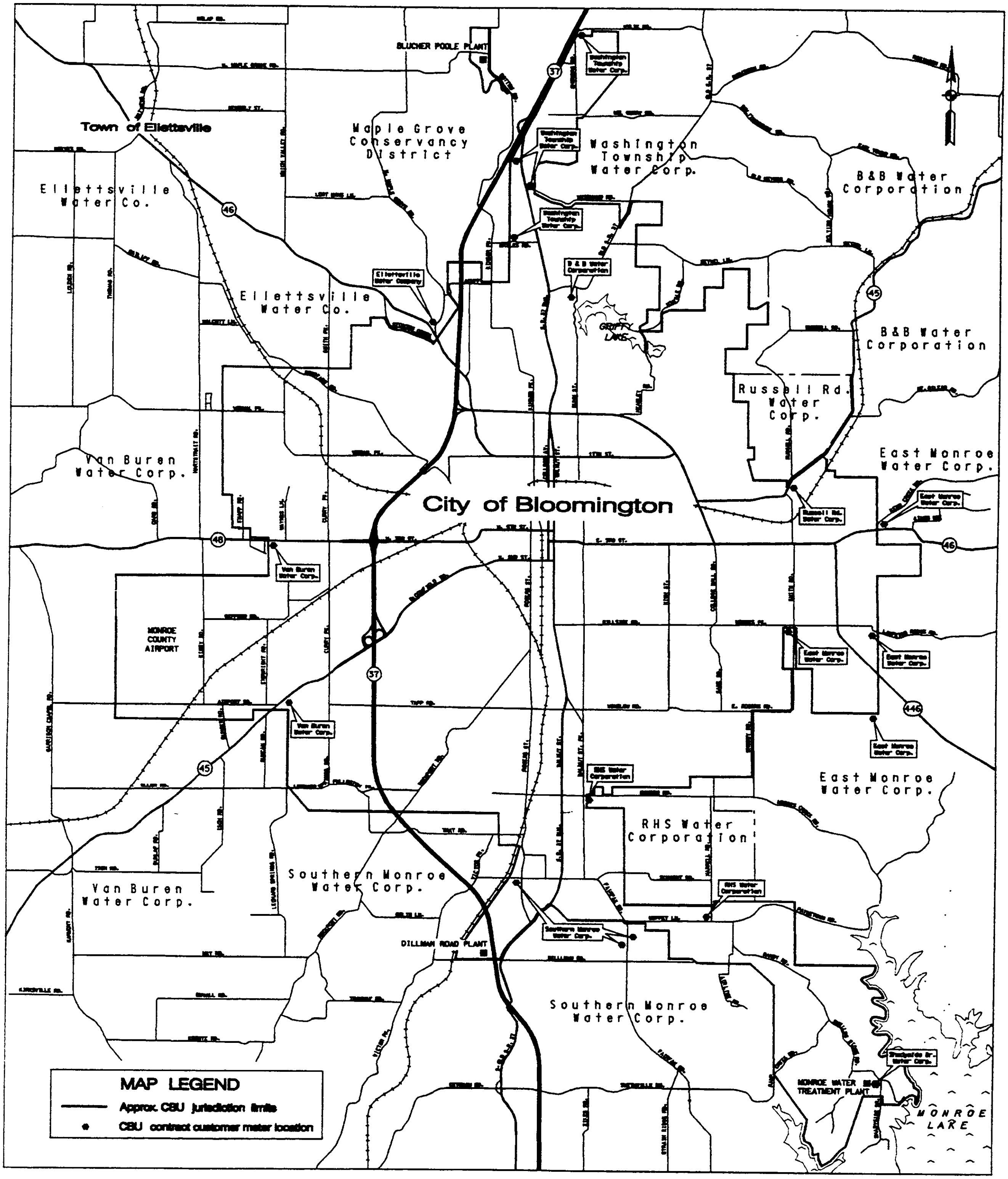
Table 2-15. Recreational Activities at Nearby Lakes

Lake	*Boating*	*Boat Ramp*	*Fishing*	*Swimming*
Brush Creek Res.	X	X	X	NO
Eagle Creek Res.	X	X	X	X
Geist Res.	X	X	X	X
Griffy Lake	X[1]	X[2]	X	NO
Lake Lemon	X	X[2]	X	X
Starve Hollow	X	X	X	X
West Boggs	X	X[2]	X	X
Yellowwood	X[1]	X	X	NO

[1]electric motors only

[2]launch fee charged

Figure 2-11. City of Bloomington Utilities—Water Jurisdiction and Contract Customer Meter Locations



The history of Bloomington has always been marked by water problems. At different times since the turn of the century, wells, Twin Lakes, Leonard Springs Lake, Weimer Lake, Griffey Lake, and Lake Lemon have all supplied Bloomington with water, and all have been outgrown (League of Women Voters, 1971). In fact, in the early part of the century, Indiana University threatened to leave the area if the city's water supply problems were not solved (Monroe County Planning Department, 1989). Monroe County is one of the most rapidly growing counties in Indiana, and its population is expected to continue to rise rapidly for at least the next 15 years. This translates into a continuously rising need for water in the area, and thus an increasing dependence upon Lake Monroe as a water source.

The City of Bloomington Utilities Department withdraws water from Lake Monroe and processes it for drinking water at its Monroe Water Treatment Plant on Shields Ridge Road. The water intake structure is at the opening of the Moore's Creek embayment. The Monroe Water Treatment Plant supplies approximately 90% of the drinking water needs of Bloomington and additional water is sold wholesale to the rural water companies.

In 1993, monthly water sales ranged from a low of 309,570,000 gallons in February (11 MGD) to a high of 393,421,000 gallons in September (13.1 MGD). Approximately 20-25% of the water sold goes to the rural water companies. The remaining water is consumed in Bloomington. Distribution of water sales among city customer classes and the wholesale customers (rural water companies) is shown for February and September 1993 in Table 2-16.

The City of Bloomington Utilities Department pays the Indiana Department of Natural Resources $33 per million gallons of raw water it withdraws from Lake Monroe. For 1993, based on total water sales, the raw water cost to the City was $135,500.

Table 2-16. Bloomington Utilities Department Drinking Water Sales in February and September 1993 (units are in gallons of finished water)

Customer Class	*February 1993 (low demand)*	*September 1993 (high demand)*
City of Bloomington		
Residential	73,466,000	90,231,000
Commercial	92,306,000	123,871,000
Industrial	9,732,000	8,684,000
Indiana University	54,579,000	76,495,000
Interdepartmental	2,547,000	1,491,000
Wholesale Customers		
B&B	9,476,000	10,018,000
East Monroe	8,060,000	15,654,000
Ellettsville	20,621,000	23,264,000
Nashville	3,155,000	6,084,000
Southern Monroe	20,792,000	9,388,000
Van Buren	9,032,000	1,398,000
Washington Township	5,645,000	6,516,000
Russell Road	87,000	235,000
Shady Side Drive	72,000	92,000
Total Wholesale	76,940,000	92,649,000
Total Water Sales	309,570,000	393,421,000

2.11.1 Habitat Managemen

The Indiana Department of Natural Resources is charged with managing the North and Middle Fork Wildlife Refuges within the Monroe watershed. Some 21,817 acres under state management (including the 10,750-acre low flow regulation pool of the lake itself) is managed for fish and wildlife. All of this land is open to hunting and fishing, subject to applicable laws.

The regulation pool and surrounding lowland fields and marshes are extensively used by waterfowl and wetland wildlife. Stillwater Marsh, in the North Fork Refuge, is planted with a variety of food crops, such as corn, sorghum, and wheat, during the summer, then flooded every October to provide food and habitat for migratory waterfowl passing through the area. The marsh is then drained again each spring. A three-day duck hunt takes place in the area each fall, during which all applicable laws apply. The Middle Fork Refuge is not currently being heavily managed, except for restricted boat traffic near the site of heavy bald eagle activity (Jim Roach, Lake Monroe Property Manager, personal communication).

The DNR also farms and contracts for farming to provide food crops for wildlife. Four hundred acres are farmed by the DNR itself in the watershed for this purpose, with some of the crops being left in the fields and some being harvested to provide winter food. Crops planted include corn, soybeans, small grains (oats, wheat, or grain sorghum), hay, and clover. Additional food strips are planted in remote areas. An additional 1,600 acres of tenant farm land are farmed for the DNR under four-year contracts. These fields are subject either to a corn-soybean-wheat-fallow, a corn-soybean-fallow, or a hay cycle, with 10% of the crops left standing for wildlife. These contracts mandate fall plowing, the maintenance of riparian breaks, and forbid the use of insecticides (Rex Watters, personal communication, 1993).

Habitat manipulation in upland areas is also used by the DNR as a tool for wildlife management. Small clear cuts, control burns, and mowing are used to prevent the encroachment of woody vegetation. These activities are carried out so as to minimize the damage to mast and den trees. These areas may be planted with natural grasses, sunflowers, or wheat. Whenever possible, existing open areas are preserved for use by the upland species and existing wooded lands are used for woodland wildlife species.

Table 2-17 is a list of the nature preserves and natural areas in the watershed. There are three nature preserves and four natural areas listed. The general location of these areas is also given.

Table 2-17. Nature Preserves and Natural Areas in the Monroe Watershed

Nature Preserves	*Location*	*Size*
Crooked Creek Nature Preserve	western Brown County	35 acres
Ogle Hollow Nature Preserve	central Brown County	41 acres
Selma Steele Nature Preserve	western Brown County	92 acres
Natural Areas		
Hitz-Rhodehamel Woods Natural Area	northern Brown County	271 acres
Lilly-Dickey Woods Natural Area	central Brown County	379 acres
Charles C. Deam Wilderness Area	Monroe/Brown/Jackson	13,000 acres
Browning Hill Natural Area	southwestern Brown County	–

In addition, two pairs of bald eagles are nesting on the lake, and 2-30 additional individuals migrate through the lake area every year. This is the result of an eagle "hacking" program in the North Fork refuge beginning in 1985. Most of the eagle activity is now located in a bay in the Middle Fork Refuge, in which boat traffic is restricted for much of the year. Prof. Don Whitehead, an Indiana University bird authority, believes Lake Monroe to be the most important Bald Eagle wintering site in Indiana (Prof. Whitehead, personal communication, 1993).

In addition to Bald Eagles, two Golden Eagles were sighted at the lake last year. A Great Blue Heron colony in Section 4, NW 1/4, NW 1/4 of the Belmont quadrangle has increased in size from 8 nests when first found to 20 nests at the present.

Several problems threaten the bird populations at the lake. Diving ducks are the most obvious group whose populations are declining. This is especially true of canvasbacks. This decline may be the result of the loss of prairie pothole habitat in northern Iowa and southern South Dakota and because of the droughts of the past decade. Shorebirds numbers are also dwindling. This could be the result of water level fluctuations at the lake or the laying of concrete on the shoreline at Fairfax beach, where counting is done by Don Whitehead, who is heavily involved in various projects related to birds in the Midwest. A major concern for bird populations is human overuse of the lake, as many species will be frightened from the area by a large number of people, and species such as eagles, Great Blue Herons, and osprey will abandon their nests as a result. There is also some cause for concern that hunters may not be very careful about identifying birds before shooting, resulting in the deaths of some species which are already in trouble (including Bald Eagles) (Don Whitehead, personal communication, 1993).

2.11.3 Mammals, Reptiles and Amphibians. There is no management practiced by the DNR for any specific species of mammals, reptiles, or amphibians. The species found in the Monroe watershed are representative of those found in southern Indiana. The food plots and habitat management practices mentioned previously are used generally to support various mammal and reptile species (Jim Roach, Lake Monroe Property Manager, personal communication, 1992). Obviously, the wetland and lake areas are conducive to amphibian species.

2.11.4 Rare and Endangered Species. Table 2-198 is a list of the rare species within the Monroe watershed. There are 1 mammal, 15 birds, 3 reptiles, 1 amphibian, and 31 plants on the list. It should be noted, however, that a recent attempt by the DNR to locate any bobcat within the state found none, and thus that species may no longer be present within the watershed (Mark Bennett, IDNR biologist, personal communication, 1992).

Table 2-18. Bird Species in the Lake Monroe Watershed

Species	*Winter*	*Spring*	*Summer*	*Fall*
LOONS &CORMORANTS				
Red-throated Loon	R	R		U
Common Loon	U	C		A
Pied Billed Grebe	U	C	U	C
Horned Grebe	U	C		C
Red-necked Grebe	R			
Northern Gannet			R	
American White Pelican				R
Double-crested Cormorant	U	C	R	C
BITTERNS & HERONS				
American Bittern		U	R	U
Least Bittern		U	R	U
Great Blue Heron	U	C	C	A
Great Egret		U	U	U
Snowy Egret		R	R	R
Little Blue Heron		U	R	U
Cattle Egret		U	R	R
Green-backed Heron		C	C	C
Black-crowned Night-Heron		U	R	U
Yellow-crowned Night-Heron		U	R	U
SWANS				
Tundra Swan		R		U
Mute Swan	R			
GEESE				
Great White-fronted Goose				R
Snow Goose	R			U
Canada Goose	C	A	C	A
DABBLING DUCKS				
Wood Duck	U	A	A	A
Green-winged Teal	R	C		C
American Black Duck	C	A	U	A
Mallard	C	A	A	A
Northern Pintail	U	C		C
Blue-winged Teal	U	A	U	A
Northern Shoveler		C		C
Gadwall	U	C		C
American Wigeon	U	C		C
DIVING DUCKS				
Canvasback	U	U		U
Redhead	R	C		C
Ring-necked Duck	U	A		A
Greater Scaup	R			
Lesser Scaup	U	A		A
Oldsquaw	R	R		R
Black Scoter	R	R		R
Surf Scoter	R	R		R
White-winged Scoter	R	R		R
Common Goldeneye	C	A		A
Bufflehead	C	C		C
Hooded Merganser	C	C		C
Common Merganser	C	C		C
Red-breasted Merganser	C	C		A
Ruddy Duck	R	U		U
VULTURES to FALCONS				
Turkey Vultures	U	A	A	A
Osprey		C	R	C
Black-shouldered Kite		R		
Mississippi Kite		R		
Bald Eagle	C	C	U	C
Northern Harrier	U	U	R	U
Sharp-shinned Hawk	U	U	U	C
Cooper's Hawk	U	U	U	C
Northern Goshawk	R			
Red-shouldered Hawk	U	U	U	U
Broad-winged Hawk		C	C	C
Red-tailed Hawk	C	C	C	C
Rough-legged Hawk	U			
Golden Eagle	R			
American Kestrel	C	C	C	C
Merlin	R	R		R
Pergrine Falcon	R	R		U
GROUSE, TURKEY, QUAIL				
Ruffed Grouse	C	C	C	C
Wild Turkey	U	U	U	U
Northern Bobwhite	U	U	U	U
RAIL to COOT				
King Rail		R		R
Virginia Rail		U	R	U
Sora		C	R	C
Common Moorhen		R	R	R
American Coot	U	A	U	A
SHOREBIRDS				
Sandhill Crane	R	U		U
Blackbellied Plover		U		U
Lesser Golden Plover		U		U
Semipalmated Sandpiper		C		C
Piping Plover		R		R
Killdeer	U	C	C	C
American Avocet				R
Greater Yellowlegs		A		A
Lesser Yellowlegs		A		A
Solitary Sandpiper		A		A
Willet		R		R
Spotted Sandpiper		C	C	C
Upland Sandpiper				R
Whimbrel				R
Hudsonian Godwit				R
Ruddy Turnstone		U		U
Red Knot		R		R
Sanderling		U		U
Western Sandpiper		U		U
Least Sandpiper		A		A

Table 2-18. Bird Species in the Lake Monroe Watershed (continued)

Species	*Winter*	*Spring*	*Summer*	*Fall*
White-rumped Sandpiper		U		U
Baird's Sandpiper		U		U
Pectoral Sandpiper		A		A
Dunlin	R	C		C
Stilt Sandpiper		U		U
Buff-breasted Sandpiper		R		R
Shortbilled Dowitcher		C		C
Long-billed Dowitcher		R		R
Common Snipe	U	C	R	A
American Woodcock		C	C	C
Wilson's Phalarope		R		R
Red-necked Phalarope		R		R
Red Phalarope				R
Parasitic Jaeger				R
GULLS & TERNS				
Laughing Gull		R	R	R
Franklin's Gull	R	U		U
Little Gull				R
Bonaparte's Gull	U	C		C
Ring Billed Gull	C	A	U	A
Herring Gull	C	C	U	C
Caspian Tern		C		C
Forster's Tern		C		C
Least Tern		R		R
Black Tern		C		C
DOVE & CUCKOO				
Rock Dove	C	C	C	C
Mourning Dove	C	C	C	C
Black-billed Cuckoo		U	U	U
Yellow-billed Cuckoo		C	C	C
OWLS				
Eastern Screech Owl	C	C	C	C
Great Horned Owl	C	C	C	C
Barred Owl	C	C	C	C
Short Eared Owl	R			
GOATSUCKERS				
Common Nighthawk		C	U	A
Chuck-will's Widow			R	
Whip-poor-will			A	
SWIFT, HUMMINGBIRD, KINGFISHER				
Chimney Swift		C	C	C
Ruby-throated Hummingbird		C	C	C
Belted Kingfisher	U	C	C	C
WOODPECKERS				
Redheaded Woodpecker	U	U	U	U
Red-bellied Woodpecker	A	A	A	A
Yellow-bellied Sapsucker	U	U		U
Downey Woodpecker	A	A	A	A
Hairy Woodpecker	C	C	C	C
Northern Flicker	C	C	C	C
Pileated Woodpecker	C	C	C	C

Species	*Winter*	*Spring*	*Summer*	*Fall*
FLYCATCHERS				
Olive-sided Flycatcher		U		R
Eastern Wood-Pewee		C	C	C
Acadian Flycatcher			C	
Alder Flycatcher		?	R	?
Willow Flycatcher		?	U	?
Least Flycatcher		U		?
Eastern Phoebe	U	C	C	C
Great Crested Flycatcher		C	C	C
Eastern Kingbird		C	C	C
LARKS to SWALLOWS				
Honed Larks	U	U	U	C
Purple Martin		U	U	U
Tree Swallow		A	C	A
North. Rough-winged Swallow		C	C	C
Bank Swallow		C	U	C
Cliff Swallow		C	C	C
Barn Swallow		A	A	A
JAYS, CROWS				
Blue Jay	A	A	A	A
American Crow	A	A	A	A
CHICKADEE to GNATCATCHER				
Blackcapped Chickadee	R			
Carolina Chickadee	A	A	A	A
Tufted Titmouse	A	A	A	A
Red-breasted Nuthatch	U	U		U
White-breasted Nuthatch	A	A	A	A
Brown Creeper	U	U		U
Carolina Wren	C	C	C	C
House Wren	R	C	C	C
Winter Wren	R	U		U
Marsh Wren	R	U		U
Golden-crowned Kinglet	C	C		C
Ruby-crowned Kinglet	U	C		C
Blue-gray Gnatcatcher		C	C	C
BLUEBIRD to THRASHER				
Eastern Bluebird	C	C	C	C
Veery		U		U
Gray-cheeked Thrush		U		U
Swanson's Thrush		C		C
Hermit Thrush	U	U		U
Wood Thrush		C	C	C
American Robin	C	A	A	A
Grey Catbird	U	C	C	C
Northern Mockingbird	C	C	C	C
Brown Thrasher	U	C	C	C
PIPITS to STARLING				
Water Pipit	R	U		C
Cedar Redwing	C	C	C	C
Loggerhead Shrike			R	
European Starling	A	A	A	A

Table 2-18. Bird Species in the Lake Monroe Watershed (continued)

Species	*Winter*	*Spring*	*Summer*	*Fall*
VIREOS				
White-eyed Vireo		A	A	A
Solitary Vireo		U		U
Yellow-throated Vireo		U	U	U
Warbling Vireo		C	C	C
Philadelphia Vireo		U		U
Red-eyed Vireo		A	A	A
WARBLERS				
Blue-winged Warbler		C	A	C
Golden-winged Warbler		U		U
Tennessee Warbler		A		A
Orange-crowned Warbler		U		U
Nashville Warbler		C		C
Northern Parula		C	C	C
Yellow Warbler		C	C	C
Chestnut-sided Warbler		C	U	C
Magnolia Warbler		C		C
Cape May Warbler		U		U
Black-throated Blue Warbler		R		R
Yellow-rumped Warbler	U	A		A
Black-throated Green Warbler		C	U	C
Blackburnian Warbler		C		C
Yellow-throated Warbler		C	A	C
Pine Warbler		U	U	U
Prairie Warbler		C	A	C
Palm Warbler		C		C
Bay-breasted Warbler		U		U
Blackpoll Warbler		C		C
Cerulean Warbler		U	U	U
Black-and white Warbler		C	U	C
American Redstart		C	U	C
Prothonotary Warbler		U	C	U
Worm-eating Warbler		U	U	U
Ovenbird		C	C	C
Northern Waterthrush		C		C
Louisiana Waterthrush		U	C	U
Kentucky Warbler		C	C	C
Connecticut Warbler		R		R
Mourning Warbler		U		U
Common Yellowthroat	R	A	A	A
Hooded Warbler		U	U	U
Wilson's Warbler		U		U
Canada Warbler		U		U
Yellow-breasted Chat		C	C	C
TANAGERS				
Summer Tanager		U	U	C
Scarlet Tanager		C	C	C
CARDINAL & GROSBEAK				
Northern Cardinal	A	A	A	A
Rose-breasted Grosbeak		C		C
Indigo Bunting		A	A	A

Species	*Winter*	*Spring*	*Summer*	*Fall*
Dickcissel	R	R	R	R
Rufous-sided Towhee	C	A	A	A
NEW WORLD SPARROWS				
American Tree Sparrow	A			
Chipping Sparrow	R	A	A	A
Field Sparrow	C	A	A	A
Vesper Sparrow		U	R	U
Lark Sparrow		R		
Savannah Sparrow	R	C	U	C
Grasshopper Sparrow		R	R	R
Henslow's Sparrow		R	R	R
Le Conte's Sparrow				R
Sharp-tailed Sparrow				R
Fox Sparrow	U	C		C
Song Sparrow	A	A	A	A
Lincoln's Sparrow		U		U
Swamp Sparrow	C	C	R	C
White-throated Sparrow	C	C		C
White-crowned Sparrow	C	C		C
Dark-eyed Junco	A	A		A
Lapland Longspur	R			
Snow Bunting	R			
BLACKBIRDS				
Bobolink				U
Red-winged Blackbird	U	A	A	A
Eastern Meadowlark	U	C	C	C
Yellow-headed Blackbird				R
Rusty Blackbird	R	C		C
Brewer's Blackbird	R	R		R
Common Grackle	U	A	A	A
Brown-headed Cowbird	U	A	A	A
Orchard Oriole		C	C	C
Northern Oriole		C	C	C
FINCHES				
Purple Finch	C	C		C
House Finch	C	C	C	C
Red Crossbill	R			
White-winged Crossbill	R			
Common Redpoll	R			
Pine Siskin	C	C		C
American Goldfinch	A	A	A	A
Evening Grosbeak	U			
WEAVER FINCH				
House Sparrow	A	A	A	A

Codes
A = Abundant (Can be seen every day with little effort)
C = Common (Likely to be seen with some effort)
U = Uncommon (Occassionally seen, but unpredictable)
R = Rare (Fewer than five occurrences per year or season)

Table 2-19. Rare and Endangered Species in the Lake Monroe Watershed

Scientific Name	*Common Name*	*Status*
Lynx rufus	bobcat	state endangered
Haliaeetus leucocephalus	bald eagle	state endangered/ federally endangered
Lanius ludovicianus	logger head shrike	state endangered
Pandion haliaetus	osprey	state endangered
Rallus elegans	king rail	state endangered
Accipiter cooperi	Cooper's hawk	special concern
Accipiter striatus	sharp-shinned hawk	special concern
Buteo lineatus	red-shouldered hawk	special concern
Buteo platypterus	broad-winged hawk	special concern
Helmitheros vermivorous	worm-eating warbler	special concern
Ixobrychus exilis	least bittern	special concern
Miniotilta varia	black and white warbler	special concern
Wilsonia citrina	hooded warbler	special concern
Dendroica cerulea	cerulean warbler	not listed
Dendroica pinus	pine warbler	not listed
Icturus spurius	orchard oriole	not listed
Clonophis kirtlandi	Kirtland's snake	state threatened/ federal candidate
Opheodrys vernalis blanchardi	western smooth green snake	state threatened
Crotalus horridus	timber rattlesnake	special concern
Hemidactylium scutatum	four-toed salamander	state threatened
Autochton cellus	gold-banded skipper	not listed
Euphydryas phaeton	Baltimore oriole	not listed
Panicum mattamuskeetense	panic grass	extirpated (?)
Stachys clingmanii	Clingman hedge-nettle	extirpated (?)
Gerardia fasciculata	false foxglove	new to state
Platanthera ciliaris	yellow fringed orchis	state endangered
Solidago hispida	hairy goldenrod	state endangered
Spiranthes orchroleuca	yellow nodding ladies' tresses	state endangered
Arenaria stricta	Michaux's stitchwort	state threatened
Cladrastis lutea	yellowwood	Istate threatened
Hypericum pyramidatum	great St. John's-wort	state threatened
Lilium superbum	turk's cap lily	state threatened
Rubus odoratus	purple flowering raspberry	state threatened
Antennaria solitaria	single-headed pussytoes	state rare
Cypripedium calceolus parviflorum	small yellow lady's-slipper	state rare
Epigea repens	trailing arbutus	state rare
Lespedeza nuttallii	Nuttail bushclover	state rare
Platanthera clavellata	small green woodland orchis	state rare
Synandra hispidula	Gyandotte beauty	state rare
Carex abscondita	thicket sedge	watch list
Cypripedium calceolus pubescens	large yellow lady's-slipper	watch list
Hydrastis canadensis	golden seal	watch list
Isotria verticillata	large whorled pogonia	watch list
Juglans cinerea	butternut	watch list
Lycopodium lucidulum	shining clubmoss	watch list
Monotropa hypopithys	American pinesap	watch list
Panax quinquefolius	American ginseng	watch list
Platanthera lacera	green-finged orchis	watch list
Platanthera peramoena	purple fingless orchis	watch list
Pychanthemum torrei	Torrey mountain mint	watch list
Tsuga canadensis	eastern hemlock	watch list

3.0 HISTORICAL DATA

The importance of Lake Monroe and its location near a major research university have lead to a variety of limnological studies of the reservoir over the years. However, it is difficult to piece together a concise water quality history from these studies because: (a) the specific purposes of the studies were different, (b) water sampling locations and depths varied considerably, and (c) field and analytical methods varied considerably.

3.1 Overview of Past Studies

3.1.1 Allanson, et al. (1973)

One of the earliest studies of Lake Monroe was conducted during September and October, 1971 by undergraduate and graduate students enrolled in Indiana University's limnology class. The purpose of this work was to provide a baseline of data which would assist future investigators.

The report documents the already extensive rooted macrophyte communities in the North and Middle forks of the Upper Basin: a *Potamogeton-Najas-Myriophyllum-Ceratophyllum* community in open water and a *Sagittaria-Potamogeton-Najas* community in shallow coves and bays. Although there were calls in the media to eliminate these "nuisance weeds" (Brang, 1971), the report emphasizes the important role the weed beds have as metabolic filters. The students hypothesized that the macrophytes filter out and assimilate inflowing nutrients, making them unavailable to algae downstream in the lake.

Several species of enteric pathogens (*Shigella* and *Salmonella*) were found in water samples from the Fairfax Marina area suggesting the need for a wastewater treatment facility.

The report closes with these prophetic words regarding the "functional evolution" of uses in multi-purpose reservoirs such as Lake Monroe, ". . . it is the responsibility of all organizations, both State and private, who benefit from the reservoir to ensure that its biological balance does not deteriorate to levels sufficient to curtail the diversity of use that it presently affords the south central region of the State."

3.1.2 National Eutrophication Survey

In 1973, Lake Monroe was one of 27 Indiana lakes included in the National Eutrophication Survey, an initiative to "investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs" (U.S. EPA, 1976a). Six lake sites were sampled from a pontoon-equipped helicopter in May, August, and October. Monthly hydraulic and nutrient loadings were monitored at nine watershed sites.

The report concluded that Lake Monroe was eutrophic, ranking eighth out of 27 Indiana waterbodies sampled in 1973. The report suggested that the productivity of the lake could diminish as a trophic equilibrium became established in the newly formed reservoir. About 21% of the phosphorus loading to the lake was from point sources while 79% was from nonpoint sources. Of the major sources, North Fork Salt Creek contributed 23.6% of the total annual phosphorus loading, South Fork 22.6%, Middle Fork 12.1%, Brummetts Creek 1.5%, and Stephens Creek 1.4%. The Nashville Wastewater Treatment Plant, a point source, accounted for 15.1% of the annual phosphorus load to the lake. The estimated net annual phosphorus accumulation in the lake (input-output) was 5,295 kilograms.

3.1.3 David G. Frey (1976)

The most complete of the early studies was conducted by Professor David Frey of Indiana University. Frey collected water quality data during the period October 1974 through April 1975, and summarized many of the data collected by others up to that time. A doctoral student working with Frey, W.Y.B. Chang, performed nutrient studies which were later reported in Bradbury, et al. (1977).

During this study, Frey reported a maximum total phosphorus concentration in the lake of 89.2 µg/L. This concentration falls within the "eutrophic" range according to Vollenweider's widely used tables (Vollenweider, 1975). The study also documented a strong gradient of nutrients, especially following runoff events, from the Upper Basin to the Lower Basin. In the nutrient studies, the authors determined that phosphorus was the limiting nutrient (the factor which most limits the growth of algae) in Lake Monroe.

3.1.4 U.S. Army Corps of Engineers (1990)

Beginning in January 1971, the Corps of Engineers has maintained water quality monitoring stations at three lake sites and at a number of stream sites. A variety of water quality data is collected in this program, which runs primarily during the summer months. The Corps generously provided us with computer disks which contained these data for 1985–1989.

3.1.5 Dixon Landers and David Frey (1980)

Dixon Landers investigated the chemical and biological effects of late summer dieback of Eurasian water milfoil (*Myriophyllum spicatum*) in the North Fork Salt Creek in Lake Monroe's Upper Basin. Using PVC enclosures, Landers estimated that nutrient release from senescing *M. spicatum* accounted for as much as 20% of the annual phosphorus budget to Lake Monroe and no more than 2.2% of the annual nitrogen budget. These nutrient inputs resulted in a large increase in phytoplankton. Chlorophyll *a* in the enclosures rose from about 10 mg/m^3 (µg/L) before dieback, to a peak of nearly 90 mg/m^3 in late September. Landers estimates that the quantity of algae attributable to macrophyte dieback in 1978 was 16.3 metric tons wet weight.

3.1.5 Miscellaneous Studies

A number of other studies of Lake Monroe contain important information on land use and watershed features but have limited original water quality data. These include: *The Lake Monroe Land Suitability Study* (Gray, et al., 1975); and the *Environmental Assessment: Indiana University Alumni Association Lake Monroe Family Camp* (Randolph et al., 1977).

3.2 Water Quality Trends Suggested by the Historic Data

Selected water quality data from these past studies are presented in Tables 3–1 and 3–2, and in Figures 3–1 to 3–3. As mentioned above, trends are difficult to determine using such disparate data. There appears to be little net change in total phosphorus concentrations over time in the historic data (Figure 3–1). The historic total phosphorus concentrations fall within the range for the samples collected during the present study (see Chapter 5). Phosphorus concentrations at the causeway site are often higher than the samples for the dam site for the same day. This is expected due to the sediment-trapping ability of the causeway.

Table 3–1. Historical Data—Lake Monroe Dam

DATE	SECCHI DISK (ft)	SURFACE NH4 (mg/l)	BOTTOM NH4 (mg/l)	SURFACE TP (ug/l)	BOTTOM TP (ug/l)	SURFACE SRP (ug/l)	BOTTOM SRP (ug/l)	LITERATURE SOURCE
09/09/71	11.5							a
10/10/71	6.6	0.08		11.10		6.00		a
05/10/73	9.0	0.04	0.08	13.00	16.00	5.00	4.00	b
08/06/73	6.7	0.06	0.84	23.00	27.00	6.00	10.00	b
10/10/73	9.0	0.12	2.10	21.00	92.00	13.00	23.00	b
08/25/74		0.01		8.50		0.70		c
09/07/74		0.05		7.00		0.40		c
09/16/74	5.0	0.07		11.00		1.00		d
10/12/74	7.0	0.04		16.50		0.70		d
11/06/74	10.0	0.02		12.50		1.00		d
12/03/74	8.5	0.03		15.70		0.60		d
01/09/75	9.5	0.03		17.00		1.30		d
02/20/75	9.5	0.01		8.00		1.90		d
03/20/75	5.0	0.00		28.50		11.50		d
04/19/75				21.00		4.80		d
04/22/75	2.5	0.01						d
05/06/75	3.0	0.01		15.30		2.00		d
06/25/75	9.5	0.00		7.00		0.50		d
07/14/75				9.20		<.10		d
07/28/75	9.5	0.02						d
08/28/75		0.01		8.00		<.10		d
05/22/85	2.0	0.10	0.20	10.00	10.00	10.00	10.00	e
07/25/85								e
08/28/85		0.20	0.70	10.00	10.00	10.00	10.00	e
05/07/86	9.0			10.00	10.00	10.00	10.00	e
06/17/86	6.5	0.10	0.80	10.00	10.00	10.00	10.00	e
08/05/86	5.0	0.10	0.80	10.00	10.00	10.00	10.00	e
05/20/87		0.10	0.20	14.00	11.00	10.00	10.00	e
07/08/87	8.0	0.10	0.60	13.00	45.00	10.00	44.00	e
08/18/87	2.0	0.10	1.00	12.00	120.00	12.00	120.00	e
05/24/88	6.0	0.10	0.10	11.00	18.00	10.00	10.00	e
06/21/88	7.0	0.10	0.40	50.00	50.00		50.00	e
08/02/88	5.5	0.10	1.20	10.00	80.00		80.00	e
05/17/89	4.0	0.10	0.10	11.00	10.00	10.00	10.00	e
07/13/89	6.0	0.10	0.50	10.00	35.00			e
08/29/89	6.0							e

(a) Allanson et al. (1973); (b) U.S. EPA (1976); (c) Frey (1975); (d) Army Corps of Engineers (1990)

Table 3–2. Historical Data—Lake Monroe Causeway

DATE	SECCHI DISK (ft)	SURFACE NH4 (mg/l)	BOTTOM NH4 (mg/l)	SURFACE TP (ug/l)	BOTTOM TP (ug/l)	SURFACE SRP (ug/l)	BOTTOM SRP (ug/l)	LITERATURE SOURCE
09/09/71	6.6							a
10/10/71	5.6							a
05/10/73	8.0	0.04	0.06	15.00	14.00	12.00	8.00	b
08/06/73	6.0	0.13	0.83	24.00	31.00	7.00	7.00	b
10/10/73	3.5	0.14	1.62	30.00	82.00	11.00	21.00	b
09/16/74	8.2	0.01		22.70		3.70		c
10/12/74	6.9	0.03		25.90		0.60		c
11/06/74	6.6	0.03		17.20		1.70		c
12/03/74	7.5	0.02		19.00		1.10		c
01/09/75	5.6	0.02		19.40		2.70		c
02/20/75	3.3					2.30		c
03/20/75	0.7	0.03		66.20		11.70		c
04/19/75				21.20		4.90		c
04/22/75	4.3	0.01		21.20				c
05/06/75	5.6	0.05		16.00		2.20		c
06/25/75	9.5	0.04		18.30		1.40		c
07/14/75				16.80		3.10		c
07/28/75	8.5	0.25						c
08/28/75	6.6	0.28		18.60		0.60		c
05/22/85	1.5							d
07/25/85	3.0							d
08/28/85	2.5			10.00	10.00	10.00	10.00	d
05/07/86	2.5							d
06/17/86	3.0			10.00	10.00	10.00	10.00	d
08/05/86	2.0							d
07/08/87	3.0							d
08/18/87	1.5							d
05/24/88				16.00	10.00	10.00	10.00	d
06/21/88	4.0			50.00	50.00	10.00	10.00	d
08/02/88	2.5			10.00	31.00	10.00	31.00	d
05/17/89	3.5			10.00	21.00	10.00	10.00	d
07/13/89	4.5			35.00	42.00			d
08/29/89	3.8							d

(a) Allanson et al. (1973); (b) U.S. EPA (1976); (c) Frey (1975); (d) Army Corps of Engineers (1990)

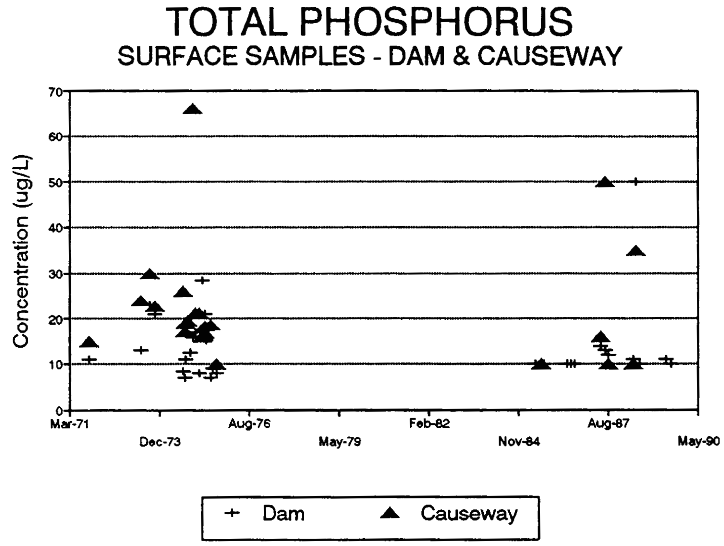


Figure 3–1. Historic Total Phosphorus Results for Lake Monroe

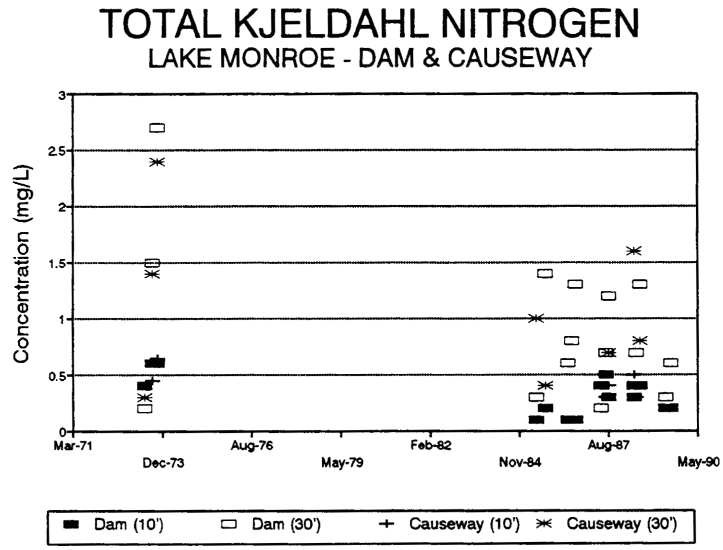


Figure 3–2. Historic Total Kjeldahl Nitrogen Results for Lake Monroe

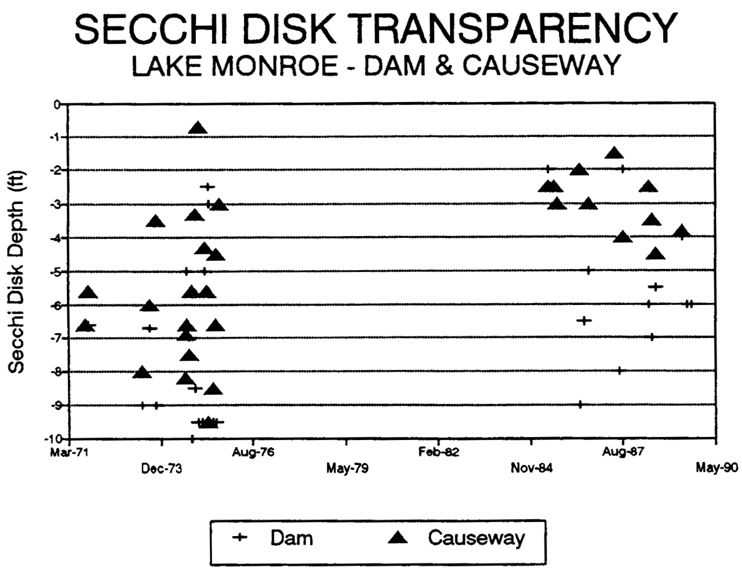


Figure 3–3. Historic Secchi Disk Transparency Results for Lake Monroe

Historic total Kjeldahl nitrogen (organic nitrogen + ammonia) concentrations are generally higher in deeper waters (Figure 3–2). Settling of organic matter could be a likely cause of this. There is little difference between the 1970s and 1980s values, and these values fall within the range of values recorded during this study (see Chapter 5).

The historic Secchi disk transparency data vary widely over time (Figure 3–3). One apparent trend is that the causeway samples from the 1980s had consistently worse transparency than the causeway samples from the 1970s and worse transparency than the dam samples from the 1980s. This suggests increasing turbidity in the Upper Basin over time and when compared to the Lower Basin.

3.3 Fisheries

Lake Monroe's fishereies are administered by the Indiana DNR Division of Fish and Wildlife, Southern District Fisheries Office at the Avoca State Fish Hatchery. Since its impoundment, the lake has been primarily managed for largemouth bass and panfish (Andrews, 1993). Prior to impoundment in 1965, rotenone was applied to the lake tributaries to eliminate the native fish species present (Andrews and Pearson, 1982). This was done to eliminate the "rough" fish from the lake, such as carp, suckers, and gizzard shad, which would have impeded the establishment of a sport fishery (Steve Andrews, personal communication). After impoundment, the lake was restocked primarily with largemouth bass, bluegill, and channel catfish. The lake was closed to fishing until 1968 to aid the establishment of these species (Andrews and Pearson, 1982).

As is common for new reservoirs, the fishing at Monroe was excellent for the first few years it was allowed, and then began to level off. This leveling off was accompanied by increases in the populations off less desirable species, such as gizzard shad, yellow perch, and yellow bass (Andrews, 1993). Gizzard shad were not stocked by the state hatchery, but were likely introduced by private fishermen (Steve Andrews, personal communication, 1993). During summer, the dissolved oxygen concentrations are adequate for fish down to depths of 20 to 25 feet in the lower basin, and down to about 15 feet in the upper basin. Since 1982 the lake community has been characterized by too few predator fish and too many forage fish (Andrews, 1993).

Consequently, the stocking program in the last 15–20 years has included several predator stockings, to utilize excess forage and to provide enhanced fishing opportunities. Early stockings included northern pike and walleye, but were largely unsuccessful in establishing these fish as a predatory force in the lake. Stockings in the last decade have included walleye and hybrid striped bass, and have proved more successful (see Table 3–3). In addition to these management oriented stockings, hatcheries also commonly stock the lake with surplus fish that they have no room for (Steve Andrews, personal communication).

3.3.1 Results of the 1992 Fisheries Survey

The results of the 1992 fish survey (Table 3–4) indicate that the Monroe fisheries are in the best condition they have been in for at least ten years. The following is a list of the major sport fish species found in their order of abundance, along with notes on the population dynamics made by Steve Andrews (1993) in his report.

1. Gizzard Shad (*Dorosoma cepedianum*). This was the most abundant species found in the lake, and its abundance was similar to its abundance in the 1988 survey. Its reproductive success (measured by observing relative numbers of fish at different ages) was fairly consistent. While shad growth rates were below average, their weights were average when compared with weights in lakes around the area.

Table 3–3. Post Impoundment Northern Pike, Walleye, and Hybrid Striped Bass (HSB) stocked at Lake Monroe

Year	*Species*	*Number*	*Size*
1973	Northern Pike	150,000	fry
	Northern Pike	8,379	1–1.5 in
	Northern Pike	302	3–3.5 in
1974	Northern Pike	1,000,000	fry
1975	Northern Pike	20,000	1.25 in
	Northern Pike	7,850	2.5 in
	Northern Pike	5,872	3.0 in
	Northern Pike	1,132	4–6 in
1976	Northern Pike	190	1–12 lbs.
	Northern Pike	532	Adults
	Northern Pike	12	15–40 in
	Northern Pike	361	16–36 in
1979	Northern Pike	4,500	10–18 in
1973	Walleye	3,000,000	fry
1975	Walleye	45,695	1 in
1980	Walleye	9,000,000	fry
1982	Walleye	73,700	1–2 in
1985	Walleye	8,300	3 in
1986	Walleye	48,147	1–2 in
1987	Walleye	37,853	3 in
1988	Walleye	573,094	1–2 in
1989	Walleye	524,362	1–2 in
1990	Walleye	642,392	1–2 in
	Walleye	11,255,325	fry
1991	Walleye	461,102	1.5–2.5 in
1992	Walleye	541,766	1–2 in
1983	HSB	58,282	1–2 in
1984	HSB	100,000	fry
	HSB	44,540	2 in
1985	HSB	107,000	1–2 in
1986	HSB	53,850	1–2 in
1988	HSB	10,710	2 in
1989	HSB	75,250	2 in
1990	HSB	53,760	1–2 in
1991	HSB	53,750	1–2 in
1992	HSB	54,716	1–2 in

Table 3–4. Results of the 1992 Lake Monroe Fisheries Survey (Andrews, 1993)

Species	*Abundance by Number (%)*	*Abundance by Weight (%)*
Gizzard shad	35	18
Bluegill	30	13
Yellow Bass	13	7
White Crappie	6	2
Largemouth Bass	3	13
Channel Catfish	3	20
Longear Sunfish	3	<1
Spotfin Shiner	2	<1
Hybrid Striped Bass	1	6
Common Carp	<1	12
Walleye	<1	4

2. Bluegill (*Lepomis macrochirus*). The growth rates and weights of bluegill were average, but the length distribution is improving (i.e., there are more larger fish than in 1988). While fewer fish were caught by electrofishing, more were caught in trap nets, possibly due to late spawning activities.

3. Yellow Bass (*Morone mississippiensis*). The gill net catch rates of the yellow bass declined since 1988, but the growth rates were similar to the 1988 rates. In addition, the size distribution improved over the 1988 sample.

4. White Crappie (*Pomoxis annularis*). The white crappie caught demonstrated consistent reproductive success. They also indicated average growth rates and weights compared to other lakes in the area.

5. Largemouth Bass (*Micropterus salmoides*). The number of small bass caught appears to have declined since the 1988 survey, however, during a later fall sampling for walleye, a much larger number of small bass was caught, indicating that the result in the summer survey may be an anomaly. The bass sampled demonstrated consistent reproductive success. Additionally, the bass weights and growth rates were above average, indicative of the surplus forage species in the lake.

6. Channel Catfish (*Ictalurus punctatus*). The channel catfish indicated consistent reproductive success and average weights compared to other lakes in the area.

7. Longear Sunfish (*Lepomis megalotis*). Fewer longears were caught in 1992 than in 1988. Most of the fish that were caught were too small to interest anglers.

8. Hybrid Striped or Palmetto Bass (*Morone saxatilis* x *M. chrysops*). More of this hybrid species were caught in 1992 than in 1988. They demonstrated fairly consistent survival and improved growth rates.

9. Walleye (*Stizostedion vitreum*). Stocked fish from each year of stocking were represented in the sample. The 1992 catch rate for young of the year was much better than ever before.

10. Common Carp (*Cyprinus carpio*). Although carp represented only 0.5% of the catch by number, they represented 12.3% of the catch by weight. Obviously, most of those caught were very large, and the lack of young indicates that their population may be suppressed.

3.4 Fish Tissue Studies

In July 1985, biologists with the Indiana Department of Environmental Management (IDEM) collected fish and sediment samples from locations within Lake Monroe as part of a statewide program to quantify contaminants at sites with suspected contamination. Results for Lake Monroe are given in Table 3–5. These results were below established action levels for fish. Previous studies (ISBH, 1983) had found PCBs in Lake Monroe fish at concentrations of 0.07 mg/kg. By comparison, PCBs have been found in Lake Superior fish at 0.02 mg/kg and 0.08 mg/kg in Lake Erie fish (Mackay, 1982). Lake Michigan sediments have been measured at 38 mg/kg and Lake Erie sediments at 162 mg/kg (NAS, 1979). For a more detailed discussion of sediment analyses, see Chapter 6.

Arsenic is not known to undergo biomagnification in the food chain (U.S. EPA, 1976b) and these data confirm that—the concentrations are higher in the sediments than in the fish. Mercury, on the other hand, is more concentrated in the fish tissue so it apparently biomagnifies. The FDA established guideline for mercury in edible fish is 0.5 mg/kg (U.S. EPA, 1976b). The largemouth bass collected from the Ramp Creek area was at this FDA level.

Table 3–5. Selected Results of 1985 Lake Monroe Fish Tissue and Sediment Analyses[1]

Sample	*Total PCB (mg/kg)*	*Total Chlordane (mg/kg)*	*Arsenic (mg/kg)*	*Cadmium (mg/kg)*	*Mercury (mg/kg)*
Carp (skin off fillets)—Dam	0.038	0.003	0.029	<0.020	0.220
Largemouth Bass (skin off fillets)—Crooked Creek	0.020	<0.001	0.053	0.100	0.390
Largemouth Bass (skin off fillets)—N. Fork Salt Creek	0.022	<0.001	0.083	<0.020	0.460
Largemouth Bass (skin off fillets)—Moores Creek	0.021	<0.001	0.410	<0.020	0.270
Largemouth Bass (skin off fillets)—Ramp Creek	0.044	<0.001	0.076	<0.020	0.500
Sediment—Crooked Creek	NA[2]	<0.010	4.600	<2.800	0.037
Sediment—Sugar Camp Creek Bay	NA[2]	<0.010	14.000	<5.300	0.055
Sediment—Dam	NA[2]	<0.010	5.900	<4.200	0.038
Sediment—N. Fork Salt Cr.	NA[2]	<0.010	4.300	<5.000	0.030
Sediment—Moores Creek	NA[2]	<0.010	2.100	<5.800	0.029
Sediment—Ramp Creek	NA[2]	<0.010	4.800	<3.000	0.045

[1] All samples analyzed by the Indiana State Board of Health Laboratory.
[2] Total PCB not analyzed but results for individual congeners (AROCLOR 1016, 1221, 1232, 1242, 1248, 1254, and 1260) were all below the 0.01 mg/kg detection limit.

Source: IDEM (1991)

4.0 HYDROLOGY

4.1 Groundwater and Surface Water Interactions

4.1.1 Previous Studies

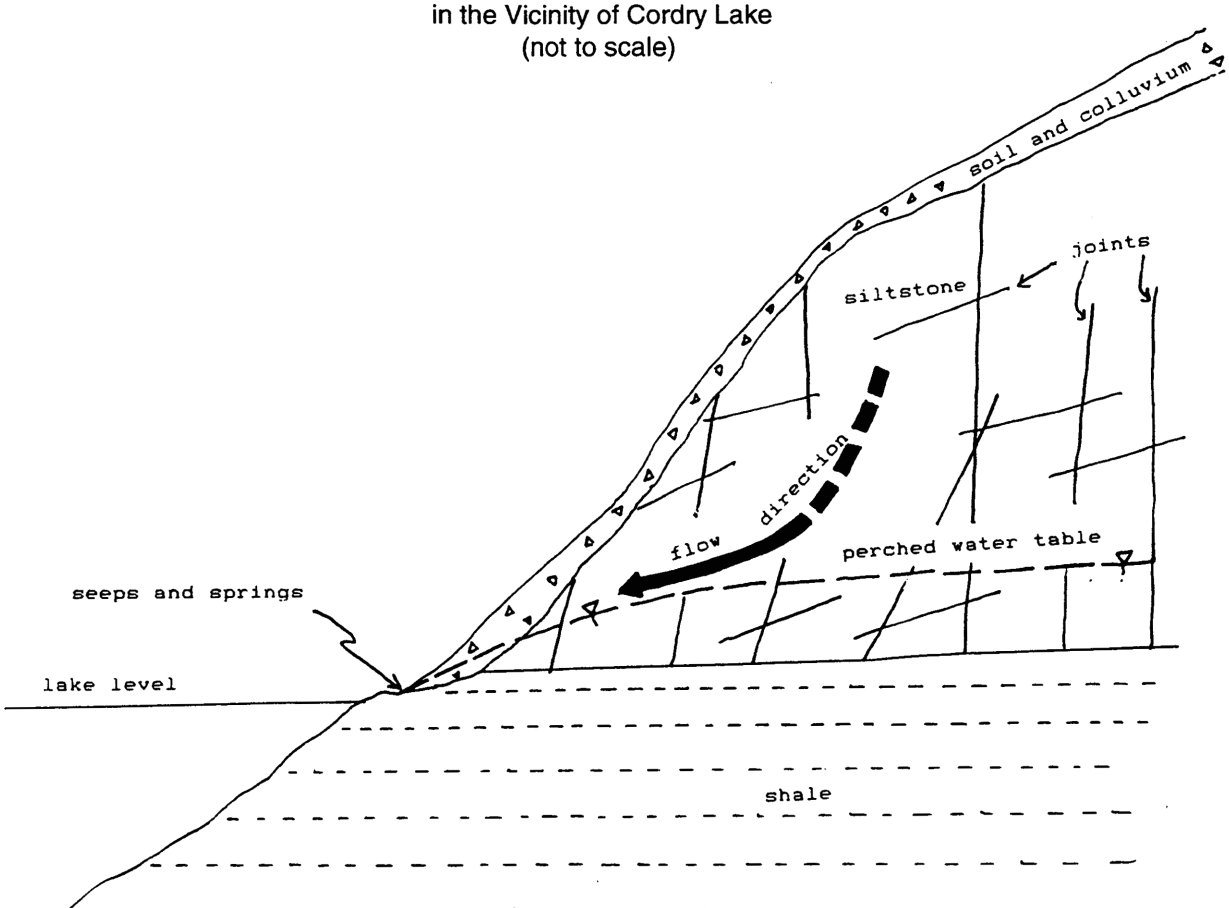
Studies concerning the groundwater and surface water interactions in the Lake Monroe watershed include both published and unpublished reports (Fleming, 1988; Fleming, 1990; Hartke and Gray, 1989). Groundwater occurs in both bedrock and unconsolidated materials in the Lake Monroe watershed. As described in Chapter 2, limestone and siltstone are the principal bedrock materials found throughout the watershed. The Harrodsburg and Salem limestone occurs as a cap over the siltstone in the vicinity of the dam and south of the lake in the vicinity of Saddle Creek, SR 446, and Hardin Ridge Recreation Area (see Figure 2–5). The limestone thickens to the southwest, reaching a thickness of several tens of feet near the dam and spillway (Fleming, 1988). The limestone in the immediate vicinity of the lake has well-defined solution features, resulting in underground streams in which flow velocities of hundred or even thousands of feet per day could be expected. Flow from these underground streams occurs primarily in association with major rainfall events. At the contact between the limestone and the less permeable siltstone, springs develop and form the headwaters of numerous steep ravines.

The siltstone formation consists mainly of fine-grained materials of low porosity and permeability. Groundwater is believed to flow through a system of mostly shallow fractures that provide pathways for shallow groundwater flow. These fractures are mostly vertical, although some horizontal openings occur along bedding planes. The fractures appear to be locally well-connected, allowing recharge to move through the fractures and into the lake and its tributaries. Deeper groundwater flow in the siltstone is not documented. Although some water wells in this area do exist, presumably due to deep fractures, many wells were reported as dry. Both the abundance and magnitude of joints and solution features decrease significantly beneath about 150 to 200 ft. (Hartke and Gray, 1989).

In the eastern portion of the watershed, in areas where the soil is relatively thin and the limestone cap is absent, groundwater movement is controlled by the difference between the fractured siltstone and the relatively impermeable shale which is interbedded with the siltstone. In a geological assessment of the Cordry and Sweetwater Lakes in the extreme northeastern tip of the watershed, Fleming (1990) documented a shallow groundwater system in which water infiltrates through shallow soils and then recharges the fractured siltstone, moving downward through the siltstone until an impervious shale layer is reached, at which point the groundwater is diverted laterally along the surface of the shale bed, ultimately discharging through seeps and small springs to the lake, which is perched on top of the impermeable shale (Figure 4–1). This type of groundwater and surface water interaction is probably occurring in many of the upland areas that occur on the siltstone formation. In addition to flow through fractured siltstone and limestone, there are also sandstone layers and infrequent and unpredictable sand lenses present in the siltstone formation. These deposits transmit enough water to provide a reliable source of water for domestic use (Hartke and Gray, 1989).

Unconsolidated deposits in the watershed consist of thin windblown silts on the flatter ridge tops, fine sand, silt and clay along low terraces, and coarse and fine-grained alluvial deposits along the major stream channels (Fleming, 1988; 1990). The presence of low permeability fragipans in these soils sometimes results in perched shallow water tables.

Figure 4–1. Schematic Diagram Showing Generalized Geology and Shallow Groundwater Flow in the Vicinity of Cordry Lake
(not to scale)



(after Fleming, 1990)

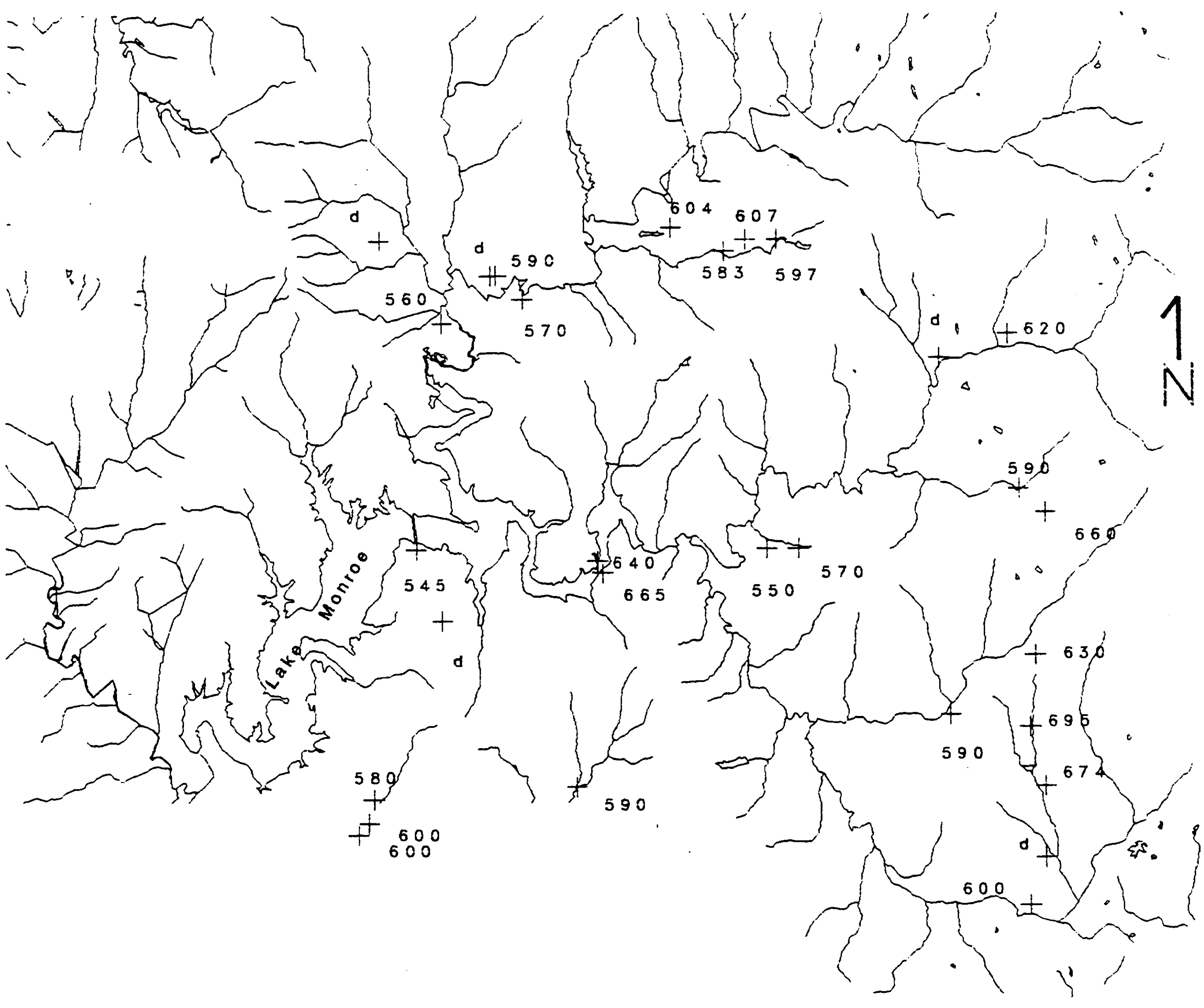
4.1.2 Water Well Survey

Drillers' records were obtained from the Indiana Department of Natural Resources for 80 wells in the watershed. Of those 80 wells, 11 were dry. Figure 4–2 shows the location of those wells that could be located, and the water level in the well at the time the well was drilled. The dry wells, indicated by a "d", are located near wells that pump at least 0.25 gallons per hour. The water table elevations are spatially, highly variable. The water levels for most of the wells occurred at depths of less than 30 ft. Figure 4–3 shows the strong correlation between ground elevation and water table elevation, indicating a shallow water table. Dry holes were found both in upland and lowland areas, mostly in deep wells (Figure 4–4). These data support the hypothesis that groundwater travels through a shallow system of fractures and sandy deposits that may be locally connected, but do not form a regional aquifer system.

4.1.3 Baseflow Analysis

One method used to investigate the groundwater and surface water relationships in a watershed is "baseflow analysis." In locations where streamflow has been monitored daily over an extended period of time, a stream hydrograph can be generated. The hydrograph is a plot of the stream discharge over time. Hydrographs show

Figure 4–2. Static Water Levels in Domestic Wells in the Lake Monroe Watershed. Dry Wells (d) are Indicated



peaks during rainfall and melting events, and valleys during dry periods. Presumably, the flow during dry periods is due to groundwater infiltration to the stream, frequently referred to as "baseflow." Kim and Hawkins (1993) developed a computer program to separate streamflow into baseflow and quick flow. This program employs a statistical technique that is based on the separation gradient technique. An example of the resulting baseflow separation is presented for Stephens Creek in Figure 4–5. As is evident from Figure 4–5, most of the flow in Stephens Creek is associated with peak discharges. During dry periods, little or no flow was measured. This pattern is typical of most of the streams in the watershed.

Streamflow in the Lake Monroe watershed is probably generated by a combination of overland flow, groundwater flow from near-stream alluvium, and groundwater flow from fractured siltstone formations. Peak discharges occur during or after storms and major snowmelts. When surface soils are saturated, rainwater runs overland, collecting in ditches and gullies and moving rapidly to the streams. As the rain subsides, stream

Figure 4–3. Correlation Between Watershed Ground Elevations and Water Table Elevations Indicates a Shallow Water Table

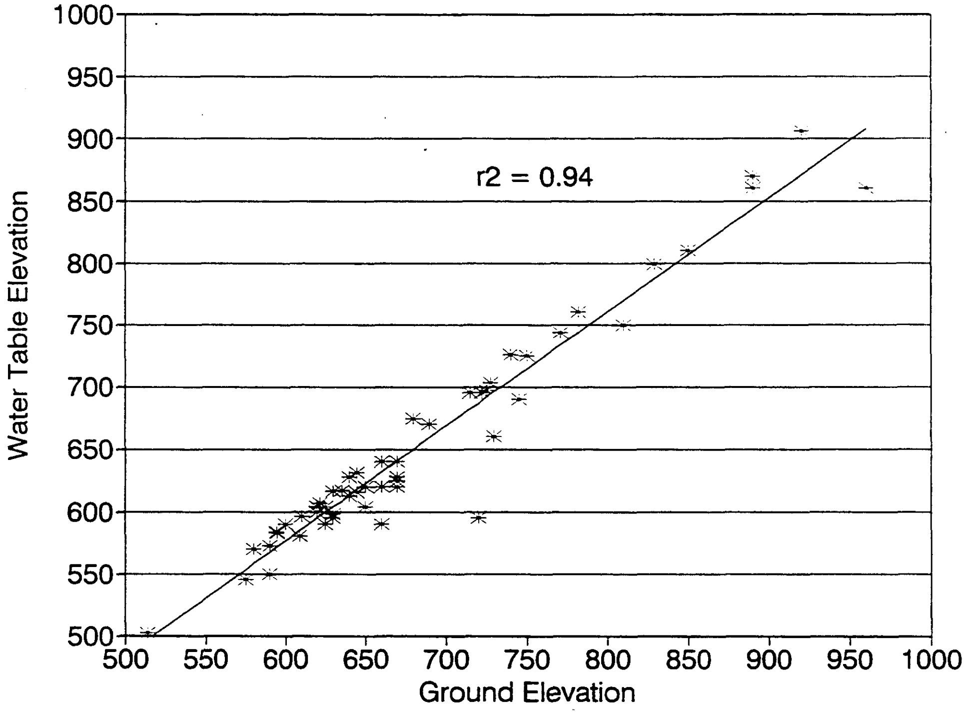


Figure 4–4. Elevation Profile of Dry Wells in the Monroe Watershed

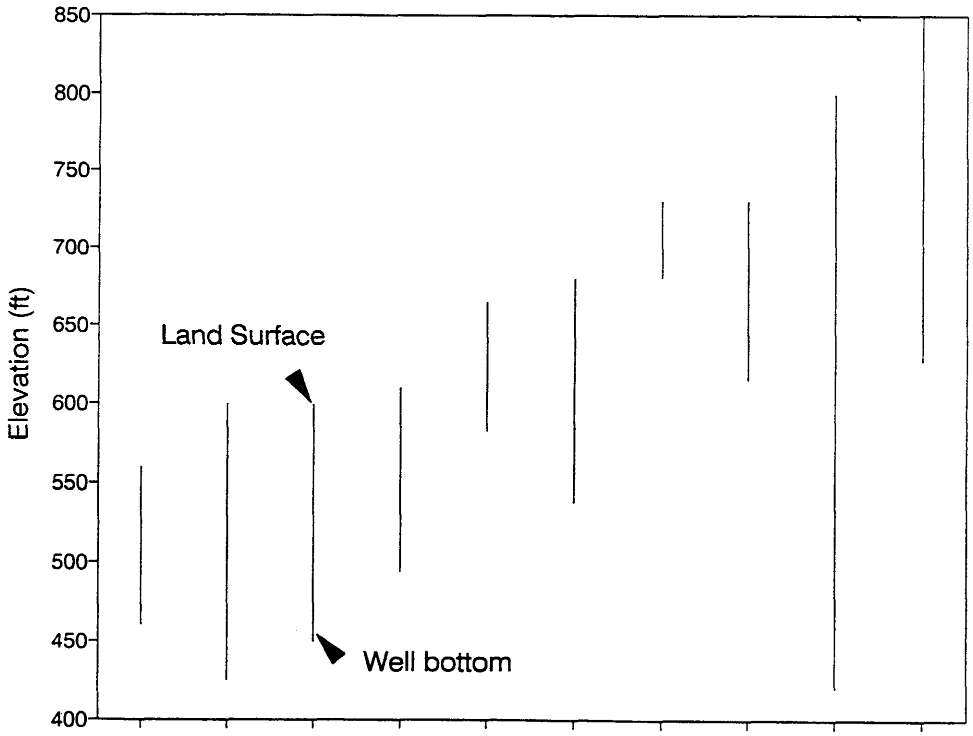
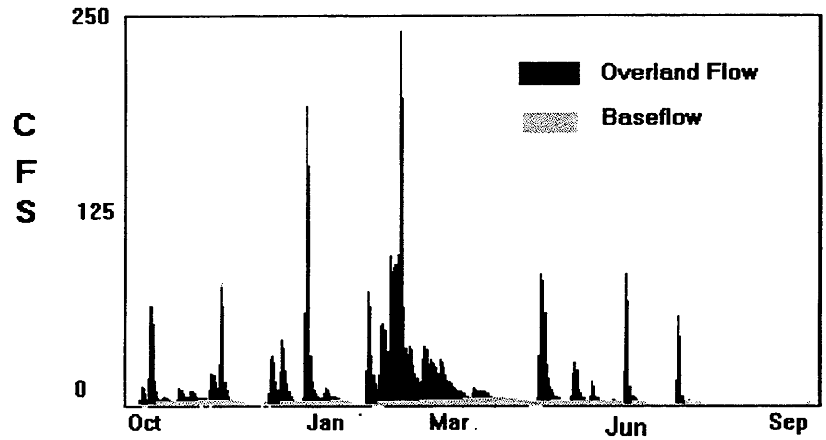


Figure 4–5. Example of Baseflow Separation Results for Stephens Creek, October 1970–September 1971



discharge is supported by surface drainage and groundwater flow from both the soil and the fractured siltstone system. During this period, flow from the saturated soil system is moving downward to the contact between the soil and the siltstone where part of the flow is recharging the siltstone system and the rest is diverted laterally towards discharge points along stream beds, springs and seepage faces. After the upland soils have drained, the stream discharge in upland streams is greatly reduced and sustained by shallow fracture flow. At this point many upland streams may dry out. Small amounts of intermittent flow may be found in these streams as a result of storage and release of water by streambed deposits. Low-lying streams retain flow for a longer period of time, receiving flow from near stream alluvial deposits and the fractured siltstone. During periods of extreme drought, even low-lying streams dry out as the water table drops below the streambed.

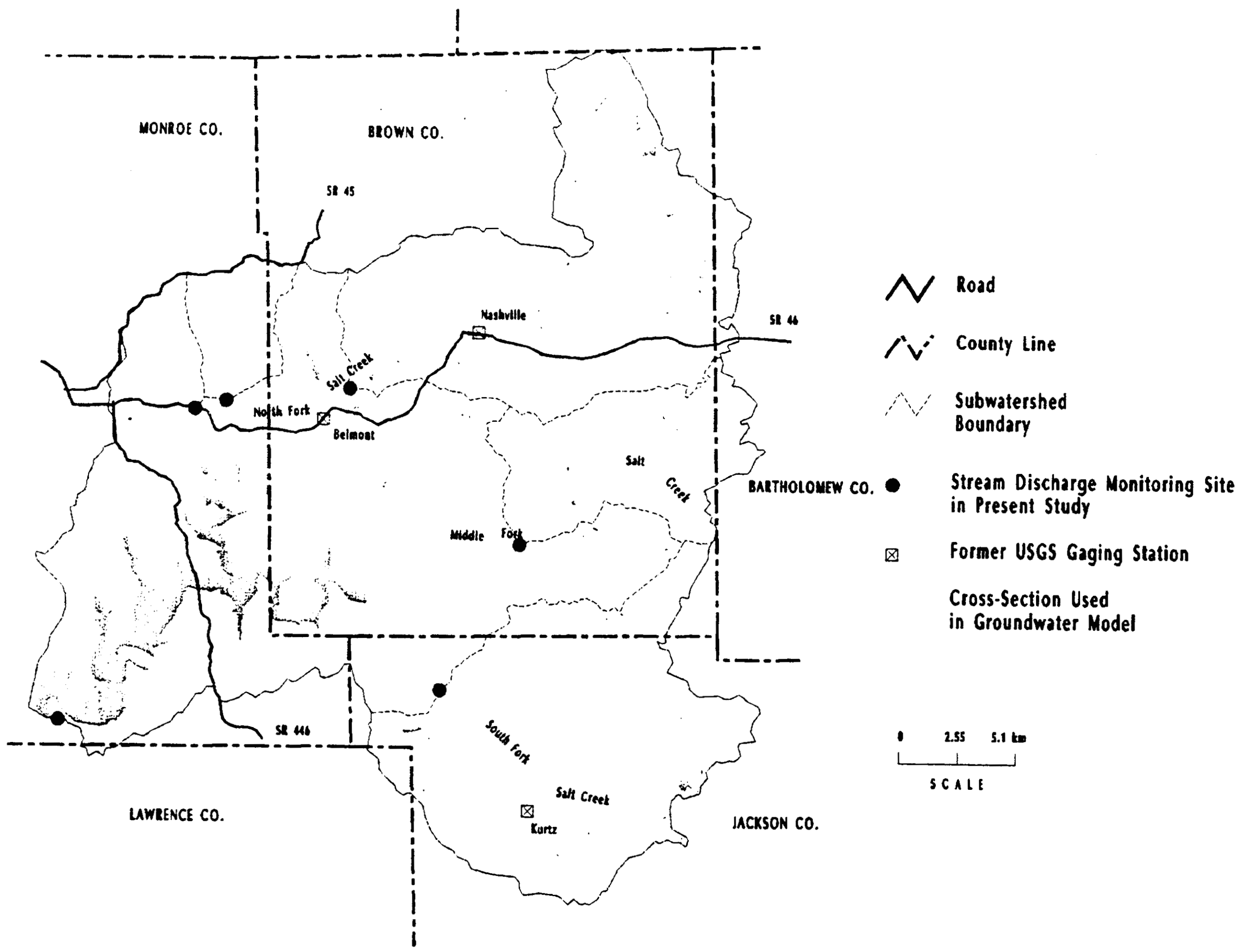
Applying this conceptual model to the hydrograph separation results, we can equate the peak discharges with the period of overland flow; the recession period as mixed overland flow and groundwater flow from both the upland and lowland areas; and the relatively flat part of the hydrograph with the groundwater flow from alluvial deposits and the fractured siltstone. Table 4–1 shows the hydrograph separation results from streamflows measured by the U.S. Geological Survey in the vicinity of Lake Monroe. The results are expressed as runoff (in/yr) , which is equal to the stream discharge divided by the watershed area. Mixed baseflows are the baseflows that occur simultaneously with overland flow. Pure baseflows are not accompanied by overland flow. Figure 4–6 indicates the location where the flows were gauged within the Lake Monroe watershed. At locations where the siltstone is capped by limestone (Stephens Creek and Clear Creek), the average streamflow is approximately 18 inches per year. Where the limestone cap is absent, average streamflow is approximately 14 inches per year. Average total baseflows within the watershed ranged from 1.7 to 2.6 inches per year. Average pure baseflows ranged from 0.2 to 0.58 inches per year, with most values falling in the range of 0.2 to 0.3 inches per year. If we assume that the pure baseflow component represents the contributions from the shallow groundwater system, then, assuming negligible losses to the impermeable shale base, we can estimate the recharge to the shallow groundwater system to be approximately 0.25 inches per year. However, if we consider pure and mixed baseflow to represent an upper limit, recharge could be as high as 2.5 inches per year. These

Stream	Year(s)	Total Mean Flow (in/yr)	Total Mean Baseflow (in/yr)	Mixed Baseflow (in/yr)	Pure Baseflow (in/yr)
Stephens	1971–1991	18.1	2.6	2.0	0.58
North Fork at Belmont	1946–1972	14.2	1.7	1.4	0.28
South Fork at Kurtz	1960–1971	14.2	–	–	0.21
Clear Creek at Harrodsburg	1960–1971	17.7	–	–	–
Beanblossom at Beanblossom[1]	1952–1991	14.9	2.2	1.7	0.5
North Fork at Nashville	1962–1976	13.2	1.9	1.6	0.3
Beanblossom at Dolan	1947–1979	14.6	3.0	2.2	0.8

Table 4–1. Baseflow Separation Results

[1]not in Lake Monroe Watershed

Figure 4–6. Location of Stream Monitoring Stations in the Lake Monroe Watershed



values will be applied to a groundwater model to estimate the effective hydraulic conductivity of the shallow aquifer system.

4.1.4 Groundwater Model

A boundary element cross-sectional groundwater model (Mitchell-Bruker, 1993) was used to provide insight into the hydraulic conductivity of the shallow aquifer system. As is the case with all models, there are assumptions implicit in the model that may or may not be violated by the shallow groundwater system at the site in question. The assumptions implicit in the boundary element model are:

- The aquifer is homogeneous and isotropic.
- Recharge is distributed uniformly across a horizontal aquifer top.
- The base of the aquifer is horizontal.
- Flow field does not change with time (steady state flow).

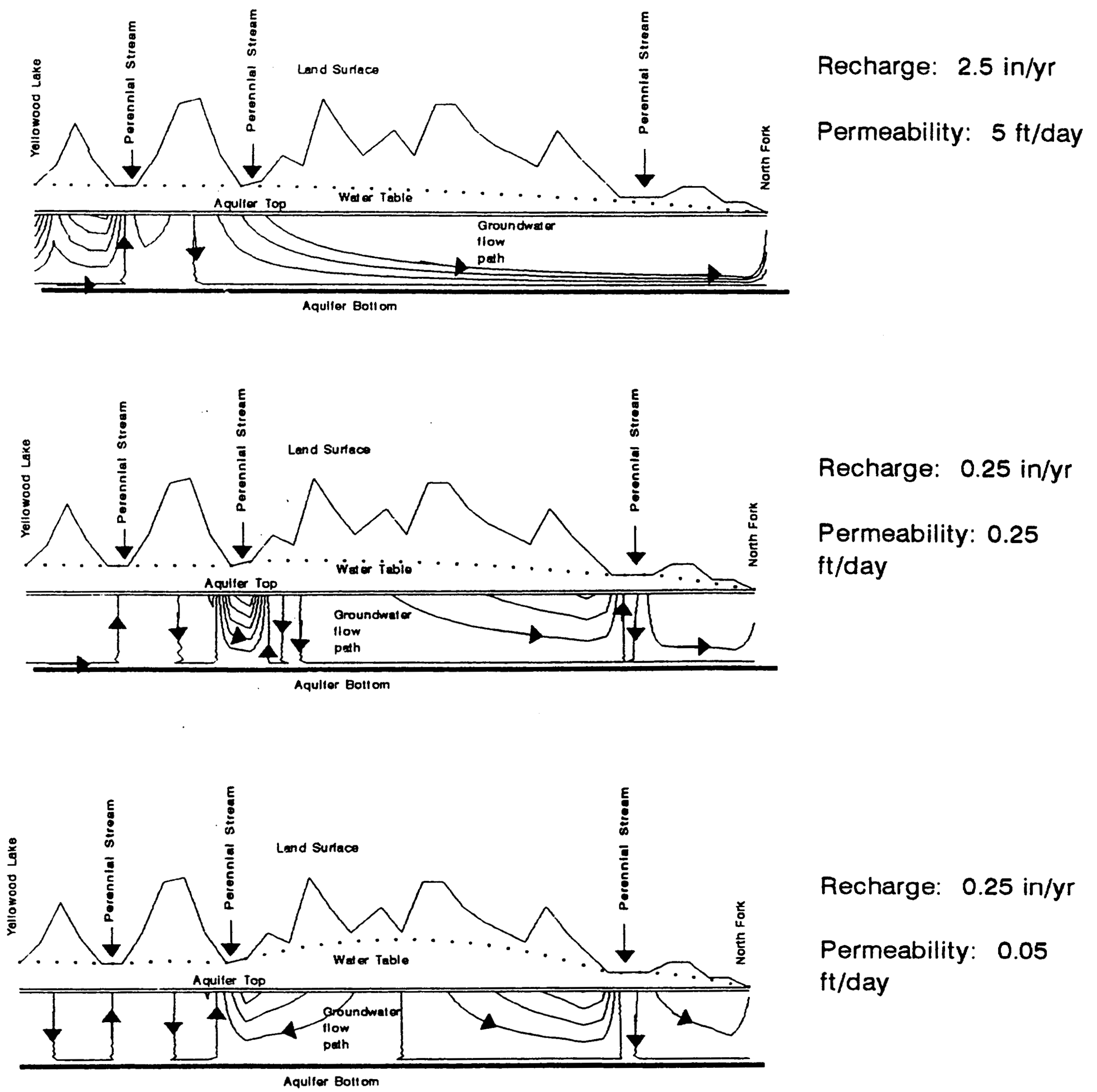
Clearly, the aquifer is not homogeneous and isotropic, since it is a fractured siltstone with interbedded shales and sandstones, however, if the fractures are locally well-connected, and major faults or interbedded layers do not dominate regional flow, the fractured siltstone can be treated as an equivalent porous media. While there may be local variations in recharge rates, we do not expect these local variations to have a significant regional effect. The assumption of a horizontal aquifer top and bottom can be taken together as indicating an aquifer of uniform thickness. Since fracturing decreases with depth, we envision the shallow flow system to have relatively uniform depth. The steady state approach is commonly applied to aquifer systems as a first order approximation of a transient system. In studying groundwater and surface water interactions, the steady state approach ignores the short-term effects of bank storage and variable source flow and provides an estimate of the time-averaged flows. Given these assumptions, the modeling results we obtain can only be seen as a crude approximation of the actual flow system.

The groundwater modeling was directed towards providing insight into the magnitude of the hydraulic conductivity of the shallow aquifer, primarily for the purposes of assessing the relative importance of groundwater to the hydrologic budget. The model was applied to a cross-section between Yellowood Lake and North Fork of Salt Creek. The topography was determined from 7.5 minute USGS topographic maps. The model was run assuming an aquifer thickness of 140 ft. The results of several model runs are presented in Figure 4–7. Using the high recharge rate and high hydraulic conductivity, Figure 4–7a illustrates the upper limit on recharge and hydraulic conductivity. If the hydraulic conductivity were raised, the water table would not reach up to the lowest perennial stream. If the minimum recharge rate of 0.25 inches per year is used, the hydraulic conductivity cannot be lower than 0.05 inches per year or the water table will reach the land surface in an area where there are no streams (Figure 4–7c). These results indicate that the hydraulic conductivity value for the shallow aquifer system should be at least 0.05 ft/day and no more than 5 ft/day.

Most of the wells completed in the bedrock are pumped at a rate of 0.25 to 1 gallon per minute. Above 1 gallon per minute, the well goes dry. For a 100-ft , six-inch-diameter well, 1 gallon per minute corresponds to a seepage rate of 0.5 ft/day, therefore the hydraulic conductivity should be less than 0.5 ft/day. The combined results of modeling and well yield data suggest that a hydraulic conductivity of 0.1–1 ft/day may be a reasonable estimate of the hydraulic conductivity for the shallow groundwater system.

According to data from the hydrogeologic atlas of aquifers in Indiana (Fenelon et al., 1994), gradients in hydraulic head favor movement of groundwater into the lake from the watersheds. From Figure 4–8, the

Figure 4–7. Groundwater Model Results



gradient (i) in hydraulic head towards the lake was determined at two points (P_1,P_2). Applying Darcy's law, we can determine the specific discharge (q_x) from these gradients.

$$q_x = -k_x * i$$

where k_x = hydraulic conductivity

Using the higher estimates for gradient and hydraulic conductivity:

$$q_x = 0.304 \text{ m/day} * 25/5000 = 1.5 \times 10^{-3} \text{ m/day}$$

Using the lower estimates of gradient and hydraulic conductivity:

$$q_x = 0.304 \text{ m/day} * 9.5/3000 = 9.6 \times 10^{-4} \text{ m/day}$$

Multiplying the specific discharge times the aquifer thickness (B) and the shoreline area (A) gives an estimate of the groundwater discharge (Q) into the lake.

$$Q = q_x * B * A$$

Using the higher estimate of specific discharge:

$$Q = 1.5 \times 10^{-3} \text{ m/d} * 43 \text{ m} * 306{,}000 \text{ m} = 19{,}737 \text{ m}^3\text{/day}$$

Using the lower estimate of specific discharge:

$$Q = 9.6 \times 10^{-5} \text{ m/d} * 43 \text{ m} * 306{,}000 \text{ m} = 11{,}632 \text{ m}^3\text{/day}$$

The results suggest that the groundwater inputs to Lake Monroe are on the order of 1% of the total inputs. Because of the fractured and variable nature of the siltstone formation, and the limited data available for analysis, this should be seen as a rough approximation and not a known quantity. However, these results support the general conclusion that groundwater flow does not contribute significantly to the overall water budget of the lake. For more information about this analytical method, see Mitchell-Bruker (1993).

4.2 Hydrologic Budget

The volumetric water budget for Lake Monroe is based on an input/output model in which:

Change in Lake Volume = Inputs-Outputs

The inputs to the lake include streamflow, overland flow, precipitation and groundwater flow. The outputs include evaporation, drinking water withdrawals, and surface water discharge at the dam.

4.2.1 Inputs

The calculated estimates of hydrologic inputs to the lake are presented in Table 4–2. Of the estimated 490,000,000 cubic meters of water entering the lake, 96% comes from streams, 4% from net precipitation (precipitation - evaporation). Most of the net inputs to Lake Monroe occurred in the winter and spring months. High evaporative losses and low runoff kept net inputs low in the summer months. In fact, there was a net loss of water from the lake in June, 1992 for these reasons.

Monitored Streamflow. Stream discharge to Lake Monroe was measured at five locations within the watershed (see Figure 4–6). The watersheds for these stations represent 59% of the total watershed area. Stream discharge was measured monthly or biweekly at each of these sites. A model was developed assuming a linear relationship between the daily mean discharge at the monitoring sites and discharge at the USGS gauging on Beanblossom Creek at Beanblossom.

Figure 4–8. Cross-Section of Water Table Near Lake Monroe

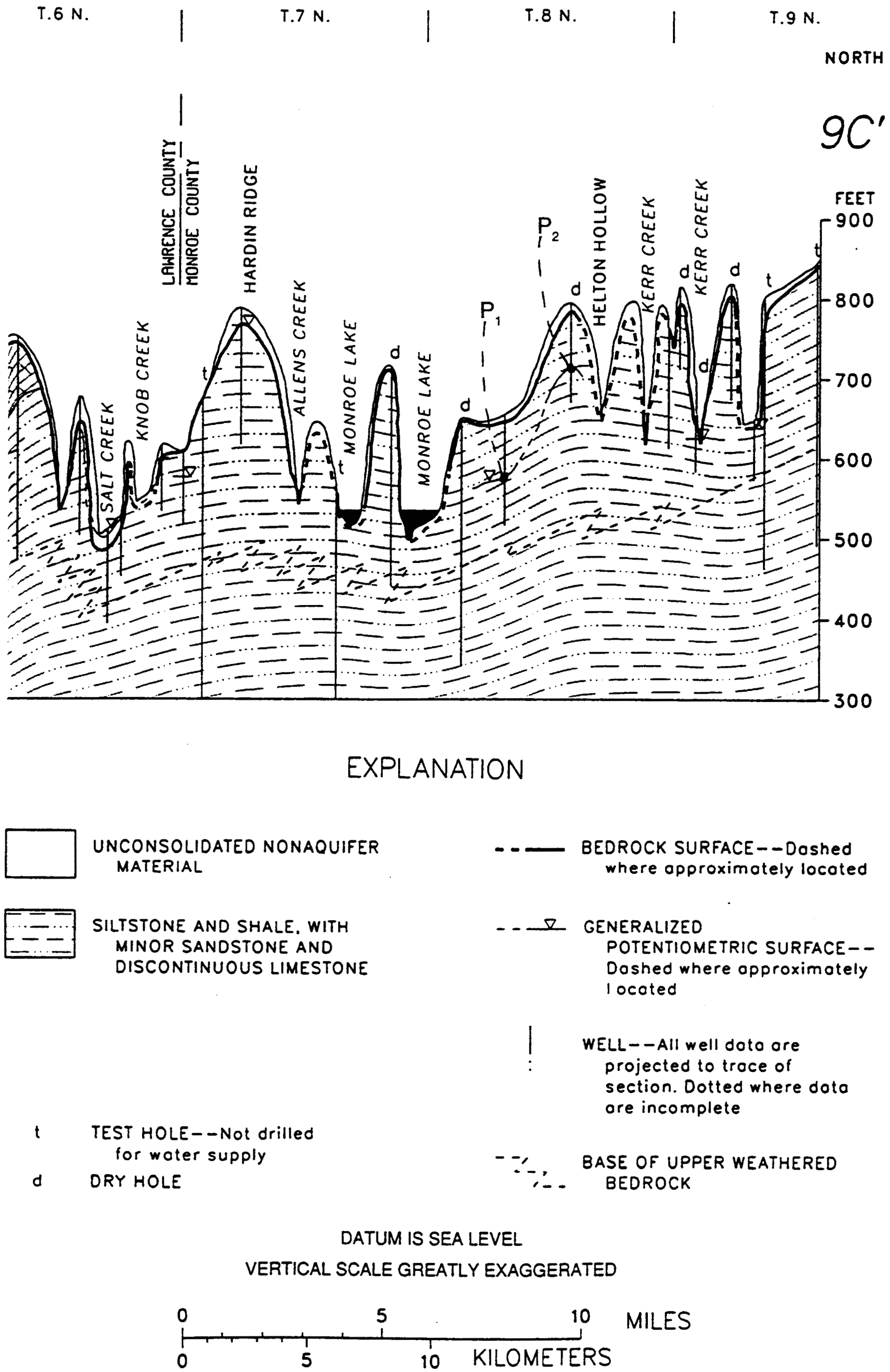


Table 4–2. Hydrologic Inputs

Month	Lake Area (m2)	Prec-evap (m3)	Monitored Inflow (m3)	Unmonitored Inflow (m3)	Total inflow (m3)	Total Inputs (m3)
Apr-92*	44190598	312600	19922783	16315367	36238150	36550750
May-92	44385073	-533251	3163318	2506970	5670288	5137037
Jun-92	43232870	-2387302	1204508	986408	2190916	-196386
Jul-92	43345353	6460503	30109818	23862422	53972240	60432744
Aug-92	43274132	-719952	9265030	7342657	16607687	15887735
Sep-92	42385282	-720236	2540731	2080681	4621412	3901175
Oct-92	41910771	595074	3280997	2600233	5881231	6476305
Nov-92	42881919	4324127	29340761	24028032	53368793	57692920
Dec-92	42911732	1569540	18162986	14394402	32557388	34126927
Jan-93	45822078	3858265	46496092	36848757	83344848	87203113
Feb-93	43855454	2623302	19807623	17379706	37187328	39810630
Mar-93	46892806	3394570	47395784	37561774	84957558	88352128
Apr-93*	44823410	1406066	29545891	24196019	53741910	55147976
Annual		20183305	260236321	210103428	470339749	490523055

* Includes one-half of April (April 15-30, 1992 and April 1-15 1993).

$Q_s = a * Q_{bb} + b$, where:

Q_s = Measured discharge at site
Q_{bb} = Gaged discharge at Beanblossom
a = x coefficient
b = y intercept

The results of these regressions are presented in Table 4–3. The proportion of the total variance in discharge explained by the regression [R^2] ranges from a high of 0.98 at Stephens Creek to a low of 0.77 at the South Fork of the Salt Creek. As the distance between the Beanblossom gage and the site increases, the R^2 value, and hence the reliability of the model decreases. The South Fork site was the farthest from the Beanblossom gage. In addition, during runoff events, the South Fork was the last site measured and peak runoff most likely passed by the time we arrived there. Thus our measured flows could be underrepresented at the South Fork site. The regression relationship was applied to model the daily mean discharge at each of the five sites. These discharges are plotted, along with measured discharges, in Figures 4–9 through 4–13.

Table 4–3. Regression Results—Discharge Estimation

STATISTIC	STEPHENS	BRUMMETTS	NORTH FORK	MIDDLE FORK	SOUTH FORK
Std. error of predicted Q	4.04	8.74	102.90	35.40	106.36
R^2	0.98	0.93	0.90	0.89	0.77
X coefficient (slope)	0.94	0.91	6.67	2.18	4.08
Std. error of x coefficient	0.03	0.05	0.47	0.16	0.44
Y intercept	0	0	0	0	0

Figure 4–9. Modeled vs. Measured Daily Mean Discharge—Stephens Creek

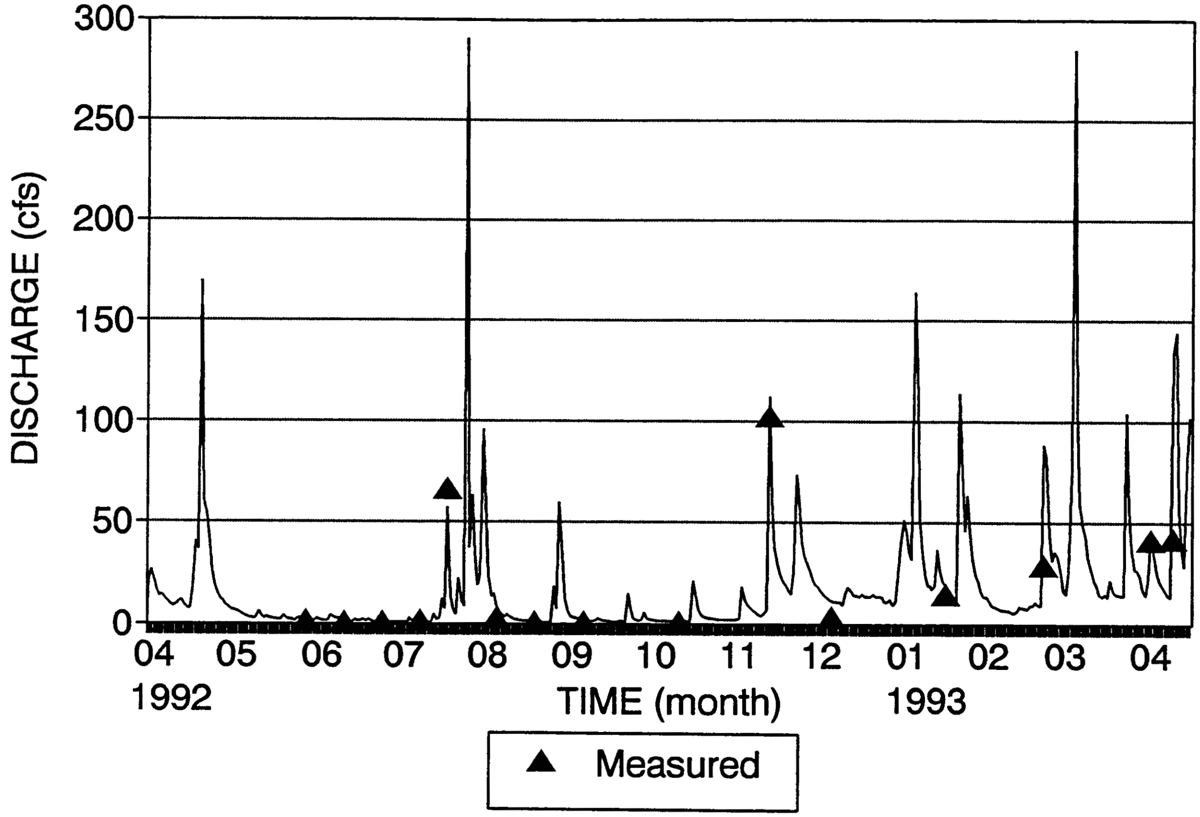


Figure 4–10. Modeled vs. Measured Daily Mean Discharge—Brummetts Creek

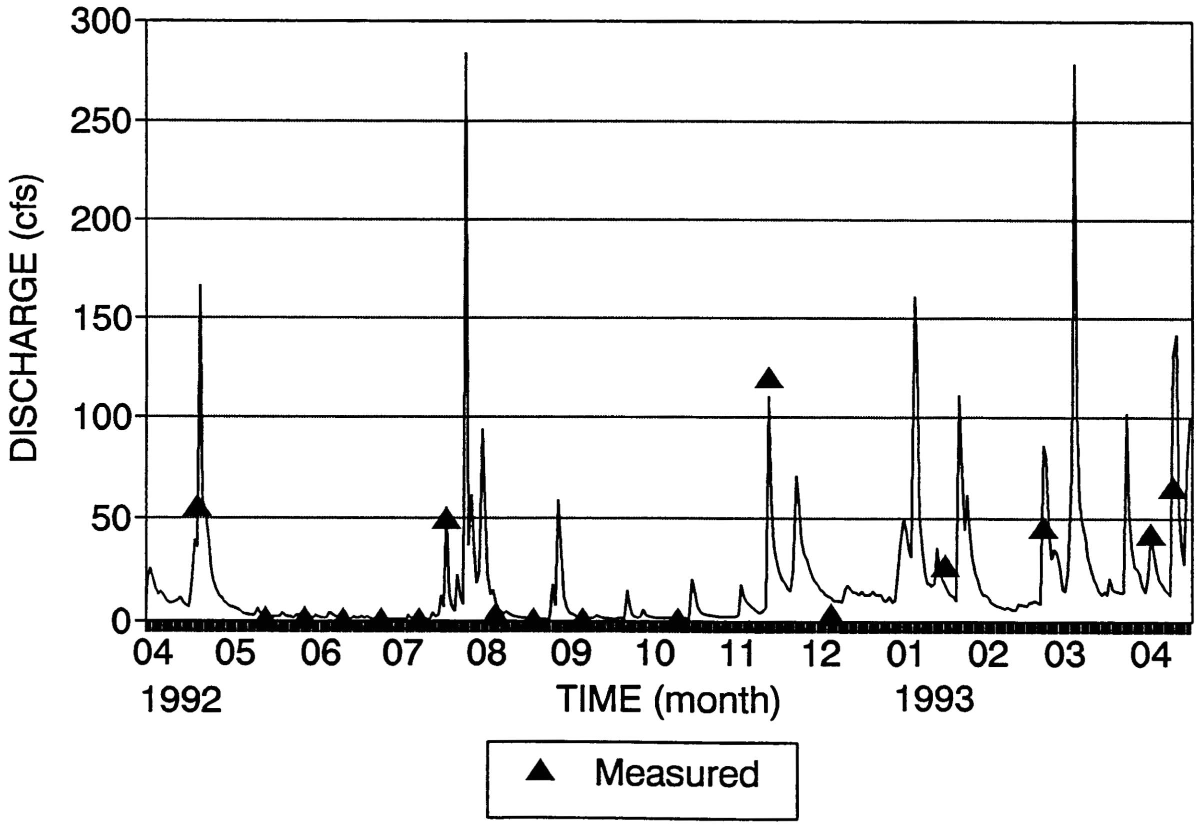


Figure 4–11. Modeled vs. Measured Daily Mean Discharge—North Fork Salt Creek

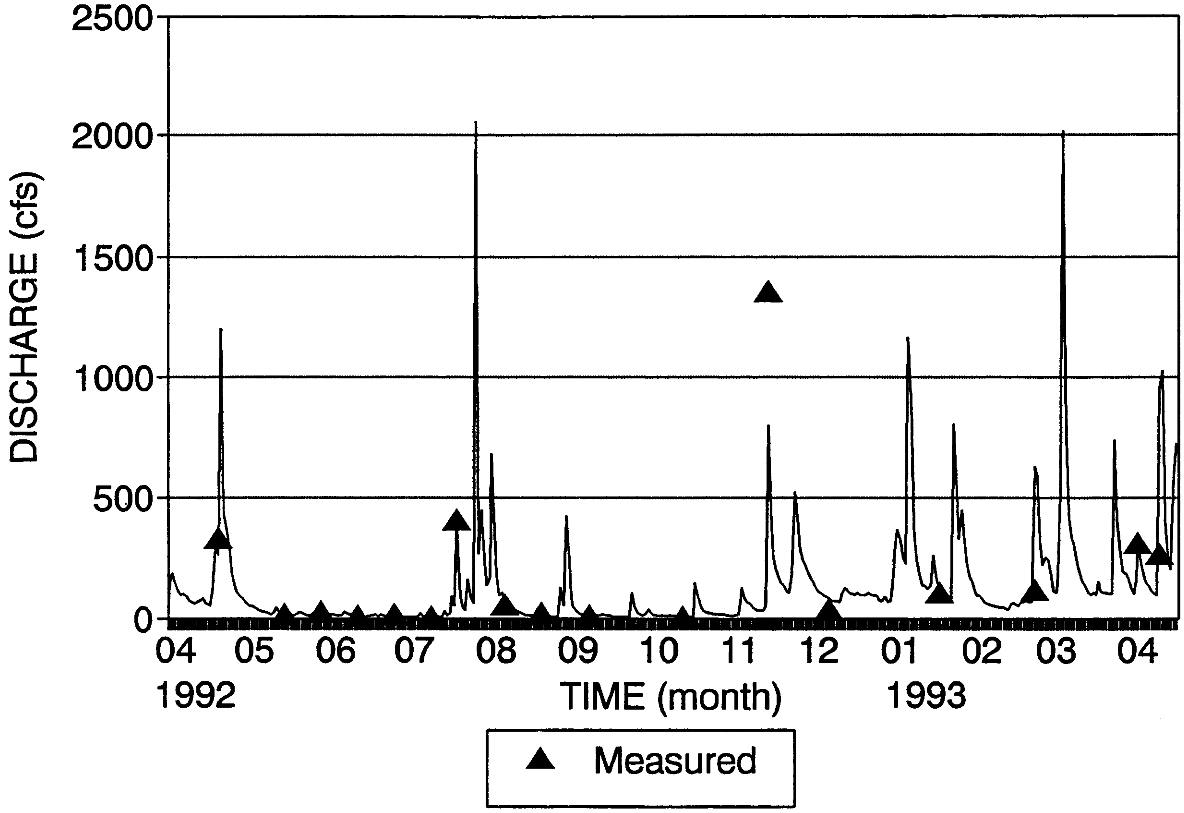


Figure 4–12. Modeled vs. Measured Daily Mean Discharge—Middle Fork Salt Creek

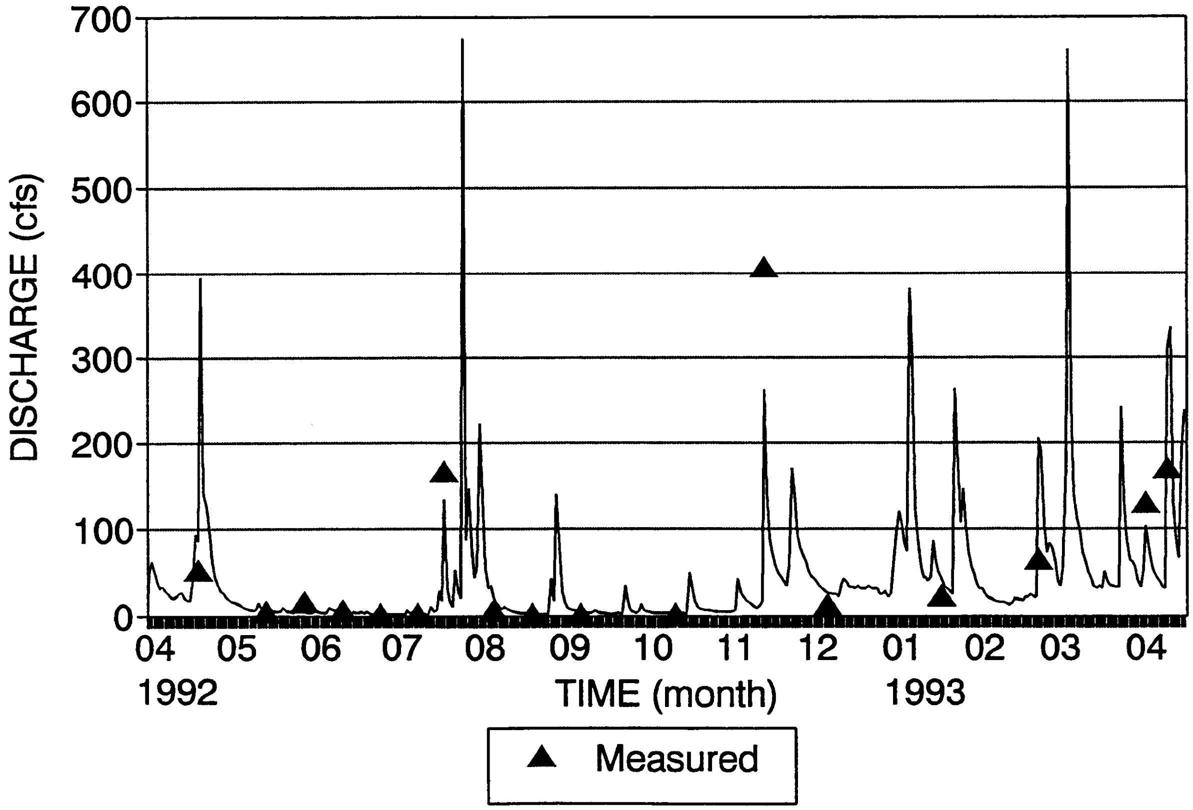
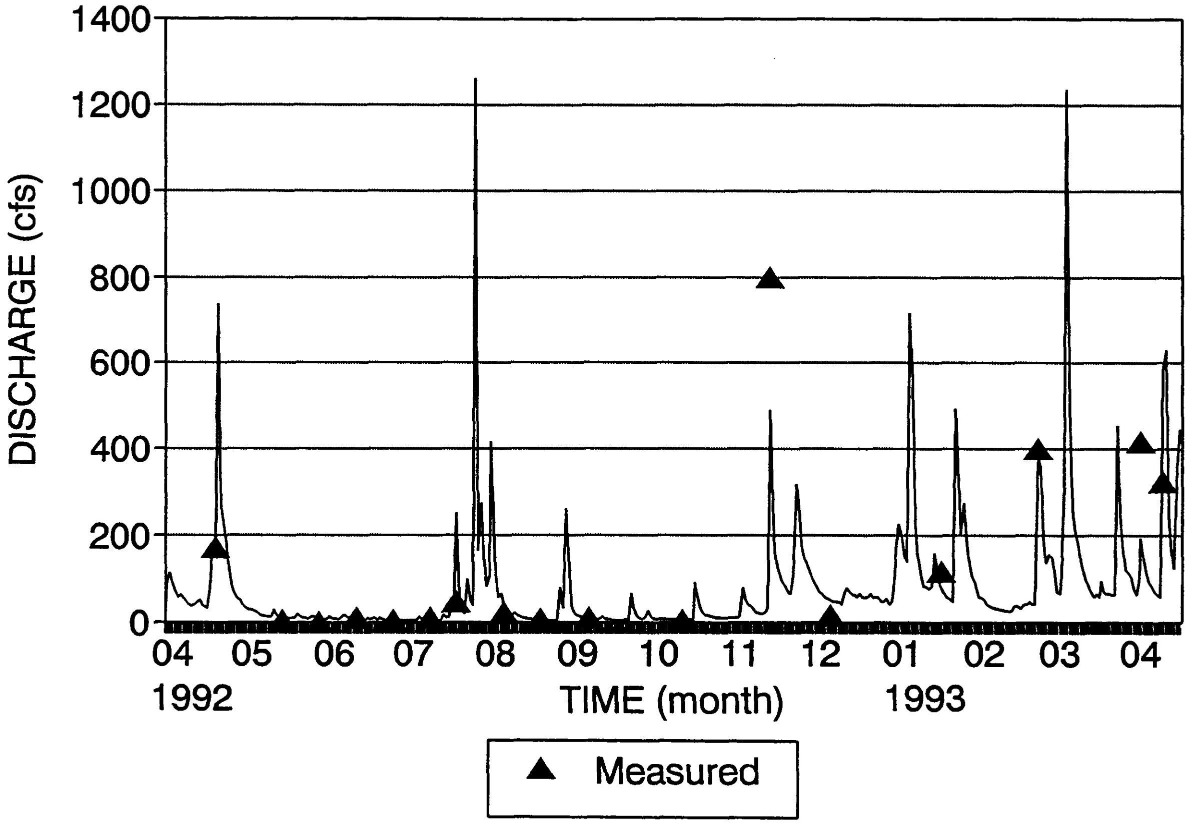


Figure 4–13. Modeled vs. Measured Daily Mean Discharge—South Fork Salt Creek



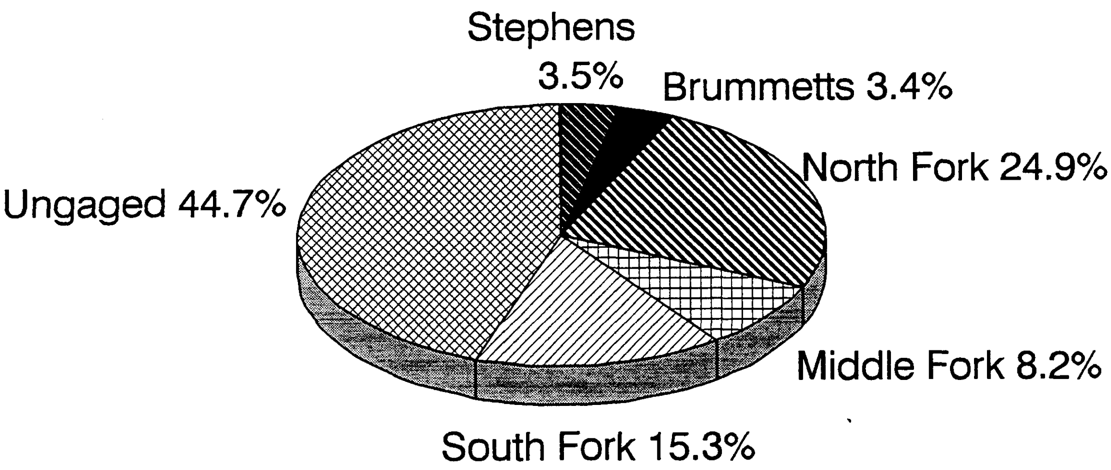
Unmonitored Streamflow. In addition to the five monitored watersheds, there are 168 additional square miles of the Lake Monroe drainage basin that can be divided into 8 small drainage basins. Since this unmonitored area has a land use distribution and size similar to the Brummetts Creek watershed, a runoff coefficient (C_{ro}) was calculated by dividing the monthly discharge for the Brummetts Creek watershed by the area of the Brummetts Creek watershed. The discharge for the unmonitored portion of the watershed was estimated by multiplying C_{ro} times the area of the unmonitiored watershed.

An estimated 470,339,749 cubic meters of streamflow entered Lake Monroe between April 15, 1992 and April 15, 1993. The unmonitored portion of the watershed contributed approximately 45% of the streamflow, while the three forks of Salt Creek contributed an estimated 48%. The remainder of the flow was attributed to Stephens Creek and Brummetts Creek (Figure 4–14).

Net Precipitation. Net precipitation was determined by taking the average precipitation measured at Nashville and Bloomington and subtracting evaporation. Evaporation was estimated by multiplying the pan evaporation measured at Oakland (the nearest evaporation recording station) by 0.7, a coefficient commonly applied to estimate evaporation from lakes. This net precipitation rate was applied to the lake surface area, which was determined from the hypsograph provided by the Army Corps of Engineers (Corps of Engineers, 1966).

Although the lake is most likely gaining groundwater from flow along joints, fractures,and open bedding planes, there are insufficient data to quantify this flow. However, given the low baseflows in the streams, and the previously estimated groundwater discharge to the lake, it is not likely that groundwater inputs represent a significant portion of the inputs to the lake.

Figure 4–14. Streamflow Inputs to Lake Monroe from April 15, 1992 to April 15, 1993



4.2.2 Outputs

The calculated estimates of hydrologic outputs from the lake are presented in Table 4–4. Of the 361,000,000 cubic meters of water leaving the lake, 96% leaves through the outlet at the dam and 4% is extracted for drinking water. The outlet losses were reported by the Army Corps of Engineers and the drinking water withdrawals were reported by the Monroe Water Purification Plant. The hydraulic retention time for the monitoring period, expressed as the average lake storage capacity divided by the total outputs per year, is approximately 230 days.

Table 4–4. Lake Monroe Hydrologic Outputs and Water Budget Results

Month	Drinking Water (m3)	Outlet (m3)	Total Outputs (m3)	In-Out (m3)	Storage (m3)	In-Out-Storage (m3)	Residual %
Apr-92	-651913	-7641509	-8293422	28257328	23617010	4640319	12.8
May-92	-1306908	-20608505	-21915412	-16778375	-15744673	-1033702	-18.2
Jun-92	-1427380	-13382146	-14809526	-15005912	-13534894	-1471018	-67.1
Jul-92	-1374334	-13844438	-15218772	45213972	19888008	25325964	46.9
Aug-92	-1404788	-24647480	-26052267	-10164532	-16573340	6408808	38.6
Sep-92	-1464012	-4744579	-6208590	-2307415	-5110113	2802698	60.6
Oct-92	-1348751	-3771332	-5120083	1356222	-2900335	4256557	72.4
Nov-92	-1189731	-11649766	-12839498	44853423	18921230	25932193	48.6
Dec-92	-1155042	-16764179	-17919221	16207706	-9253448	25461154	78.2
Jan-93	-1251431	-40608730	-41860161	45342952	38118682	7224270	8.7
Feb-93	-1194974	-61127209	-62322183	-22511553	-24169454	1657901	4.5
Mar-93	-1196132	-85942574	-87138706	1213423	11463227	-10249804	-12.1
Apr-93	-651913	-40280259	-40932172	14215803	13811117	404687	0.8
Annual	-15617307	-345012706	-360630013	129893041	38533016	91360026	19.4

4.2.3 Storage

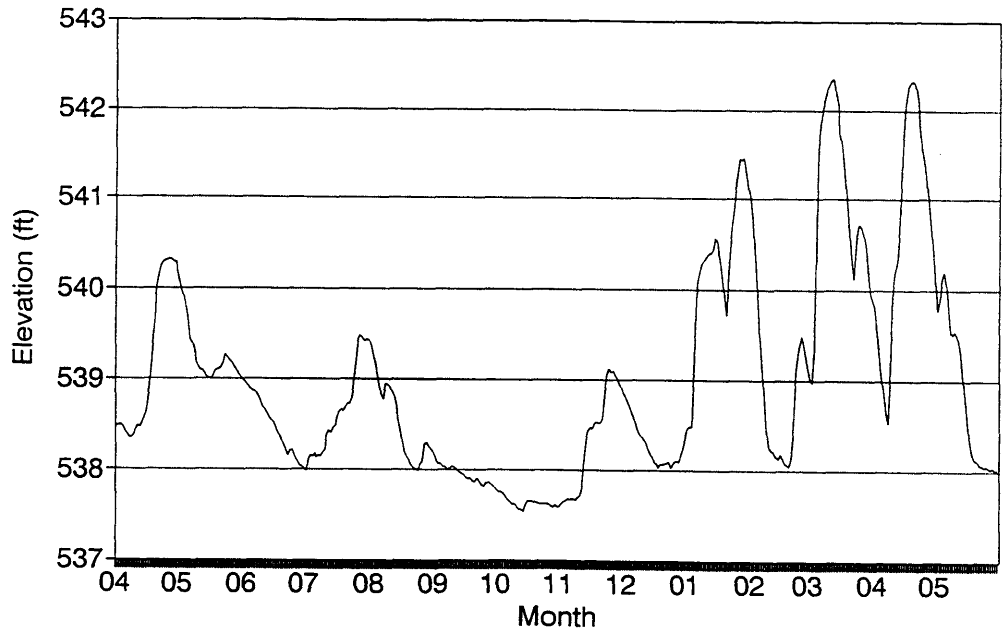
The stage level of the lake was recorded daily by the Army Corps of Engineers (Figure 4–15). As this figure shows, lake levels during most of the reporting period were at or above the 538 foot normal pool elevation but well within the 538 to 556 foot range allocated for flood storage.

Using an old hypsograph and depth-volume curve, a linear approximation for area and volume was determined. Lake volumes were averaged for each month and changes in storage from one month to the next were determined by subtracting these volumes (Table 4–4).

4.2.4 Uncertainty

Uncertainty arises when approximations are made and when errors in measurement are made. While it is desirable to minimize the uncertainty, there is always a tradeoff between cost and uncertainty. When more data are available, fewer extrapolations are made, and the results become more reliable. Because it is economically unfeasible, as well as impossible, to measure all of the components of the hydrologic budget, the budget has been formulated based on a combination of measurement and extrapolation. The measurements involved in determining the water budget are relatively simple to perform, and every precaution has been taken to avoid errors of this type. The more significant source of uncertainty stems from the interpolation of data from one site to the other. Precipitation data were obtained from weather stations at Bloomington and Nashville—both outside of the watershed. Evaporation data were obtained from the nearest available station, in Oakland, which is 56 miles from the lake. However, because net precipitation is such a small part of the total hydrologic budget, we do not expect the errors associated with these extrapolations to be significant. Another source of uncertainty is the contribution of groundwater. Again, because of the small amounts of baseflow observed in streams within the watershed, and the low permeability of the rocks underlying the lake, we do not expect contributions from groundwater to represent a significant portion of the uncertainty in the water budget. A more important source

Figure 4–15. Daily Lake Monroe Stages from April 1992 to May 1993



measurements at five sites within the watershed to continuous measurements made at a site outside of the watershed. Because stream inputs represent 96% of the water budget, the errors in estimating stream inputs will have a significant impact on the overall water budget.

In water budgets, the uncertainty can be investigated by examining the water budget residual. The residual is the result of applying the water balance equation:

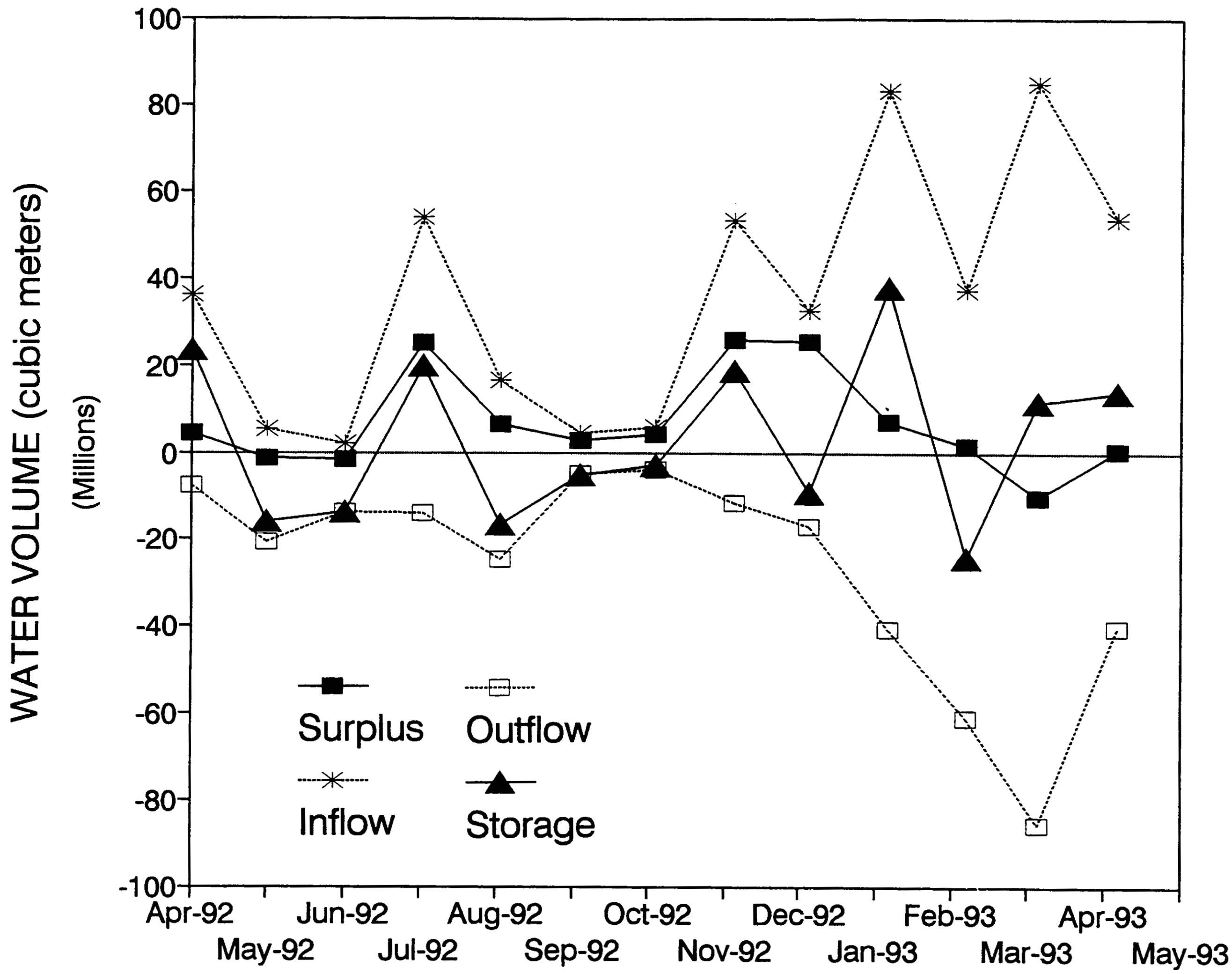
V – Inputs – Outputs = Residual, where:

V = Change in Lake Volume
R = Residual

If the residual is zero, then the water budget is "balanced" and we may assume that the budget is fairly reliable. This assessment is not always true however, since errors that are equal in magnitude but opposite in sign could produce the effect of a "balanced budget". The residual for the 1992–93 water budget is greater than 38,000,000 cubic meters (Table 4–4) which indicates a 19.4% surplus in the water budget. This surplus can be attributed to the combined effects of underestimation of changes in storage, overestimation in streamflow inputs and underestimation of outflow at the dam. Since outflow at the dam was measured, rather than interpolated, we expect the uncertainty in the water budget to be due primarily to the overestimation of stream inputs and the underestimation of storage increases.

Figure 4–16 suggests that errors occur in all three estimations. For the most part, large surpluses occur when inflow is large. However, not all large inflows correspond to large surpluses. When the outflow is also large, the surplus is reduced, suggesting that errors in estimating inflow are balanced by errors in estimating outflow. The third possibility, that the change in storage is underestimated, is supported by the observation that most high surpluses occur when changes in storage are high and positive. A high and positive change in storage corresponds to a large increase in lake stage. If the upper shoreline of the lake has become wider due to erosion, the old depth-volume curves would underestimate the increase in storage and create a surplus in the water budget. However, this error should also be evident when the stage level decreases, as an underestimated decrease in volume. The net annual effect would be determined by the net change in stage from the beginning of the year to the end of the year. Since the stage increased 2.37 feet from April 15, 1992 to April 15, 1993, we would expect the annual change in storage to be underestimated, creating a surplus in the water budget.

Figure 4–16. Comparison of Lake Monroe Water Budget Surplus to Inflow, Outflow, and Storage



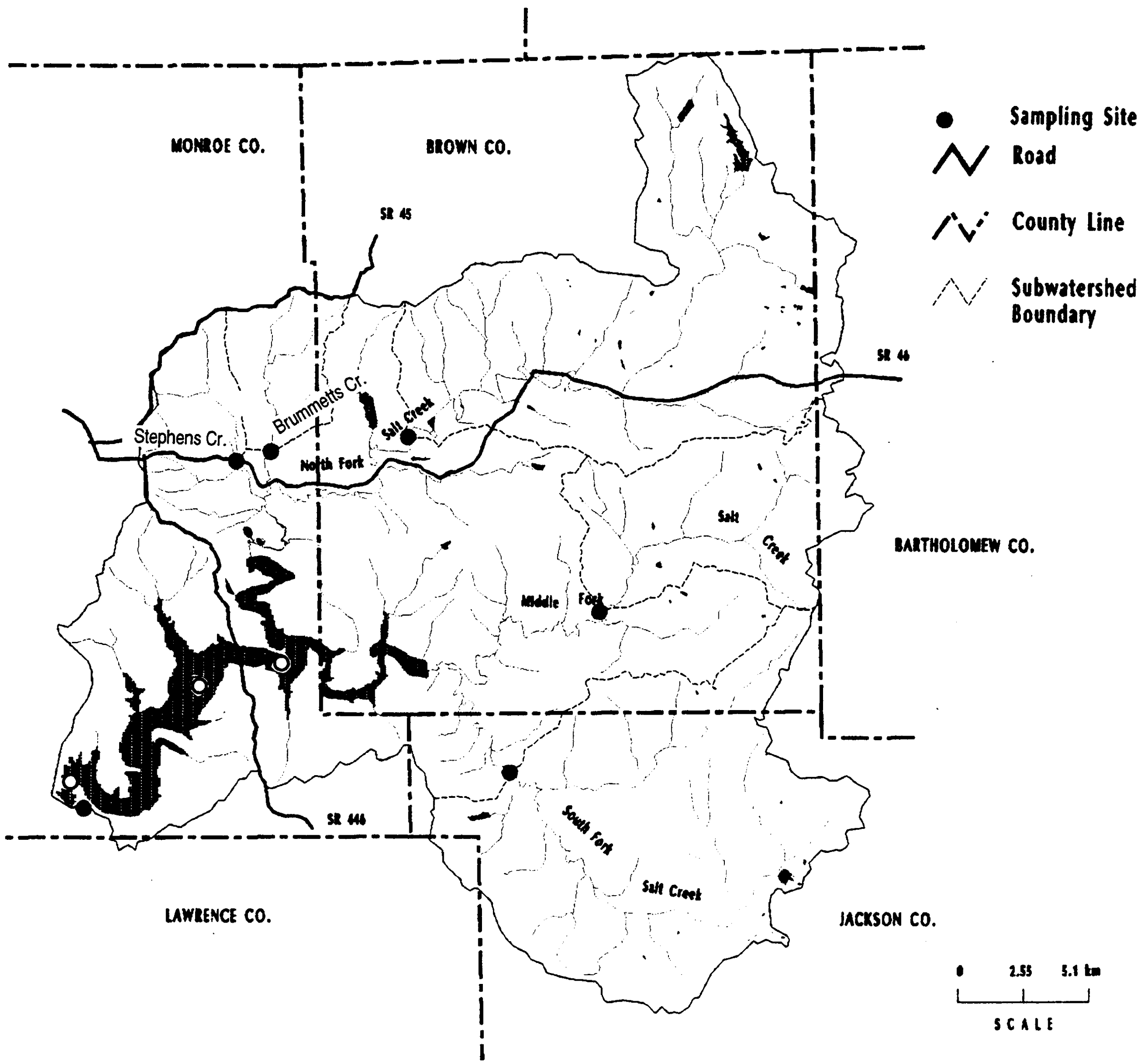
surplus is reduced, suggesting that errors in estimating inflow are balanced by errors in estimating outflow. The third possibility, that the change in storage is underestimated, is supported by the observation that most high surpluses occur when changes in storage are high and positive. A high and positive change in storage corresponds to a large increase in lake stage. If the upper shoreline of the lake has become wider due to erosion, the old depth-volume curves would underestimate the increase in storage and create a surplus in the water budget. However, this error should also be evident when the stage level decreases, as an underestimated decrease in volume. The net annual effect would be determined by the net change in stage from the beginning of the year to the end of the year. Since the stage increased 2.37 feet from April 15, 1992 to April 15, 1993, we would expect the annual change in storage to be underestimated, creating a surplus in the water budget.

5.0 WATER QUALITY

5.1 Methods

In accordance to U.S. EPA regulations (see Appendix A) we collected water quality samples from three lake sites and six stream sites (Figure 5–1). The five inlet stream sites were selected to represent the major surface discharges into Lake Monroe. The lake outlet at the dam was sampled to assist with mass balances of water, phosphorus and suspended solids into and out of the lake. Because of the time needed to complete the sampling, the lake and streams were sampled on successive days. At each lake site, we collected samples at one-half meter below the surface and one-half meter off the bottom and at 1.5 meter intervals in-between, up to a maximum of six sample depths. Using this guideline, we sampled three depths in the Upper Basin, four depths in the Middle

Figure 5–1. Location of Lake and Stream Sampling Sites Used in the Study



Basin, and six depths in the Lower Basin. At each depth, we collected water samples for or measured the following determinations:

—temperature
—dissolved oxygen
—pH
—alkalinity
—total phosphorus
—soluble reactive phosphorus
—nitrate-nitrite
—ammonia
—total organic nitrogen
—suspended solids

Temperature and dissolved oxygen were measured *in situ* with a YSI Model 54A Dissolved Oxygen Meter and pH was determined on site with a Corning Model 610A pH meter with an Orion glass electrode. The remaining samples were placed into the appropriate bottle with preservative (if needed) and stored in an ice chest until analysis in the laboratory. At each lake site, the following additional collections or measurements were made:

—Secchi disk transparency
—light transmission at three feet (Beckman Enviroeye)
—determination of the one percent light level (Beckman Enviroeye)
—chlorophyll a (in epilimnion only; filtered in the field and stored on ice)
—plankton genera biomass (tow from the 1% light level with a 55 micron net)

At each stream site, water was analyzed for the same ten parameters (above) which were analyzed at each lake depth. In addition, discharge was determined using either a pygmy or Price current meter (Teledyne-Gurley). We collected stream measurements during at least four runoff events, however, we were not able to sample all the largest runoff events during the project period due to time constraints. For example, it took a minimum of seven hours to collect samples and measure discharge from the five inflowing stream sites. Because of this, we could not sample late afternoon or early evening storm events.

All sampling techniques and laboratory analytical methods were performed in accordance to procedures in *Standard Methods for the Examination of Water and* Wastewater, 17th Edition (APHA, 1989). The ion electrode method was used for ammonia, nitrate+nitrite, and total Kjeldahl (TKN) nitrogen analyses for most of the study period. In March, 1993, we began using a newly acquired and more accurate piece of equipment, an Alpkem FLOW Solution Autoanalyzer Model 3570 to analyze these parameters and total phosphorus (Perstorp Analytical, 1992). This resulted in different digestion and analytical procedures for total phosphorus and TKN. This switch caused some analytical difficulties, particularly with TKN during subsequent sample sets.

Plankton counts were made using a standard Sedgewick-Rafter counting cell. Fifteen fields per cell were counted. Plankton identifications were made according to: Prescott (1982), Ward and Whipple (1959), and Whitford and Schumacher (1984). Biomass determinations were made by measuring ten plankton cells and using formulas in Wetzel and Likens (1991) to calculate cell biovolume. Biovolume measurements were checked and adjusted periodically to account for seasonal differences.

Weather conditions at the start of each of the lake water quality sampling trips (unless otherwise noted) is presented in Table 5–1. These data are presented because ambient weather conditions can affect some sampled parameters, for example: wind mixing, temperature profile, Secchi disk transparency, etc.

Table 5–1. Weather Conditions at Time of Sampling

Date	*Temperature (°F)*	*Sky*
4/18/92	80	ptly cloudy, 10 mph wind
5/13/92	72	clear, 5–10 mph wind
5/27/92	50s	cloudy, turning sunny
6/10/92	80	sunny, 0–5 mph wind
6/24/92	70	ptly cloudy, 5–10 mph wind
7/08/92	80	hazy, 10–15 mph wind
7/22/92	75	hazy, 0–5 mph wind
8/5/92	70	cloudy, 0–5 mph wind
8/19/92	70	cloudy, 5–10 mph wind
9/06/92	70	mostly sunny
10/11/92	–	sunny
11/15/92	–	ptly sunny
12/5/92	25	cloudy, 10 mph wind (stream sample only)
1/17/93	31	overcast, 5–10 mph wind
2/21/93	35	cloudy (stream sample only)
3/28/93	55	ptly cloudy to sunny, calm
4/01/93	45	rain (stream storm event)
4/9/93	–	rain (stream storm event)
4/18/93	65	sunny (lake sampling only)
5/18/93	55	rainy

5.2 Sampling Schedule

We sampled the Lake Monroe sampling sites on 16 different occasions between 17 April 1992 and 18 May 1993. No samples were collected during December due to conflicts with University final examinations and the Christmas holiday. An outboard motor failure in January kept us from sampling the Middle Basin. Thin ice cover on the lake in February prevented the use of our boat or sampling through the ice. We collected additional samples through May 1993 to compensate for the previous sampling shortfalls.

Stream sites were sampled on eighteen dates between 17 April 1992 and 14 April 1993. Extra sampling trips were made in April 1993 to catch runoff events.

5.3 Results

All of the raw water quality data are presented completely in tables in Appendix B. Refer to these tables for specific values.

5.3.1 Temperature

Figures 5–2 to 5–4 show temperature isopleths for the three lake basins. The isopleth lines show areas of equal temperature. Straight vertical lines means that conditions are uniform from the lake surface to the lake bottom. For the most part, the Upper and Middle Basins did not thermally stratify during the sampling period. These basins are relatively shallow and stay well-mixed due to turbulence caused by winds, currents, and possibly motor boats. The Lower Basin shows weak thermal stratification from mid-June to late August. During thermal stratification, the bottom waters (*hypolimnion*) of the lake are isolated from the surface waters (*epilimnion*)

Figure 5–2. Temperature Isopleth for the Upper Basin, Lake Monroe

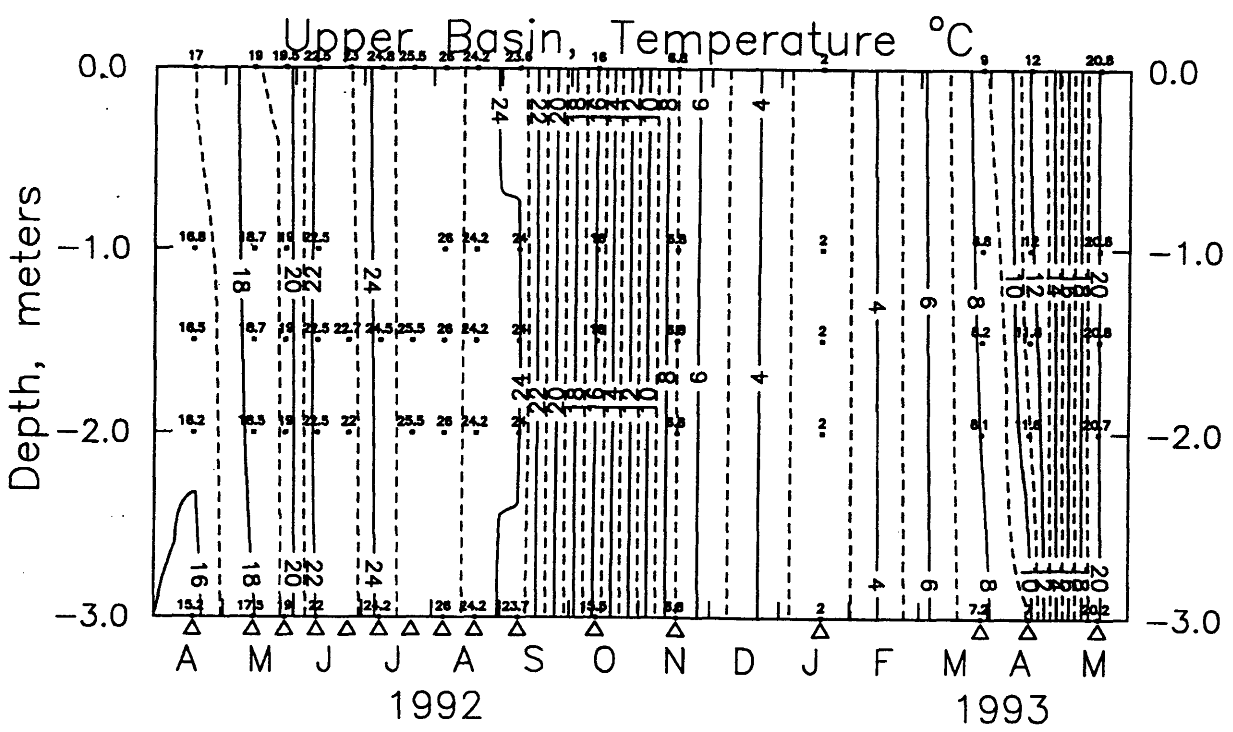


Figure 5–3. Temperature Isopleth for the Middle Basin, Lake Monroe

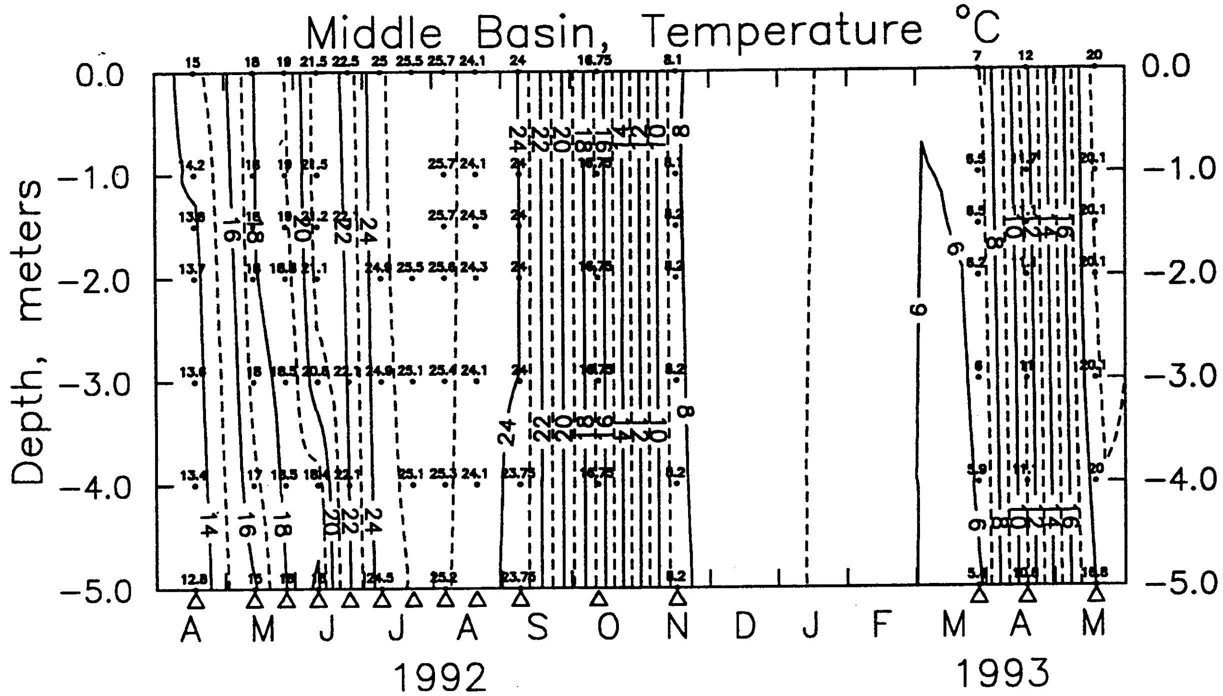
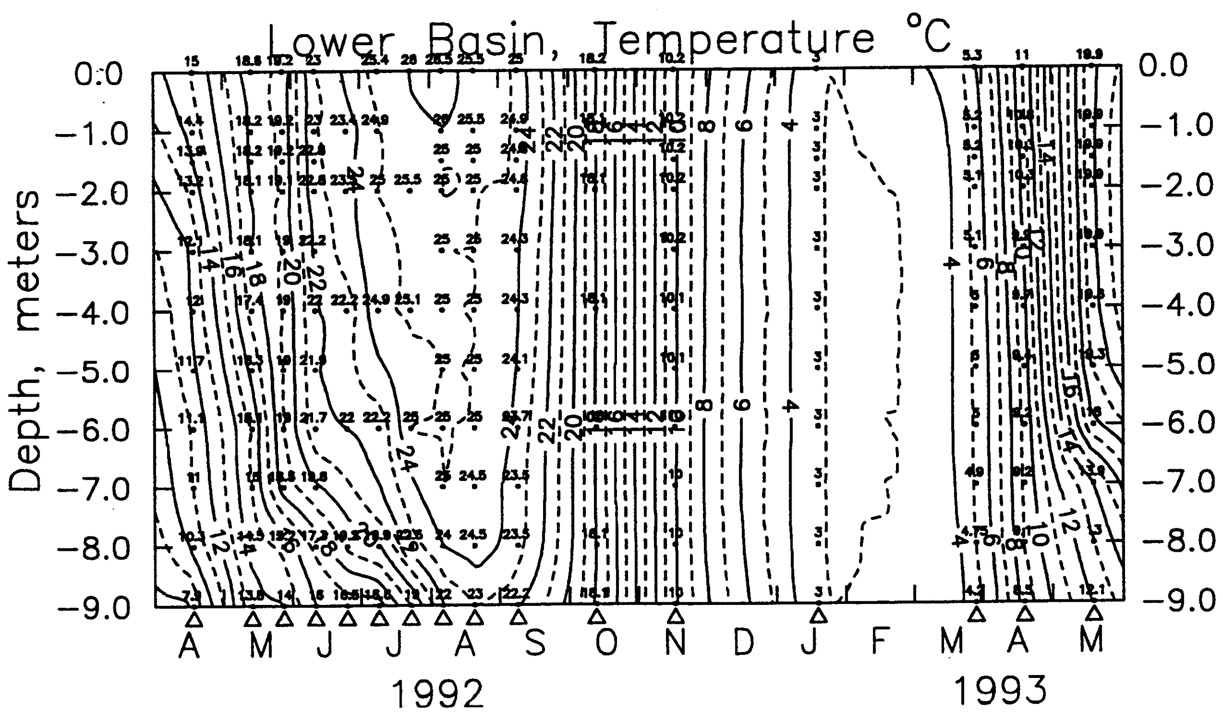


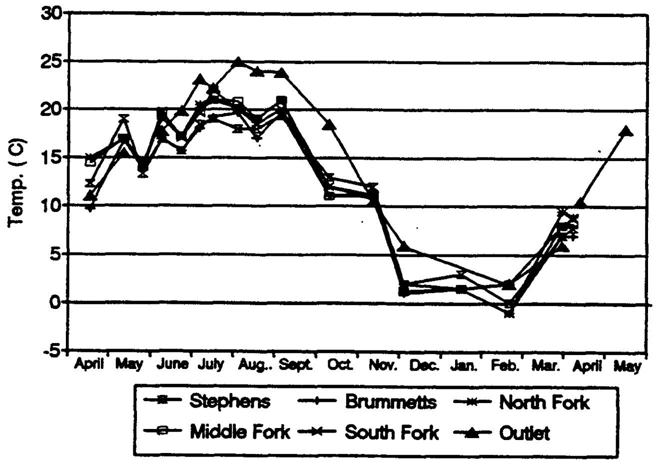
Figure 5–4. Temperature Isopleth for the Lower Basin, Lake Monroe



by temperature-induced density differences. The boundary between these two zones, where temperature changes most rapidly with depth is called the *metalimnion.*

Stream temperatures follow an expected annual cycle—cooler in the winter and warmer in the summer (Figure 5–5). Temperatures of the outlet water are warmer than the inlet stream temperatures during much of the year due to the warmer lake temperatures.

Figure 5–5. Stream Temperatures at Sampling Sites, 1992–93



5.3.2 Dissolved Oxygen

Isopleths for dissolved oxygen (DO) concentrations in Lake Monroe are given in Figures 5–6 to 5–8. The Upper Basin remained oxygenated throughout the sampling period. Oxygen remained well-mixed vertically in the Middle Basin for most of the sampling period. For a brief period in July there is indication of a negative heterograde DO profile, as indicated by the lower DO concentrations at the three-meter depth. Oxygen consumption by heterotrophic bacteria is often the cause of such mid-water DO sags.

The Lower Basin shows a small area of anoxia below eight meters from mid-June through September. Bacterial decomposition of organic matter (dead plant and animal material) at the sediment surface is the likely cause of this. Hypolimnetic anoxia results in poor habitat for aquatic organisms and may cause chemical changes which allow phosphorus to be released from the sediments into the water column. This can be an important source of internal phosphorus loading in more productive lakes.

Dissolved oxygen varies seasonally in Lake Monroe (Figure 5–9) but this wide oscillation is largely due to temperature differences. Cold water has the capacity to hold more oxygen than warm water. Thus, dissolved oxygen solubility is controlled by temperature and dissolved oxygen variation is the inverse of temperature variation.

Stream dissolved oxygen concentrations vary annually as well in response to changing temperatures (Figure 5–10). Dissolved oxygen at the lake's outlet was often higher than the stream concentrations due to the turbulence at the spillway which saturates the water with oxygen.

5.3.3 Alkalinity

Alkalinity is a measure of the water's ability to resist change in pH, or acid content. It is also referred to as acid neutralizing capacity or buffering capacity. This buffering action is important because it ensures a relatively constant chemical and biological environment in lakes. Alkalinity is determined largely by the availability and chemistry of carbonate in water. Sources of carbonate to natural waters include limestone (calcium carbonate) and carbon dioxide.

Figure 5–6. Dissolved Oxygen Isopleth for the Upper Basin, Lake Monroe

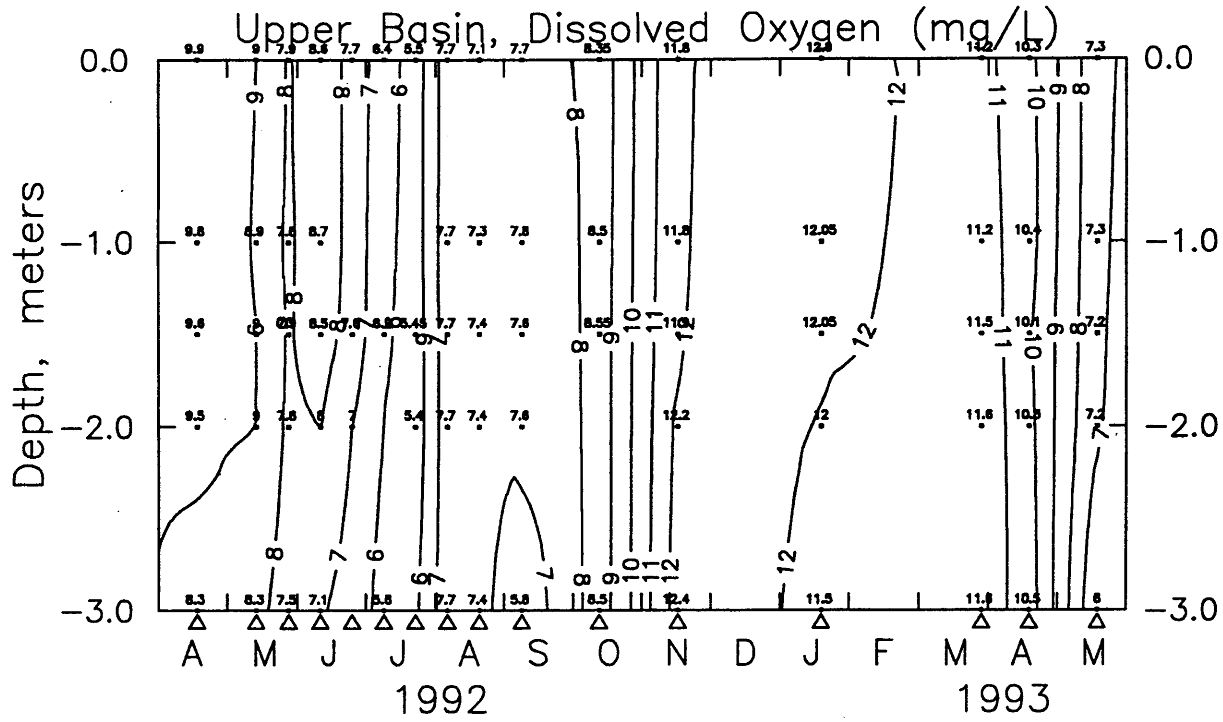
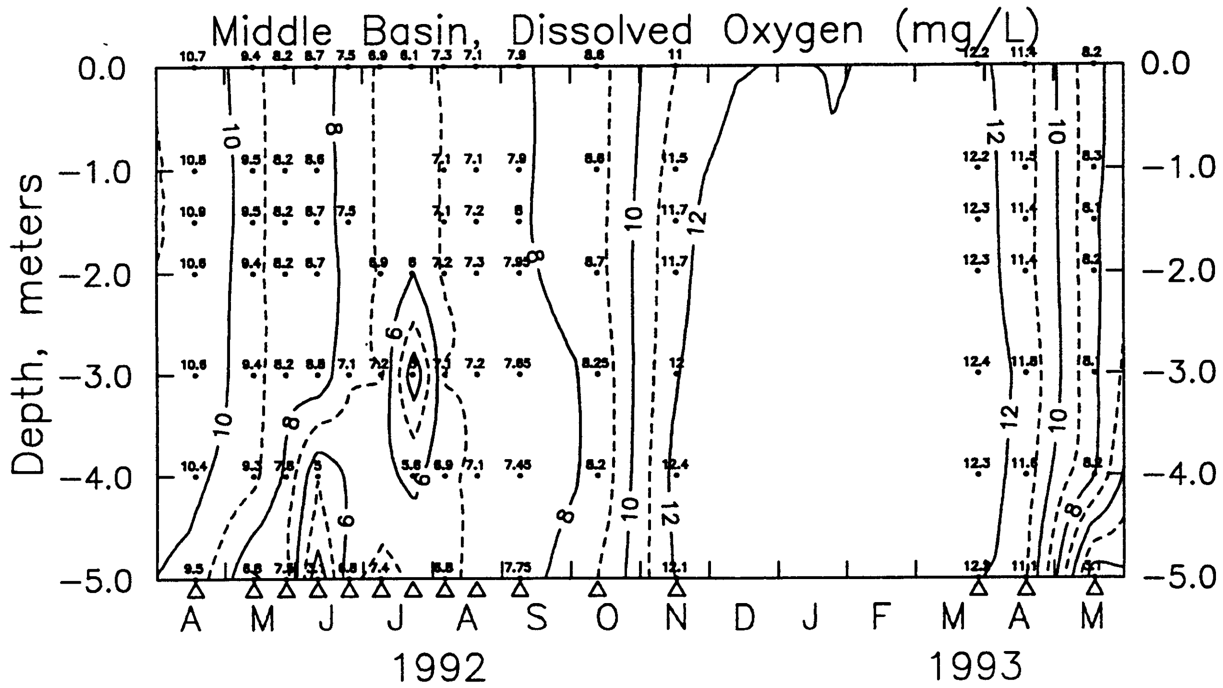
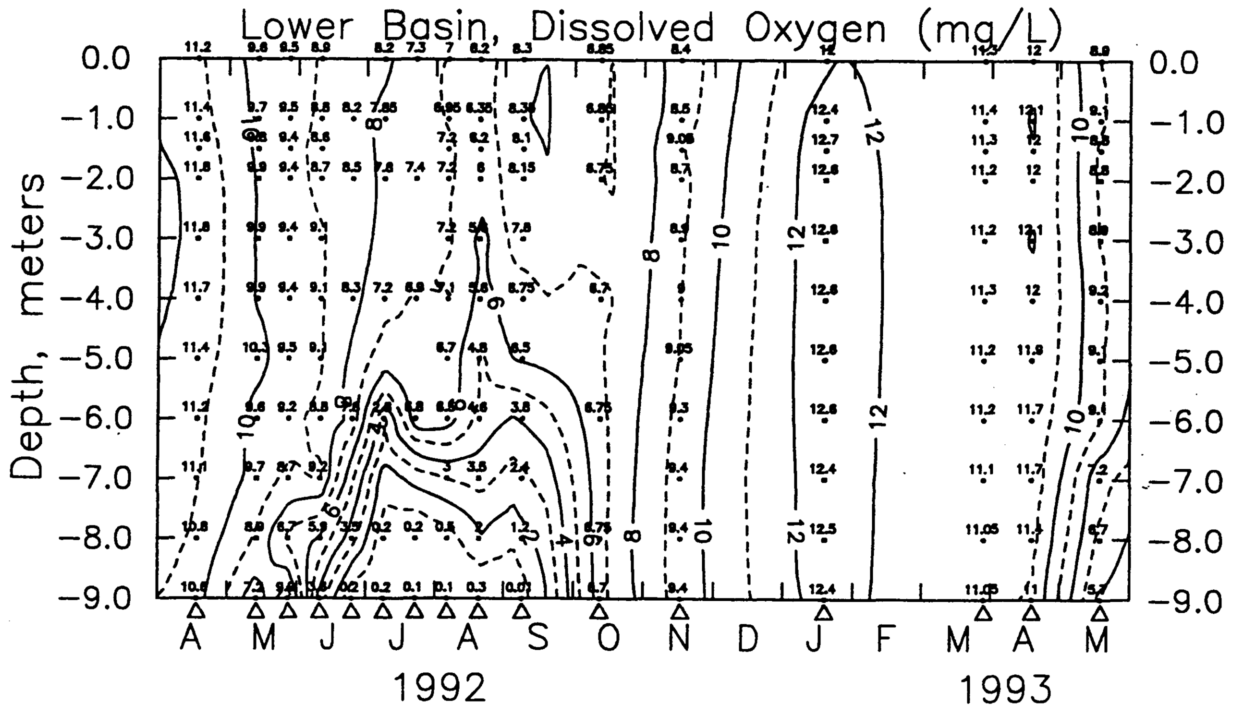


Figure 5–7. Dissolved Oxygen Isopleth for the Middle Basin, Lake Monroe



Alkalinity values for Lake Monroe show little spatial variation among basins and range from 25–30 mg/L in the spring to 45 mg/L in the fall (Figure 5–11). The U.S. EPA (1976b) recommends an alkalinity criterion of 20 mg/L or more for freshwater aquatic life. The low-to-moderate alkalinity values for Lake Monroe are consistent

Figure 5–8. Dissolved Oxygen Isopleth for the Lower Basin, Lake Monreo



with the chemical nature of the Bordon rocks and the general lack of limestone in most of the watershed (Frey, 1976).

Stream alkalinities are shown in Figure 5–12. Stephens and Brummetts creeks typically have higher alkalinities because the upper portions of these drainages lie partially within the Sanders Group of mostly coarse-grained limestone (Hartke and Gray, 1989). Alkalinity is often inversely proportional to discharge. At high discharges, the water has little contact time with carbonate-bearing rocks and does not gain much alkalinity. Data comparing the mean stream alkalinities with the mean stream discharges show this relationship (Figure 5–13).

5.3.4 pH

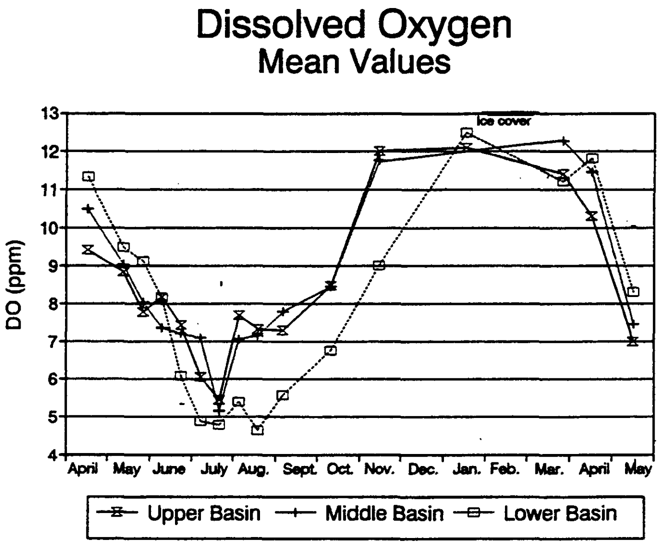
Values of pH show little variation with depth in Lake Monroe. Epilimnetic pH values are shown in Figure 5–14. Values range around neutrality from 6.5 to nearly 8. Seasonal values of pH are highest in the summer when phytoplankton are most actively photosynthesizing. Photosynthesis consumes carbon dioxide (a weak acid) which, in turn, raises pH. There is no apparent pattern of pH among the three lake basins.

Stream pH values vary around neutrality and tend to be slightly lower than lake pH values (Figure 5–15). There is generally less photosynthesis in streams than in lakes. The highest stream pH values often occur in the outlet water.

5.3.5 Soluble Reactive Phosphorus

Soluble reactive phosphorus (SRP) is an important plant nutrient and is the form of phosphorus most readily usable by algae for growth. In many lakes, SRP concentrations are highest in the spring following turnover and before algae begin growing; and are lowest in the summer when algal growth is maximized. Overall, SRP concentrations in Lake Monroe are relatively low except for several discrete events (Figure 5–16). The highest

Figure 5–9. Relationship Between Temperature and Dissolved Oxygen in Lake Monroe



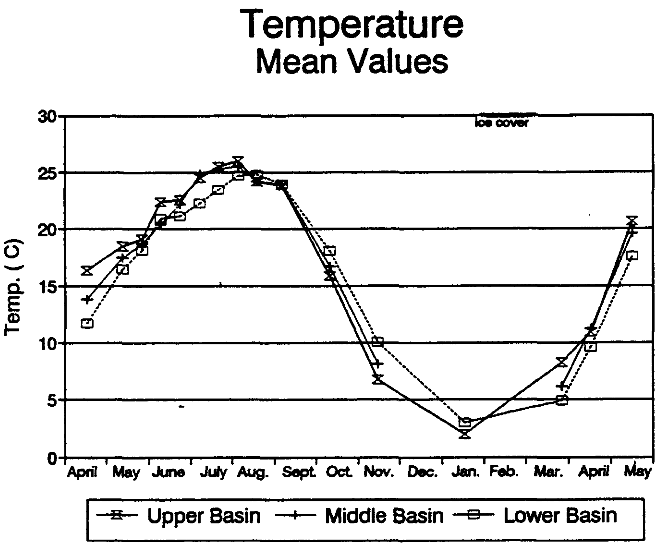


Figure 5–10. Dissolved Oxygen Concentrations in the Monroe Watershed Streams

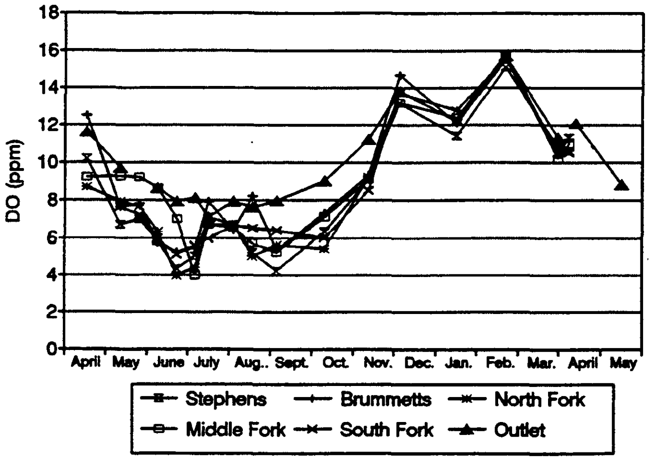
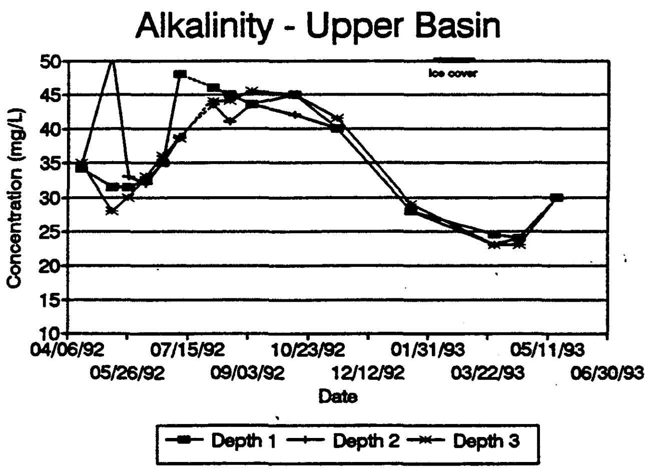
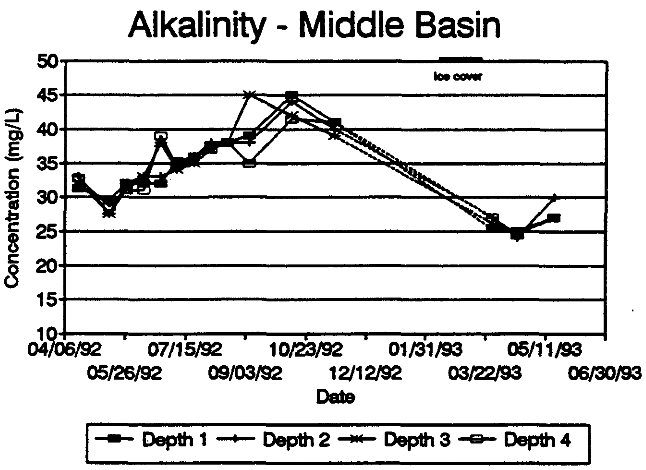


Figure 5–11. Alkalinities—Lake Monroe Sites





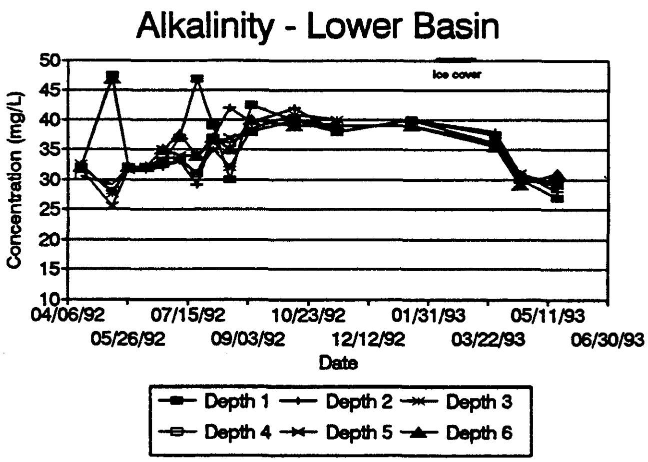


Figure 5–12. Alkalinities—Monroe Watershed Streams

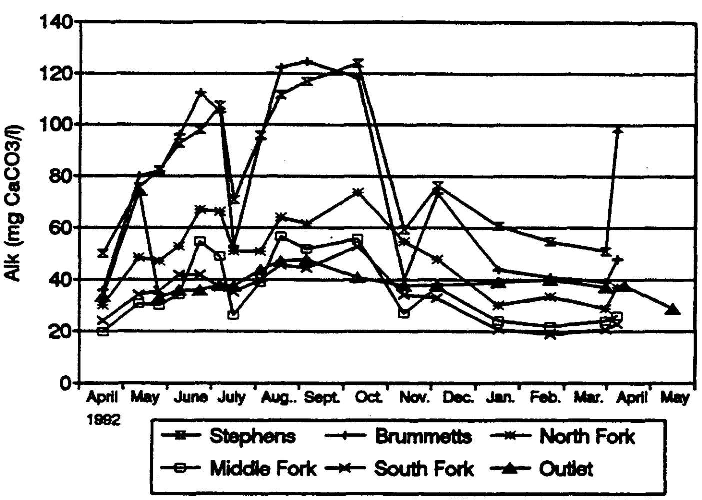


Figure 5–14. pH—Lake Monroe Sites (Epilimnion)

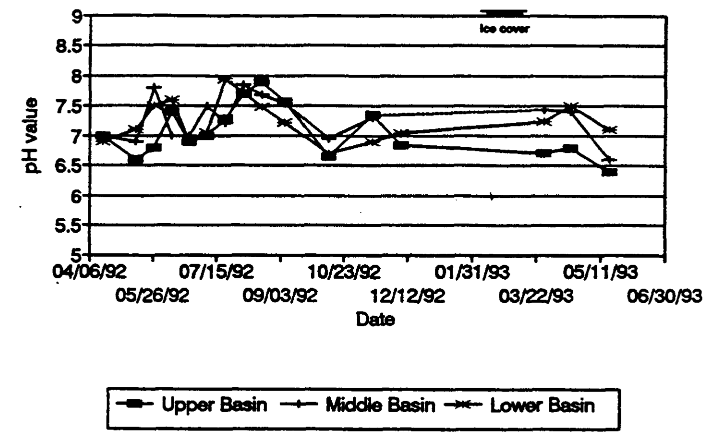


Figure 5–13. Relationship Between Alkalinity and Discharge in the Monroe Watershed Streams

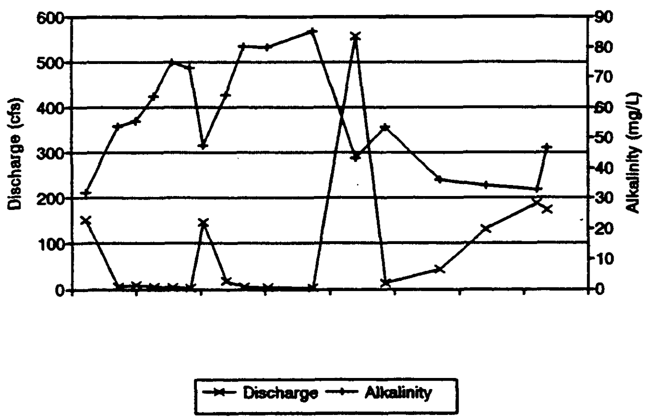
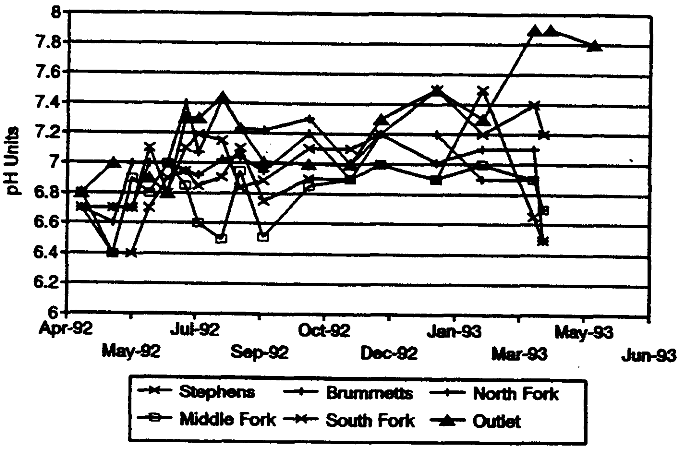


Figure 5–15. pH—Monroe Watershed Streams



concentration in the Upper Basin occurred in October, following the die-back of Eurasian water milfoil (*Myriophyllum spicatum*) and the release of SRP from the senescing plant tissue. Landers and Frey (1980) demonstrated this phenomenon with in-lake experiments. This peak also shows up in the Middle and Lower basins at the same time suggesting either that die-back of macrophytes in those basins also adds SRP to the water or that flow through the lake transports SRP relatively quickly from the Upper Basin.

The large July SRP peak in the Lower Basin is likely due to an analytical error, especially since total phosphorus concentrations from the same location are lower than the SRP concentrations. There is little evidence of SRP release from the sediments during the brief period of anoxia in the lower basin. Sediment phosphorus release would cause higher SRP concentrations in the Depth 6 (deepest) samples but we do not see this in the data. The annual SRP variation and the magnitude of the July Lower Basin anomaly are better illustrated in Figure 5–17 which shows mean values for each basin over time.

Stream SRP concentrations are shown in Figure 5–18. The highest concentrations occur during periods of

Figure 5–16. Soluble Reactive Phosphorus—
Lake Monroe Sites

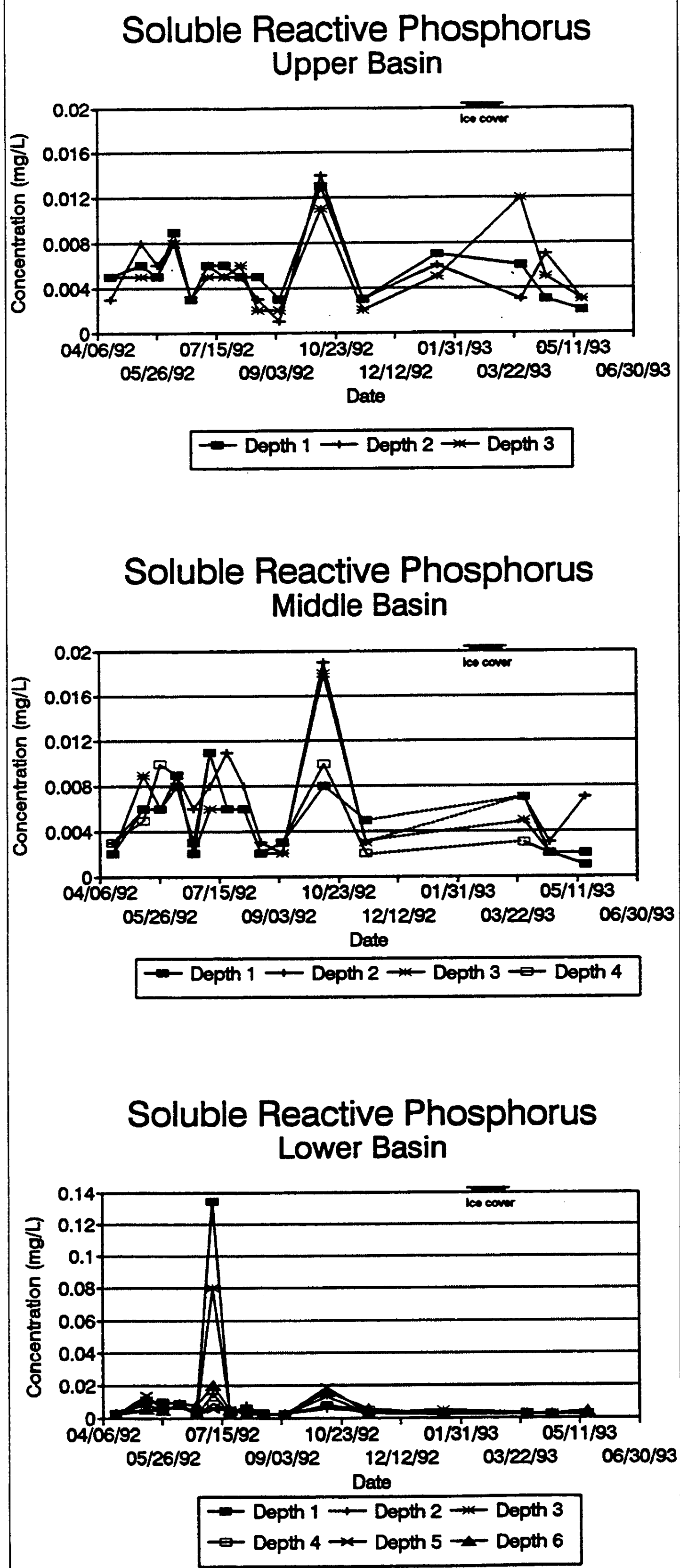


Figure 5–17. Soluble Reactive Phosphorus—
Lake Basin Means

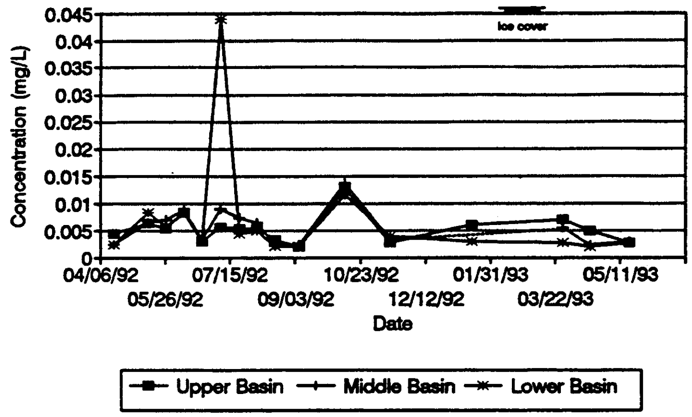
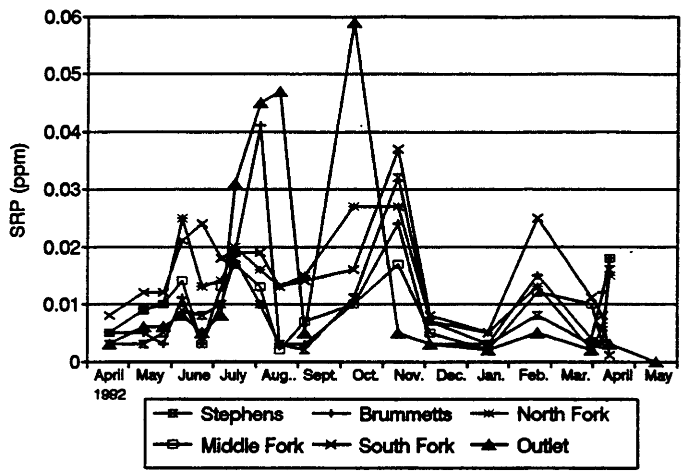


Figure 5–18. Soluble Reactive Phosphorus—Monroe
Waterhed Streams



high runoff following storms. Runoff from land surfaces may contain substantial amounts of SRP and this runoff increases during storm events. SRP concentrations during runoff events (for example, in August, November and April) were usually highest in the lake outlet samples. Higher flow through the lake may agitate sediments near the dam's outlet, causing higher SRP concentrations.

5.3.6 Total Phosphorus

Total phosphorus (TP) includes both soluble and particulate forms of phosphorus. Thus, for any given sample, TP concentrations must be greater than or equal to SRP concentrations. TP is the best indicator of a lake's overall phosphorus budget. In general, TP concentrations in Lake Monroe are low in early summer, rise during the summer and then fall throughout the winter months (Figure 5–19). The summer increase is likely due to the particulate form of phosphorus. Particulate phosphorus includes phosphorus incorporated in algae or adsorbed to suspended sediments. Algae populations generally increase in the summer. Increased summer motor boat traffic on the lake stirs up bottom sediments and boat-generated waves can promote shoreline erosion. These events may all contribute to increased total phosphorus concentrations.

Total phosphorus concentrations in most unpolluted lakes range between 0.01 and 0.05 mg/L (Wetzel, 1983). Natural variation is high due to geochemical features of each watershed. The widely quoted work of Vollenweider (1968) suggests that epilimnetic total phosphorus concentrations exceeding 0.03 mg/L are generally sufficient to cause eutrophic conditions in lakes. Mean TP concentrations in Lake Monroe range from 0.02 to 0.07, with the highest concentrations in the Upper Basin where suspended sediments are highest (Figure 5–20). Of 279 lakes sampled by Indiana Clean Lakes Program from 1989 through 1991 (IDEM, 1990; IDEM, 1992), the median TP concentration was 0.091 mg/L, with a minimum of 0.005 mg/L and a maximum of 2.093 mg/L. While Lake Monroe values fall below the state median, the phosphorus concentrations are high enough to be of concern to the local community.

Total phosphorus concentrations in the streams is given in Figure 5–21. The highest values are related to runoff events since a major fraction of total phosphorus measured is particulate phosphorus which is transported in runoff. These total phosphorus values are used in Section 7 to estimate phosphorus loading to Lake Monroe.

5.3.7 Nitrate-Nitrogen

Nitrate-nitrogen is a soluble form of nitrogen which is often the most abundant form of inorganic nitrogen in natural waters. It is an important plant nutrient. Natural nitrate concentrations are frequently below 1.0 mg/L (Lind, 1985). Nitrate concentrations in Indiana lakes sampled under the Indiana Clean Lakes Program from 1989–91 ranged from 0.047 to 16.679 mg/L, with a median value of 0.36 mg/L (IDEM, 1990; IDEM, 1992).

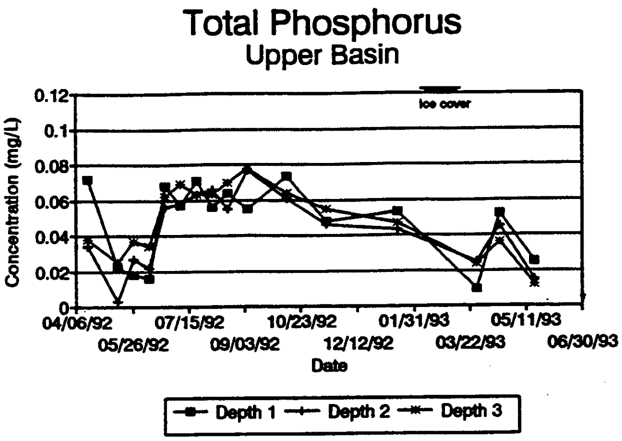
Nitrate concentrations for Lake Monroe were relatively uniform and similar among the three basins for most of 1992 (Figure 5–22). The lowest seasonal concentrations occurred in the summer, possibly due to algal utilization. Overall, concentrations increased toward the end of the year to levels above the state median value.

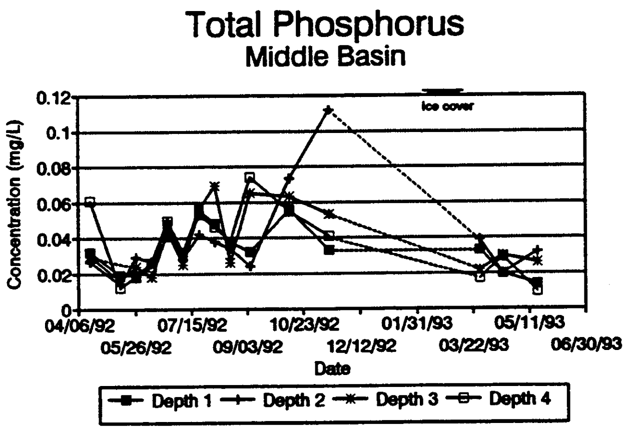
Nitrate concentrations in the streams varied seasonally (Figure 5–23). Stephens Creek generally had higher concentrations than the other streams. The lower concentrations in the lake outlet demonstrates the relationship between the streams as a nitrate source and the lake's algae as a nitrate processor.

5.3.8 Ammonia-Nitrogen

Ammonia-nitrogen is highly soluble, biologically active compound present in most waters as a normal degradation product of nitrogenous organic matter. It is formed as bacteria decompose leaves, twigs, and other

Figure 5–19. Total Phosphorus—Lake Monroe Sites





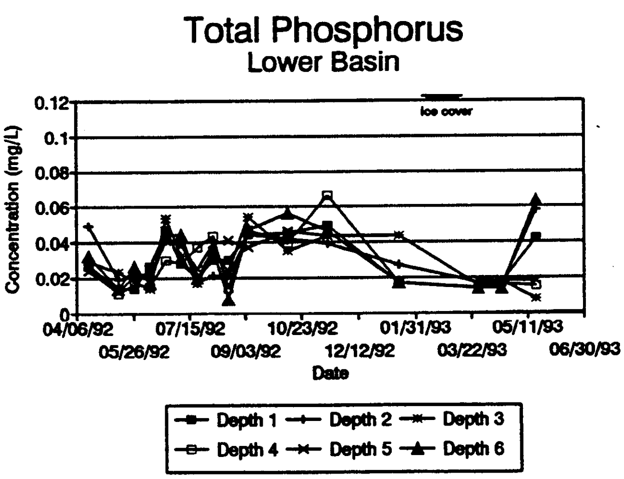


Figure 5–20. Total Phosphorus—Lake Basin Means

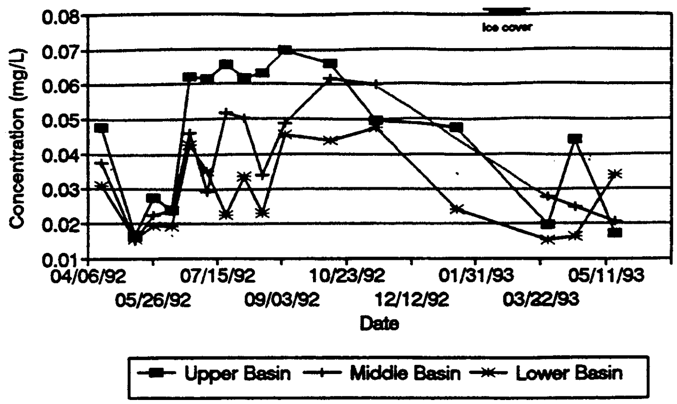


Figure 5–21. Total Phosphorus—
Monroe Watershed Streams

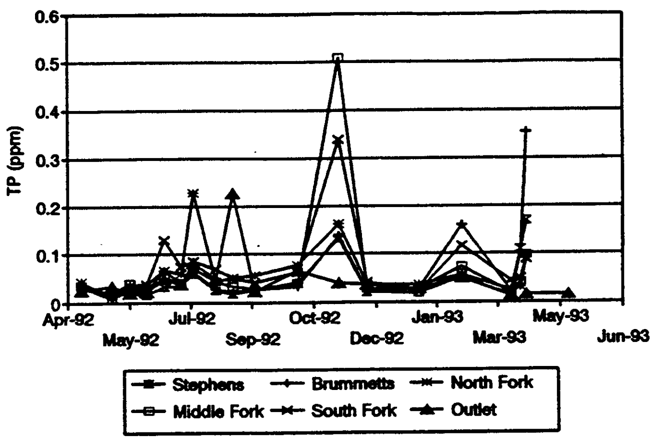


Figure 5–22. Nitrate—Lake Monroe Sites

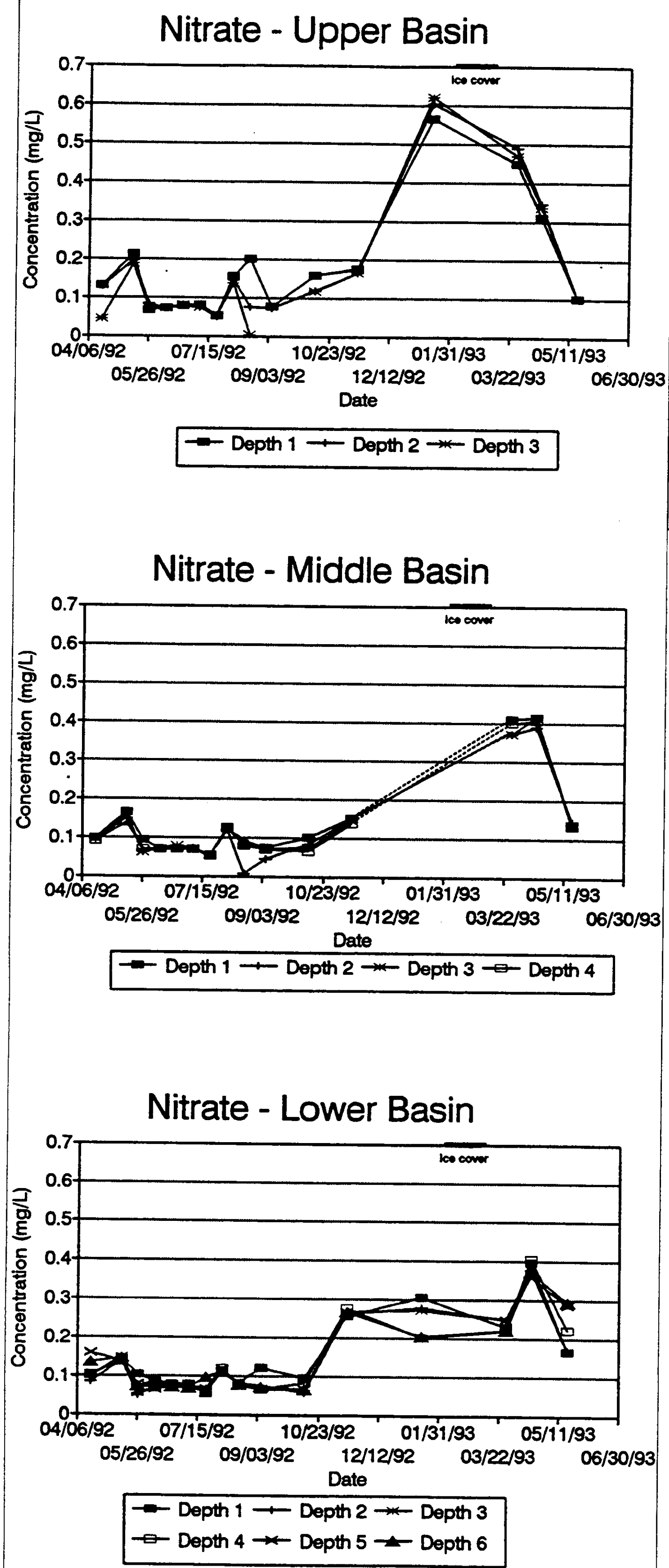
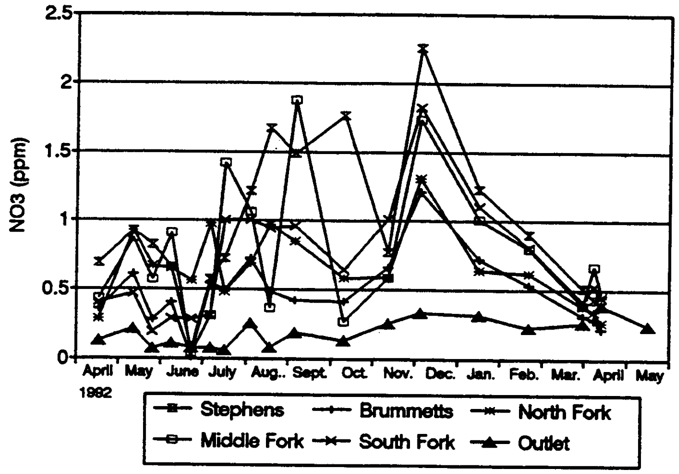


Figure 5–23. Nitrate—Monroe Watershed Streams



organic matter in the lake and its sediments. It is easily assimilated and used by algae. Ammonia is usually present in low (less than 1 mg/L) quantities in nonpolluted, well-oxygenated water, but may reach 5 to 10 mg/L in the anaerobic hypolimnion of a eutrophic lake (Lind, 1985). Ammonia concentrations in lakes sampled under the Indiana Clean Lakes Program from 1989–1991 ranged from 0.01 to 13.67 mg/L, with a median value of 0.68 mg/L (IDEM, 1990; 1992).

Ammonia concentrations for Lake Monroe are well below the median value for other Indiana lakes (Figure 5–24). Highest concentrations occurred in the deepest water of the Lower Basin in late summer, when oxygen concentrations are depressed. Ammonia patterns are otherwise similar among the lake basins.

The well-oxygenated streams had low concentrations of ammonia (Figure 5–25). Highest concentrations were in the lake outlet. This represents ammonia formed and exported from the lake.

5.3.9 Organic Nitrogen

Organic nitrogen compounds represent a major reservoir of nitrogen in aquatic systems. Organic nitrogen occurs largely in particulate and organic detritus and is not readily available to photosynthetic organisms. Typical organic nitrogen concentrations range from 0.200–2.0 mg/L in natural waters to more than 20 mg/L in raw sewage (APHA, 1989). Organic nitrogen concentrations in lakes sampled under the Indiana Clean Lakes Program from 1989–91 ranged from 0.05 to 9.7 mg/L with a median value of 1.3 mg/L (IDEM, 1990; IDEM, 1992).

Organic nitrogen concentrations for Lake Monroe are shown in Figures 5–26 and 5–27. Values generally remain below 1 mg/L except during several occasions. The very high values in May 1993 are related to an algal bloom at that time. Overall, seasonal trends in organic nitrogen among the basins are similar.

Stream concentrations are quite variable (Figure 5–28). Because there is little photosynthesis in these small streams, the source of the organic nitrogen is organic matter washed into the streams from the adjacent land.

5.3.10 Total Suspended Solids

Total suspended solids (TSS) is a measure of organic (e.g., plants) and inorganic (e.g., soil) material which is suspended in the water. In streams, it is a measure of extent of erosion. Suspended material decreases water clarity and settles to the lake bottom, where it contributes to sediment accumulation. Concentrations of 80 mg/L have been shown to reduce benthic (bottom dwelling) populations of aquatic organisms (U.S. EPA, 1976b).

Total suspended solids data for Lake Monroe and its streams are presented in Figures 5–29 and 5–30. TSS is highest in the Upper Basin where the energy of the flowing incoming water is sufficient to keep the solids suspended in the water. Values decrease in the Middle and Lower basins as the solids settle to the lake bottom. TSS concentrations in the streams increase with increasing discharge. The four peaks all correspond with runoff events.

5.3.11 Transparency

Transparency refers to water clarity. We determined transparency using two instruments: the venerable Secchi disk and a photometer. Secchi disk transparency is the most widely collected lake water quality parameter in the United States. The technique has been used, virtually unchanged, since the late 1800s. The depth at which the eight-inch diameter, black-and-white disk disappears from view is affected by suspended organic and inorganic matter and, to a lesser extent, water color. Secchi disk transparencies for 279 Indiana lakes sampled under the Indiana Clean Lakes Program during 1989–91 ranged from 26.3 feet to 0.8 feet, with a median value of 5.25 feet (IDEM 1990; 1992).

Figure 5–24. Ammonia—Lake Monroe Sites

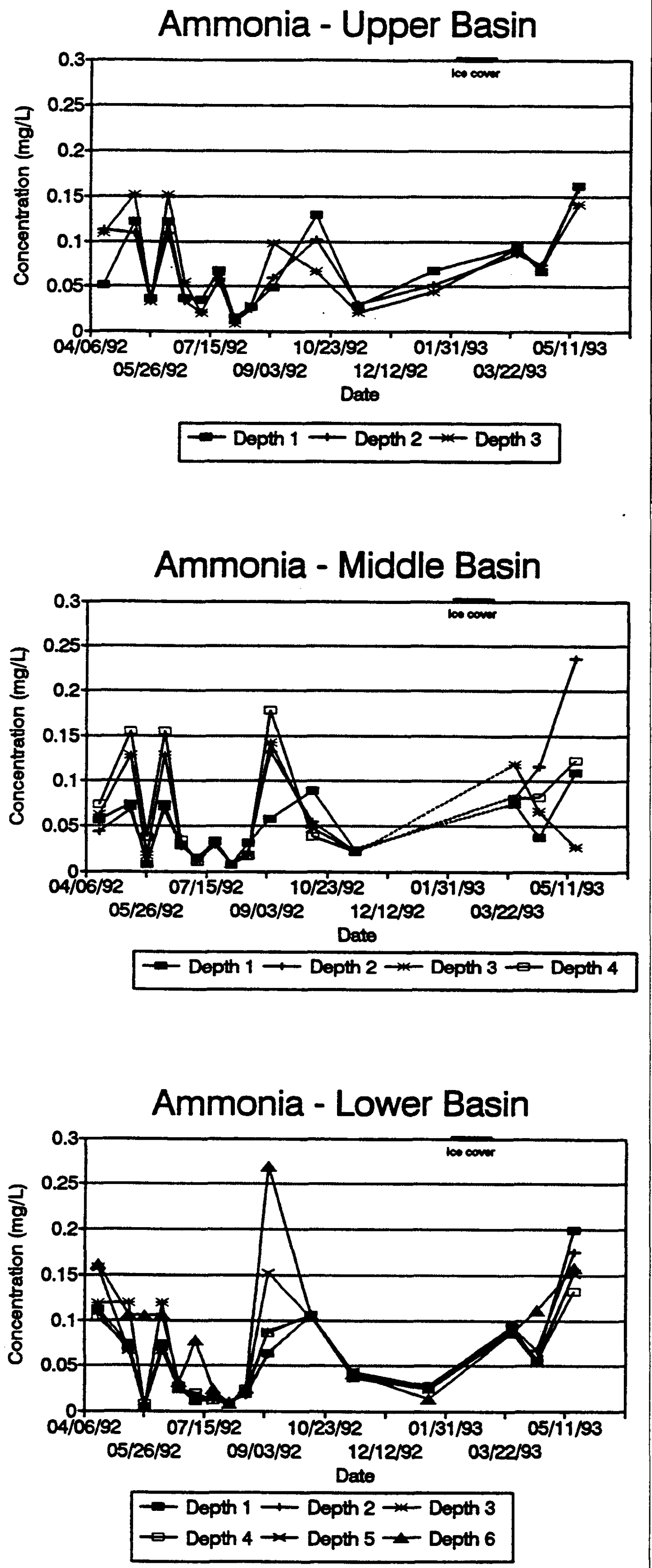


Figure 5–25. Ammonia—Monroe Watershed Streams

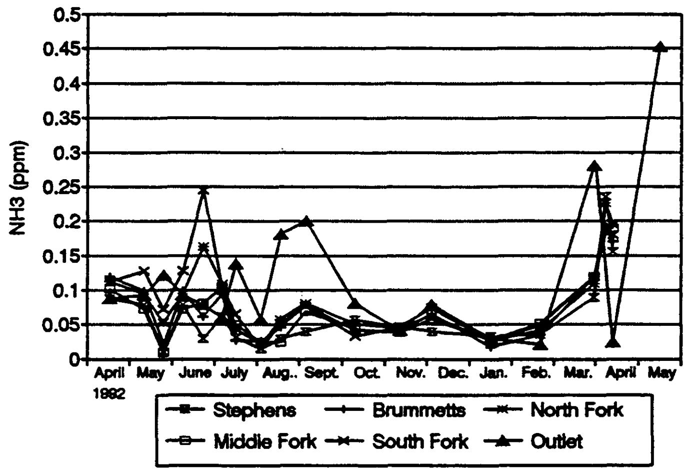
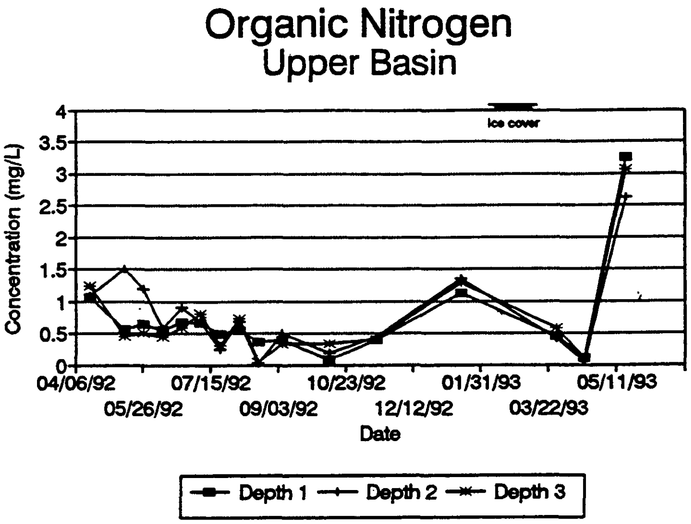
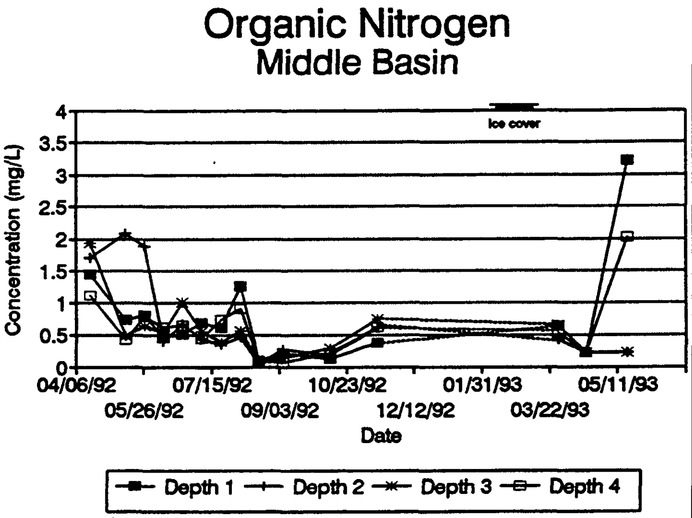


Figure 5–26. Organic Nitrogen—Lake Monroe Sites





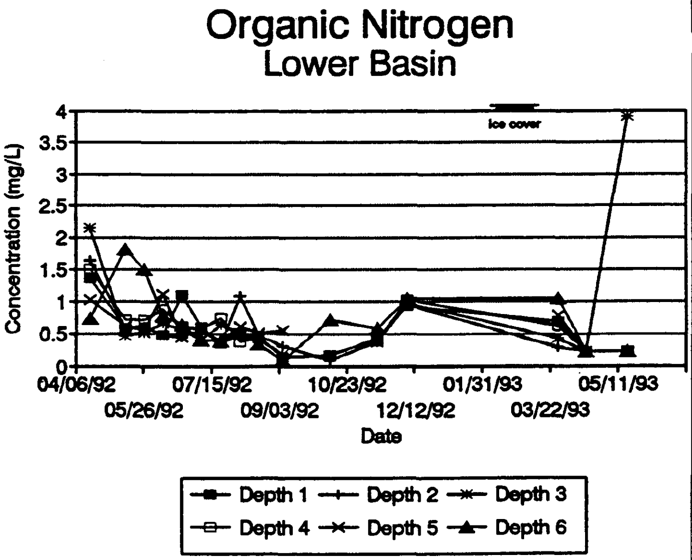


Figure 5–27. Organic Nitrogen—Lake Basin Means

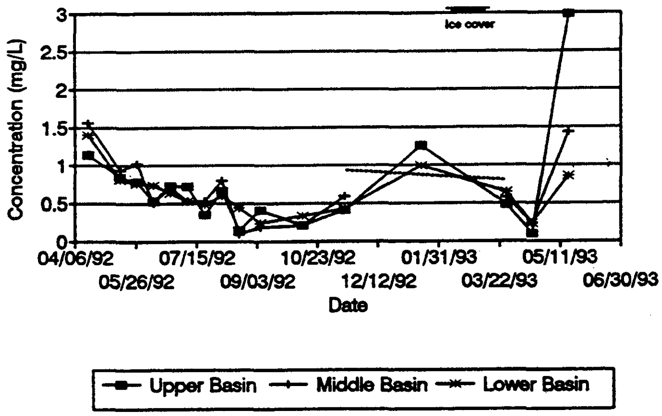
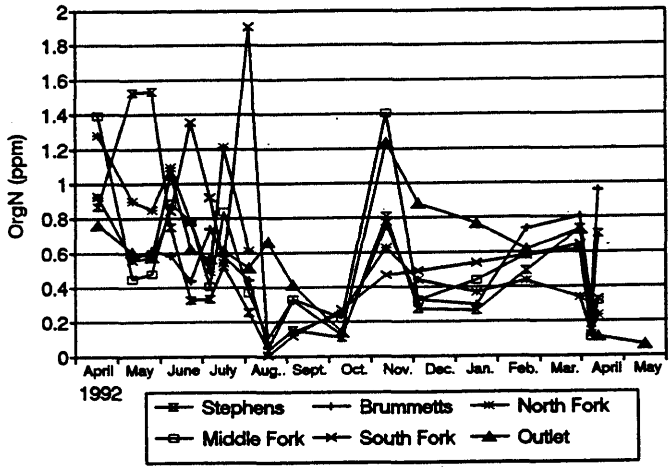


Figure 5–28. Organic Nitrogen—
Monroe Watershed Streams



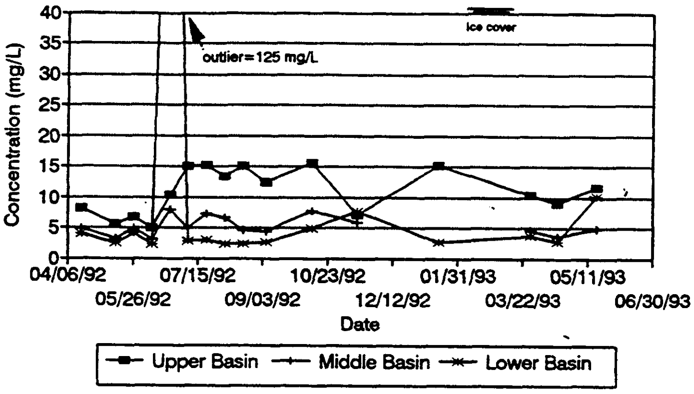


Figure 5–29. Suspended Solids—
Lake Monroe Basin Means

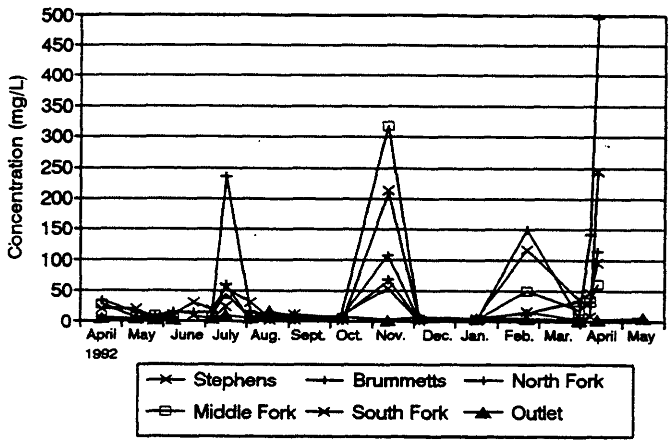


Figure 5–30. Suspended Solids—
Monroe Watershed Streams

Secchi disk transparencies for Lake Monroe were lowest in the Upper Basin and increased toward the Lower Basin (Figure 5–31). Incoming, silt-laden water reduces transparency in the Upper Basin and the suspended matter settles out as the water flows through the lake, yielding higher transparencies in the Middle and Lower basins. Upper and Middle basin transparencies were considerably lower than the median for other Indiana lakes. The Upper Basin transparencies were consistently 0.5 meters (1.6 feet) during most of the year. Overall, transparencies in Lake Monroe were highest in the spring and lowest in the summer and fall. The spring 1992 transparencies were worse than those for the same period in 1991.

The one percent light level is that water depth where one percent of the surface light remains. This depth is considered the lower limit for photosynthesis by algae and rooted plants. The area of a lake from the surface to the one percent light level is called the *euphotic zone*. Data for Lake Monroe (Figure 5–32) show that photosynthesis is possible in a relatively small portion of the total depth of the lake. The 1% light level is deepest in the Lower Basin and most shallow in the Upper Basin.

5.3.12 Chlorophyll *a*

The plant pigments of algae consist of the chlorophylls and carotenoids. Of these, chlorophyll *a* is by far the most dominant chlorophyllous pigment and occurs in great abundance. Thus, chlorophyll *a* is often used to estimate algal biomass (Wetzel and Likens, 1991).

Chlorophyll values are generally highest in Lake Monroe's Upper Basin and decrease in the Middle and Lower Basins (Figure 5–33). Chlorophyll peaks correspond with algal blooms in the lake but chlorophyll can also be released by rooted plants as well. The peak in October is likely caused by phosphorus, and possibly chlorophyll, release from decaying Eurasian water milfoil in the Upper Basin, a seasonal phenomenon which has been shown to stimulate fall algal growth in Lake Monroe (Landers and Frey, 1980). Chlorophyll *a* concentrations in the Middle and Lower basins range between 1–9 mg/L, a range that Carlson (1977) considers typical for mesotrophic (intermediate productivity) lakes. Concentrations in the Upper Basin range from 2–23 mg/L. Chlorophyll *a* levels between 8–25 are typical of eutrophic (high productivity) lakes.

Figure 5–31. Secchi Disk Transparency—
Monroe Lake Sites

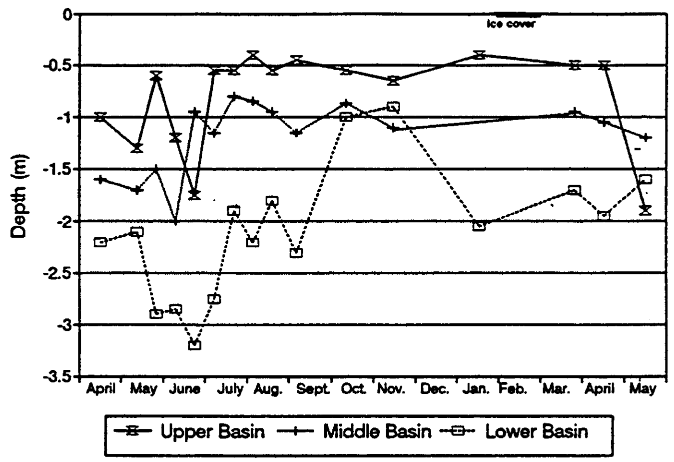
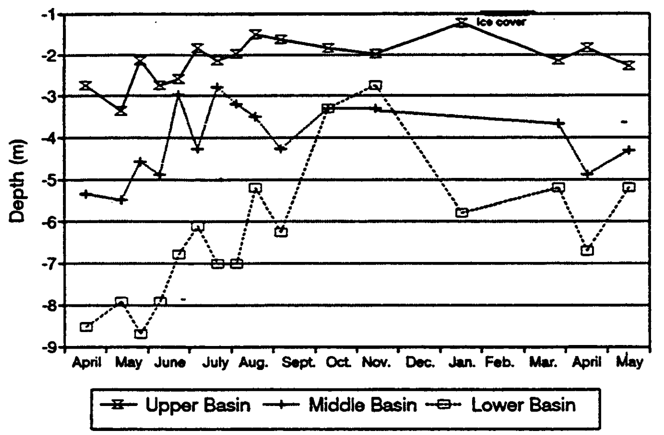


Figure 5–32. Location of 1% Light Levels—
Monroe Lake Sites



5.3.13 Plankton

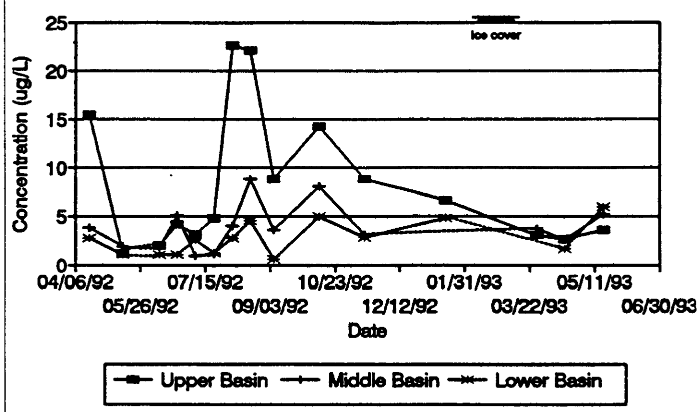
Plankton include algae (microscopic green plants) and zooplankton (microscopic, primarily crustacean animals). Ecologically, the algae are the chief primary producers in lakes and form the base of the aquatic food chain. Zooplankton are the primary consumers of algae and are, in turn, preyed upon by many fish. Ecologically healthy lakes need healthy, balanced plankton populations.

In Lake Monroe, we determined both plankton densities (numbers per liter) and biomass (mass per liter). Plankton densities are shown in Figure 5–34. Densities are similar in the Upper and Middle Basins while densities in the Lower Basin are higher, particularly in the spring of 1993. Higher plankton densities would be expected in the Lower Basin due to the higher transparency and deeper euphotic zone. Highest plankton densities during the sampling period occurred in the spring of 1993 when a bloom of blue-green algae occurred in the Upper Basin and blooms of diatoms occurred in the Middle and Lower basins.

The Upper Basin plankton populations are dominated by blue-green algae during certain times of the year while diatoms (a yellow-brown algae) are often most abundant in the Middle and Lower basins. Blue-green algae are less desirable than other algae because they may:

a. form nuisance blooms which can result in floating mats of algae,
b. generate foul odors,
c. be unpalatable to zooplankton grazers,
d. release toxins under extremely high densities.

Figure 5–33. Chlorophyll *a*—Lake Basin Means



They are indicators of more eutrophic (overproductive) lake conditions. Diatoms, on the other hand, are typically abundant in spring because they prefer cooler water temperatures and their chief micronutrient, silica, is available at this time. Diatom abundance in many lakes is limited by the availability of silica.

The blue-green alga, *Chroococcus*, was the dominant species in the Upper Basin in the June 1993 bloom. *Chroococcus* is a free-floating, single or colonial algal which is common in many lakes of the Great Lakes region (Prescott, 1982). *Asterionella* spp. and *Fragilaria* spp. are the two diatom species responsible for the large number of plankton in the Upper and Middle basins during the same period. Certain *Asterionella* species are known to cause taste and odor problems in drinking water and *Fragilaria* can clog water treatment plant filters (Terrel and Perfetti, 1989).

Zooplankton densities are highest in the Upper Basin. Zooplankton are herbivorous grazers on algae and are, in turn, preyed upon by planktivorous fish. Thus, the presence of a large number of zooplankton can help keep algal populations in check but this also suggests that fish predation on zooplankton is not occurring. Many planktivorous fish (for example, young sunfish) select prey individually after first sighting them (Eggers, 1982; O'Brien, Evans and Luecke, 1985). The high turbidity in the Upper Basin may limit the ability of the visual feeding fish to find and select prey (zooplankton) to feed on. Zooplankton densities are lower in the Middle and Lower Basins where transparency is higher and fish predation on zooplankton should not be limited by high turbidity.

Phytoplankton biovolume data are given in Figure 5–35. Units are cubic millimeters of phytoplankton per liter (mm^3/L). There are 10^9 mm^3 per m^3. Thus, a phytoplankton biovolume concentration of 1.0 mm^3/L would

Figure 5–34A. Plankton Densities—Upper Basin, Lake Monroe

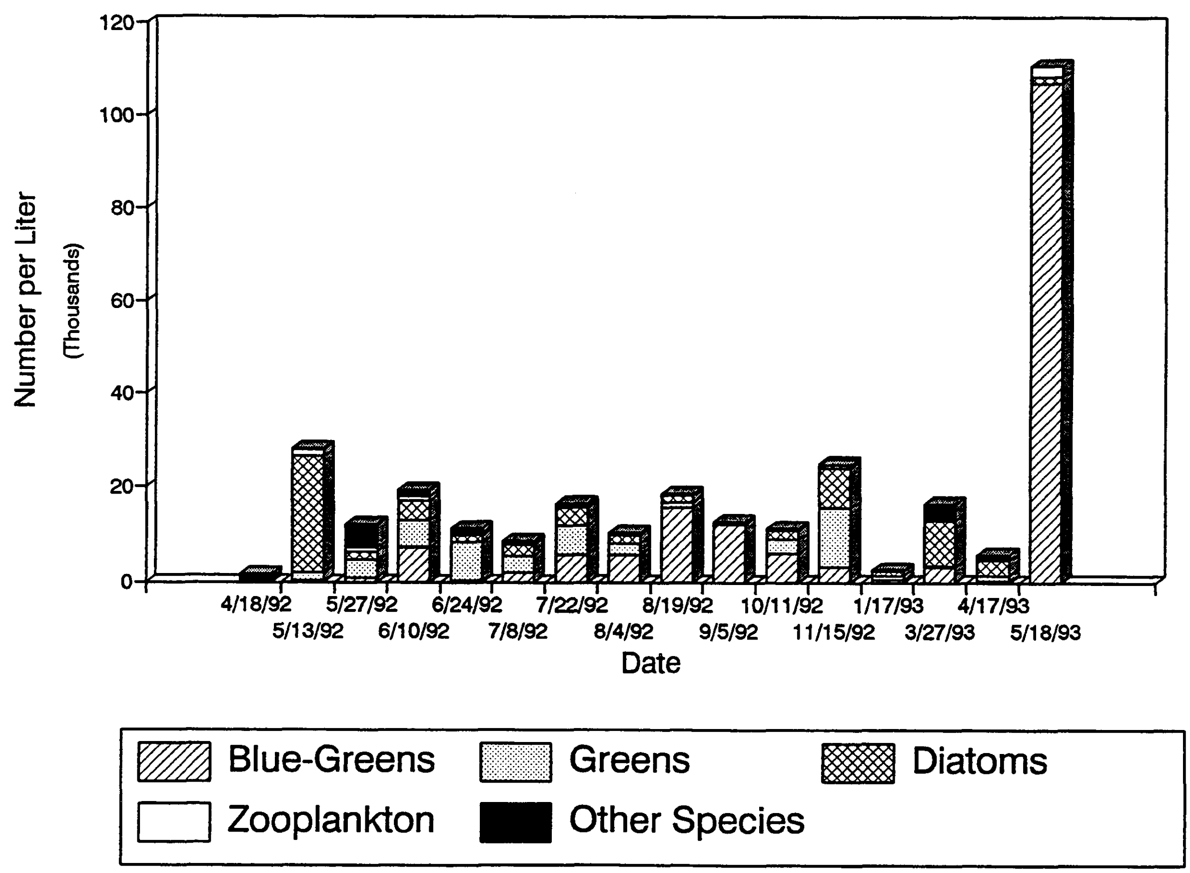


Figure 5–34B. Plankton Densities—Middle Basin, Lake Monroe

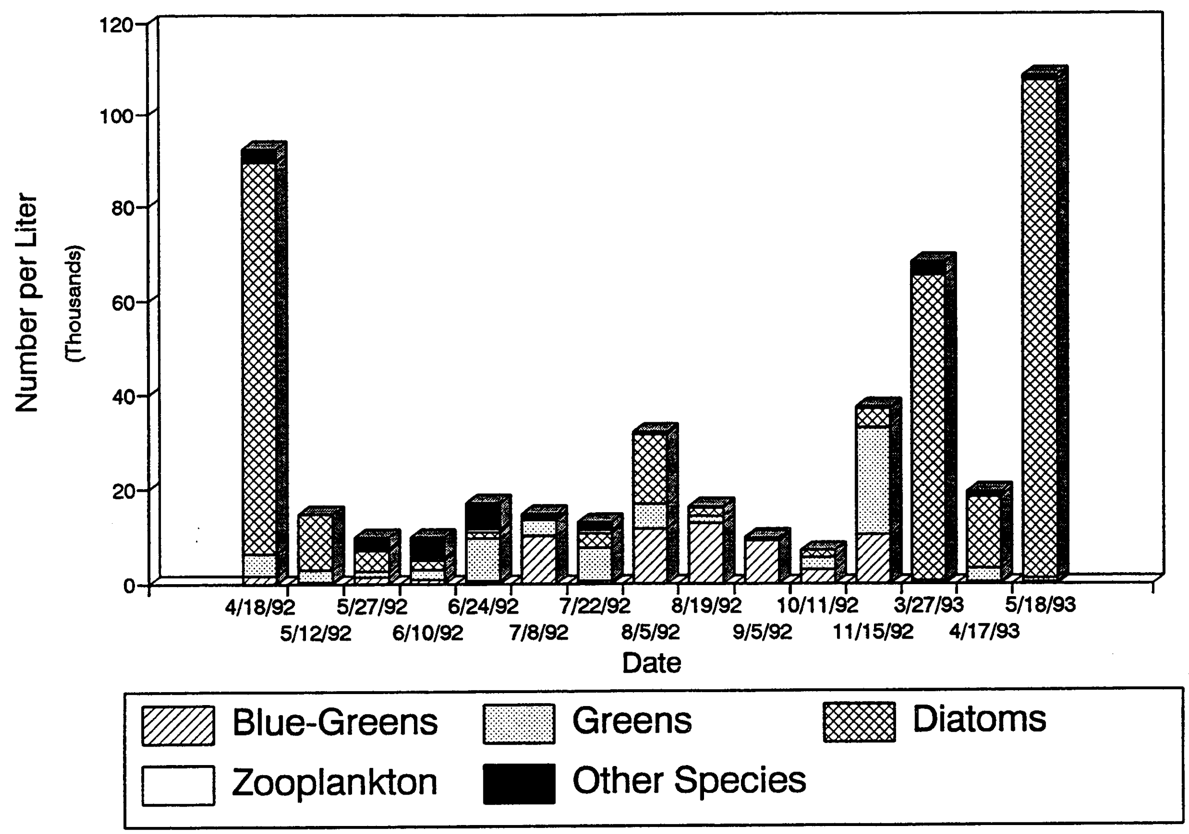


Figure 5–34C. Plankton Densities—Lower Basin, Lake Monroe

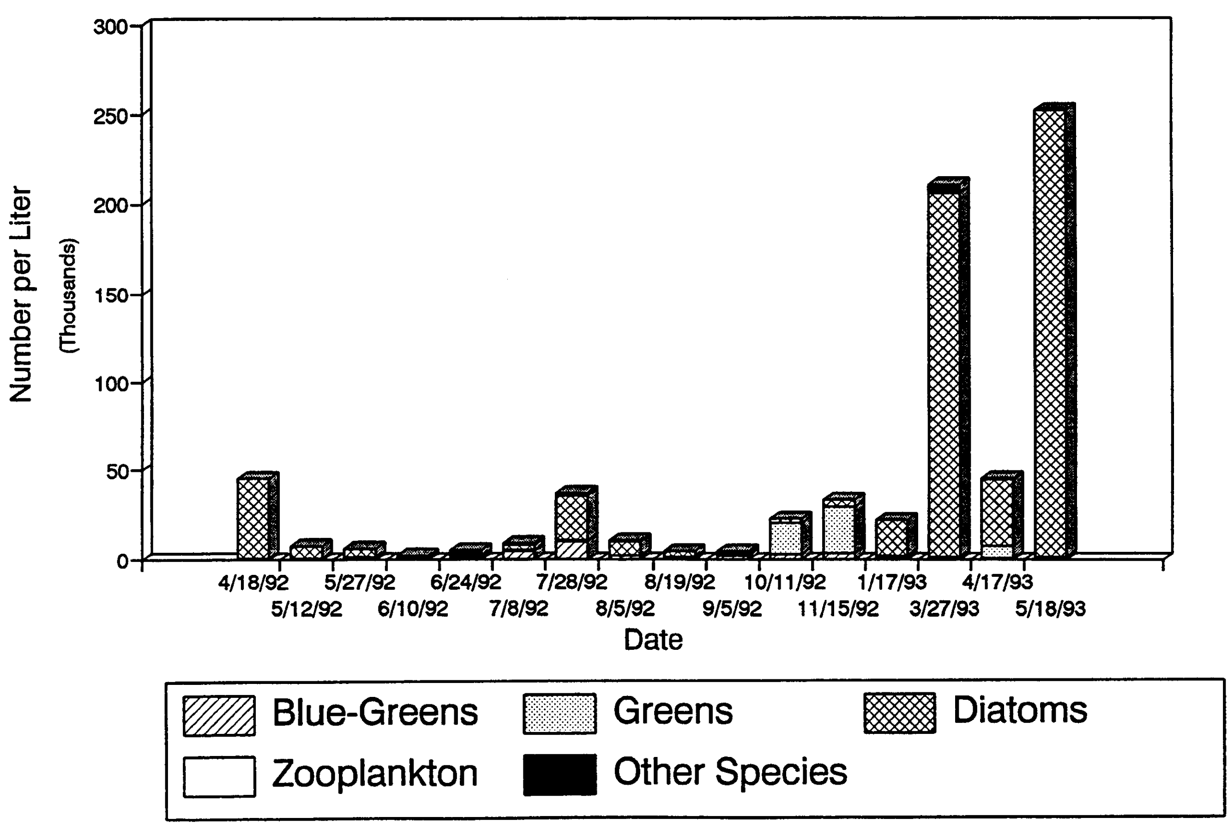


Figure 5–35A. Plankton Biovolumes—Upper Basin, Lake Monroe

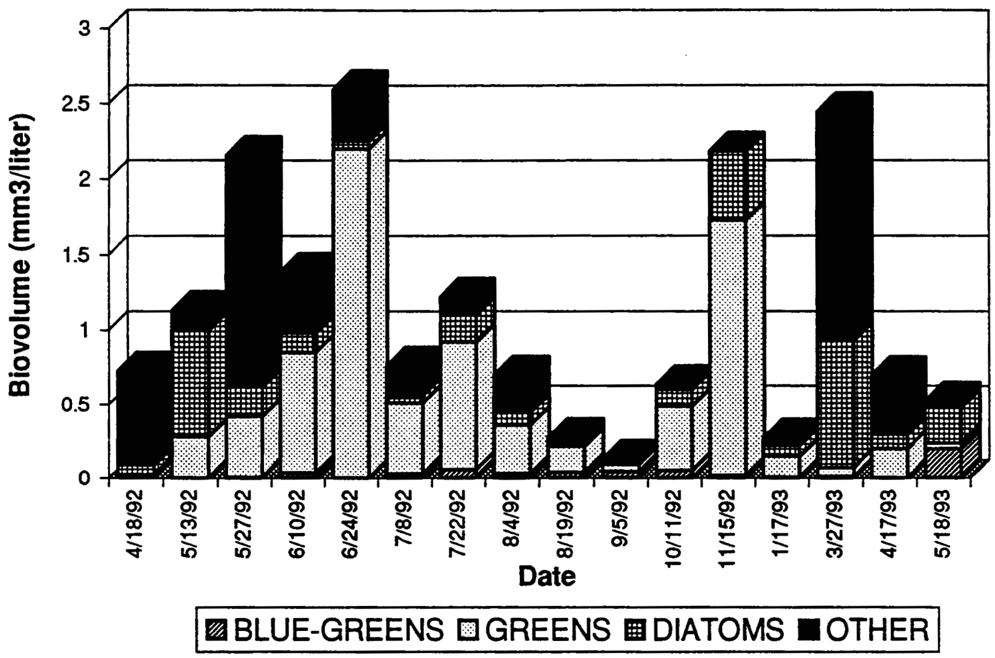
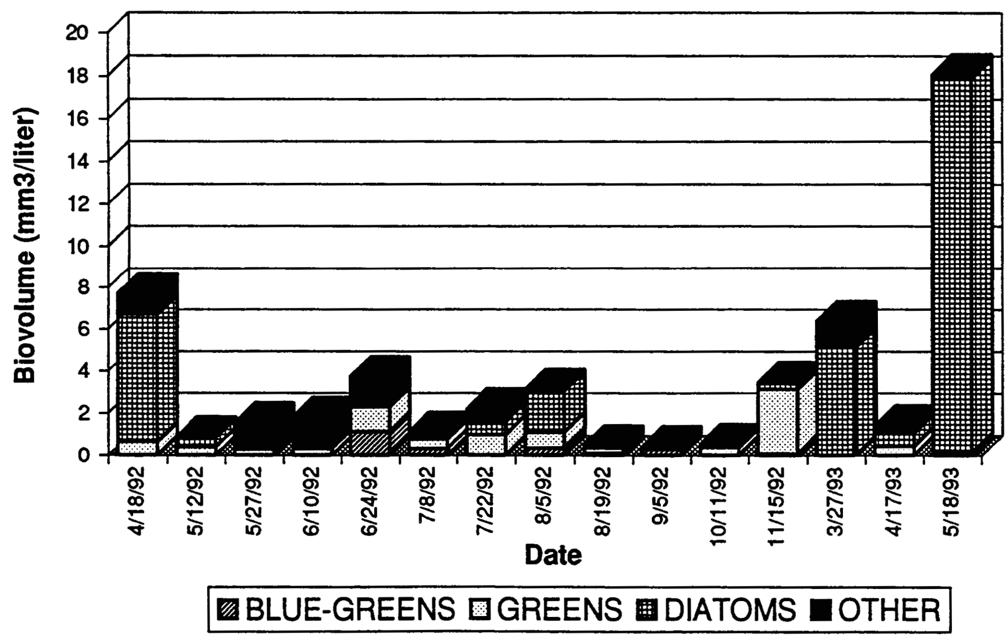


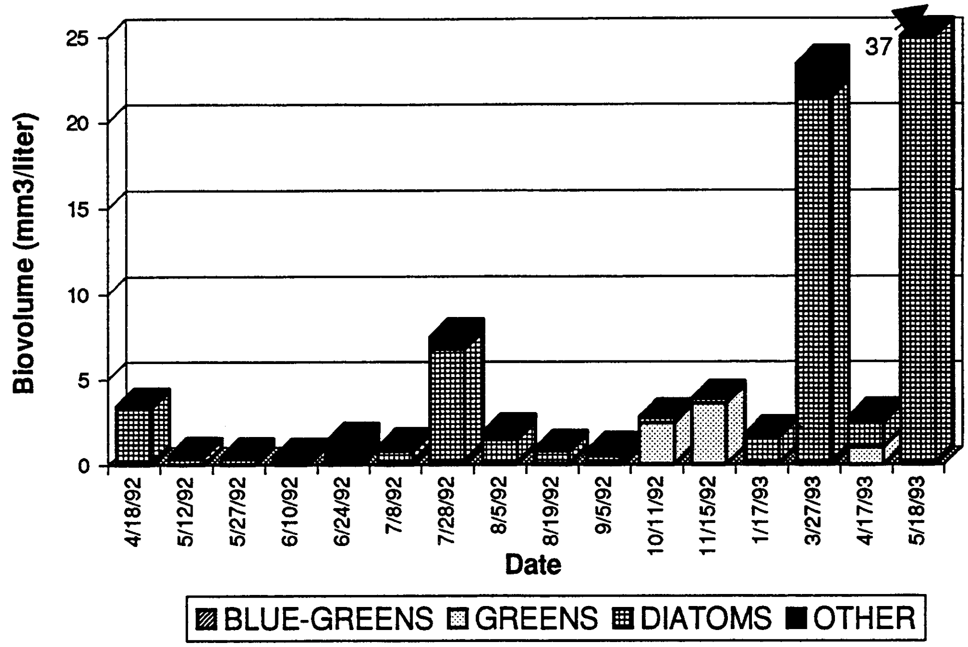
Figure 5–35B. Plankton Biovolumes—Middle Basin, Lake Monroe



represent a total phytoplankton biovolume of 28.7 m^3 for the entire lake. At this concentration, the lake contains 1 part phytoplankton per one million parts of water.

Phytoplankton biovolume is generally highest in the Lower Basin and lowest in the Upper Basin. Mean biovolumes are 1.1 mm^3/L (Upper Basin); 3.5 mm^3/L (Middle Basin); and 5.6 mm^3/L (Lower Basin). Decreased transparency in the Upper Basin limits phytoplankton growth there. The Middle Basin has intermediate levels of both phosphorus and transparency (Figure 5–36) so with neither of these parameters at limiting levels, Middle

Figure 5–35C. Plankton Biovolumes—Lower Basin, Lake Monroe



Basin phytoplankton volumes are generally higher. Greater transparency in the Lower Basin apparently compensates for the somewhat lower phosphorus concentrations so phytoplankton biovolumes are greatest here. A massive diatom bloom occurred in the Lower Basin in spring 1993. Phosphorus concentrations in the Lower Basin were elevated on 5/18/93 (Figure 5–20) but were low on 3/27/93, the date of a similar diatom peak. Peak diatom biomass is usually in the spring on many lakes.

Limiting Nutrient. A limiting nutrient is that nutrient or factor which is in short enough supply to restrict the growth of algae in lakes. Of the major nutrients required for algal growth, phosphorus is most often the limiting nutrient. This means that in most lakes, the addition of phosphorus will result in additional algal growth. In green plants, carbon, nitrogen, and phosphorus generally occur in a ratio of 40C:7N:1P in the plants themselves. When the nitrogen to phosphorus ratio in water is greater than 10N:1P, phosphorus is considered limiting to additional algal growth.

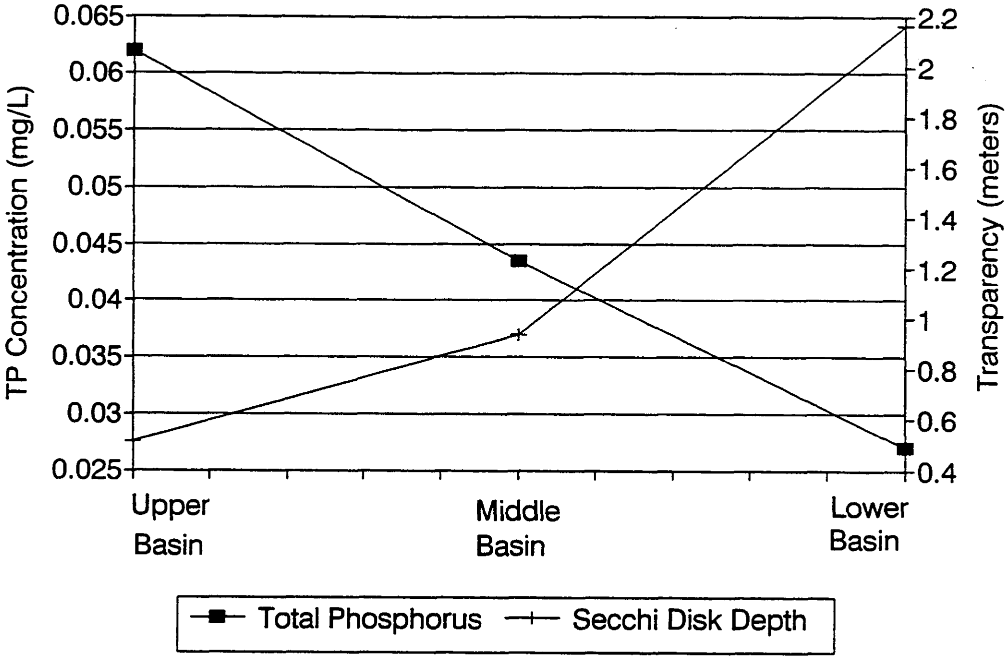
Table 5–2 illustrates the mean inorganic nitrogen (nitrate + ammonia) to inorganic phosphorus (soluble reactive phosphorus) ratios for the Upper, Middle, and Lower basins of Lake Monroe. The inorganic forms of nitrogen and phosphorus are the forms most readily available for algae to use in growth. In all but two cases, on July 8, 1992, the N:P ratio exceeded 10N:1P. This illustrates, for the most part, that phosphorus is the limiting nutrient in the lake. In general, N:P ratios were lowest during the mid-summer months, particularly in the Middle and Lower basins.

5.3.14 Macrophytes

Diverse, moderately dense stands of aquatic plants are desirable in a lake's *littoral* (shallow water) zone. Many have positive attributes which enhance ecological and aesthetic values (Table 5–3).

Emergent aquatic plant communities protect the shoreline from erosion by dampening the force of waves and stabilizing shoreline soils. Vegetation can also provide screening for the lakeshore homeowner and buffer noise

Figure 5–36. Relationship Between Epilimnetic Total Phosphorus and Secchi Disk Transparency in Lake Monroe: July/August Means



from motor boats. Many species of aquatic plants, such as the white water lily and pickerelweed, are aesthetically pleasing because they have showy flowers or interesting shapes. Aquatic vegetation also provides fish habitat and spawning sites, waterfowl cover and food, and habitat for aquatic insects. For example, sedges (*Carex* spp.) become spawning beds for northern pike in spring, wild rice beds (*Zizania aquatica*) attract shorebirds in summer, and wild celery (*Vallisneria americana*) develops tubers that attract canvasbacks in fall and is one of the finest fish food and cover plants (Engel, 1988).

Approximately 1,600 acres (648 hectares) of Lake Monroe's 10,700-acre (4350 hectare) surface area supports rooted aquatic macrophytes (Table 5–4 and Figure 5–37). The majority of these plants grow in the Upper Basin where shallow water predominates and the most dominant species is American lotus, which covers 895 acres in the Upper Basin. American lotus occurs in dense stands which offer little habitat value to aquatic organisms because they crowd out other species which provide needed diversity. Eurasian watermilfoil also occurs in dense stands but it may be underestimated since it is a submersed plant and poor water clarity can prevent observers from seeing this species during surveys. Research by Dixon Landers demonstrated that the fall die-back of Eurasian watermilfoil releases significant phosphorus into Lake Monroe and stimulates autumn algal growth (Landers and Frey, 1980).

Table 5–2. Mean Inorganic Nitrogen to Inorganic Phosphorus Ratios for Upper, Middle, and Lower Basins of Lke Monroe

	LAKE BASIN		
DATE	Upper	Middle	Lower
04/17/92	44.5	61.4	96.3
05/13/92	51.6	39.9	27.2
05/27/92	20.3	12.9	16.3
06/10/92	23.8	20.1	18.9
06/24/92	40.6	31.2	31.4
07/08/92	18.1	9.1	2.2
07/22/92	21.3	11.8	19.3
08/05/92	29.8	20.1	24.9
08/19/92	36.3	38.3	45.9
09/06/92	304.0	77.1	91.5
10/11/92	18.2	10.1	15.2
11/15/92	73.4	51.5	76.6
01/17/93	108.6	-	92.3
03/28/93	80.1	86.6	122.7
04/18/93	80.4	213.8	224.7
05/18/93	95.6	87.3	142.1

Table 5–3. Aquatic Plant Attributes				
	Nuisance Rank[1]	*Waterfowl Food Value*[2]	*Positive Aesthetic Value*	*Other*
Emergent species				
Acorus calamus		S	X	human food[3]
Clyceria borealis		F		
Leersia oryzoides		F–G		
Pontederia cordata		S–F	X	
Sagittaria spp.		F	X	human food[3] shoreline protection
Scirpus cyperinus				shoreline protection
Scirpus validus		S–F		
Sparganium chlorocarpum		F	X	
Typha latifolia				food for aquatic fur bearers and human[3]; shoreline protection
Zizania aquatica		E	X	human food[3]
Floating-leaved species				
Brasenia schreberi	L	F–E	X	
Lemna minor		F–E		
Nelumbo lutea	L		X	
Nuphar spp.	L	F	X	
Nymphaea odorata	L	S	X	
Nymphaea tuberosa	L	S	X	
Polygonum coccineum		G–E		
Polygonum natans		G–E		
Wolfia spp.		F		
Submerged species				
Ceratophyllum demersum	R	S–F		good macroinvertebrate habitat[4]
Chara vulgaris	L	G–E		
Eleocharis acicularis		F–G		suppresses nuisance macrophytes
Elodea canadensis	R	S		
Heteranthera spp.				good macroinvertebrate habitat[4]
Myriophyllum spp.	R	S–F		good macroinvertebrate habitat[5]
Najas flexilis	L	E		
Najas quadalupensis	L	E		
Najas minor	L			
Potamogeton amplifolius		F		
P. Crispus	R			good macroinvertebrate habitat[5]
P. foliosus		F–G		
P. gramineus		F–G		
P. natans		F–G		
P. pectinatus	L	E		
P. pusillus		F–G		
P. richardsonii		G		
P. strictifolius		F		
P. zosteriformes		F		
Ruppia sp.		E		
Utricularia vulgaris	L			
Vallisneria americana	L	E		
Zanichellia sp.	L	F–G		

[1] After Trudeau, 1982. R = regional problem, L = local problem
[2] After Carlson and Moyle, 1968. S = slight, F = fair, G = good, E = excellent
[3] Fernald, et al. 1958
[4] Krull, 1970
[5] Krecker, 1939

Source: Nichols (1986).

Table 5–4. Aquatic Macrophyte Coverage (acres) in Lake Monroe

Species	*Upper Basin*	*Below Causeway*	*Total*
American lotus	895	6	901
Water lily	400	25	425
Eurasian watermilfoil	151	117	268
Water willow	8	0	8
Cattail	0	1	1
Water smartweed	1	0	1
TOTAL	1455	149	1604

Figure 5–37. Areal Coverage of Rooted Macrophytes in Lake Monroe

5.4.1 Introduction

How do we interpret the large amount of water quality data collected during this study to assess the overall condition of Lake Monroe? Limnologists have established guidelines for the "acceptable" amounts of phosphorus, algae and other parameters in lakes. These guidelines were discussed in the previous sections. For example, the Upper Basin of Lake Monroe had relatively high levels of total phosphorus, high turbidity, but low algae densities. Does high phosphorus alone mean poor water quality? What about high phosphorous *and* high turbidity? Or do all parameters need to be over some threshold before concluding that a particular lake is polluted?

The most widely used standard for assessing the condition of a lake is by considering its *trophic state*. The trophic state of a lake refers to its overall level of nutrition or biological productivity. Trophic categories include: *oligotrophic, mesotrophic, eutrophic,* and *hypereutrophic,* with productivity increasing from oligotrophic to eutrophic. For example, a eutrophic lake is likely to suffer from dense algae concentrations, aesthetic deterioration, and swimming impairment (Heiskary and Walker, 1987). The changes in a lake from oligotrophy to a higher trophic state is called *eutrophication*. Cooke, et. al. (1993) defines eutrophication as the loading of inorganic nutrients, organic matter, and silt to lakes and reservoirs at rates sufficient to increase the potential for high biological production and to lead to a decrease in lake volume. By this definition, high phosphorus alone does not make a lake eutrophic. The phosphorus levels must also cause an increase or potential increase in plant production and/ or sedimentation.

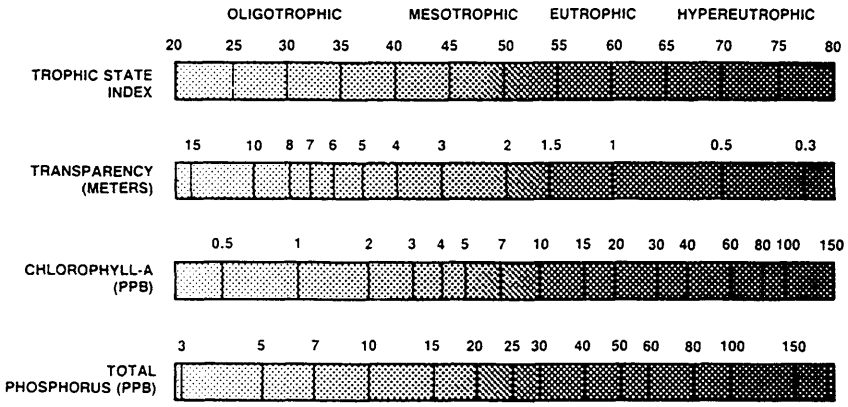
5.4.2 Trophic State Indices

The large amounts of water quality data collected during lake water quality assessments can be confusing to evaluate. Because of this, Indiana and many other states use a trophic state index (TSI) to help evaluate water quality data. A TSI condenses water quality data into a single, numerical index. Different index (or eutrophy) points are assigned for various water quality concentrations. The index total, or TSI, is the sum of individual eutrophy points for a lake.

The most widely used and accepted TSI is one developed by Bob Carlson (1977) called the "Carlson TSI." Carlson analyzed total phosphorus, chlorophyll *a*, and Secchi disk transparency data for numerous lakes and found statistically significant relationships among the three parameters. He developed mathematical equations for these relationships and these form the basis for the Carlson TSI. Using this index, a TSI value can be generated by one of three measurements: Secchi disk transparency, chlorophyll *a*, or total phosphorus. Data for one parameter can also be used to predict a value for another. The TSI values range from 0 to 100. Each major TSI division (10, 20, 30, etc.) represents a doubling in algal biomass.

In the early 1970s, biologists with the Indiana State Board of Health developed a multi-parameter TSI for use in understanding water quality differences between two particular lakes. While values for this index have not been statistically validated as with Carlson's TSI, the Indiana TSI (ITSI) has nonetheless been used since that time to evaluate changes in all Indiana lakes. The Indiana TSI ranges from 0 to 75 total points. The ITSI totals are grouped into the following three lake quality classifications:

Figure 5–38. Carlson'sTrophic State Index



ITSI Total	*Water Quality Classification*
0–25	oligotrophic
26–50	mesotrophic
51–75	eutrophic

Indiana TSI scores are calculated from ten water quality parameters (Table 5–5). Eutrophy points are assigned according to the value of the measured parameter. The mean of an epilimnetic and hypolimnetic water sample is used to calculate the parameter value from which the eutrophy points for phosphorus and nitrogen are assigned. For example, a total phosphorus concentration of 0.043 ppm would be assigned 2 eutrophy points while a concentration of 0.29 would be assigned 4 eutrophy points. The eutrophy points assigned for each parameter are summed to give the total ITSI score.

The Indiana TSI is heavily weighted toward plankton. Up to 35 of the 75 total points (47%) are assigned to plankton parameters. Thus, there can be large ITSI differences between lakes due only to plankton. For example, ten points are assigned if the plankton is dominated by blue-green algae. Secchi disk transparency is also an absolute scale (0 *or* 6 points) rather than a variable scale like total phosphorus has. These factors cause the Indiana TSI to be less acceptable outside Indiana and Indiana TSI scores do not correlate well with Carlson's or other TSIs in use around the country.

5.4.3 Trophic State Results

Lake Monroe scores using the Indiana TSI (Figure 5–39) generally fall within the oligotrophic (least productive) range except for late summer/early autumn in the Upper Basin and for the May 1993 sampling date when values for all basins fall in the mesotrophic range. The late summer/early autumn ITSI peaks in the Upper and Middle Basins are likely associated with increased phosphorus and chlorophyll concentrations due to macrophyte die-back, a phenomenon which does not have much immediate effect on the Lower Basin. The Lower Basin ITSI increase in late autumn may represent a time-delayed response to the die-back. The Lower Basin consistently had lower ITSI scores throughout the year.

Carlson TSI scores are shown in Figure 5–40. Lake Monroe has sufficient phosphorus to score within the eutrophic (most productive) range from summer to winter. Secchi disk transparency TSI scores for the Upper and Middle Basins are within the eutrophic range while those for the Lower Basin are generally within the

Table 5–5. The Indiana Trophic State Index

Parameter and Range	*Eutrophy Points*
I. Total Phosphorus (ppm)	
A. At least 0.03	1
B. 0.04 to 0.05	2
C. 0.06 to 0.19	3
D. 0.2 to 0.99	4
E. 1.0 or more	5
II. Soluble Phosphorus (ppm)	
A. At least 0.03	1
B. 0.04 to 0.05	2
C. 0.06 to 0.19	3
D. 0.2 to 0.99	4
E. 1.0 or more	5
III. Organic Nitrogen (ppm)	
A. At least 0.5	1
B. 0.6 to 0.8	2
C. 0.9 to 1.9	3
D. 2.0 or more	4
IV. Nitrate (ppm)	
A. At least 0.3	1
B. 0.4 to 0.8	2
C. 0.9 to 1.9	3
D. 2.0 or more	4
V. Ammonia (ppm)	
A. At least 0.3	1
B. 0.4 to 0.5	2
C. 0.6 to 0.9	3
D. 1.0 or more	4
VI. Dissolved Oxygen: Percent Saturation at 5 feet from surface	
A. 114% or less	0
B. 115% to 119%	1
C. 120% to 129%	2
D. 130% to 149%	3
E. 150% or more	4
VII. Dissolved Oxygen: Percent of measured water column with at least 0.1 ppm dissolved oxygen	
A. 28% or less	4
B. 29% to 49%	3
C. 50% to 65%	2
D. 66% to 75%	1
E. 76% to 100%	0
VIII. Light Penetration (Secchi Disk)	
A. Five feet or under	6
IX. Light Transmission (Photocell) Percent of light transmission at a depth of 3 feet	
A. 0 to 30%	4
B. 31% to 50%	3
C. 51% to 70%	2
D. 71% and up	0
X. Total Plankton per liter of water sampled from a single vertical tow between the 1% light level and the surface:	
A. less than 3,000 organisms/L	0
B. 3,000–6,000 organisms/L	1
C. 6,001–16,000 organisms/L	2
D. 16,001–26,000 organisms/L	3
E. 26,001–36,000 organisms/L	4
F. 36,001–60,000 organisms/L	5
G. 60,001–95,000 organisms/L	10
H. 95,001–150,000 organisms/L	15
I. 150,001–500,000 organisms/L	20
J. greater than 500,000 organisms/L	25
K. Blue-Green Dominance: additional points	10

mesotrophic range. Chlorophyll TSI scores, on the other hand, are generally within the oligotrophic and mesotrophic ranges. The fact that chlorophyll TSI scores are lower than total phosphorus and Secchi disk TSI scores suggest that something else is limiting chlorophyll production in the lake. As we discussed previously, this limiting factor is very likely light, which is restricted by the high turbidity in Lake Monroe.

Because of the universal acceptance of Carlson's trophic state index by the scientific community we feel that this index is the more appropriate one to apply to Lake Monroe. The reliance of the Indiana TSI on plankton, along with the fact that plankton production in Lake Monroe is limited by light, make the Indiana TSI less suitable in this case.

Figure 5–39. Trophic State Index Scores Using the Indiana TSI
Lake Monroe 1992–93

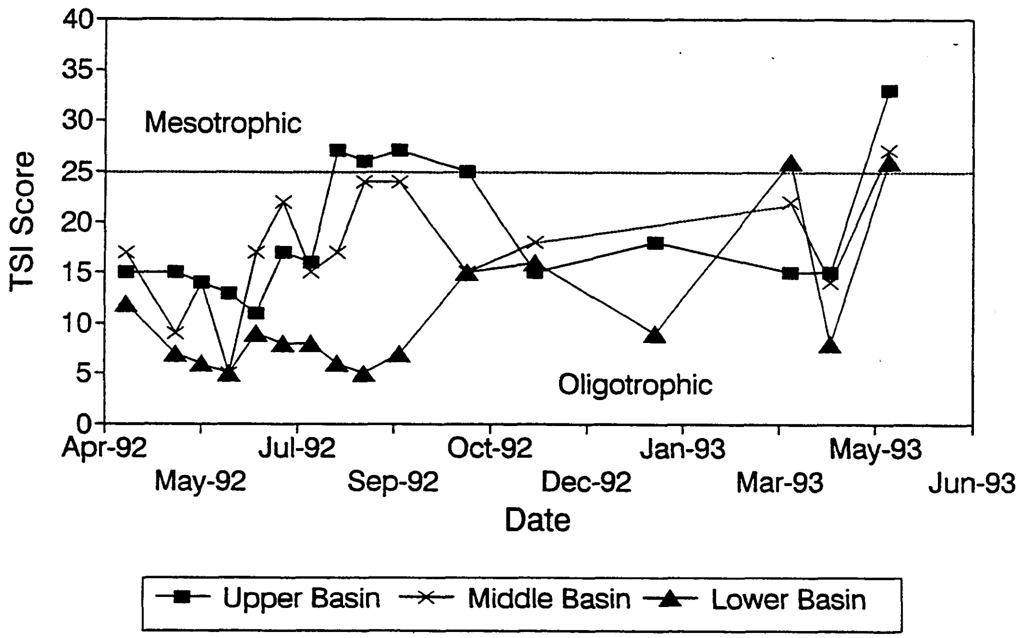
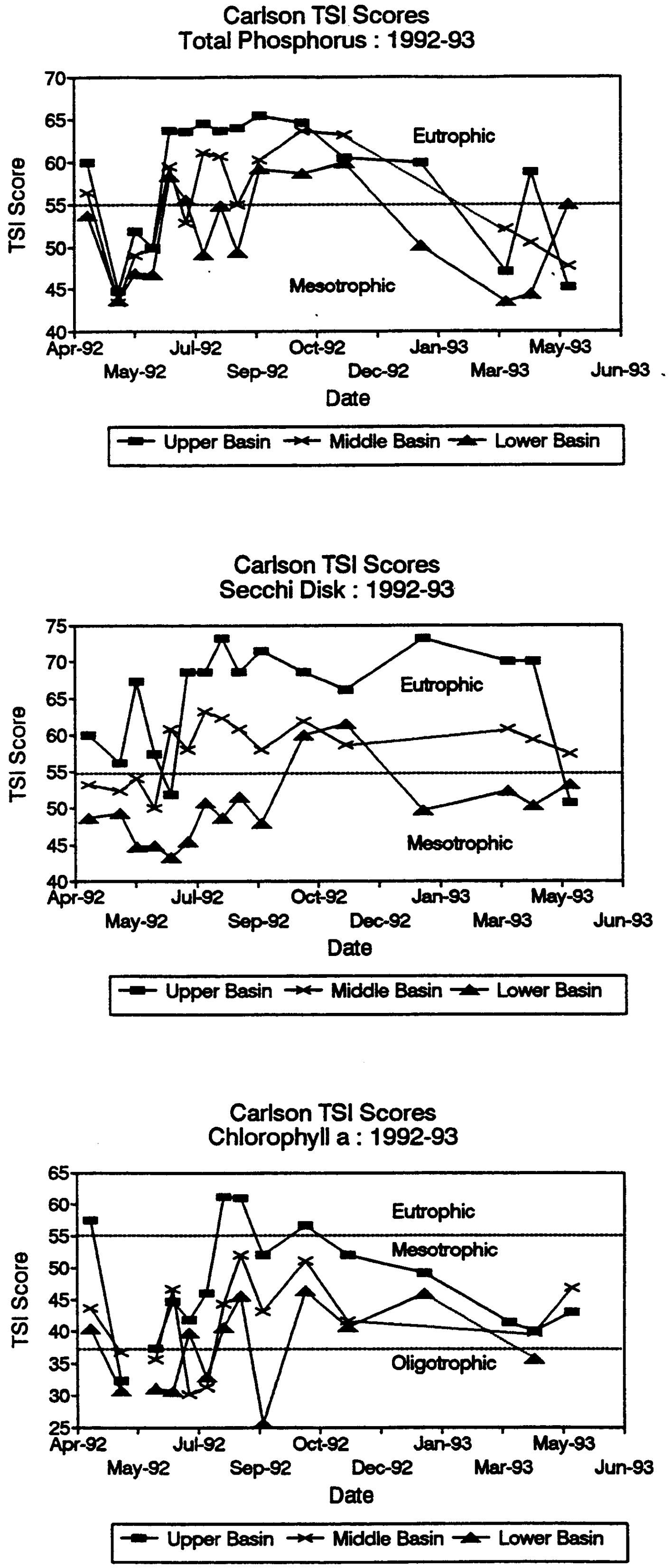


Figure 5–40. Trophic State Index Scores for Lake Monroe Using Carlson's TSI



6.0 SEDIMENTS

Sediments refer to material, both organic and inorganic, which are deposited on the bottom of lakes, reservoirs, and rivers. There are many sources of sediments to lakes. Some sediments are generated outside the lake such as eroded soil and eroded organic material (e.g., leaves, twigs) which are then transported into the lake by runoff. Sediments can also be generated within the lake as rooted plants and algae die and settle to the lake bottom. Internal sediment sources such as these are usually only a small part of overall accumulated lake sediments.

In this section of the report, we will describe the sediment budget for Lake Monroe and discuss some characteristics of sediments in the lake.

6.1 Sediment Budget

6.1.1 Sediment Inputs

The sediment budget was determined using an approach similar to the approach for estimating the hydrologic budget in Chapter 4. The sediment load was taken as the total suspended sediment [g/m^3 or ppm] multiplied by the modeled stream discharge [m^3/s]. The total suspended sediment [TSS] was measured from water samples collected at the five monitoring sites and a regression relationship was determined relating TSS to the stream discharge as follows:

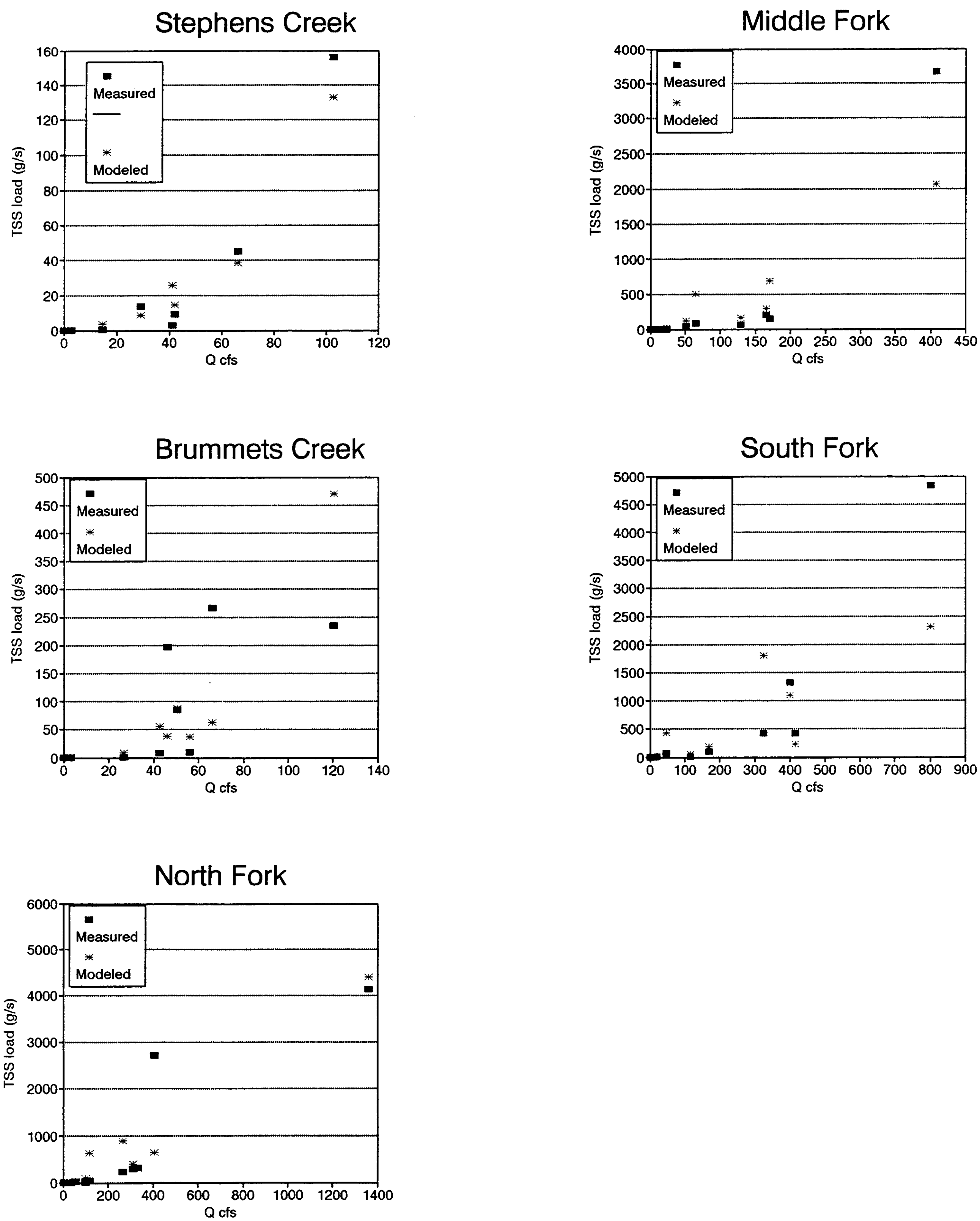
$TSS = a * Q + b$ where:
Q = stream discharge
a = x coefficient (slope)
b = y intercept

The results of these regressions are presented in Table 6–1. The R^2 values ranged from a high for the Middle Fork of 0.80 to a low for the North Fork of 0.32. Although the regression relationship does not account for a large part of the variance in TSS for Brummetts and North Fork Salt creeks, Figures 6–1 b and 6–1c indicate that the exponential type curve has been emulated and the modeled estimates agree reasonably well with the measured TSS. Since the major sediment load from streams occurs during high flow, it is important to model these loads as precisely as possible. While we made every attempt to sample during peak flows, it was difficult to anticipate when the peaks would occur and they often occurred at times (for example, at night) when we were unable to

Table 6–1. Regression Results—Total Suspended Solids Estimation for Monroe Watershed Streams

STATISTIC	STEPHENS	BRUMMETTS	NORTH FORK	MIDDLE FORK	SOUTH FORK
Std. error of predicted TSS	7.18	41.10	48.90	33.90	27.10
R^2	0.79	0.38	0.32	0.80	0.77
X coefficient (slope)	14.59	31.79	3.42	21.32	7.37
Std. error of x coefficient	2.27	10.75	1.30	2.40	1.08
Y intercept	0.002	5.00	16.25	0	8.75

Figure 6–1. Comparison of Measured vs. Modeled TSS Loads, Monroe Watershed



sample them. Therefore, most of our samples occurred during low to moderate flow periods and the peak flow behavior is not well represented in our regression relationships. The comparison of modeled and measured sediment loads for the Middle Fork and the South Fork (Figures 6–1d and 6–1e) reveal that, for these streams, sediment loads during high flow periods are underestimated, in spite of a relatively high R^2. There is relatively good agreement between modeled and measured TSS for high flows in Stephens Creek and the North Fork (Figures 6–1a and 6–1c). The modeled flows for Brummetts Creek tend to be higher than the measured flows during low flow periods (Figure 6–1b). The resulting modeled sediment loads are plotted in Figure 6–2.

To model the sediment load from the unmonitored portion of the watershed, we applied a loading coefficient derived from the loadings in the monitored portion of the watershed. We used the Brummetts Creek watershed to determine this coefficient since it is similar to the unmonitored watersheds in terms of both watershed size, land use, and topography. TSS/Area for Brummetts relates to discharge as:

$$TSS_b / Area_b \ [ppm/m^2] = 422.83 * Q_b \ [cfs]$$

We estimated TSS for the unmonitored zone as:

$$TSS_{um} \ [ppm/m^2] = 422.83 * Q_{um} \ [cfs] * Area_{um} \ [m^2])$$

The total sediment loads estimated by the model are summarized in Figure 6–3.

6.1.2 Sediment Output

Sediment output was estimated by determining the monthly average measured TSS for the outlet and multiplying by the flow measured at the outlet. The results are tabulated in Table 6–2.

6.1.3 Sediment Accumulation

According to these results, 95% of the sediment entering the lake is trapped. This 95% trapping efficiency agrees with the expected trapping efficiency of a lake with the capacity-to-inflow ratio found in Lake Monroe (Brune, 1953). If we assume that the sediment is deposited evenly across the entire lake, and that the lake bottom has the same area as the lake top, sediment would accumulate at a rate of 0.03 in/yr. This is higher than the 0.01 in/yr sedimentation rate reported in previous studies (Bradbury, et al., 1977). In this 1976 study, sedimentation was also studied by examining bottom cores and surveying the lake bottom. These data showed that only an inch or so of sediment had accumulated in the middle and lower basins during the first 11 years since the reservoir was completed. The thickness of accumulated sediment for that same time period in the upper basin was between 2 and 4 inches.

The 0.03 in/yr of sediment accumulation represents a whole-lake sedimentation rate of 0.02 percent per year. This is a low sedimentation rate when compared to other Indiana reservoirs (Table 6–3).

The results from the current study along with the results from the 1976 study indicate that sediment is accumulating in the lake, but that the suspended sediment delivered by streams alone cannot account for the observed accumulation of sediment in the lake. Heavier soil particles (for example, sand and small pebbles) can be transported downstream along the streambed. Under most circumstances, these particles are too heavy to become suspended in the water column where they would be included in our samples of suspended sediments. As this bedload enters the lake, it is deposited in the upper reaches of the lake and does not likely move much.

Figure 6–2. Modeled Sediment Loads for 1992–93.

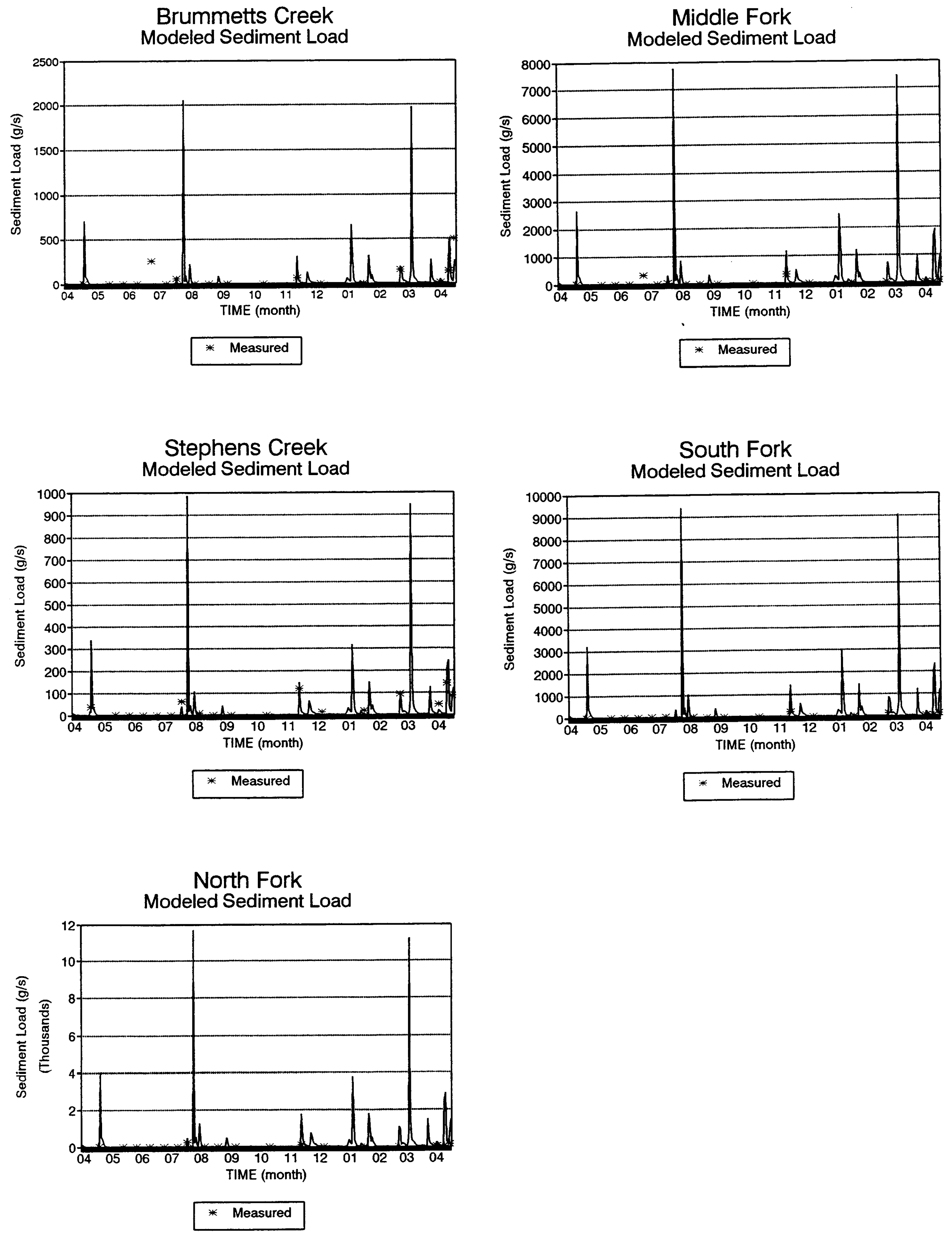


Figure 6–3. Sediment Contributions to Lake Monroe (32,825 tons/yr)

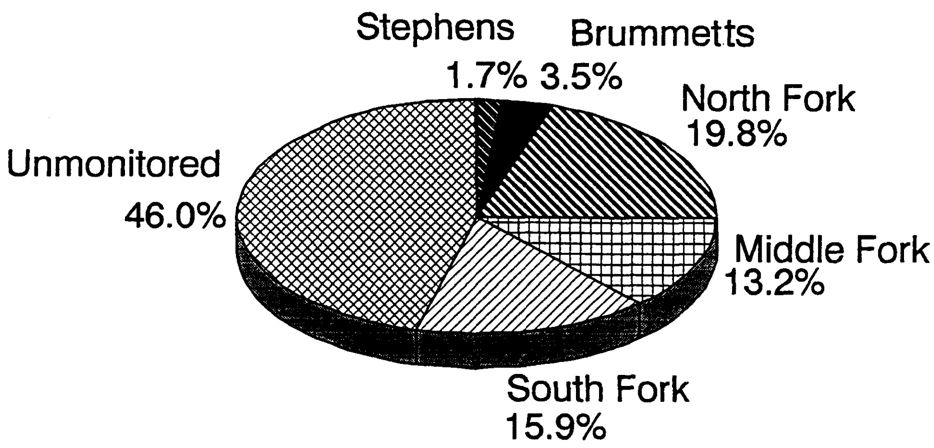


Table 6–2. Modeled Sediment Inputs and Outputs

		IN		OUT	IN - OUT
Year	Month	Unmonitored (kg)	Monitored (kg)	Outflow (kg)	(kg)
1992	April	616,840	726,270	36,491	1,306,600
	May	7,699	9,009	83,279	-66,570
	June	1,532	1,782	61,460	-58,145
	July	3,025,100	3,562,400	121,750	6,465,800
	August	190,640	224,360	333,470	81,526
	September	10,413	12,217	48,427	-25,797
	October	21,467	25,223	10,599	36,091
	November	1,018,800	1,199,400	83,457	2,134,800
	December	264,320	310,980	91,388	483,910
1993	January	2,435,900	2,868,200	154,880	5,149,300
	February	619,690	729,500	243,060	1,106,100
	March	3,608,600	4,249,400	178,630	7,679,400
	April	1,854,800	2,184,000	90,051	3,948,800
	ANNUAL	13,676,000	16,103,000	1,536,900	28,242,000

Table 6–3. Sedimentation Rates for Other Indiana Reservoirs

Reservoir	*Sedimentation Rate (%/year)*	*Source*
Cagles Mill	0.07	DNR (1965)
Shakamak	0.15	Jones and Levine (1989)
Lemon	0.17	Hartke and Hill (1974)
Shaffer	0.28	DNR (1965)
Whitewater	0.55	DNR (1965)
Brush Creek	0.93	DNR (1965)

In practice, bedload is exteremely difficult to measure and is generally 5–10% of the toatal sediment load (Allan, 1995).

Shoreline erosion removes sediment from the sides of the lake and deposits these sediments along the bottom, creating a shallower, wider lake which would be more vulnerable to algal booms and aquatic weed growth. This increased plant growth can, in turn, contribute to increased sediment loading. Shoreline erosion does not affect overall lake water storage because the lake volume does not change. Human accounts suggest that there has been significant loss of shoreline in several areas around Lake Monroe. A number of sediment bars are visible off points of land where they were deposited by shoreline erosion. Unfortunately, there has been no organized effort to document the extent of shoreline erosion over time at the lake.

We surveyed Lake Monroe's shoreline in September 1993. We divided the shoreline into 67 sections and documented the type of shoreline substrate (bedrock, talus, soil), the extent of vegetative cover, and bank height. The results are given in Table 6–4 and Figure 6–4. Lakeshore sections with bedrock, talus or rip-rapped substrate would contribute little soil erosion to the lake. Likewise, vegetated shoreline sections with low banks would also have limited erosion. However, lakeshore sections with less than 100% vegetation, >2 foot banks, and silt/clay substrates are the most likely candidates for shoreline erosion problems. Many of the shoreline sections have these erosive characteristics, particularly in the Middle and Lower basins.

We extracted intact sediment cores on 5/23/93 from three transects across the upper basin of the lake and from several spot locations to document the amount of sediment accumulation (Figure 6–5). The boundary between lake sediments and the original land surface in sediment cores is quite easy to see since lake sediments tend to be darker due to their greater organic matter content. However, at Lake Monroe, this boundary was somewhat difficult to see due to the extent of silt and clay in the surficial sediments and the lower organic matter content of Lake Monroe sediments. Sediment deposition along Transect 1 immediately behind the Highway 446 causeway ranged up to 27 cm. (Figure 6–6). Because the causeway acts as a dam to retard water flow, we expected deeper sediment accumulation here than we measured. There was very little sediment accumulation in the Salt Creek channel portion of this transect due to the flushing action of water flow in the channel. Sediment accumulation along Transect 2 near the Pinegrove Ramp ranged from 3–8 cm. (Figure 6–7) while depths along Transect 3 near the Crooked Creek Ramp ranged from 10–35 cm. (Figure 6–8). Most of the sediment reaching the lake in these upper reaches is likely deposited above these two transects. Cores from the channel upstream from the Crooked Creek Ramp and from near the dam had 17 cm. and 14 cm. of deposited sediment, respectively.

Applying an empirical relationship (Brune, 1953) that relates the capacity-to-inflow ratio and the trapping efficiency of the lake, we can calculate what changes in storage can be expected due to the sediment delivered from streams. The results of these calculations are presented in Table 6–5 and Figure 6–9. Using the results of these calculations we estimate that the original allocated silt pool of Lake Monroe will be filled when 14% of the total storage capacity is consumed.

Table 6–4. Results of the Lake Monroe Shoreline Survey

Shoreline Section	Length (miles)	Bedrock	Talus	Status of Vegetation Cover	% Eroded <2 ft. bank	% Eroded >2 ft. bank	Other Substrates Present
1	0.38			50% (grasses, shrubs)	40%	60%	clay/silt
2	0.81			none		100%	rip-rap
3	0.35			10% (shrubs)	30%	70%	clay/silt
4	0.54		100%	15% (shrubs)		100%	
5	0.81		100%	20% (shrubs, trees)		100%	
6	0.73	80%	10%	5% (grasses, trees)		100%	10% clay/silt
7	1.35			80% (annuals, shrubs)		100%	clay/silt
8	1.81		15%	grasses from 1ft.	100%		85% clay/silt
9	0.81		20%	none	5%	95%	80% clay/silt
10	0.50			100%	100%		clay/silt
11	0.46			20%	20%	80%	80% clay/silt
12	0.35	5%		100%	100%		95% clay/silt
13	1.19			100%	100%		clay/silt
14	1.08		70%	none	30%	70%	30% silt
15	0.69			100%	100%		clay/silt
16	1.38	30%	30%	40%	40%	60%	40% clay/silt
17	1.15			90%	90%	10%	clay/silt
18	0.96		100%	none		100%	
19	2.23		90%	10%	10%	90%	10% clay/silt
20	1.15		25%	75%	75%	25%	75% clay/silt
21	0.77			100%	100%		clay/silt
22	14.31			100%	100%		clay/silt
23	2.38		50%	50%	50%	50%	50% clay/silt
24	0.85			none		100%	clay/silt
25	1.42		50%	90% (grass, saplings)		100%	50% clay/silt/gravel
26	2.69		70%	40%		100%	30% clay/silt
27	2.08			100%	90%	10%	clay/silt
28	2.65	5%	70%	none		100%	25% clay/silt
29	1.54			none		100%	clay/silt
30	1.27		90%	10% (grass)		100%	10% clay/silt
31	0.92			none		100%	silt/gravel
32	0.85		10%	none		100%	90% clay/silt
33	3.00			100% (grass)	20%	80%	90% clay/silt; 10% rip-rap
34	1.50			100% (grass)	25%	75%	silt/gravel
35	2.73	5%	10%	15% (grass, saplings)		100%	85% silt/gravel
36	3.35	5%	50%	95%	60%	40%	45% silt/gravel
37	0.81		5%	none		100%	95% silt/gravel
38	2.19		75%	30% (trees)		100%	20% rip-rap; 5% sand
39	2.27	5%	35%	25% (grass, shrubs)	25%	75%	60% silt/gravel
40	1.46	10%	65%	30% (grass, shrubs)	20%	80%	25% clay/silt
41	0.62	10%	85%	10% (grass)		100%	5% clay/silt
42	1.69	10%		20% (grass)		100%	90% clay/silt
43	1.12		30%	100%		100%	80% clay/silt
44	0.15			none		100%	100% clay/silt
45	1.54	15%	15%	75%	20%	80%	70% clay/silt
46	0.25			none		100%	100% gravel
47	0.50	10%	90%	15%		100%	
48	1.38	10%	90%	5%		100%	
49	1.88	20%	30%	15%		100%	50% silt/gravel
50	2.58	20%	25%	10%		100%	55% clay/silt/gravel
51	2.27	45%	40%	10%		100%	15% clay/silt/gravel
52	2.69	10%	10%	20%	20%	80%	90% clay/silt/gravel
53	1.27	5%		none		100%	90% clay/silt/gravel; 5% rip-rap
54	1.19			90%	90%	10%	100% clay/silt/gravel
55	0.35			100% (grass)	100%		100% clay/silt/gravel
56	2.15			5% (grass, shrubs)	5%	95%	100% clay/silt/gravel
57	9.15	20%	20%	25%	20%	80%	60% clay/silt/gravel
58	0.46	100%		none		100%	

59	0.65		100%	30%		100%	
60	1.88	25%	25%	65%		100%	50% clay/silt/gravel
61	0.96	5%	80%	20%		100%	10% silt/gravel; 5% rip-rap
62	0.81		95%	70%	5%	95%	5% clay/silt/gravel
63	10.15	5%	20%	80%	65%	35%	75% clay/silt/gravel
64	4.54			5%	20%	80%	90% clay/silt/gravel; 10% rip-rap
65	2.42			none		100%	75% clay/silt/gravel; 25% rip-rap
66	2.04			25%	25%	75%	100% clay/silt/gravel
67	0.62			none		100%	100% rip-rap
TOTALS							
Length (mi)	123.1	7.9	30.6		31.3	91.8	
% of total		6.4	24.8		25.4	74.6	

Figure 6–4. Shoreline Survey Segments

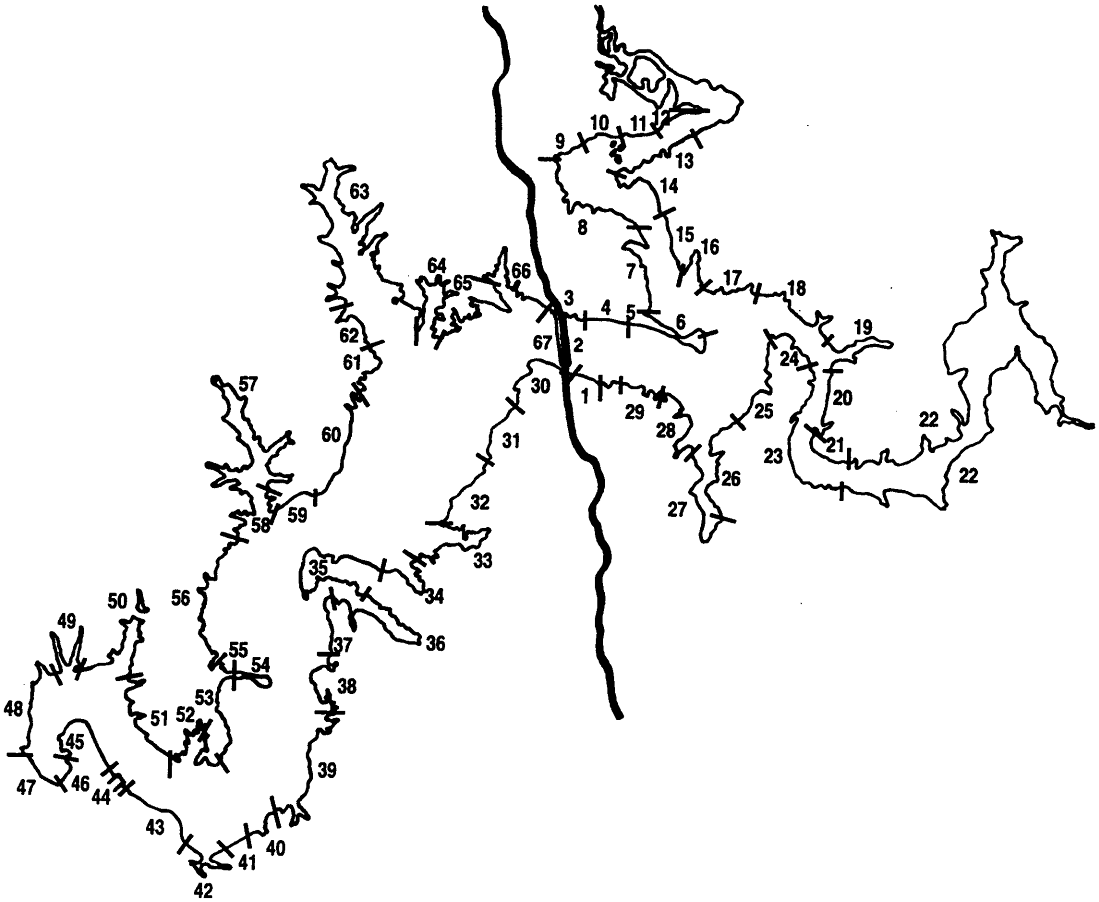


Figure 6–5. Locations of Sediment Cores and Grab Samples

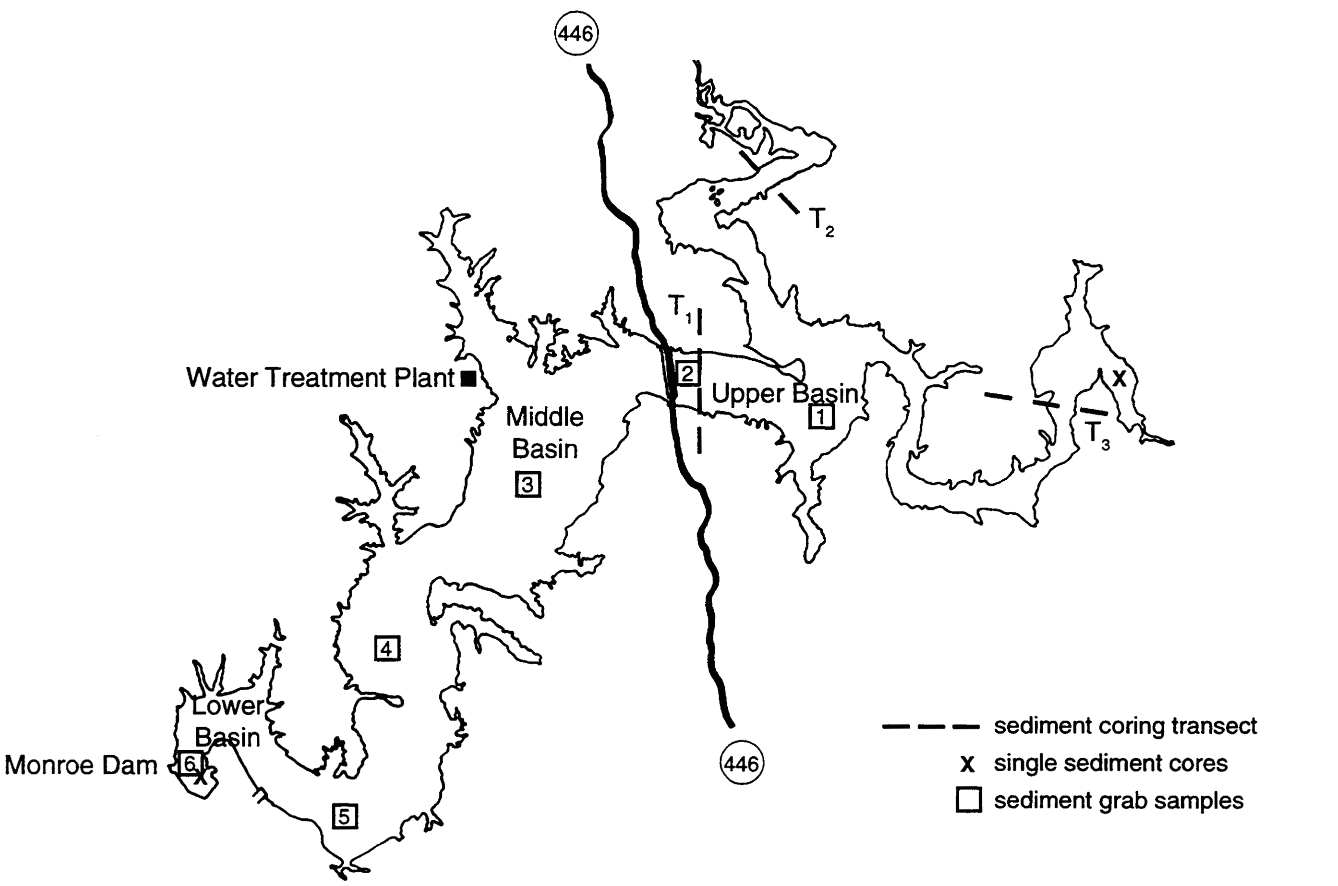


Figure 6–6. Sediment Depth Cross-Section for Transect 1, Lake Monroe

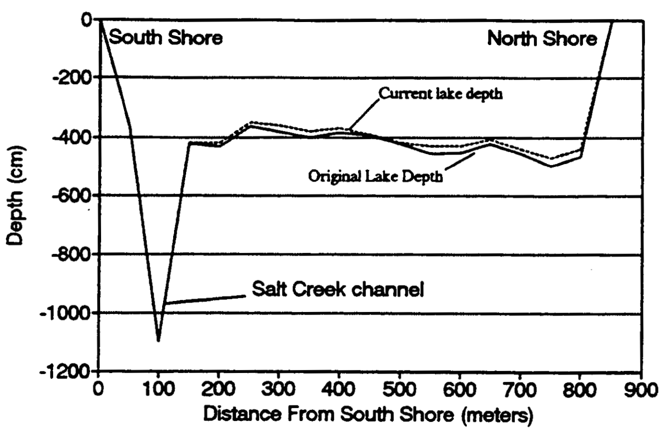
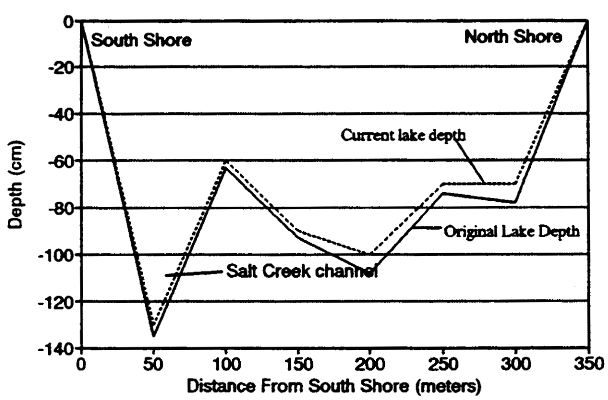


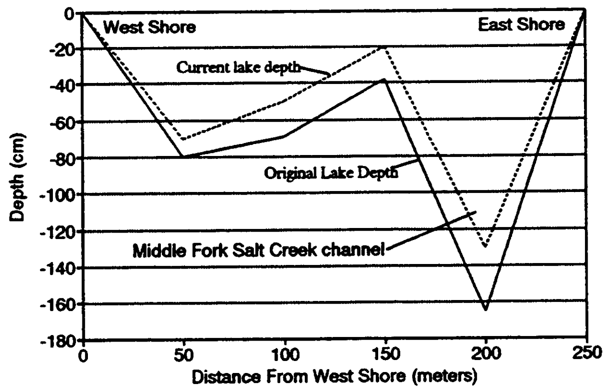
Figure 6–7. Sediment Depth Cross-Section for Transect 2, Lake Monroe



Our estimates of sediment accumulation and reservoir capcity clearly underestimate the total sedimentation rate at Lake Monroe because:

- They do not account for bedload carried in the streams.
- Discharge and, therefore, total sediment load, is underestimated for the South Fork Salt Creek basin (see Section 4.2.1).
- We could not account for sedimentation caused by shoreline erosion or by internally produced plant material.

Figure 6–8. Sediment Depth Cross-Section for Transect 3, Lake Monroe



In addition, our sediment accumulation rates are based on 1992–93 sediment loadings that we measured. Should soil erosion or runoff rates increase in the future, so will sediment accumulation in Lake Monroe. Therefore, considerable caution must be used in drawing conclusions from these results.

Our best estimate suggests that the annual sediment accumulation rate in Lake Monroe has increased by a factor of three (0.01 in/yr to 0.03 in/yr) over the last 20 years, with relatively little new land use disruption in the watershed. If stable forest cover is converted to other uses in the future at a rate greater than that of the past 20 years, the sedimentation rate will likely increase at a faster rate.

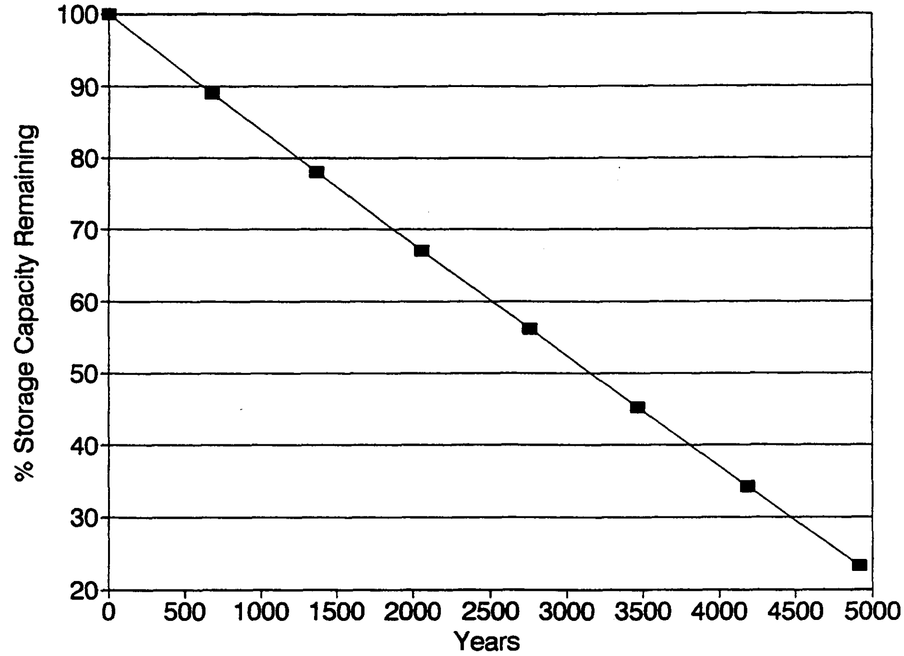
The previous calculations have been based on assumptions that sediment is deposited uniformly along the lake bottom. In fact, data from the 1976 study indicate that sediment accumulates 2 to 4 times faster in the upper basin than in the lower basin. Additionally, some local sites are more likely to accumulate sediment than other sites. So, while the lake as a whole, may not be rapidly accumulating sediment, particular locations may be filling in rather rapidly. This may be especially true in and around the Upper Basin macrophyte beds, where incoming flow velocities are reduced as the stream meets the relatively stagnant lake water. A more detailed study would be necessary to determine the locations of intensified sedimentation and the sources of the sediment.

Table 6–5. Monroe Reservoir Life Based on Modeled Sediment Load and Inflow Rate

Capacity	% Capacity	S/I	% Sed Trap*	Avg %	acre-ft/yr	Years	Cumulative Years
182527	100	0.479	95	0	0	0	0
162527	89	0.426	95	95	29.34	681.62	681.62
142527	78	0.374	94	94.5	29.19	685.22	1366.84
122527	67	0.321	93	93.5	28.88	692.55	2059.39
102527	56	0.269	92	92.5	28.57	700.04	2759.43
82527	45	0.216	91	91.5	28.26	707.69	3467.12
62527	34	0.164	90	90.5	27.95	715.51	4182.63
42527	23	0.112	86	88	27.18	735.84	4918.46

*from Brune (1953)

Figure 6–9. Projected Changes in Lake Monroe Storage Based on Current Stream Suspended Sediment Loads



6.1.4 Potential Watershed Sources of Sediments

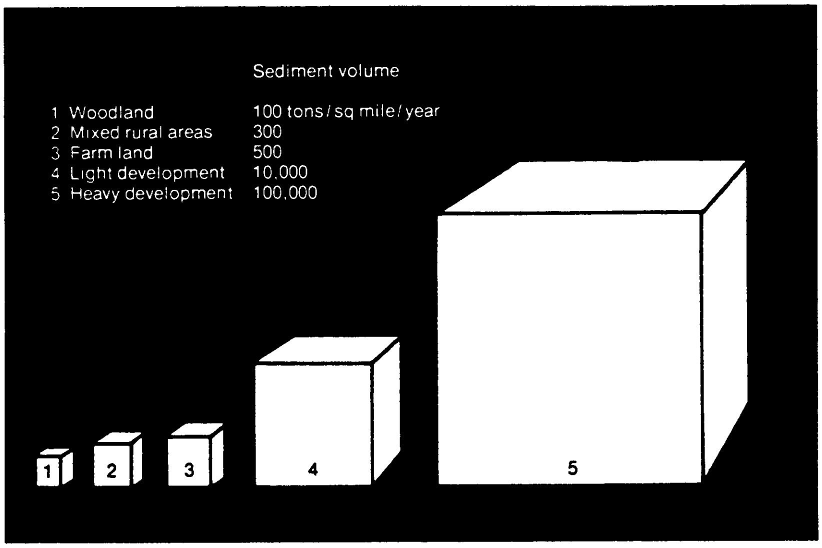
We can gain some understanding of the causes of lake sedimentation by considering the sub-watershed contributions along with land uses within those watersheds. Recall Figure 6–3 above which illustrated the percentage contribution of sediments from each subwatershed. If we also consider the land area within each subwatershed, we can derive a relative rate of sedimentation (Table 6–6). For example, although the Middle Fork of Salt Creek contributes a smaller percentage of total sediment to Lake Monroe than either the North or South Forks, its relative contribution is greater. The land within the Middle Fork subwatershed contributed, on average, 0.45 tons of sediment per year per hectare of land. The Stephens Creek subwatershed contributed the smallest relative rate of sediments (0.20 tons/ha • yr).

What can explain this variation in sediment loading among the subwatersheds? Research has shown that land use can affect erosion rates (Figure 6–10). Wooded land has the lowest soil erosion rates because the vegetation cover allows more water to infiltration into the ground rather than run off the land. Cultivation for

Table 6–6. Relative Suspended Sediment Loading to Lake Monroe

Watershed %	*Suspended Sediment Load*	*% Watershed Area*	*Areal Sediment Load (tons/ha • yr)*
Stephens	1.7	2.5	0.20
Brummetts	3.5	3.1	0.34
North Fork	19.8	23.5	0.26
Middle Fork	13.2	9.0	0.45
South Fork	15.9	21.5	0.23
Unmonitored	46.0	44.4	0.35

Figure 6–10. Volume of Sediment Eroded from Lands in Different Uses (Source: Thurow, et al., 1975)



row crops temporarily removes the protective vegetation cover and soil erosion rates increase. Development can further increase erosion rates. Construction activities may also leave large areas of land without a protective vegetation cover. The increase of roads and buildings on the landscape increase the amount of impervious surfaces which increases runoff. Increased runoff volume and velocity, in turn, increases soil erosion rates. Care must be taken in interpreting Figure 6–10 because not all soil eroded due to a given land use is delivered to a stream or lake. Much of the eroded soil is deposited on land downslope from the activity and may not directly reach a water body.

Land use by subwatershed is illustrated in Figure 6–11. All the watersheds have a relatively large percentage of forest land. The South Fork has the greatest percentage of agricultural land followed by Middle Fork. It is the Middle Fork which has the highest sediment delivery rates so there is not a conclusive correlation with agricultural activities at this level of analysis. Urban land uses are low overall, with Stephens, North Fork and Unmonitored subwatersheds having the highest percentage in this land use.

Erosion rates and the delivery of eroded soil is also influenced by land slope. The South Fork, which has the greatest percentage of agricultural land, has relatively shallow land slopes so this likely affects sediment delivery to Lake Monroe (Table 6–7). Brummetts Creek and the Unmonitored area have the steepest slopes and this may help account for their higher sediment losses. The Middle Fork remains an enigma since its slope and land use characteristics are similar to those of the North Fork but sediment losses are much higher. Management practices applied to the land use activities are other variables which must be considered before definitive relationships can be identified.

6.2 Sediment Characteristics

6.2.1 Methods

Surficial sediment samples were collected from Lake Monroe at six different sites along the length of the lake (Figure 6–5). At the first site, two replicate samples were collected to test for precision. The samples were collected using an Ekman dredge, then transferred into whirl-pac bags and kept in a cooler filled with ice.

In the laboratory, the following were determined for each sample: color, particle size distribution, percent organic matter, total phosphorus, and total Kjeldahl nitrogen. Munsell color charts were used to determine color. Particle size was determined using hydrometers according to ASTM methods. Organic matter content of the dried sediment samples were determined by weight loss following ashing in a muffle furnace at 550°C for four hours. Total phosphorus and total Kjeldahl nitrogen was determined following mercuric sulfate digestion on an Alpkem FLOW Solution Autoanalyzer Model 3570.

Figure 6–11. Land Use Categories by Lake Monroe Sub-Watershed

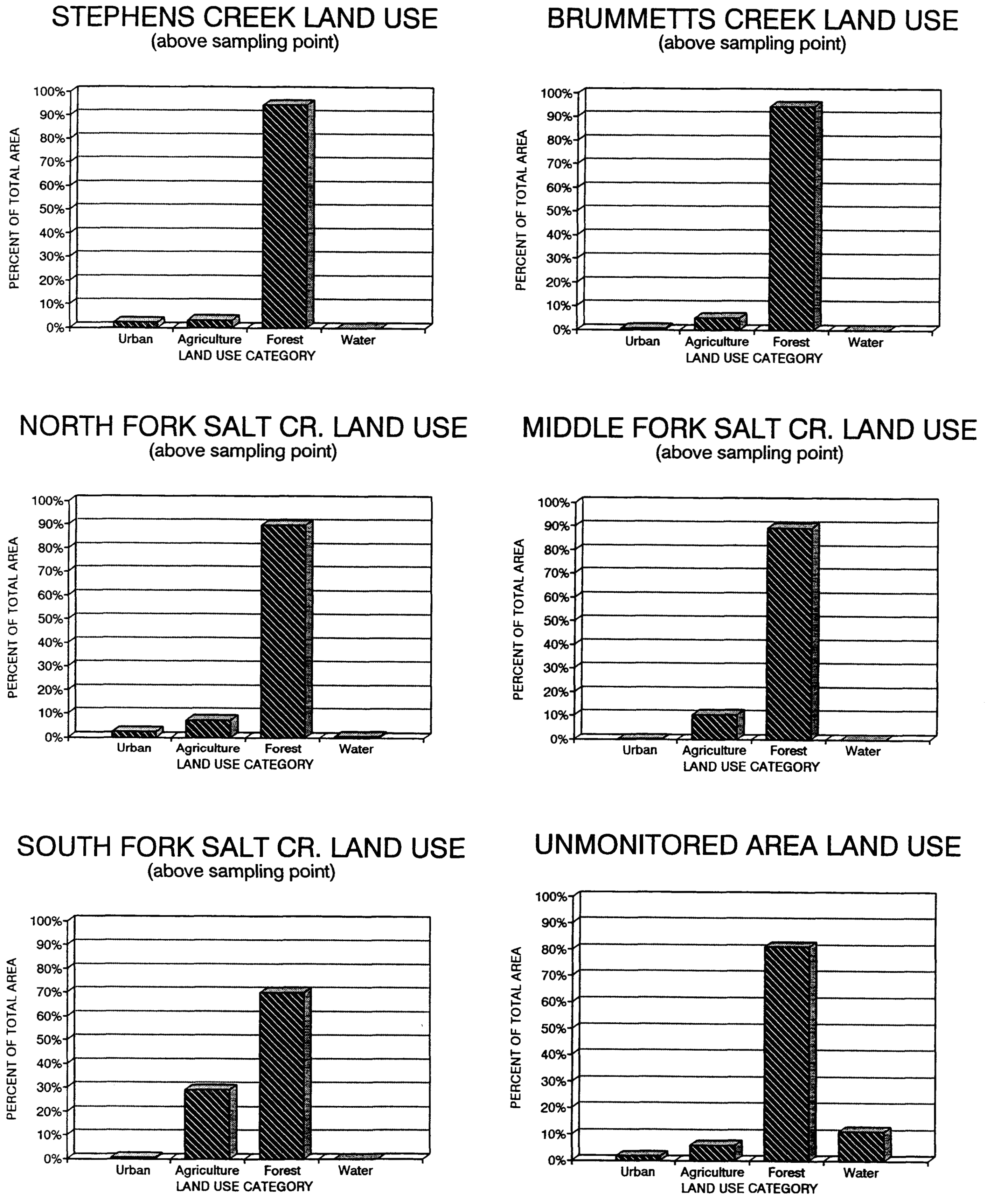


Table 6–7. Percentage of Subwatershed Land in Various Slope Classes

Slope Class	*Stephens*	*Brummetts*	*North Fork*	*Middle Fork*	*South Fork*	*Unmonitored*
0–5 %	43.3 %	43.1 %	46.9 %	47.9 %	68.0 %	48.1 %
5–10%	41.7	35.5	37.8	37.0	28.1	33.5
10–15%	12.3	15.3	12.1	12.1	3.5	13.3
15–20%	2.3	4.9	2.5	2.6	0.4	3.7
20–25%	0.3	0.8	0.5	0.4	<0.1	1.0
25–30%	0.1	0.2	0.1	<0.1	<0.1	0.3
30–35%	<0.1	0.2	<0.1	<0.1	<0.1	0.1

6.2.2 Color Analysis

Table 6–8 shows the results of the color analyses. Sediments lying at approximately the same depths were similar in color. The darker colors correspond to those samples extracted at greater depth, namely Sites 4, 5, and 6.

6.2.3 Particle Size

The particle size distribution of a sediment sample defines the percentage amounts of the different size ranges in the sediment (by dry weight). The common classification of sedimentary particles was devised by C.K. Wentworth in 1922 according to the following (Twenhofel, 1950):

Name of Particles	*Dimensions, mm*
Boulder	256 or above
Cobble	64 to 256
Pebble	4 to 64
Granule	2 to 4
Very coarse sand grain	1 to 2
Coarse sand grain	0.5 to 1
Medium sand grain	0.25 to 0.5
Fine sand grain	0.125 to 0.25
Very fine sand grain	0.0625 to 0.125
Silt particle	3.9×10^{-3} to 0.0625
Clay particle	Smaller than 3.9×10^{-3}

Table 6–8. Lake Monroe Sediment Color

Sample	*Water Depth (ft)*	*Munsell Soil Color (wet)*	*Munsell Soil Color (dry)*
1A	12	Olive Gray; 5Y 4/2	Light Yellowish Brown; 2.5Y 6/3
1B	12	Olive; 5Y 4/3	Light Yellowish Brown; 2.5Y 6/3
2	17	Olive; 5Y 4/3	Light Yellowish Brown; 2.5Y 6/3
3	20	Olive; 5Y 4/3	Light Yellowish Brown; 2.5Y 6/3
4	27	Dark Olive Gray; 5Y 3/2	Light Yellowish Brown; 2.5Y 6/3
5	34	Black; 5Y 2.5/2	Light Yellowish Brown; 2.5Y 6/3
6	33	Dark Olive Gray; 5Y 3/2	Light Yellowish Brown; 2.5Y 6/3

The particle size distributions of all seven samples (Table 6–9) show a high percentage of extremely small particles. The majority of the samples were less than 0.0625 mm in diameter, classifying them as silt and clay. The percentage of particles retained on a #200 sieve, and therefore larger than 0.075 mm, was less than 1% in all of the samples that were examined. These particles are classified as very fine sand grains.

The fine clay particles which characterize Lake Monroe's sediment load have a very slow settling rate and thus, stay in suspension in the water column for a long time (Table 6–10). It takes very little water movement energy to overcome the low density of these particles to prevent their settling. For example, a coarse clay with a settling rate of 0.0015 cm/sec, would take 11.7 days to settle through five feet of absolutely calm, undisturbed water. Given this, it is no wonder that Lake Monroe's water appears turbid and brown in color due to the suspended clay particles.

In lakes and reservoirs having a single major inlet, the largest soil particles drop out initially because it takes more energy to keep them suspended. As the water moves through the lake, losing energy along the way, finer particles drop out. This creates a gradient of larger to smaller particles from the inlet to the outlet. Because there is little variation in particle size in Lake Monroe sediments, we do not observe this gradient in our particle size data. Deposited sediments may continue to move along the lake bottom downgradient to deeper areas of the lake. This movement is called *focusing.*

Sample 2 had the largest percentage of clay which may be attributed to the sample location near the Highway 446 causeway where settling of fine particles can occur. In Lake Monroe, the causeway acts like a dam and significantly slows down water and sediment movement through the lake (Figure 6–12). Sediments suspended in runoff should undergo more settling in the Upper Basin because of this.

Table 6–9. Particle Size Distribution in Lake Monroe Sediments

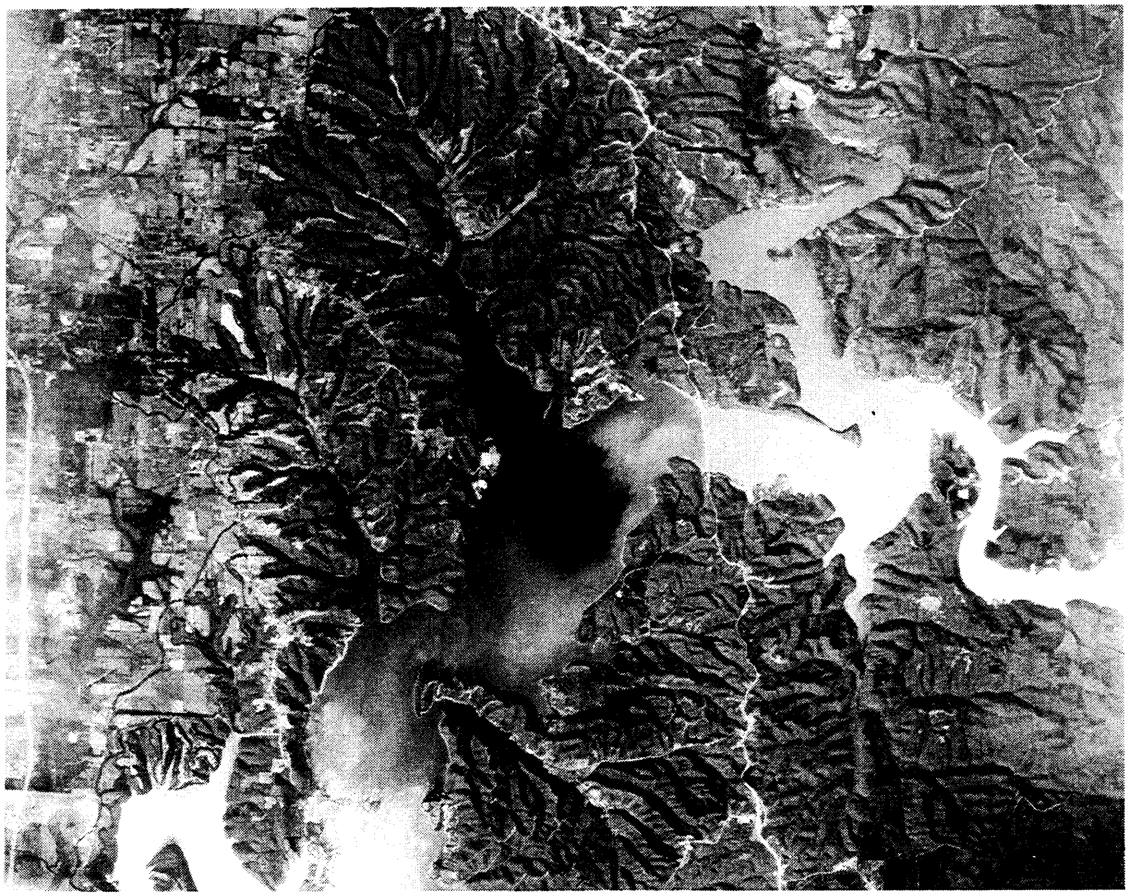
Sample	*Clay % less than 0.0039 mm*	*Silt % between 0.0039 and 0.0625 mm*	*Very Fine Sand % between 0.0625 and 0.125 mm*
1A	41.0	58.5	0.36
1B	45.0	54.5	0.27
2	57.0	43.0	0.27
3	36.0	63.5	0.46
4	32.5	66.5	0.90
5	48.0	51.5	0.34
6	37.5	62.0	0.43

Table 6–10. Settling Rates for Soil Particles of Different Sizes

Material	*Diameter (mm)*	*Settling Rate (cm/sec)*	*Time Needed to Settle 5 Feet*
Coarse Sand	1.0	10.0	5.2 min
Coarse Sand	0.2	2.1	1.2 min
Fine Sand	0.1	0.8	3.2 min
Fine Sand	0.06	0.38	6.7 min
Fine Sand	0.04	0.21	2.1 min
Silt	0.01	0.015	2.8 hrs
Coarse Clay	0.001	0.00015	11.7 days
Fine Clay	0.0001	0.00000015	11759.0 days

Source: Tourbier and Westmacott (1976)

Figure 6–12. Suspended Sediment Pattern in Lake Monroe Following a Spring 1986 Runoff Event (Note Sediment Plumes from Watershed to the East and from Erosion of the Fairfax Peninsula to the Southwest)



6.2.4 Organic Matter

The amount of organic carbon in lake sediments is a measure of how well organic matter, either produced in the lake or entering the lake, is processed by decomposers, largely bacteria. A significant amount of organic matter in sediments suggests a high biological oxygen demand (BOD) which can consume oxygen in the deeper water. Table 6–11 gives the calculated amount of organic matter for each of the samples. Overall, organic matter content ranged from 2.14 to 3.53 %. These are relatively low amounts for lake sediments. Lake Monroe has relatively low organic matter production. This, along with a reasonable water flushing rate, well-oxygenated water, and deposition of new sediments all contribute to lower the organic matter content of the sediments.

The organic matter content in Lake Lemon's sediments are similarly low, ranging from 2.2 to 4.3 % (Zogorski, et al., 1986). An extremely rapid water flushing rate (five times per year) and heavy sedimentation of eroded soils contribute to dilute the organic matter in these sediments. In highly productive and poorly flushed Cedar Lake, a natural lake in Lake County, Indiana, the sediment organic matter content is much higher, ranging from 17–20 % (Echelberger, et al., 1984).

The slightly higher organic contents seen at Sites 4 and 5 correspond to the greater water depth at these sites. Focusing could concentrate organic material in these deeper areas. In addition, the bottom water at these depths is not as well mixed and since anaerobic decomposition of the organic matter is slower, this could result in greater accumulation. Although Sample 6 was also extracted from a greater depth, it has the lowest organic content

Table 6–11. Organic Carbon Content in Lake Monroe Sediments

Sample	*Sample Wt. Before Drying (g)*	*Sample (g) Lost From Drying*	*Organic Carbon (%)*
1A	4.6526	0.1361	2.92
1B	4.6782	0.1400	2.99
2	3.9934	0.1020	2.55
3	4.1280	0.1060	2.57
4	4.2145	0.1454	3.45
5	4.2546	0.1501	3.53
6	4.0361	0.0862	2.14

indicating that the waters in this area are more mixed and decomposition of organic matter is occurring too fast to allow for much accumulation. Currents in this section of the lake, which is situated near the old channel as well as the dam outlet, could also lessen accumulation.

6.2.5 Nitrogen and Phosphorus

Sediment-bound nutrients represent a potential pool of nutrients which can, under certain circumstances, be released back into the water column to nourish algae. Unfortunately, there are no guidelines for assessing the amounts of nutrients in lake sediments. In hypereutrophic Cedar Lake, concentrations of total Kjeldahl nitrogen (TKN) and total phosphorus (TP) in surficial sediments were 11.0 mg/g and 1.0 mg/g dry weight respectively (Echelberger, et al., 1984). In this case, these sediments were a major source of nutrients to the water. In Lake Lemon, TKN concentrations ranged from 1.16 – 2.01 mg/g and TP ranged from 0.18 – 0.54 mg/g (Zogorski, et al., 1986).

In Lake Monroe surficial sediment samples, TKN ranged from 1.10 to 3.47 mg/g dry weight (Table 6–12). Highest values were in the Upper Basin where most of the rooted plants are located and in the Lower Basin where focusing is most likely to be important. Total phosphorus concentrations ranged from 0.31 to 0.60 mg/g dry weight. Phosphorus concentrations were also highest in Lower Basin samples.

6.2.6 Toxic Compounds

The most recent examination of Lake Monroe sediments for analysis of toxic compounds was conducted by the Indiana Department of Environmental Management on July 23, 1985. Surface grab samples of sediments from six locations in the lake were analyzed for: 13 metals, 18 pesticides, 24 volatile organic compounds (VOC) and 7 PCB congeners. Pesticides, VOCs and PCBs were all below the detection limit of the method used. Selected results for metals are given in Table 6–13.

Table 6–12. Lake Monroe Sediment Nutrient Concentrations (dry weight)

Sample Site	*Total Kjeldahl Nitrogen (mg/g)*	*Total Phosphorus (mg/g)*
1	1.76	0.31
2	1.58	0.47
3	1.10	0.32
4	1.36	0.51
5	2.13	0.52
6	3.47	0.60

Table 6–13. Sediment Toxic Compound Results (units in mg/kg dry wt.)

Sample Site	*Arsenic*	*Chromium*	*Lead*	*Mercury*	*Nickel*	*Zinc*
Dam	5.9	18.0	<12.0	0.038	18.0	66.0
Sugar Camp Creek Bay	14.0	52.0	<16.0	0.055	32.0	120.0
Ramp Creek	4.8	21.0	13.0	0.045	16.0	83.0
Moores Creek	2.1	11.0	<17.0	0.029	13.0	45.0
N. Fork Salt Creek	4.3	14.0	<15.0	0.030	15.0	56.0
Crooked Creek	4.6	17.0	13.0	0.037	17.0	70.0
EPA Guidelines						
Heavily polluted	>8	>75	>60	>1.0	>50	>200
Non-polluted	<3	<25	<40		<20	<90

(U.S. EPA, 1977)

Arsenic content of Lake Monroe sediments exceeds the U.S. EPA guidelines for non-polluted sediments (U.S. EPA, 1977) at all but the Moores Creek site, and exceeds the heavily polluted guideline for the Sugar Camp Creek Bay sample. The Sugar Camp Creek Bay site also exceeds the non-polluted guidelines for chromium, nickel, and zinc. The other sites all tested below the non-polluted guideline for the remaining metals. Sugar Creek enters the north side of Lake Monroe immediately to the west of the Fairfax State Recreation Area. The source(s) of metals to this creek and bay is not known.

7.0 NUTRIENT BUDGET

Of the major plant nutrients, phosphorus is most often targeted by lake and reservoir management plans (Cooke, et al. 1993). Phosphorus is the limiting plant nutrient in Lake Monroe and it is possible to control phosphorus loading into the lake with careful management.

In this chapter, we present the phosphorus budget for Lake Monroe based on our stream sampling results. We also use an empirical phosphorus loading model to estimate the amount of phosphorus loading to Lake Monroe as further verification of our measurements. Finally, we present the results of more detailed modeling efforts on several smaller sub-watersheds using the Agricultural Nonpoint Source Model (AGNPS). With the AGNPS model, we can investigate how future land use changes and management efforts will affect the loading of water, phosphorus, nitrogen and sediments to Lake Monroe.

7.1 Phosphorus Budget

7.1.1 Inputs

The phosphorus load was determined by multiplying the total phosphorus [g/m^3] measured at the five stream sites times the modeled stream discharge [m^3/s] for the same sites. A regression relationship was determined relating the measured total phosphorus to the stream discharge as follows:

$TP = a\,Q + b$ where:
TP = total phosphorous
Q = stream discharge
a = x coefficient (slope)
b = y intercept

This relationaship was needed to estimate phosphorus loading for the times in between our own water sampling. The results of these regressions are presented in Figure 7–1. The R^2 values ranged from a high for Middle Fork of 0.73 to a low for the North Fork of 0.36. The resulting modeled phosphorus loads are plotted in Figures 7–2 through 7–6.

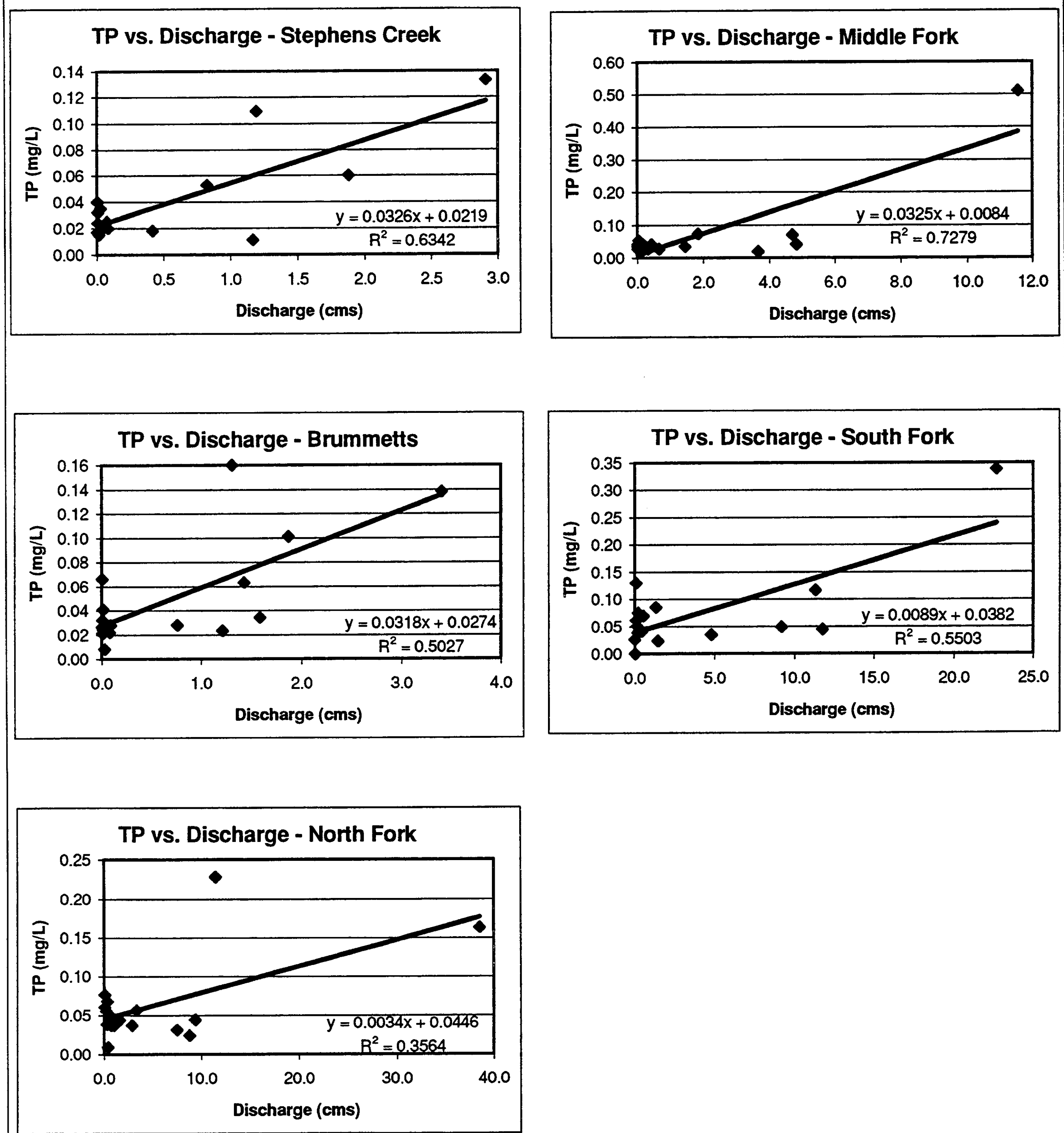
To model the phosphorus load from the unmonitored portion of the watershed, we applied the regression relationship for Brummetts Creek to the unmonitored area. We used the Brummetts Creek watershed to determine this relationship since it is similar to the unmonitored watersheds in terms of watershed size, topography, and land use. We estimated total phosphorous loading for the unmonitored areas as:

$P_{um}[mg/sec] = P_{Br}[mg/sec] * A_{um}/A_{Br}$ where:
P = phosphorous
A_{um} = area of unmonitored area
A_{Br} = area of Brummetts Creek watershed

The total phosphorus loads calculated from our stream measurements are summarized in Table 7–1 by month and in Table 7–2 by stream, and in Figure 7–7.

Total estimated phosphorus loading to Lake Monroe was 46,544 kg/yr. Seasonal variation in phosphorus loading to the lake is associated with seasonal differences in precipitation and land use activities. The greatest amount of this phosphorus loading comes from the unmonitored areas followed by the North Fork Salt Creek watershed. The greatest rate of loading (kg/ha-yr) comes from the South Fork Salt Creek watershed. This is somewhat expected since the South Fork watershed has the most agricultural land use. In fact, the South Fork

Figure 7–1. Results of Phosphorus vs. Discharge Regressions for Measured Values, Lake Monroe Watershed



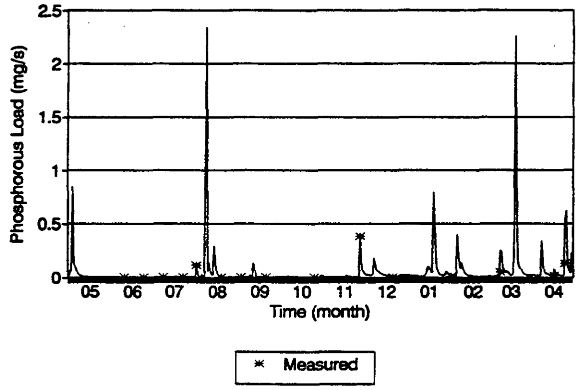


Figure 7–2. Modeled Phosphorus Load for Stephens Creek

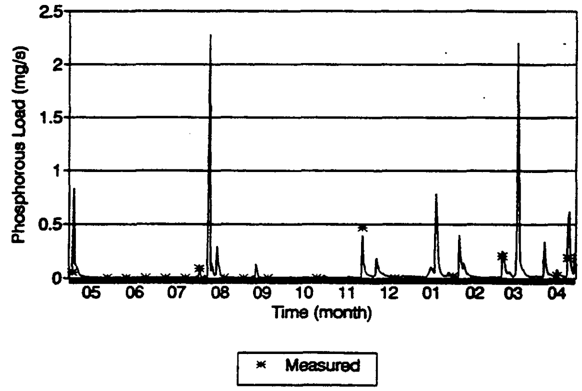


Figure 7–3. Modeled Phosphorus Load for Brummetts Creek

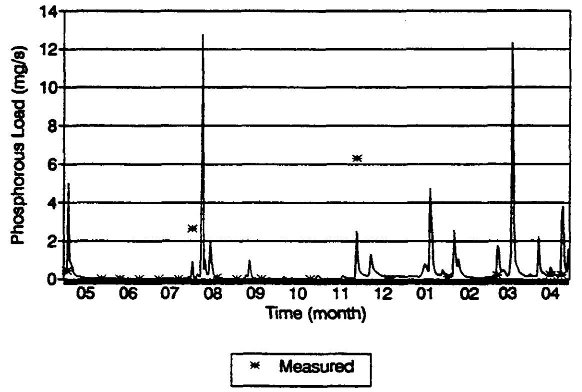


Figure 7–4. Modeled Phosphorus Load for North Fork Salt Creek

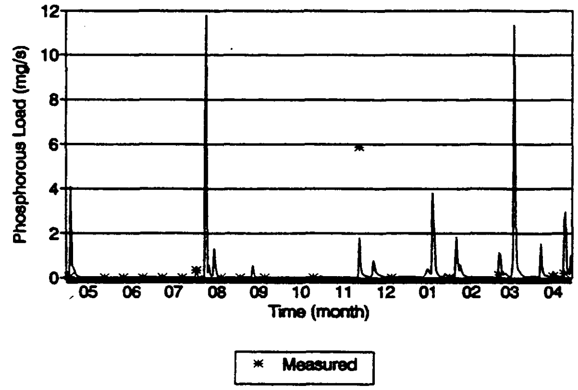


Figure 7–5. Modeled Phosphorus Load for Middle Fork Salt Creek

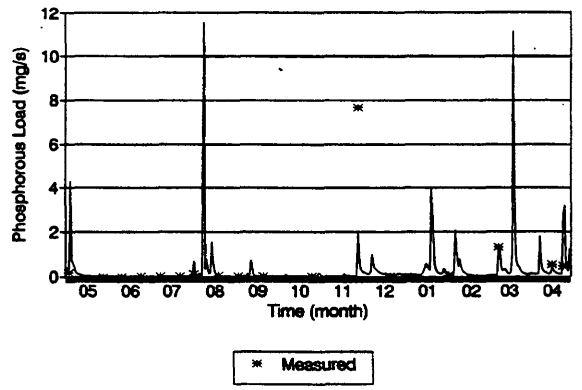


Figure 7–6. Modeled Phosphorus Load for South Fork Salt Creek

had the highest measured mean total phosphorus concentration for the five stream sites (72.8 µg/L). However, because it's likely that discharge was underestimated at the South Fork in the discharge model (see Chapter 4), the total phosphorus loads in the South Fork would also be underestimated.

7.1.2 Phosphorus Outputs

The discharge of phosphorus at the outlet was obtained by multiplying the measured total phosphorus times the monthly outlet discharge. The results indicate that 33% of the phosphorus delivered annually to the lake was discharged at the outlet, suggesting that the lake acts as a phosphorus sink, trapping 67% (31,490 kg/yr) of the incoming phosphorus. In the 1973 National Eutrophication Survey of Lake Monroe, the U.S. EPA (1976a) estimated the net annual phosphorus accumulation in the lake as 5,295 kg. This large difference indicates a substantial increase in annual phosphorus loading to Lake Monroe during the 20 years separating the two studies. Estimation error could also account for some of this difference.

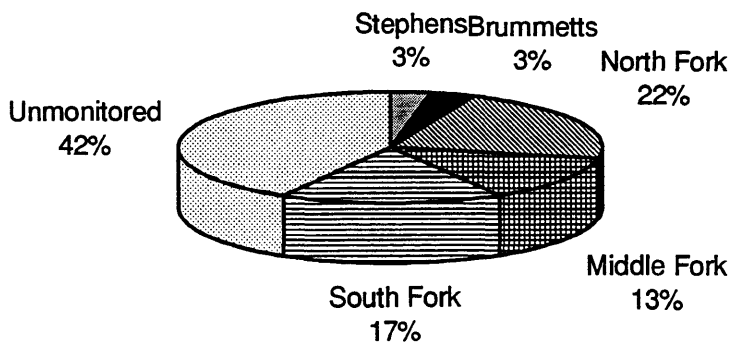
Table 7–1 Modeled Monthly Phosphorus Inputs and Outputs for Lake Monroe

		IN		OUT	IN-OUT
Year	Month	Unmonitored (kg)	Monitored (kg)	Outlet (kg)	(kg)
1992	April 15	917	1290	-199	2007
	May	78	120	-570	-372
	June	28	44	-526	-454
	July	3713	5102	-913	7902
	August	398	577	-3582	-2607
	September	67	102	-143	26
	October	94	143	-338	-101
	November	1677	2385	-514	3549
	December	669	985	-663	992
1993	January	3484	4881	-1130	7235
	February	1064	1519	-3116	-534
	March	4684	6485	-2788	8381
	April 14	2523	3513	-573	5463
	Annual	19396	27148	-15055	31490

Table 7–2. Phosphorus Budget

Watershed	*TP Load (kg/yr)*	*% of Total Load*	*Areal TP Loading Rate (kg/ha-yr)*	*Mean Measured TP (µmg/L)*
Stephens	1447	3.1	1.8	61.1
Brummetts	1472	3.2	2.2	66.4
North Fork	10201	21.9	2.2	64.2
Middle Fork	6191	13.3	1.6	67.6
South Fork	7831	16.8	2.9	72.8
Unmonitored	19402	41.7	2.5	–

Figure 7–7. Annual Phosphorus Loading to Lake Monroe (46,544 kg/yr)



7.2 Phosphorus Export Model

To help validate our phosphorus budget and to gain a better understanding of the relationship between land use and phosphorus loading, we applied a phosphorus export model to the Lake Monroe watershed. Reckhow, et al. (1980) compiled phosphorus export coefficients from 134 measured plots under various conditions of land use. These coefficients represent the mass loading of phosphorus to a surface water body per year per unit of source (e.g., per hectare of forested area). Box plots summarizing these coefficients are illustrated in Figure 7–8. Row crop agriculture and feedlots have the highest mean phosphorus export coefficients with urban land uses the third highest.

To use these phosphorus export coefficients, the export coefficient for a specific land use is multiplied times the area of land in that use. The mean values should be used unless specific land use practices or other conditions which could increase or decrease the likelihood of phosphorus export are known. For example, Reckhow, et al. (1980) suggest that land slope can affect the export of phosphorus from the land.

We applied Reckhow's phosphorus export model to the Lake Monroe subwatersheds broken down by land use and slope. Mean export coefficients were used for 0–5% slopes. Higher export coefficient values, up to the 75th percentile, were used for higher slopes. For agricultural lands, we used the mean value of the row crop plus pasture coefficients.

The phosphorus export model results are given in Table 7–3. The total annual phosphorus load to Lake Monroe using export coefficients is 46,257 kg. This compares remarkably well to the 46,537 kg of phosphorus estimated from the measured stream data. Using export coefficients, the South Fork drainage contributes a greater share of total phosphorus loading (32.8%) to the lake (Figure 7–9) than it did from our measured values (16.8%). Some of this difference may be due to the likely underestimation of discharge in the South Fork which was used to calculate our measured phosphorus loads.

When broken down by land use, agricultural land contributes 48.5% of total phosphorus loading, followed by forests (47.2%) (Figure 7–10). The forest contribution is so large due to the substantial amount of watershed area in forested land use. The estimated contribution from urban land uses is only 4.3% of the total phosphorus load. The urban contribution is likely underestimated because many of the smaller urban/residential plots were too small for the geographic information system to resolve (see Chapter 2).

7.3 AGNPS Modeling

Potential watershed nonpoint sources of pollution are numerous. Sources of such pollution include soil erosion and sedimentation on rural and urban land, eroding streambanks, and nutrient and organic materials from livestock wastes and agricultural land (Young et al., 1987). The identification of specific nonpoint sources is difficult because these sources are often distributed over the entire area of a lake's watershed. To assist us in identifying potential nonpoint sources in Lake Monroe's watershed and assessing their magnitude, we used the Agricultural Nonpoint Source Model (AGNPS).

The AGNPS model was developed by the Agricultural Research Service (ARS) in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service (SCS) (now the Natural Resources Conservation Service) . The model was developed to analyze and provide estimates of runoff water quantity and quality from agricultural watersheds ranging in size from a few hectares to upwards of 20,000 ha (50,000 acres). AGNPS provides information on runoff volume and peak runoff, and estimates upland erosion, channel erosion, and sediment yield. In addition, AGNPS estimates the concentrations and masses of nitrogen (N), phosphorus (P), and chemical oxygen demand (COD) contained in the runoff and the sediment.

Table 7–3. Phosphous Export Model Results for the Lake Monroe Watershed

Land Use/ Slope Class	STEPHENS CREEK Area (ha)	Export Coef. (kg/ha-yr)	Phos. Exported (kg/yr)	BRUMMETTS CREE Area(ha)	Export Coef. (kg/ha-yr)	Phos. Exported (kg/yr)	NORTH FORK Area(ha)	Export Coef. (kg/ha-yr)	Phos. Exported (kg/yr)	MIDDLE FORK Area(ha)	Export Coef. (kg/ha-yr)	Phos. Exported (kg/yr)	SOUTH FORK Area(ha)	Export Coef. (kg/ha-yr)	Phos. Exported (kg/yr)	UNMONITORED Area(ha)	Export Coef. (kg/ha-yr)	Phos. Exported (kg/yr)
URBAN																		
0-5%	43.3	1.1	47.7	16.5	1.1	18.1	326.0	1.1	358.6	23.1	1.1	25.4	126.7	1.1	139.4	494.8	1.1	544.3
5-10%	17.7	1.5	26.6	4.0	1.5	6.0	183.0	1.5	274.4	8.3	1.5	12.4	0.0	1.5	0.0	162.9	1.5	244.3
10-15%	0.2	1.9	0.4	0.0	1.9	0.0	50.8	1.9	96.5	4.3	1.9	8.2	0.0	1.9	0.0	28.6	1.9	54.4
15-20%	0.0		0.0	0.0		0.0	6.0	2.3	13.8	1.7	2.3	3.8	0.0	2.3	0.0	8.7	2.3	20.0
20-25%	0.0		0.0	0.0		0.0	0.8	2.6	2.1	0.0	2.6	0.0	0.0	2.6	0.0	6.1	2.6	16.0
25-30%	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	1.1		0.0
subtotal	61.3		74.7	20.5		24.1	566.5		745.4	37.3		49.8	126.8		139.4	702.2		878.9
AGRICULTURE																		
0-5%	70.6	0.9	63.5	105.9	0.9	95.3	1350.0	0.9	1215.0	639.5	0.9	575.5	5822.4	0.9	5240.1	2696.6	0.9	2426.9
5-10%	13.4	1	13.4	32.3	1	32.3	394.5	1	394.5	149.9	1	149.9	848.4	1	848.4	598.4	1	598.4
10-15%	2.0	1.1	2.2	15.2	1.1	16.7	73.5	1.1	80.9	24.9	1.1	27.4	71.7	1.1	78.8	135.6	1.1	149.2
15-20%	0.0	1.2	0.0	3.9	1.2	4.6	11.4	1.2	13.7	0.7	1.2	0.8	1.2	1.2	1.4	7.5	1.2	9.1
20-25%	0.0	1.3	0.0	4.1	1.3	5.3	1.2	1.3	1.6	0.0	1.3	0.0	0.0	1.3	0.0	0.2	1.3	0.2
25-30%	0.0	1.4	0.0	3.2	1.4	4.4	0.9	1.4	1.3	0.0	1.4	0.0	0.0	1.4	0.0	0.0	1.4	0.0
30-35%	0.0	1.5	0.0	6.3	1.5	9.4	0.0	1.5	0.0	0.0	1.5	0.0	0.0	1.5	0.0	0.0	1.5	0.0
subtotal	86.0		79.1	170.9		168.2	1831.5		1706.9	815.0		753.7	6743.5		6168.7	3438.4		3183.8
FOREST																		
0-5%	1050.3	0.22	231.1	1332.7	0.22	293.2	10011.6	0.22	2202.6	3989.4	0.22	877.7	9743.1	0.22	2143.5	15427.5	0.22	3394.1
5-10%	1090.6	0.24	261.7	1164.7	0.24	279.5	8985.9	0.24	2156.6	3426.6	0.24	822.4	5627.1	0.24	1350.5	15255.8	0.24	3661.4
10-15%	327.4	0.26	85.1	500.5	0.26	130.1	2936.1	0.26	763.4	1146.7	0.26	298.1	740.1	0.26	192.4	6196.5	0.26	1611.1
15-20%	60.8	0.28	17.0	162.8	0.28	45.6	603.4	0.28	169.0	249.0	0.28	69.7	71.1	0.28	19.9	1732.3	0.28	485.0
20-25%	8.4	0.3	2.5	24.4	0.3	7.3	135.4	0.3	40.6	36.8	0.3	11.0	0.0	0.3	0.0	477.6	0.3	143.3
25-30%	2.1	0.32	0.7	2.8	0.32	0.9	29.9	0.32	9.6	2.2	0.32	0.7	0.0	0.32	0.0	138.5	0.32	44.3
30-35%	0.0	0.34	0.0	0.8	0.34	0.3	4.0	0.34	1.4	0.0	0.34	0.0	0.0	0.34	0.0	30.2	0.34	10.3
subtotal	2539.6		598.2	3188.9		757.0	22706.4		5343.1	8850.7		2079.6	16187.8		3706.3	39258.3		9349.4
TOTALS	2687.1		751.9	3380.3		949.3	25269.7		7795.4	9703.6		2883.1	23084.6		10014.4	47760.8		13412.2

*percentage totals other than 100% are due to round-off error and the omission of water bodies.

Figure 7–8. Box Plots of Phosphorus Export Coefficients from Various Land Uses (From: Reckhow et al., 1980)

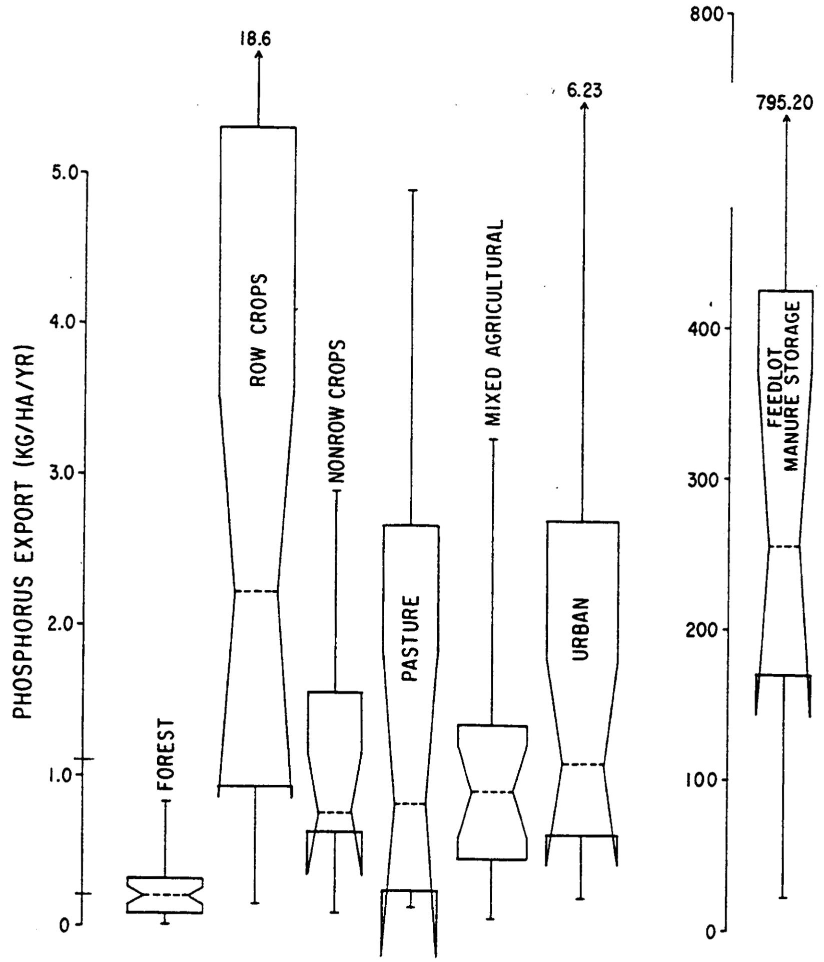


Figure 7–9. Phosphorus Loading to Lake Monroe Estimated from Export Coefficients (35,806 kg/yr)

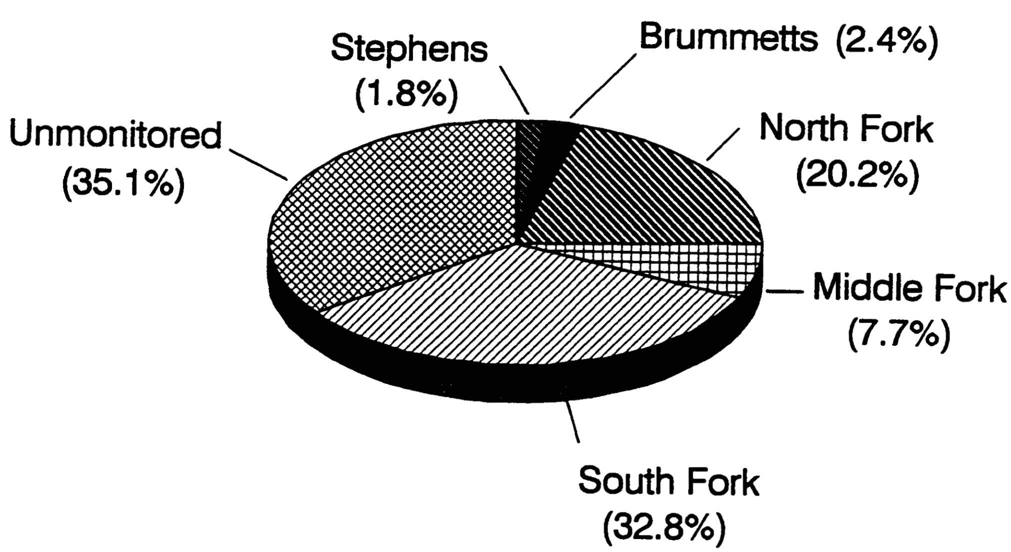
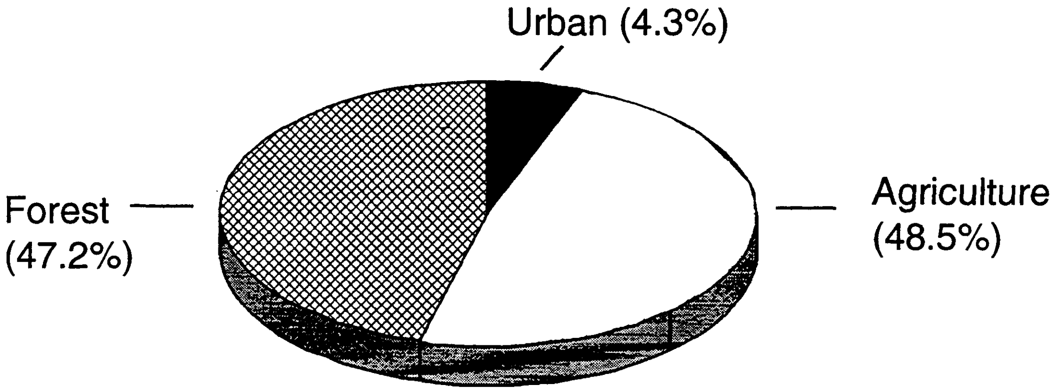


Figure 7–10. Estimated Phosphorus Loading to Lake Monroe by Land Use



7.3.1 Methods

AGNPS is event-based. As such, it works only for a single storm event of known volume and intensity. For Lake Monroe, we used a 3.1 inch rainstorm with an intensity of 54 foot-tons per acre-inch. This represents conditions that would be expected during a 24-hour storm with a frequency of once every two years. These values were obtained from the Soil Conservation Service (1966) from data for Indiana.

Because AGNPS can be run only for single storm events, annual yields of runoff, sediment, and nutrients from the modeled watershed cannot be calculated. However, the model is still useful in comparing relative yields of these materials from specific watershed areas and under different management conditions.

U.S. Geological Survey 7.5 minute topographical maps (scale 1:24,000) were used as base maps for Lake Monroe and its watershed. Clear acetate containing a grid of cells was laid over the base map. Each cell represented 40 acres. Only those cells with more than 50% of their area within the watershed boundaries were included. Where land features within a 40-acre cell were substantially different, the cell was divided into four 10-acre cells.

For Lake Monroe, we modeled three smaller watersheds with three different land use assemblages: Stephens Creek, Hamilton Creek and Ramp Creek. Stephens Creek watershed has mixed land uses with forests, agriculture, and some urban/built-up areas. The Hamilton Creek watershed, located within the Middle Fork Salt Creek basin, is also dominated by forests but has a substantial amount of agricultural land. The Ramp Creek watershed, located to the north of the Lake Monroe dam, has mixed amounts of agriculture (primarily pasture) and forest, but is receiving increasing development pressure.

For each of the cells in the three watersheds, 22 separate parameters were determined. The following is a brief description of each parameter.

Cell Numbering. Each cell was numbered beginning in the northwest corner of the watershed and proceeding from west to east, southward. This numbering scheme, used in AGNPS for labeling cells, aided in quickly identifying specific cells in the program's output (see Figures 7–11 through 7–13). Using this numbering scheme, Stephens Creek watershed required 172 cells, Hamilton Creek 224 cells, and Ramp Creek 64 cells.

Receiving Cell. The receiving cell is the number of the cell into which the most significant portion of the runoff from another cell drains. As arrows showing flow to receiving cells are connected, the patterns of surface water drainage within the watershed emerge.

Figure 7–11. AGNPS Cells for the Stephens Creek Watershed (Unionville Quad)

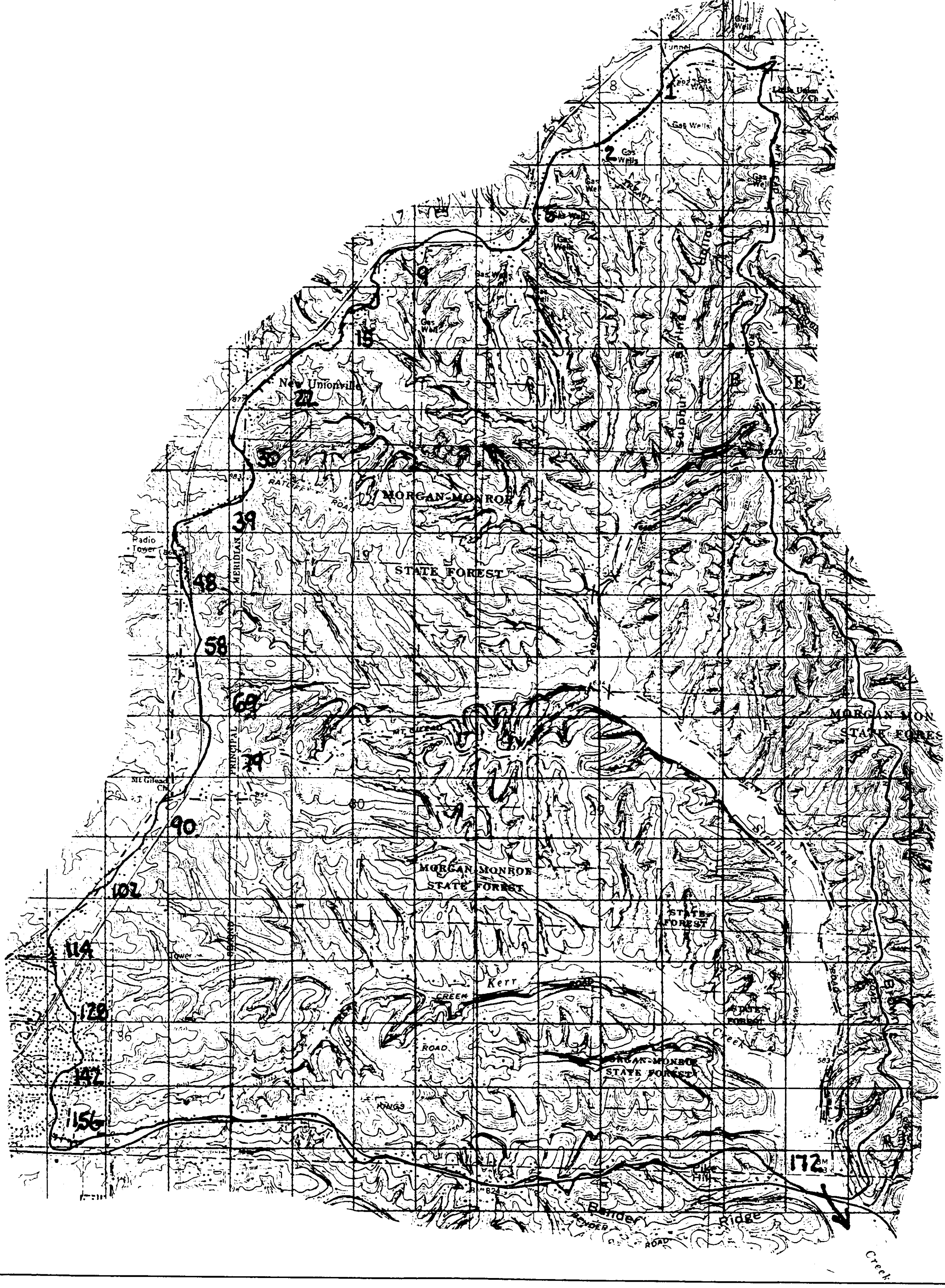


Figure 7–12. AGNPS Cells for the Hamilton Creek Watershed (Story and Waymansville Quads)

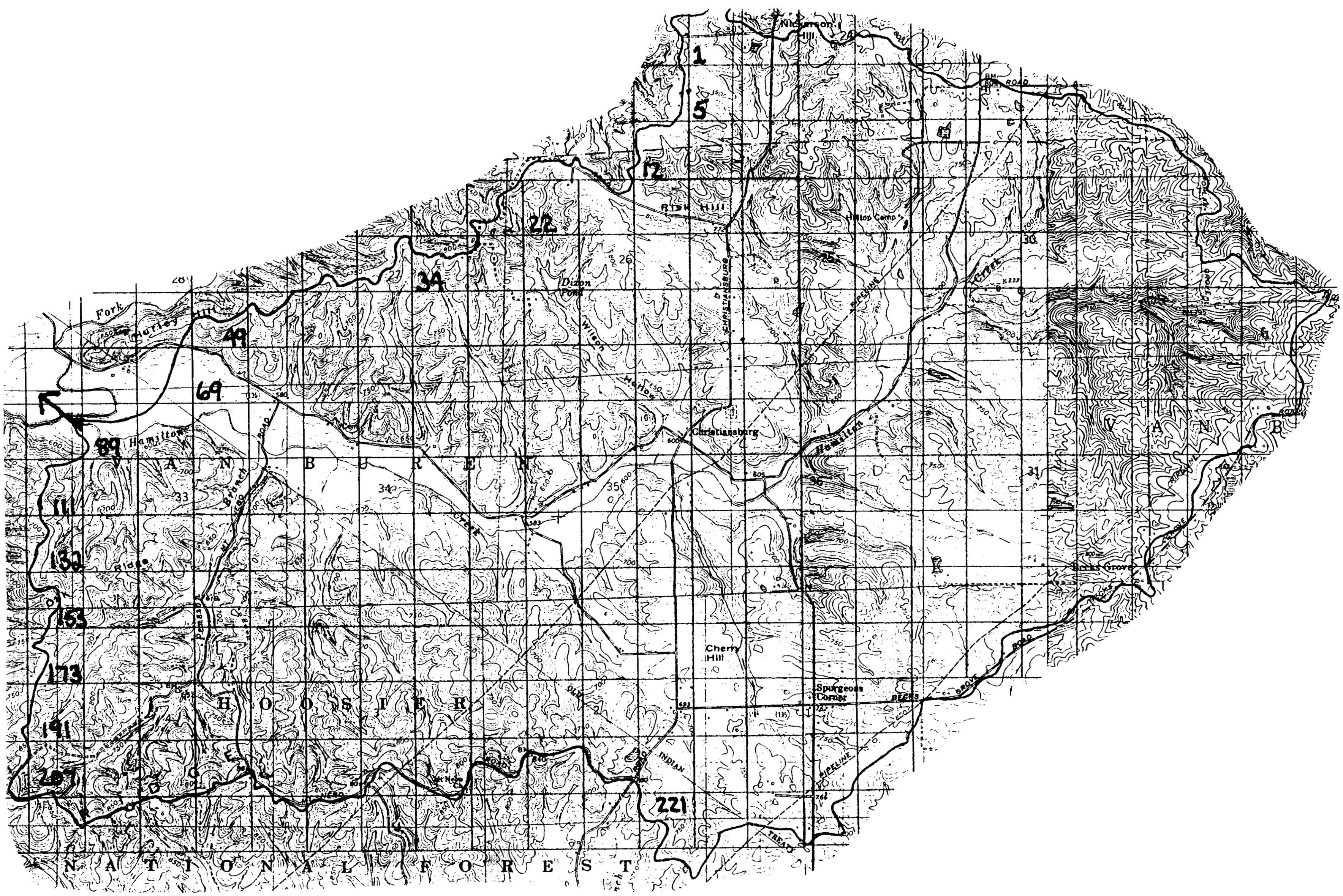
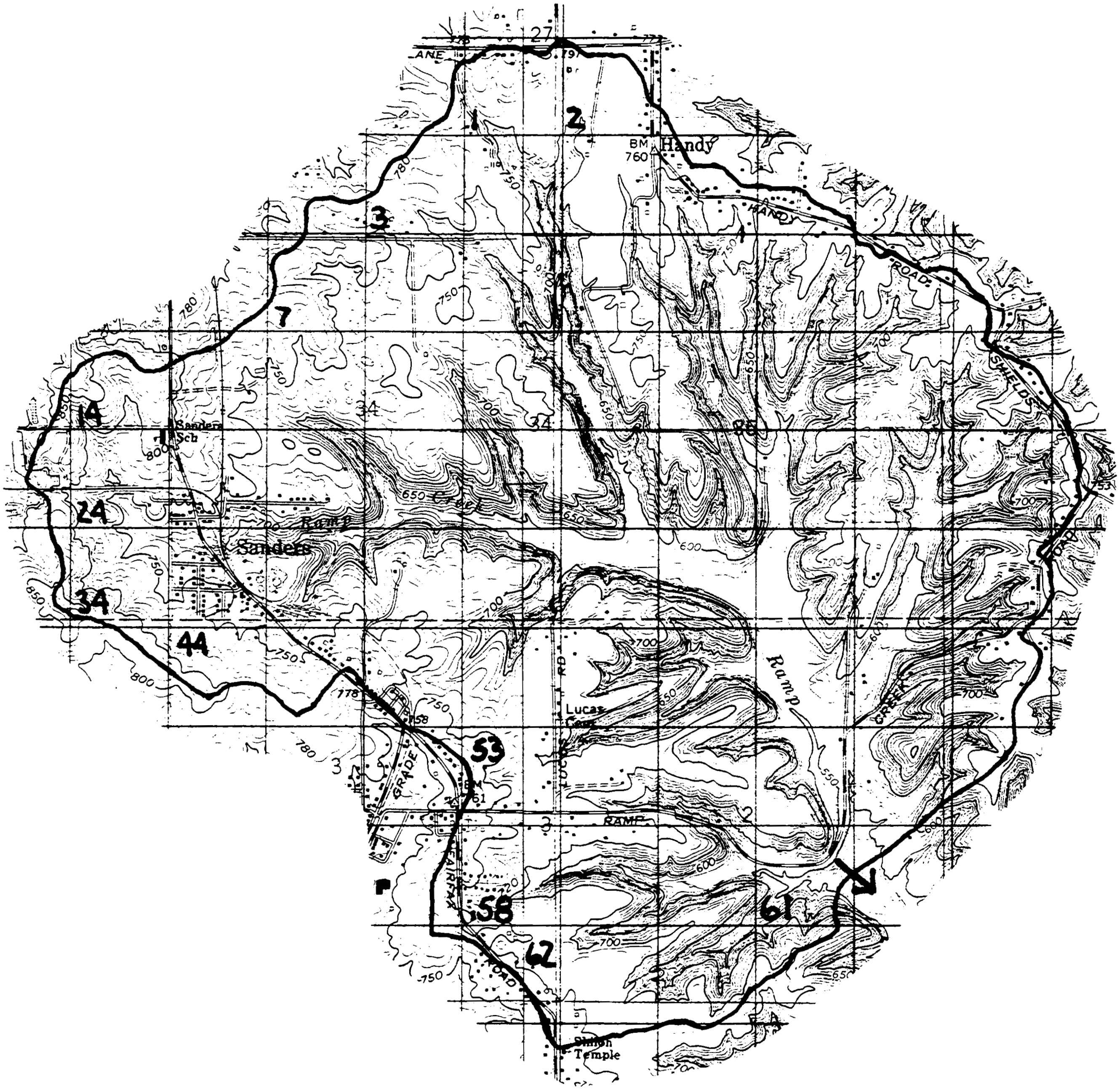


Figure 7–13. AGNPS Cells for the Ramp Creek Watershed (Clear Creek and Allens Creek Quads)



SCS Curve Number. The SCS (Soil Conservation Service) runoff curve number is used to estimate the direct runoff following storm rainfall. The amount of runoff is influenced not only by the amount of rainfall per storm, but also the amount of moisture in the soil prior to the storm (the more water in the soil, the less rain can penetrate into the soil, the more rain runs over the land). To keep the analyses constant, an average soil moisture condition was assumed. The values of the SCS curve number were obtained from a table in the AGNPS manual (Young et al., 1987) by matching land use descriptions with the hydrologic soil type of the major soils in the cell. We based land use designations on areal photos and field checks. If more than one land-use was present in a cell, a weighted average value was calculated.

Land Slope. Land slope influences the velocity of storm runoff and therefore the extent to which soil erodes. The land slope (in percent of rise) was determined from U.S.G.S. 7.5 topographic maps by measuring the rate of elevation change versus distance.

Slope Shape Factor. The shape of the land surface within each cell was numbered one, two, or three for uniform, convex, or concave slopes, respectively. The slope shape factor was determined by examining the contour lines on the topographical maps.

Field Slope Length. The field slope length was determined from information provided by the Monroe and Brown County Soil Conservation Service Agents and based on a weighted average of the soil types found in the individual cells.

Channel Slope. The channel slope was the average slope (in percent of rise) of the defined channel(s) within each cell that were visible on the topographic maps. If there was no definable channel within the cell, we input one-half the land slope value for the channel slope.

Channel Sideslope. The channel sideslope is the average sideslope (in percent) of the channel(s) within each cell. We estimated channel sideslopes in the field at representative points in the watershed and extrapolated from these for input values for the rest of the channels in the watershed.

Manning's Roughness Coefficient. The flow velocity of runoff depends on the roughness of the channel in which it flows. The rougher the channel bottom, the slower the water moves and therefore, the lower the erosive power. The Manning's roughness coefficient varies between zero and one (the higher the number, the smoother the surface), depending on the type of channel bottom. Roughness was estimated in the field at representative points in the channels in the watershed. If no channel was definable within the cell, the roughness coefficient was chosen according to the main surface condition in the cell. If the cell was mainly water or marsh a value of 0.99 was used.

Soil Erodibility (K) Factor. The K-factor is also used in the Universal Soil Loss Equation (USLE). Its value varies between zero and one; the higher the number, the more erodible the soil. K-factors were taken from values reported in the soil surveys. If the cell was mainly water or marsh, a value of zero was used.

Cover and Management (C-factor). Another USLE parameter, the C-factor, is used to represent the cover and management of the land within the three watersheds. Values are related to land use and in the case of agriculture, the crop and tillage practice used. For example, C-factors for corn after soybeans vary from 0.41 for conventional tillage, 0.29 for chisel plowing, and 0.09 for no-till. We selected values after field inspecting representative fields and discussing management practices with the District Conservationists. For forest land, we used a value of 0.02. Values for forest land range from 0.0001 for undisturbed woodland with 100% canopy, to 0.35 for harvested woodlands. We used C-factor values of 0.01 for residential and 0 for water or wetlands.

Support Practice (P) Factor. The P-factor is a parameter used in the Universal Soil Loss Equation to represent various conservation practices on agricultural lands. The worst-case condition during the fallow or seedbed periods is represented by a value of one for agricultural and urban lands. If the cell was mainly water or marsh, zero was used.

Surface Condition Constant. The surface condition constant was based on the land use at the time of the storm to make adjustments for the time overland flow takes to channelize. The lower the value, the greater the overland flow velocity. Values were taken from Table 2 of the AGNPS manual.

Cell Aspect. The cell aspect is defined as the direction of flow leaving each cell. Each of the eight possible flow directions were numbered, beginning with number 1 at the northern position and proceeding clockwise to number 8 at the northwestern position.

Soil Texture. The major soil texture found within each cell was characterized as either water, sand, silt, clay, or peat by using the Monroe and Brown County Soil Surveys (Thomas, 1981; Noble et al., 1990) and the textural triangle found in Young et al. (1987).

Fertilization Level. The fertilization level was a single digit designation for the level of fertilization on each agricultural field. In general, medium levels of fertilization were assumed for all agricultural lands based on the recommendation of Joe Peden, Monroe County SCS District Conservationist. Zero fertilization was used for water, wetlands, and forest; and low levels for urban areas.

Fertilizer Availability Factor. The fertilizer availability factor is the percentage of fertilizer left in the top half inch of soil at the time of the storm. If none of the fertilizer had been incorporated into the soil, 100% (the worst case) would be available. For agricultural land, we used a value of 67% to characterize chisel plow tillage practices except in areas where the District Conservationists knew otherwise. Where water or marsh conditions were found, a value of zero was used. If a cell was primarily urban or forest, 100% was used.

Point Source Designator. The point source designator is a single digit representing the number of discrete pollution sources (feedlots, springs, waste treatment plants, etc.) found within each cell. The watersheds analyzed had no significant point sources designated.

Gully Source Level. While the AGNPS model provides estimates of soil erosion from channels and various land surfaces, it may underestimate soil losses from gullies. If desired, the modeler may make an on-site estimate of tons of soil lost from gullies and enter the amount under this parameter. We saw little evidence of gully erosion outside of established channels and for what little we did see, we were unable to visually estimate the tons of soil that could be lost during our modeled storm event.

Chemical Oxygen Demand (COD). Oxygen that is consumed or removed from the lake by nonbiological combination with chemicals in the water and mud is called the Chemical Oxygen Demand or COD. The values for the COD per cell depend directly on the land uses, from zero for water to 170 mg/l for row crops, and were obtained from Table 8 in the AGNPS manual. The higher the COD value, the more oxygen will be removed.

Impoundment Factor. The impoundment factor indicates the presence of an impoundment terrace system within the cell. Since no impoundment terrace systems were found within the watersheds, this parameter was set to zero.

Channel Indicator. The channel indicator denotes the presence of a defined channel within the cell: zero indicates no defined channels; any other number signifies the number of channels in the cell.

Once the 22 parameters were compiled for each of the cells within the watersheds, the model was run.

7.3.2 AGNPS Results

Stephens Creek. Surface drainage patterns determined and used in AGNPS for the 2,784 hectare (6,880 acres) Stephens Creek watershed are shown in Figure 7–14. The 18 subdivided cells are indicated. Drainage leaves this watershed from cell #172 at the southeast corner.

Figure 7–15 shows soil erosion from each of the watershed cells for the modeled storm event. Cells with high erosion rates generally have steeper topography. Not all soil eroded from a cell makes its way into the creek. Much of the soil is deposited in other cells lying downslope. Figure 7–16 shows the sediment yield from each cell. This is the amount of soil (in tons) that is actually lost from each cell and transported downgradient to the next cell. Because the land drains toward Stephens Creek, the streambed is the ultimate destination of the eroded soil. Accumulated soil moves along the streambed as the storm progresses and this is shown by the increasing sediment yield of cells containing the main branch of Stephens Creek. For example, at the outlet cell, the sediment yield is 5,500 to 6,000 tons for the modeled storm event.

Figure 7–17 shows the rate of phosphorus lost from each cell with the eroded sediment. Cells with the greatest phosphorus loss are predominantly forests on steep slopes with channels within the cell.

Hamilton Creek. Surface drainage patterns for the 3,626 ha (8,960 acres) Hamilton Creek watershed are shown in Figure 7–18. Cell #89 at the western end of the watershed is the outlet cell. Cell soil erosion and sediment yield from the modeled storm event are shown in Figures 7–19 and 7–20. The greatest soil erosion occurs in cells having steeper slopes. The main stem of Hamilton Creek can be seen by the accumulating sediment in cells running the length of the watershed. This watershed yields less sediment at its outlet than does the Stephens Creek watershed for the same storm event. Overall, land slopes are less steep in this watershed.

Sediment phosphorus yields for the Hamilton Creek watershed are shown in Figure 7–21. Overall, sediment phosphorus yields are relatively low and uniform across this watershed. The highest yields occur in the southwest corner which has steep slopes with permanent channels.

Ramp Creek. Surface drainage patterns for the 1,036 ha (2,560 acre) Ramp Creek watershed are shown in Figure 7–22. Cell #61 at the southeast corner of the watershed is the outlet. Cell soil erosion from the modeled storm event is shown in Figure 7–23. The highest rate of soil erosion occurs in Cell #11 and adjacent cells. These cells are characterized by steep slopes, channels and cultivated land. Sediment yield from the storm event is shown in Figure 7–24. Accumulation of sediments along the streambed is evident and the sediment yield from the outlet cell due to the modeled storm event is 1,259 tons. Sediment phosphorus yields (Figure 7–25) have a similar pattern as the cell soil erosion.

Figure 7–14. Surface Drainage—Stephens Creek

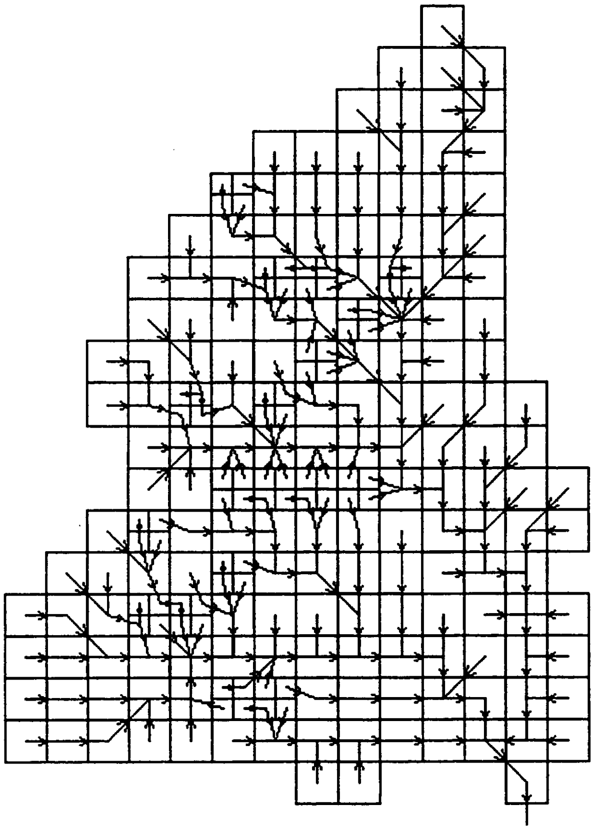


Figure 7–15. AGNPS Soil Erosion—Stephens Creek

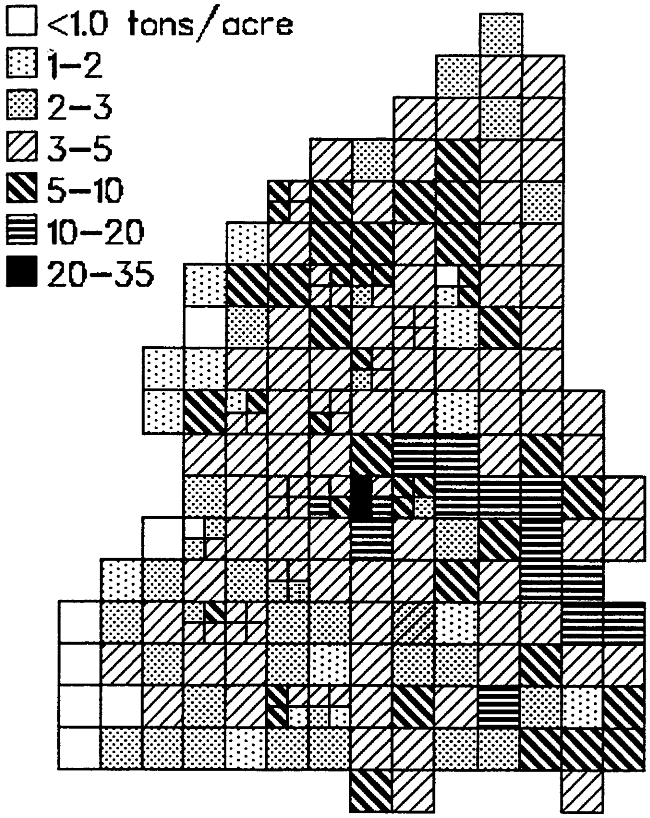


Figure 7–16. AGNPS Sediment Yield—
Stephens Creek

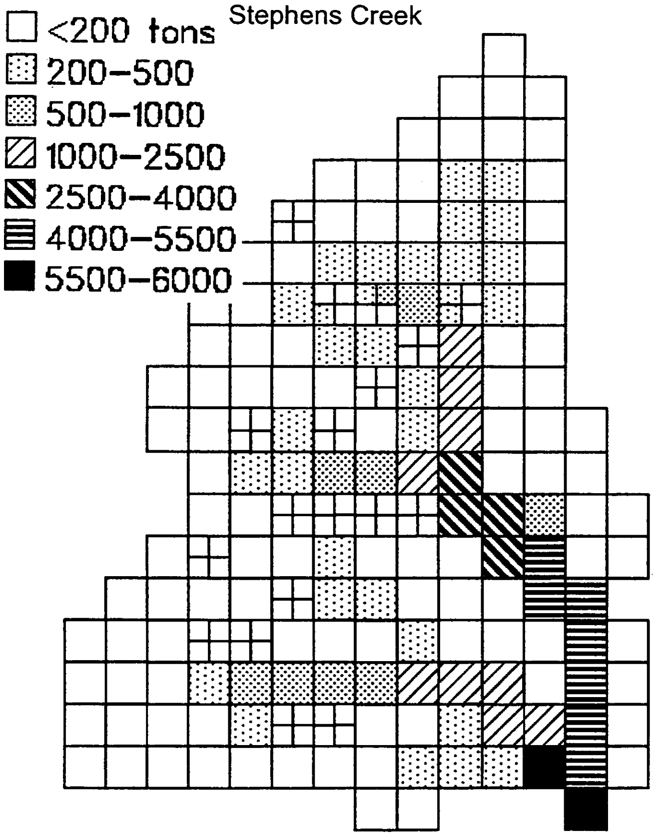


Figure 7–17. AGNPS Sediment Phosphorus—
Stephens Creek

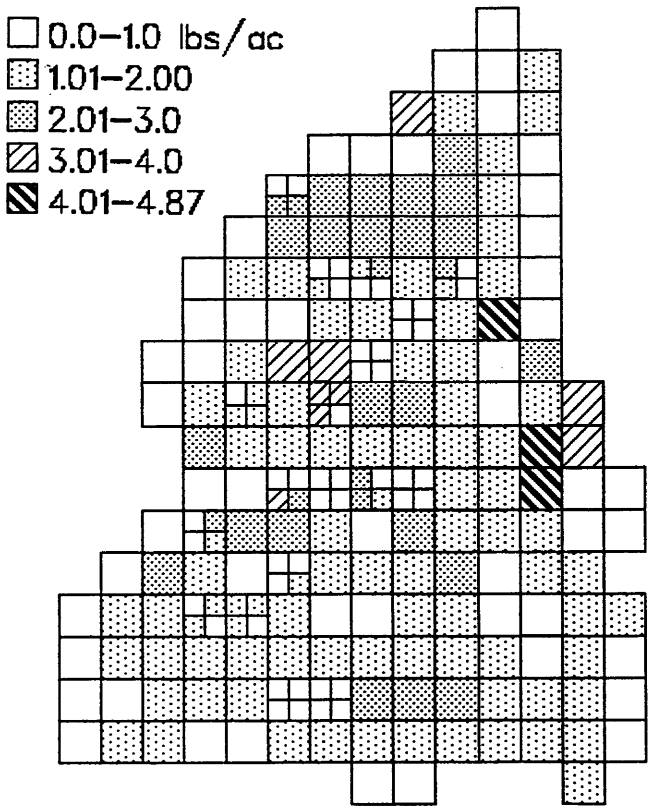


Figure 7–18. Surface Drainage—Hamilton Creek

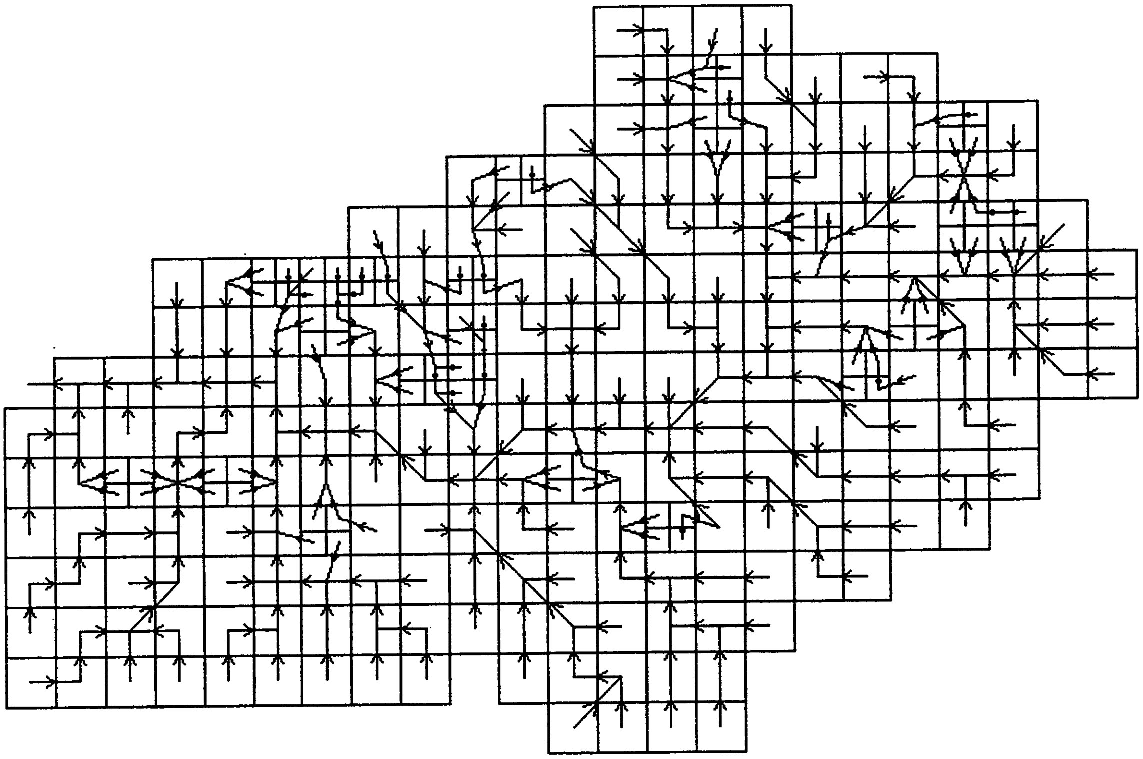


Figure 7–19. AGNPS Soil Erosion—Hamilton Creek

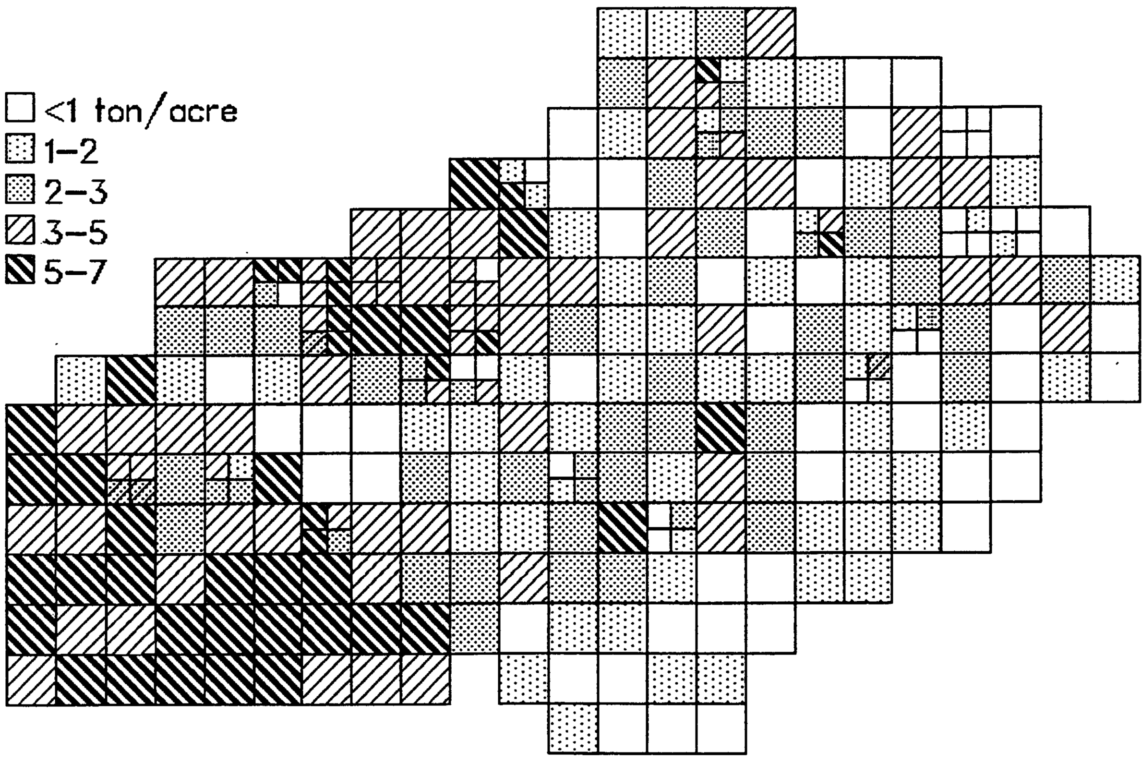


Figure 7–20. AGNPS Sediment Yield—Hamilton Creek

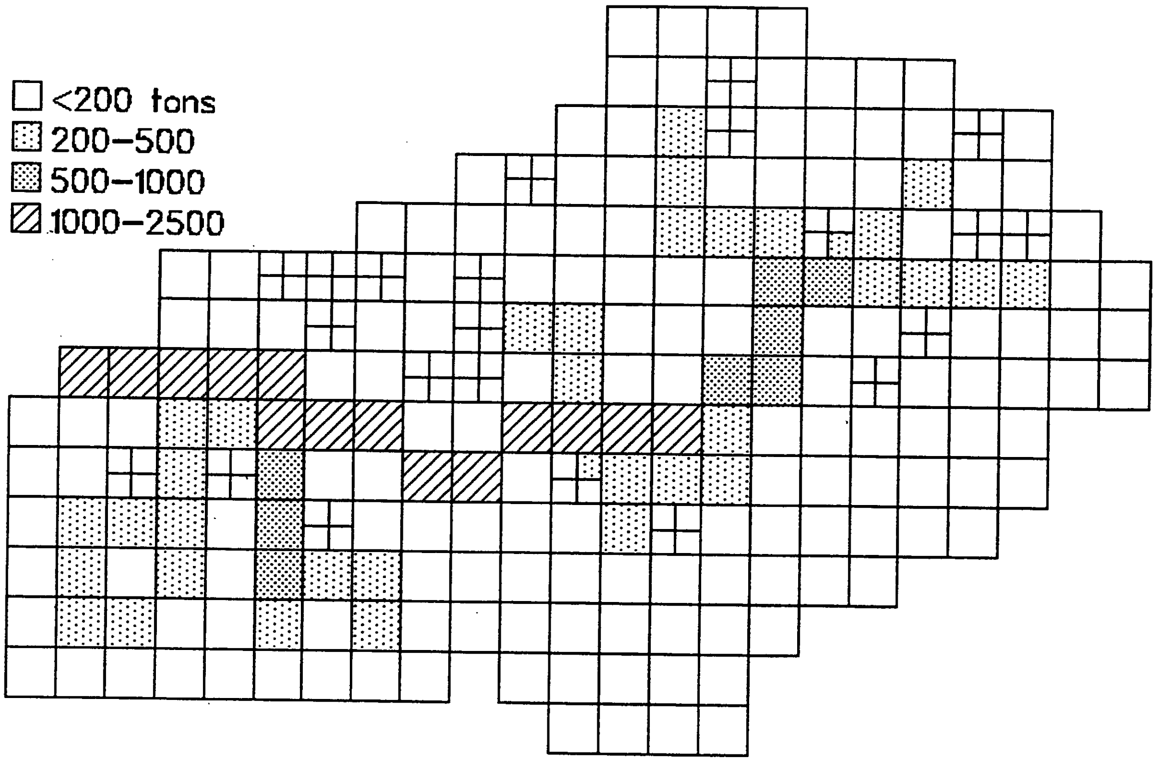
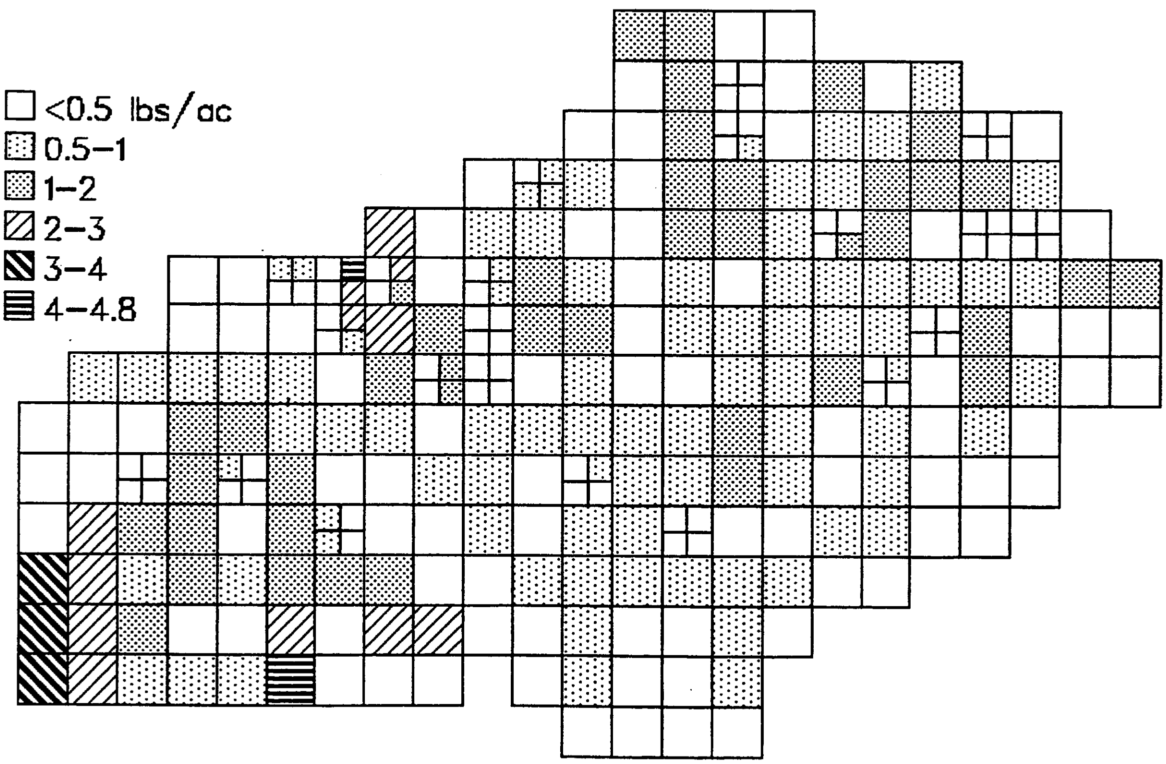


Figure 7–21. AGNPS Sediment Phosphorus—Hamilton Creek



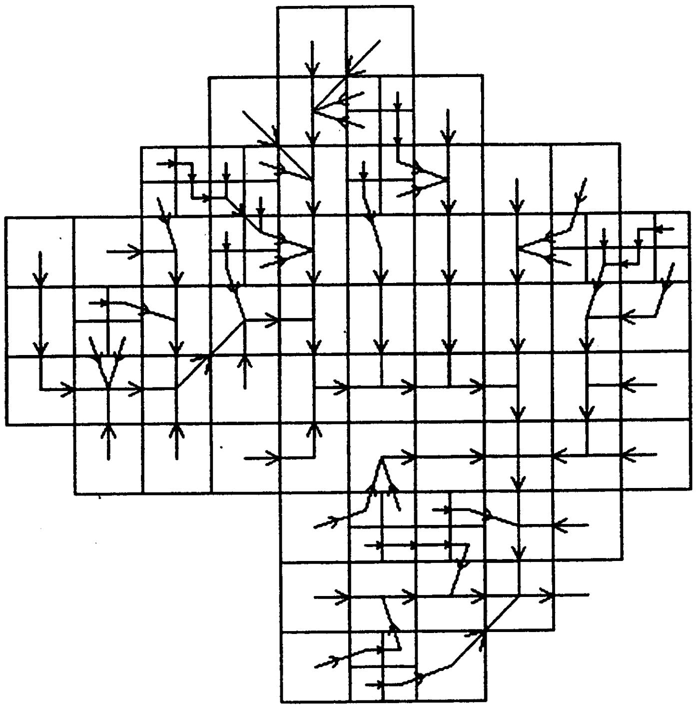


Figure 7–22. Surface Drainage—Ramp Creek

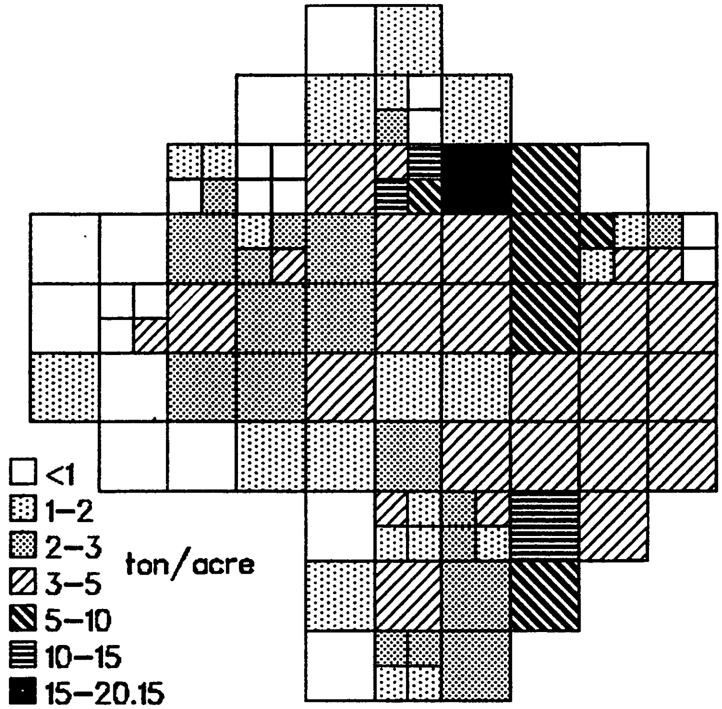


Figure 7–23. AGNPS Soil Erosion—Ramp Creek

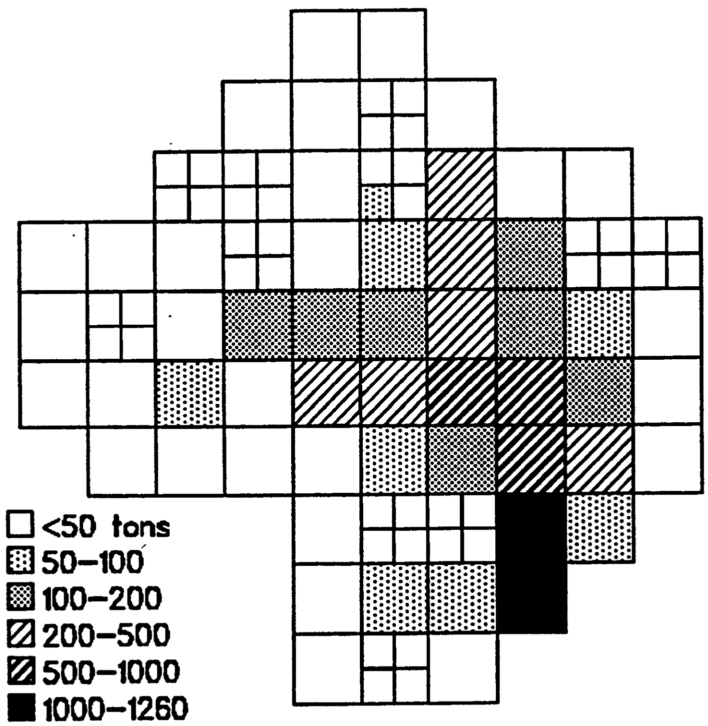


Figure 7–24. AGNPS Sediment Yield—Ramp Creek

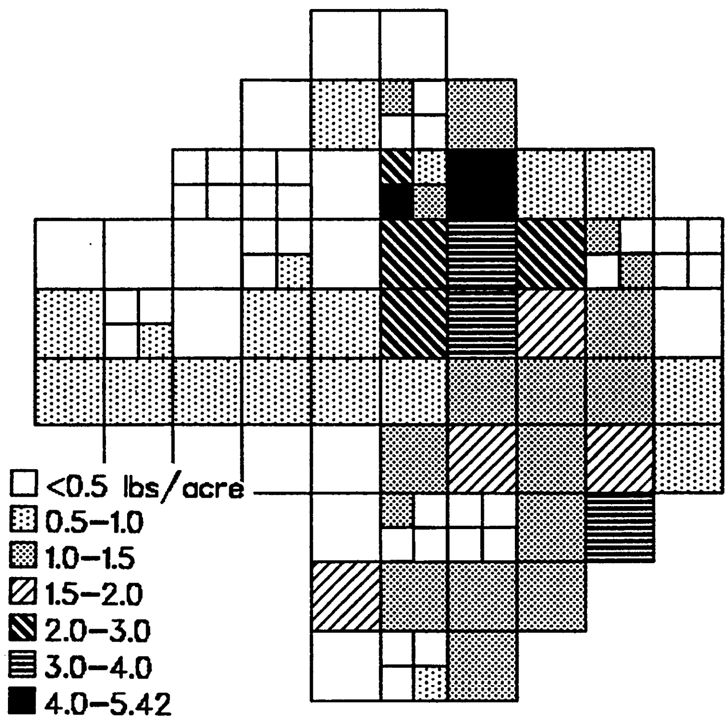


Figure 7–25. AGNPS Sediment Phosphorus—Ramp Creek

7.3.3. AGNPS Summary

Table 7–4 summarizes the AGNPS data for the modeled watersheds. The steeper slopes within the Stephens Creek watershed result in a greatest areal sediment yield and sediment phosphorus loss. Eighteen percent of soil eroded from the land ultimately is lost from the watershed through the outlet. In addition, more runoff leaves this watershed due to the modeled storm event even though the watershed area is significantly smaller than the Hamilton Creek watershed. Again, this may likely be attributed to the steep slopes and well-developed channels.

Although the Hamilton Creek watershed contains the most agricultural land of the three modeled watersheds, most of the agricultural activities occur on relatively flat bottomlands. Still, the agricultural presence results in the highest soluble phosphorus and nitrogen concentrations in water leaving the outlet cell. This agrees with our measured values in which we found that the highest nutrient concentrations in runoff came from the South Fork Salt Creek watershed which also has the highest percentage of agricultural land uses. Overall, land slopes are less steep in the Hamilton Creek watershed and this is apparently important in calculating sediment losses. Only 10% of the soil eroded is delivered from the watershed.

The Ramp Creek watershed has the lowest upland erosion rate (2.2 tons/acre), however 24% of this eroded soil is lost from the watershed. The small size and well-developed channels makes this wate,rshed more efficient in sediment transport than the other watersheds. There is simply less distance for the eroded soils to travel before they reach a channel and exit the watershed. The concentrations of sediment, nitrogen and phosphorus in runoff water is less than that for Stephens Creek but more than that for Hamilton Creek.

The Ramp Creek watershed is currently under more housing development pressure than the other watersheds. To simulate the effects of future development, we did an additional AGNPS run in which we set land use in cells 1, 2, 3, 7, 8, 26, 53, 54, and 58 as predominately residential. These cells are those closest to Bloomington and to current residential developments. This represents an approximately 14% increase in residential land uses in the Ramp Creek watershed as a whole. Results of this simulation are shown in the last column of Table 7–4. It should be noted that these results reflect the effects of completed development and do not represent impacts during construction. Overall soil erosion is slightly lower for this scenario but areal sediment yield is slightly higher. Peak runoff from the watershed increases 23%, from 483 cfs to 594 cfs, due to the increase in impervious surfaces. The biggest differences in this scenario are in soluble nitrogen and phosphorus losses. The concentration of soluble nitrogen at the outlet increases 480% while soluble phosphorus concentrations

Table 7–4. Summary of AGNPS Results

Parameter	*Stephens Creek*	*Hamilton Creek*	*Ramp Creek*	*Ramp Cr. w/development*
Watershed area (acres)	6880	8960	2560	2560
Upland erosion (tons/acre)	4.6	2.7	2.2	2.1
Delivery ratio (%)	18	10	24	24
Mean sediment conc. (ppm)	8682	3771	6454	5415
Yield (tons)	5558	2332	1259	1317
Areal yield (tons/acre)	0.81	0.26	0.49	0.51
VALUES AT THE OUTLET				
Peak runoff rate (cfs)	1405	1399	483	594
Soluble N conc. (ppm)	1.65	2.19	1.48	8.64
Total P in sediment (lbs/acre)	1.33	0.54	0.90	0.93
Soluble P conc. (ppm)	0.22	0.34	0.18	1.78

increase 889%. This is due to greater fertilizer use on residential lawns and to greater transport of materials by impervious surfaces.

In summary, although the AGNPS model could not be applied to the entire Lake Monroe Watershed, it was useful to gain insight into how areas of different land uses respond to the same storm event. Land clearing, vegetative cover, slope, and distance to channels all affected the rate of runoff and sediment delivery.

8.0 POLLUTION SOURCES

8.1 Overview

Pollution entering lakes can be divided into two broad types: point and nonpoint. Point source pollution is that which comes from a discrete point, for example, a discharge pipe. Point sources are relatively easy to identify and are often regulated by state and federal statutes. Nonpoint sources (NPS) are diffuse. NPS pollution includes runoff from agricultural lands and parking lots, erosion from construction sites, etc. The U.S. Environmental Protection Agency (1989) estimates that 76% of all pollution to lakes in the U.S. is of nonpoint origin.

8.2 Point Sources

There are 11 point source discharges in the Lake Monroe watershed that require NPDES (National Pollutant Discharge Elimination System) permits. Point source discharges are regulated by the Indiana Department of Environmental Management (IDEM) under authority of the Federal Clean Water Act. Discharge limits are established for each facility and the facilities are required to regularly monitor their discharges and report the results monthly to IDEM. Minor violations of discharge permits are designated as a *reportable non-compliance* (RNC). Two or more consecutive RNCs can lead to a *significant non-compliance*. This can result in a warning letter and ultimately a notice of violation. These compliance procedures are prescribed by the Clean Water Act.

Information about the 11 permitted point source discharges in Lake Monroe's watershed is given in Table 8–1. The final column contains information about each facility's compliance history. This information was provided by IDEM and from the "Coordinator's Quarterly Non-Compliance Report" for 12/01/93 to 2/28/94. Several of the facilities had RNC violations during the period but they have not required a notice of violation. The Paynetown State Recreation Area facility had the most incidences of non-compliance during the period of record. All the facilities listed are considered "minor facilities" because they discharge less than one million gallons per day (MGD). The small size of these facilities along with their compliance records suggest that point sources have only a minor impact on Lake Monroe's water quality.

8.3 Nonpoint Sources

Nonpoint or diffuse sources of pollution to Lake Monroe include soils, nutrients, pesticides and other materials which wash off the land in the lake's watershed. Lack of adequate vegetative cover facilitates the loss of these materials particularly on steep slopes and stream banks, but even well-vegetated lands can become nonpoint sources when water flow is fast enough to create channels. Inadequately treated wastewater from household septic systems is also considered a nonpoint source of pollution.

One of the most extensive studies of nonpoint sources of pollution in the Great Lakes Basin was undertaken by the International Reference Group on Great Lakes Pollution from Land Use Activities for the U.S.-Canadian International Joint Commission (Sonzogni et al., 1980). The results of this study found significant differences in land uses and the nonpoint pollution they generate (Table 8–2). As we have stated previously, agriculture generates significant amounts of nonpoint source pollutants but urban sources can be equally important too, particularly in developing areas.

Table 8–1. Status of Wastewater Treatment Plant—Monroe Reservoir Watershed

Facility	Quad	Location	NPDES Requirements	Compliance History
Brown County State Park IN 0030325 Schooner Creek[1]	Nashville	NW1/4, SE1/4 SE1/4 S6 T8 R3	Seasonal Discharge Design flow-40,000 gpd; BOD:10/15; S.S.:10/15; pH:6-9; $C1_2$:0.5-1.0	Recent treatment plant renovation/new construction. BOD numeric violation (RNC) 7/93 thru 10/93.
Camp Moneto, Brown Co. IN 0048453 Gnaw Bone Creek	Nashville	NE1/4, NE1/4 NE1/4 S24 T9 R3	Controlled discharge Design:18,000 gpd BOD:30mg/1; S.S.:70 mg/l; pH:6.0-9.0; $C1_2$:0.5-1.0; Total P:1.0 or 80%	Non-compliance with total phosphorus due to non-functional alarm feed equipment. Poor flow monitoring and chlorine residual control. Non-submittal of monitoring data in 1988.
Nashville STP, Brown Co. IN 0023876 Salt Creek	Belmont	SW1/4, SE1/4 NW1/4 S24 T9 R2	Design Flow:0.575 MGD CBOD:25; SS:45; pH:6.0-9.0; $C1_2$:0.05; Total P:1.0 or 80%	Poor sludge handling from flooding of sludge holding lagoons (located on flood plain). Generally in compliance with limits.
Sprunica Elementary School, Brown County IN 0049883 Trib. of N. Fork Salt Cr.	Bean Blossom	NW1/4, NW1/4 NW1/4 SR24 T10 R3	Design flow:6,000 gpd; BOD:30/45; SS:30/45; pH:6-9; $C1_2$:0.5-1.0	In for enforcement - questionable lab practices and data. BOD violation (RNC) 7/93 thru 1/94; Total solids violation (RNC) 7/93 thru 19/93, & 1/94.
Maumee Scout Reservation Brown County IN 0037681 Negro Creek, Salt Creek	Elkinsville	NW1/4, NW1/4 NE1/4 S35 T7 R2	Seasonal discharge Design flow-4,500 gpd; BOD:30/45; SS:30/45; Fecal C:200/400; $C1_2$:0.5-1.0; Permit Expired 1985	No monitoring
USDAG USFS Hardin Ridge Recreation Area Monroe County IN 0024953 Monroe Reservoir	Allens Creek	SE1/4, NE1/4 NW1/4 S30 T7 R1	Seasonal discharge Design Flow-34,000 gpd; BOD:10/15; SS:10/15; NH_3:2/3; Permit Expired	In compliance

Facility	Quad	Location	NPDES Requirements	Compliance History
Hardin Monroe, Inc. Monroe County IN 0038326 Monroe Reservoir	Allens Creek	SW1/4, NW1/4 SW1/4 S19 T7 R1	Design flow:6,000 gpd; BOD:10/15; TSS:10/15; NH_3-N:1.5/2.3; pH:6.9; $C1_2$:0.5-1.0	Generally no flow, new construction. Total phos violation (RNC) 7/92.
Paynetown SRA, Monroe County IN 0030163 Monroe Reservoir	Allens Creek	SW1/4, NE1/4 SW1/4 S32 T8 R1	Design flow BOD:10/15; TSS:10/15; NH_3:1.5/2.3; Total P:1.0 or 80%; removed $C1_2$:0.5-1.0; Permit expired	Not meeting total P limits. Total phos violation (RNC) 10/93 thru 11/93; BOD violation (RNC) 10/93 thru 11/93; total solids violation (RNC) 10/93 thru 11/93; ammonia violation (RNC) 10/93 thru 11/93.
Ransburg Scout Reservation IN 0045411 Monroe Reservoir	Allens Creek	NW1/4, NE1/4 SE1/4 S8 T7 R1	Design flow 28,400 gpd; BOD: 30/45; SS: 30/45; Total P: 1.0; Expired 1988	No discharge reported for 14 years. Camp used only from June-August.
Salt Creek Subdivision IN 0043699 Monroe Reservoir	Elkinsville	NW1/4, SR1/4 NE1/4 S35 T8 R1	Design flow 15,000 gpd; BOD: 10; SS: 10; pH: 6.0-9.0; $C1_2$: 0.5-1.0	Subject to serious inflow related problems. Suspended solids violation (RNC) 1/94
Unionville School Monroe County IN 0041009 Trib. to Brummet Creek	Unionville	NE1/4, NW1/4 SE1/4 S9 T9 R1	BOD: 10/15; SS: 10/15; pH: 6.0-9.0; $C1_2$:0.5-1.0	Sinkhole discharge limits. Past sampling data questionable.

These plants will be reinspected to determine correct status. Permits will be reissued requiring P removal and other appropriate additions and a compliance schedule will be established in the near future.

[1] Water body receiving discharge from facility.

Table 8–2. Ranges of Nonpoint Source Pollutant Loads by Land Use, kg/ha per Year (Source: Sonzogni et al., 1980)

Land Use	*Suspended Solids*	*Total Phosphorus*	*Total Nitrogen*	*Chloride*
Rural				
Cropland	20–5100	0.2–4.6	4.3–31	10–50
Improved pasture	30–80	0.1–0.5	3.2–14	–
Forest/Woodland	1–820	0.02–0.67	1–6.3	2–20
Idle/perennial	7–820	0.02–0.67	0.5–6.0	20–35
Urban				
Residential	620–2300	0.4–1.3	5–7.3	1050
Commercial	50–830	0.1–0.9	1.9–11	10–150
Industrial	450–1700	0.9–4.1	1.9–14	75–160
Developing urban	27500	23	63	–

Most studies of nonpoint source pollution focus on identifying and quantifying NPS loads from various use activities. However, land *form* can be more important in determining the extent of NPS pollution (Sonzogni et al., 1980). Land form characteristics include soil texture, soil type, surficial geology, slope, and soil chemistry. Of these, the single most important characteristic has generally been found to be soil texture (particle size distribution). Overall, runoff is more prevalent on fine-grained clay soils than on coarse sandy soils. Clay-sized particles are easily suspended, but usually settle very slowly, so the probability of transport over land in runoff is very high. In addition, the high adsorption of pollutants on clay-sized particles generally results in clay soils having more associated pollutants.

Table 8–3 gives runoff coefficients (% of rainfall which runs off the land surface) for some common rural surfaces based on cover, soil type and slope. As slope increases and soils become more clayey, runoff increases. Runoff can be as high as 60% of rainfall in woodlands in clay soils on 10–30% slopes (Marsh and Borton, 1976).

In summary, the assessment of potential nonpoint source loading from the land must consider both land *use* and land *form*.

Table 8–3. Runoff Coefficients for Various Rural Land Uses (Source: Marsh and Borton, 1976)

Topography & Vegetation	*Open Sandy Loam*	*Clay and Silt Loam*	*Tight Clay*
Woodland			
Flat (0–5% slope)	0.1	0.3	0.4
Rolling (5–10% slope)	0.25	0.35	0.5
Hilly (10–30% slope)	0.3	0.5	0.6
Pasture			
Flat (0–5% slope)	0.1	0.3	0.4
Rolling (5–10% slope)	0.16	0.36	0.55
Hilly (10–30% slope)	0.22	0.42	0.6
Cultivated			
Flat (0–5% slope)	0.3	0.5	0.6
Rolling (5–10% slope)	0.4	0.6	0.7
Hilly (10–30% slope)	0.52	0.72	0.82

8.3.1 Agriculture

Agriculture has the potential for being the most significant source of NPS pollution in Lake Monroe's watershed (Figure 8–1). Many factors affect pollution loads from agricultural activities. Among these are the types of crops or animals raised, crop rotation, the soils on which the crops are grown, climatic conditions, farming technology, and irrigation and drainage. Close proximity of agricultural activities to watercourses is one of the major causes of agricultural pollution (Novotny and Olem, 1994). On the other hand, the use of agricultural Best Management Practices (BMPs) can greatly reduce pollutant loads from agricultural lands.

There are a number of good reviews of pollutant levels caused by various agricultural activities. These include: Reckhow et al., 1980; Ritter, 1988; and Novotny and Olem, 1994. Refer to Figure 7–8 and Table 8–2 for previously summarized loadings from various agricultural activities.

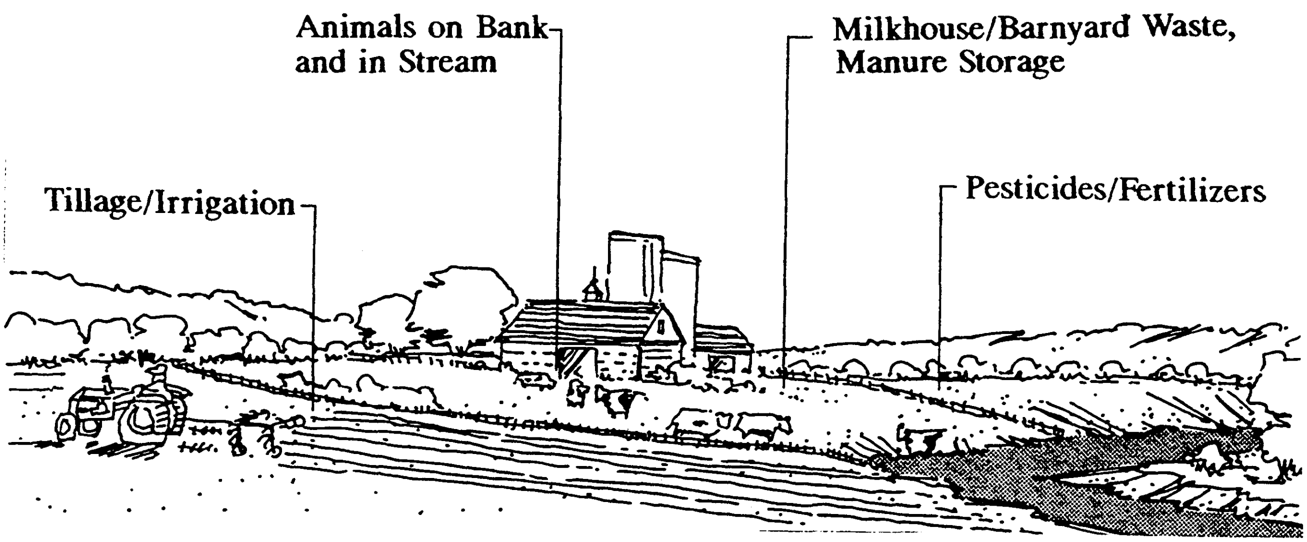
The major pollutants associated with agriculture include eroded soil, nutrients (especially nitrogen and phosphorus), pesticides and other toxins, bacteria or pathogens, and salts. Phosphorus is most often carried from farmlands adsorbed to eroded soils and other particulates while nitrate and ammonia are most often found dissolved in runoff water. Pesticides may be lost either in dissolved or particulate form, depending on the particular pesticide.

In the Lake Monroe watershed, we have identified the following specific agricultural practices which generate nonpoint source pollutants:

- Crop fields plowed right up to the edge of stream banks. This destabilizes the banks, causing them to collapse or erode. In addition, the lack of a vegetated strip between the stream and field allows runoff from the field to carry nutrients and eroded soils directly into the stream.

- In many areas, livestock are permitted uncontrolled access to streams. Livestock eat streambank vegetation and trample the streambanks. Both of these activities destabilize the banks, causing bank erosion. In addition, direct deposit of animal wastes to the stream is a source of nutrients, bacteria and potentially pathogens.

Figure 8–1. Agricultural Sources of NPS Pollution (Source: Humstone Squires Associates, 1990)



- Although agricultural policies encourage conservation tillage, a number of bottomland fields are still tilled using conventional practices which leave almost no vegetative residue on the soil surface to facilitate infiltration. Conventional tillage is also used on some fields containing heavy clay soils where no-till systems have difficulties.

- Fall plowing of fields leaves the soil surface bare throughout the fall and winter months. In south-central Indiana we often receive heavy rains during this period and the resulting soil erosion from fall-plowed fields can be significant.

- There are a number of animal operations where barnyard wastes are not properly contained on site. Runoff from barnyards contain large amounts of ammonia, nitrate, phosphorus, and bacteria. This can cause "shock loading" to receiving streams which can negatively impact stream biota.

8.3.2 Silviculture

Undisturbed forests or woodlands represent the best protection of lands from soil erosion and pollutant losses (Novotny and Olem, 1994). Leaves and ground mulch have a high capacity for water storage and the protected soils promote infiltration. Uncontrolled logging operations, however, disturb the forest's resistance to erosion. Clearcuts, logging roads and clearing along streams cause significant erosion and discharges of silt, mud, petroleum products and woody debris into the water (Figure 8–2).

A significant portion of the Lake Monroe watershed is forest land and much of this is considered commercial by the Indiana Department of Natural Resources (IDNR, 1993). While there aren't large tracts of land currently being logged in the Lake Monroe watershed, the unmanaged clearing of smaller woodlots can produce significant impacts in local areas.

Hoosier National Forest Clearcutting Study. Hoosier National Forest (HNF) hydrologists studied the effects of clearcutting on water quality in the Hoosier National Forest areas of Pate Hollow and South Pate Hollow (north of Paynetown near Lake Monroe) from 1989 to 1990 (Moss, 1989). Control and experimental watersheds were

Figure 8–2. Logging Sources of NPS Pollution (Humstone Squires Associates, 1990)

used. Watershed PH–1 was used as a control, with no logging disturbance. However, the upper reaches of this watershed contained some areas of private ownership and livestock grazing. Watershed PH–2 was an experimental watershed in which a typical clearcutting was practiced over approximately 20% of the watershed. Cutting occurred across part of a stream and a logging road runs across the stream in one place in this watershed. Watershed PH–3 is a control area composed of a mature stand of trees. Watershed PH–4 is another experimental area with about 15% of the watershed clear-cut.

The data from this study have not been finalized in that there are no quantitative results available yet. This is because stream discharge and loading rates have not yet been calculated. Only relative concentrations between the watersheds are available. Preliminary results are contained in Table 8–4.

Suspended sediment levels in the water from Watershed PH–2 exceeded those of the control watershed only once, immediately following the construction of the main access road. At all other times, suspended sediments from PH–1 have exceeded those from PH–2. Watersheds PH–3 and PH–4 produce very little sediment.

Nitrate nitrogen levels were elevated in Watershed PH–4 following clearcutting, and remained elevated for two years (relative to the control watershed). This relative elevation did not occur in the other harvested watershed (PH–2). The highest level of nitrate nitrogen measured during the study was 1.9 mg/L.

Phosphorus levels in the stream draining the northern control watershed (PH–1) were consistently higher than those draining the northern harvested watershed (PH–2). However, it is likely that private lands and agricultural activities within Watershed PH–1 influenced phosphorous concentrations. The phosphorus outputs from the two southern watersheds are very similar.

Clearcutting also appeared to have no effect upon sulfate, calcium, magnesium, potassium, and sodium. These levels for all studied areas were higher than other areas of the United States, but the conclusion reached was that these high values were due to geological or geochemical characteristics of the landscape.

Table 8–4. Mean Nutrient Concentrations (mg/L) from Harvested and Control Watersheds in Hoosier National Forest (Source: Moss, 1989)

Year	*Watershed*	*Nitrate*	*Total Phos*	*Sulfate*	*Ca*	*Mg*	*K*	*Na*
1984–85	PH–1	0.75	0.04	26.5	9.32	4.9	2.44	3.02
	PH–2	0.42	0.03	24.6	9.32	4.9	1.85	2.84
1985–86	PH–1	0.64	0.04	28.2	6.99	4.25	2.36	2.67
	PH–2	0.44	0.03	27.8	9.03	4.56	1.82	3.51
	PH–3	0.15	0.01	28.4	6.34	3.99	1.16	2.18
	PH–4	0.09	0.01	27.3	5.34	4.17	1.29	2.13
1986–87	PH–1	0.53	0.04	34.9	14.14	7.37	2.38	3.3
	PH–2	0.61	0.01	34.8	13.73	6.96	1.84	4.97
	PH–3	0.16	0.01	36.7	9.43	5.29	1.33	2.6
	PH–4	0.29	0.01	34.8	6.88	4.92	1.37	2.95
1987–88	PH–1	0.67	0.02	27	9.48	5.38	2.28	2.78
	PH–2	0.51	0.02	29	9.75	5	1.75	3.65
	PH–3	0.24	0.02	25	6.5	4	1.35	1.92
	PH–4	0.56	0.02	24.6	5.45	4	1.35	2.18
1988–89	PH–1	0.3	0.02	27.8	11.42	6.68	2.14	3.07
	PH–2	0.41	0.02	27.9	11.14	6.1	1.73	4.07
	PH–3	0.09	0.01	25	7.07	4.68	1.2	2.08
	PH–4	0.07	0.01	25.4	5.46	4.56	1.32	2.37

8.3.3 Urbanization

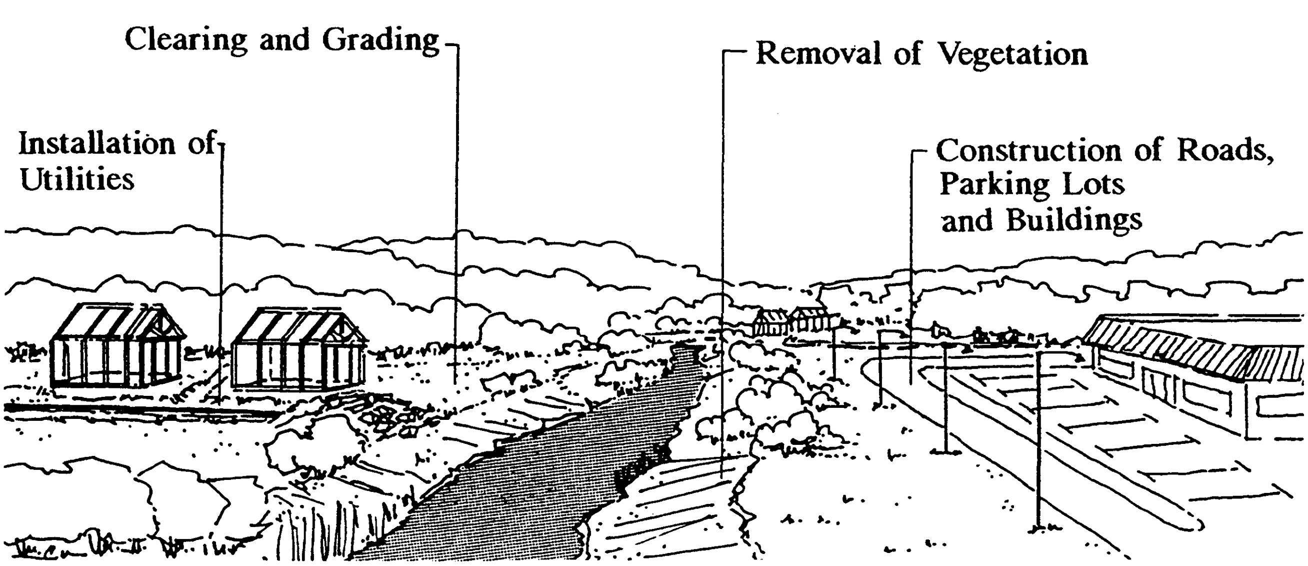
The urbanization of watersheds can have important impacts on both the quantity and quality of stormwater runoff. For example, paved surfaces prevent the infiltration of precipitation resulting in a greater volume and velocity of runoff. Auto and bus exhaust, construction activities, and residential fertilizers are all urban sources of pollutants that can adversely affect lakes and receiving streams. In a study of urban runoff in Bellevue, Washington, Pitt (1985) calculated annual mass yields of 183 lbs/acre of total solids, 80 lbs/acre of chemical oxygen demand, 1.6 lbs/acre of total nitrogen and 0.4 lbs/acre of total phosphorus. Residential lawns contributed 83% of the total solids and streets contributed 45% of the COD, 32% of the phosphorus, and 31% of the total nitrogen. Driveways, parking lots and residential lawns were the next highest sources of COD, phosphorus, and nitrogen in the runoff. See Table 8–2 for additional data on urban NPS loading rates.

Construction activities associated with urbanization have the potential to produce extremely high rates of pollutant loading to streams and lakes. Clearing and grading of land for building sites, roads, and utilities removes vegetation, exposes soil, smooths the land surface, and compacts soils (Figure 8–3). These alterations increase runoff and promote soil erosion. Impervious surfaces created by roads, driveways, parking areas and buildings increase runoff volume and velocity. This may lead to downstream flooding and erosion.

Sediment losses from construction sites can be orders of magnitude greater than sediment losses from other land uses (see Figure 6–10). The most critical problem of sedimentation occurs during the early construction stages when vegetation is stripped and the land surface graded. The severity of the problem depends upon previous land use, the grade of the slope, the length of the slope, and the soil type.

The clay soils covering much of the Lake Monroe watershed are highly susceptible to erosion and once eroded, are easily transported long distances with runoff water. Plumes of soil suspended in runoff flow from nearly every construction site in the watershed following a moderate rain. Where best management practices such as silt fences or sedimentation ponds are used, they are often improperly designed, installed or maintained.

Figure 8–3. Construction Sources of NPS Pollution (Humstone Squires Associates 1990)



8.3.4 Septic System Failure

Effluent from improperly installed and/or maintained on-site septic systems may contribute nutrients, bacteria, and biological oxygen demand (BOD) to Lake Monroe. The shallow soils, slow percolation rates, and steep slopes which characterize much of the land within the lake's watershed are not ideal for septic systems.

Due to concerns over potential inadequate septic system performance, the Monroe County Health Department created a Wastewater Task Force of citizens and professionals to assess the suitability of existing statewide domestic septic system regulations in protecting the county's drinking water supplies. The recommendations of the task force, adopted in 1989, require more stringent septic system regulations than the minimum regulations established by the State Department of Health for Indiana in general. These new regulations apply only to systems located within the watersheds of the three drinking water supply reservoirs in Monroe County—Lake Monroe, Lake Lemon, and Griffy Lake. The remaining counties within the Lake Monroe watershed (Brown, Jackson, Bartholomew, Johnson, and Lawrence counties) use the less-strict state standards and have no separate requirements or record keeping for systems within the watershed.

The more stringent septic regulations which Monroe County has imposed pertain to certain site characteristics, site locations, absorption field requirements, inner coating of tanks, pumping of effluent, surface water diversion, and system maintenance (see Table 8–5). While it is the intent of the new septic system regulations to provide minimum standards to be used in the design, construction, and operation of subsurface sewage disposal in the targeted watersheds, there is an allowance for variances to be issued from certain portions of the guidelines under special circumstances. A variance can be issued if the applicant presents clear and convincing evidence that:

A. Special conditions warrant such a variance because certain aspects of these regulations cannot be met, and

B. Other acceptable alternative systems are not available, and

C. The variance, if granted, will present no significant risk that sewage will flow off-site or pollute groundwater.

Between the time the new regulations were adopted in 1989 and July 1992, Monroe County issued 941 septic permits: 695 outside the boundaries of the Lake Monroe watershed, and 246 within the boundaries. Of those permits issued for residences which lie within the Lake Monroe watershed, 80, or 32.5%, included a variance from septic system regulations: 29 with a dual-field exception, 14 from mound system regulations, 14 with inadequate distance to 12% slope, 16 which were in a pre-existing sub-division, 2 which were less than 100 feet from a lake tributary, 1 with inadequate lot size, 1 with insufficient depth to bedrock, 2 which were within a drainage way, and 1 with a pre-existing holding tank.

According to Tim Rogers of the Monroe County Health Department (pers. comm., 1993), his agency has been successful in most cases in working with applicants for septic permits to assist them in designing a system which meets Health Department criteria (either with or without a variance). Rogers could recall only about six permits which were denied because septic requirements could not be met, although he stated that early records did not always reflect when permits were denied, because some applicants did not pursue the application process when they were told they would be required to build a more expensive system to meet Monroe County standards.

Table 8–5. Monroe County Septic System Regulations for Lake Watersheds

SITE CHARACTERISTICS

No portion of a septic system absorption field shall be installed in an area which does not meet the following criteria:

A. Natural slope must be 12% or less.

B. Soil depth must be adequate to provide a depth of soil from the bottom of the trench to bedrock of no less than:

—six (6) feet in areas underlain by limestone, or

—four (4) feet in areas not underlain by limestone

SITE LOCATION

A. There must exist a buffer zone one hundred (100) feet wide, measured horizontally, immediately adjacent to and in any down slope direction from the site, which consists of a natural slope of 12% or less and does not itself contain any component of a septic absorption field.

B. In no case may any portion of a septic system be installed within two hundred (200) feet, measured horizontally, of the edge of a floodplain or, if there is no designated floodplain, the center of a tributary.

C. In no case may any portion of a septic system be installed at a lesser distance, measured horizontally, from a lake margin than the State Board of Health requires in its regulation(s) setting minimum distances between septic systems and public water supplies.

D. In no case may any component of a septic system be placed on a lot other than the lot on which stands the structure which is serviced by that septic system.

ABSORPTION FIELD REQUIREMENTS

All septic systems must have two (2) absorption fields with a switch valve between them to alternate effluent flow, or, one (1) absorption field that will be pumped, flush or pressure dosed with a reserve absorption field set aside, or, a mound system, constructed according to all state and local regulations and requirements. The minimum buffer zone required for the installation of a mound system shall be 25' to any slope greater than 12%. The minimum buffer zone required for all other systems shall be 100'. Each field must be sized at full capacity for the structure served.

INNER COATING OF TANKS

The inside surfaces of all septic tanks and pump tanks must be completely coated above the water line with non-corrosive water-repellant material.

PUMPING OF EFFLUENT

Septic effluent may not be pumped farther than (300) feet.

SURFACE WATER DIVERSION

When the elevation of the landscape adjoining the proposed septic system site is equal to or higher than that of the proposed site and the higher landscape may be expected to discharge excessive amounts of water onto the septic system site the Health Department may require a diversion ditch or waterway to divert surface water away from the septic system site. Diversion ditches or waterways shall have a positive grade of a least one foot per 100 feet.

SYSTEM MAINTENANCE AND INSPECTION

A. The use of degreasers, oxidizers and other additives to improve system performance is forbidden unless approved in writing by the Monroe County Health Department.

B. Each septic tank and pump tank should be pumped and cleaned every three to five years.

C. No roads or structures may be placed over septic tanks, pump tanks, or any portion of an absorption field.

8.3.5 Streambank Erosion

Streambank erosion is a serious problem along portions of nearly all stream channels in the watershed. In many areas, landowners clear out bank-stabilizing woody vegetation along the streams, allow cattle unlimited access to the streams, or cultivate up to the edge of a streambank. Each of these actions destabilize stream banks and promote bank erosion. In addition, the deep, silty alluvial soils in the flood plains are easily eroded by the high flood waters that characterize the Salt Creek watershed. For example, heavy summer rains in 1993 resulted in substantial discharge through Brummetts Creek which washed out a large section of streambank, including trees, approximately 100 feet long by 15 feet wide.

Snags which often form naturally in the streams are also a cause of streambank erosion. When trees along the bank fall into the stream, the resulting snags divert water against the opposite bank, often causing erosion. For example, along the North Fork Salt Creek near Yellowwood Lake, water flowing around a single snag has eroded approximately 300 cubic yards of soil from a corn field on the opposite bank.

This eroded soil may be temporarily deposited in the floodplain downstream but it eventually is transported into Lake Monroe. Silt deposits on forested floodway terraces are over one meter deep in some areas along North Fork Salt Creek.

8.3.6 Lakeshore Erosion

The shoreline of Lake Monroe is characterized by steep, bare, and eroding banks (see Section 6.1). Natural instability of the banks contributes to this problem but other factors such as lack of vegetative cover, heavy use by humans, and wave action contributes to the erosion problem. The long fetch of Lake Monroe, particularly when winds come out of the southwest or northeast, results in the generation of considerable waves. Heavy boat traffic, particularly when boats travel faster than idle speed within 200 feet of shore, also contributes to shoreline erosion.

Yousef et al., (1978) identified shoreline erosion as one of the more acute problems related to boating. Waves created by boats erode lakeshores at an increased rate, contributing to turbidity in the water. Wagner (1990) notes that the shoreline erosion problem is largely a function of shoreline conditions. Vegetative cover, soil conditions, and shoreline uses all influence the magnitude of shoreline erosion. Shoreline activities and development alter shoreline conditions by removing existing vegetation and loosening compacted soils. Rooted littoral plants help hold soils intact and help absorb the impacts of wake and wave action on the shoreline. Different soil conditions have different levels of susceptibility to erosion as well. For example, loose soils with small particle sizes and steep banks will erode more quickly than highly compacted rocky shores with gradual grades. Low water levels at Lake Monroe often expose shoreline more susceptible to erosion (no vegetation covering and soils with small particle sizes).

8.3.7 Recreation Impacts

Many lake users responding to our survey (Section 2.8) felt that heavy recreational use at Lake Monroe had more of an impact on lake uses than did watershed pollution (Table 12–2). There is no question that Lake Monroe can be very crowded at times.

Of the many recreational uses at Lake Monroe, motorized watercraft probably cause the most impacts. Motorized watercraft have a number of potential impacts upon the water, sediments, flora, and fauna of the lakes they are operated on. These impacts can be traced to three general sources: emissions from the motor itself, waste from the occupants of the watercraft, and physical impacts from the boat and motor.

Lake Vulnerability. There are several characteristics of lakes which influence the impact of motorized watercraft. For example, smaller lakes are less likely to support dense boat traffic. Larger lakes, on the other hand, are more likely to experience denser use from larger boats. Lakes with large epilimnetic volumes are better able to counteract watercraft emissions through dilution of inputs. The hydraulic residence time determines the length of time required to flush pollutants from the system. The shallowness ratio (the area <10 ft deep/total area) is indicative of the portion of the lake which is vulnerable to the direct effects of boat traffic. Large populations of rooted plants serve to minimize resuspension of bottom sediments, and, finally, sediments composed of fine material such as silt or clay are more easily resuspended than sediments composed of gravel or sand (Wagner, 1990).

Lake Monroe has a number of characteristics that make it vulnerable to motorized watercraft impacts. Nearly one-third of the lake's area is less than ten feet deep and thus very susceptible to resuspension of sediments by motor craft (Figure 8–4). The bottom sediments are composed primarily of silts and clays which are readily resuspended. Only 15% of the lake bottom is covered by rooted macrophytes to help reduce the erosive effects of waves. The relatively long hydraulic residence time (~230–260 days) means that pollutants which enter the lake do not flush out very rapidly. On the positive side, the large epilimnetic volume (volume <20 feet deep) of the lake (82% of the total) provides greater dilutional capacity for pollutants entering the surface water (Figure 8–5)

Fuel and Hydrocarbon Discharges. Hallock and Falter (1987) tested motors on Twin Lakes, Idaho to determine the effect of motor discharges into the lake. They found insignificant phosphorus and nitrogen loading from motors, but large quantities of inorganic carbon were found. They concluded that even high boat use would be unlikely to affect lake biota through direct discharges in the short term, but long-term effects have never been studied. Jackivicz and Kuzminski (1973) were able to detect over 100 hydrocarbons emitted from motorized watercraft (along with up to 55% of the original fuel), but many of the compounds detected will not persist due to volatility and natural degradation. Kuzminski et al. (1973, as cited in Wagner, 1990) indicated that most of these hydrocarbons are components of unburned fuel, a problem which has largely been dealt with through the increased fuel efficiency of modern engines.

Two-cycle and jet propulsion engines both waste and dump much less fuel than do four-cycle engines, while jet propulsion engines cause more underwater disturbances than conventional engines. Older engines (pre-1977) are also less fuel efficient than newer engines. Engines with large crankcases, improperly tuned motors or which

Figure 8–4. Depth-Area Curve for Lake Monroe

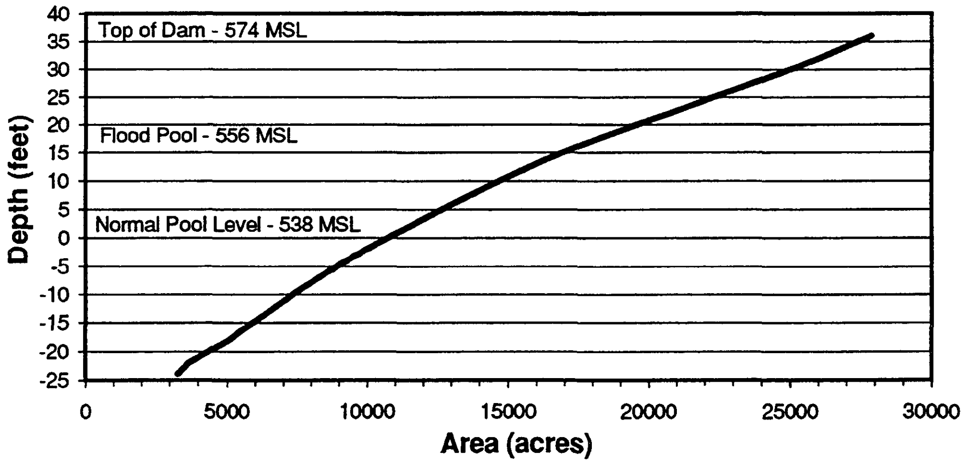
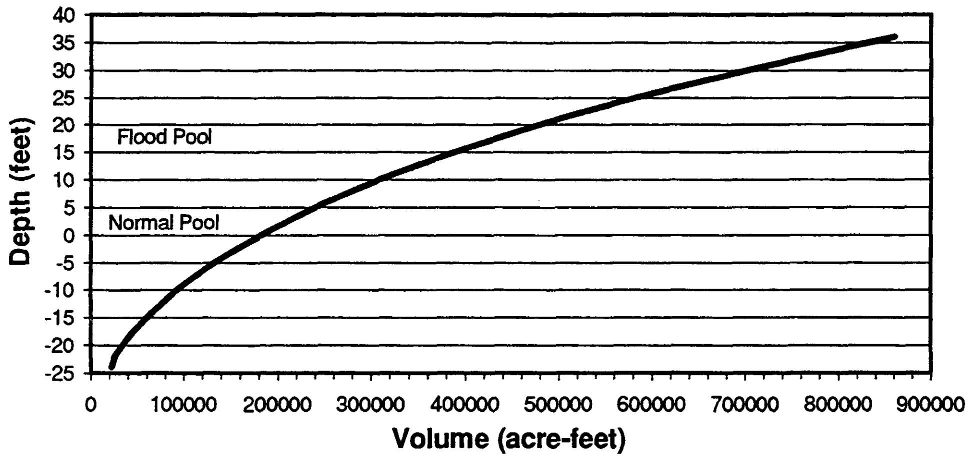


Figure 8–5. Depth-Volume Curve for Lake Monroe



are filled with oil to gas ratios that do not meet engine specifications are all less fuel efficient than small, tuned engines that are properly fueled.

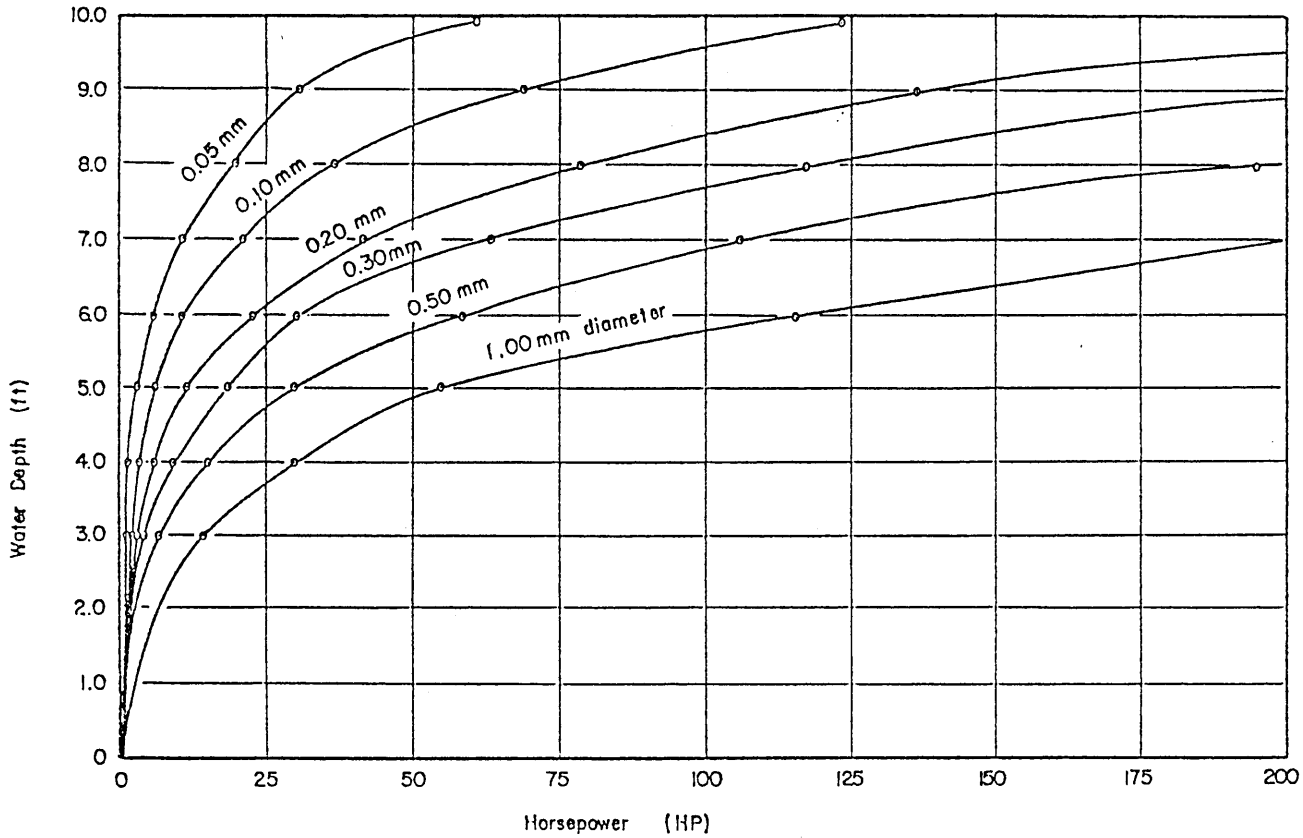
There is little evidence that motorboats elevate metal levels in the water upon which they are operated. However, evidence does exist that metals such as lead, cadmium, and tin can accumulate in lake sediments due to emissions by boat motors. These metals have the potential to bioaccumulate in benthic organisms, filter feeders, and their predators, but non-lethal effects are difficult to separate from other influences (Wagner, 1990). Exhaust discharges may also affect the taste and odor of lake water, but an extremely high density of motorboats is needed to do so, such as are present in marina areas.

Sewage. Sewage discharges by boaters is a largely unquantified problem. Wagner (1990) indicates that the problem is only severe in harbor areas where large boats congregate, and that it is difficult to separate the sewage impacts of boaters from those of shore dwellers. This makes it a very difficult problem to evaluate. There has been continued concern about sewage discharge from the many houseboats using Lake Monroe. The Indiana DNR has regulations designed to prevent discharge from houseboats into Lake Monroe but enforcement is difficult. A dockside boat dumping station exists at the Fourwinds Marina and this has helped some. According to Conservation Officer Steve McClain (personal communication., 1993), most houseboats dump "graywater" directly into the lake.

Sewage disposal from the many hundreds of other boats is another, unquantifiable problem. One can only imagine how human sewage is disposed of when 100 boats are anchored off the Monroe Dam ramp on a summer weekend and when hundreds more boats are on the water all day with skiers and sightseers.

Sediment Resuspension. There is growing evidence linking motorized watercraft with increased turbidity levels in lakes due to resuspension of settled materials from the lake bottom. Yousef et al. (1980) observed increased turbidity after use by motorboats in both an experimental setting and through simple observation of three Florida lakes. They further demonstrated that the magnitude of turbidity increase is related to the size and horsepower of the boat. Furthermore, in 1974, Yousef demonstrated that a 75 hp motor operating in 10 feet of water can stir up bottom sediments (see Figure 8–6). Larger boat motors can resuspend clay-sized sediments from deeper depths.

Figure 8–6. Bottom Sediment Resuspension by Recreational Motorboats in Shallow Lakes
(Source: Yousef et al., 1978)



As might be suspected, the stirring of lake sediments can result in the resuspension of settled nutrients as well. Normally, nutrients are exchanged between sediments and the overlying water in a concentration dependent manner. Typically, the phosphorus concentration of the sediments may be up to 50 times the concentration of the overlying water (Yousef et al., 1979). Zicker et al. (1956; as cited in Wagner, 1990) showed that the rate of phosphorus release from the sediments doubles due to agitation from turbulence. At the same time, Yousef, et al. found increases in phosphorus and chlorophyll *a* levels in three Florida lakes after mixing by motors. It should also be noted that these phosphorus levels declined much more slowly than they increased. As phosphorus is generally considered the limiting nutrient in lakes, this should result in an increase in algal growth (Yousef, et al., 1980).

Intuitively, motorboats would seem a likely source of increased oxygen levels because of their agitation of the water. However, Hallock and Falter (1987) observed no such increase in oxygen (even a slight decrease was observed) after running outboard motors in enclosures. Wagner (1990) suggests that the discharge of oxygen demanding substances counteracts the oxygenation by boat propellers.

Effects on Rooted Plants. Another problem caused by aquatic motor craft is the destruction of rooted plants. Direct damage occurs when boats damage aquatic vegetation physically. Yousef (1974) noticed that plant material and the sediments attached to plants contributed to increased turbidities after boat activities. Wagner (1990) noted that most direct impacts will occur in water under five feet deep. Indirect suppression of aquatic plants occurs when turbidities are elevated beyond acceptable levels. Murphy and Easton (1983; as cited in

Wagner, 1990) noted that a threshold level of 2000 passes per year was needed to suppress plant growth due to turbidity, but noted that 300–600 passes during the spring development period is adequate to alter, but not eliminate, certain plant species (this study was done on canals, not lakes). It should also be noted that plant suppression by boat activity may be mitigated in cases where plant fragments, chopped up by boats, re-sprout and spread.

Wildlife Effects. Finally, boating may have adverse effects upon fish and waterfowl. Lagler, et al. (1950) found no significant impacts upon warmwater fish populations that could be linked to boats. They found little effect upon both reproductive behavior and success. However, resuspended sediments are known to cover fish eggs and nests. Watercraft do seem to affect the reproduction of waterfowl. Ahlund and Gotmark (1989; as cited in Wagner, 1990) found that predation on eider ducklings by gulls increased two to three times in the presence of motorized watercraft because the boats scared away the parents. In addition, Wagner (1990) notes that all watercraft (not only motorized) increase human disturbances of nesting areas, placing greater stress on reproducing waterfowl.

CHAPTER 9: MANAGEMENT ALTERNATIVES

9.1 Introduction

It is often said that a lake is a reflection of its watershed. This means that natural features, such as geology and land slope, within the watershed, as well as human influences on land uses will influence the water quality characteristics within the lake. For example, good land stewardship practices will yield better quality water draining into a lake and this, in turn, can help maintain or create good lake water quality. On the other hand, plowing of steep slopes, overuse of pesticides and fertilizers, and lack of adequate erosion controls on construction sites yield runoff water of very poor quality and this will ultimately create poor lake water quality.

For these reasons, lake management begins in the watershed. Until watershed sources of pollution are controlled, lake management is doomed to failure. Watershed management practices treat the *causes* of lake pollution whereas many of the in-lake management techniques (for example, dredging or herbicide applications) treat only the *symptoms*. Once watershed management practices are implemented, in-lake techniques may be used to speed up the recovery of degraded lakes.

The results of our sampling, of the AGNPS modeling, and of the phosphorus loading modeling all suggest that human and land use activities in Lake Monroe's watershed are the primary sources of sediment and nutrient loadings to the lake. This is consistent with Willett (1980) who estimated that 70% of all sediment pollution nationally is caused by human activities. Although it is unrealistic to expect that all nonpoint source pollution can be eliminated, Best Management Practices (BMPs) can be used to prevent or reduce nonpoint source pollution. While BMPs were developed originally for agricultural pollution control, they have also been adopted for forestry and urban nonpoint source control as well.

The degree to which BMPs should be used depends upon many factors including soils, topography, and the individual farm or land management operation. It is not practical to select a specific set of BMPs without knowledge of these factors. Making specific recommendations for each site in the Lake Monroe watershed is beyond the scope of this project.

Therefore, in the following section, we give an overview of BMPs and other practices for controlling agricultural, woodland, and urban sources of nutrients and sediments. We refer the reader to a number of excellent publications for more detailed information on the subject. We have used the following publications to prepare the material in this section: Moore and Thornton (1988); UWEX (1989); and Novotny and Olem (1994). Novotny and Olem includes design specifications and formulas for sizing many of these BMPs.

9.2 Agricultural BMPs

The following practices are designed to control the loss of both soils and nutrients from agricultural lands. Practices that prevent soil erosion are also important in controlling particulate forms of nutrients. Soluble (or dissolved) nutrients are controlled along with runoff.

Soil erosion from agricultural lands in the U.S. causes about $44 billion in damages each year. Pimentel et al. (1995) estimate that it would take an investment of $40/ha•yr to reduce U.S. cropland erosion rates from about 17 tons/ha•yr to a sustainable rate of about 1 ton/ha•yr. An additional investment of $5/ha•yr is needed to reduce erosion on U.S. pastureland. This total investment for U.S. erosion control would be about $8.4 billion per year. This means that for every $1 invested, $5.24 in damages would be saved. Thus, soil erosion controls are very cost-effective.

9.2.1 Conservation Tillage

Conservation tillage is a farming practice that leaves at least 30% of the crop stalks or stems and roots intact in the field after harvest. Its purpose is to enhance water infiltration, and to reduce water runoff and soil erosion compared to conventional tillage where the topsoil is mixed and turned over by a plow. This practice can reduce sediment loss by 40–90%, particulate phosphorus loss by 25–70%, and dissolved phosphorus loss by 25–42%.

9.2.2 Contour Stripcropping

In this practice, the farmer plows across the slope of the land. Strips of close growing crops or meadow grasses are planted between strips of row crops like corn or soybeans. Contour stripcropping on 2–7% slopes can reduce soil erosion by 75% compared to plowing up and down the slope. Particulate and dissolved nutrient losses can be reduced by up to 50%.

9.2.3 Crop Rotation

Crop rotation involves periodically changing the crops grown on a particular field. Rotations are most effective if row crops are alternated with pasture in two- to four-year rotations. Pasture rotations improve soil structure, increase organic matter content and increase soil porosity relative to continuous row cropping. Nutrient losses can be reduced by 50% or more when pasture rotation is used.

9.2.4 Grassed Waterways

Grassed waterways are natural or constructed waterways or outlets, shaped or graded, and established in suitable vegetation to provide for removal of excess surface water. They are probably the least expensive but most effective means of conveying water across the land. These vegetated channels reduce gully erosion, increase water infiltration, and trap sediment and nutrients. Generally, the efficiency of pollutant removal by grassed waterways is about 30%, but sediment removal efficiencies of 60–80% have been reported in properly designed and maintained waterways. Removal efficiencies are maximized by low channel slopes and water velocities. Table 9–1 gives basic design criteria for grassed waterways.

9.2.5 Filter Strips

Filter strips are strips of grass or other close-growing vegetation intended to remove sediment or other pollutants from sheet flow runoff. They are usually placed along streams or lake shores, around feedlots, and at the edges of fields to prevent pollutant transport from human-disturbed areas. When used to control runoff from feedlots, sediments can be reduced by up to 80% and nutrients reduced by 60–70%. A minimum of 85% sediment removal can be achieved with a 2.5-meter-wide grass strip during shallow (nonsubmerged) flow (Novotny and Olem, 1994).

Filter strips are eligible for the U.S. Department of Agriculture's Conservation Reserve Program (CRP). They must be at least 66 feet wide and no more than 99 feet wide, unless additional width is required to meet SCS criteria. In Indiana, filter strips are also eligible for tax relief under the Classified Filter Strip Act (HEA 1604) passed by the Indiana General Assemble in 1991. To qualify, the strips must be between 20 and 75 feet wide and meet certain other requirements. By establishing vegetated filter strips, landowners can have those parcels assessed at only $1.00 per acre for general taxation purposes.

Table 9–1. Maximum Permissible Design Velocities for Grassed Waterways

Cover	Range of Channel Gradient (%)	Permissible Velocity (m/sec)
Vegetative		
1. Tufcote, Midland and Coastal Bermuda Grass	0–5.0	1.8
	5.1–10.0	1.5
	Over 10	1.2
2. Reed canary grass, Kentucky 31 tall fescue, Kentucky bluegrass	0–5.0	1.5
	5.1–10.0	1.2
	Over 10	0.9
3. Red fescue	0–5.0	0.75
4. Annuals[a] - ryegrass	0–5.0	0.75
Unlined Channels[b]		
5. Fine gravel		0.75–1.5
6. Coarse gravel		1.2–1.8

[a]Annuals-use only as temporary protection until permanent vegetation is established.
[b]Lower velocity is recommended for clean water; higher is allowed for silty water.

Source: Novotny and Olem (1994)

9.2.6 Animal Waste Management

Livestock operations produce a tremendous amount of nutrients which, if unmanaged, can lead to eutrophication of receiving waters. For example, a 50-cow dairy herd and associated youngstock produce approximately 1,400 tons of manure annually. This manure contains approximately 15,000 pounds of nitrogen, 6,000 pounds of phosphorus, and 12,000 pounds of potassium (Graves, 1986). These nutrients are best managed as a fertilizer for growing plants rather than as a waste material.

Animal wastes should be temporarily held in waste storage structures or basins until they can be safely utilized or disposed. Outside storage areas should be covered to prevent water accumulation and runoff. Once fields have thawed in the spring, the stored wastes can be applied and the nutrients contained within them can infiltrate into the soil. Animal wastes should *not* be applied to frozen fields in the winter. Runoff over the frozen soil can transport the wastes and their nutrients off site.

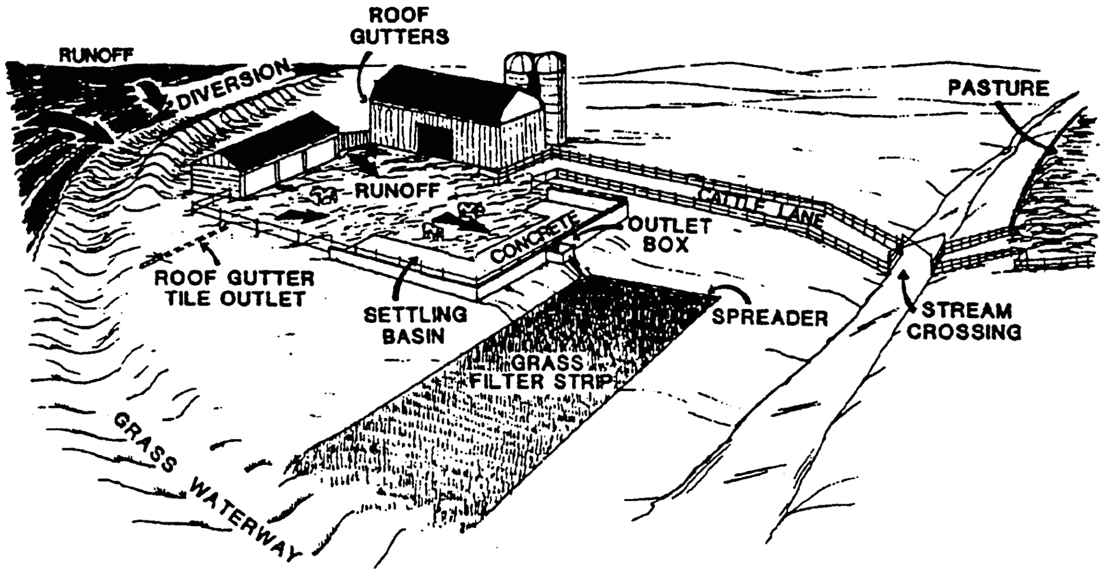
In feedlots, barnyards, or other areas where animals (and their wastes) are concentrated, a shallow detention basin can be constructed to collect runoff and liquid wastes, rather than let these materials run off the site.

Livestock should be kept off streambanks and lakeshores where they can erode the banks and deposit wastes directly into the water. Streambanks and lakeshores should be fenced off to prevent these problems. Livestock access for watering and crossing can be provided by a stabilized crossing area with gravel or concrete bottom. Figure 9–1 illustrates many of these animal waste management BMPs.

9.2.7 Water and Sediment Control Basins

Water and sediment control basins (WASCOBS) are generally small, shallow basins located in or at the downgradient end of agricultural fields. The basins catch and retain runoff water before the water volume and

Figure 9–1. Typical Barnyard Runoff Management System



Source: Linquist et al., 1987.

velocity becomes great enough to cause rill erosion in the field. Sediments in the retained water settle out and the water infiltrates into the ground. If the basin fills following particularly heavy runoff, riser outlets allow settled water to drain into grassed waterways or streams. WASCOBS are often constructed in series down long sloping fields.

9.2.8 Fertilizer Management

Fertilizer management is a practice used to decrease the availability of nutrients to runoff while providing optimum amounts of plant nutrients for crop production. It is the most important practice in controlling water pollution by nutrients from agricultural lands. Soil tests are probably the most important guide to the proper use of fertilizers. These tests, combined with information about soil type, previous cropping, and the anticipated soil moisture level, should be used to estimate fertilizer requirements. Apply fertilizer as close to the time of plant demand as possible, especially nitrogen fertilizers. If practical, all fertilizer should be incorporated into the soil to reduce loss by volatilization and surface runoff.

Recent emphasis in fertilizer management has been in accurately crediting the nutrients added by manure applications. Simple computer programs have been developed to calculate these additions. Local Soil and Water Conservation Districts will have more information about manure credits.

9.3 Forestry BMPs

Despite the large percentage of forest land in the watershed, commercial timber harvesting is limited. Where timber harvesting does occur, forestry BMPs should be used. Some of these are listed below (W.Va. Department of Agriculture, undated).

9.3.1 Planning

The landowner and logger should mutually spend time planning and laying out roads and landings to prevent potential problems. This includes fitting the roads to the lay of the land and keeping grades low. Well planned and properly located roads can be a great asset to the landowner's property. Permanent roads permit access for fire protection, firewood cutting, future timber management, and harvesting.

9.3.2 Stream Buffers

Roads and landings should be sited at least 100 feet from streams and ponds. Equipment should be kept out of streams. A filter strip of vegetation should be left along the stream.

9.3.3 Stream Crossings

When a stream must be crossed, a culvert or bridge should be used. The crossing should be at a right angle to the stream, and the approaching reads should not drain water into the stream.

9.3.4 Drainage

The logger should use ditches, culverts, dips, and grade breaks, and should log in favorable weather when possible. Drainage structures need to be maintained during operation to keep them working. To prevent water from washing down long stretches of road or standing in landings or dips, the logger should inspect ditches, culverts, etc., periodically to make sure they are effective. If muddy water is noticed entering a stream, or if there is a possibility of this, steps need to be taken to correct the problem.

9.3.5 Site Closure

Retire logging roads as soon as they are not needed. Do not wait until the whole job is completed. For example:

1. Smooth and grade landings and main haul road for drainage, utility and appearance.
2. Clean ditches and culverts which are permanent.
3. Pull out temporary culverts and bridges and regrade cross-ditch. All natural drainages should flow across, not down, the road.
4. Plant a cover crop on all exposed soil using lime, fertilizer, mulch and seed such as Kentucky 31 fescue (grass) as needed.
5. Gate road or use a deep trench to eliminate vehicle access.

6. Plan for future maintenance —the cleaning or repairing of water control structures.
7. Install water bars or water-breaks at recommended intervals. Rocks, brush and logging debris can often be used as water retardants on skid trails.

9.4 Urban BMPs

The *Urban Planning Development Guide* prepared by the Hoosier Heartland RC&D Council (1985) is an essential, well-illustrated reference for urban nonpoint source problems and management practices. The book by Novotny and Olem (1994) entitled, *Water Quality— Prevention, Identification and Management of Diffuse Pollution* is also an excellent reference for both urban and rural nonpoint sources. Readers are encouraged to acquire a copy of these resources.

9.4.1 Stormwater Management

The traditional approach to stormwater management was to use curbs, gutters, and underground pipes to remove stormwater as quickly as possible to minimize on-site flooding. However, while these measures may relieve flooding of upstream areas, they contribute to the flooding and erosion of downstream areas that receive the rerouted stormwater. Recommended objectives and approaches to stormwater management have now expanded to include the mitigation of downstream flooding by:

1. Reducing the amounts of impervious surfaces such as driveways and roads. Porous pavement can be used for streets, driveways and parking lots. This pavement allows water to infiltrate into the ground while providing a firm, smooth surface for traffic.

2. Temporary stormwater storage in streets and parking lots, in grassy areas, and in percolation trenches.

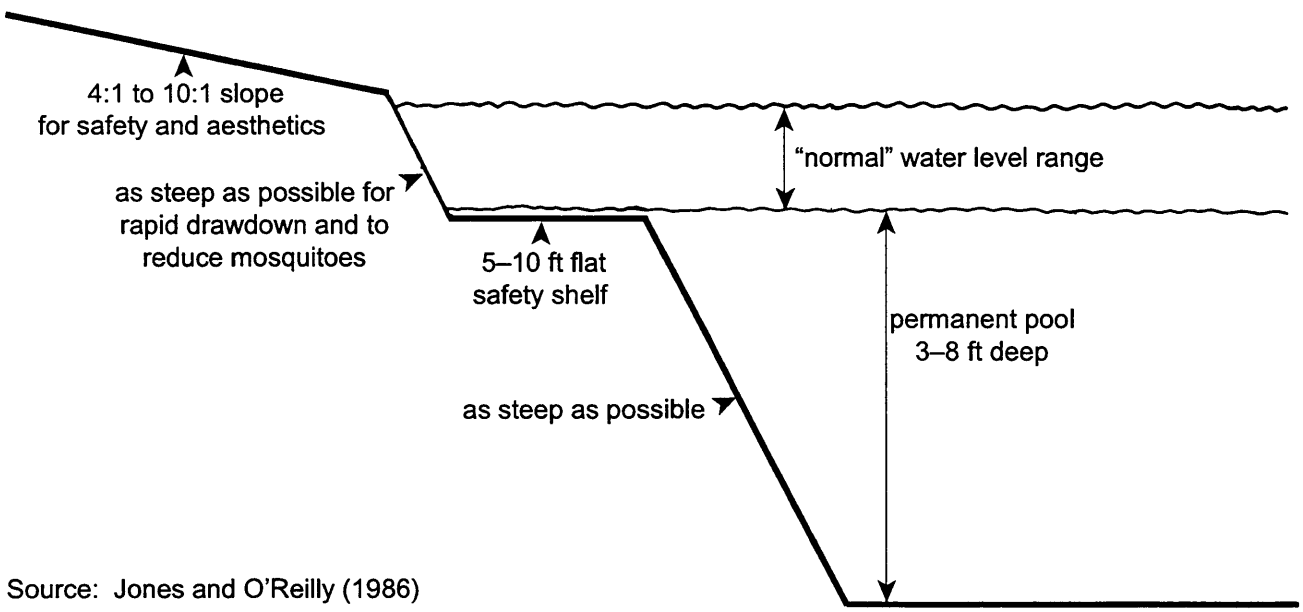
3. Using grassed swales (vegetated channels) instead of curb and gutter. This costs less ($1–2/foot vs. $40/ft) and can remove up to 90% of total solids and 70% of phosphorus. Infiltration in the swales reduces runoff volume and the vegetation reduces runoff velocity. Homeowners can mow across the swales which remain dry following storm events. An example of grassed swales can be found along Longview Avenue and Morningside Drive in the Parkridge Subdivision on Bloomington's east side.

   Grassed swales can be incorporated into the urban landscape to direct stormwater runoff through residential areas, much like grassed waterways in agricultural areas. Such swales are inconspicuous and can be maintained by mowing like lawns. They reduce the volume and velocity of runoff water and help reduce nutrient and sediment loading. A good example of such a swale crosses Rural Street in the Fairwood Terrace Subdivision north of Bloomington. This swale has stood up to extreme discharges with no damage.

4. Using catch basins at the entrances to gutters to trap sediments.

5. Using sedimentation basins to detain stormwater and trap sediments and nutrients. Well designed wet sedimentation basins can remove 70–90% of solids and 60–70% of nutrients from stormwater runoff (Pitt, 1989). Basins need at least six feet of permanent standing water to protect the trapped sediments from scouring, to minimize rooted plant growth and to increase winter survival of fish (Figure 9–2). Correct

Figure 9–2. Sediment Retention Basin Cross Section (not to scale)



Source: Jones and O'Reilly (1986)

basin side slopes are important to improve safety and to minimize rooted plant growth (Jones and O'Reilly, 1986).

The size and shape of sedimentation basins is important to their proper functioning. Width to length ratios of at least 5:1 are recommended for optimal trapping efficiency but if that isn't possible, baffles can be used to lengthen the flow path between the inlet and outlet (Pitt, 1989). Wet detention basins should be sized according to the size of the upstream watershed draining into the pond. Trapping efficiencies for many pollutants are maximized when the pond area is 0.5% of its watershed (Figure 9–3) (Driscoll, 1986). The pond must have a volume large enough to hold runoff from a 1.5 inch storm and must detain the water long enough for most sediment to settle out (6–24 hours) (UW Extension, 1995).

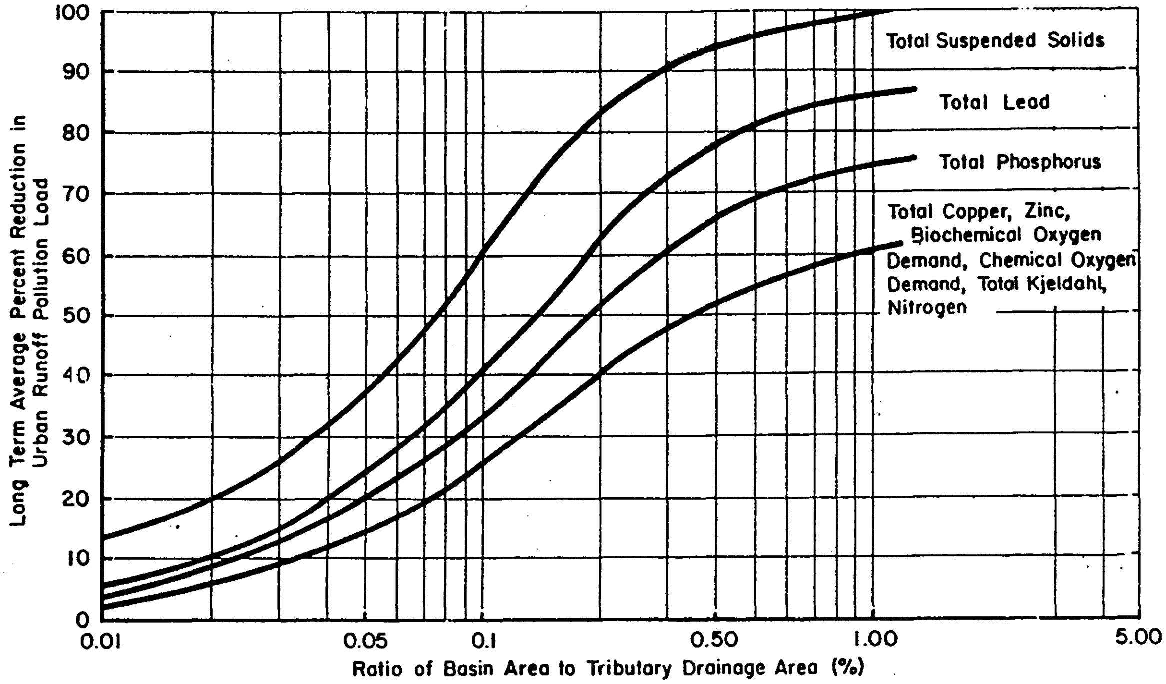
9.4.2 Construction Sites

Urban construction activities account for 10% (or 500 million tons) of all sediments that reach U.S. waters each year. This is equal to the combined contributions of forestry, mining, industrial and commercial activities (Willett, 1980). In urban areas, construction activities may account for 50% of the sediment load. Construction sites have an erosion rate of approximately 10 to 200 tons per acre per year, a rate that is about 2 to 100 times that of croplands (Pitt, 1989). This high erosion rate means that even a small construction project may have a significant detrimental effect on local water bodies. For example, for a quarter-acre homesite cleared of vegetation, up to five tons of soil (one-half a truck-load) erodes from the site every month (Wisconsin DNR, 1982).

The following no-cost and low-cost practices can be useful in preventing erosion from construction sites (Wisconsin DNR, 1982):

1. Plan construction activities so that the soil is disturbed a minimal amount of time. For example, install gas pipelines, sewer laterals, and other utilities at close time intervals.

Figure 9–3. The Pollutant Removal Effectiveness of Sediment Retention Basins in the Great Lakes Area (Source: Driscoll, 1986)



2. Leave grass, trees, and shrubs in place wherever you can. The more vegetation, the less sediment-laden water leaves the site.

3. When excavating the basement, pile the soil away from storm sewer drains—in the back or side yard area, for example. After backfilling around the basement, remove any excess soil from the site.

4. Park cars and trucks on the street, not on the site. This keeps the soil less compacted and more water-absorbent, and helps prevent mud from being tracked onto the street.

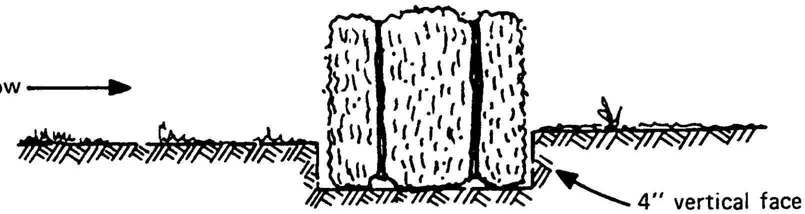
5. Arrange to have the street cleaned regularly during construction to remove sediment that preventative measures failed to keep off the street.

6. Soon after construction begins, install a gravel driveway and encourage cars and trucks to use only this route on the site. Later, install the permanent driveway over the gravel.

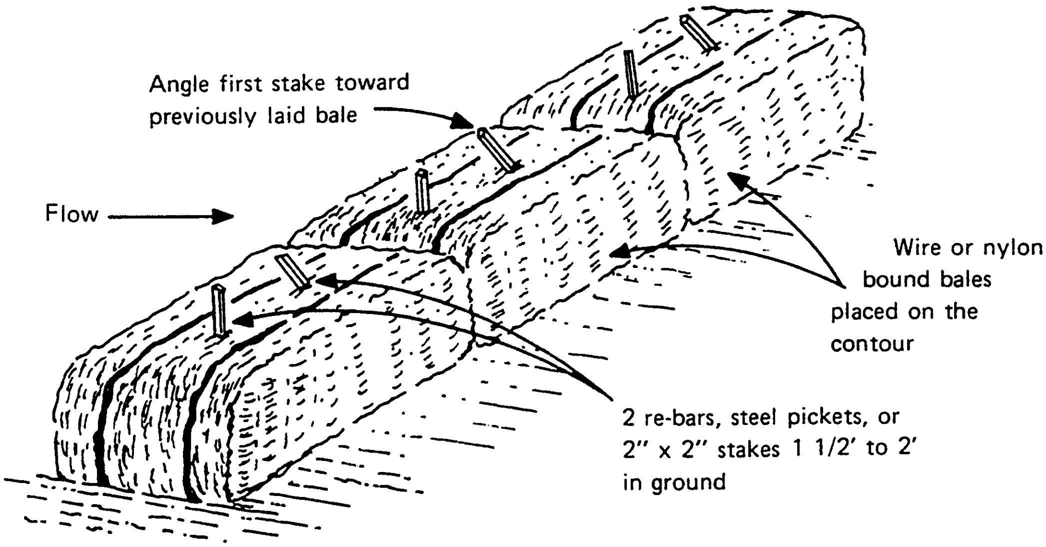
7. Build a berm to divert rainwater away from steep slopes or other highly erodible areas.

8. Install straw bales or filter fences along curbs to filter rainwater before it reaches the gutter and stormsewer drains and along the edges of bare ground and soil piles to prevent offsite damage. Both straw bales and filter fences must be installed below grade to be effective (Figures 9–4 and 9–5). Otherwise, water, eroded soils and pollutants flow under the bale or fence.

Figure 9–4. Straw Bale Dike Installation (for Drainage Area Less than 0.5 Acre) (Source: U.S. EPA, 1976c)



Embedding detail



Anchoring detail

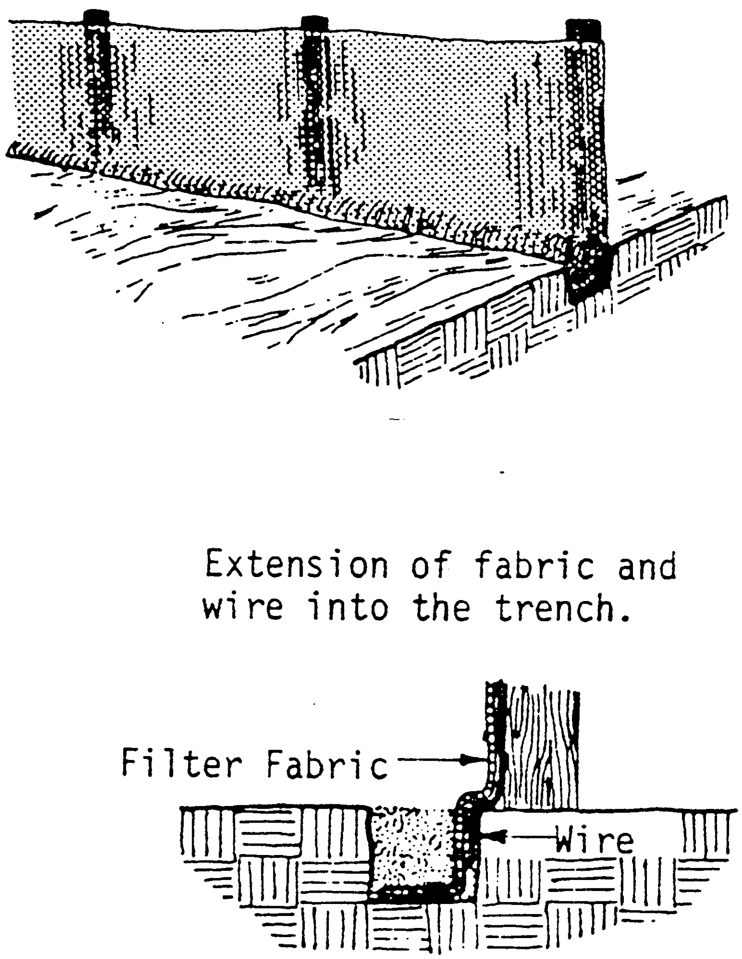
Construction Specifications

1. Bales shall be placed in a row with ends tightly abutting the adjacent bales.
2. Each bale shall be embedded in the soil a minimum of 4".
3. Bales shall be securely anchored in place by stakes or re-bars driven through the bales. The first stake in each bale shall be angled toward previously laid bale to force bales together.
4. Inspection shall be frequent and repair or replacement shall be made promptly as needed.
5. Bales shall be removed when they have served their usefulness so as not to block or impede storm flow or drainage.

9. Seed and mulch, or sod the site as soon as you complete outside construction. This will control erosion, and will increase the lot's salability by making it more attractive.

10. If the entire lot cannot be seeded and mulched, critical areas should be covered with a temporary protective material, such as filter fabric or netting. Later, this temporary cover can be removed to install utility lines.

Figure 9–5. Filter Fence Installation (Source: Bauman, 1988)



11. Use roof downspout extenders and sump pump drain tubes to funnel water away from exposed soils and directly to the curb and stormsewer or grassed swale. After the site is vegetated, downspout extenders and drain tubes should outlet to the vegetated area to maximize infiltration.

12. Use sediment retention basins where the above practices will be insufficient to retain runoff water and soil on site (see Section 9.4.1 above).

While these practices are useful on individual lots, they are no substitute for an area-wide erosion control or storm drainage control regulation. Rule 5 of the Indiana Administrative Code (327 IAC 15–5), required by the Federal Water Quality Act of 1987 and administered by the Indiana Department of Environmental Management, provides erosion control requirements for all construction sites greater than five acres in size. The City of Bloomington's Soil Erosion Control Ordinance (Bloomington Code Chapter 20.20) extends these basic protections to any construction site with at least 1,000 ft^2 of disturbed land. Construction sites of less than 5 acres in the watershed, but outside Bloomington's jurisdiction, are not protected by these soil erosion rules. Monroe County has a draft soil erosion control ordinance which mirrors Rule 5 but it has not been promulgated.

The Highway Extension and Research Project has published a model erosion control ordinance (HERPICC, 1989). This, along with the *Urban Development Planning Guide* prepared by the Hoosier Heartland RC&D Council, Inc. (1985), are indispensable references for communities developing their own erosion control regulations. Remember, the most complete ordinance is meaningless unless it is enforced. Funds and personnel must be made available for active enforcement.

9.4.3 Fertilizer Management

Lawn and garden fertilizers can be important sources of nutrients to lakes, especially when applied to lakeshore property. In a recent survey of lawn care practices in a suburban area of Prince William County, Virginia (Schuler, 1994), researchers discovered the following:

- 79% of the lawns had been fertilized in the past year.
- Pesticides had been applied to 66% of the lawns.
- 35% of the homeowners spent more than $100 on lawn chemicals per year and labored on their lawns for more than four hours per week.
- Less than 20% of residents tested their soil to determine whether their lawn actually needed fertilization.

Fertilizer application rates should be sized to what the lawn or garden needs. Excess fertilizer can wash away, possible into a nearby stream or lake. This wastes the landowner's money and contributes to nutrient enrichment of surface waters. Because grass has a high need for nitrogen, and because phosphorus is the nutrient which most often causes algae blooms in lakes, use lawn fertilizer formulas low in phosphorus. For example, fertilizers should contain less than .5% phosphorus if in liquid form or 3% if in granular form. It is best to have the soil tested *before* applying fertilizer on a lawn or garden. Contact your county extension agent for instructions or a simple kit for taking a soil sample. Soil samples can be mailed to testing laboratories for analysis for a modest fee.

Follow these guidelines for wise fertilizer management on properties located along a lakeshore or streambank:

1. Use fertilizers containing less than .5% phosphorus if in liquid form or 3% if in granular form.

2. Use organic fertilizers whenever possible. They release their nutrients slowly as the plants need them.

3. Make and use your own compost on your garden. It serves as a valuable weed-controlling mulch and organic fertilizer. By using grass clippings and leaves in compost, they won't wash into the lake either.

4. Make sure that your soil is rich in organic matter. Nutrients in fertilizers stick to organic matter until needed by plants.

5. Do not apply fertilizers to your lawn or garden between November 15 and April 15. The plants can't use fertilizers during this period and the ground may be frozen, allowing the fertilizer to run off into the lake.

6. Leave a 25-foot fertilizer-free buffer along the lakeshore.

Lawn care demonstration sites can be effective in educating homeowners on water quality oriented lawn care practices. In Prince William County, Virginia, homeowner recruits were trained on how to implement recommended lawn care practices. During the year, a Master Gardener visited the homeowner to provide additional one-on-one training and conduct a soil test. After a year of practice and demonstrating the recommended practices, the homeowner's lawn may be designated as a demonstration lawn, with an attractive sign to pique neighborhood curiosity. Not only do lawn care practices on the demonstration lawns improve, but neighbors learn by example and transfer the practices to their own lawns (Schuler, 1994).

9.4.4 Constructed Wetlands for Wastewater Treatment

New advances for treating on-site wastewater have been made in the past few years using constructed wetlands. Constructed wetlands are being used to treat stormwater and polish wastewater from conventional treatment facilities (Green, 1994; Wass and Fox, 1995) and more recently, to treat effluent from on-site septic systems for individual homes (Brennan, 1994), for a 50-room motel in LaGrange County, Indiana (Karlovich, 1993), and for a new subdivision in Porter County (Zorn, 1994). The LaGrange County motel system was the first commercial wetland permitted by the Indiana Department of Health. All of the Indiana applications have been installed by J.F. New and Associates, Inc. located in Walkerton, Indiana.

The design of these systems is relatively straightforward (Figure 9–6). Solids first settle out in a conventional septic tank. The wastewater then flows into the wetland treatment cell, a two-foot deep rectangular basin lined with heavy plastic, two layers of gravel, and topped with a layer of soil. Vegetation (cattails, rushes, reed grasses) grows in the cell and the roots are spread throughout the gravel substrate. Bacteria in the gravel, oxygenated by the plant roots, break down organic matter in the wastes. The residence time of wastewater in the constructed wetland is seven days.

Reported decreases in pollutants within the wetland cell include: fecal coliform bacteria reduced 1,700%, ammonia reduced 220%, phosphorus reduced 407%, BOD reduced 1,000%, and total suspended solids reduced 1,000% (Karlovich, 1993). Nitrification reactions slow down significantly in winter but treatment of the other pollutants continues during cold weather. The treated effluent emerging from the wetland drains into an infiltration basin where it evaporates or seeps into the ground.

The size of constructed wetland systems mentional above is about 500 ft^2 for a single-family home; 6,500 ft^2 for the 50-room motel; and 51,000 ft^2 for the subdivision.

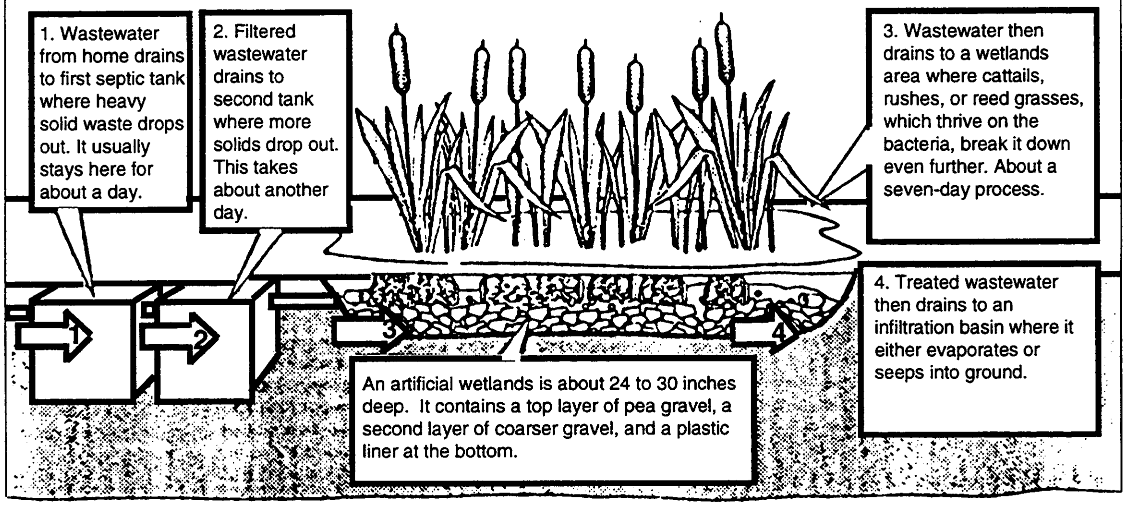
9.4.5 Management of Sensitive Lands

Sensitive lands often require special land use management controls due to their susceptablility to damage which can lead to water pollution. In the Lake Monroe watershed, lake and stream shores and hillsides are two obvious examples of sensitive lands.

Shorelands. Lake and stream shorelines receive special protection in a number of states to prevent direct impacts on water resources. Wisconsin, which passed the nation's first shoreland management program in 1966 (Yanggen, 1973), establishes a shoreland boundary of 1,000 feet from the ordinary high water mark of lakes and up to 300 feet from streambanks or to the landward side of the flood plain (Figure 9–7) (Kusler, 1980). Protecting stream corridors is as important as protecting lake shorelines because once pollutants (for example, eroded soil or excess runoff) reach a permanent or intermittent stream, they will eventually also reach the lake downstream.

Figure 9–6. Typical Design of Artificial Wetlands (Source: J.F. New and Associates, 1995)

Here is a look at how an artificial wetlands works to clean up residential and commercial waste. The artificial wetlands are generally 500 sq. ft. for a single-family residence. If there were 10 residences using the wetlands, it would be about 5,000 sq. ft.



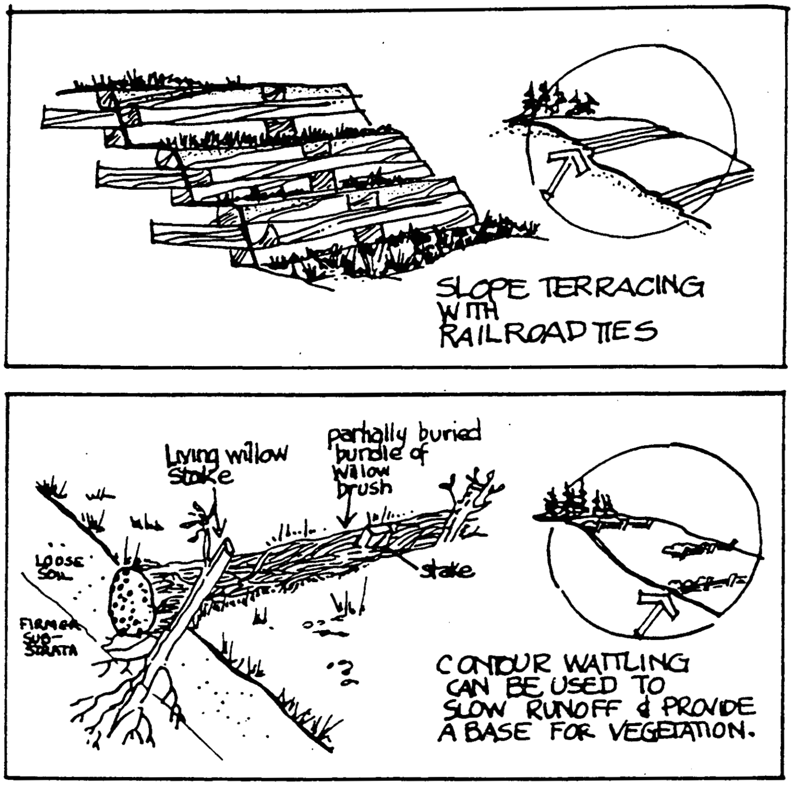
Shoreline use standards vary according to lot size, water frontage, building setbacks and other matters. Such standards permit only low density residential and recreational uses in shoreland areas and place tight restrictions on wetland areas and floodways. For example, in Wisconsin, building setbacks must be at least 75 feet from the ordinary high water mark, lots should average at least 100 feet in width, and a 35-foot shore buffer zone can only have 30% of its vegetation clearcut (MacBeth, 1991). The shoreland zoning programs of all states make extensive use of special permit procedures (Kusler, 1980). Generally, a special permit is required for any use with a substantial potential impact upon adjacent areas, water quality or scenic beauty. Case-by-case evaluations are carried out by the zoning boards of adjustment or planning commissions.

As another example, North Carolina identifies a "critical area" of 1/2 mile around the shorelines of water supply reservoirs such as Lake Monroe, and allows densities of up to one dwelling unit per acre as a "low density option" within this area and two dwellings per acre as a "high density option". High density sites require engineered stormwater controls to prevent runoff (Environmental Management Commission, 1992). No explicit provisions are made for steep slopes but local governments can implement more restrictive rules.

In Maryland, a Critical Area is defined as a 1,000-foot wide strip that extends landward from the mean high tide line of all state tidal waters. Within this area, one class of land known as "Intensively Developed Areas" can sustain new or improved residential, commercial, institutional or industrial development only if practices are installed which reduce pollutant loads from the site to at least 10% *below* the load generated at the site prior to development (Schuler and Bley, 1987).

Hillsides. Hillsides are geological features on the landscape whose slope and soils are in balance with vegetation, underlying geology, and the amount of precipitation. Poorly designed and constructed hillside developments upset this balance and frequently result in substantial costs to the public, either for repairs or for protective measures to prevent further damage (Thurow et al., 1975). Increased runoff and soil erosion from denuded hillsides require increased public expenditures for flood control and stormwater management.

Figure 9–7. Modifications for Long Slopes (Source: Michigan Sea Grant Program, 1988)



Steeply sloping areas are particularly vulnerable to erosion, and certain soils are more susceptible to erosion than others. For example, the clay soils characteristic of the Lake Monroe watershed do not absorb water and are more easily eroded than sands or gravels, which absorb precipitation. Vegetative cover plays an important role in moderating soil erosion, even on steep slopes.

Two viable approaches to the regulation of hillside development are: (1) slope-density provisions, which decrease allowable development densities as slope increases; and (2) soil-overlay provisions, which assign use and density on the basis of soil characteristics in sloped areas (Thurow et al., 1975). Three variations of the slope-density approach are slope-lot size, slope-natural area, and slope-dwelling units. In these cases, the lot size and the percent of a lot left in a natural state both increase with increasing slope while the number of dwelling units allowed decreases with increasing slope. All of these slope-determined density requirements have been used to regulate development on steep slopes. Some representative examples are shown in Table 9–2.

A second approach to the regulation of hillside development is through the use of soil overlay maps. The overlays are published by the Natural Resources Conservation Service. A soil overlay map shows which areas are suitable for particular types of development based on soil content and capability. For example, modern soil surveys evaluate the capability of soils for supporting: dwellings, basements, lawns, roads, and septic tank adsorption fields. They also identify soil limitations with regard to: flooding, depth to bedrock, frost action, and erosion (Thomas, 1981).

9.5 Shoreline and Streambank Protection

Few things are a bigger eyesore and problem for lakeshore property owners than an ugly, eroding shoreline. There are a variety of lake shoreline and streambank protection practices designed to stabilize and protect these

Table 9–2. Some Representative Examples of Slope-Density Requirements

Percent Mean Slope	*Lot size (acres)—Santa Fe, N.M*	*Percent of Site in Natural State—Thousand Oaks, CA*	*Dwellings per Acre—Thousand Oaks, CA*
5	0.25	–	No Req.
10	0.5	32.5	2
15	1	40	1.6
20	2	55	1.2
25	5	70	0.8
30	No Develop.	85	0.4
35	No Develop.	100	0.1
40	No Develop.	100	0.1

Source: Thurow et al. (1975)

areas against scour and erosion from forces such as wave action, ice action, seepage, and runoff from upland areas. Shoreline stabilization methods fall into two broad categories: nonstructural (vegetation or beach sloping) and structural (flexible structures such as rip-rap and rigid structures like seawalls) (McComas, 1986).

9.5.1 Revegetation

Vegetation effectively controls runoff erosion on slopes or banks leading down to the water's edge. However, vegetation is generally ineffective against direct wave action or seepage-caused bank slumping. The type of vegetation to establish depends on the steepness of the slope. If the slope angle is steeper than 1:1 (i.e., 1 foot horizontal for every 1 foot vertical), the soil is probably unstable and the possibility of establishing protective vegetative cover is slight (McComas, 1986). Steep slopes should be re-graded to a 2:1 slope or flatter (SCS, 1989). All materials excavated from sloped banks may be placed on the bank, leveled, and seeded to prevent erosion during high water, or may be hauled to other areas for use. Do not place excavated material into the lake or stream, or form barriers which interfere with runoff entering natural channels.

On long, steep slopes leading down to the water's edge where regrading to a gentler slope is impractical, consider slope modifications which will allow vegetation to become established. Slope terracing provides horizontal steps in which to plant vegetation. Contour wattles are bundles of live willow cuttings anchored into the bluff face with either construction or live willow cuttings (Michigan Sea Grant Program, 1988). The bundles trap surface runoff and soil particles and lets vegetation become established.

Once an appropriate slope is created, seed or plant the bare soil immediately. Use erosion control mats of nylon mesh or wood excelsior on top of the soil to assist in seed germination, seedling protection, and erosion control. Time your work to coincide with optimal planting times. Grasses can be planted in the spring or fall while woody plants should be planted when they are dormant. A protective grass cover can be established within one year. Slopes should be 3:1 or flatter to facilitate mowing. Herbaceous ground covers, shrubs and trees may take several years to become established. Ground covers are useful when mowing isn't desired. When using trees or shrubs to stabilize banks, plant grasses initially until the woody vegetation becomes established. A guideline for vegetative covers is presented in Table 9–3.

If regrading steep, eroded lakeshore slopes isn't possible, dormant woody plant cuttings can be used to vegetatively stabilize shorelines and streambanks. The Illinois Water Survey has successfully stabilized eight-foot, 1:1 slope eroded streambanks with dormant willow posts (Illinois Resources, 1990; SCS, 1990). The willow post method uses 7–12-foot posts (one-half to three inches in diameter) that are placed in holes driven into the streambank (Figure 9–8). The willow posts are placed about four feet apart in offset rows. Within a few months, the posts regrow root systems and branches. Post length will vary with the depth to saturated soil and the bank elevation. About 40% of the post length must be buried in the bank, with the bottom of the post in the saturated zone. The Illinois Department of Conservation has used willow posts to successfully control erosion on near-vertical, 12-foot high streambanks. There is an excellent video (Illinois Department of Conservation, 1989) and guide (SCS, 1990) documenting the technique. The Soil Conservation Service has approved the willow post technique for cost sharing funds. The SCS (1990) estimates that the average cost of regrading a 12-foot-high bank to 1:1 slope is $77 per 100-foot length, and the cost per hole is $2.40 per 6-foot-post and $2.90 per 9-foot-post. Labor to cut and transport the posts can be calculated at 10 posts per person per hour.

In April 1993, a portion of eroding lakeshore near the Paynetown SRA boat ramp on Lake Monroe was graded and several shoreline erosion BMPs were installed as a demonstration of shoreline erosion control techniques. This activity was a cooperative effort of the Indiana Department of Environmental Management and the Indiana Department of Natural Resources, divisions of Reservoirs and Soil Conservation. The upper portion of the bank was reseeded with red fescue and covered with an excelsior-filled erosion control blanket. The lower portion of the bank was planted with semi-dormant willow stakes in hand-dug holes. Within two weeks the fescue growth was very thick and the willows began to send out leaves. After one month, about 75% of the willow stakes had new growth.

Today, approximately 60% of the willow stakes planted are alive and growing and the shoreline area in which they are planted is stable. It appears that the willows are being heavily browsed by animals as growth is limited to small sprouts. The success of the willow post planting might have been improved by installing the posts earlier in the spring when the willows were completely dormant, and by using machine-drilled holes which could penetrate deeper than the hand-dug holes. At times, low lake levels likely lower the saturated zone to below the bottom of the willow posts so deeper holes and extending the willow plantings lakeward would offer better rooting conditions. Nonetheless, the willow post technique could be a very beneficial and cost effective shoreline erosion control at Lake Monroe.

9.5.2 Littoral Zone Revegetation

Diverse, moderately dense stands of aquatic plants are desirable in a lake's littoral zone. Emergent aquatic plant communities protect the shoreline from erosion by dampening the force of waves and stabilizing shoreline soils. Vegetation can also provide screening for the lakeshore homeowner and buffer noise from motor boats. Many species of aquatic plants, such as the white water lily and pickerelweed, are aesthetically pleasing because they have showy flowers or interesting shapes. Aquatic vegetation also provides fish habitat and spawning sites, waterfowl cover and food, and habitat for aquatic insects. For example, sedges (*Carex* spp.) become spawning beds for northern pike in spring, wild rice beds (*Zizania aquatica*) attract shorebirds in summer, and wild celery (*Vallisineria americana*) develops tubers that attract canvasbacks in fall and is one of the finest fish food and cover plants (Engel, 1988). Table 5–3 lists the positive attributes of some aquatic plant species.

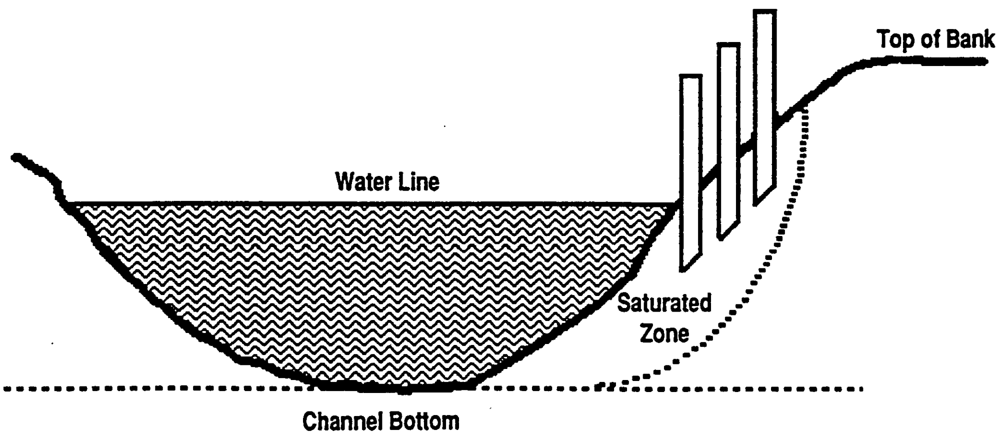
A management goal should be to produce stable, diverse, moderately dense aquatic plant communities containing high percentages of species with desirable attributes (Nichols, 1986). This technique has been used successfully to enhance the benefits of aquatic vegetation in several Wisconsin lakes (Nichols, 1986; Engel, 1988, 1989a). For example, 15,900 tubers of nine emergent and two submergent species were planted along the

Table 9–3. Vegetation for Lakeshore and Streambank Slopes (Adapted from: McComas, 1986)

Vegetation	*>3:1 Slope*	*> 1:1 Slope*
Grasses	Kentucky bluegrass[a]	red fescue[a] switchgrass big bluestem little bluestem
Ground Covers	(same as >1:1 slope)	goutweed bearberry crown vetch[a] memorial rose creeping juniper purple wintercreeper
Shrubs	(same as >1:1 slope)	red chokecherry gray dogwood sumac common juniper common witch hazel border privet snowberry tatarian honeysuckle[a]
Trees	(same as >1:1 slope)	red maple silver maple paper birch[a] white ash white pine black cherry

[a]non-native species that the Indiana DNR considers potentially invasive.

Figure 9–8. Willow Post Technique for Steep Streambanks and Lakeshores



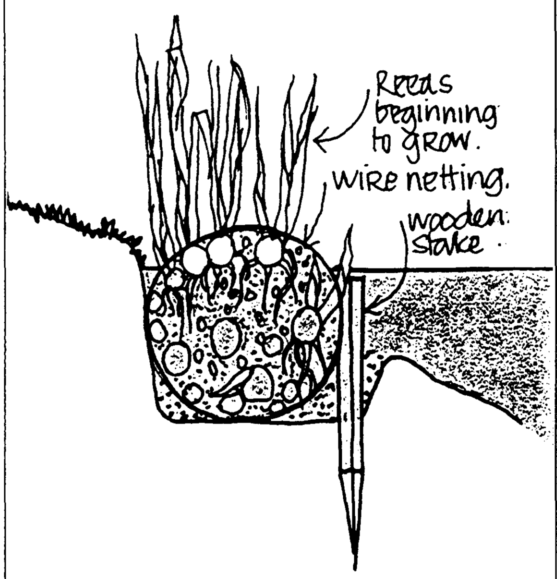
lakeshore and constructed islands in Elk Creek Lake, a 54-acre Wisconsin impoundment, to stabilize slopes, improve water clarity, and attract waterfowl. Plant species with rapid growth rates, high productivity, and long growing seasons may interfere with water uses and should be avoided.

At Lake Monroe, there is little emergent vegetation along the shoreline of the Middle and Lower basins. Steep shoreline slopes and heavy wave action may limit the natural expansion of emergents in some locations and poor substrate may prevent rooting in others. Bioengineering techniques could be useful in these cases. For example, reed rolls or bio-logs (Figure 9–9) can be anchored in the lake's littoral zone to provide some structural protection while offering an excellent medium for plant growth. Reed rolls are wire rolls filled with gravel and bio-logs are rolls of compressed coconut fiber which have an extremely slow decomposition rate and high tensile strength. Tubers or roots of emergent plants can be placed within the rolls which provide a stable substrate for growth. These materials can provide stability for five to ten years, which helps establish a dense stand of herbaceous vegetation capable of providing permanent shoreline protection and aquatic habitat (UW Extension, 1993).

Plantings in shallow areas with good substrate can increase the populations of aquatic plant species or the area of cover. Planting is labor intensive but plant stock is relatively inexpensive. Plant propagules must be collected or purchased from a commercial source. They then have to be weighted or placed directly in bottom sediment (Nichols, 1986). For example, tubers of wild celery and sago pondweed should be weighted with a 16 penny nail attached by a rubber band or sunk in mesh bags containing stones (Engel, 1988). Tubers and roots should be planted in the early spring. For some species that produce seed, the seed can be broadcast in the fall. An alternative method is to pack the seeds in mud balls before sowing.

Table 9–4 lists some rooted plants to grow in Midwestern lakes needing habitat. Bulrushes (*Scirpus spp.*) are among the best emersed plants as far as withstanding the physical action of waves and currents. By buffering wind and wave action, this species allows other aquatic plants to gain a foothold and grow. Reed canary grass (*Phalaris arundinacea*) has deep and intertwined root systems that bind shoreline soil well and provide excellent cover for aquatic insects, fish fry, and waterfowl. Eurasian species of this plant are invasive and should be avoided. The extensive root system of Sago pond weed (*Potamogeton pectinatus*) makes it carp-resistant and it is proclaimed as the best all-around duck food in North America (Wildlife Nurseries, 1990).

Figure 9–9. Reed Roll for the Rapid Population of the Reed Bank Zone



Three sources of aquatic plants and seeds in the Upper Midwest are:

J.F. New & Associates, Inc.
708 Roosevelt Rd.
Walkerton, Indiana 46574

Wildlife Nurseries
P.O. Box 2724
Oshkosh, Wisconsin 54903

Country Wetland Nursery, Ltd.
Box 126
Muskego, Wisconsin 53150

Table 9–4. Some Rooted Plants to Grow in Midwestern Lakes Needing Habitat

Common name	*Scientific name*
Emergent species: plant rootstock in ankle-deep water.	
Common arrowhead	*Sagittaria latifolia*
Pickerelweed	*Pontederia cordata*
Slender spikerush	*Eleocharis acicularis*
Sweetflag	*Acornia calamus*
Reed canary grass	*Phalaris arundinacea*
Emergent species: plant rootstock or seed no greater than waist deep.	
Hardstem bulrush	*Scirpus acutus*
Common cattail	*Typha latifolia*
Sedge	*Carex spp.*
Wild rice*	*Zizania aquatica*
Floating-leaved species: plant rhizome no deeper than about 0.9 m (3 ft.).	
American lotus	*Nelumbo lutea*
White water lily	*Nuphar advena*
Yellow water lily	*Nymphaea tuberosa*
Submergent species: plant seed, cutting with leaf node, or whole plant no deeper than 10% of surface light.	
Broad-leaved pondweeds	*Potamogeton amplifolius, illinoensis, natans, richardsonii*
Narrow-leaved pondweeds	*Potamogeton berchtoldii, foliosus, pectinatus*
Wild celery**	*Vallisneria americana*

*Plant seeds only.
**Plant tubers or whole plant only.

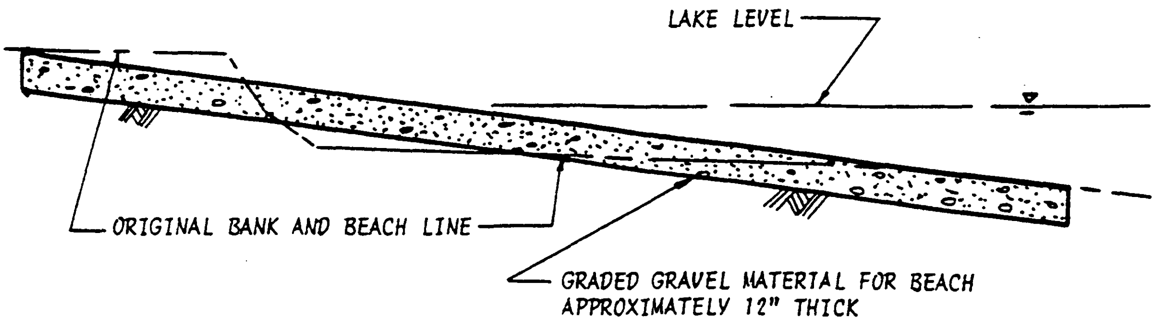
Source: Engel (personal communication, 1993); Wildlife Nurseries (1990)

9.5.3 Beach Sloping

Beach sloping takes advantage of the ability of semifluid sands to dissipate the energy of the breaking and receding waves (McComas, 1986). A typical cross section is shown in Figure 9–10. The final slope of the beach line is based on the size of the material used. Design considerations include:

1. Minimum thickness of the sand blanket is one foot.
2. Extend the blanket to a water depth two times the design wave height.
3. Extend the beach blanket the distance equal to the computed runup plus one foot.
4. The size of the material used and the final slope should be determined by a professional engineer.

Figure 9–10. Cross Section of Beach Sloping (Source: McComas, 1986)



One problem with beach sloping is that a strong along-shore current may erode the blanket material. Periodic replenishment will be necessary in this case.

9.5.4 Structural Methods

Riprap is a flexible structure constructed of stone and gravel which is designed to protect steeper (slope > 1:1) shorelines from wave action, ice action and slumping due to seepage. The riprap is flexible in that it will give slightly under certain conditions. This improves its ability to dissipate wave energy. Riprapping involves more than simply dumping rocks on the shoreline. Filter fabric or graded stone must be used on the soil base to prevent soil from moving through the stone and undercutting it. The toe (bottom) of the riprap must be protected by burying it at least three feet below the sediment surface (Figure 9–11). The size of the largest stones used depends on the design wave height. See SCS Standards and Specifications 580 entitled, "Streambank and Shoreline Protection" (SCS, 1989) or your county SCS agent for more information.

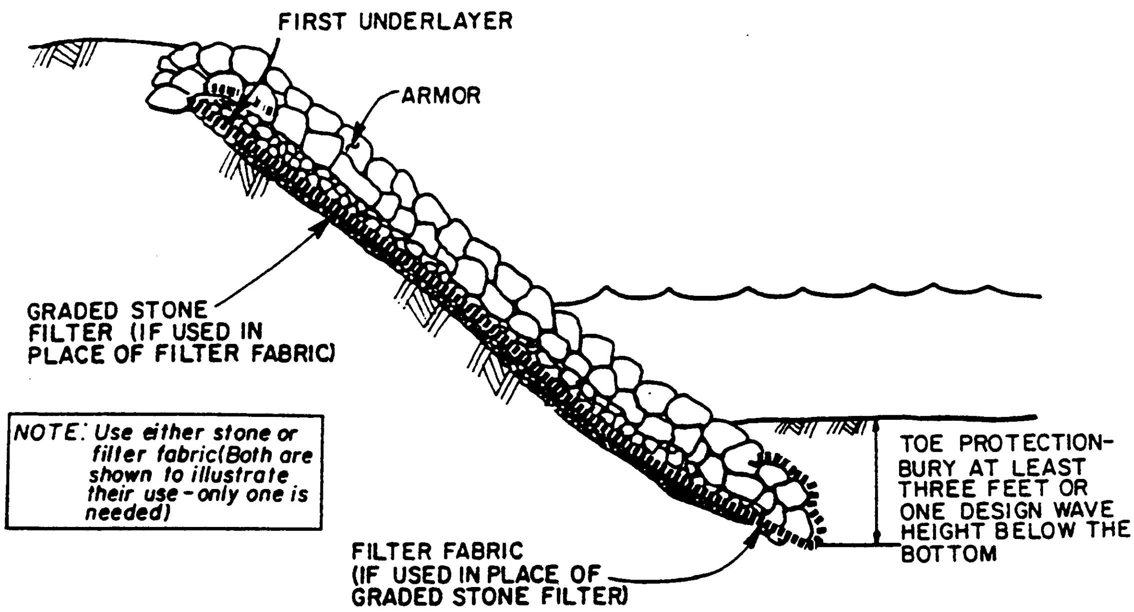
Seawalls, bulkheads, and retaining walls are rigid structures used where steep banks prohibit the sloping forms of protection. Seawalls primarily prevent land masses from sliding from the shore into the water and secondarily prevent wave action from damaging the shoreline. Seawalls do not dissipate wave energy but rather, redirect the wave energy away from the shore. This often erodes the shoreline at the base of the wall and may affect the slope of the lake bottom some distance from shore. The cumulative effect of too many seawalls around a lake can be devastating to aquatic species.

The placement of riprap and seawalls is best left to the professional. *The use of both of these methods requires a permit from the Indiana Department of Natural Resources and may require a 404 Permit from the U.S. Army Corps of Engineers. These agencies must be contacted before any material is placed or deposited in a stream channel or on a lake bed.*

9.5.5 Streambank Fencing

Cattle, hogs, and other farm animals can destroy streambank structure and vegetative cover when they walk down or along streambanks to get water. This leads to serious erosion and sediment transport to downstream areas. Farm animals should not have unrestricted access to streams. Streambank fencing can be used to protect banks from farm animals. Stabilized crossings or access points should be constructed to allow farm animals access to the water if there are no other watering alternatives.

Figure 9–11. Cross Section of a Riprapped Shore (Source: McComas, 1986)



9.6 Wetlands Treatment of NPS Pollutants

9.6.1 Purpose

Wetlands are emerging as a low-cost, efficient treatment system for a wide variety of wastewaters, including: municipal wastewater, acid mine drainage, urban runoff and more recently, nonpoint source pollution (Watson et al., 1989). For example, the Indiana Department of Natural Resources T–by–2000 Lake and River Enhancement Program has supported the use of constructed and reconstructed wetlands to protect lakes from sediment and nutrient inputs from their watersheds. Under this program, wetland treatment systems have been constructed at Lake Maxinkuckee and Koontz Lake in Marshall County and at Prides Creek Reservoir in Pike County. Treatment efficiencies vary with design, vegetation used, soil conditions, and loading rates, but removal rates of 95% for sediment, 90% for total phosphorus, and 75% for total nitrogen are reported in the literature (Livingston, 1989).

9.6.2 Design Considerations

There are several important design considerations to consider for enhancing the sediment and nutrient removal efficiencies of constructed or enhanced wetlands. These include:

1. Sizing the wetland to the drainage area.
2. Reducing water velocities through the system.
3. Maintain optimal water levels.
4. Pretreatment to remove sediments.

Wetland surface area must be sized to meet the expected volume of water it receives. Design features should maximize runoff residence time which, in turn, enhances contact with wetland sediments, vegetation and microorganisms. Maryland's urban stormwater regulations suggest a designed detention time of 24 hours for the one-year storm event (Livingston, 1989). This will enhance pollutant removal and provide storage volume recovery between storms. If extended detention is not possible, then the wetland surface area should be a minimum of 3% of the contributing drainage area. Extended detention can be provided by incorporating a sedimentation basin into the wetland design.

High water velocities through wetlands can reduce soil and plant removal efficiencies and may even wash out rooted vegetation. Mechanical stress due to high water velocities can cause changes in vegetation leaf form, reduction in plant growth, and may shift biomass from the leaves to the roots (Guntenspergen, et al., 1989).

The wetland hydroperiod must be consistent with the needs of the vegetation used. Hydroperiod is the depth and duration of inundation measured over an annual wet or dry cycle. The proper hydroperiod determines the form, nature, and function of the wetland (Livingston, 1989). Water depth and inundation period can change the vigor and species composition of the wetland plant community. This can have detrimental impacts on the wetland or its nonpoint pollutant removal capability.

Finally, many wetland treatment systems incorporate presedimentation basins to remove some of the sediment load before it reaches the wetland. Sediment accumulation within the wetland can change plant species composition or even bury rooted vegetation. Pretreatment can not only enhance the functioning of the wetland but also extend its usable lifetime.

9.7 In-Lake Treatment

In-lake management techniques are most effective when applied following the implementation of watershed BMPs. In-lake techniques can help speed up the recovery of degraded lakes. All of the in-lake management techniques discussed in the following sections have been tested to varying degrees. The success of any one technique depends on the extent to which a lake has been characterized (physically, chemically, and biologically) before choosing the appropriate alternative, and the precision with which that alternative is applied to the particular situation. Specific management goals must be established prior to embarking on any comprehensive lake management program.

A number of excellent publications describing in-lake management are available. The *Survey of Lake Rehabilitation Techniques and Experiences* (Dunst et al., 1974) is a comprehensive treatment of pioneering restoration techniques, including case studies. The *Lake and Reservoir Restoration Guidance Manual* (Olem and Flock, 1990) prepared by the North American Lake Management Society was written to provide guidance to homeowners and other lay people. A book entitled, *Restoration and Management of Lakes and Reservoirs* (Cooke, et al., 1993) is a more detailed scientific account of the latest lake renovation and management techniques. The reader is referred to these sources for more information.

9.7.1 Phosphorus Precipitation/Inactivation

Precipitation and inactivation of phosphorus is designed to remove phosphorus from the water column and to prevent release of phosphorus from sediments. This nutrient control strategy is aimed at minimizing planktonic algal growth. A floc is an agglomeration of small particles formed when aluminum salts are added to the lake. This floc ($Al[OH_3]$) acts in two ways: (a) it absorbs phosphorus from the water column as it settles, and (b) it seals the bottom sediments if a thick enough layer has been deposited. Phosphorus can also precipitate out as an aluminum salt ($AlPO_4$).

Most phosphorus precipitation treatments have employed liquid aluminum sulfate (alum) or sodium aluminate. The dosages are determined by a standard jar test, keeping in mind that aluminum solubility is lowest in the pH range 6.0 to 8.0. Cooke and Kennedy (1981) offer a detailed dose determination method. Aluminum toxicity does not appear to be a problem at treatment concentrations in well-buffered lakes as long as the pH remains above 6.0. Chemicals added for phosphorus control are applied either to the lake surface or to the hypolimnion, depending upon whether water column or sediment phosphorus control is most necessary.

The application procedure of aluminum salts to lake water has changed little since the first treatment in Horseshoe Lake, Wisconsin (Peterson, et al., 1973). At Horseshoe Lake, alum slurry was pumped from a barge through a manifold pipe that trailed behind the vessel just below, and perpendicular to, the water surface. Today, new LORAN-guided high-speed barges applying 115 m^3 of liquid alum per day are the most advanced application vessels available (Cooke, et al., 1993).

The season of application is critical for phosphorus removal, since different forms of phosphorus predominate in the water column on a seasonal basis. Phosphorus removal is most effective in early spring when most phosphorus is in an inorganic form which can be removed almost entirely by the floc.

Phosphorus inactivation has been effective for as long as twelve years. In shallow, wind-swept lakes or in such parts of lakes, however, the floc may break up and lose its capabilities as a sealant. Application costs using the new, high-speed barges is about $640/hectare (Cooke, et al., 1993).

Applicability to Lake Monroe. Phosphorus concentrations in the Upper Basin of Lake Monroe are elevated enough to consider the use of alum if watershed sources of additional phosphorus loading are controlled. However, the very shallow waters of the Upper Basin will allow boats to resuspend the floc and water currents will redistribute the floc. There is little evidence of phosphorus release from Lake Monroe's hypolimnion in the Lower Basin during brief periods of anoxia. Thus, alum application would have little effect on phosphorus concentrations in the lake.

9.7.3 Dredging

Sediment removal by dredging removes phosphorus enriched sediments from lake bottoms, thereby reducing the likelihood of phosphorus release from the sediments. Dredging also deepens lakes for recreational purposes and for limits the growth area for rooted macrophytes. Because this technique is capital-intensive, it can only be justified in small lakes or in lakes where the sediment-bound phosphorus is limited to a small, identifiable area. Dredging is not effective in lakes where additional sediment loading cannot be controlled. In deep lakes, the cost of dredging can be prohibitive. Sediment removal might also be justified in a seepage lake, where watershed controls are not applicable.

A potentially troublesome consequence of dredging is the resuspension of sediments during the dredging operation and the possible release of toxic substances bound loosely to sediments. Because of this, sediment cores must be analyzed prior to dredging to determine sediment composition. Such an analysis would also provide a profile of phosphorus concentrations with depth in the sediments. If phosphorus concentrations do not decline with depth, dredging for phosphorus control would not be effective since phosphorus could continue to be released from the sediments.

Perhaps the most economically and logistically prohibitive part of a dredging operation is disposal of the sediments removed. Sediment disposal must be carefully investigated before the decision to dredge can be made.

Hydraulic dredging costs commonly range from $2.25/$m^3$ to $5.65/$m^3$ (Cooke et al., 1993).

Applicability to Lake Monroe. Because Lake Monroe's sediments are not highly enriched with phosphorus, there is no reason to consider dredging for nutrient control. However, there are a number of localized areas where sedimentation has created boat navigation problems. In these areas, particularly near the mouths of the North and Middle Forks of Salt Creek, dredging could deepen channels for boats. Dredging these areas would also remove the rooted macrophytes growing in the shallow water. These macrophytes provide important fish and waterfowl habitat and much of this area is designated as state fish and wildlife refuges. More importantly, the macrophyte beds function as filters to slow down runoff water, allowing suspended sediments and associated nutrients to drop out. This is an extremely important function for Lake Monroe. By concentrating sedimentation in small, localized areas, the bulk of the lake will fill in at a much slower rate. Thus, for the present time, the upper basin macrophyte beds should not be dredged.

9.7.4 Aeration

Hypolimnetic aeration is a technique used to remedy oxygen depletion in the bottom waters of a stratified lake without disturbing the existing thermal conditions. There are two basic aeration strategies: (a) air or oxygen is introduced directly to the hypolimnion, and (b) the hypolimnetic water is pumped to the lake surface or to an onshore splash basin where it is aerated before being returned to the lake bottom. Crucial to the success of this process is the size of the aerator. Cooke, et al. (1993) provide guidance on determining aeration capacity needs.

The effects of hypolimnetic aeration on the improvement of water quality are both direct and indirect. Aeration has direct effects on taste and odor, the lake's cold water fishery and winter fish kills, and indirect effects on phytoplankton. Hypolimnetic aeration can remove iron and hydrogen sulfide, both of which contribute to taste and odor problems. It can also prevent phosphorus release from the sediments. In stratified eutrophic lakes, aeration provides a source of oxygen for otherwise anoxic bottom water, creating a suitable environment for cold water fishes, a refuge for zooplankton, and preventing winter fish kills. It is the expansion of zooplankton habitat, if anything, that aids in control of algae. Because the zooplankton can better escape their predators, they become more effective in controlling their prey, the algae. Hypolimnetic aeration has no known adverse effects on water quality.

A similar technique, artificial circulation, produces some different results. The strategy is the same—to provide oxygen to anoxic bottom waters in stratified lakes. Circulation techniques range from high-energy mixing devices to low-energy aerators, and include mechanical pumps, rising air bubbles, and jets of water. Aeration is accomplished via atmospheric exchange at the lake surface. Since lakes are most often artificially mixed after stratification occurs, the procedure is also known as artificial destratification. One advantage to mixing before stratification is that bottom waters will be low in nutrients.

In addition to improving taste and odor qualities and reducing incidents of winter fish kills, artificial circulation can decrease turbidity and algal blooms by distributing the algae throughout the water column. However, circulation may destroy a lake's cold water fishery by introducing warmer epilimnetic waters into the hypolimnion.

Applicability to Lake Monroe. Only a small volume of Lake Monroe suffers from temporary anoxia. Aeration is not needed at this time.

9.7.5 Rooted Macrophyte Control

Dense, monotypic macrophyte beds, especially beds composed of American lotus and milfoil, have limited habitat value and interfere with boat navigation. Although only about 16% (650 ha) of Lake Monroe's surface area is covered with macrophytes, the dense beds can cause localized problems and some selected control in these small areas is likely warranted.

Mechanical Harvesting. Although macrophyte harvesting is not a long-term restoration method, it can manage the growth of aquatic macrophytes and give the lake user immediate access to areas and activities that had been affected by excessive macrophyte growth; these include swimming, boating, and water-skiing. Plants harvested several times during the growing season, especially late in the season, often grow more slowly the following season (Cooke, et al., 1993). Further benefits are derived if the cut plants and the nutrients they contain are removed from the lake. Harvested vegetation that is cut and left in the lake ultimately decomposes, contributing nutrients and consuming oxygen. Many harvested plants, especially milfoil, can re-root or reproduce vegetatively from the cut pieces if left in the water.

Algal blooms following harvesting have been reported in some lakes because the rooted plants no longer compete with the algae for available nutrients. Few other adverse environmental impacts have been identified.

Mechanical harvesting costs vary according to capital cost and capacity of the harvester, amortization rate, amount of time required to unload harvested material, size of lake, and other factors. Depending upon the specific situation, harvesting costs can range up to $1,600 per hectare (Prodan, 1983; Adams, 1983). Estimated costs of the mechanical harvesting program at Lake Lemon averaged $659 per hectare (Zogorski, et al., 1986).

Drawdown. Lake level drawdown can be used as a macrophyte control technique or as an aid to other lake improvement techniques. Drawdown can be used to provide access to dams, docks, and shoreline stabilizing structures for repairs; to allow dredging with conventional earthmoving equipment; and to facilitate placement of sediment covers.

As a macrophyte control technique, drawdown is recommended in situations where prolonged (one month or more) dewatering of sediments is possible under conditions of severe heat or cold and where susceptible species are the major nuisances. *Myriophyllum spicatum* control, for example, apparently requires three weeks or longer of dewatering prior to a one-month freezing period (Cooke, 1980). Cooke (1980) classifies 63 macrophyte species as decreased, increased, or unchanged after drawdown. One must note the presence of resistant as well as susceptible species, since resistant species can experience a growth surge after a successful drawdown operation.

Macrophyte control is achieved by destroying seeds and vegetative reproductive structures (e.g., tubers, rhizomes) via exposure to drying or freezing conditions. To do so, complete dewatering and consolidation of sediments is necessary. Dewatering may not be possible in seepage lakes.

There are a number of other benefits to lakes and reservoirs from drawdown. Game fishing often improves after a drawdown because it forces smaller fish out of the shallow areas and concentrates them with the predators (bass, walleye, pike). This decreases the probability of stunted fish and increases the winter growth of the larger game fish. Drawdown has also been used to consolidate loose, flocculent sediments that can be a source of turbidity in lakes. Dewatering compacts the sediments and they remain compacted after reflooding (see Born et al., 1973 and Fox, et al., 1977).

A final consideration in implementation of lake level drawdown is season—winter or summer are usually chosen because they are most severe. According to Cooke (1980b), "it is not clear whether drawdown and exposure of lake sediments to dry, hot conditions is more effective than exposure to dry, freezing conditions." One factor to consider is which season is most rigorous. Advantages of winter drawdown include less interference with recreation, ease of spring versus autumn refill, and no invasion of terrestrial plants. Sediment dewatering is easier in summer.

In Murphy Flowage, a 73 ha (180 acre) reservoir in Wisconsin, a five-foot drawdown from mid-October to March greatly reduced the presence of aquatic macrophytes the following growing season. *Myriophyllum* spp. was reduced from 8 ha to <1 ha coverage, *Nuphar* spp. was reduced from 17 ha to 5 ha, and *Potamogeton* spp. was reduced from 46 ha to 3 ha (Beard, 1973).

Lake level drawdown is an attractive restoration technique due to its low cost and because introduction of chemicals and machinery is not necessary.

Bottom Sealing. Covering bottom sediments with fiberglass or plastic sheeting materials provides a physical barrier to macrophyte growth. Buoyancy and permeability are key characteristics of the various sheeting materials. Buoyant materials (polyethylene and polypropylene) are generally more difficult to apply and must be weighted down. Sand or gravel anchors can act as substrate for new macrophyte growth. Materials must be permeable to allow gases to escape from the sediments; gas escape holes must be cut in impermeable liners. Commercially available sheets made of fiberglass-coated screen, coated polypropylene, and synthetic rubber are nonbuoyant and allow gases to escape, but cost more (up to $27,000 per hectare for materials only) (Cooke et al., 1993).

Due to the prohibitive cost of the sheeting materials, sediment covering is recommended for only small portions of lakes, such as around docks, beaches, or boat mooring areas. This technique may be ineffective in lakes with high siltation rates, since silt accumulated on the sheeting material provides an area for macrophyte growth.

Applicability to Lake Monroe. Selective harvesting of rooted macrophyte beds in Lake Monroe could open up boating channels to provide improved fishing access. Such channels also create "cruising lanes" for predatory fish. Winter drawdown could be a useful technique to reduce milfoil populations in the upper reaches of Lake Monroe, however, it may have little affect on American lotus (Cooke, et al., 1993). Drawdown is a non-selective control and desirable species could be impacted as well. Bottom covers could be useful around boat docks and piers.

9.8 Lake Use Management

An additional loading to lakes which is often overlooked, but which can be every bit as damaging as point or nonpoint sources is "human loading." Lakes are primarily used for aesthetic enjoyment and active recreation. As they are used, they are loaded with people in a way fully analogous to phosphorus loading (Klessig, 1994). A crowded lake where lake users have their experience diminished by the presence and behavior of other users is the equivalent of a eutrophic lake. Lakes have an ecological carrying capacity and a sociological carrying capacity. They often need limits that protect them from too many users and from vessels that are simply too large or in densities too great for the lake.

The high demand for recreation at Lake Monroe along with the physical and ecological limits of certain lake areas (for example, shallow water zones, the wildlife refuges, etc.) suggest that some controls must be placed on recreational uses. Most public lakes have some form of lake use restriction in place. For example, at 45-acre Dow's Lake in Ottawa, Canada, recreation demand was so high that up to 170 boats were reported using this lake at one time (Jaakson, 1984). In cases like this, resource damage and conflicts among recreational uses are inevitable without the use of controls.

Lake use controls or limits must be a part of a carefully developed lake use management plan. Goals for such a plan must be fashioned in a clear, logical manner and should consider: (a) resource limitations, (b) recreational demand, (c) recreational use compatibility, (d) alternative siting, and (e) health, safety, and liability issues. Water and adjacent land-based uses, such as hiking and birdwatching, should be included in this evaluation. However, the desire to provide for a large diversity of uses should not diminish the quality of the recreational experience, nor does diversity of use imply equal amounts of use. This approach was used successfully in developing a lake use management plan for Griffy Lake, Indiana (Jones et al., 1984). The Griffy Lake plan, which included upland areas, is still a viable, working plan ten years after it was adopted.

Once goals are established, strategies can be developed to achieve them. Lake use restrictions, time zoning and space zoning are among the more common options available for managing aquatic resources.

9.8.1 Use Restrictions

One of the most common lake use restrictions is boat speed limits. Speed limits are used on small lakes to insure safety, to maintain a more tranquil setting or to reduce boat-induced waves and the shoreline erosion they cause. In Indiana, there is a 10 mph speed limit on all public lakes less than 300 acres for these reasons (IC 14–1–1–24)

Other lake use restrictions include:

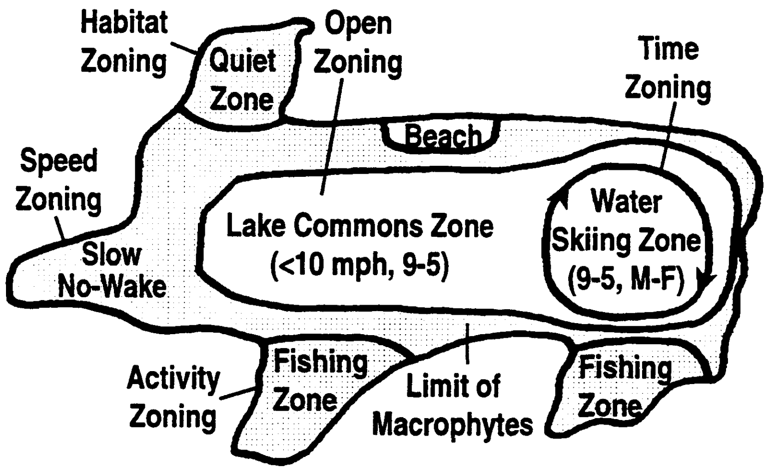
- Gasoline motors—often prohibited on small lakes within fish and wildlife areas to reduce disruption of nesting waterfowl or other animals.
- Swimming—may be prohibited in lakes or areas where supervision is not possible or where poor water quality creates a health risk.
- Fishing seasons and limits—imposed to protect spawning fish, to manage fish population size structure, and to maintain a healthy fishery.

In some cases, designated uses may be established for entire lakes (Engel, 1989a). Shallow lakes can be designated for fishing or waterfowl hunting. Deep basins could support motorboating and water skiing. This approach is most feasible in a region with numerous diverse lakes. For example, Vermont has established the Use of Public Waters Policy which designates permitted lake uses on some 283 public lakes according to four lake types: wilderness/solitude, nonmotorized, low speed motorized, and high speed motorized (Bulmer and Garrison, 1994).

9.8.2 Space Zoning

Lakes under intense recreational use pressure can be zoned to partition the use of water space (Engel 1989a; Engel 1989b). Activity zoning in large, diverse lakes allocates space for all allowed water uses (Figure 9–12). Open water areas can be reserved for motorboats and skiing. A shoreline area can be designated for swimming. Shallow bays can be designated as quiet zones for fish or waterfowl habitat where only minimal disturbance is allowed. In these areas, motors may be prohibited or idle speed only may be allowed. For example, the shallow, eastern half of Monroe Reservoir is designated as an idle zone to promote fishing, fish and waterfowl habitat, and to prevent resuspension of sediments by boats. Another form of space zoning in Indiana is the state law which prohibits boat speeds greater than 10 mph within 200 feet of shoreline on all public lakes (IC 14–1–1–29).

Figure 9–12. Time and Space Zoning Options for Human Use Management of Lakes



Each of the zoned areas should be separated from other areas by clearly designated boundaries and buffers. Aquatic vegetation can be used to separate adjacent zones or slow approaching boats. Harvested channels can serve as boat corridors. Zoning regulations should be posted at lake access points to inform lake users.

9.8.3 Time Zoning

Time zoning can be applied successfully in small lakes where space limits multiple uses (Engel, 1989a). For example, water skiing may be allowed during certain mid-day hours or on alternate days to avoid conflicts with fishing or quiet enjoyment of the lake. At 109-acre Great Pond on Cape Cod, motorized watercraft are not permitted on odd numbered days to allow time for windsurfers, canoeists, and anglers to enjoy themselves without interference from motorboats (Wagner, 1994). Time zoning was an integral component of the management plan for Dow's Lake where incompatible lake uses were scheduled at different times of the week (Jaakson, 1984).

Another form of time zoning is night speed limits for boats. In Indiana, boats may travel no faster than 10 mph between sunset and sunrise (IC 14–1–1–23).

9.9 Drinking Water Treatment

The use of Lake Monroe as a source of drinking water has become one of the most important uses of the lake. Approximately 13 million gallons of finished drinking water from the lake is supplied each day to over 100,000 customers served by Bloomington Utilities Department and nine rural water companies. According to a recent report by Hartke and Gray (1989), there are no additional sites in Monroe County for future water supply reservoirs. Therefore, the preservation of Lake Monroe's water quality for drinking water is a high priority of many people.

The quality of the finished drinking water processed from Lake Monroe continues to meet or exceed the standards set forth in the Safe Drinking Water Act. With regard to the pollutant of most concern locally, polychlorinated biphenyl (PCB), the drinking water is tested approximately every 10 days and is below the detection limit of 5 parts per trillion. The drinking water standard for PCB is 500 parts per trillion.

Two relatively new classes of contaminants are of concern at many drinking water treatment facilities around the U.S.— trihalomethanes (THMs) and algal toxins. Both of these contaminants could cause future problems in Lake Monroe if the lake becomes more eutrophic.

THMs are disinfectant by-products produced when surface water is chlorinated in treatment plants. They form when chlorine reacts with naturally occurring organic matter (THM precursors) in surface water supplies. The U.S. EPA has set a maximum contaminant level (MCL) of 100 µg/L for total THMs in treated drinking water (Martin and Cooke, 1994). Recent tests for total THMs in finished drinking water treated from Lake Monroe have included 56 µg/L (Sept 1993) and 41 µg/L (Jan 1994). While these levels are below the Federal MCL, they could rise with increasing eutrophication in the lake. Bloomington Utilities uses chloramine (chlorine + ammonia) as a preliminary disinfectant and this does not form THMs as readily as chlorine alone.

THMs in finished water can be controlled by costly changes in treatment protocol or by reducing the amount of THM precursors in surface water before it reaches the treatment facility. Sources of THM precursors include terrestrially derived decomposing plant matter that washes into the lake, lake sediments, algae and aquatic macrophytes (Martin and Cooke, 1994). All of these materials increase with increasing eutrophication. Martin and Cooke recommend both water supply and watershed monitoring as a means of detecting changes in water quality over time, either to assess the effectiveness of management techniques or to detect declining water quality due to eutrophication.

A second threat to drinking water supplies related to eutrophication is the production of toxins by certain species of bloom-forming blue-green algae. These compounds are acutely toxic to animals, and likely also to humans. A number of animal deaths have been reported in the literature and include deaths to livestock, cats, dogs, deer, muskrats, waterfowl, and shorebirds (Kotak et al., 1994). In humans, acute poisonings have not been reported in the U.S., but research has shown that humans have suffered liver damage, gastroenteritis, diarrhea and dermatitis from algal toxins in water. More recently, studies have also shown that these toxins are potent cancer promoters (Chu and Wedepohl, 1994).

Blue-green algae produce two classes of toxins: neurotoxins and hepato-(liver)-toxins. Neurotoxins are produced primarily by species of *Anabaena*, although *Aphanizomenon flos-aquae*, a common blue-green in many lakes, has been known to produce neurotoxins as well (Kotak et al., 1994). Hepatotoxins were first reported as produced by *Microcystis aeruginosa* and are, therefore, referred to as microcystins. Microcystin-LR, the most commonly produced microcystin in Alberta lakes, is more toxic than dioxins with an LD–50 value of 50 µg/kg (part per billion). Other species of blue-greens such as *Anabaena* sp. and *Oscillatoria* sp. also produce microcystins.

Few water treatment processes are capable of adequately removing microcystins from drinking water. Conventional water treatment including flocculation, filtration and chlorination has been reported to remove between 10 and 30% of microcystin-LR from water. Flocculents such as ferric chloride may lyse the algal cells and release the microcystin into the water. Flocculents such as lime or alum may coat and precipitate the cells without releasing the microcystin. Advanced treatment using activated carbon is more effective, removing almost 100% of dissolved microcystin-LR from water (Kotak et al., 1994).

In a study of four drinking water utilities using Lake Winnebago (Wisconsin) water, at least a trace of microcystin-LR was found in all raw lake water samples collected during the summer (Chu and Wedepohl, 1994). Of 380 samples of blue-green algae from 19 Alberta lakes, 70% had detectable (>1µg/g of dry algal biomass) concentrations of microcystin-LR (Kotak et al., 1994).

In one trial copper sulfate was used to kill the algae before water treatment but this caused lysis of the algal cells and a 35-fold increase in microcystin-LR compared to untreated bloom material (Kotak et al., 1994). Therefore, prevention of algal blooms in water supply reservoirs by actively managing nutrients appears to be the most viable and cost-effective measure to avoid toxin production by blue-green algae.

10.0 RECOMMENDATIONS

10.1 Management Needs

As a result of conducting the Diagnostic Study of Lake Monroe, we have identified the following areas that require management actions:

1. Water transparency is poor, particularly in the Upper Basin and somewhat less so in the Middle Basin. Fine clay particles—due to runoff, shoreline erosion, and sediment resuspension by boats and wind—color the water brown. This limits the light available to algae and decreases the aesthetic quality of the lake.

2. Phosphorus concentrations are high enough in the Upper Basin to classify that area as eutrophic. If poor transparency wasn't limiting algal growth, the Upper Basin would experience extensive algal blooms.

3. Naturally erosive alluvial soils along streambanks and valley bottoms in the watershed contribute sediment loading to the lake.

4. Shoreline erosion is a serious problem along much of the lakeshore. This erosion contributes to poor water transparency, sediment accumulation, degraded aesthetics, and property damage.

5. Sediment accumulation, while not excessive at current rates, causes localized navigation problems in the upper ends of the lake.

6. Urbanization of the watershed is proceeding at increasing rates as Bloomington expands southward and more people desire "country living." Construction on steep slopes and shallow clay soils characteristic of much of the watershed has the potential to increase the current sedimentation rate 10- to 100- fold.

7. Sediments taken from Sugar Camp Creek Bay had elevated concentrations of arsenic, chromium, nickel, and zinc.

8. Heavy human recreational use of Lake Monroe contributes to lake degradation, interferes with human enjoyment of the resource, and causes safety problems.

9. Little is known of the presence (or absence) of algal toxins in Lake Monroe. This potential threat is becoming important to drinking water utilities nationally.

10. The scenic beauty of Lake Monroe's shoreline zone is one of its strongest assets and is a major reason people visit the lake. Aesthetics must therefore be considered in the management plan.

11. No comprehensive, coordinated program is underway to protect and manage Lake Monroe and its watershed. This complacency is, perhaps, the greatest threat to the lake.

Before undertaking resource management of any kind, it is useful to establish management goals so the progress of management activities may be evaluated. For example, one reasonable goal would be to implement practices and policies necessary to maintain the overall sedimentation rate at no more than the current 0.03 inches/year, or approximately 33,000 tons/year. Another would be to maintain scenic resources at their present values or at some other agreed upon value.

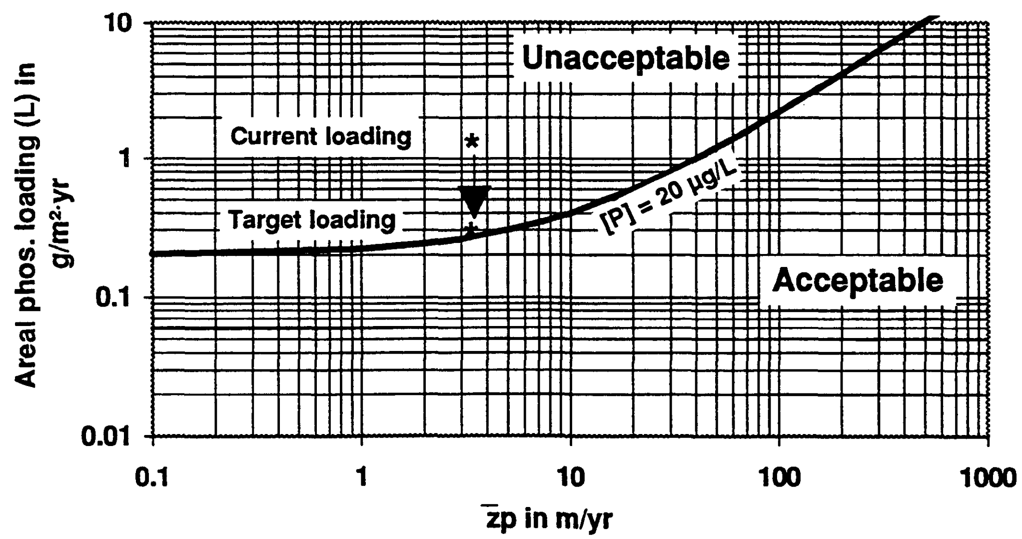
Phosphorus concentrations, on the other hand, must be reduced if this management plan is to work. It is possible to gain understanding of how much reduction is needed by using the widely used nutrient loading relationships developed by Richard Vollenweider (1975). Vollenweider's model relates areal phosphorus loading (L), mean lake depth ($\bar{z}$), and hydraulic flushing rate (ρ) with resulting in-lake summertime phosphorus concentration ([P]). Figure 10–1 shows the current areal phosphorus loading rate for Lake Monroe (1.07 $g/m^2 \bullet yr$) plotted against these other parameters. The position of L is in the unacceptable loading area of the graph. Unacceptable loadings will likely produce eutrophic conditions. Areal phosphorus loading must be reduced to approximately 0.3 $g/m^2 \bullet yr$ to bring L out of the unacceptable loading area. At the target loading rate, the resulting in-lake summertime phosphorus concentration would be 20 μg/L. To achieve this target rate, areal phosphorus loading must be reduced 72% over current rates. Likewise, if the target in-lake phosphorus concentration is 30 μg/L, L needs to be reduced to 0.4 $g/m^2 \bullet yr$, a 63% reduction.

10.2 Management Approach

The recommended management plan for Lake Monroe includes a combination of watershed management practices and in-lake controls to manage the problems identified above. For the most part, this plan includes technically feasible techniques which have been proven in numerous cases on other lakes.

For this plan to work, three additional requirements are absolutely necessary: the *will* to make it work, *money* to pay for the work, and a *political structure* to facilitate the work. Even the best-laid plan is doomed to failure if there is little will or commitment to make it work and, of course, the work is not possible if the financial requirements are too severe for the community to bear. There is a strong will in the community to protect Lake Monroe but this will is fragmented and is often narrowly focused on the particular issue affecting the lake at the current time. Comprehensive management requires more than "putting out fires." It requires broad vision, purposeful planning, and integration of resources.

Figure 10–1. Lake Monroe Phosphorus Loading Rate Plotted Against Vollenweider's Loading Curve



We believe that financial resources exist in the community to implement this plan. We propose several additional revenue generating options in Chapter 11 following to help with this. In addition, the human resources required to implement the plan are substantial. We also propose several options to provide a more conducive management framework which will better focus the will of the community and available human resources.

Our recommendations for managing Lake Monroe center on six main areas:

1. Reducing the delivery of point source pollutants to the lake.
2. Reducing the generation and delivery of nonpoint source pollutants to the lake.
3. Controlling shoreline erosion.
4. Maintaining water quality to the extent necessary to insure drinking water quality.
5. Managing human use of the lake.
6. Creating an organizational structure conducive to watershed management.

10.3 Point Source Management

Point sources of pollutants to Lake Monroe are few and of relatively low volume compared to nonpoint source pollutants. Discharges from all point sources are regulated by NPDES permits. However, monitoring of operations and enforcement of violations have been limited due to staff shortages at IDEM. Recently, IDEM received authority to hire 300 new employees to help bolster its permits sections and other areas in the agency. Hiring these needed people has been slowed by lack of available funds and by a long turnaround at the state personnel office. As these new staff are added, we are hopeful that compliance with NPDES permits will be monitored and violations corrected more timely than in the past.

10.4 Nonpoint Source Management

Comprehensive management programs are needed to reduce the generation and delivery of soil, nutrients, and other NPS pollutants from agricultural, timbered, and urbanized lands within Lake Monroe's watershed, and from eroding streambanks and lakeshores. If implemented, these programs will improve transparency within the lake and help lower nutrient concentrations in the lake's water.

10.4.1 Agricultural Areas

Best Management Practice (BMP) technology exists to significantly reduce soil erosion and nutrient losses from agricultural lands. All of the BMPs described in Section 9.2 should be applied to watershed lands where specific problems exist. The identification and ranking of specific sites needing BMPs should be determined in cooperation with the Soil and Water Conservation Districts and with the NRCSDistrict Conservationists within each county. Specifically:

- Eroding streambanks must receive high priority. Vegetative stabilization techniques, such as willow posts, are preferred. Little regrading of streambanks is needed using willow posts. Snags must be identified and removed as soon as possible before significant bank erosion results. Landowners can contact the county drainage board, the county surveyor, or Rebecca Kerr at the IDNR Project Development Section @ 317-232-4162 for assistance with removing snags.

- Vegetated filter strips along stream and river corridors are essential in preventing delivery of nutrients, pesticides, and runoff water to waterways and this, in turn, reduces streambank erosion. Provisions requiring vegetated streambank filter strips should be incorporated into city and county zoning ordinances.

- Downstream erosion and flooding can be minimized best by retaining floodwaters in the upper ends of the watershed where runoff volumes are less. The cumulative increase in discharge of floodwater as it moves downstream magnifies erosion problems and may overwhelm BMPs applied first to downstream areas. Sediment and runoff retention ponds can be sized smaller in upstream areas because the watershed areas draining into them are also smaller.

- Livestock access to streams must be restricted by fencing. Woven wire fencing may cost $2.50–$3.00 per foot installed. Stable access and crossings for livestock can be provided where necessary but alternative water supplies utilizing streamwater directed to water troughs are preferred. Developing an alternative water supply for livestock may cost $3.00 per foot of pipe plus the cost of the tank.

- Educational programs are needed to convince watershed landowners that downstream lake users are not the only beneficiaries of watershed BMPs. It is in the landowner's best interest to keep soil and nutrients on their own lands where they are economically valuable resources.

Toward this end, the Monroe, Brown and Jackson County Soil and Water Conservation Districts have received a $112,000 U.S. EPA Section 319 grant from IDEM to begin implementing agricultural BMPs in the Lake Monroe watershed. Approximately $82,000 of these grant funds will be used to pay for BMP installation. The organizing committee, known as the Lake Monroe-Salt Creek Watershed Alliance, has been meeting monthly to identify specific sites on which to apply BMPs. While these funds will treat only a small fraction of the lands needing BMPs, it is an important first step in reducing NPS pollution in the watershed. Other sources of funds, including the Indiana Department of Natural Resources Lake and River Enhancement Program, should be sought to continue this important work.

10.4.2 Forested Lands

Although forest cover usually provides maximum runoff and erosion control benefits, the steep slopes on which much of the forested land exists in the watershed promote greater runoff, sediment, and nutrient losses than would otherwise occur on flatter slopes. Great care must be taken with any land-disturbing activities on these steep-sloped, forested areas. As with agricultural BMPs, there are adequate silviculture BMPs available for application in Lake Monroe's watershed, but many landowners must be educated on their proper use.

Since 1994, the Indiana Department of Natural Resources Division of Forestry, in cooperation with the Woodland Steward Institute, has been developing a voluntary program to encourage the use of BMPs in all forest activities. The program will initially focus on the Lake Monroe watershed (Woodland Steward Institute, 1995). The grant, awarded through IDEM from the U.S. EPA Section 319 Program, has these goals:

1. "Develop and use a cooperative process involving the forest owners, resource managers, forest industry, local government and other local interests to identify Indiana's forestry best management practices (BMPs) that are practical and effective and cover primary NPS pollution generating activities.

2. Develop and sponsor technical training programs for forest managers, owners and operators on these practices to minimize NPS before it occurs and implement a widely endorsed voluntary best management practices program.

3. Develop new and additional resources to inform and educate landowners, forest managers, operators and others on technical and practical methods to minimize NPS pollution.

4. Collect baseline information on the current use of forestry BMPs and conduct a monitoring program to determine rate of compliance and program strengths/weakness after program implementation.

5. Develop a model of the above for statewide implementation" (IDNR, 1993).

This program, when fully implemented, will provide needed guidance and education and should satisfy the forestry BMP needs in the watershed.

10.4.3 Urbanized Lands

Urban and developing lands raise significant environmental and policy issues in the watershed of Lake Monroe. The private lands immediately along the Lake Monroe shoreline have remained remarkably undeveloped when compared to other reservoirs and natural lakes in Indiana. Recent proposals to develop some of this land for new housing has led to a number of attempts to regulate development, including: arbitrary set-backs, septic system regulations, and overlay zones. Each of these programs have important functions but are not well suited, by themselves, to provide comprehensive guidance for developing lands.

Monroe County is in the final stages of preparing a Master Plan but such planning has not occurred in the other counties within the watershed. While this report is not intended to serve as a zoning plan for the watershed, information included can provide guidance in developing such plans and, more importantly, for preventing the generation and transport of NPS pollution from developing areas.

For several years, graduate and undergraduate students enrolled in an Indiana University course in lake and watershed management have documented serious NPS pollution from construction sites in the City of Bloomington, the Indiana University campus, and Monroe County. The simple conclusion drawn from this is that current programs to reduce construction site erosion, no matter how well designed or intended, are not working.

Specific needs regarding developing areas in the watershed include:

1. ***Better education for developers and contractors.*** Over the past several years, developers have constructed a number of sedimentation basins and siltation fences are now common at construction sites. This demonstrates a willingness of developers and contractors to employ BMPs in developing areas. However, most of the time, these BMPs fail because they are not installed properly or in the correct location. Continuing education including demonstration sites, workshops, and concise fact sheets or pamphlets are needed to provide better guidance on the use of urban BMPs. For example, an urban conservation demonstration was held in August 1992 at the Hidden Forest subdivision in Ellettsville which demonstrated a wide variety of techniques to control erosion and water in a subdivision development. This demonstration offered an excellent hands-on opportunity to see the actual applications of these BMPs. Likewise, workshops could be held in conjunction with the Monroe County Builders Association and similar groups throughout the watershed to update developers and contractors on proper use of BMPs.

2. ***Basin-wide runoff and erosion control regulations.*** The City of Bloomington currently has an erosion control regulation and Monroe County has a draft plan, but the vast majority of the Lake Monroe watershed is not served by erosion control regulations. Such controls must be implemented uniformly throughout the watershed. Runoff must be controlled as well. Excess on-site runoff causes erosion downstream. Rule 5 of the Indiana Administrative Code (327 IAC 15–5), Bloomington's Soil Erosion Control Ordinance (Bloomington Code Chapter 20.20), and HERPICC (1989) provide examples and guidance on what erosion control regulations should contain.

Compliance with these regulations should be based on *performance standards*, not just the presence or specification of BMPs. For example, construction on 5% slopes with poorly-installed BMPs can cause more runoff and erosion than construction on 15% slopes with properly installed, state-of-the-art BMPs. A good rule to use, and one which other jurisdictions have adopted, is that runoff and erosion following development must be no more than pre-development runoff and erosion from that same site. This will insure that NPS pollution reaching Lake Monroe from new developments will not exceed current, natural rates from those same undeveloped lands.

3. ***Better enforcement of existing erosion regulations.*** The sight of muddy plumes of water running off construction sites is clear evidence that current regulations and erosion control BMPs are not working. Periodic, routine inspections of construction sites can insure that BMPs are installed properly and are being maintained. If more inspectors are needed, then they must be hired. If a better protocol is needed for conducting on-site inspections, then it must be developed. Regulation without adequate enforcement is meaningless.

4. ***Maintenance of Control Structures.*** Many urban BMPs become permanent fixtures in the landscape. Grassed swales, infiltration trenches, and sedimentation basins all continue to provide NPS control benefits after construction is finished. For example, because sedimentation basins are designed to trap and retain sediments, they eventually fill in. Who is responsible for cleaning out filled basins after the contractors are gone? Is there adequate equipment access to the basin to clean it out once the development is complete? Who decides when it needs cleaning? Who pays for it? Who inspects the berm or dam to insure its stability? How often is this done? All of these questions are absolutely critical to the long-term effectiveness of sedimentation basins and other NPS controls. They must be resolved during the permit approval process, before construction begins.

5. ***Protect sensitive lands.*** Sensitive lands such as shoreland areas and lands having steep slopes have the potential to generate significant amounts of NPS pollutants when disturbed. Such areas require special protection. Other states have determined that 1,000-foot zones from lakeshores and 300-foot zones from streams provide adequate protective zones around these water resources (Kusler, 1980). Development can take place in these zones but it is tightly controlled. It is essential to extend the buffer along intermittent as well as permanent streams because pollutants reaching intermittent streams will eventually be transported downstream to the lake. Likewise, steep slopes require special restrictions to protect them.

6. ***Consider innovative techniques for land preservation and protection.*** Low density residential zoning is often used to limit the density of development but this results in an entire area blanketed with homes, albeit at low density, along with the roads needed to reach each individual home. A number of other measures have be used to protect the aesthetics and NPS pollution potential of sensitive lands.

- *Transferrable development rights.* Developers or environmental groups could purchase development rights from landowners of critical areas which would protect them from being developed. Developers could transfer those rights to more developable parcels of land to gain concessions (e.g., higher densities).

- *Mutually restrictive covenants.* To limit or control the future use of shorelands, neighboring landowners could sign a binding agreement containing covenants that mutually protect the lake's aesthetics. The agreement goes with the property and is enforceable by any of the present or future owners of the land (Macbeth, 1991).

- *Scenic easements.* Landowners can voluntarily establish permanent limitations on the use of their shorelands by selling or donating scenic easements, thereby protecting the lake's aesthetics into the future. Under this approach, the lakeshore property would remain in private ownership. The easement holder, typically a private organization or public agency, would be responsible for enforcing the specific terms of the agreement (Macbeth, 1991).

- *Deed restrictions.* Restrictive covenants guiding the future use of lakeshore property can be placed in the deed at the time of a transfer (Macbeth, 1991).

- *Mitigation banks.* Wetlands or other critical areas close to the lake can be purchased for permanent protection to mitigate damage to lands farther from the lake.

- *Aesthetic performance standards.* Rules could be established that specify sets of scenic conditions within which various lakeshore development or alteration must fall. The rules could deal with such things as standards for construction and for clearing vegetation. For example, requiring building heights which do not exceed tree canopy heights would protect the aesthetic value of the lake. Standards could also limit the amount of natural vegetation removed from a site during development. Aesthetic performance standards could be administered by local or state governments under their permitting authority (Macbeth, 1991).

- *Scenic zoning.* A regulatory program could be developed and administered by local or state governments to control certain types of land use that are incompatible within established aesthetic zones. An existing law could be updated to include aesthetic considerations (Macbeth, 1991).

7. ***Maintain and enforce the watershed septic system regulations***. The special rules regulating septic systems within the Monroe County portion of the Lake Monroe, Lemon and Griffy watersheds will prevent septic system effluent from reaching surface waters if systems are installed properly and variances are not routinely granted. Inspectors must inspect sites during and after construction to insure compliance. Brown County and Jackson County are encouraged to adopt more stringent septic system regulations similar to the Monroe County regulations.

10.5 Shoreline Erosion

The extensive shoreline erosion around Lake Monroe is a serious threat to water quality, aesthetic enjoyment, and even public safety. (Two people drowned in 1995 when they stepped off a steep shoreline bank that was obscured by high water. A gently sloping bank likely would not have resulted in this tragedy.) Shoreline erosion itself is not a threat to lake volume because the shoreline erodes and deposits on the lake bottom. While the lake becomes more shallow and larger in surface area, there is little change in overall volume. Because of this, the Corps of Engineers is limited by Federal regulation to what actions they can take to manage shoreline erosion.

Several things contribute to shoreline erosion in Lake Monroe: variations in water level, boat wakes, and wind-driven waves. Seasonal variations in water levels can be significant. For example, water levels during the early summer of 1995 were 10 feet above normal pool level. By comparison, flood control water level fluctuations at Norris Reservoir, a large TVA reservoir, may exceed 59 feet in a year (Glen Rierley, personal communication, 1994). These fluctuations are a normal part of operating a flood storage reservoir and will continue. The impact of boat wakes could be minimized by adherence, through education and enforcement, to the motorcraft idle speed limit within 200 feet of the shore. The large fetch of Lake Monroe makes it difficult to control wind-generated waves.

Eroding shorelines can be repaired and maintained to prevent future erosion and this should be a relatively high priority of future lake management. Rip-rap has been used in some areas of the lake and as long as filter fabric is laid down first, rip-rap can be a long-term shoreline erosion control. However, rip-rap is not particularly attractive, is dangerous to walk on, and it offers little habitat value. In fact, waves reflected by rip-rap can contribute to scouring of the littoral zone.

Re-grading and re-vegetating eroded shoreline segments with appropriate vegetation is the preferred shoreline stabilization method for Lake Monroe. Plant species must be able to withstand periodic inundation with water. For this reason, willows are particularly well-suited for shoreline stabilization. If bore holes are deep enough, the willow stakes will be able to reach the saturated zone during low water, and willows can also withstand periodic high water levels. Willows have extensive root systems which hold even steep banks in place. This technique is relatively cheap—about $220 per 100-foot long bank for boring holes and planting willow stakes, and another $77 per 100-foot length for re-grading with a bulldozer.

10.6 Maintaining Drinking Water Quality

The most pressing concerns regarding Lake Monroe as a drinking water supply are THMs and algal toxins. The reduction of point and nonpoint sources of pollution, as recommended above, will not only protect Lake Monroe from future eutrophication but will also improve the lake's current trophic state. These reductions will reduce the formation of THM precursors within the lake and the inputs of THM precursors in watershed runoff. Rooted macrophytes in the lake also produce THM precursors but the benefits of a diverse, rooted macrophyte population outweigh possible problems with THM precursor formation at this time.

Lower nutrient concentrations will also reduce the likelihood of dense blue-green algal blooms and the production of algal toxins. While there is no evidence of algal toxins being produced in Lake Monroe at this time, we recommend that the Bloomington Utilities Department develop a regular testing protocol to detect algal toxins in both raw and finished drinking water. Raw water samples should be collected during summer or early fall algal blooms, and algal mat material should also be sampled and analyzed. With the rapid development of new testing procedures and the discovery of algal toxins in a number of water supplies, routine monitoring of Lake Monroe is needed to insure public safety.

The Bloomington Utilities Department produces excellent quality water for its consumers. We'd like to see them take a more active role in protecting the source of that water—Lake Monroe.

As an example of what can be done, consider the case of Lake Springfield. Lake Springfield is the drinking water supply for the City of Springfield, Illinois. The reservoir, built in 1935, is 4,300 acres (1,740 hectares) in surface area with a maximum depth of 30 feet (9 meters) and an original volume of 19.5 billion gallons (Skelly et al., 1992). By 1984, the reservoir had lost nearly 13% of its original volume due to sediment accumulation. Dredging Lake Springfield to restore lost capacity was estimated to cost $5.16 per metric ton of sediments removed from the reservoir. In 1982, the City of Springfield began working with the local Soil and Water Conservation District to reduce NPS loading in the watershed. They purchased a no-till planter to loan to farmers and provided 65% of the cost of agriculture BMPs to watershed landowners. These successful programs cost $4.10 per metric ton of soil protected from erosion—a savings of $1.06 per ton compared to dredging (Skelly and Hinsman, 1988). The utility company and city also realized substantial intangible benefits, such as enhanced public image and improved public education, from the goodwill generated by their actions. The City of Springfield experience doemonstrated that NPS pollution prevention is a cost-effective and necessary action for utilities to take to protect their source of drinking water.

Finally, the elevated concentrations of arsenic, chromium, nickel, and zinc detected in sediments collected from Sugar Camp Creek Bay raise some concern. While this contamination is likely isolated, the presence and extent of these metals should be confirmed by additional testing. If concentrations remain elevated, the source of the contamination should be identified and corrected.

10.7 Managing Human Use

As visitorship to Lake Monroe continues to increase, the negative impacts of recreation on other recreational users and on the lake itself will also increase. As stated previously, these impacts not only affect aesthetics and the recreational experience, but also water quality and biota. In addition, increasing boat density, increasing horsepower and the increased use of personal watercraft (aka, jet skis) also create numerous safety problems. The most urgent human use-related lake problems which must be addressed are:

1. Sediment resuspension by boats motoring too fast in the shallow water of the Upper Basin and within 200 feet of the shoreline throughout the lake.

2. Threats to human safety where boat densities are high and boat speeds are too fast for conditions.

10.7.1 Safety

During 1995, there were two boating fatalities on Lake Monroe and more accidents than in previous years. Conservation Officers Steve McClain and Dennis Koontz raised the following safety concerns when we spoke with them:

- Some boats travel as fast as 60–70 mph on Lake Monroe.
- Boats often exceed the idle speed limit in the Upper Basin.
- Radar does not work very effectively on water.
- The starts of fishing tournaments often find boats speeding en masse to their favorite fishing spots, often i in the Upper Basin.
- Operators of personal watercraft take too many risks.
- Boats, especially personal watercraft, don't obey the idle zone within 200 feet of shore.

Four Conservation Officers (COs) are assigned to Monroe County. This total has not increased since 1973 despite the rise in visitorship and increase in safety problems. On summer weekends and holidays, they try to keep at least two patrol boats on the lake at a time but officers are often called away from their water patrols to respond to calls on shore. Off-duty COs are used along with the regular COs during aggressive "boating while intoxicated" (BWI) campaigns.

Recently enacted legislation regarding personal watercraft went into effect in Indiana on July 1, 1995. These new rules address the most serious of problems related to personal watercraft. They include:

- No riding backwards.
- No towing water-skiers or aquaplanes unless the watercraft is at least 10 feet long, designed to seat at least three people, and has an observer on board in addition to the driver.
- The personal watercraft must be designed to idle down and circle its operator if the operator falls off, unless the operator is attached to a cut-off switch by a cord known as a lanyard.
- A personal watercraft cannot be used for such acts as weaving through congested water traffic, following a craft which is towing skiers, and jumping the wake of another craft in ways that endanger "human life, human physical safety, or property."

Anyone caught violating the new laws can be cited with misdemeanors or infractions which carry a fine of $64.

Recommendations for addressing safety issues on Lake Monroe include:

1. ***Better Education.*** Having a boater population that is well-informed of boating regulations, safety issues, and Lake Monroe regulations would go a long way toward improving current boating problems on the lake. Boating safety education programs are offered regularly by the Indiana DNR to meet this need but attendance is usually poor. All participants in fishing tournaments and boats entering the SRAs should be given a **boldly printed** list of the most important boating regulations on the lake, especially:

- Location of idle zones.
- Reminder of the 200-foot-wide idle zone along the shoreline.
- Location of the wildlife refuges.
- Important safe operating tips.

2. ***More marker buoys.*** A number of lakes in northern Indiana have regularly-spaced marker buoys marking the 200-foot shoreline zone all around the lake. The aesthetic impact of this must be weighed against the benefits, but some well-placed marker buoys should be used to designate this zone on Lake Monroe.

3. ***Additional Conservation Officers.*** The number of COs assigned to Monroe County has not kept pace with increasing visitorship on the largest lake in Indiana. A stronger presence on Lake Monroe would emphasize that the IDNR is serious about boater safety.

10.7.2 Overuse

Klessig (1994) views the use of public lakes as analogous to use of public highways. Currently trucks are allowed to carry 80,000 lbs on Indiana's best highways. If 1,000,000-pound trucks were used on our public highways, there would be a public outcry. Bigger and more powerful boats are launched on Lake Monroe each year but the physical dimensions of the lake remain fixed. We could soon see the equivalent of the 1,000,000-pound truck on the lake. There is little doubt that these vessels change the lake—its water clarity, its shoreline, its wildlife, and its aquatic life. There is no doubt that other lake users find the speed, power, and noise of such boats offensive and often physically intimidating. In fact, lake users surveyed stated that the impacts of other lake users did more to interfere with their enjoyment of the lake than did eutrophication.

These concerns have lead to the establishment of various lake use restrictions on other lakes in Indiana and throughout the Midwest. These restrictions include: boat density, boat size, horsepower size, boat speed, time zoning, space zoning, limits on fishing tournaments, and limits on commercially-sponsored events (such as fishing tournaments and July 4th boat parties). Before we recommend a specific course of action, we would like to see an *ad hoc* working group formed to consider these issues and the need for additional use restrictions on Lake Monroe. This committee should be composed of representatives from the Indiana DNR Enforcement, Reservoir, and Fish & Wildlife divisions; Corps of Engineers; Monroe County government, the Lakes Task Force, and a representative of marinas or commercial businesses near the lake.

Passive users who are primarily interested in the aesthetic qualities of Lake Monroe are an important user group. We must remember that 742,594 out of 1,344,843 total visitors (55%) to Lake Monroe in 1992 stated that they visited the lake to sightsee, camp, or picnic. All of these activities do not take place on the water but are enhanced by the presence of water. The needs of these non-water lake users must be considered when developing management guidelines for lake uses.

Klessig (1994) presents an dire, tongue-in-cheek warning of lakes without load limits. In his scenario (Table 10–1), lakes become amusement parks where the biggest motors perform and all other citizens either place their bets, just watch, or leave in disgust. I do not believe that any of us want this scenario for Lake Monroe.

10.8 Potential Problems Not Requiring Action at the Time

There are several conditions at Lake Monroe which may concern some individuals or interest groups but which do not require management at this time. Two of these which will be discussed further here are aquatic macrophytes and sediment accumulation.

Table 10–1. An Overloaded Lake!

6 a.m.	Walleye Hookers Fishing Tournament (lake stocked with genetically-improved fish, courtesy of the Wisconsin Dept. Of Natural Resources ($1000 prize)
10 a.m.	Conspicuous Sailors Regatta ($3000 purse) ($20 minimum bet)
12 noon	Open Fishing, Boating, Skiing, Swimming, and Scuba Diving —Rental equipment available at the Dock Shop —Please use public access ramps —Please be off the water by 1:30 p.m.
2 p.m.	Aqua Knights Ski Show
4 p.m.	Computerized Fishing Short Course
5 p.m.	Loonie 500 Boat Race (open to any boat with over 500 hp, $500 purse)($20 min bet)
6 p.m.	Pontoon Parade (two cocktails for the price of one)
7 p.m.	Personal Watercraft Demolition Derby
8 p.m.	Sunset Canoe Rides (led by certified naturalists)

Source: Klessig, 1994

10.8.1 Aquatic Macrophytes

The rapid expansion of American lotus to cover nearly 900 acres of Lake Monroe's surface is a condition which warrants watching. Monotypic stands of a single plant species do not offer the multiple benefits that diverse stands of macrophytes do. If this expansion continues, selective harvesting should be considered to increase the diversity of rooted macrophytes in lotus-dominated stands.

Dense stands of milfoil, coontail, and other rooted macrophytes occur in some areas of Lake Monroe. These plants help trap sediments, retain nutrients, and provide habitat for aquatic organisms. While they interfere with navigation, regular control is not warranted at this time.

Where macrophytes infringe on swimming beaches or boat docks, they can be controlled using commercially available, hand-held aquatic plant cutters.

10.8.2 Sediment Accumulation

Sediment accumulation has created very shallow water in localized areas of the upper lake basin. This is particularly true in the Crooked Creek and Pinegrove areas. Shallow water makes boat navigation difficult and promotes the growth of emergent plants. These emergent plants, however, provide important wetland habitat and serve to slow inflowing water, allowing suspended sediments to settle out. This further contributes to the sedimentation of these areas but it concentrates the sediments in relatively small areas and keeps some of the sediments from traveling all the way down to lower lake areas. As new sediments accumulate in these wetland flats, fish habitat will likely be lost. But the shallow water wetlands will migrate and net fish habitat should remain relatively unchanged.

The positive benefits of these expanding, emergent wetlands outweigh the disadvantages to boating. Therefore, we do not recommend dredging of any kind in these areas at this time.

11.0 INSTITUTIONAL FRAMEWORK FOR IMPLEMENTATION

11.1 Introduction

When it impounded Lake Monroe in 1965, the U.S. Army Corps of Engineers' primary objective was to provide flood control for low-lying areas in the southern parts of the Salt Creek drainage basin. The reservoir created by this project has since come to serve many other purposes. The largest inland body of water in the state of Indiana, Lake Monroe has become a favorite destination for fishermen throughout the state. Other recreational users, such as boaters, water skiers, jet-skiers, and swimmers flock to the reservoir by the thousands each summer. The lake has also become the main source of drinking water for nearby Bloomington and surrounding townships. The aesthetic appeal of the lake and the hilly, heavily wooded lands which make up much of its watershed has additionally created a high demand for land development in areas surrounding the lake.

11.2 Legal Authority for Water Management

Lakes such as Lake Monroe are public resources which are available for anyone to use as often as they like. Prolonged, intensive use of such resources may lead to what Garrett Hardin (1968) called the "Tragedy of the Commons." Hardin described how a public pasture became increasingly overused as herdsmen grazed more and more sheep to get the maximum benefit but suffered little from the overgrazing caused by each additional animal. As each herdsman added more animals to the commons, the tragedy inevitably followed: the pasture is destroyed. As Korth and Klessig (1990) observe, lakes are classic candidates for the "tragedy of the commons": use by everybody, management by no one.

The State of Indiana's authority to manage public resources such as lakes comes from provisions in the Northwest Ordinance of 1787 which transferred land from Virginia's territories to create Indiana and other Great Lakes states. Virginia wanted assurances of rights to commerce and navigation on the lands it was giving up to the new states, including Indiana, so the North West Ordinance provided that the rights to use navigable waters were to be held in public trust for all citizens of the United States (Sperling, 1991). Therefore, Indiana has a number of laws and regulations designed to protect these public waters. On Lake Monroe, these include: idle zones, fishing regulations, and water quality standards.

11.3 Existing Jurisdictions

Management of activities occurring in the lake and its watershed reflects the importance of preserving Lake Monroe's water quality. The Indiana Department of Natural Resources, for example, has established an idle zone for boaters in the shallow upper basin of the lake to minimize the risk of stirring up nutrient-rich sediments. Guidelines for land development in the watershed have been proposed by the Monroe County Master Plan in order to reduce erosion from construction activities and nutrient loading from sewage disposal. While these and other regulations have targeted some of the practices which can negatively affect water quality in the lake, no framework has been established to allow soil and water resource agencies to manage the watershed as a whole.

The Lake Monroe watershed encompasses about 415 square miles in six counties, including Brown, Jackson, Monroe, and Bartholomew, and small portions of Johnson and Lawrence Counties. The large area of the watershed and variety of land uses within it have made localities subject to the jurisdiction of numerous governing bodies, such as County Commissions, Boards of Health, Zoning Boards, and so on. Furthermore, jurisdiction over the lake and its watershed are divided among three federal and three state agencies (Table 11–1). In all, over 30 governing and managing jurisdictions in the watershed make decisions affecting Lake Monroe (Appendix E).

11.4 Who Gains?

There can be little argument that a clean, well-managed Lake Monroe will provide multiple benefits to many public and private interests. For example:

- drinking water for 100,000+ water consumers
- recreational opportunities for 1.5 million visitors per year

Table 11–1. Lake Monroe Jurisdictions

I. FEDERAL AGENCIES:
   A. Department of Defense
      1. United States Army Corps of Engineers

   B. Department of Agriculture
      1. United States Forest Service
      2. United States Soil Conservation Service

   C. U.S. Environmental Protection Agency

II. STATE AGENCIES:
   A. Indiana Department of Natural Resources
      1. Division of Forestry
      2. Division of Fish and Wildlife
      3. Division of Water Management
      4. Division of State Parks and Reservoirs
      5. Law Enforcement Division
      6. Division of Soil Conservation

   B. Indiana Department of Environmental Management
      1. Office of Water Management

   C. Indiana State Board of Health

   D. Water Pollution Control Board

   E. Office of the State Chemist

III. REGIONAL AGENCIES:
   A. Lake Monroe Regional Waste District

IV. LOCAL AGENCIES:
   A. County Boards of Health
   B. County Health Departments
   C. County Commissioners
   D. County Plan Commissions
   E. County Board of Zoning Appeals
   F. City of Bloomington Plan Commission
   G. City of Bloomington Utilities Service Board
   H. City of Bloomington Utilities Service Department

- increased property values (for land owners and for developers)
- strong sales and property tax base
- sales for private businesses (marinas, groceries, bait shops, gasoline stations, restaurants, etc.) which service lake visitors
- flood control for downstream property owners

11.5 Management Approaches

There are two spatial approaches to consider for managing Lake Monroe and its watershed: (1) management according to existing geopolitical boundaries, and (2) management according to the watershed boundary.

We currently have management of the land within Lake Monroe's watershed according to various county and city boundaries. The political body with jurisdiction within each of these boundaries makes their own decisions which ultimately affect the lake. This turns out to be a very fragmented approach at a spatial scale much smaller than that of the watershed (Figure 11–1). Each political body has its own agenda and unified management of the watershed is not high on the agenda. This is also an "unnatural" management approach as rivers know no political boundaries. They flow from one county to another, through cities, carrying pollutants generated in the upstream jurisdiction into other jurisdictions downstream. In this sense, management simply involves passing pollutants downstream out of the jurisdiction of origin.

With management according to political jurisdictions, upstream actions are detached from their downstream consequences. For example, upstream levees designed to protect adjacent land from flooding, increase the velocity and volume of flood water downstream. The disastrous consequences of this shortsighted management were apparent during the great Midwest flooding of 1993. For another example closer to home, one can witness the consequences of poor construction and farming practices upstream which result in transporting tons of sediment downstream into Lake Monroe each year. These eroded soils unfortunately do not stop at the county line.

Watershed management, on the other hand, transcends political boundaries and treats the watershed as the functioning ecosystem that it is (Figure 11–2). If practiced correctly, it becomes a form of *Integrated Resource Management*, an approach which seeks to restore the structure and function of whole ecosystems by recognizing natural linkages and interactions. For example, wetlands store and filter water which passes through them. Integrating wetlands into the watershed ecosystem restores these important natural functions. The integrated resource management approach has been endorsed by the National Research Council (1993) in a recent report.

Another argument in favor of establishing an integrated management framework for Lake Monroe's watershed is that watersheds are most effectively managed as systems, rather than as discrete units which comprise a whole. Efforts to reduce erosion in one portion of the watershed, for example, may do little to improve water quality if erosion is left unchecked in other, unmanaged areas. Attempting to regulate only small portions of the watershed may reduce the total sediment and nutrient load to the lake, but these reductions in themselves may not be enough to significantly reduce sedimentation and eutrophication. For a watershed management program to be successful, land-use policies need to be uniform and applied in a consistent manner. Uniform application also more equitably distributes the costs and burdens associated with management.

Integrated watershed management produces important advantages over existing political jurisdictions which can result in substantial savings of both time and money. These advantages include:

- *Pooling limited technical resources.* Each jurisdiction does not need to have technical expertise in watershed planning, engineering, resource management, etc. Existing expertise within the watershed can be used and a

Figure 11–1. A Fragmented Watershed Management Approach According to Standard Geopolitical Divisions

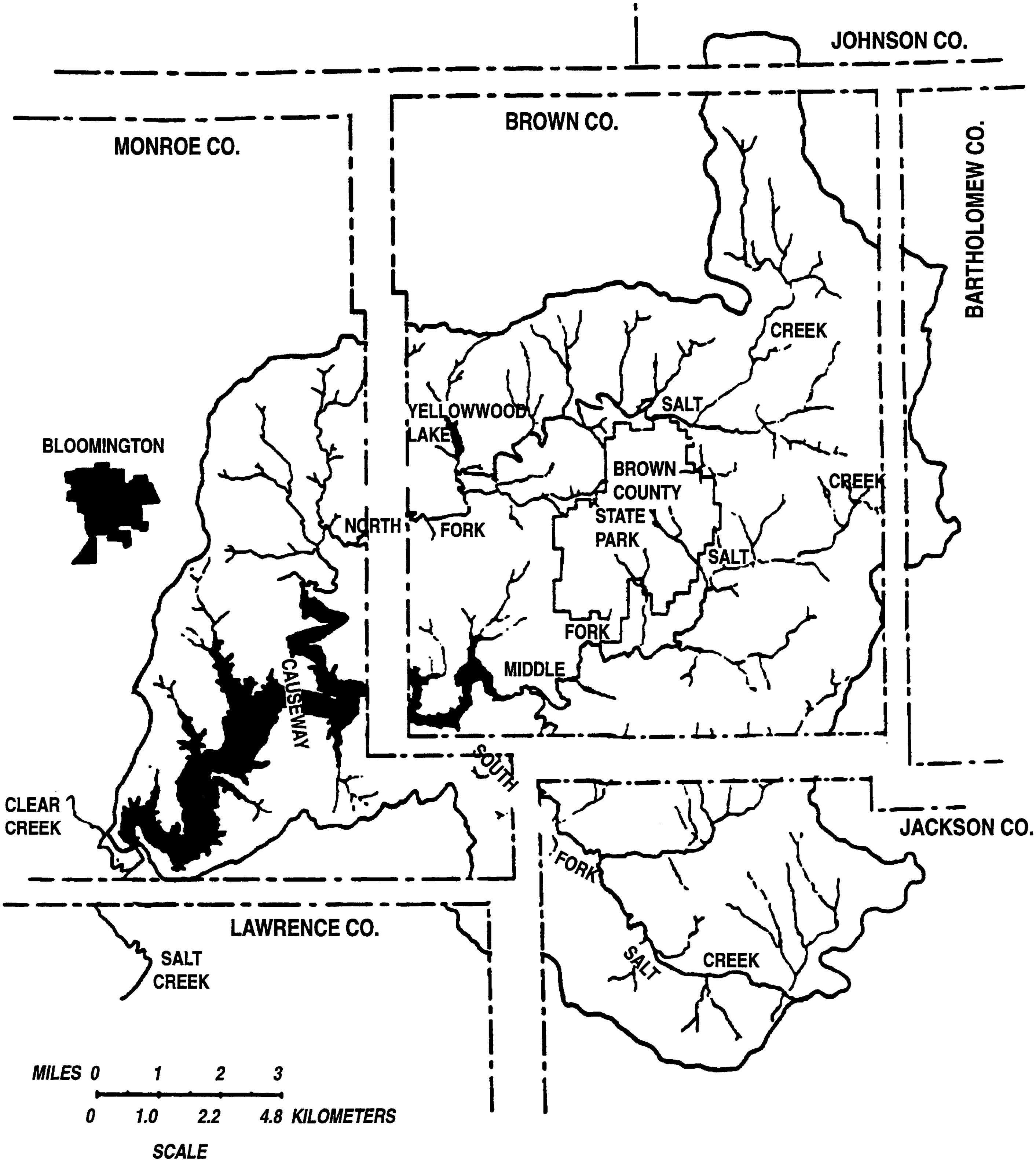
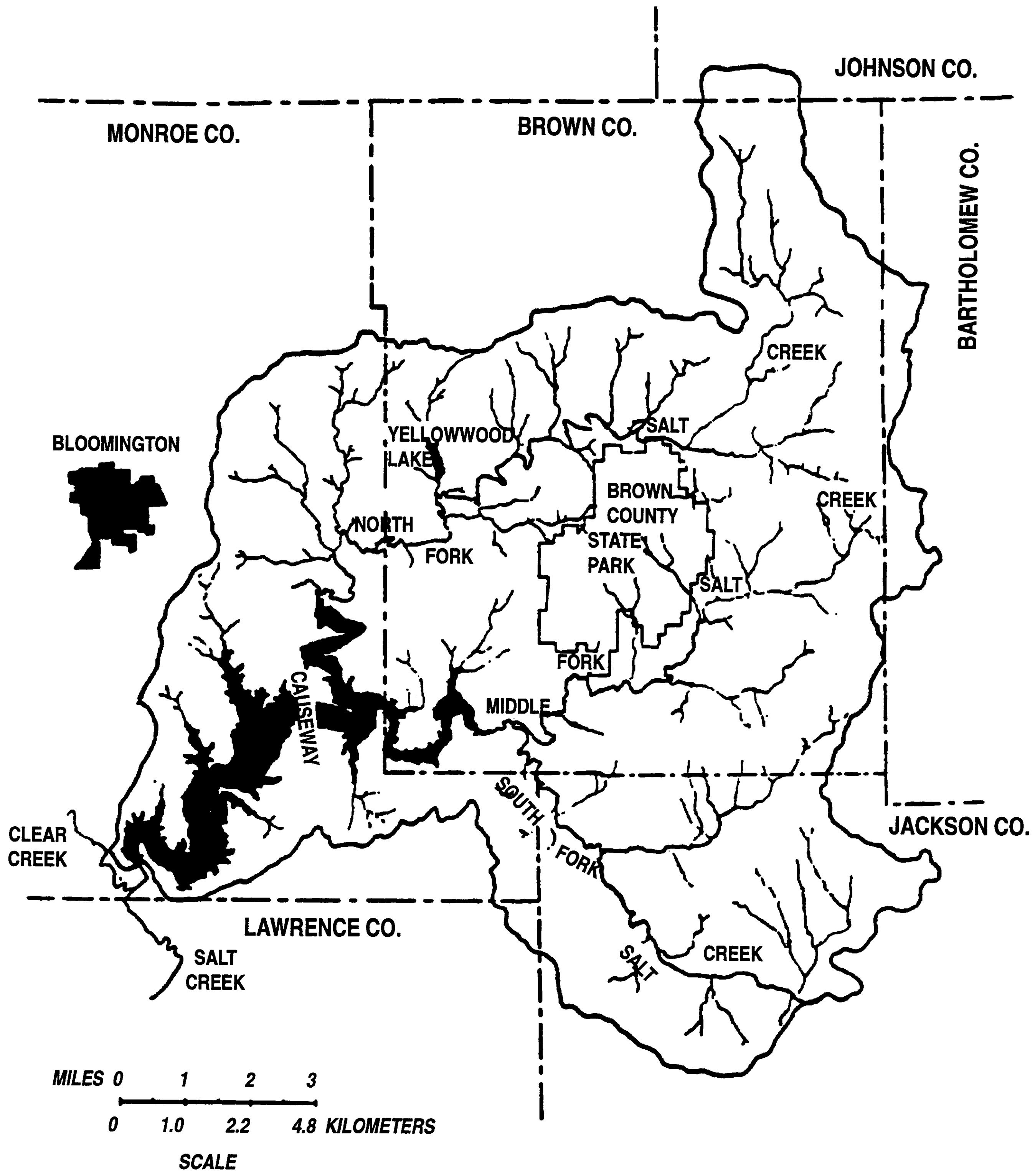


Figure 11–2. An Integrated Watershed Management Spatial Approach



applied where needed. Pooled resources can be used to collect data needed to formulate good policy. Without adequate data collection, programs are likely to waste limited technical and financial resources by setting poor priorities (Rubin, 1992). Watershed projects which would be cost-prohibitive for a single jurisdiction may be possible with pooled resources.

- *Avoiding duplication of services.* For example, each jurisdiction does not have to develop erosion control ordinances if one is established for the entire watershed.

- *Improved communication.* A watershed management structure provides a formal channel of communication among jurisdictions which will allow government to function with more efficiency and speed. With the fragmented approach, it is often difficult to identify the appropriate agency or jurisdiction to respond to a particular problem. Centralization achieved with the integrated approach can avoid this.

11.6 Case Studies

The large size of the Lake Monroe watershed, the number of governmental entities and private interests represented within its boundaries, and the variety of problems which threaten the lake all contribute to the complexity of developing a management plan for the watershed. Water resource managers across the United States have grappled with similar problems affecting other watersheds. Consequently, examining case studies of existing interjurisdictional watershed management programs may provide insight for addressing our local issues.

Successful watershed management programs utilize one of three implementation models: (1) mutual consent, (2) enabling legislation, and (3) special purpose legislation.

11.6.1 Mutual Consent Model

In the mutual consent model, the jurisdictions (for example, several affected city or county governments) agree on what needs to be done and have the will and means to do it. This is an idealistic approach which is difficult to successfully implement. The jurisdictions must be willing to give up some of their own control and share responsibility for the program.

University Lake (North Carolina). The University Lake Reservoir was created in 1932 to provide drinking water for greater Chapel Hill, North Carolina. The lake's watershed is 30 square miles, 80% of which lies in Orange County, 10% in the town of Carrboro, and 10% in Chatham County. Seventy percent of the watershed is forested, 11% is devoted to agricultural use, and about 8% consists of residential lots two acres or smaller in size (Camp, Dresser, and McKee, 1989).

In 1989 the State of North Carolina enacted the North Carolina Water Supply Protection Act (Environmental Management Commission, 1993). This statute mandates that any local government having jurisdiction in an area which is part of a drinking water supply's watershed must enact ordinances to comply with standards set by the state. The legislation provides for the classification of watersheds based on variables such as lake/reservoir size, watershed size, susceptibility to pollution, and the amount of pre-existing development in the watershed. There are four classifications, each of which places a different set of restrictions on land uses within a watershed (Environmental Management Commission, 1992). WS-I watershed classification is for publicly held land and restricts development totally. The remaining three classifications—WS-II, WS-III, and WS-IV—were assigned based on a variety of criteria, including: watershed size, the amount of existing development, susceptibility to contamination, etc. The land use restrictions are greater in the WS-II classification than in the WS-III, which are greater than those in the WS-IV. Within the classifications, restrictions in critical areas closer to the lake or permanent streams are more severe than those within the balance of the watershed.

A proposal to locate a 177-unit cluster development within the Carrboro portion of the watershed, along with the need to meet both EPA drinking water quality criteria and guidelines prescribed by the North Carolina Water Supply Protection Act led three separate governmental bodies to create an interjurisdictional work group. The group consisted of elected officials from Orange County, the City of Carrboro, and the City of Chapel Hill (which has no jurisdiction in the watershed but consumes 80% of the water supply).

Each of the three groups had a different stake in managing the watershed. Carrboro wanted to maintain cluster development provisions which would require laying new sewer and water lines in the watershed. Orange County favored allowing new development but preferred the use of septic systems for waste disposal. Chapel Hill's goal was to decrease density in order to protect the water supply (Godschalk, 1992). The differences in desired outcomes made the watershed management plan a subject of great controversy.

Using direct negotiation among the principal parties, a three-member negotiating subgroup was able to uncover the most important issues, work out joint gains, and draft an agreement in principle. Because urban non-point pollution presented the greatest threat to University Lake, the work group enlisted the help of a consulting firm to develop a model to determine relationships between development densities and water quality. Lot sizes of 5, 2, 1, 0.5, and 0.25 acres were used as variables (Camp, Dresser, and McKee, 1989). In each scenario, the effects on levels of total phosphorus, total nitrogen, lead, and zinc were predicted. An intensive data collection effort and the formulation of a model considered reliable by all three interested parties allowed the work group to come to an agreement, the terms of which included:

- A five-acre minimum lot size with a 4% impervious surface limit,
- A hardship provision allowing up to five two-acre lots with a 6% impervious surface limit to be subdivided from an existing parcel,
- Creation of a watershed protection fund,
- Prohibition of public sewer extensions into the watershed,
- Further study of potential transfer of development rights, and
- Development of staff recommendations for regulatory details (Godschalk, 1992).

After some minor revisions, these recommendations became part of a joint planning agreement which was submitted to the North Carolina legislature and enacted into law. In the end, no party was completely satisfied, but the agreement attempted to reach a compromise which acknowledged the interests of all stakeholders.

11.6.2 Enabling Legislation Model

Enabling legislation establishes the mechanism to accomplish special governmental functions, often allowing for special units of government. The legislation enables the formation of special units of government but the actual formation is left up to the local people. Strict guidelines are established for the creation of these special units but the duties themselves may be very broad. Examples include conservancy districts and lake districts.

Conservancy Districts. The Indiana Conservancy Act, IC 13–3–3, provides a vehicle by which landowners can organize a special taxing district to solve problems related to water resources management. A conservancy district may be established for one or more of the following purposes (Department of Natural Resources, 1988):

- flood prevention and control
- improving drainage
- providing for irrigation
- providing water supply
- providing for the collection, treatment, and disposal of sewage
- developing forests, wildlife areas, parks, and recreational facilities
- preventing the loss of topsoil from water erosion
- storage of water for stream flow augmentation
- operation, maintenance, and improvement of any work of improvement for water-based recreational purposes

Any area may be included in a Conservancy District regardless of its political boundaries, although the district does need to be contiguous with all other parts of the district. To form a district, a petition is circulated in the area to be included in the district and is filed in circuit court of the largest land holding county of the district. The petition needs to include at least 30% of freeholders in districts of 1,000 or less freeholders; 15% of 1,001 to 5,000 freeholders; 10% of 5,001 to 25,000 freeholders; and 5% of 25,001 or more freeholders (Department of Natural Resources, 1988).

If correct in form and content, the circuit court refers the petition to the Indiana's Natural Resources Commission for approval based on its necessity and economic and engineering feasibility. When the court receives the Commission's findings, the court will schedule a hearing for the establishment of a district. If approved by the circuit court, the county commissioners appoint the initial board of directors for the district, which are subsequently elected at annual meetings. One of the board's responsibilities is to develop a district plan that physically defines the district and describes how the purposes of the district will be accomplished.

Of 77 Conservancy Districts in Indiana most are designated for flood control, water supply or sewerage—activities not directly associated with lake management (Department of Natural Resources, 1989). Nonetheless, Conservancy Districts remain a potential multi-purpose, multijurisdictional management tool for Lake Monroe and other Indiana lakes.

Lake Districts. In Wisconsin, a similarly structured district, the Lake Protection and Rehabilitation District, has been more broadly used. Created in 1974 by a legislative act, the Wisconsin lake district law allows communities to form special purpose units of government to manage individual lakes or a closely related group of lakes (Klessig et al., 1989). By 1989, 160 lake districts had formed for this purpose. The lake district can raise revenues through contributions, taxes, or grants. A 1987 survey of the lake districts showed that the most frequent watershed management activities of the districts were: zoning advocacy, septic system inspection, drinking water testing, shoreline protection, and streambank fencing. The five most common in-lake management activities were: weed harvesting, fish stocking, chemical weed control, algae control, and fish habitat improvement (Klessig et al., 1989).

11.6.3 Special Purpose Legislation

Special purpose legislation is used to create a specific solution to a particular problem. Each extra-governmental unit created has its own specific legislation.

Yahara River Watershed (Wisconsin). The Yahara River watershed, most of which lies in Dane County, Wisconsin, includes four lakes—Mendota, Monona, Waubesa, and Kegonsa—connected by the Yahara River. The lakes are situated in the center of the county and are highly valued for the recreational opportunities they provide. The watershed contains over 85% of the county's surface water. Land use in the watershed is primarily agricultural; 74% of the land in Dane County is devoted to farming (Nakamura and Born, 1993). Urban growth in and around the state capital, Madison, has contributed to the eutrophication of lakes Mendota, Monona, and Waubesa.

Degradation of water quality in the lakes has been a problem since the 1800s when agriculture became prevalent in the area. Urban growth promoted eutrophication as well; the lakes received discharges of untreated sewage until 1971, and treated sewage until 1980 (Nakamura and Born, 1993). While point source pollution had been drastically curtailed by the mid-1980s, nonpoint pollution from agricultural and urban sources continued to be a problem.

Until the late 1980s, management of the Yahara River watershed was marked by a lack of coordination among water resource agencies. Lack of coordination was not the only problem: "... Institutional arrangements—the rules and entities—for managing Dane County waters were [also] limited in both authority and scope" (Nakamura and Born, 1993). Local land use regulations lacked uniformity and tended to favor rural property owners. In order to combat the problems threatening the watershed, many felt that a wholly new watershed management framework needed to be established.

This perceived need led to the formation of the Dane County Lakes and Watershed Commission (DCLWC). The commission was established and empowered by county ordinance in July 1988, and was formalized by the state legislature in April 1990 (Nakamura and Born, 1993). The DCLWC has nine members, including the County Executive or designee, the Mayor of Madison or designee, two County Supervisors from the City of Madison, as well as two from outside districts, a Madison resident nominated by the Mayor, a non-Madison resident nominated by the Dane County Towns Association, and a resident of a municipality outside Madison, nominated by that municipality's chief executive (Nakamura and Born, 1993).

Enabling legislation granted the board a variety of powers:

- DCLWC can plan, and develop and implement projects.
- DCLWC can propose minimum standards, regulations, and ordinances.
- DCLWC has rule-making powers related to its legislation-granted duties and powers.
- DCLWC can initiate and coordinate surveys and research, access and control information, develop public information and education programs, create technical advisory committees.
- DCLWC can coordinate and integrate county programs, and act as liaison among federal, state, and local water-related entities.
- DCLWC can propose levying charges to implement projects related to dredging, streambank stabilization, and buffer strips; boating fees to support recreation services; DCLWC develops and recommends watershed activities budget.

Perhaps the most notable function of the DCLWC is that of liaison; the commission provides channels of interagency communication where there were none before. While the commission does have the power to propose standards and regulations, the County Board decides whether or not those proposals become policy.

In an evaluation of the DCLWC, Eagan (1991) concludes that the commission has been fairly effective. However, water resources management functions still remain divided among local, state, and federal governments and within each layer of government additional levels of fragmentation occur. Dane County has tried to address this by placing the DCLWC as a division within the County Executive's office. Elevation of the commission in this way has helped establish its identity and garnish cooperation from other departments and agencies.

Maumee River Basin Commission (Indiana). Formally created by the Indiana General Assembly in 1986, the Maumee River Basin Commission (MRBC) is a state agency dedicated to flood control in northeast Indiana. The MRBC originated as an alliance between Adams, Allen, DeKalb, Noble, and Steuben counties in 1985. The MRBC Board is bipartisan, consisting of the commissioners and surveyors of each county. Representatives from each county's Soil and Water Conservation District also assist in formulating policy and developing flood control projects (MRBC, 1992). Urban and rural interests are both represented.

The MRBC promotes water and soil conservation and provides administrative and technical aid to communities implementing local flood control projects. The commission also acts as a clearinghouse for information regarding stormwater management, sponsoring presentations and seminars. The MRBC is a major lobbying power in the Indiana General Assembly and actively seeks funding for flood control projects within its jurisdiction. Finally, the commission plays a coordinating role as a contact with the States of Michigan and Ohio, relaying information concerning major flood control projects.

Enabling legislation granted the MRBC a variety of powers, including the ability to purchase floodplain land for conservation purposes, and also to purchase and remove from floodplains existing structures (IC 36–7–6.1–21). The commission may also restrict new construction in 100 year floodplains, and has the authority to purchase real and personal property as necessary to carry out its mission. Indiana Code also requires the MRBC to hold hearings prior to exercising any of the above powers (IC 36–7–6.1–22).

11.6.4 The Monroe County Lakes Task Force

The value of providing an institutional framework for protecting Lake Monroe has already been recognized locally. The Monroe County Lakes Task Force (LTF) was established in 1989 by the Monroe County Planning Commission for the purpose of protecting local lakes—Griffy, Lemon, and Monroe—which do or could potentially provide local drinking water supplies. The LTF has been effective in providing advice to local governments concerning lake management. Its open membership structure, however; while providing multiple viewpoints, has made decisionmaking cumbersome at times due to its size.

Reorganization of the LTF has been proposed. Under a structure proposed by the reorganization committee in March, 1994, LTF would include representatives from federal and state agencies with jurisdiction in the Lake Monroe watershed (Table 11–2). However, board membership would be weighted more heavily in favor of local governmental representatives, including county commissioners and municipal appointees. The draft proposal for reorganization of the LTF also suggests that private interests, such as environmental and land development groups, might have a role on the task force. A similar structure was successfully used in the Lake Monroe Wastewater Task Force, a nine-member committee created by the Monroe County Board of Health to make recommendations (later adopted) for new septic system regulations around the lake (List, 1989).

A non-profit entity, the LTF would apply for grants from a variety of government agencies and private foundations such as the IDNR's Lake and River Enhancement Program or the U.S. EPA Section 319 nonpoint source pollution grant program. Once obtained, grants would be used to fund education programs, BMP projects, and technical policy advisory programs. The education programs would provide information to both policy makers and the public. This information would be disseminated through presentations to local groups, video productions, and events sponsored by LTF (Lakes Task Force, 1994). Educating policymakers would encompass identifying local watershed management issues, creating a focus on those issues, and compiling data into a format accessible to policymakers.

The target number of board members should be around 12–16. Weighting of membership should be on the local side, rather than heavier from the state and federal agencies. Local appointments may also require a commitment of funding to the organization.

Table 11–2. Proposed Reorganization of the Lakes Task Force

The proposed new structure of the Lakes Task Force, excerpted from notes of the draft proposal meeting of April 8, 1994, is as follows:

Membership would be open to anyone from the areas and jurisdictions affected. Membership qualifications would be similar to those in current bylaws.

The Board of Directors would be appointed from the membership at large by the government organizations having management responsibility in the watersheds. Examples of appointing authorities:

Federal—Army Corps of Engineers, Forest Service, Soil Conservation Service

State—Indiana Department of Natural Resources (possibly more than one division), Indiana Department of Environmental Management, Indiana State Board of Health

Local—County, Municipal, Utilities Boards. Monroe, Brown, and Jackson counties would have appointments (also possibly Lawrence, Bartholomew, and Johnson counties).

Municipalities would include, according to the specific county, either county seats, second class cities, or the largest population concentration. Appointments would be by mayor or town board. Each utility would probably not be represented; possibly only one appointment for that category.

Public—representatives from environmental groups, realtor groups, etc. may be represented.

It was observed that local authorities making appointments should have a clear understanding of the role of their appointee and of the organization. Decisionmakers should value the input from their appointee.

Projects sponsored by LTF would promote the use of BMP's in the watershed. The LTF's role in funding these projects would be to apply for grants directly, and to support member organizations and other agencies applying for grants to fund BMP's in the watershed. The Task Force would also promote partnerships between private interests and the public, and would document projects to determine their effectiveness for future reference (Lakes Task Force, 1994).

The present role of LTF in providing technical advice is limited to broad policy issues rather than specific projects. LTF would provide a link between agencies needing technical assistance and agencies and individuals providing it. A technical subcommittee might also be established to "create standard responses to recurring questions or issues" (Lakes Task Force, 1994). Under the current proposal, providing technical assistance would be the smallest of LTF's roles.

11.7 Recommendations

The Lakes Task Force provides a useful model for the type of interjurisdictional entity needed to manage Lake Monroe. However, the LTF does have some shortcomings which arise out of its status as a strictly advisory body and its lack of authority to propose rules and ordinances or raise revenue. We suggest an alternative organization which we will call the Lake Monroe Watershed Commission (LMWC), for lack of a better title. The structure and objectives of the LMWC is similar to LTF's but would include some additional powers which would ensure a more comprehensive and more easily implemented watershed management plan.

Creating the LMWC and endowing it with the authority it will need to manage the watershed will require legislative action at the state level.

The actions of the LMWC should be directed by a board. Establishing a board which includes representatives from all or most of the major agencies and government bodies in the watershed is crucial to establishing a dialogue concerning problems within the watershed. The following list suggests a possible make-up of the board:

- Brown County—2 representatives
- Jackson County—2 representatives
- Monroe County—2 representatives
- City of Bloomington—1 representative
- State of Indiana—2 representatives (1 from IDNR and 1 from IDEM)
- U.S. Government—2 representatives (1 from Corps of Engineers and 1 from U.S. Forest Service)
- Private sector citizens—engineer, developer/real estate representative, environmental advocate

County members should be appointed by the county commissioners or county councils in each county and the Bloomington city representative selected by the Mayor. It is absolutely essential for the local representatives to be appointed by local bodies to instill legitimacy and garner local support. Local citizens are less wary of their own than they would be of Indianapolis appointments. The state representatives and the citizen members could be selected by the governor or other appropriate state office.

There must also be a full-time, paid employee of the LMWC to coordinate watershed activities and carry out the wishes of the board. A clerical staff member may also be required. The watershed coordinator is essential to establish a constant presence in the watershed and keep the board up-to-date on activities affecting the watershed.

Providing a forum in which watershed problems can be discussed is critical to deriving equitable and efficient solutions. The LMWC's emphasis on educating the public and providing information to local policy makers would recognize the importance of attacking watershed management problems at the grass-roots level. That the proposed structure also encourages the involvement of private interest groups ensures that all voices will be heard during the policy making process. However, the proposed group may be too large for effective decision making. Therefore, an executive committee, composed of 3–5 members, should have authority for implementing LMWC actions, setting meeting agendas and handling day-to-day decisions.

11.7.1 The State's Role

Specifically, the Indiana General Assembly would first have to recognize the LMWC formally and set out the guidelines for its membership, as the legislature did in the formation of the Maumee River Basin Commission. It will then have to clearly delineate the role the LMWC will have in watershed management, insuring that its powers do not conflict with those of other agencies with jurisdiction in the watershed.

The State of Indiana could also benefit from adopting a watershed classification system similar to that used by North Carolina. State-mandated water quality standards would provide criteria by which the success of the LMWC could be evaluated, and guidelines for land-use within the watershed could be established. These standards and guidelines would also provide a clearly defined framework in which the LMWC could operate. Additionally, creating such a classification system might promote watershed preservation efforts in other parts of the state.

11.7.2 LMWC's Role

Building Partnerships. The success of integrated watershed management will depend on how well the LMWC, or alternative watershed management agency, develops working partnerships with the many various jurisdictions existing today in Lake Monroe's watershed. In a speech at the fifth Indiana Lake Management Conference in May 1993, Frank Lapensee, Chief of U.S. EPA's Clean Lakes Program, emphasized the importance of creating partnerships in order to resolve conflict (Lapensee, 1993). Watershed land-use issues have generated fierce debate in the past and will undoubtedly continue to do so in the future. Encouraging parties with opposing views to resolve conflicts in a productive and agreeable way will be critical to managing the watershed successfully. Each partner brings unique assets to the relationship. Mr. Lapensee outlined the following keys in maintaining partnerships:

1. Keep focused on common goals.
2. Keep focused on tasks before the group.
3. Keep tasks achievable.
4. Be realistic—consider time, money, and politics.
5. Respect partners' time (with well-planned events).
6. Keep communication open and ongoing (keep group informed).
7. Build ownership at all levels.
8. Repeat #3; don't push beyond capabilities.
9. Respect the history and culture of the community.
10. Recruit your opposition (enemies included).
11. Never blame an individual; take group responsibility. (The process needs change, not the individual).

A new interjurisdictional watershed commission would need to solicit the views of the public and involve citizens in watershed projects. Giving the public a voice in determining how watershed problems are resolved will ensure that projects are planned and implemented smoothly.

Proposing Rules and Ordinances. As an advisory body, the current LTF can make recommendations to county commissions and zoning boards regarding land-use policies. The extent to which policy makers incorporate these recommendations in the decision-making process may vary greatly from locality to locality. Consequently, it is conceivable that, despite LTF's best efforts, a patchwork of land-use regulation may result under the current system.

Granting the LMWC power to propose rules and ordinances would promote more consistent land-use policies throughout the watershed. Under such a system, the LMWC would act under the same constraints faced by the Dane County Lakes and Watershed Commission. While the LMWC could propose rules and ordinances, the various county commissions ultimately would have the authority to approve or disapprove the proposals. Political resistance in some areas might require a reworking of the terms of some proposed ordinances. However, it seems likely that allowing the LMWC to initiate the proposals would reduce inconsistencies in land-use policies within the watershed, because new ordinances would originate from a common source, rather than individual county commissions.

Sources of Revenue. Enabling legislation for a LMWC should include provisions for the creation of a Watershed Protection Fund. The Watershed Protection Fund would be used to pay for BMP implementation, such as establishing streambank buffer strips or installing structural erosion controls. Part of the fund would also be used to purchase land to set aside for the purpose of soil conservation; this would supplement the Conservation Reserve Program.

One of the central issues in creating a workable plan for intergovernmental management of the watershed is making such a plan equitable; that is, ensuring that "local costs . . . are proportional to the benefits received (Camp, Dresser, and McKee, 1989). Evaluating the extent to which each county benefits from protecting the lake and its watershed will be a critical part of establishing an equitable watershed management plan and will require intensive intergovernmental cooperation. Any evaluation of potential revenue sources to fund management activities of the LMWC must also consider this equitability issue. Possible sources of revenue are considered below.

Watershed Tax. Assessment of a tax is often used to fund special units of government such as lake districts or river basin commissions. For example, Wisconsin lake districts may impose a property tax, not to exceed 2.5 mills, to fund normal operating expenses (Klessig and Yanggen, 1975). The Maumee River Basin Commission in Indiana receives funds from the five counties within the watershed proportional to the watershed acreage within each county. Remember that property taxes do not directly affect non-resident users so other revenue generating options must be used to equitably distribute lake and watershed management costs.

User Fees. User fees are fees charged to those who wish to use certain resources. For example, in the Lake Monroe area, user fees are charged to use the following public resources: to enter a State Recreation Area, to launch a boat, and to camp. These fees help pay the costs of providing the particular service. Each of these uses is made more valuable by having a clean, well-managed lake. Therefore, an add-on to the existing fee, dedicated to lake and watershed management, is justifiable. User fees could also be assessed to private businesses near the lake which benefit directly from the lake, for example, private marinas, hotels, and bait shops.

Drinking Water Surcharge. Over 100,000 customers receive drinking water processed from Lake Monroe. These customers, as well as the Bloomington Utilities Department, receive benefits from a clean Lake Monroe by reduced water treatment costs. As raw water quality degrades, treatment costs rise. A surcharge on finished drinking water would be passed along to drinking water customers who benefit directly. The revenue generated could be used by the LMWC to fund watershed protection measures needed to maintain adequate water quality in the lake.

The notion of drinking water utilities paying to protect their water supply watersheds is not new. Some water utilities take a very proactive role in watershed protection. For example, in 1983, the Springfield, Illinois municipal utility began funding soil conservation programs in Lake Springfield's 689 km^2 watershed (Skelly and Hinsman, 1988). The utility provided cost-share funds for conservation structures and purchased a no-till planter for farmers to use. They discovered that it was more cost effective to control watershed erosion and sedimentation ($4.10/metric ton) than to dredge the aftermath ($5.16/metric ton). The utility also realized substantial intangible benefits such as an enhanced public image and improved public education.

Raw Water Purchase Fee. The City of Bloomington Utilities Department pays the State of Indiana a fee for the water they withdraw for drinking water treatment. The fee currently amounts to $33 per one million gallons of water withdrawn. This amounted to approximately $145,000 paid to the State in 1993 according to Jeff Underwood, Assistant Director of Finance with the Bloomington Utilities Department (personal communication, 1994). The City has been purchasing water since the Lake Monroe Water Treatment Facility was completed in late 1965. The money generated is placed in a fund which was originally to be used for new reservoir construction. However, most of this revenue reverted back to the state's general fund. Recent revisions in the original legislation allow a portion of these funds to be used for lake studies. It seems reasonable that a portion of this annual fund be dedicated for management of Lake Monroe and its watershed.

Impact Fees on New Construction. Impact fees on new construction in the watershed would promote erosion mitigation on building sites. Impact fees could be based on a number of variables pertaining to soil erosion, such as lot size, percentage of the building site disturbed during construction, land slope, and erosiveness of soils at the site. The proper use of mitigation techniques, such as sediment traps and erosion netting, would qualify home builders for credits that would significantly offset the fee. This system would not discourage new construction, but rather would provide incentives to practice soil conservation during the construction process.

Managing Land Development. Both Monroe County and the City of Bloomington are in the process of preparing comprehensive master plans. All counties within Lake Monroe's watershed have their own land use zoning authority. While we do not suggest that the LMWC have zoning authority over the entire watershed, the organization could work toward implementing a uniform master plan which could involve a classification of zones based on environmental sensitivity, such as those established by the North Carolina Water Supply Protection Act. Among the criteria which should be considered are a site's proximity to the lake or its tributaries, the degree of slope and soil erosivity, and the site's potential for erosion mitigation. Using these criteria, tighter restrictions can be placed on construction in the most erosion-prone areas. The LMWC could hold public hearings to solicit the views of interested parties. It would then be the task of the LMWC to balance these private interests with those of the public, based on information provided by building density models and other relevant data.

The implementation of construction site erosion controls throughout the watershed should also be a priority of the LMWC. Enforcement of the controls would rest with each county but the LMWC could serve as a catalyst for the development and implementation of the controls. The City of Bloomington soil erosion control ordinance (Bloomington Municipal Code, Chapter 20.20) or state rules on storm run-off associated with construction activity (IC Title 327, Water Pollution Control Board, Rule 5) would be useful models for adoption on all construction sites.

Supporting Agricultural Land Management. One of LMWC's functions would be to promote soil conservation through the use of agricultural best management practices (BMP's). These practices, such as conservation tillage and the use of grassed waterways, are not mandated, but rather are used voluntarily. While BMPs do reduce erosion drastically in most instances, areas which are sloped or prone to flooding may still suffer significant soil loss. The LMWC could address such problems through programs created by the Food Security Act of 1985. These programs use incentives to promote soil conservation in areas most susceptible to erosion. For example, under the Conservation Reserve Program (CRP), the Natural Resources Conservation Service has the authority to pay farmers rent on highly erodible land. The CRP allows land within thirty meters of waterways to be taken out of production and planted with groundcover (Novotny and Olem, 1994). The Watershed Protection Fund could contribute to CRP payments on highly erodible farmlands. Another program, the Conservation Compliance Program, requires farmers to comply with locally developed and approved conservation plans or risk losing benefits, such as price supports and disaster assistance, provided by the federal government. The LMWC could also contribute to cost-sharing of BMP implementation similar to the Springfield, Illinois case (Skelly and Hinsman, 1988).

11.8 Conclusion

Most of the mechanisms needed to protect Lake Monroe and its watershed already exist. Providing a framework in which various soil and water resource agencies can coordinate their efforts will lead to greater efficiency and will promote more comprehensive watershed management efforts. The Lakes Task Force has already begun the task of constructing this framework. Expanding the role of the Lakes Task Force beyond advisory functions will create an organization with greater versatility in solving the problems which face Lake Monroe and its watershed. Watershed management at this scale will inevitably require what Hardin referred to as "mutual coercion" (Korth and Klessig, 1990). To protect and preserve the "commons," in this case Lake Monroe, some individual freedom has to be relinquished.

As a final cautionary, we must emphasize that the job ahead is a difficult one. The major barriers to successful lake management are institutional. Born and Rumery (1989) discuss the most important of these barriers. They include:

- Overlapping areal jurisdiction among governmental units
- Fragmented functional program responsibilities
- Ineffective coordination
- Limited authority
- Financial constraints
- Limited private-sector roles
- Inadequate public awareness and consensus

If it can overcome these barriers, a responsive, accountable Lake Monroe Watershed Commission will be the appropriate agency to guide the management of Lake Monroe and its watershed into the future and help avert a "tragedy of the commons."

12.0 IMPLEMENTATION

12.1 Technical and Financial Feasibility

The proposed management activities for Lake Monroe and its watershed are both technically and financially feasible. The implementation of agricultural, forestry, and urban BMPs has been proven over the years to be very effective in reducing watershed erosion and runoff, and ultimately, in reducing the delivery of NPS pollutants to lakes. Lake use management and enforcement of boating regulations have also been widely implemented and proven. The success of public education and planning programs in promoting the implementation of these measures has also been demonstrated.

The financial resources needed to implement watershed BMPs in such a large watershed are substantial, but it is significantly more cost-effective to manage and prevent the delivery of pollutants to lakes than it is to remove the pollutants and restore the lake after degradation. It is difficult to estimate BMP costs for such a large watershed area, however conservative estimates are:

- watershed BMPs : $2–4 million
- lakeshore erosion control of worst areas (willow posts + grading): $800,000

Implementation represents a long-term financial commitment in the watershed and we have identified a number of potential local revenue-generating sources to fund the management program. In particular, the following government programs are also available to provide assistance:

- Section 319 Nonpoint Source Pollution Program (Federal)
- NRCS cost-share programs (Federal)
- Lake and River Enhancement Program (State)
- Reservoir fund from water purchase fees (State)

12.2 Public Participation .

There has been ample opportunity for the public to participate in this project. The monthly Lakes Task Force meetings are publicized and open to the public. Project Director Bill Jones has spoken at or attended a number of these meetings to communicate information and to solicit public comment.

In 1992 we surveyed 179 lake users on two summer Saturdays (July 25 and August 1) at two boat ramps, one swimming area and a campground on Monroe Reservoir. Our survey results (Table 12–1) corresponded well with the lake user data collected by the Corps of Engineers. Respondents to our survey felt that their favorite lake recreational activities had been adversely affected by deteriorating water quality and they supported management activities to improve the recreational experience. Respondents also listed unsafe boating and overcrowding as the two most important problems affecting the lake (Table 12–2). Additionally, our survey showed that lake users are willing to travel great distances to recreate at their favorite lake. Lake users surveyed came from 28 Indiana counties throughout the state. Those who traveled more than 100 miles averaged four visits to Monroe Reservoir per year. Those from nearby counties averaged more than 20 visits per year. Written comments received during this survey are included in Appendix F.

Table 12–1. Public Use of Monroe Reservoir and Opinions of 179 Lake Users Surveyed during Summer, 1992

Lake use	*Participation in Lake Use (%)*	*Uses Adversely Affected by Deteriorating Water Quality (%)*	*Which Uses Should be Improved by Management (%)*
Swimming	75.1	52.4	64.6
Fishing	57.1	26.5	31.2
Lake Beauty	55.0	25.4	28.6
Power Boating	45.5	20.6	12.2
Observe Wildlife	42.3	16.9	20.1

Table 12–2. Public Perception of Monroe Reservoir problems:
Opinions of 179 Lake Users Surveyed during Summer, 1992

Potential Lake Problem	*% Indicating this as a Major Problem*[a]
Unsafe boaters	53.4
Over crowding	42.9
Water clarity	31.7
Rooted aquatic weeds	25.4
Sedimentation	22.7

[a]survey respondents could select more than one problem.

A special meeting and discussion was organized for the 5th Indiana Lake Management Conference held at Lake Monroe on Friday April 30, 1993. The purpose of this meeting, organized by the Monroe County Lakes Task Force, was to get representatives of the various Federal, State and local jurisdictions together to discuss ways to establish cooperative management efforts in the Lake Monroe watershed. The meeting served to identify the current jurisdictions involved in management activities within Lake Monroe's watershed, their responsibilities, and their interests in integrated watershed management. Results of this preliminary meeting were incorporated into Chapter 11 of this report, and will serve as a nucleus for future meetings. The following invited people attended this meeting:

Frank Lapensee
Clean Lakes Program Manager
U.S. Environmental Protection Agency

Charles Gossett
Asst. State Conservationist
U.S. Soil Conservation Service

Gary Doxtater
Deputy Director, Division of Water
Indiana Dept. of Natural Resources

Don Basham
Deputy District Eng., Louisville District
U.S. Army Corps of Engineers

Ellen Jacquart
Ecosystems Team Leader
Brownstown Dist., U.S. Forest Service

Durland Patterson
Director, Div. Of Sanitary Engineering
Indiana State Board of Health

John Winters
Chief of Water Standards
Office of Water Management
Indiana Dept. of Environmental Management

Greg Lindsey
Center for Urban Policy and the Env.
School of Public & Env. Affairs
Indiana University, Indianapolis

Tim Tilton
President, Monroe County Commissioners

David Hamilton
President, Monroe County Council

Tomilea Allison
Mayor, City of Bloomington

Jack Hopkins
President, Bloomington City Council

Jerry Floyd
President, Brown County Commissioners

Jeanine Richardson
President, Brown County Council

Gary Darlage
President, Jackson County Commissioners

David Godschalk
Professor, Dept. of City & Regional Planning
University of North Carolina

Mike Jenson
Research Assistant
School of Public & Env. Affairs
Indiana University, Bloomington

Host—Tim Tilton | Facilitator—David Godschalk | Recorder—Mike Jenson

Two formal public meetings, announced in the local newspaper and on local radio stations, have been held thus far. An introductory meeting was held at the Monroe County Courthouse on July 16, 1992. Project purposes and methods were explained and the participants voiced their concerns over a number of issues (Appendix F). The public was informed of the results of the diagnostic survey at a public meeting held December 16, 1993 at the Monroe County Public Library. A final public meeting was held March 25, 1996 at the Monroe Co. Public Library Auditorium. This meeting was planned by the Lakes Task Force. At this meeting, the feasibility study was presented and discussed.

Public comments from these meetings, from correspondence received from citizens, and from written reviews of the draft report have been incorporated into this final report.

12.3 Timetable

Implementation of this plan has already begun with the receipt of a section 319 Federal nonpoint source grant by the Monroe, Brown and Lawrence county SWCDs. We know that all BMP needs cannot be met immediately but an aggressive program could accomplish the majority of implementation over a ten-year period. Discussions for forming an integrated institutional framework for watershed management should begin immediately because the effective implementation of this management plan requires the coordination and efficiency that such a framework can bring.

12.4 *Operation and Maintenance Plan*

Many of the BMPs recommended in the management plan require periodic inspection and maintenance. Sediment will accumulate behind WASCOBS and sedimentation basins. Removal of these accumulations is the responsibility of the individual land owners, and this responsibility should be incorporated into funding agreements and plan approvals prior to their construction. Conventional earthmoving equipment can be used to remove the accumulations and in most cases, accumulated silt can be applied to adjacent lands for re-use.

Animal waste management facilities also require periodic maintenance. Maintenance of these systems is also the responsibility of the individual owners and should be incorporated into the funding agreements.

Snags and log jams in streams should be removed as they occur to prevent streambank erosion.

Vegetation planted for lakeshore or streambank stabilization should be inspected periodically until well established. Re-seeding or re-planting should occur as needed.

Erosion control structures and practices installed on construction sites must be inspected regularly and corrected if not functioning at specification.

12.5 *Permit Requirements*

Indiana law requires a permit before any structural controls (rip-rap) or earthmoving activities (grading) are implemented on streambanks or in the floodway of any river or stream with a drainage area greater than one square mile. This requirement would apply to nearly all streams in the Lake Monroe watershed. For more information, contact:

Indiana Department of Natural Resources
Division of Water—Permit Section
IGC South W264
204 West Washington Street
Indianapolis, IN 46204–2748
(317) 232–5660

12.6 *Environmental Evaluation*

Socioeconomic and environmental impacts were considered as a part of the alternatives analysis conducted for this study. Results are presented below in response to the 14-question environmental evaluation checklist included in Appendix A of the Clean Lakes Program regulations (U.S. EPA, 1980).

1. "Will the proposed project displace any people?"

   No

2. "Will the proposed project deface existing residences or residential areas? What mitigative actions such as landscaping, screening, or buffer zones have been considered? Are they included?"

   No residential areas will be defaced as a result of this project. Watershed management controls should not deface any residential properties but instead are likely to enhance them.

3. "Will the proposed project be likely to lead to a change in established land use patterns, such as increased development pressure near the lake? To what extent and how will this change be controlled through land use planning, zoning, or through other methods?"

This plan encourages land use planning to limit the impact of land use changes on Lake Monroe.

4. "Will the proposed project adversely affect a significant amount of prime agricultural land or agricultural operations on such land?"

No land use changes will remove prime agricultural land from production as a result of this project. Agricultural operations on marginal land having steep slopes or lands along stream bottoms may be affected by management recommendations to reduce erosion and runoff.

5. "Will the proposed project result in a significant adverse effect on parkland, other public land, or lands of recognized scenic value?"

No significant adverse impacts are anticipated. The implementation of lake and watershed management programs will likely enhance the scenic resources of public lands around the lake.

6. "Has the State Historical Society or State Historical Preservation Officer been contacted? Has he responded, and if so, what was the nature of that response? Will the proposed project result in a significant adverse effect on lands or structures of historic, architectural, archaeological or cultural value?"

The Indiana State Historical Society was not contacted during this study. While historical artifacts are likely to be located along most river bottoms and ridge tops in Monroe and Brown Counties, no significant sites will be affected by the proposed project.

7. "Will the proposed project lead to a significant long–range increase in energy demands?"

No.

8. "Will the proposed project result in significant and long-range adverse changes in ambient air quality or noise levels? Short term?

No.

9. "If the proposed project involves the use of in-lake chemical treatment, what long and short term adverse effects can be expected from that treatment? How will the project recipient mitigate these effects?"

No in-lake chemical treatments are recommended under the proposed plan.

10. "Does the proposal contain all the information that EPA requires in order to determine whether the project complies with Executive Order 11988 on floodplains? Is the proposed project located in a floodplain? If so, will

the project involve construction of structures in the floodplain? What steps will be taken to reduce the possible effects of flood damage to the project?"

The proposed plan recommends watershed management controls in the floodplain to reduce the possible effects of flood damage, e.g., buffer strips, streambank erosion controls. No other structures will be built in the floodplain to implement this plan.

11. "If the project involves physically modifying the lake shore or its bed or its watershed, by dredging, for example, what steps will be taken to minimize any immediate and long term adverse effects of such activities? When dredging is employed, where will the dredged material be deposited, what can be expected and what measures will the recipient employ to minimize any significant adverse impacts from its deposition?"

Dredging has not been proposed at this time for Lake Monroe. A complete assessment of potential adverse environmental impacts is strongly recommended should dredging be considered in the future. Lakeshore modifications are recommended in the management plan to stabilize banks and prevent erosion.

12. "Does the project proposal contain all information that EPA requires in order to determine whether the project complies with Executive Order 11990 on wetlands? Will the proposed project have a significant adverse effect on fish and wildlife, or on wetlands or any other wildlife habitat, especially those of endangered species? How significant is this impact in relation to the local or regional critical habitat needs? Have actions to mitigate habitat destruction been incorporated into the project? Has the recipient properly consulted with appropriate State and Federal fish, game and wildlife agencies and with the U.S. Fish and Wildlife Service? What were their replies?"

The management plan will not have adverse impacts on natural wetlands. Recommendations are included to protect existing wetlands. The plan recognizes the importance of the North and Middle Fork Wildlife Refuges and includes provisions to protect these significant habitats. Bald Eagles nest along Lake Monroe and feed in its waters. The management plan will have no foreseeable impact on these, or other endangered or threatened species.

13. "Describe any feasible alternatives to the proposed project in terms of environmental impacts, commitment of resources, public interest and costs and why they were not proposed."

The environmental impacts, costs, public interest, and resource requirements of feasible alternatives are described elsewhere in this report (see Chapters 9 and 10).

14. "Describe other measures not discussed previously that are necessary to mitigate adverse environmental impacts resulting from the implementation of the proposed project."

No others to discuss.

13.0 LITERATURE CITED

Adams, R.W. 1983. "Guidelines for use of the herbicide 2, 4–D to control Eurasian water milfoil in British Columbia." In: *Lake Restoration, Protection and Management. Proceedings of the Second Annual Conference of the North American Lake Management Society.* EPA 440/5–83–00. U.S. EPA, Washington, D.C.

Agricultural Experimental Station of Purdue University and the U.S. Soil Conservation Service. 1971. *General Soil Maps for the Counties of Indiana.*

Allan, J.D. 1995. *Stream Etiology—Structure and Function of Running Waters.* Chapman and Hall Publishers, London.

Allanson, B.R.; C.J. Zimmerman; and D.K. Smith. 1973. *A Report on the Limnology of Monroe Reservoir, Indiana. Occasional Paper No. 1,* School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Andrews, S.J. 1989. *Monroe Reservoir—1988 Fish Management Report.* Division of Fish and Wildlife, Indiana Department of Natural Resources, Indianapolis, IN.

_____. 1993. *Monroe Reservoir 1992 Fish Management Report.* Fisheries Section, Division of Fish and Wildlife, Indiana Dept. of Natural Resources.

_____. and J. Pearson. 1982. *Monroe Reservoir 1982 Fish Management Report.* Fisheries Section, Division of Fish and Wildlife, Indiana Dept. of Natural Resources.

APHA et al. 1989. *Standard Methods for the Examination of Water and Wastewater*, 17th edition. American Public Health Association, Washington, D.C.

Bauman, J. 1988. *Wisconsin Construction Site Best Management Practice Handbook.* Bureau of Water Resources Management, Wisconsin Department of Natural Resources, Madison, Wisconsin.

Beard, T.D. 1973. *Overwinter Drawdown—Impact on the Aquatic Vegetation in Murphy Flowage, Wisconsin. Tech. Bull. No. 61.* Wisconsin Dept. Nat. Resour., Madison, WI.

Born, S.M. and C. Rumery. 1989. "Institutional aspects of lake management." *Environmental Management,* 13(1): 1–13.

Bradbury, K.R.; M.J. Graham; R.V. Ruhe; W.Y.B. Chang; and D.G. Frey. 1977. *Monroe Reservoir, Part I: Hydrologic Circulation, Sedimentation and Water Chemistry; Part II: Nutrient Relations. Technical Report No. 89.* Water Resources Research Center, Indiana University, Bloomington, IN.

Brang, J. 1971. "Weeds a Problem at Lake Monroe." *Bloomington-Bedford Sunday Herald Times.* November 1971.

Brennan, J.P. 1994. "Artificial wetlands are more 'natural' disposal systems." *South Bend Tribune,* August 14, 1994.

Brune, G.M. *Trap Efficiency of Reservoirs*. 1953. Trans. Am. Geophys. Union, 34:407–18.

Bulmer, S.K. and V. Garrison. 1994. "Statewide lakes and ponds recreation management in Vermont." *LakeLine* 14(2): 29–31.

Bureau of the Census. 1991. *1990 Census of Population and Housing—Summary Population and Housing Characteristics: Indiana*. 1190 CPH–1–16, U.S. Dept. of Commerce, Washington, D.C.

Burger, A.M.; C.B, Rexroad; A.F. Schneider; and R.H. Shaver. 1966. *Excursions in Indiana Geology. Guidebook 12*. Indiana Department of Natural Resources Geological Survey, Bloomington, IN.

Camp; Dresser; and McKee. 1989. *University Lake Watershed Study*. Raleigh, NC.

Carlson, R.E. 1977. "A trophic state index for lakes." *Limnology and Oceanography*, 22(2): 361–69.

Carlson, R.A. and J.B. Moyle. 1968. "Key to common aquatic plants of Minnesota." *Minn. Dep. Conserv. Spec. Publ. No. 53*. Minneapolis.

Chu, F.S. and R. Wedepohl. 1994. "Algal toxins in drinking water?—research in Wisconsin." *LakeLine*, 14(1): 41–2.

Clark, G.D. (Ed.). 1980. *The Indiana Water Resource—Availability, Uses, and Needs*. Indiana Department of Natural Resources, Indianapolis, IN.

Cooke, G.D. 1980. "Lake level drawdown as a macrophyte control technique." *Water Resources Bulletin*, 16(2):317–22.

______ and R.H. Kennedy. 1981. *Precipitation and Inactivation of Phosphorus as a Lake Restoration Technique*. EPA–600/3–81–012. Corvallis Environmental Research Laboratory, U.S. EPA, Corvallis, OR.

_____ ; E.B. Welch; S.A. Peterson; and P.R. Newroth. 1993. *Restoration and Management of Lakes and Reservoirs*, Second Edition. Lewis Publishers, Boca Raton, FL.

Corps of Engineers. 1966. *Wabash River Basin, Indiana, Reservoir Regulation Plan—Appendix C: Lake Monroe*. U.S. Army Corps of Engineers, Louisville, KY.

_____. 1967. *Monroe Reservoir, Ohio River Basin, Indiana—Master Plan. Design Memorandum No. 4B*. U.S. Army Engineer District, Louisville, KY.

_____. 1981. *Monroe Lake Indiana* (brochure). U.S. Army Corps of Engineers, Louisville District, Louisville, KY.

_____. 1989. *Monroe Reservoir water quality parameters computer database*. U.S. Army Corps of Engineers, St. Louis, MO.

_____. 1993. *Visitorship Records—Files*. U.S. Army Corps of Engineers, Bloomington, IN.

Creeth, Terry (Ed.). 1992. *The Indiana Factbook.* Indiana Business Research Center, Indiana University School of Business, Bloomington, IN.

Department of Natural Resources. 1965. *Summary Report—Sedimentation Surveys in Indiana.* Div. of Water, Indiana Department of Natural Resources, Indianapolis, IN.

Department of Natural Resources. 1988. *The Indiana Conservancy Act.* Indiana Department of Natural Resources, Indianapolis, IN.

_____. 1989. *Indiana Conservancy Districts Directory.* Indiana Department of Natural Resources, Indianapolis, IN.

_____. Undated. *Lake Monroe Bird Checklist.* Indiana Department of Natural Resources, Division of Reservoir Management, Indianapolis, IN.

Driscoll, E.D. 1986. "Detention and Retention Controls for Urban Stormwater." In: B. Urbonas and L.A. Roesner, (Eds.), *Engineering Foundation Conference: Urban Runoff Quality—Impact and Quality Enhancement Technology, Henniker, New Hampshire.* Published by American Society of Civil Engineers, New York, NY.

Dunst, R.C., et al. 1974. *Survey of Lake Rehabilitation Techniques and Experiences. Technical Bulletin No. 75.* Wisconsin DNR, Madison, WI.

Eagan, L.L. 1991. " Evaluation of an institutional framework designed to retard cultural eutrophication." *Lake & Reservoir Management,* 7(1): 131–36.

Echelberger, W.F.; W.W. Jones; et al. 1984. *Cedar Lake Restoration/Feasibility Study, ESAC–84–01.* Environmental Systems Application Center, School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Eggers, D.M. 1982. " Planktivore preference by prey size." *Ecology,* 63(2): 381–90.

Engel, S. 1988. "The shallow lakes initiative: restoring aquatic habitat in Wisconsin." *Research Management Findings, No. 15.* Bureau of Research, Wisconsin Department of Natural Resources, Madison, WI.

_____. 1989a. "The restructuring of littoral zones." *Lake and Reservoir Management* 2:235–42.

_____. 1989b. "Lake use planning in local efforts to manage lakes." In: *Enhancing States' Lake Management Programs.* N.E. Illinois Planning Commission and North American Lake Management Society.

Environmental Management Commission. 1992. *Revised report of the proceedings of the final adopted surface water supply protection rules pursuant to the Water Supply Watershed Protection Act.* State of North Carolina Department of Environment, Health, and Natural Resources, Raleigh, NC.

_____. 1993. *Administrative Code Section: 15A NCAC 2B .0100—Procedures for Assignment of Water Quality Standards; and 15A NCAC 2B .0200—Classifications and water quality standards applicable to surface waters of North Carolina.* State of North Carolina Department of Environment, Health, and Natural Resources, Raleigh, NC.

Fenelon, J., K. Bobay, et al. 1994. *Hydrogeologic Atlas of Aquifers in Indiana. WRI Report #92–4142*. U.S. Geological Survey, Indianapolis, IN.

Fernald, M.L.; A.C. Kinsey; and R. Rollins. 1958. *Edible Wild Plants of Eastern North America*. Harper and Row, New York.

Fernandes, Susan. 1989. *Lake Monroe Issues*. Monroe County Planning Department, Bloomington, IN.

Fleming, Tony. 1988. *The Relationship between Geologic Conditions and Septic System Performance at Monroe Lake, Monroe County, Indiana*. Internal Report, Indiana Geological Survey. Indiana Department of Natural Resources, Bloomington, IN.

_____. 1990. "Impacts of septic tank systems on the quality of lakes and shallow ground water in a fractured rock environment." *Groundwater*, 28(5):789.

Fox, J.L.; P.L. Brezonick; and M.A. Keirn. 1977. *Lake Drawdown as a Method of Improving Water Equality*. EPA–600/3–77–005. U.S. EPA, Washington, D.C.

Frey, D.G. 1976. *Dynamics of the Lake Monroe System. Report on a research contract from the Indiana Department of Natural Resources*. Indiana University, Bloomington, IN.

Godschalk, David R. 1992. *Negotiating Intergovernmental Development Policy Conflicts: Practice-Based Guidelines*. American Planning Association Journal 58:368–78.

Graham, M. 1993. Telephone interview.

Graves, R.E. (Ed). 1986. *Manure Management for Environmental Protection*. Pennsylvania Department of Environmental Resources, Harrisburg, PA.

Gray, H.H.; R.S. Howe; J.C. Randolph; M.C. Roberts; and N.L. White. 1975. *Lake Monroe Land Suitability Study: A Technical Report on a Selected Portion of the Lake Monroe Watershed*. School of Public and Environmental Affairs and the Center for Urban and Regional Analysis, Indiana University, Bloomington, IN.

Green, B. 1994. "Constructed wetlands are big in small communities." *Water Environment & Technology*, February 1994.

Guntenspergen, G.R.; F. Stearns; and J.A. Kadlec. 1989. "Wetland Vegetation." In: D.A. Hammer (Ed.), *Constructed Wetlands for Wastewater Treatment—Municipal, Industrial and Agricultural*. Lewis Publishers, Chelsea, MI.

Hall, Robert D. 1989. *Geology of Indiana*. Kendall/Hunt Publishing Co., Dubuque, IA.

Hallock, D.D. and C.M. Falter. 1987. "Powerboat engine discharges as a nutrient source in high use lakes." *Lake Reserve. Manage.* 3:172–81.

Hardin, G. 1968. "The tragedy of the commons." *Science*, 162:1243–48.

Hartke, E.J. and J.R. Hill. 1974. *Sedimentation in Lake Lemon, Monroe County, Indiana. Geological Survey Occasional Paper 9*. Department of Natural Resources, Bloomington, IN.

Hartke, E.J. and H.H. Gray. *1989. Geology for Environmental Planning in Monroe County, Indiana. Geological Survey Special Report 47.* Indiana Department of Natural Resources, Bloomington, IN.

Heiskary, S. and W.W. Walker. 1987. "Developing phosphorus criteria for Minnesota lakes." *Lake Reserv. Manage.* 4(1):1–9.

HERPICC. 1989. *A Model Ordinance for Erosion Control on Sites with Land Disturbing Activities.* H–89–5. Highway Extension and Research Project for Indiana Counties and Cities, Purdue University, West Lafayette, IN.

HHRC&DC. 1985. *Urban Development Planning Guide.* Hoosier Heartland RC&D Council, Inc., Indianapolis, IN.

Humstone Squires Associates. 1990. *Planning for Lake Water Quality Protection—A Manual for Vermont Communities.* Vermont Agency of Natural Resources, Department of Environmental Conservation, Waterbury, VT.

Illinois Department of Conservation. 1989. *Willow Post Stabilization Techniques* (video). Watershed Planning Program, Springfield, Illinois.

Indiana Business Research Center. 1986. *Indiana Township Populations Projections, 1985–2020.* School of Business, Indiana University, Bloomington, IN.

Indiana Clean Lakes Program. 1994. *Lake Database.* School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Indiana Code 36–7–6.1. (Maumee River Basin Commission).

IDEM. 1986. *Indiana Lake Classification System and Management Plan.* Indiana Department of Environmental Management, Indianapolis, IN.

_____. 1990. *Indiana 305 (b) Report: 1988–89.* Office of Water Management, Indiana Department of Environmental Management, Indianapolis, IN.

_____. 1991. "Fish tissue contamination results." OWM—Bilogical Studies, Indiana Department of Environmental Management, Indianapolis, IN.

_____. 1992. *Indiana 305 (b) Report: 1990–91.* Office of Water Management, Indiana Department of Environmental Management, Indianapolis, IN.

IDNR. 1993. *Forestry and the Lake Monroe watershed: A proposal for statewide improvement.* Division of Forestry, Indiana Department of Natural Resources, Indianapolis, IN.

Illinois Resources. 1990. "State Water Survey study results provide invaluable information on effective methods of streambank stabilization." *Illinois Resources*, Nov./Dec. 1990:6–7.

Jaakson, R. 1984. "Recreation planning for a small urban lake." *Town Planning Review*, 56: 90–111.

Jackivicz, T.P. and L.N. Kuzminski. 1973. " A review of outboard motor effects on the aquatic environment." *J. Water Pollut. Control Fed.* 45:1759–770.

Jones, W.W. et al. *1984. Griffy Lake Long-Range Use and Management Plan*. ESAC–84–02. School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

_____. and D.A. Levine. 1989. *Lake Shakamak Feasibility Study and Management Plan*. School of Public and Environmental Affairs, Indiana University, Bloomington.

_____. and N. O'Reilly. 1986. "Lake Sediment Management Workshop Summary." *Lake and Reservoir Management*, 2:443–46.

Karlovich, J. 1993. " 'Wetland' replaces sewer, septic system." *Ft. Wayne Journal Gazette.*

Kim, K.A. and R. Hawkins. 1993. *Water Resources Bulletin*, 29(3):449–59.

Klessig, L.L. 1994. " Load limits for lakes." *Lake and Reservoir Management*, 10(1):69–73

_____; and D.A. Yanggen. 1975. *The Role of Lake Property Owners and Their Organizations in Lake Management.* Environmental Resources Unit, University of Wisconsin-Extension, Madison, WI.

_____; B. Sharp; and R. Wedepohl. 1989. "Using a special purpose unit of government to manage lakes." *Lake and Reservoir Management*, 5(1):37–44.

Korth, R.M. and L.L. Klessig. 1990. "Overcoming the tragedy of the commons: Alternative lake management institutions at the community level." *Lake & Reservoir Management*, 6(2):219225.

Kotak, B.G.; E.E. Prepas; and S.E. Hrudey. 1994. "Blue-green algal toxins in drinking water supplies—research in Alberta." *LakeLine*, 14(1):37–40.

Krecker, F.H. 1939. "A comparative study of animal populations of certain submerged aquatic plants." *Ecology*, 20: 553–62.

Krull, J.N. 1970. "Aquatic plant-macroinvertebrate associations and waterfowl." *J. Wildl. Manage.*, 34: 707–18.

Kusler, Jon A. 1980. *Regulating Sensitive Lands*. Ballinger Publishing Company, Cambridge, MA.

Lagler, K.F.; A.S. Hazzard; W.E. Hazen; and W.A. Tompkins. 1950. "Outboard motors in relation to fish behavior, fish production and angling success." *Trans. N. Am. Wildl. Conf.* 15:280–303.

Lakes Task Force. 1994. *Draft Proposal for Reorganization of Lakes Task Force*. Bloomington, IN.

Landers, D.H. and D.G. Frey. 1980. *The Die-Back Role of* Myriophyllum spicatum *in Monroe Reservoir. Technical Report No. 134*. Purdue University Water Resources Research Center, West Lafayette, IN.

Lapensee, Frank. 1993. "Think globally, act locally." *Water Column*, 5(2):3–5.

League of Women Voters. 1971. *A Study of the Water Supply and Sewage Disposal Systems of Bloomington, Indiana.* Bloomington, IN.

Lind, O.T. 1985. *Handbook of Common Methods in Limnology*, Second Edition. Kendall/Hunt Publishing Company, Dubuque, IA.

Lindquist, P.; R. Springman; G. Korb; R. Anderson; and S. Gayan. 1987. *BarnyardRunoff Management*. Wis. Dept. Nat. Res.—Wis. Dept. Ag., Trade, Cons. Protection. Madison, WI.

List, M. 1989. *Report of the Lake Monroe Wastewater Task Force.* Monroe County Board of Health, Bloomington.

Livingston, E.H. 1989. "Use of Wetlands for Urban Management". In: D.H. Hammer (Ed.), *Constructed Wetlands for Wastewater Treatment—Municipal, Industrial and Agricultural.* Lewis Publishers, Chelsea, MI.

MacBeth, E.J. 1991. "Protecting aesthetics and the visual resource quality of lakes." *Enhancing the States' Lake Management Programs*, 1991: 17–23.

Mackay, D. 1982. *Environ. Sci. Technology*, 16: 274–278.

Marsh, W.M. and T.E. Borton. 1976. *Inland Lake Watershed Analysis—A Planning and Management Approach.* Bureau of Water Management, Michigan Dept. of Natural Resources, Lansing, MI.

Martin, A. and G.D. Cooke. 1994. "Health risks in eutrophic water supplies." *LakeLine*, 14(1):24–6.

Maumee River Basin Commission. 1992. *Protecting Flood-Prone Property and Natural Resources* (Pamphlet). Fort Wayne, IN.

McComas, S. 1986. "Shoreline protection." *Lake and Reservoir Management*, 2:421–25.

Michigan Sea Grant Program. 1988. *Vegetation and its Role in Reducing Great Lakes Shoreline Erosion.* Michigan Sea Grant Communications, Ann Arbor, MI.

Mitchell-Bruker, S. 1993. *Modeling Steady State Groundwater and Surface Water Interactions.* Ph.D. thesis, Indiana University, Bloomington.

Monroe County Planning Department. 1989. *Lake Monroe Issues* (booklet). Bloomington, IN.

Moore, L. and K. Thornton (Eds.) . 1988. *Lake and Reservoir Restoration Guidance Manual*, First Edition. Prep. by North American Lake Management Society for U.S. EPA, Washington, D.C.

Moss, Bob. 1989. "Water quality studied" (news release). Hoosier National Forest, Brownstown, IN.

Nakamura, Liane and Stephen M. Born. 1993. "Substate Institutional Innovation for Managing Lakes and Watersheds: A Wisconsin Case Study." *Water Resources Bulletin* 29: 807–21.

NAS. 1979. *Polychlorinated Biphenyls*. National Academy of Sciences, Washington, D.C.

National Research Council. 1992. *Restoration of Aquatic Ecosystems—Science, Technology, and Public Policy*. National Academic Press, Washington, D.C.

New, J.F. and Assoicates. 1995. Brochure describing artificial wetlands for wastewater treatment. Walkerton, IN.

Nichols, S.A. 1986. "Innovative approaches for macrophyte management." *Lake and Reservoir Management*, 2:245–51.

Noble, Richard A.; Robert C. Wingard, Jr.; and Thomas R. White. 1990. *Soil Survey of Brown County and Part of Bartholomew County, Indiana*. U.S. Soil Conservation Service. United States Government Printing Office 1990 0–205–513: QL3.

Novotny, Vladimir and Harvey Olem. 1994. *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*. Van Nostrand Reinhold, NY.

O'Brien, W.J.; B. Evans; and C. Luecke. 1985. " Apparent size choice of zooplankton by planktivorous sunfish: exceptions to the rule." *Environ. Biol. of Fishes*, 13(3): 225–33.

Olem, H. and G. Flock (Eds.) 1990. *Lake and Reservoir Restoration Guidance Manual*. 2nd edition, EPA 440/4–90–006. Prep. by North American Lake Management Society for U.S. EPA, Washington, D.C.

Pena, V. 1992. Personal communication.

Perstorp Analytical. 1992. *The FLOW Solution Operations Manual*. Perstorp Analytical Environmental, Wilsonville, OR.

Peterson, J.O., J.D. Wall, T.L. Wirth, and S.M. Born. 1973. *Eutophication Control: Nutrient Inactivation by Chemical Precipitation at Horsehoe Lake, Wisconsin*. Technical Bulletin 62. Inland Lake Demontration Project, Wisconsin Dept. Nat. Res.

Pimentel, D.; C. Harvey; P. Resosudarmo; K. Sinclair; D. Kurz; M. McNair; S. Crist; L. Shpritz; L. Fitton; R. Saffouri; and R. Blair. 1995. " Environmental and economic costs of soil erosion and conservation benefits." *Science*, 267:1117–23.

Pitt, R. 1985. *Characterizing and Controlling Urban Runoff Through Street and Sewage Cleaning.* EPA/600/52–038. U.S. Environmental Protection Agency, Water Engineering Research Laoratory, Cincinnati, OH.

_____. 1989. *Detention Pond Design Basics.* Department of Civil Engineering, University of Alabama at Birmingham, Birmingham, Alabama.

Prodan, W.T. 1983. "Milfoil control in Seattle and the King County Region : METRO's harvesting program." In: *Lake Restoration, Protection and Management. Proceedings of the Second Annual Conference of the North American Lake Management Society.* EPA 440/5–83–001. U.S. EPA, Washington, D.C.

Prescott, G.W. 1982. *Algae of the Western Great Lakes Area.* Otto Koeltz Science Publishers, West Germany.

Randolph, J.C. et al. 1977. *Environmental Assessment of the Indiana University Alumni Association Lake Monroe Family Camp.* School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Reckhow, K.H.; M.N. Beaulac; and J.T. Simpson. 1980. *Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients.* EPA 440/5–80–011. Office of Water Regulations and Standards, U.S. Environmental Protection Agency, Washington, D.C.

Ritter, W.F. 1988. "Reducing impact of nonpoint pollution from agriculture: A review." *J. Environ. Sci. Health,* 25:821.

Rubin, R.S. (Ed.). *1992. Multi-Jurisdictional Case Studies in Public Policy.* The 1992 Lilly Fellows Program, School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

SCS. 1990. "Use of dormant woody plantings for streambank and shoreline protection." *Woodland Technical Note–IL–16.* Soil Conservation Service, U.S. Department of Agriculture, Champaign, IL.

Schuler, T.R. and M.R. Bley. 1987. *A Framework for Evaluating Compliance with the 10% Rule in the Chesapeake Bay Critical Area.* Department of Environmental Programs, Metropolitan Washington Council of Governments, Washington, D.C.

Schuler, T. R. 1994. "Homeowner survey reveal lawn management practices in Virginia," Technical Note 26. *Watershed Protection Techniques,* 1(2): 85–6.

Skelly, T.M. and W.J. Hinsman. 1988. "Cost-sharing soil conservation practices: economic pros and cons from a lake management perspective." *Lake and Reservoir Management,* 4(2):237–242.

_____; M.J. Luepke; M.A. Bodamer; J.H. Buckler; C.L. Johnson; W.G. Zyznieuski; M.D.Wothke; and R.J. Kirschner. 1992. *Lake Springfield Ecology and Management: A Leaseholder and Community Guide.* City Water, Light and Power, Springfield, IL.

Soil Conservation Service. 1966. *Engineering Memorandum IN–7.* U.S. Department of Agriculture, Indianapolis, Indiana.

_____. 1989. "Standards and Specifications 580, Stream bank and shoreline protection." *Technical Guide Section IV*. U.S. Department of Agriculture, Indianapolis, IN.

Sonzogni, W.C.; G. Chesters; D.R. Coote; D.N. Jeffs; J.C. Conrad; R.C. Ostry; and J.B. Robinson. 1980. "Pollution from land runoff." *Environmental Science & Technology*, 14(2): 148–53.

Sperling, D.L. 1991. "Public trust doctrine; a solid foundation for water rights." *Wisconsin Natural Resources*, April, 1991.

Terrell, C.R. and P.B. Perfetti. 1989. *Water Quality Indicator Guide: Surface Waters*. SCS–TP–161. USDA, Soil Conservation Service, Washington, D.C.

Thomas, J.A. 1981. *Soil Survey of Monroe County, Indiana*. U.S. Soil Conservation Service. United States Government Printing Office: 1981–328–684/99. Washington, D.C.

Thurow, C.; W. Toner; and D. Erley. 1975. *Performance Controls for Sensitive Lands—A Practical Guide for Local Administrators. Report Nos. 307, 308*. Planning Advisory Service, American Society of Planning Officials, Chicago, IL.

Tourbier, J. and R. Westmacott. 1976. *Lakes and Ponds. Technical Bulletin 72*. The Urban Land Institute, Washington, D.C.

Trudeau, P.N. 1982. *Nuisance Aquatic Plants and Aquatic Plant Management Programs in the United States*. Vol. 3. Northeastern and North Central Region. The Mitre Corp., McLean, VA.

Twenhofel W.H. 1950. *Principles of Sedimentation*, 2nd edition, McGraw-Hill Book Company, Inc., NY.

Underwood, J. 1994. Telephone conversation with W.W. Jones, 22 September, 1994.

U.S. EPA. 1977. *Guidelines for the Pollutional Classification of Great Lakes Harbor Sediments*. U.S. Environmental Protection Agency, Region V, Chicago.

_____. 1976a. *Report on Monroe Reservoir, Brown and Monroe Counties, IN*. Working Paper No. 336. U.S. Environmental Protection Agency, Corvallis Environmental Research Laboratory, Corvallis, OR.

_____. 1976b. *Quality Criteria for Water*. U.S. Environmental Protection Agency, Washington, D.C.

_____. 1976c. *Erosion and Sediment Control*. Technology Transfer Seminar Publication EPA–625/3–76–006. U.S. Environmental Protection Agency, Washington, D.C.

_____. 1980. "Cooperative agreements for protecting and restoring publicly owned freshwater lakes." *Federal Register*, 45(25):7788–99.

_____. 1989. N*onpoint Sources—Agenda for the Future: Nonpoint Source Solutions*. WH–556. Office of Water Quality, U.S. Environmental Protection Agency, Washington, D.C.

USGS. 1990. *U.S. Geodata—Land use and land cover digital data from 1:250,000 and 1:100,000 scale maps*. U.S. Geological Survey, Reston, VA.

UWEX. 1989. *Nutrient and Pesticide Best Management Practices for Wisconsin Farms. WDATCP Technical Bulletin ARM–1*. University of Wisconsin—Extension and Wisconsin Department of Agriculture, Trade and Consumer Protection, Madison, WI.

UW Extension. 1993. "Roots rival riprap." *Keeping Current*, 1(7): 3. University of Wisconsin Extension, Madison, WI.

_____. 1995. *Stormwater Ponds—An Effective Way to Control Urban Runoff*. GWQ 017, University of Wisconsin Extension, Madison, WI.

Vollenweider, R.A. 1968. *Scientific Fundamentals of the Eutrophication of Lakes and Flowing Waters, with Particular Reference to Nitrogen and Phosphorus as Factors in Eutrophication*. Organization for Economic Cooperation and Development, Paris.

Vollenweider, R.A. 1975. "Input-output models with special reference to the phosphorus loading concept in limnology". *Schweiz Z. Hydrol.* 37(1):53–84.

Wagner, K.J. 1990. " Assessing impacts of motorized watercraft on lakes: issues and perceptions." *Nat. Conf. Enhanc. States' Lake Manage. Prog.* 77–93.

_____. 1994. "Of hammocks and horsepower: The noise issue at lakes." *LakeLine* 14: 24–28.

Ward, H.B. and G.C. Whipple. 1959. *Freshwater Biology*, Second Edition. W.T. Edmondson (Ed.). John Wiley & Sons, Inc., NY.

Wass, R.D. and P. Fox. 1995. "Constructed wetlands enhances stormwater quality in Arizona." *Industrial Wastewater*, March/April 1995.

Watson, J.T.; S.C. Reed; R.H. Kadlec; R.L. Knight; and A.E. Whitehouse. 1989. "Performance Expectations and Loading Rates for Constructed Wastewater Treatment Wetlands." In: D.A. Hammer (Ed.), *Constructed Wetlands for Wastewater Treatment—Municipal, Industrial and Agricultural*. Lewis Publishers, Chelsea, MI.

West Virginia Department of Agriculture. Undated. *Clean Streams Handbook for Forest Landowners*. Forestry Division. W.Va. Department of Agriculture, Charleston, WV.

Wetzel, R.G. 1983. *Limnology*, Second Edition. Saunders College Publishing, Philadelphia, PA.

_____. and G.E. Likens. 1991. *Limnological Analyses*, Second Edition. Springer-Verlag, New York.

Whitford, L.A. and G.J. Schumacher. 1984. *A Manual of Fresh-Water Algae*. Sparks Press, Raleigh, NC.

Wildlife Nurseries. 1990. *What Brings Them In? Food is the Secret*. Wildlife Nurseries, Oshkosh, WI.

Willett, G. 1980. *Urban Erosion, in National Conference on Urban Erosion and Sediment Control; Institutions and Technology*. EPA 905/9–80–002. U.S. Environmental Protection Agency, Washington, D.C.

Wischmeier, W.H. and D.D. Smith. 1978. " Predicting rainfall erosion losses." *U.S. Department of Agriculture Handbook 537.*

Wisconsin DNR. 1982. *No-cost and Low-cost Construction Site Erosion Control Practices* (brochure). Wisconsin Department of Natural Resources, Madison, WI.

Woodland Steward Institute. 1995. "Forestry update." *The Woodland Steward*, 4(2): 10.

Yanggen, D.A. 1973. "Wisconsin's shoreland protection program: A state/local regulatory approach to natural resource protection." In: C.R. Goldman; J. McElvoy; and P.J. Richardson (Eds.), *Environmental Quality and Water Development*, W.R. Freeman, San Francisco.

Young, R.A.; C.A. Onstad; D.D. Bosch; and W.P. Anderson. 1987. *AGNPS, Agricultural Nonpoint Source Pollution Model : A Watershed Analysis Tool.* U.S. Department of Agriculture, Conservation Research Report 35, Morris, MN.

Yousef, Y.A. 1974. Assessing effects on water quality by boating activity. EPA 670/2–74–072. U.S. Environ. Prot. Agency.

_____ et. al. 1978. "Mixing effects due to boating activities in shallow lakes." *Draft Rep.* to OWRT, U.S. Dep. Inter. Tech. Rep. ESEI 78–10, Washington, D.C.

_____ ; W.M. McLellon; and H.H. Zebuth. 1980. "Changes in phosphorus concentration by boating in shallow lakes." *Water Res.* 14:841–52.

Zogorski, J.S.; W.W. Jones; et al. 1986. *Lake Lemon Diagnostic/Feasibility Study.* ESAC–86–02. Environmental Systems Application Center, School of Public and Environmental Affairs, Indiana University, Bloomington, IN.

Zorn, T. 1994. " A natural way to treat waste water." *Gary Post Tribune.*

APPENDIX A:

U.S. EPA CLEAN LAKES PROGRAM REGULATIONS

CLEAN LAKES PROGRAM REGULATIONS

(1) Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes (40 CFR 35 Subpart H, February 5, 1980).

(2) Availability of Clean Lakes Grant Assistance (Federal Register, Vol. 43, No. 132, pp. 29617-8, July 10, 1978).

comments is appropriate. Comments with respect to cost limits for a given location should be sent to the address indicated above.

A Finding of Inapplicability respecting the National Environmental Policy Act of 1969, has been made in accordance with HUD procedures. A copy of this Finding of Inapplicability will be available for public inspection during regular business hours in the Office of the Rules Docket Clerk, Office of General Counsel, Room 5218, 451 7th Street, S.W., Washington, D.C. 20410.

Accordingly, the per unit cost schedules setting Prototype Cost Limits for Low-Income Housing are amended as follows:

At 24 CFR Part 841, Appendix A, Prototype Cost Limits for Low-Income Public Housing, revise the per unit cost schedule for elevator dwellings, as shown on the prototype per unit cost schedule, Region X, Kennewick, Washington.

(Sec. 7(d), Department of HUD Act, 42 U.S.C. 3535(d); Sec. 6(b) U.S. Housing Act of 1937, 42 U.S.C. 1437(d))

Issued at Washington, D.C. on January 28, 1980.

Lawrence B. Simons,

Assistant Secretary for Housing-Federal Housing Commissioner.

Region X

	Bedrooms						
	0	1	2	3	4	5	6
Kennewick, Wash.:							
Detached and semidetached							
Row dwellings							
Walkup							
Elevator-structure	27,200	30,600	38,860				

[FR Doc. 80-3883 Filed 2-4-80; 8:45 am]

BILLING CODE 4210-01-M

DEPARTMENT OF DEFENSE

Department of the Army

35 CFR Part 253

Panama Canal Commission Personnel Matters

AGENCY: Secretary of the Army.

ACTION: Final rule.

SUMMARY: The Panama Canal Act of 1979, Pub. L. No. 96-70, 93 Stat. 452, creates two statutory positions in the Panama Canal Commission: A Chief Engineer and an Ombudsman. This rule excludes those positions and their principal assistants from the Merit System established pursuant to section 10 of an Act of July 25, 1958, Pub. L. No. 85-550, 72 Stat. 408 and continued under Title 2, Canal Zone Code, Section 148, 76A Stat. 18, and section 1214 of the Panama Canal Act of 1979. The rule will also exclude the positions from various other provisions of the employment system applicable to employment in Federal agencies in the Republic of Panama. Because this rule pertains to personnel matters of the Panama Canal Commission it is unnecessary to issue a notice of proposed rulemaking under Title 5, U.S.C., Section 553.

EFFECTIVE DATE: January 13, 1980.

ADDRESS: Department of the Army, Washington, D.C. 20310.

FOR FURTHER INFORMATION CONTACT: Colonel Michael Rhode, Jr., Office of the Assistant Secretary of the Army (CW), Washington, D.C. 20310; telephone (202) 695-1370.

Adoption of Amendment

Accordingly, effective January 13, 1980, 35 CFR 253.8(b) is amended by adding a new subparagraph (14) to read as follows:

§ 253.8 Exclusions.

* * * * *

(b) * * *

(14) The positions in the Panama Canal Commission of Ombudsman, Chief Engineer, Assistant to the Ombudsman, and Deputy Chief Engineer.

* * * * *

(Panama Canal Act of 1979, sec. 1212, 93 Stat. 452, 465; 35 CFR 251.2(a)(1))

Clifford L. Alexander, Jr.,

Secretary of the Army.

[FR Doc. 80-3881 Filed 2-4-80; 8:45 am]

BILLING CODE 3940-01-M

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Part 35

[FRL 1388-4]

Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes

AGENCY: Environmental Protection Agency (EPA).

ACTION: Final rule.

SUMMARY: This regulation establishes policies and procedures by which States may enter into cooperative agreements to assist in carrying out approved methods and procedures for restoring publicly owned freshwater lakes, and protecting them against degradation, as authorized by section 314 of the Clean Water Act (33 U.S.C. 1251 *et seq.*). This regulation was proposed on January 29, 1979 (44 FR 5685) for a sixty-day public comment period. EPA received 48 letters of comment which we have considered in developing this regulation.

EFFECTIVE DATE: This regulation governs only clean lakes cooperative agreements which are awarded after February 5, 1980. Cooperative agreements and grants that are awarded before February 5, 1980, will continue according to their original terms subject to the regulations under which the funds were awarded. Clean lakes applications received before February 5, 1980 will be processed according to past procedures.

ADDRESSES: Comments submitted on these regulations may be inspected at the Public Information Reference Unit, EPA Headquarters, Room 2922, Waterside Mall, 401 M Street, SW., Washington, D.C. 20460, between 8 a.m. and 4 p.m. on business days.

FOR FURTHER INFORMATION CONTACT: Joseph A. Krivak, Criteria and Standards Division (WH-585), Environmental Protection Agency, Washington, D.C. 20460. Telephone: (202) 755-0100.

SUPPLEMENTARY INFORMATION: This regulation contains the policies and procedures governing the provision of Federal financial assistance to States for the protection and restoration of publicly owned freshwater lakes as authorized by the Clean Water Act (33 U.S.C. 1251 *et seq.*) Section 314. The program is called the clean lakes program.

The Federal Grant and Cooperative Agreement Act requires all Federal Agencies to classify each assistance transaction as either a grant or a cooperative agreement. EPA will award grants when little Federal involvement in the project is expected, and cooperative agreements when significant Federal involvement is anticipated. We expect significant EPA involvement in all Clean Lakes projects and have designated cooperative agreements as the appropriate award instrument.

Section 314 requires each State to prepare and submit a report to EPA including: (1) An identification and classification of all publicly owned freshwater lakes in that State according to eutrophic condition; (2) procedures, processes, and methods (including land use requirements) to control sources of pollution of these lakes; and (3) methods and procedures, in conjunction with appropriate Federal agencies, to restore the quality of these lakes. Section 314 also provides financial assistance to States to implement lake restoration and protection methods and procedures approved by the Administrator.

Pub. L. 95–217, amended section 314(b) of the Clean Water Act by adding the following: "The Administrator shall provide financial assistance to States to prepare the identification and classification surveys required in subsection (a)(1) of this section." On July 10, 1978, EPA published a notice of availability in the Federal Register for States to: identify and classify their publicly owned freshwater lakes according to trophic condition, establish priority rankings for lakes in need of restoration; and conduct diagnostic-feasibility studies to determine methods and procedures to protect or restore the quality of those lakes (43 FR 29617). Total assistance of up to $100,000 is available to each State for this lake classification survey. No award can exceed 70 percent of the eligible cost of the proposed project.

EPA carefully evaluated the performance of the clean lakes program during 1977 to determine how it might be improved. Based on this evaluation, we developed the revised procedures contained in this regulation. We published the proposed section 314 regulation, in the Federal Register (44 FR 5885) on January 29, 1979, for a sixty-day public comment period. In addition, we sent approximately 1000 copies of the proposed rule to the people identified on the current mailing list of the Environmental Resources Unit of the University of Wisconsin—Extension, to State agencies, environmental interest groups and specific requestors. The official comment period closed on March 30, 1979, and EPA has received 48 comment letters.

The following discussion responds to the comments received on the proposed regulation and is arranged in the order of the sections of the regulation. Changes made in the final form of the regulation in response to public comment are discussed. Our responses to significant comments that did not lead to changes are also discussed.

Definitions

Freshwater lake

Some commenters believed that the definition of freshwater lake (§ 35.1605–2) should not include a limiting value for total dissolved solids (TDS). Section 314 allows funding only for publicly owned "freshwater" lakes. Since TDS is found in various scientific texts as a measure to distinguish freshwater from brackish water and saltwater, we believe it is relevant. We have selected a value of 1 percent TDS which is ten times the value used on page 306 in the *Water Encyclopedia*, Water Information Center, Inc., Port Washington, New York, 1970. We used the high value so that freshwater lakes that have received a high TDS loading a result of irrigation return flows and other land management practices (primarily in the far West) can be eligible.

Publicly owned freshwater lake

Several comments concerned the definition of "publicly owned freshwater lake" (§ 35.1605–3). We proposed that a publicly owned freshwater lake is, "[a] freshwater lake that offers public access to the lake through publicly owned contiguous lands so that any member of the public may have the same or equivalent opportunity to enjoy privileges and benefits of the lake as any other member of the public or as any resident around the lake." We understand that a lakeshore property owner stands to receive greater benefit from a lake than a day visitor. We have omitted reference to the lakeside resident, but we are still concerned about the potential for the clean lakes program providing benefits to the lakeshore property owner rather than the general public. However, since projects demonstrating the greatest public benefits will receive the highest priority under the review criteria in § 35.1640–1, we do not expect problems.

Other commenters questioned the appropriateness of requiring publicly owned contiguous land as the public access point. We believe the requirement is necessary to ensure that the public maintains unrestricted use of a lake after it is improved. Even so, in some cases where publicly owned contiguous land is not available, the lake may have substantial public use and benefit. One State indicated that by State statute all lakes greater than 10 acres surface area are in the public domain even if the shoreline is totally private. The State statute also guarantees that public access will be provided. In these cases EPA will require the State to define exactly where the public access points are, and to provide written agreements between the State and particular private property owners specifying the conditions and limitations of the public access. We will also require permanent signs to show the public access points and specify any lake use limitations. Similarly, States could negotiate long terms leases or similar arrangements with private land owners, including private non-profits groups, to provide the necessary public access points. Again, we will require signs to indicate the limitations and extent of the public access. These arrangements would have to be completed before the award.

Eligibility

Some commenters suggested that section 314 cooperative agreements should continue to be awarded to local agencies. They contend that, otherwise, there will be a substantial erosion of the grassroots orientation of the program. We support the need to keep a grassroots thrust in the clean lakes program because of the voluntary nature of this assistance program. However, section 314 permits award of assistance only to States. Even so, since some States may not provide all the matching support required in clean lakes cooperative agreements, local agencies may provide the required remaining matching funds. We believe this funding partnership will preserve the grassroots nature of the program. We will work with the appropriate State agencies to assure that they minimize associated paperwork and "redtape," and provide clear concise guidance to local agencies. This will help to maintain the enthusiasm and involvement of local agencies.

EPA received several comments concerning the eligibility of Indian Tribes for section 314 funding. The commenters were concerned that, because Indian lands do not fall under the dominion of State Government, Tribal Governments may not be able to participate in this program. The statutory requirements of section 314 restricts award of assistance only to States. Section 35.1615 allows States to make financial arrangements with agencies located within the State including Indian Tribes to support lake restoration projects.

Some commenters objected to EPA's policy of not awarding assistance for lakes that are used only as drinking water supplies. EPA has operated under this policy since the first awards under the clean lakes program in January 1978. We believe that the primary purpose of section 314 is to implement the goals of the Clean Water Act stated in section 101(a) as they relate to publicly owned freshwater lakes. Section 101(a)(2) states that, "* * * it is the national goal that wherever attainable, an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for *recreation* in and on the water be achieved by July 1, 1983." (emphasis added) The conference committee report of the 95th Congress, first session (House Report No. 95–830) made special note on page 94 in the comments of changes made to the Clean Water Act by the 1977 Amendments, that EPA should give special attention to restoring lakes which offer the potential for high utility as recreation areas. In keeping with the existing EPA policy and in support of the Congressional intent, we do not believe it is appropriate to allow funding of projects for lakes that are used only as drinking water supplies. Other funding sources are available to assist municipalities and States with protecting or improving drinking water supplies. Most communities accomplish this by assessing an appropriate water users fee under a regular billing procedure to support reservior and processing plant operation and maintenance costs. Also, a portion of city and county taxes is likely to be used for such high priority community expenses.

Funding Levels

In the preamble of the proposed regulation, we requested comments on the proposed phasing of clean lakes cooperative agreements and the funding levels designated for each. The seventeen commenters who responded did not present persuasive arguments that the program would be more effective if the proposed matching requirements were reduced.

We continue to believe that the 50 percent matching requirement requires sufficient State/substate (non-Federal) commitment to assure the best project is implemented and proper maintenance of the project is continued after implementation is complete.

Lake Classification Requirement

A number of the comments concerned § 35.1630, requiring States to classify their publicly owned freshwater lakes in need of protection and restoration by January 1, 1982 in order to be eligible for funding support after that date under section 314. As explained in the preamble of the proposed rule, this requirement does not mean that all of a State's publicly owned freshwater lakes must be surveyed, but a State must provide EPA with survey results of their priority lakes and the rationale for selecting the lakes surveyed. Other comments concerned EPA financial assistance to the States to perform the lake classification requirement. EPA will continue to award this cooperative agreement to States on a one-time-basis, under the July 10, 1978, Federal Register notice, until September 30, 1981. Approximately 20 States applied for this funding assistance. Most projects will be conducted over 18 months. We will restrict funding of this activity to a one-time award until all States electing to participate have initiated these efforts, and we have reviewed the overall program results.

Monitoring

A few commenters suggested the EPA should make available a third award phase for intensive monitoring of perhaps 10 percent of the implementation projects. The projects would be carefully selected to evaluate those lake restorative techniques that have little documentation on their capabilities and effectiveness. Although committed to strengthen the understanding of procedures to protect and restore the quality of the Nation's lakes, we continue to believe that some monitoring of each project during and after project implementation will provide us with a better review of program effectiveness than intensive monitoring in a few projects. However, we are encouraging EPA's Office of Research and Development to conduct a greater number of intensive investigations of lake protection and restoration techniques under the 104(h) authority of the Clean Water Act. We believe this approach will be responsive to both the program needs and the intent of the legislation.

Application and Priority

Several commenters asked how many Phase 1 and Phase 2 project applications an individual State could submit for funding consideration. The regulation does not specify a number. However, all applications must receive a State priority and we will consider the State priority placed on an application along with the other criteria presented in § 35.1640–1 when developing funding recommendations. We do foresee instances where, after considering all of these factors, a State may receive more than one of each type of cooperative agreement.

A significant number of comments where received on the required content of Phase 1 project applications. Most of these comments indicated that the information required is excessive and costly to assemble or obtain. As discussed in the preamble of the proposed rule, we believe that this information should be readily available to States and local agencies. No study or water quality monitoring is necessary to obtain the information since only the presentation of existing information is required. Furthermore, the information required in Phase 1 applications is precisely the information that participating States are required to assemble under their lake classification surveys conducted under the July 10, 1978, Federal Register notice.

We have reduced the mandatory information required in Phase 1 applications in response to those comments. Although not mandatory, § 35.1620–2(b) still includes a list of information that EPA believes should be in a Phase 1 application to allow EPA to effectively evaluate project applications and make funding decisions. Applications describing a proposed project in more complete terms may receive higher rating when evaluated according to the review criteria in § 35.1640–1.

EPA received four comments on the State requirement to set priorities on Phase 1 and Phase 2 projects as stated in § 35.1620–5. The commenters were concerned principally with the State capability to foresee specific projects 12 to 18 months in advance in sufficient detail to allow them to apply realistic funding priorities. We understand the problems associated with these procedures and realized that projects and associated priorities set more than a year in advance are subject to change. In § 35.1620–5 we have allowed States to alter project priority lists with a minimum of State effort. We need the information contained on State priority lists to determine program needs. We also need it to provide a basis for adjusting our workforce to match the identified workload.

Allotment

In the preamble of the proposed regulation we request comments regarding the allocation of clean lakes program appropriations to assure an equitable distribution of funds among the States. We received 6 comments on this issue: 4 supporting the status quo, one supporting the specification in the regulation of an annual deadline for application submission, and the other suggesting that an allocation of appropriations be made directly to the

States, although no formula was proposed. EPA's Office of General Counsel (OGC) and Grants Administration Division (GAD) suggested that a Regional allocation formula be considered as a means of providing equitable funding distribution. Despite the relatively small amount of program appropriations, we believe an allocation procedure has considerable merit. The advantages include: Regional flexibility in the negotiations with States for lake restoration projects, and better Regional capability to forecast workloads and develop appropriate manpower plans for annual budget submissions. Considering the advantages mentioned above, EPA will provide each Regional office a resource target from the section 314 appropriation based on State's identification of clean lakes work in the State WQM work programs. The State identification will consist of a two year forecasting of clean lakes applications, with funding needs, as part of the annual work program. The summation of these forecasts, coupled with the Congressional appropriation, will permit EPA to provide equitable resource targets. Regional offices will use these targets to negotiate projects within each State.

Targetting, based upon two year forecasting in work programs, will take effect in fiscal year 1982. For fiscal year 1981, EPA will target resources based on State-supplied information in existing State/EPA agreements, WQM work programs, and from the WQM Needs Survey.

Review Criteria

We have changed the application review criteria presented under § 35.1640-1 to reflect several comments. We have added a criterion to emphasize the importance of improving fish and wildlife habitat, and improving the populations of fish species.

A few commenters questioned the applicability of application review criteria § 35.1640-1(a)(4)(ii-iv). We believe that these criteria should be considered by States to judge the cost of a project in relation to public benefits derived, e.g., the more persons using a restored or protected lake the greater the benefits from the expenditure of public funds. Further, persons with low incomes cannot travel easily to lakes for recreational purposes unless the lakes are close to have sufficient public transportation to them. Such factors should be considered in the decision making process. This component is not intended to preclude lakes in rural settings from receiving financial assistance under the clean lakes program.

The project award procedures under § 35.1650 have been changed. All EPA funding decisions will be made in the EPA Regional office by officials designated by the Regional Administrator. Program guidance and technical assistance will be supplied by EPA Headquarters, and all project applications will receive Headquarters review and technical recommendations.

Limitations on Award

Most comments on § 35.1650-2 were editorial and only minor changes in the language of this section have been made. Specific comments questioned the exclusion of aquatic plant harvesting as a lake restoration procedure. Section 35.1650-2(b)(5) does not exclude aquatic plant harvesting from supportable lake restoration programs. However, we believe that aquatic plant harvesting is only a temporary restorative measure in cases where pollution control measures are not implemented in the watershed to the greatest practicable extent. Even in cases where such pollution controls are in place, nutrient loading to the lake may be so great that harvesting aquatic vegetation may be required regularly to allow use of the lake. We will not generally consider a project for aquatic plant harvesting unless it will result in long lasting improvements.

A few commenters were confused regarding the relationship between 208 State and areawide wastewater management planning and the eligibility of a State to receive section 314 support. Section 208 planning does not have to be approved for a State to receive clean lakes assistance. If a 208 plan has been approved, the pertinent and applicable pollution controls identified in the 208 plan must be included in a clean lakes implementation plan. If a 208 plan has not been approved but has been developed, the pertinent and applicable pollution controls identified in the 208 plan should be included in the clean lakes project. If there is no 208 planning, then the lake protection and restoration procedures developed under a section 314 project should be consistent with 208 planning procedures so that the lake restoration planning can be included in any future 208 planning activities for the particular lake area.

In order to assure that these procedures are followed, States must certify under § 35.1620-2(a), that a project is consistent with the State Water Quality Management work program (see § 35.1513). Under § 35.1620-2(b), Phase 1 applications shall include written certification from the appropriate areawide or State 208 planning agency that work conducted under the proposed project will not duplicate work completed under any 208 planning grant, and that the applicant proposes to use any applicable approved 208 planning in the clean lakes project design. Under § 35.1620-2(c), Phase 2 applications must contain written certification from appropriate areawide or State 208 planning agencies that the proposed Phase 2 lake restoration proposal is consistent with any approved 208 planning.

One commenter suggested that 314 funding should be restricted so that it is not used to enhance boating or onshore recreational opportunities. EPA did not include these restrictions in the regulations for a variety of reasons. Lakes are traditionally used as recreational sites by the general public, and the degradation of those recreational sites through water pollution prompted the Congress to include section 314 in the Clean Water Act. EPA is supportive of the multiple use concept in the use of public funds. Frequently, the heavy use of the immediate lake shore will promote excessive pollutant loading, e.g., sediment and plant nutrients. In some cases, outright purchase of these lands to provide buffer strips is the most effective method of pollution control. Often lake shores can be used for low intensity recreational activities. Similarly, land abutting the lake may be purchased to provide an area to build a lake treatment structure and these areas should be considered for recreational opportunities.

Since recreational opportunities and water quality can sometimes be improved by removal of accumulated lake sediments, it would be inappropriate for EPA to ban dredging as an element of a comprehensive lake restoration project solely because it would benefit recreational activities.

As a means to assure that adverse environmental impact mitigation procedures are implemented in a lake restoration project, we have removed the 20 percent restriction on the cost of mitigation activities. All necessary mitigation activities should be included in the project. If mitigation costs are excessive, then the public benefits, when evaluated against project costs, will be lower and a proposed project will have lower priority for funding.

Conditions on Award

Numerous commenters were concerned about payment of the non-Federal share of a project by the State. We have modified § 35.1650-3(a)(2) to allow a State to arrange financing through substate financial agreements.

We understand that in many instances local agencies will be providing some or all of the required non-Federal matching share for clean lakes projects. It should be noted that as the only eligible award recipient, the State assumes the ultimate responsibility for the non-Federal share.

Some commenters argued that the monitoring program required under Appendix A (b)(3) is defined too rigidly. We agree, so we have modified the regulation to allow States and project officers to negotiate a program that is appropriate for each project.

Most commenters on the award conditions believe the requirement that States must maintain a project for ten years after a project is completed is excessive. We believe that States should agree to an operation and maintenance program that would assure that effective pollution controls are maintained to maximize the benefits in relation to the cost of the project. We believe that 10 years is a reasonable amount of time. Because we have no data to defend the cost effectiveness of this condition, it has been modified to cover only the project period. We believe the commitment by a State to an effective operation and maintenance program in the post project period is important and should be given special consideration in the evaluation of project proposals. Therefore, the evaluation criteria have been modified in § 35.1640-1 to include an assessment of the adequateness of the proposed post project operation and maintenance program.

We have changed section 35.1650-3(b) to allow Phase 1 recipients to negotiate with the project officer the project scope of work that is stated in section (a)(10) of Appendix A. Many commenters argued that the information required by section (a)(10) should be determined on a case by case basis. We believe that flexibility is desirable and will minimize project costs without sacrificing program integrity and public benefits. Similarly, we have modified § 35.1650-3(c) to allow flexibility on the design of Phase 2 monitoring programs to fulfill the requirement of section (b)(3) of Appendix A. Again, EPA project officer approval is required before the scope of work can be modified.

EPA received a significant number of comments on the reporting requirements in § 35.1650-5. The commenters were critical of the number of reports required and the amount of information required in Phase 1 project progress reports. Accordingly, we have modified the reporting requirements so that Phase 1 reports are only required semi-annually, and the final report will be the only Phase 1 report requiring the submission of water quality data. The frequency of Phase 2 reporting will not exceed quarterly and will be based on the complexity of the project. The reporting requirement will be stipulated in the cooperative agreement.

Several commenters requested clarification of subsection (a)(7) of Appendix A. We believe that recipients and EPA should have sufficient information about the usability of other lakes in proximity to the project lake to evaluate the benefits in relation to the costs of a proposed project. The funds available to support lake protection and restoration activities are limited. Information required by subsection (a)(7) should be helpful to States in establishing priorities for projects. The regulations do not require States to conduct exhaustive surveys of lake resources within a 80 kilometer radius of the project lake, but we do need an understanding of similar lake use opportunities in that distance to assure appropriate use of public funds.

A few comments concerned the procedures used to determine the limiting nutrient in lakes. Section (a)(10) of Appendix A requires the calculation of total nitrogen to total phosphorus ratios and/or the use of the algal assay bottle tests. One commenter stated that the algal assay bottle test should be a required procedure. Although the bottle test is an excellent investigative procedure, we believe that many States lack the appropriate equipment to perform these analyses and the costs would be excessive in some cases. Other commenters suggested that other forms of nitrogen and phosphorus should be used to calculate the N/P ratio. We are aware of the significant controversy over the appropriateness and reproducibility of tests using other fractional chemical forms of these nutrients. EPA believes that at this time, the total nitrogen and total phosphorus ratio is the most desirable test. Appendix A calls for the measurement of several chemical forms of these nutrients. Investigators and EPA may wish to calculate other ratios in addition to total nitrogen to total phosphorus using these measurements.

Since the publication of the proposed rules, EPA's Administrator on June 14, 1979, signed a memorandum to assure that all environmental measurements done with EPA funding result in usable data of known quality. Any clean lakes cooperative agreements, awarded after OMB approves the Administrator's directive under the Federal Reports Act will contain a condition requiring compliance.

State/EPA Agreement

In these and other regulations, we are developing the concept of a State/EPA Agreement. The Agreement will provide a way for EPA Regional Administrators and States to coordinate a variety of programs under the Clean Water Act, the Resource Conservation and Recovery Act, the Safe Drinking Water Act and other laws administered by EPA. This subpart governs only that part of the State/EPA Agreement which relates to cooperative agreements under the clean lakes program. Other programs included in the State/EPA Agreement will be governed by provisions found elsewhere in this chapter. Beginning in FY 1980, State programs funded under section 314 of the Act will be part of the State/EPA Agreement and the State/EPA Agreement must be completed before grant award. EPA will issue guidance concerning the development and the content of the State/EPA Agreement.

Regulatory Analysis

We have determined that this regulation does not require regulatory analysis under Executive Order 12044.

Evaluation

Section 2(d)(8) of Executive Order 12044 requires that each regulation be accompanied by a plan for evaluating a regulation after it issued. In order to comply with this requirement, EPA will conduct an evaluation of this regulation which will either be presented in the section 304(j) report, which is scheduled to be published in December 1981, or published separately.

Dated: January 28, 1980.

Douglas M. Costle,

Administrator.

PART 35, SUBPART H ADDED

EPA is amending Title 40 of the Code of Federal Regulations by adding a new Subpart H to Part 35 to read as follows:

PART 35—STATE AND LOCAL ASSISTANCE

* * * * *

Subpart H—Cooperative Agreements for Protecting and Restoring Publicly Owned Freshwater Lakes

Sec.
35.1600 Purpose.
35.1603 Summary of clean lakes assistance program.
35.1605 Definitions.
35.1605-1 The Act.
35.1605-2 Freshwater lake.
35.1605-3 Publicly owned freshwater lake.
35.1605-4 Nonpoint source.
35.1605-5 Eutrophic lake.

Sec.

35.1605-6 Trophic condition.
35.1605-7 Desalinization.
35.1605-8 Diagnostic-feasibility study.
35.1610 Eligibility.
35.1613 Distribution of funds.
35.1615 Substate agreements.
35.1620 Application requirements.
35.1620-1 Types of assistance.
35.1620-2 Contents of applications.
35.1620-3 Environmental evaluation.
35.1620-4 Public participation.
35.1620-5 State work programs and lake priority lists.
35.1620-6 State and local clearinghouse procedures.
35.1630 State lake classification surveys.
35.1640 Application review and evaluation.
35.1640-1 Application review criteria.
35.1650 Award.
35.1650-1 Project period.
35.1650-2 Limitations on awards.
35.1650-3 Conditions on awards.
35.1650-4 Payment.
35.1650-5 Allowable costs.
35.1650-6 Reports.
Appendix A Requirements for diagnostic-feasibility studies and environmental evaluations.

Authority: Secs. 314 and 501, Clean Water Act (86 Stat. 816; 33 U.S.C. 1251 *et seq.*)

Subpart H—Cooperative Agreements For Protecting and Restoring Publicly Owned Freshwater Lakes

§ 35.1600 Purpose.

This subpart supplements the EPA general grant regulations and procedures (Part 30 of this chapter) and establishes policies and procedures for cooperative agreements to assist States in carrying out approved methods and procedures for restoration (including protection against degradation) of publicly owned freshwater lakes.

§ 35.1603 Summary of clean lakes assistance program.

(a) Under section 314 of the Clean Water Act, EPA may provide financial assistance to States to implement methods and procedures to protect and restore publicly owned freshwater lakes. Although cooperative agreements may be awarded only to States, these regulations allow States, through substate agreements, to delegate some or all of the required work to substate agencies.

(b) Only projects that deal with publicly owned freshwater lakes are eligible for assistance. The State must have assigned a priority to restore the lake, and the State must certify that the lake project is consistent with the State Water Quality Management Plan (§ 35.1521) developed under the State/EPA Agreement. The State/EPA Agreement is a mechanism for EPA Regional Administrators and States to coordinate a variety of programs under the Clean Water Act, the Resource Conservation and Recovery Act, the Safe Drinking Water Act and other laws administered by EPA.

(c) These regulations provide for Phase 1 and 2 cooperative agreements. The purpose of a Phase 1 cooperative agreement is to allow a State to conduct a diagnostic-feasibility study to determine a lake's quality, evaluate possible solutions to existing pollution problems, and recommend a feasible program to restore or preserve the quality of the lake. A Phase 2 cooperative agreement is to be used for implementing recommended methods and procedures for controlling pollution entering the lake and restoring the lake. EPA award of Phase 1 assistance does not obligate EPA to award Phase 2 assistance for that project. Additionally, a Phase 1 award is not a prerequisite for receiving a Phase 2 award. However, a Phase 2 application for a proposed project that was not evaluated under a Phase 1 project shall contain the information required by Appendix A.

(d) EPA will evaluate all applications in accordance with the application review criteria of § 35.1640-1. The review criteria include technical feasibility, public benefit, reasonableness of proposed costs, environmental impact, and the State's priority ranking of the lake project.

(e) Before awarding funding assistance, the Regional Administrator shall determine that pollution control measures in the lake watershed authorized by section 201, included in an approved 208 plan, or required by section 402 of the Act are completed or are being implemented according to a schedule that is included in an approved plan or discharge permit. Clean lakes funds may not be used to control the discharge of pollutants from a point source where the cause of pollution can be alleviated through a municipal or industrial permit under section 402 of the Act or through the planning and construction of wastewater treatment facilities under section 201 of the Act.

§ 35.1605 Definitions.

The terms used in this subpart have the meanings defined in section 502 of the Act. In addition, the following terms shall have the meaning set forth below.

§ 35.1605-1 The Act.

The Clean Water Act, as amended (33 U.S.C. 1251 *et seq.*).

§ 35.1605-2 Freshwater lake.

Any inland pond, reservoir, impoundment, or other similar body of water that has recreational value, that exhibits no oceanic and tidal influences, and that has a total dissolved solids concentration of less than 1 percent.

§ 35.1605-3 Publicly owned freshwater lake.

A freshwater lake that offers public access to the lake through publicly owned contiguous land so that any person has the same opportunity to enjoy non-consumptive privileges and benefits of the lake as any other person. If user fees are charged for public use and access through State or substate operated facilities, the fees must be used for maintaining the public access and recreational facilities of this lake or other publicly owned freshwater lakes in the State, or for improving the quality of these lakes.

§ 35.1605-4 Nonpoint source.

Pollution sources which generally are not controlled by establishing effluent limitations under sections 301, 302, and 402 of the Act. Nonpoint source pollutants are not traceable to a discrete identifiable origin, but generally result from land runoff, precipitation, drainage, or seepage.

§ 35.1605-5 Eutrophic lake.

A lake that exhibits any of the following characteristics: (a) Excessive biomass accumulations of primary producers; (b) rapid organic and/or inorganic sedimentation and shallowing; or (c) seasonal and/or diurnal dissolved oxygen deficiencies that may cause obnoxious odors, fish kills, or a shift in the composition of aquatic fauna to less desirable forms.

§ 35.1605-6 Trophic condition.

A relative description of a lake's biological productivity based on the availability of plant nutrients. The range of trophic conditions is characterized by the terms of oligotrophic for the least biologically productive, to eutrophic for the most biologically productive.

§ 35.1605-7 Desalinization.

Any mechanical procedure or process where some or all of the salt is removed from lake water and the freshwater portion is returned to the lake.

§ 35.1605-8 Diagnostic-feasibility study.

A two part study to determine a lake's current condition and to develop possible methods for lake restoration and protection.

(a) The diagnostic portion of the study includes gathering information and data to determine the limnological, morphological, demographic, socio-economic, and other pertinent characteristics of the lake and its watershed. This information will provide recipients an understanding of the quality of the lake, specifying the location and loading characteristics of significant sources polluting the lake.

(b) The feasibility portion of the study includes: (1) Analyzing the diagnostic information to define methods and procedures for controlling the sources of pollution; (2) determining the most energy and cost efficient procedures to improve the quality of the lake for maximum public benefit; (3) developing a technical plan and milestone schedule for implementing pollution control measures and in-lake restoration procedures; and (4) if necessary, conducting pilot scale evaluations.

§ 35.1610 Eligibility.

EPA shall award cooperative agreements for restoring publicly owned freshwater lakes only to the State agency designated by the State's Chief Executive. The award will be for projects which meet the requirements of this subchapter.

§ 35.1613 Distribution of funds.

(a) For each fiscal year EPA will notify each Regional Administrator of the amount of funds targeted for each Region through annual clean lakes program guidance. To assure an equitable distribution of funds the targeted amounts will be based on the clean lakes program which States identify in their State WQM work programs.

(b) EPA may set aside up to twenty percent of the annual appropriations for Phase 1 projects.

§ 35.1615 Substate agreements.

States may make financial assistance available to substate agencies by means of a written interagency agreement transferring project funds from the State to those agencies. The agreement shall be developed, administered and approved in accordance with the provisions of 40 CFR 33.240 (Intergovernmental agreements). A State may enter into an agreement with a substate agency to perform all or a portion of the work under a clean lakes cooperative agreement. Recipients shall submit copies of all interagency agreements to the Regional Administrator. If the sum involved exceeds $100,000, the agreement shall be approved by the Regional Administrator before funds are released by the State to the substate agency. The agreement shall incorporate by reference the provisions of this subchapter. The agreement shall specify outputs, milestone schedule, and the budget required to perform the associated work in the same manner as the cooperative agreement between the State and EPA.

§ 35.1620 Application requirements.

(a) EPA will process applications in accordance with Subpart B of Part 30 of this subchapter. Applicants for assistance under the clean lakes program shall submit EPA form 5700-33 (original with signature and two copies) to the appropriate EPA Regional Office (see 40 CFR 30.130).

(b) Before applying for assistance, applicants should contact the appropriate Regional Administrator to determine EPA's current funding capability.

§ 35.1620-1 Types of assistance.

EPA will provide assistance in two phases in the clean lakes program.

(a) *Phase 1—Diagnostic-feasibility studies.* Phase 1 awards of up to $100,000 per award (requiring a 30 percent non-Federal share) are available to support diagnostic-feasibility studies (see Appendix A).

(b) *Phase 2—Implementation.* Phase 2 awards (requiring a 50 percent non-Federal share) are available to support the implementation of pollution control and/or in-lake restoration methods and procedures including final engineering design.

§ 35.1620-2 Contents of applications.

(a) All applications shall contain a written State certification that the project is consistent with State Water Quality Management work program (see § 35.1513 of this subchapter) and the State Comprehensive Outdoor Recreation Plan (if completed). Additionally, the State shall indicate the priority ranking for the particular project (see § 35.1620-5).

(b) Phase 1 applications shall contain: (1) A narrative statement describing the specific procedures that will be used by the recipient to conduct the diagnostic-feasibility study including a description of the public participation to be involved (see § 25.11 of this chapter);

(2) A milestone schedule;

(3) An itemized cost estimate including a justification for these costs;

(4) A written certification from the appropriate areawide or State 208 planning agency that the proposed work will not duplicate work completed under any 208 planning grant, and that the applicant is proposing to use any applicable approved 208 planning in the clean lakes project design; and

(5) For each lake being investigated, the information under subparagraph (5)(i) of this paragraph and, when available, the information under subparagraph (5)(ii) of this paragraph.

(i) Mandatory information.

(A) The legal name of the lake, reservoir, or pond.

(B) The location of the lake within the State, including the latitude and longitude, in degrees, minutes, and seconds of the approximate center of the lake.

(C) A description of the physical characteristics of the lake, including its maximum depth (in meters); its mean depth (in meters); its surface area (in hectares); its volume (in cubic meters); the presence or absence of stratified conditions; and major hydrologic inflows and outflows.

(D) A summary of available chemical and biological data demonstrating the past trends and current water quality of the lake.

(E) A description of the type and amount of public access to the lake, and the public benefits that would be derived by implementing pollution control and lake restoration procedures.

(F) A description of any recreational uses of the lake that are impaired due to degraded water quality. Indicate the cause of the impairment, such as algae, vascular aquatic plants, sediments, or other pollutants.

(G) A description of the local interests and fiscal resources committed to restoring the lake.

(H) A description of the proposed monitoring program to provide the information required in Appendix A paragraph (a)(10) of this section.

(ii) Discretionary information. States should submit this information when available to assist EPA in reviewing the application.

(A) A description of the lake watershed in terms of size, land use (list each major land use classification as a percentage of the whole), and the general topography, including major soil types.

(B) An identification of the major point source pollution discharges in the watershed. If the sources are currently controlled under the National Pollutant Discharge Elimination System (NPDES), include the permit numbers.

(C) An estimate of the percent contribution of total nutrient and sediment loading to the lake by the identified point sources.

(D) An indication of the major nonpoint sources in the watershed. If the sources are being controlled describe the control practice(s), including best land management practices.

(E) An indication of the lake restoration measures anticipated, including watershed management, and a projection of the net improvement in water quality.

(F) A statement of known or anticipated adverse environmental impacts resulting from lake restoration.

(c) Phase 2 applications shall include: (1) The information specified in Appendix A in a diagnostic/feasibility study or its equivalent; (2) certification by the appropriate areawide or State 208 planning agencies that the proposed Phase 2 lake restoration proposal is consistent with any approved 208 planning; and (3) copies of all issued permits or permit applications (including a summary of the status of applications) that are required for the discharge of dredged or fill material under section 404 of the Act.

§ 35.1620-3 Environmental evaluation.

Phase 2 applicants shall submit an evaluation of the environmental impacts of the proposed project in accordance with the requirements in Appendix A of this regulation.

§ 35.1620-4 Public participation.

(a) *General.* (1) In accordance with this Part and Part 25 of this chapter, the applicant shall provide for, encourage, and assist public participation in developing a proposed lake restoration project.

(2) Public consultation may be coordinated with related activities to enhance the economy, the effectiveness, and the timeliness of the effort, or to enhance the clarity of the issue. This procedure shall not discourage the widest possible participation by the public.

(b) *Phase 1.* (1) Phase 1 recipients shall solicit public comment in developing, evaluating, and selecting alternatives; in assessing potential adverse environmental impacts; and in identifying measures to mitigate any adverse impacts that were identified. The recipient shall provide information relevant to these decisions, in fact sheet or summary form, and distribute them to the public at least 30 days before selecting a proposed method of lake restoration. Recipients shall hold a formal or informal meeting with the public after all pertinent information is distributed, but before a lake restoration method is selected. If there is significant public interest in the cooperative agreement activity, an advisory group to study the process shall be formed in accordance with the requirements of § 25.3(d)(4) of this chapter.

(2) A formal public hearing shall be held if the Phase 1 recipient selects a lake restoration method that involves major construction, dredging, or significant modifications to the environment, or if the recipient or the Regional Administrator determines that a hearing would be beneficial.

(c) *Phase 2.* (1) A summary of the recipient's response to all public comments, along with copies of any written comments, shall be prepared and submitted to EPA with a Phase 2 application.

(2) Where a proposed project has not been studied under a Phase 1 cooperative agreement, the applicant for Phase 2 assistance shall provide an opportunity for public consultation with adequate and timely notices before submitting an application to EPA. The public shall be given the opportunity to discuss the proposed project, the alternatives, and any potentially adverse environmental impacts. A public hearing shall be held where the proposed project involves major construction, dredging or other significant modification of the environment. The applicant shall provide a summary of his responses to all public comments and submit the summary, along with copies of any written comments, with the application.

§ 35.1620-5 State work programs and lake priority lists.

(a)(1) A State shall submit to the Regional Administrator as part of its annual work program (§ 35.1513 of this subchapter) a description of the activities it will conduct during the Federal fiscal year to classify its lakes according to trophic condition (§ 35.1630) and to set priorities for implementing clean lakes projects within the State. The work plan must list in priority order the cooperative agreement applications that will be submitted by the State for Phase 1 and Phase 2 projects during the upcoming fiscal year, along with the rationale used to establish project priorities. Each State must also list the cooperative agreement applications, with necessary funding, which it expects to submit in the following fiscal year. This information will assist EPA in targeting resources under § 35.1613.

(2) A State may petition the Regional Administrator by letter to modify the EPA approved priority list established under paragraph (a)(1) of this section. This may be done at any time if the State believes there is sufficient justification to alter the priority list contained in its annual work program, e.g., if a community with a lower priority project has sufficient resources available to provide the required matching funding while a higher priority project does not, or if new data indicates that a lower priority lake will have greater public benefit than a higher priority lake.

(b) Clean lakes restoration priorities should be consistent with the Statewide water quality management strategy (see § 35.1511-2 of this subchapter). In establishing priorities on particular lake restoration projects, States should use as criteria the application review criteria (§ 35.1640-1) that EPA will use in preparing funding recommendations for specific projects. If a State chooses to use different criteria, the State should indicate this to the Regional Administrator as part of the annual work program.

§ 35.1620-6 State and local clearinghouse procedures.

In accordance with § 30.305 of this subchapter, all requirements of OMB Circular A-95 must be met before States submit applications to EPA.

§ 35.1630 State lake classification surveys.

States that wish to participate in the clean lakes program shall establish and submit to EPA by January 1, 1982, a classification, according to trophic condition, of their publicly owned freshwater lakes that are in need of restoration or protection. After December 31, 1981, States that have not complied with this requirement will not be eligible for Federal financial assistance under this subpart until they complete their survey.

§ 35.1640 Application review and evaluation.

EPA will review applications as they are received. EPA may request outside review by appropriate experts to assist with technical evaluation. Funding decisions will be based on the merit of each application in accordance with the application review criteria under § 35.1640-1. EPA will consider Phase 1 applications separately from Phase 2 applications.

§ 35.1640-1 Application review criteria.

(a) When evaluating applications, EPA will consider information supplied by the applicant which address the following criteria:

(1) The technical feasibility of the project, and where appropriate, the estimated improvement in lake water quality.

(2) The anticipated positive changes that the project would produce in the overall lake ecosystem, including the watershed, such as the net reduction in sediment, nutrient, and other pollutant loadings.

(3) The estimated improvement in fish and wildlife habitat and associated beneficial affects on specific fish populations of sport and commercial species.

(4) The extent of anticipated benefit to the public. EPA will consider such factors as (i) the degree, nature and sufficiency of public access to the lake

(ii) the size and economic structure of the population residing near the lake which would use the improved lake for recreational and other purposes; (iii) the amount and kind of public transportation available for transport of the public to and from the public access points; (iv) whether other relatively clean publicly owned freshwater lakes within 80 kilometer radius already adequately serve the population; and (v) whether the restoration would benefit primarily the owners of private land adjacent to the lake.

(5) The degree to which the project considers the "open space" policies contained in sections 201(f), 201(g), and 208(b)(2)(A) of the Act.

(6) The reasonableness of the proposed costs relative to the proposed work, the likelihood that the project will succeed, and the potential public benefits.

(7) The means for controlling adverse environmental impacts which would result from the proposed restoration of the lake. EPA will give specific attention to the environmental concerns listed in Section (c) of Appendix A.

(8) The State priority ranking for a particular project.

(9) The State's operation and maintenance program to ensure that the pollution control measures and/or in-lake restorative techniques supported under the project will be continued after the project is completed.

(b) For Phase 1 applications, the review criteria presented in paragraph (a) of this section will be modified in relation to the smaller amount of technical information and analysis that is available in the application. Specifically, under criterion (a)(1), EPA will consider a technical assessment of the proposed project approach to meet the requirements stated in Appendix A to this regulation. Under criterion (a)(4), EPA will consider the degree of public access to the lake and the public benefit. Under criterion (a)(7), EPA will consider known or anticipated adverse environmental impacts identified in the application or that EPA can presume will occur. Criterion (a)(9) will not be considered.

§ 35.1650 Award.

(a) Under 40 CFR 30.345, generally 90 days after EPA has received a complete application, the application will either be: (1) Approved for funding in an amount determined to be appropriate for the project; (2) returned to the applicant due to lack of funding; or (3) disapproved. The applicant shall be promptly notified in writing by the EPA Regional Administrator of any funding decisions.

(b) Applications that are disapproved can be submitted as new applications to EPA if the State resolves the issues identified during EPA review.

§ 35.1650-1 Project period.

(a) The project period for Phase 1 projects shall not exceed three years.

(b) The project period for Phase 2 projects shall not exceed four years. Implementation of complex projects and projects incorporating major construction may have longer project periods if approved by the Regional Administrator.

§ 35.1650-2 Limitations on awards.

(a) Before awarding assistance, the Regional Administrator shall determine that:

(1) The applicant has met all of the applicable requirements of § 35.1620 and § 35.1630; and

(2) State programs under section 314 of the Act are part of a State/EPA Agreement which shall be completed before the project is awarded.

(b) Before awarding Phase 2 projects, the Regional Administrator shall further determine that:

(1) When a Phase 1 project was awarded, the final report prepared under Phase 1 is used by the applicant to apply for Phase 2 assistance. The lake restoration plan selected under the Phase 1 project must be implemented under a Phase 2 cooperative agreement.

(2) Pollution control measures in the lake watershed authorized by section 201, included in an approved 208 plan, or required by section 402 of the Act have been completed or are being implemented according to a schedule that is included in an approved plan or discharge permit.

(3) The project does not include costs for controlling point source discharges of pollutants where those sources can be alleviated by permits issued under section 402 of the Act, or by the planning and construction of wastewater treatment facilities under section 201 of the Act.

(4) The State has appropriately considered the "open space" policy presented in sections 201(f), 201(g)(6), and 208(b)(2)(A) of the Act in any wastewater management activities being implemented by them in the lake watershed.

(5)(i) The project does not include costs for harvesting aquatic vegetation, or for chemical treatment to alleviate temporarily the symptoms of eutrophication, or for operating and maintaining lake aeration devices, or for providing similar palliative methods and procedures, unless these procedures are the most energy efficient or cost effective lake restorative method. (ii) Palliative approaches can be supported only where pollution in the lake watershed has been controlled to the greatest practicable extent, and where such methods and procedures are a necessary part of a project during the project period. EPA will determine the eligibility of such a project, based on the applicant's justification for the proposed restoration, the estimated time period for improved lake water quality, and public benefits associated with the restoration.

(6) The project does not include costs for desalinization procedures for naturally saline lakes.

(7) The project does not include costs for purchasing or long term leasing of land used solely to provide public access to a lake.

(8) The project does not include costs resulting from litigation against the recipient by EPA.

(9) The project does not include costs for measures to mitigate adverse environmental impacts that are not identified in the approved project scope of work. (EPA may allow additional costs for mitigation after it has reevaluated the cost-effectiveness of the selected alternative and has approved a request for an increase from the recipient.)

§ 35.1650-3 Conditions on award.

(a) *All awards.* (1) All assistance awarded under the Clean Lakes program is subject to the EPA General Grant conditions (Subpart C and Appendix A of Part 30 of this chapter). (2) For each clean lakes project the State agrees to pay or arrange the payment of the non-Federal share of the project costs.

(b) *Phase 1.* Phase 1 projects are subject to the following conditions:

(1) The recipient must receive EPA project officer approval on any changes to satisfy the requirements of (a)(10) of Appendix A before undertaking any other work under the grant.

(2) (i) Before selecting the best alternative for controlling pollution and improving the lake, as required in paragraph (b)(1) of Appendix A of this regulation, and before undertaking any other work stated under paragraph (b) of Appendix A, the recipient shall submit an interim report to the project officer. The interim report must include a discussion of the various available alternatives and a technical justification for the alternative that the recipient will probably choose. The report must include a summary of the public involvement and the comments that occurred during the development of the alternatives. (ii) The recipient must obtain EPA project officer approval of

the selected alternative before conducting additional work under the project.

(c) *Phase 2.* Phase 2 projects are subject to the following conditions:

(1) (i) The State shall monitor the project to provide data necessary to evaluate the efficiency of the project as jointly agreed to and approved by the EPA project officer. The monitoring program described in paragraph (b)(3) of Appendix A of this regulation as well as any specific measurements that would be necessary to assess specific aspects of the project, must be considered during the development of a monitoring program and schedule. The project recipient shall receive the approval of the EPA project officer for a monitoring program and schedule to satisfy the requirements of Appendix A paragraph (b)(3) before undertaking any other work under the project. (ii) Phase 2 projects shall be monitored for at least one year after construction or pollution control practices are completed.

(2) The State shall manage and maintain the project so that all pollution control measures supported under the project will be continued during the project period at the same level of efficiency as when they were implemented. The State will provide reports regarding project maintenance as required in the cooperative agreement.

(3) The State shall upgrade its water quality standards to reflect a higher water quality use classification if the higher water quality use was achieved as a result of the project (see 40 CFR 35.1550(c)(2)).

(4) If an approved project allows purchases of equipment for lake maintenance, such as weed harvesters, aeration equipment, and laboratory equipment, the State shall maintain and operate the equipment according to an approved lake maintenance plan for a period specified in the cooperative agreement. In no case shall that period be for less than the time it takes to completely amortize the equipment.

(5) If primary adverse environmental impacts result from implementing approved lake restoration or protection procedures, the State shall include measures to mitigate these adverse impacts as part of the work under the project.

(6) If adverse impacts could result to unrecorded archeological sites, the State shall stop work or modify work plans to protect these sites in accordance with the National Historic Preservation Act. (EPA may allow additional costs for ensuring proper protection of unrecorded archeological sites in the project area after reevaluating the cost effectiveness of the procedures and approving a request for a cost increase from the recipient.)

(7) If a project involves construction or dredging that requires a section 404 permit for the discharge of dredged or fill material, the recipient shall obtain the necessary section 404 permits before performing any dredge or fill work.

§ 35.1650-4 Payment.

(a) Under § 30.815 of this chapter, EPA generally will make payments through letter of credit. However, the Regional Administrator may place any recipient on advance payment or on cost reimbursement, as necessary.

(b) Phase 2 projects involving construction of facilities or dredging and filling activities shall be paid by reimbursement.

§ 35.1650-5 Allowable costs.

(a) The State will be paid under § 35.1650-4 for the Federal share of all necessary costs within the scope of the approved project and determined to be allowable under 40 CFR 30.705, the provisions of this subpart, and the cooperative agreement.

(b) Costs for restoring lakes used solely for drinking water supplies are not allowable under the Clean Lakes Program.

§ 35.1650-6 Reports.

(a) States with Phase 1 projects shall submit semi-annual progress reports (original and one copy) to the EPA project officer within 30 days after the end of every other standard quarter. Standard quarters end on March 31, June 30, September 30, and December 31. These reports shall include the following:

(1) Work progress relative to the milestone schedule, and difficulties encountered during the previous six months.

(2) A brief discussion of the project findings appropriate to the work conducted during the previous six months.

(3) A report of expenditures in the past six months and those anticipated in the next six months.

(b) *Phase 2.* States with Phase 2 projects shall submit progress reports (original and one copy) according to the schedule established in the cooperative agreement. The frequency of Phase 2 project progress reports shall be determined by the size and complexity of the project, and shall be required no more frequently than quarterly. The Phase 2 progress report shall contain all of the information required for Phase 1 progress reports indicated in paragraph (a) of this section. This report also must include water quality monitoring data and a discussion of the changes in water quality which appear to have resulted from the lake restoration activities implemented during the reporting period.

(c) *Final Report.* States shall prepare a final report for all grants in accordance with § 30.635-2 of this subchapter. Phase 1 reports shall be organized according to the outline of information requirements stated in Appendix A. All water quality data obtained under the grant shall be submitted in the final report. Phase 2 reports shall conform to the format presented in the EPA manual on "Scientific and Technical Publications," May 14, 1974, as revised or updated. The States shall submit the report within 90 days after the project is completed.

(d) *Financial Status Report.* Within 90 days after the end of each budget period, the grantee shall submit to the Regional Administrator an annual report of all expenditures (Federal and non-Federal) which accrued during the budget period. Beginning in the second quarter of any succeeding budget period, payments may be withheld under § 30.615-3 of this chapter until this report is received.

Appendix A—Requirements for Diagnostic-Feasibility Studies and Environmental Evaluations

Phase 1 clean lakes projects shall include in their scope of work at least the following requirements, preferably in the order presented and under appropriate subheadings. The information required by paragraph (a)(10) and the monitoring procedures stated in paragraph (b)(3) of this Appendix may be modified to conform to specific project requirements to reduce project costs without jeopardizing adequacy of technical information or the integrity of the project. All modifications must be approved by the EPA project officer as specified in §§ 35.1650-3(b)(1) and 35.1650-3(c)(1).

(a) A diagnostic study consisting of:

(1) An identification of the lake to be restored or studied, including the name, the State in which it is located, the location within the State, the general hydrologic relationship to associated upstream and downstream waters and the approved State water quality standards for the lake.

(2) A geological description of the drainage basin including soil types and soil loss to stream courses that are tributary to the lake.

(3) A description of the public access to the lake including the amount and type of public transportation to the access points.

(4) A description of the size and conomic structure of the population esiding near the lake which would use he improved lake for recreation and ther purposes.

(5) A summary of historical lake uses, ncluding recreational uses up to the resent time, and how these uses may ave changed because of water quality egradation.

(6) An explanation, if a particular egment of the lake user population is or vill be more adversely impacted by lake egradation.

(7) A statement regarding the water se of the lake compared to other lakes vithin a 80 kilometer radius.

(8) An itemized inventory of known oint source pollution discharges ffecting or which have affected lake vater quality over the past 5 years, and he abatement actions for these lischarges that have been taken, or are n progress. If corrective action for the pollution sources is contemplated in the uture, the time period should be pecified.

(9) A description of the land uses in he lake watershed, listing each land use lassification as a percentage of the vhole and discussing the amount of nonpoint pollutant loading produced by each category.

(10) A discussion and analysis of historical baseline limnological data and one year of current limnological data. The monitoring schedule presented in paragraph (b)(3) of Appendix A must be ollowed in obtaining the one year of current limnological data. This presentation shall include the present rophic condition of the lake as well as ts surface area (hectares), maximum depth (meters), average depth (meters), hydraulic residence time, the area of the watershed draining to the lake hectares), and the physical, chemical, and biological quality of the lake and mportant lake tributary waters. Bathymetric maps should be provided. If dredging is expected to be included in the restoration activities, representative bottom sediment core samples shall be collected and analyzed using methods approved by the EPA project officer for phosphorus, nitrogen, heavy metals, other chemicals appropriate to State water quality standards, and persistent synthetic organic chemicals where appropriate. Further, the elutriate must be subjected to test procedures developed by the U.S. Army Corps of Engineers and analyzed for the same constituents. An assessment of the phosphorus (and nitrogen when it is the limiting lake nutrient) inflows and outflows associated with the lake and a hydraulic budget including ground water flow must be included. Vertical temperature and dissolved oxygen data must be included for the lake to determine if the hypolimnion becomes anaerobic and, if so, for how long and over what extent of the bottom. Total and soluble reactive phosphorus (P), and nitrite, nitrate, ammonia and organic nitrogen (N) concentratons must be determined for the lake. Chlorophyll *a* values should be measured for the upper mixing zone. Representative alkalinities should be determined. Algal assay bottle test data or total N to total P ratios should be used to define the growth limiting nutrient. The extent of algal blooms, and the predominant algal genera must be discussed. Algal biomass should be determined through algal genera identification, cell density counts (numbers of cells per milliliter) and converted to cell volume based on factors derived from direct measurements; and reported in biomass of each major genus identified. Secchi disk depth and suspended solids should be measured and reported. The portion of the shoreline and bottom that is impacted by vascular plants (submersed, floating, or emersed higher aquatic vegetation) must be estimated, specifically the lake surface area between 0 and the 10 meter depth contour or twice the Secchi disk transparency depth, whichever is less, and that estimate should include an identification of the predominant species. Where a lake is subject to significant public contact use or is fished for consumptive purposes, monitoring for public health reasons should be part of the monitoring program. Standard bacteriological analyses and fish flesh analyses for organic and heavy metal contamination should be included.

(11) An identification and discussion of the biological resources in the lake, such as fish population, and a discussion of the major known ecological relationships.

(b) A feasibility study consisting of:

(1) An identification and discussion of the alternatives considered for pollution control or lake restoration and an identification and justification of the selected alternative. This should include a discussion of expected water quality improvement, technical feasibility, and estimated costs of each alternative. The discussion of each feasible alternative and the selected lake restoration procedure must include detailed descriptions specifying exactly what activities would be undertaken under each, showing how and where these procedures would be implemented, illustrating the engineering specifications that would be followed including preliminary engineering drawings to show in detail the construction aspects of the project, and presenting a quantitative analysis of the pollution control effectiveness and the lake water quality improvement that is anticipated.

(2) A discussion of the particular benefits expected to result from implementing the project, including new public water uses that may result from the enhanced water quality.

(3) A Phase 2 monitoring program indicating the water quality sampling schedule. A limited monitoring program must be maintained during project implementation, particularly during construction phases or in-lake treatment, to provide sufficient data that will allow the State and the EPA project officer to redirect the project if necessary, to ensure desired objectives are achieved. During pre-project, implementation, and post-project monitoring activities, a single in-lake site should be sampled monthly during the months of September through April and biweekly during May through August. This site must be located in an area that best represents the limnological properties of the lake, preferably the deepest point in the lake. Additional sampling sites may be warranted in cases where lake basin morphometry creates distinctly different hydrologic and limnologic sub-basins; or where major lake tributaries adversely affect lake water quality. The sampling schedule may be shifted according to seasonal differences at various latitudes. The biweekly samples must be scheduled to coincide with the period of elevated biological activity. If possible, a set of samples should be collected immediately following spring turnover of the lake. Samples must be collected between 0800 and 1600 hours of each sampling day unless diel studies are part of the monitoring program. Samples must be collected between one-half meter below the surface and one-half meter off the bottom, and must be collected at intervals of every one and one-half meters, or at six equal depth intervals, whichever number of samples is less. Collection and analyses of all samples must be conducted according to EPA approved methods. All of the samples collected must be analyzed for total and soluble reactive phosphorus; nitrite, nitrate, ammonia, and organic nitrogen; pH; temperature; and dissolved oxygen. Representative alkalinities should be determined. Samples collected in the upper mixing zone must be analyzed for chlorophyll *a*. Algal biomass in the upper mixing zone should be determined through algal genera

identification, cell density counts (number of cells per milliliter) and converted to cell volume based on factors derived from direct measurements; and reported in terms of biomass of each major genera identified. Secchi disk depth and suspended solids must be measured at each sampling period. The surface area of the lake covered by macrophytes between 0 and the 10 meter depth contour or twice the Secchi disk transparency depth, whichever is less, must be reported. The monitoring program for each clean lakes project must include all the required information mentioned above, in addition to any specific measurements that are found to be necessary to assess certain aspects of the project. Based on the information supplied by the Phase 2 project applicant and the technical evaluation of the proposal, a detailed monitoring program for Phase 2 will be established for each approved project and will be a condition of the cooperative agreement. Phase 2 projects will be monitored for at least one year after construction or pollution control practices are completed to evaluate project effectiveness.

(4) A proposed milestone work schedule for completing the project with a proposed budget and a payment schedule that is related to the milestone.

(5) A detailed description of how non-Federal funds will be obtained for the proposed project.

(6) A description of the relationship of the proposed project to pollution control programs such as the section 201 construction grants program, the section 208 areawide wastewater management program, the Department of Agriculture Soil Conservation Service and Agriculture Stabilization and Conservation Service programs, the Department of Housing and Urban Development block grant program, the Department of Interior Heritage Conservation and Recreation Service programs and any other local, State, regional and Federal programs that may be related to the proposed project. Copies of any pertinent correspondence, contracts, grant applications and permits associated with these programs should be provided to the EPA project officer.

(7) A summary of public participation in developing and assessing the proposed project which is in compliance with Part 25 of this chapter. The summary shall describe the matters brought before the public, the measures taken by the reporting agency to meet its responsibilities under Part 25 and related provisions elsewhere in this chapter, the public response, and the agency's response to significant comments. Part 25.8 responsiveness summaries may be used to meet appropriate portions of these requirements to avoid duplication.

(8) A description of the operation and maintenance plan that the State will follow, including the time frame over which this plan will be operated, to ensure that the pollution controls implemented during the project are continued after the project is completed.

(9) Copies of all permits or pending permit applications (including the status of such applications) necessary to satisfy the requirements of section 404 of the Act. If the approved project includes dredging activities or other activities requiring permits, the State must obtain from the U.S. Army Corps of Engineers or other agencies the permits required for the discharge of dredged or fill material under section 404 of the Act or other Federal, State or local requirements. Should additional information be required to obtain these permits, the State shall provide it. Copies of section 404 permit applications and any associated correspondence must be provide to the EPA project officer at the time they are submitted to the U.S. Army Corps of Engineers. After reviewing the 404 permit application, the project officer may provide recommendations for appropriate controls and treatment of supernatant derived from dredged material disposal sites to ensure the maximum effectiveness of lake restoration procedures.

(c) States shall complete and submit an environmental evaluation which considers the questions listed below. In many cases the questions cannot be satisfactorily answered with a mere "Yes" or "No". States are encouraged to address other considerations which they believe apply to their project.

(1) Will the proposed project displace any people?

(2) Will the proposed project deface existing residences or residential areas? What mitigative actions such as landscaping, screening, or buffer zones have been considered? Are they included?

(3) Will the proposed project be likely to lead to a change in established land use patterns, such as increased development pressure near the lake? To what extent and how will this change be controlled through land use planning, zoning, or through other methods?

(4) Will the proposed project adversly affect a significant amount of prime agricultural land or agricultural operations on such land?

(5) Will the proposed project result in a significant adverse effect on parkland, other public land, or lands of recognized scenic value?

(6) Has the State Historical Society or State Historical Preservation Officer been contacted? Has he responded, and if so, what was the nature of that response? Will the proposed project result in a significant adversely effect on lands or structures of historic, architectural, archaeological or cultural value?

(7) Will the proposed project lead to a significant long-range increase in energy demands?

(8) Will the proposed project result in significant and long range adverse changes in ambient air quality or noise levels? Short term?

(9) If the proposed project involves the use of in-lake chemical treatment, what long and short term adverse effects can be expected from that treatment? How will the project recipient mitigate these effects?

(10) Does the proposal contain all the information that EPA requires in order to determine whether the project complies with Executive Order 11988 on floodplains? Is the proposed project located in a floodplain? If so, will the project involve construction of structures in the floodplain? What steps will be taken to reduce the possible effects of flood damage to the project?

(11) If the project involves physically modifying the lake shore or its bed or its watershed, by dredging, for example, what steps will be taken to minimize any immediate and long term adverse effects of such activities? When dredging is employed, where will the dredged material be deposited, what can be expected and what measures will the recipient employ to minimize any significant adverse impacts from its deposition?

(12) Does the project proposal contain all information that EPA requires in order to determine whether the project complies with Executive Order 11990 on wetlands? Will the proposed project have a significant adverse effect on fish and wildlife, or on wetlands or any other wildlife habitat, especially those of endangered species? How significant is this impact in relation to the local or regional critical habitat needs? Have actions to mitigate habitat destruction been incorporated into the project? Has the recipient properly consulted with appropriate State and Federal fish, game and wildlife agencies and with the U.S. Fish and Wildlife Service? What were their replies?

(13) Describe any feasible alternatives, to the proposed project in terms of environmental impacts, commitment of resources, public interest and costs and why they were not proposed.

(14) Describe other measures not discussed previously that are necessary to mitigate adverse environmental impacts resulting from the implementation of the proposed project.

[FR Doc. 80-3684 Filed 2-4-80; 8:45 am]
BILLING CODE 6560-01-M

40 CFR Parts 51, 52

[FRL-1404-8]

Prevention of Significant Deterioration; Partial Stay of Regulations

AGENCY: Environmental Protection Agency (EPA).

ACTION: Partial stay of regulations.

SUMMARY: By the administrative order which appears below, EPA stays its existing regulations for the prevention of significant air quality deterioration, 40 CFR 51.24 and 52.21 (1978), as to any source or modification which either (1) would not be major under the amendments to those regulations proposed at 44 FR 51924 (September 5, 1979) or (2) would be located in an area designated under Section 107 of the Clean Air Act as nonattainment for each pollutant for which the source or modification would be major under the proposed amendments.

EFFECTIVE DATE: The effective date of the stay is the date of signature of this notice. (January 30, 1980)

FOR FURTHER INFORMATION CONTACT: James Weigold, Standards Implementation Branch (MD-15), Office of Air Quality Planning and Standards, Research Triangle Park, N.C. 27711, 919/541-5292.

SUPPLEMENTARY INFORMATION: In June 1979, the United States Court of Appeals for the District of Columbia Circuit in a preliminary opinion held invalid certain key provisions of the regulations for the prevention of significant air quality deterioration which EPA had promulgated approximately one year earlier ("the 1978 PSD regulations"). *See Alabama Power Company* v. *Costle*, 13 ERC 1225. Those regulations appear at 40 CFR 51.24 and 52.21 (1978).

In September 1979, EPA proposed comprehensive amendments to the 1978 PSD regulations in response to the preliminary opinion in *Alabama Power*. *See* 44 FR 51924. Among those amendments are rules that would replace the provisions the court held invalid. Also among them are important provisions that would complement the replacements, for example, certain *de minimis* exemptions (*see id.* at 51937-38).

On December 14, 1979, the Court of Appeals in a final opinion reaffirmed its earlier decisions on the validity of the provisions at issue in *Alabama Power*. *See* 13 ERC 1993. Hence, when the opinion comes into effect, it will render ineffective key elements of the 1978 PSD regulations.

EPA will be unable to complete the rulemaking it began in September until at least June 1980. The comments EPA has received so far are voluminous and raise important issues that deserve serious consideration. In addition, in response to numerous requests, EPA recently reopened the comment period for comment on the September proposals in light of the final opinion of the court. Furthermore, EPA is reanalyzing the proposed *de minimis* exemptions and completing an economic impact assessment of the proposals. Finally, internal review of drafts of the final amendments will require considerable time.

To avoid the uncertainty and confusion that would occur if the opinion came into effect before EPA completed the rulemaking it began in September, EPA and many of the petitioners in *Alabama Power* have asked the court to keep the opinion from coming into effect until June 2, 1980, on the condition that EPA issue the administrative stay which appears below.

The purpose of the administrative stay is to relieve from the permitting requirements of the 1978 PSD regulations roughly those sources and modifications that would not be subject to the permitting requirements of valid replacement regulations that would comport with the *Alabama Power* opinion. Obviously, it would be unfair and unnecessary to force such sources and modifications to get a PSD permit under the 1978 PSD regulations during this transition period.

EPA has decided to issue the administrative stay before the court acts on the request of the various parties in *Alabama Power*. Many persons are ready to begin construction of sources and modifications that would need a PSD permit under the 1978 PSD regulations, but not under valid replacement regulations. EPA has concluded that to allow the 1978 PSD regulations to interfere any longer with such construction would be both unfair and unnecessary. Hence, it is issuing the administrative stay which appears below.

EPA regards the issuance of the administrative stay as "nationally applicable" "final action" within the meaning of Section 307(b)(1) of the Clean Air Act (the "Act"), 42 U.S.C. 7607(b)(1). EPA does not, however, regard the stay as the "promulgation or revision of regulations" within the meaning of Section 307(d)(1)(I) of the Act, 42 U.S.C. 7607(d)(1)(I). The stay is merely an order providing equitable relief during the period before the completion of the rulemaking that EPA began in September. The procedural requirements of Section 307(d), therefore, do not apply to the issuance of the administrative stay.

In any event, those requirements, as well as the notice and comment requirements of Section 4 of the Administrative Procedure Act (the "APA"), 5 U.S.C. 553, do not apply for other reasons. First, meeting either set of requirements would be "contrary to the public interest" within the meaning of Section 4(b)(B) of the APA, 5 U.S.C. 553(b)(B), since it would unnecessarily delay the construction of those sources and modifications to which the stay applies. Meeting those requirements would also be "unnecessary" within the meaning of that section, since the stay provides relief which is generally consistent with the final opinion of the court in *Alabama Power*. Finally, meeting those requirements would be "impracticable" within the meaning of Section 4(b)(B), since it would defeat the very purpose of the stay: to provide relief as soon as possible and, together with a judicial stay of the effect of the final opinion, free the agency to concentrate on the rulemaking it began in September. *See* Clean Air Act § 307(d)(1)(N), 42 U.S.C. 7607(d)(1)(N). For the same reasons, EPA finds that it has good cause to make the administrative stay immediately effective. See APA § 4(d), 5 U.S.C. 553(d).

The administrative stay opens a gap in the coverage of the new source review requirements for nonattainment areas that EPA intends to close in the near future through the promulgation of final rules. In general, those nonattainment requirements currently do not apply to a source or modification that, although locating in an area designated nonattainment for each pollutant for which it would be major, would not significantly impact those portions of the area where pollution actually exceeds the applicable national ambient air quality standard or standards (NAAQS). *See, e.g.*, 40 CFR Part 51, Appendix S, § II.D), 44 FR 3283 (January 16, 1979). In establishing that "clean pocket" exemption, EPA assumed that PSD permitting requirements would apply to any such source or modification, thereby filling the gap in the coverage of the

APPENDIX B:

WATER QUALITY DATA—
LAKE MONROE AND WATERSHED

Lake Monroe Raw Data- Upper Basin

DATE	pH 1	pH 2	pH 3	Alkalinity (mg/l) 1	Alkalinity (mg/l) 2	Alkalinity (mg/l) 3	Secchi Disk (m)	1% Light Level(ft)	Light Trans. 3 ft.(%)	Total Phosphorus (mg/l) 1	Total Phosphorus (mg/l) 2	Total Phosphorus (mg/l) 3	Soluble Phosphorus (mg/l) 1	Soluble Phosphorus (mg/l) 2	Soluble Phosphorus (mg/l) 3	Organic Nitrogen (mg/l) 1	Organic Nitrogen (mg/l) 2	Organic Nitrogen (mg/l) 3
04/17/92	7.0	7.0	7.0	34.2	34.5	35.0	1.0	9.0	17	0.072	0.034	0.038	0.005	0.003	0.005	1.055	1.095	1.239
05/13/92	6.6	6.7	6.9	31.5	51.0	28.0	1.3	11.0	44	0.022	0.003	0.025	0.006	0.008	0.005	0.565	1.495	0.448
05/27/92	6.8	6.9	6.9	31.5	33.0	30.0	0.6	7.0	21	0.018	0.027	0.037	0.005	0.006	0.005	0.647	1.188	0.516
06/10/92	7.4	7.8	7.5	32.5	32.0	33.0	1.2	9.0	38	0.016	0.022	0.034	0.009	0.008	0.008	0.550	0.571	0.440
06/24/92	6.9	7.2	7.3	35.0	35.0	36.0	1.8	8.5	27	0.068	0.056	0.062	0.003	0.003	0.003	0.673	0.912	0.589
07/08/92	7.0	7.0	7.0	48.0	38.7	38.5	0.6	6.0	10	0.057	0.058	0.069	0.006	0.006	0.005	0.659	0.689	0.803
07/22/92	7.3	7.2	7.2	40.0	40.0	41.0	0.6	7.0	12	0.071	0.063	0.063	0.006	0.005	0.005	0.490	0.247	0.303
08/05/92	7.7	7.9	7.9	46.0	43.5	44.0	0.4	6.5	9	0.056	0.066	0.063	0.005	0.005	0.006	0.549	0.682	0.729
08/19/92	7.9	7.9	7.9	45.0	41.0	44.0	0.6	4.9	7	0.064	0.055	0.070	0.005	0.003	0.002	0.365	0.036	0.041
09/06/92	7.6	7.9	7.8	43.5	43.5	45.5	0.5	5.3	9	0.055	0.077	0.078	0.003	0.001	0.002	0.385	0.503	0.338
10/11/92	6.7	6.9	6.8	45.0	42.0	45.0	0.6	6.0	10	0.073	0.061	0.064	0.013	0.014	0.011	0.081	0.197	0.334
11/15/92	7.4	7.5	-	40.0	40.0	41.5	0.7	6.5	10	0.048	0.046	0.055	0.003	0.003	0.002	0.391	0.435	0.397
01/17/93	6.9	7.1	7.2	28.0	28.0	29.0	0.4	4.0	4	0.053	0.043	0.047	0.007	0.006	0.005	1.131	1.352	1.284
03/28/93	6.7	7.1	-	24.5	23.0	23.0	0.5	7.0	10	0.010	0.025	0.024	0.006	0.003	0.012	0.455	0.413	0.569
04/18/93	6.8	7.1	7.2	24.0	24.0	23.0	0.5	6.0	12	0.052	0.045	0.036	0.003	0.007	0.005	0.112	0.053	0.099
05/18/93	6.4	7.1	7.2	30.0	30.0	30.0	1.9	7.5	18	0.025	0.015	0.012	0.002	0.003	0.003	3.258	2.625	3.054

(shaded) = at or below detection limit for method.

(black) = extreme value most likely due to laboratory error or contamination.

Lake Monroe Raw Data - Upper Basin (continued)

	Nitrate (mg/l)			Ammonia (mg/l)			Chlorophyll (ug/l)		Suspended Solids (mg/l)		
DATE	1	2	3	1	2	3	1	2	1	2	3
04/17/92	0.132	0.128	0.044	0.052	0.113	0.109	14.7	16.2	7.60	8.37	8.77
05/13/92	0.213	0.197	0.189	0.122	0.109	0.151	1.1	1.3	5.47	5.30	6.03
05/27/92	0.067	0.083	0.072	0.036	0.034	0.033			6.48	6.60	7.25
06/10/92	0.072	0.070	0.071	0.122	0.109	0.151	1.9	2.1	3.60	3.90	7.47
06/24/92	0.079	0.079	0.081	0.037	0.034	0.055	5.9	2.6	163.97	10.35	10.52
07/08/92	0.082	0.075	0.075	0.035	0.021	0.020	5.2	1.1	14.62	14.87	15.37
07/22/92	0.052	0.051	0.054	0.068	0.057	0.059	3.9	5.7	13.94	15.50	16.26
08/05/92	0.157	0.148	0.139	0.015	0.010	0.008	26.5	18.8	11.84	12.08	16.20
08/19/92	0.201	0.076	0.005	0.027	0.025	0.029	24.8	19.4	13.12	15.29	16.80
09/06/92	0.077	0.072	1.468	0.049	0.060	0.098	8.3	9.5	10.72	13.12	13.33
10/11/92	0.159	0.118	0.117	0.130	0.102	0.067	13.9	14.7	15.33	15.35	16.30
11/15/92	0.176	0.165	0.166	0.029	0.030	0.021	7.5	10.2	5.69	7.28	8.32
01/17/93	0.565	0.604	0.621	0.068	0.052	0.044	4.3	8.9	15.59	14.43	15.79
03/28/93	0.450	0.490	0.470	0.093	0.087	0.093	3.4	2.7	12.45	10.72	7.97
04/18/93	0.312	0.345	0.337	0.067	0.074	0.071	2.8	2.5	12.70	13.11	1.46
05/18/93	0.101	0.101	0.101	0.162	0.159	0.141	2.8	4.4	11.48	11.86	11.50

= at or below detection limit for method.

= extreme value most likely due to laboratory error or contamination.

Lake Monroe Raw Data - Middle Basin

	pH				Alkalinity (mg/l)				Secchi	1% Light	Light Trans.	Total Phosphorus (mg/l)				Soluble Phosphorus (mg/l)			
DATE	1	2	3	4	1	2	3	4	Disk (m)	Level (ft)	@ 3 ft. (%)	1	2	3	4	1	2	3	4
04/17/92	7.0	7.0	7.0	7.0	31.3	33.0	32.2	32.8	1.6	17.5	36	0.032	0.027	0.030	0.061	0.002	0.003	0.002	0.003
05/13/92	6.9	6.9	6.9	6.9	29.5	27.5	27.5	28.5	1.7	18.0	30	0.019	0.014	0.016	0.012	0.006	0.006	0.009	0.005
05/27/92	7.8	6.9	7.4	7.8	32.0	32.0	31.0	31.0	1.5	15.0	39	0.019	0.029	0.024	0.018	0.006	0.006	0.006	0.010
06/10/92	7.0	7.2	7.5	6.8	32.0	33.0	33.0	31.0	2.0	16.0	60	0.026	0.027	0.018	0.024	0.008	0.009	0.009	0.009
06/24/92	7.0	7.0	7.0	7.0	32.0	33.0	38.0	39.0	1.0	9.7	29	0.041	0.050	0.044	0.050	0.003	0.006	0.002	0.002
07/08/92	7.5	7.5	7.4	7.6	35.3	34.0	34.0	34.5	1.2	14.0	34	0.032	0.028	0.025	0.032	0.011	0.008	0.006	0.011
07/22/92	7.2	7.4	7.5	7.3	36.0	36.0	35.0	36.0	0.8	9.1	20	0.056	0.042	0.056	0.053	0.006	0.011	0.006	0.006
08/05/92	7.8	8.0	7.6	7.7	37.5	38.0	37.0	37.0	0.9	10.5	33	0.048	0.038	0.069	0.046	0.006	0.008	0.006	0.006
08/19/92	7.7	7.6	7.6	7.8	38.0	38.0	38.0	38.0	1.0	11.5	29	0.038	0.034	0.026	0.038	0.002	0.003	0.002	0.002
09/06/92	7.5	7.7	7.8	7.7	39.0	38.0	45.0	35.0	1.2	14.0	29	0.032	0.024	0.065	0.074	0.003	0.002	0.002	0.003
10/11/92	7.0	7.3	7.4	7.5	45.0	44.0	42.0	41.5	0.9	10.8	28	0.056	0.073	0.063	0.055	0.008	0.019	0.018	0.010
11/15/92	7.3	7.5	7.6	7.7	41.0	40.0	39.0	41.0	1.1	10.8	12	0.033	0.112	0.053	0.041	0.005	0.003	0.003	0.002
01/17/93	Boat Failure - no data																		
03/28/93	7.4	7.5	7.5	7.6	25.5	27.0	26.0	27.0	1.0	12.0	30	0.033	0.039	0.022	0.017	0.007	0.007	0.005	0.003
04/18/93	7.4	7.4	7.5		25.0	24.0	25.0	24.5	1.1	16.0	40	0.020	0.020	0.030	0.029	0.002	0.003	0.002	0.002
05/18/93	6.6	7.3	7.4	7.4	27.0	30.0		27.0	1.2	14.1	37	0.014	0.032	0.026	0.010	0.001	0.007	0.002	0.002

(grey shading) = at or below detection limit for method.

(black shading) = extreme value most likely due to laboratory error or contamination.

Lake Monroe Raw Data - Middle Basin (continued)

DATE	Organic Nitrogen (mg/l)				Nitrate (mg/l)				Ammonia (mg/l)				Chlorophyll (µg/l)		Suspended Solids (mg/l)			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	1	2	3	4
04/17/92	1.440	1.703	1.936	1.119	0.097	0.097	0.093	0.091	0.056	0.044	0.062	0.074	1.0	6.5	5.23	5.23	4.40	4.67
05/13/92	0.738	2.083	0.492	0.424	0.165	0.158	0.149	0.138	0.074	0.068	0.129	0.156	2.2	1.6	3.23	3.20	3.57	3.33
05/27/92	0.803	1.886	0.638	0.783	0.093	0.062	0.062	0.069	0.008	0.011	0.017	0.038	-	-	4.63	4.85	4.77	5.24
06/10/92	0.462	0.401	0.540	0.619	0.069	0.070	0.070	0.069	0.074	0.068	0.129	0.156	3.2	0.2	2.80	2.50	3.05	4.28
06/24/92	0.514	0.673	1.004	0.652	0.068	0.068	0.077	0.070	0.029	0.028	0.030	0.035	4.7	5.6	6.83	7.20	7.55	10.46
07/08/92	0.680	0.436	0.546	0.446	0.069	0.070	0.070	0.069	0.015	0.014	0.011	0.011	0.6	1.4	4.21	4.74	4.99	5.65
07/22/92	0.615	0.352	0.395	0.734	0.054	0.055	0.053	0.053	0.033	0.033	0.029	0.033	1.2	1.0	7.29	7.53	7.71	6.91
08/05/92	1.252	0.467	0.558	0.906	0.126	0.120	0.122	0.122	0.007	0.009	0.008	0.008	-	4.1	6.60	6.63	6.60	6.65
08/19/92	0.099	0.052	0.111	0.091	0.078	0.007	0.093	0.079	0.032	0.021	0.018	0.017	8.7	9.1	4.91	4.73	4.35	4.70
09/06/92	0.216	0.276	0.142	0.070	0.074	0.045	0.071	0.068	0.058	0.133	0.143	0.179	3.6	-	4.30	4.22	4.03	5.08
10/11/92	0.133	0.194	0.290	0.219	0.101	0.083	0.073	0.065	0.089	0.055	0.048	0.039	10.0	6.1	7.66	7.21	8.28	8.09
11/15/92	0.375	0.607	0.741	0.625	0.151	0.149	0.144	0.136	0.023	0.022	0.022	0.022	3.5	2.7	5.84	5.48	6.06	6.09
01/17/93																		
03/28/93	0.640	0.432	0.652	0.543	0.410	0.370	0.370	0.400	0.075	0.081	0.118	0.081	3.2	4.4	4.63	4.83	4.41	4.44
04/18/93	0.230	0.230	0.230	0.230	0.413	0.389	0.415	0.405	0.038	0.116	0.066	0.082	2.3	2.8	3.40	3.54	3.65	3.85
05/18/93	3.220	0.230	0.230	2.024	0.132	0.144	0.139	0.137	0.110	0.236	0.027	0.123	5.2	5.2	5.57	5.50	2.84	5.52

(shaded) = at or below detection limit for method.

(black) = extreme value most likely due to laboratory error or contamination.

Lake Monroe Raw Data - Lower Basin

	pH						Alkalinity (mg/l)						Secchi	1% Light	Light Trans.	Total Phosphorus (mg/l)					
DATE	1	2	3	4	5	6	1	2	3	4	5	6	Disk (m)	Level (ft)	@ 3 ft. (%)	1	2	3	4	5	6
04/17/92	6.9	6.9	6.9	6.9	6.7	6.6	32.0	31.9	32.5	30.5	31.5	32.0	2.2	28.0	40	0.027	0.049	0.029	0.026	0.024	0.032
05/13/92	7.1	7.0	7.0	7.0	7.0	7.0	47.5	28.0	27.5	29.0	25.5	47.0	2.1	26.0	48	0.014	0.019	0.023	0.011	0.012	0.014
05/27/92	7.5	7.3	7.5	7.5	7.4	7.2	32.0	31.5	32.0	32.0	31.5	32.0	2.9	28.5	57	0.014	0.021	0.018	0.016	0.021	0.026
06/10/92	7.6	8.2	7.4	7.9	8.1	7.8	32.0	31.5	32.0	32.0	32.0	32.0	2.9	26.0	50	0.026	0.021	0.014	0.015	0.022	0.017
06/24/92	6.9	7.0	6.9	7.1	7.4	7.3	33.0	32.0	32.5	33.5	35.0	35.0	3.2	22.2	41	0.047	0.041	0.053	0.030	0.041	0.044
07/08/92	7.1	7.0	7.1	7.0	6.8	6.8	37.0	33.0	33.0	33.5	34.0	37.5	2.8	20.0	52	0.028	0.041	0.032	0.028	0.038	0.044
07/22/92	7.9	8.0	7.9	7.8	7.5	7.0	47.0	29.0	31.0	31.0	34.0	34.0	1.9	23.0	49	0.020	0.017	0.017	0.037	0.025	0.020
08/05/92	7.7	7.6	7.6	7.4	7.1	7.7	39.0	37.0	35.0	37.0	36.0	37.0	2.2	23.0	60	0.030	0.021	0.033	0.043	0.039	0.036
08/19/92	7.5	7.4	7.4	7.3	7.2	7.1	30.0	42.0	32.0	36.0	37.0	35.0	1.8	17.0	32	0.030	0.021	0.024	0.014	0.041	0.008
09/06/92	7.2	7.5	7.5	7.6	7.2	7.1	42.5	39.5	38.5	38.0	38.0	40.0	2.3	20.5	45	0.044	0.044	0.054	0.047	0.037	0.047
10/11/92	6.7	7.1	8.0	8.3	8.3	8.4	40.0	42.0	41.0	40.0	40.0	39.0	1.0	10.8	30	0.045	0.042	0.035	0.039	0.046	0.056
11/15/92	6.9	7.1	7.2	7.2	7.1	7.4	38.0	38.0	40.0	39.0	38.0	39.0	0.9	9.0	28	0.049	0.039	0.043	0.066	0.043	0.046
01/17/93	7.0	7.4	7.4	7.5	7.4	7.7	40.0	40.0	40.0	39.0	39.0	39.0	2.1	19.0	35	0.017	0.027	0.043	0.017	-	0.017
03/28/93	7.2	7.4	7.5	7.6	7.7	7.7	37.5	38.0	36.0	36.0	36.0	35.5	1.7	17.0	28	0.014	0.017	0.015	0.014	0.018	0.014
04/18/93	7.5	7.6	7.6	7.6	7.6		30.0	31.0	30.0	30.0	31.0	29.0	2.0	22.0	55	0.017	0.015	0.018	0.016	0.018	0.014
05/18/93	7.1	6.6	8.1	8.0	7.8	7.5	27.0	28.0	29.0	29.0	29.0	31.0	1.6	17.0	33	0.042	0.058	0.008	0.015	0.018	0.063

(shaded box) = at or below detection limit for method.

(black box) = extreme value most likely due to laboratory error or contamination.

Lake Monroe Raw Data - Lower Basin (continued)

	Soluble Phosphorus (mg/l)						Organic Nitrogen (mg/l)						Nitrate (mg/l)					
DATE	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
04/17/92	0.003	0.002	0.003	0.002	0.002	0.003	1.359	1.639	2.137	1.510	1.030	0.729	0.101	0.084	0.099	0.105	0.160	0.135
05/13/92	0.011	0.005	0.009	0.005	0.014	0.006	0.583	0.587	0.460	0.725	0.625	1.814	0.144	0.141	0.149	0.137	0.138	0.146
05/27/92	0.010	0.005	0.005	0.005	0.005	0.005	0.602	0.611	0.516	0.719	0.566	1.505	0.105	0.051	0.054	0.074	0.079	0.073
06/10/92	0.009	0.008	0.008	0.008	0.008	0.009	0.493	0.489	0.660	0.880	1.123	0.769	0.086	0.068	0.068	0.068	0.065	0.084
06/24/92	0.003	0.002	0.002	0.002	0.002	0.008	1.104	0.445	0.556	0.612	0.446	0.632	0.079	0.073	0.071	0.070	0.073	0.070
07/08/92	0.134	0.015	0.080	0.009	0.006	0.020	0.601	0.568	0.411	0.580	0.564	0.408	0.079	0.076	0.073	0.069	0.068	0.069
07/22/92	0.003	0.003	0.005	0.005	0.005	0.005	0.356	0.347	0.638	0.744	0.375	0.395	0.055	0.058	0.068	0.061	0.067	0.097
08/05/92	0.005	0.008	0.003	0.006	0.005	0.003	0.482	1.076	0.508	0.378	0.616	0.521	0.114	0.116	0.116	0.121	0.118	0.111
08/19/92	0.003	0.002	0.002	0.002	0.002	0.002	0.462	0.481	0.432	0.442	0.510	0.339	0.082	0.081	0.076	0.076	0.079	0.078
09/06/92	0.002	0.003	0.002	0.002	0.002	0.002	0.148	0.313	0.193	0.147	0.545	0.084	0.123	0.074	0.068	0.066	0.066	0.071
10/11/92	0.008	0.006	0.013	0.008	0.019	0.016	0.171	0.092	-	-	-	0.718	0.096	0.058	0.064	0.082	0.066	0.066
11/15/92	0.003	0.004	0.003	0.005	0.003	0.006	0.426	0.375	0.383	0.396	0.373	0.585	0.256	0.262	0.268	0.277	0.262	0.267
01/17/93	0.002	0.003	0.005	0.003	0.002	0.002	0.927	0.947	0.986	1.031	-	1.044	0.307	0.280	0.272	0.201	-	0.205
03/28/93	0.003	0.003	0.003	0.003	0.002	0.002	0.688	0.289	0.426	0.622	0.781	1.042	0.230	0.250	0.250	0.220	0.250	0.220
04/18/93	0.002	0.002	0.002	0.002	0.002	0.002	0.230	0.230	0.230	0.230	0.230	0.230	0.397	0.378	0.380	0.407	0.362	0.372
05/18/93	0.002	0.004	0.002	0.002	0.002	0.004	0.230	0.230	3.910	0.230	0.230	0.230	0.167	0.170	0.167	0.222	0.286	0.293

= at or below detection limit for method.

= extreme value most likely due to laboratory error or contamination.

Lake Monroe Raw Data - Lower Basin (continued)

	Ammonia (mg/l)						Chlorophyll (µg/l)		Suspended Solids (mg/l)					
DATE	1	2	3	4	5	6	1	2	1	2	3	4	5	6
04/17/92	0.112	0.108	0.119	0.103	0.158	0.161	2.6	2.9	3.63	4.90	3.87	4.33	3.57	3.57
05/13/92	0.074	0.067	0.120	0.072	0.067	0.107	0.9	1.2	2.57	2.23	3.13	2.23	1.93	3.33
05/27/92	0.005	0.007	0.004	0.008	0.004	0.105	-	-	3.79	3.57	3.27	4.43	4.68	5.00
06/10/92	0.074	0.067	0.120	0.072	0.067	0.107	1.0	1.1	1.88	2.12	2.08	1.91	2.82	2.84
06/24/92	0.028	0.027	0.025	0.024	0.024	0.032	-	1.0	2.05	77.91	105.68	97.60	134.23	337.00
07/08/92	0.011	0.011	0.011	0.020	0.018	0.078	0.2	5.0	0.98	1.96	2.18	2.68	3.16	6.16
07/22/92	0.015	0.013	0.018	0.012	0.014	0.024	1.4	1.1	2.42	2.55	2.56	2.18	3.29	4.97
08/05/92	0.009	0.011	0.008	0.008	0.008	0.008	2.3	3.3	1.60	2.42	2.68	3.04	2.52	2.26
08/19/92	0.019	0.017	0.019	0.024	0.021	0.025	5.7	3.5	3.35	1.98	2.18	2.24	2.44	2.10
09/06/92	0.064	0.062	0.088	0.086	0.152	0.269	0.0	1.2	1.91	1.74	2.55	3.37	1.22	5.34
10/11/92	0.105	0.106	0.105	0.106	0.104	0.106	5.3	4.6	6.35	3.54	4.97	4.55	5.14	5.01
11/15/92	0.037	0.039	0.043	0.043	0.043	0.042	2.2	3.4	9.69	7.48	7.14	6.97	6.84	8.24
01/17/93	0.025	0.029	0.024	0.028	0.024	0.014	2.2	3.4	2.72	2.87	2.66	2.71	-	2.59
03/28/93	0.093	0.093	0.087	0.093	0.090	0.087	4.6	5.0	3.18	3.89	3.79	3.77	3.74	3.87
04/18/93	0.056	0.067	0.053	0.055	0.058	0.111	1.1	2.3	2.85	2.95	3.36	-	2.72	2.27
05/18/93	0.199	0.175	0.153	0.132	0.151	0.158	6.6	5.3	4.68	5.08	5.44	4.83	5.40	35.64

= at or below detection limit for method.

= extreme value most likely due to laboratory error or contamination.

APPENDIX C:

PLANKTON DATA

LAKE MONROE PLANKTON RESULTS

041892 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	10	26.32	520	4.61
Dinobryon	13	34.21	676	28.38
Fragillaria	2	5.26	104	3.96
Oscillatoria	4	10.53	208	0.34
Synedra	2	5.26	104	0.04
Synura	4	10.53	208	59.74
Ulothrix	3	7.89	156	2.93
Total Organisms	38			
Arthropods				
Bosmina	1	20.00	1	
Nauplius	4	80.00	3	
Total Organisms	5			

041892 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	661	82.52	76237	57.20
Closterium	1	0.12	115	0.00
Dinobryon	22	2.75	2537	9.02
Fragillaria	22	2.75	2537	8.19
Fragillaria sp.	1	0.12	115	3.86
Keratella	1	0.12	115	2.86
Mallomonas	1	0.12	115	0.03
Melosira	7	0.87	807	0.19
Oscillatoria	13	1.62	1499	0.14
Polyarthra	1	0.12	115	7.08
Stephanodiscus	2	0.25	231	0.03
Synedra	15	1.87	1730	0.52
Synura	1	0.12	115	2.80
Tabellaria-sections	13	1.62	1499	0.76
Ulothrix	40	4.99	4613	7.33
Total Organisms	801			
Arthropods				
Bosmina	38	26.21	18	
Calanoid	2	1.38	1	
Cyclopoid	50	34.48	24	
Daphnia	3	2.07	1	
Nauplius	52	35.86	25	
Total Organisms	145			

Lake Monroe Plankton

041892 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	1476	93.42	44011	82.32
Closterium?	1	0.06	30	0.00
Dinobryon	17	1.08	507	4.49
Fragillaria	41	2.59	1223	9.83
Oscillatoria	2	0.13	60	0.14
Phormidium	2	0.13	60	0.00
Synedra	9	0.57	268	0.20
Tabellaria	1	0.06	30	0.00

Tabellaria-sections	8	0.51	239	0.30
Ulothrix	23	1.46	686	2.72
Total Organisms	1580			
Arthropods				
Bosmina	1	3.03	1	
Cyclopoid	8	24.24	4	
Nauplius	24	72.73	12	
Total Organisms	33			

Lake Monroe plankton

5-13-92 UB	Total Count	Num/cell	Num/L	% of Biomass
Asterionella	35		2169	2.07
Dynobryon	7		434	1.96
Keratella	3		186	5.86
Phormidium	1		62	0.00
Polyarthra	16		991	77.38
Synedra	366		22678	8.60
Ulothrix	33		2045	4.13
Bosmina		72	75	
Calanoid		8	8	
Cyclopoid		9	9	
Daphnia		6	6	
Diaphanozoma		1	1	
Nauplius		245	255	

Lake Monroe Plankton
Bad sample
051292 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	263	21.72	3361	13.30
Ceratium	2	0.17	26	0.66
Dinobryon	4	0.33	51	0.96
Fragillaria	2	0.17	26	0.43
Keratella	3	0.25	38	5.01
Melosira	1	0.08	13	0.02
Microcystis	6	0.50	77	0.20
Polyarthra	10	0.83	128	41.35
Staurastrum	2	0.17	26	0.07
Synedra	693	57.23	8856	13.92
Ulothrix	225	18.58	2875	24.10
Total Organisms	1211			
Arthropods				
Bosmina	13	46.43	3	
Cyclopoid	9	32.14	2	
Daphnia	1	3.57	0	
Nauplius	5	17.86	1	
Total Organisms	28			

Lake Monroe Plankton

051292 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	295	68.60	5410	66.96

Ceratium	1	0.23	18	1.47
Dinobryon	13	3.02	238	13.97
Fragillaria	2	0.47	37	1.95
Phormidium	2	0.47	37	0.01
Synedra	104	24.19	1907	9.38
Ulothrix	13	3.02	238	6.25
Total Organisms	430			
Arthropods				
Bosmina	58	13.98	18	
Calanoid	59	14.22	18	
Cyclopoid	64	15.42	20	
Daphnia	21	5.06	6	
Harpacticoid	3	0.72	1	
Nauplius	210	50.60	65	
Total Organisms	415			

Lake Monroe Plankton

052792 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	1	0.27	40	0.01
Aphanocapsa	15	4.04	607	0.09
Asterionella	47	12.67	1903	2.13
Ceratium	3	0.81	121	0.84
Dinobryon	121	32.61	4900	24.62
Gloeotrichia	1	0.27	40	0.01
Kellicottia	1	0.27	40	1.79
Keratella	2	0.54	81	2.84
Pediastrum	1	0.27	40	0.00
Phormidium	3	0.81	121	0.01
Polyarthra	17	4.58	688	59.73
Synedra	58	15.63	2349	0.99
Ulothrix	100	26.95	4050	6.76
Tabellaria sp.	1	0.27	40	0.19
Total Organisms	371			
Arthropods				
Bosmina	103	29.94	70	
Calanoid	19	5.52	13	
Cyclopoid	25	7.27	17	
Daphnia	55	15.99	37	
Diaphanozoma	16	4.65	11	
Harpacticoida	1	0.29	1	
Nauplius	120	34.88	82	
Ostracoda	2	0.58	1	
Unknown	3	0.87	2	
Total Organisms	344			

Lake Monroe Plankton

052792 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Aphanocapsa	18	5.22	554	0.00
Asterionella	138	40.00	4250	2.40
Ceratium	10	2.90	308	2.22
Characium obtusatus	1	0.29	31	0.00

Dinobryon	70	20.29	2156	16.55
Fragillaria	1	0.29	31	0.19
Gloeocapsa aeruginosa?	2	0.58	62	0.02
Kellicottia	1	0.29	31	1.43
Keratella	2	0.58	62	2.26
Mallomonus	3	0.87	92	0.03
Oscillatoria	3	0.87	92	0.01
Phormidium	4	1.16	123	0.00
Polyarthra	25	7.25	770	69.89
Scattered BG	15	4.35	462	0.00
Synedra	9	2.61	277	0.12
Tetraspora Cylindrica	1	0.29	31	1.52
Ulothrix	40	11.59	1232	3.37
Unknown BG	2	0.58	62	0.00
Total Organisms	345			
Arthropods				
Bosmina	68	28.69	35	
Calanoid	19	8.02	10	
Cyclopoid	27	11.39	14	
Daphnia	57	24.05	30	
Diaphanozoma	6	2.53	3	
Nauplius	60	25.32	31	
Total Organisms	237			

Lake Monroe Plankton

052792 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	171	70.66	4598	24.93
Bulbochaete rectangulus?	1	0.41	27	2.36
Ceratium	4	1.65	108	3.78
Chroococcus Dispersus	42	17.36	1129	0.18
Dinobryon	11	4.55	296	7.59
Fragillaria	1	0.41	27	0.63
Mallomonus	2	0.83	54	0.09
Polyarthra	5	2.07	134	59.61
Staurastrum	1	0.41	27	0.10
Synedra	1	0.41	27	0.06
Ulothrix	3	1.24	81	0.69
Total Organisms	242			
Arthropods				
Bosmina	7	4.76	3	
Calanoid	60	40.82	27	
Cyclopoid	9	6.12	4	
Daphnia	48	32.65	22	
Diaphanozoma	5	3.40	2	
Harpacticoid	1	0.68	0	
Nauplius	17	11.56	8	
Total Organisms	147			

Lake Monroe Plankton

Date and Location

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	2	1.33	261	0.20

Asterionella	5	3.33	652	0.98
Chroococcus	24	16.00	3132	0.14
Dinobryon	10	6.67	1305	9.30
Keratella	3	2.00	391	19.45
Mallomonus	2	1.33	261	0.12
Microcystis	0	0.00	0	0.00
Oscillatoria	14	9.33	1827	0.35
Phormidium	14	9.33	1827	0.08
Polyarthra	3	2.00	391	48.18
Synedra	25	16.67	3262	1.95
Ulothrix	46	30.67	6003	19.14
Melosira	2	1.33	261	0.12
Total Organisms	150			
Arthropods				
Bosmina	7	4.79	15	
Calanoid	5	3.42	11	
Cyclopoid	27	18.49	59	
Daphnia	7	4.79	15	
Diaphanozoma	12	8.22	26	
Nauplius	88	60.27	193	
Total Organisms	146			

Lake Monroe Plankton

061092 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	1	0.21	25	0.02
Aphaonocapsa	8	1.64	200	0.04
Asterionella	44	9.03	1097	1.69
Ceratium	10	2.05	249	2.49
Dinobryon	169	34.70	4215	30.73
Fragilaria	5	1.03	125	0.83
Kellicottia	3	0.62	75	4.81
Keratella	6	1.23	150	7.61
Mallomonus	1	0.21	25	0.01
Phormidium	13	2.67	324	0.01
Polyarthra	14	2.87	349	43.96
Small BG	3	0.62	75	0.00
Stephanodiscus	1	0.21	25	0.01
Synedra	37	7.60	923	0.56
Ulothrix	89	18.28	2220	7.24
Total Organisms	487			
Arthropods				
Bosmina	1	0.50	0	
Calanoid	2	1.00	1	
Cyclopoid	39	19.50	16	
Daphnia	13	6.50	5	
Diaphanozoma	16	8.00	7	
Nauplius	129	64.50	54	
Total Organisms	200			

Lake Monroe Plankton

061092 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass

Asterionella	74	37.56	1089	5.72
Ceratium	4	2.03	59	2.72
Dinobryon	70	35.53	1030	34.73
Fragillaria	3	1.52	44	1.35
Kellicottia	1	0.51	15	4.37
Keratella	4	2.03	59	13.84
Navicula(clamatis)	1	0.51	15	0.02
Polyarthra	8	4.06	118	32.90
Synedra	2	1.02	29	0.08
Ulothrix	19	9.64	280	4.22
Chrococcus dispersus	11	5.58	162	0.03
Total Organisms	197			
Arthropods				
Bosmina	3	1.05	1	
Calanoid	29	10.14	7	
Cyclopoid	21	7.34	5	
Daphnia	9	3.15	2	
Diaphanozoma	20	6.99	5	
Nauplius	203	70.98	50	
Unknown(Eubrachipus)	1	0.35	0	
Total Organisms	286			

Lake Monroe Plankton

062492 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	3	1.82	202	0.30
Ceratium	3	1.82	202	1.87
Dinobryon	10	6.06	673	5.73
Fragillaria	1	0.61	67	0.42
Karetella	1	0.61	67	3.17
Mallomonus	2	1.21	135	0.06
Melosira	3	1.82	202	0.09
Phormidium	2	1.21	135	0.01
Polyarthra	5	3.03	337	39.24
Synedra	9	5.45	606	0.34
Ulothrix	126	76.36	8481	48.78
Total Organisms	165			
Arthropods				
Bosmina	3	1.70	3	
Calanoid	5	2.84	6	
Cyclopoid	40	22.73	45	
Daphnia	21	11.93	24	
Diaphanozoma	10	5.68	11	
Nauplius	97	55.11	110	
Total Organisms	176			

Lake Monroe Plankton

062492 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	9	1.83	329	0.22
Asterionella	6	1.22	220	0.29
Ceratium	18	3.67	659	2.88

Dinobryon	107	21.79	3916	24.65
Fragillaria	5	1.02	183	1.05
Kellicottia	8	1.63	293	16.25
Keratella	1	0.20	37	1.61
Mallomonus	30	6.11	1098	0.43
Oscillatoria	1	0.20	37	0.01
Phormidium	2	0.41	73	0.00
Polyarthra	7	1.43	256	27.85
Small BG	1	0.20	37	0.00
Synedra	32	6.52	1171	0.62
Ulothrix	255	51.93	9332	24.15
Total Organisms	491			
Arthropods				
Bosmina	2	0.65	1	
Calanoid	6	1.96	4	
Cyclopoid	53	17.32	33	
Daphnia	25	8.17	15	
Diaphanozoma	47	15.36	29	
Nauplius	173	56.54	107	
Total Organisms	306			

Lake Monroe Plankton

062492 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	27	11.20	678	1.47
Ceratium	1	0.41	25	0.35
Dinobryon	114	47.30	2863	37.05
Fragillaria	8	3.32	201	1.87
Kellicottia	3	1.24	75	6.82
Keratella	9	3.73	226	16.19
Mallomonus	25	10.37	628	0.40
Phormidium	1	0.41	25	0.00
Polyarthra	7	2.90	176	31.18
Synedra	7	2.90	176	0.15
Ulothrix	35	14.52	879	4.37
Microcystis	4	1.66	100	0.14
Total Organisms	241			
Arthropods				
Bosmina	1	0.43	0	
Calanoid	17	7.30	7	
Cyclopoid	74	31.76	31	
Daphnia	17	7.30	7	
Diaphanozoma	21	9.01	9	
Nauplius	101	43.35	43	
Unknown	2	0.86	1	
Total Organisms	233			

Lake Monroe Plankton

070892 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	6	7.79	684	1.39
Asterionella	1	1.30	114	0.46
Ceratium	2	2.60	228	5.92

Dinobryon	4	5.19	456	6.31
Keratella	1	1.30	114	15.07
Melosira	3	3.90	342	0.43
Phormidium	8	10.39	912	0.10
Polyarthra	1	1.30	114	37.32
Synedra	15	19.48	1710	2.72
Synedra (s)	2	2.60	228	0.02
Ulothrix	31	40.26	3534	29.97
Anabaena (small)	1	1.30	114	0.06
Elakatothrix viridis	1	1.30	114	0.15
Cylindrospernum catenatum	1	1.30	114	0.06
Total Organisms	77			
Arthropods				
Bosmina	4	3.42	8	
Calanoid	3	2.56	6	
Cyclopoid	20	17.09	38	
Daphnia	1	0.85	2	
Diaphanozoma	7	5.98	13	
Nauplius	82	70.09	157	
Total Organisms	117			

Lake Monroe Plankton

060892 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	323	64.86	9966	20.92
Asterionella	2	0.40	62	0.25
Ceratium	2	0.40	62	1.65
Dinobryon	21	4.22	648	12.64
Fragillaria	8	1.61	247	4.37
Kellicottia	1	0.20	31	5.31
Keratella	1	0.20	31	4.20
Mallomonus	14	2.81	432	0.52
Phormidium	1	0.20	31	0.00
Polyarthra	2	0.40	62	20.79
Synedra	5	1.00	154	0.25
Ulothrix	108	21.69	3332	29.09
Total Organisms	498			
Arthropods				
Bosmina	1	0.31	1	
Calanoid	16	4.92	8	
Cyclopoid	61	18.77	32	
Daphnia	32	9.85	17	
Diaphanozoma	36	11.08	19	
Nauplius	179	55.08	93	
Total Organisms	325			

Lake Monroe Plankton

070892 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	59	19.87	2039	0.92
Asterionella	25	8.42	864	3.40
Dinobryon	26	8.75	899	14.87
Fragillaria	59	19.87	2039	26.53

Mallomonus	5	1.68	173	0.17
Oscillatoria	69	23.23	2385	1.07
Polyarthra	5	1.68	173	42.99
Synedra	12	4.04	415	0.58
Ulothrix	37	12.46	1279	9.47
Total Organisms	297			
Arthropods				
Calanoid	3	2.63	2	
Cyclopoid	32	28.07	19	
Daphnia	21	18.42	12	
Diaphanozoma	13	11.40	8	
Harpacticoid	2	1.75	1	
Nauplius	42	36.84	24	
Ostracoda	1	0.88	1	
Total Organisms	114			

Lake Monroe Plankton

072292 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	13	3.32	552	0.87
Ceratium	7	1.79	297	5.97
Fragillaria	8	2.04	340	4.53
Keratella	7	1.79	297	30.41
Melosira	4	1.02	170	0.17
Oscillatoria	97	24.74	4120	1.63
Phormidium	24	6.12	1019	0.09
Polyarthra	1	0.26	42	10.76
Synedra	77	19.64	3271	4.02
Synedra (s)	4	1.02	170	0.01
Ulothrix	149	38.01	6329	41.53
Unknown 4	1	0.26	42	0.00
Total Organisms	392			
Arthropods				
Bosmina	5	1.45	4	
Calanoid	39	11.30	28	
Cyclopoid	30	8.70	21	
Daphnia	22	6.38	16	
Diaphanozoma	53	15.36	38	
Nauplius	196	56.81	140	
Total Organisms	345			

Lake Monroe Plankton

072292 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	2	1.08	143	0.12
Asterionella	4	2.16	285	0.46
Ceratium	8	4.32	571	5.95
Dinobryon	15	8.11	1070	8.15
Fragillaria	30	16.22	2140	14.80
Kellicottia	2	1.08	143	9.58
Keratella	2	1.08	143	7.58
Mallomonus	3	1.62	214	0.10

Oscillatoria	2	1.08	143	0.03
Phormidium	1	0.54	71	0.00
Polyarthra	3	1.62	214	28.15
Synedra	12	6.49	856	0.55
Ulothrix	101	54.59	7206	24.55
Total Organisms	185			
Arthropods				
Bosmina	1	0.46	1	
Calanoid	18	8.22	22	
Cyclopoid	43	19.63	52	
Daphnia	22	10.05	26	
Diaphanozoma	22	10.05	26	
Nauplius	112	51.14	134	
Ostracoda	1	0.46	1	
Total Organisms	219			

Lake Monroe Plankton

072892 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	33	3.04	1175	1.13
Asterionella	2	0.18	71	0.04
Ceratium	21	1.93	748	1.67
Dinobryon	40	3.68	1424	6.75
Fragillaria	656	60.41	23361	79.81
Keratella	8	0.74	285	5.54
Mallomonus	2	0.18	71	0.02
Oscillatoria	157	14.46	5591	0.57
Phormidium	78	7.18	2778	0.36
Polyarthra	1	0.09	36	1.90
Staurastrum	2	0.18	71	0.04
Synedra	65	5.99	2315	0.73
Ulothrix	21	1.93	748	1.45
Total Organisms	1086			
Arthropods				
Bosmina	2	2.02	1	
Calanoid	10	10.10	6	
Cyclopoid	19	19.19	11	
Daphnia	9	9.09	5	
Diaphanozoma	12	12.12	7	
Harpacticoid	1	1.01	1	
Nauplius	46	46.46	28	
Total Organisms	99			

Lake Monroe Plankton

080492 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	1	0.47	51	0.16
Ceratium	11	5.14	564	22.98
Dinobryon	1	0.47	51	1.53
Fragillaria	3	1.40	154	4.16
Keratella	3	1.40	154	31.94
Melosira	2	0.93	103	0.20

Oscillatoria	52	24.30	2667	2.15
Phormidium	51	23.83	2616	0.47
Phormidium ?	10	4.67	513	0.09
Synedra	33	15.42	1693	4.23
Ulothrix	47	21.96	2411	32.10
Total Organisms	214			
Arthropods				
Bosmina	3	1.30	3	
Calanoid	23	10.00	20	
Cyclopoid	17	7.39	15	
Daphnia	8	3.48	7	
Diaphanozoma	20	8.70	17	
Nauplius	159	69.13	137	
Total Organisms	230			

Lake Monroe Plankton

080592 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	70	11.88	3937	2.57
Aphanocapsa	1	0.17	56	0.01
Ceratium	3	0.51	169	1.40
Fragillaria	111	18.85	6243	34.38
Keratella	6	1.02	337	14.28
Lyngbya	1	0.17	56	4.19
Merismopedia	4	0.68	225	0.02
Oscillatoria	10	1.70	562	0.09
Phormidium	120	20.37	6749	0.25
Polyarthra	4	0.68	225	23.57
Small BG	2	0.34	112	0.00
Synedra	150	25.47	8436	4.29
Ulothrix	98	16.64	5512	14.96
Total Organisms	589			
Arthropods				
Bosmina	2	1.18	2	
Calanoid	32	18.82	30	
Cyclopoid	14	8.24	13	
Daphnia	8	4.71	8	
Diaphanozoma	44	25.88	42	
Nauplius	68	40.00	64	
Unknown	2	1.18	2	
Total Organisms	170			

Lake Monroe Plankton

080592 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	41	6.83	870	2.71
Ceratium	3	0.50	64	2.60
Dinobryon	59	9.83	1252	14.41
Fragillaria	351	58.50	7445	48.21
Kellicottia	2	0.33	42	4.31
Keratella	3	0.50	64	6.43

Oscillatoria	5	0.83	106	0.03
Phormidium	57	9.50	1209	0.10
Polyarthra	4	0.67	85	16.87
Staurastrum	3	0.50	64	0.10
Synedra	41	6.83	870	0.84
Ulothrix	31	5.17	658	3.39
Total Organisms	600			
Arthropods				
Bosmina	8	4.49	3	
Calanoid	6	3.37	2	
Chaoborus	1	0.56	0	
Cyclopoid	40	22.47	14	
Daphnia	15	8.43	5	
Diaphanozoma	19	10.67	7	
Nauplius	89	50.00	32	
Total Organisms	178			

Lake Monroe Plankton

081992 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	11	4.89	930	1.94
Ceratium	1	0.44	85	3.54
Keratella	4	1.78	338	72.26
Mallomonus	1	0.44	85	0.16
Melosira	1	0.44	85	0.17
Nostoc	1	0.44	85	0.08
Oscillatoria	7	3.11	592	0.49
Phormidium	166	73.78	14042	1.46
Staurastrum	1	0.44	85	0.36
Stephanodiscus	1	0.44	85	0.10
Synedra	9	4.00	761	1.96
Synedra (s)	7	3.11	592	0.09
Ulothrix	15	6.67	1269	17.38
Total Organisms	225			
Arthropods				
Bosmina	1	0.81	1	
Calanoid	13	10.57	19	
Cyclopoid	20	16.26	28	
Daphnia	11	8.94	16	
Diaphanozoma	26	21.14	37	
Nauplius	52	42.28	74	
Total Organisms	123			

Lake Monroe Plankton

081992 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	278	59.53	10079	7.26
Aphanocapsa	1	0.21	36	0.03
Ceratium	1	0.21	36	1.27
Dynobryon	1	0.21	36	0.93
Fragillaria	5	1.07	181	4.23
Keratella	7	1.50	254	45.46

Mallomonus	1	0.21	36	0.06
Oscillatoria	18	3.85	653	0.45
Phormidium	54	11.56	1958	0.30
Polyarthra	1	0.21	36	16.08
Spirulina	2	0.43	73	0.02
Synedra	50	10.71	1813	3.91
Ulothrix	48	10.28	1740	20.00
Total Organisms	467			
Arthropods				
Bosmina	1	0.59	1	
Calanoid	22	12.94	13	
Cyclopoid	9	5.29	5	
Daphnia	6	3.53	4	
Diaphanozoma	22	12.94	13	
Nauplius	110	64.71	67	
Total Organisms	170			

Lake Monroe Plankton

081992 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	36	16.90	1016	2.07
Ceratium	2	0.94	56	0.53
Dinobryon	14	6.57	395	6.81
Fragillaria	87	40.85	2454	38.42
Keratella	2	0.94	56	6.78
Mallomonus	2	0.94	56	0.05
Mallomonus akrokomas	2	0.94	56	0.01
Phormidium	11	5.16	310	0.02
Polyarthra	5	2.35	141	42.00
Synedra	35	16.43	987	1.43
Ulothrix	17	7.98	480	1.87
Total Organisms	213			
Arthropods				
Bosmina	2	1.35	1	
Calanoid	30	20.27	14	
Cyclopoid	18	12.16	9	
Daphnia	15	10.14	7	
Diaphanozoma	23	15.54	11	
Nauplius	60	40.54	28	
Total Organisms	148			

Lake Monroe Plankton

090592 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	23	15.33	2018	2.20
Ceratium	1	0.67	88	2.59
Synedra (small)	2	1.33	175	0.02
Phormidium	116	77.33	10178	0.57
Polyarthra	3	2.00	263	91.43
Spirulina	1	0.67	88	0.02
Ulothrix	4	2.67	351	3.16

Total Organisms	150		
Arthropods			
Bosmina	2	1.54	3
Calanoid	12	9.23	18
Cyclopoid	37	28.46	55
Daphnia	6	4.62	9
Diaphanozoma	8	6.15	12
Nauplius	65	50.00	96
Total Organisms	130		

Lake Monroe Plankton

090592 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	227	82.55	8463	14.00
Diffugia?	4	1.45	149	39.53
Fragillaria	2	0.73	75	1.04
Melosira	1	0.36	37	0.04
Oscillatoria	1	0.36	37	0.02
Phormidium	11	4.00	410	0.04
Polyarthra	4	1.45	149	39.61
Spirulina	1	0.36	37	0.01
Synedra	1	0.36	37	0.05
Ulothrix	22	8.00	820	5.64
Stephanodiscus	1	0.36	37	0.02
Total Organisms	275			
Arthropods				
Bosmina	6	2.80	4	
Calanoid	12	5.61	8	
Cyclopoid	34	15.89	21	
Daphnia	27	12.62	17	
Diaphanozoma	29	13.55	18	
Nauplius	106	49.53	66	
Total Organisms	214			

Lake Monroe Plankton

090592 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	56	21.54	1306	3.06
Asterionella	1	0.38	23	0.11
Ceratium	4	1.54	93	2.78
Coelospharium	1	0.38	23	0.06
Dinobryon	38	14.62	886	19.30
Fragillaria	38	14.62	886	17.52
Kellicottia	2	0.77	47	8.95
Keratella	9	3.46	210	31.87
Mallomonus	2	0.77	47	0.06
Mallomonus Akrokomas	1	0.38	23	0.00
Oscillatoria	16	6.15	373	0.22
Phormidium	22	8.46	513	0.07
Synedra	17	6.54	397	0.72
Synura	1	0.38	23	3.47
Ulothrix	52	20.00	1213	11.81

Total Organisms	260		
Arthropods			
Bosmina	10	4.52	4
Calanoid	15	6.79	6
Ceriodaphnia	2	0.90	1
Chaoborus	2	0.90	1
Cyclopoid	10	4.52	4
Daphnia	36	16.29	14
Diaphanozoma	35	15.84	14
Harpacticoid	1	0.45	0
Nauplius	105	47.51	41
Ostracoda	1	0.45	0
Unknown Copepod	4	1.81	2
	0	0.00	0
Total Organisms	221		

Lake Monroe Plankton

101192 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	4	1.50	176	0.23
Asterionella	3	1.13	132	0.27
Dinobryon	1	0.38	44	0.54
Fragillaria	7	2.63	308	3.43
Melosira	3	1.13	132	0.11
Oscillatoria	121	45.49	5324	1.76
Peridinium	1	0.38	44	0.80
Phormidium	10	3.76	440	0.01
Tetraspora	1	0.38	44	0.08
Polyarthra	8	3.01	352	74.48
Stephanodiscus	1	0.38	44	0.02
Synedra	17	6.39	748	0.77
Synedra (s)	18	6.77	792	0.05
Ulothrix	70	26.32	3080	17.38
Cylindrodapsa	1	0.38	44	0.07
Total Organisms	266			
Arthropods				
Bosmina	16	9.14	12	
Calanoid	10	5.71	7	
Cyclopoid	39	22.29	29	
Daphnia	8	4.57	6	
Diaphanozoma	2	1.14	1	
Nauplius	100	57.14	74	
	0	0.00	0	
Total Organisms	175			

Lake Monroe Plankton

101192 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	9	3.80	273	0.99
Asterionella	7	2.95	213	1.51
Ceratium	2	0.84	61	2.80
Dynobryon	1	0.42	30	1.02
Fragellaria	7	2.95	213	6.49

Keratella	1	0.42	30	7.13
Mallomonus	4	1.69	121	0.25
Oscillatoria	34	14.35	1033	0.94
Phormidium	43	18.14	1306	0.27
Polyarthra	2	0.84	61	35.29
Small BG	2	0.84	61	0.00
Synedra	36	15.19	1093	3.09
Ulothrix	88	37.13	2673	40.23
Total Organisms	237			
Arthropods				
Bosmina	25	17.61	13	
Calanoid	3	2.11	2	
Cyclopoid	35	24.65	18	
Daphnia	12	8.45	6	
Diaphanozoma	5	3.52	3	
Nauplius	62	43.66	32	
Total Organisms	142			

101192 Lower Basin

Date and Location

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	10	0.93	219	0.21
Asterionella	46	4.29	1009	1.92
Dinobryon	1	0.09	22	0.20
Fragillaria	36	3.36	790	6.48
Kellicottia	1	0.09	22	1.75
Keratella	2	0.19	44	2.76
Mallomonus	2	0.19	44	0.02
Oscillatoria	113	10.54	2479	0.61
Polyarthra	4	0.37	88	13.69
Synedra	50	4.66	1097	0.83
Ulothrix	807	75.28	17701	71.53
Total Organisms	1072			
Arthropods				
Bosmina	9	6.12	3	
Calanoid	8	5.44	3	
Cyclopoid	32	21.77	12	
Daphnia	32	21.77	12	
Diaphanozoma	3	2.04	1	
Nauplius	63	42.86	23	
Total Organisms	147			

Lake Monroe Plankton

111592 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	100	25.00	6300	8.36
Keratella	10	2.50	630	27.60
Merismopedia	1	0.25	63	0.01
Oscillatoria	24	6.00	1512	0.26
Phormidium	25	6.25	1575	0.06
Polyarthra	4	1.00	252	27.24
Synedra	32	8.00	2016	1.06

Synedra (s)	4	1.00	252	0.01
Ulothrix	200	50.00	12599	35.41
Total Organisms	400			
Arthropods				
Bosmina	30	17.96	32	
Calanoid	7	4.19	7	
Cyclopoid	42	25.15	45	
Daphnia	21	12.57	22	
Nauplius	67	40.12	71	
	0	0.00	0	
Total Organisms	167			

Lake Monroe Plankton

111592 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	4	0.31	116	0.09
Aphanocapsa	1	0.08	29	0.00
Asterionella	45	3.44	1301	1.89
Ceratium	1	0.08	29	0.27
Coelospharium	1	0.08	29	0.02
Dinobryon	4	0.31	116	0.79
Fragillaria	15	1.15	434	2.71
Keratella	6	0.46	173	8.32
Mallomonus	1	0.08	29	0.01
Melosira	51	3.90	1474	0.68
Microcystis	1	0.08	29	0.03
Oscillatoria	283	21.64	8180	1.52
Phormidium	74	5.66	2139	0.09
Polyarthra	4	0.31	116	13.73
Staurastrum	3	0.23	87	0.08
Synedra	36	2.75	1041	0.60
Ulothrix	778	59.48	22489	69.17
	0	0.00	0	0.00
Total Organisms	1308			
Arthropods				
Bosmina	81	36.32	39	
Calanoid	6	2.69	3	
Cyclopoid	36	16.14	18	
Daphnia	19	8.52	9	
Diaphanozoma	4	1.79	2	
Nauplius	73	32.74	36	
Unknown	4	1.79	2	
Total Organisms	223			

Lake Monroe Plankton

111592 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	49	4.99	1715	2.40
Fragillaria	9	0.92	315	1.89
Kellicottia	1	0.10	35	2.04
Keratella	4	0.41	140	6.46

Mallomonus	1	0.10	35	0.01
Microsystis	1	0.10	35	0.03
Oscillatoria	107	10.91	3745	0.67
Polyarthra	2	0.20	70	8.00
Synedra	57	5.81	1995	1.11
Tabelaria (???)	1	0.10	35	0.03
Ulothrix	747	76.15	26142	77.36
Chrococcus dispersus	2	0.20	70	0.00
Total Organisms	981			
Arthropods				
Bosmina	6	10.91	4	
Cyclopoid	6	10.91	4	
Daphnia	15	27.27	9	
Nauplius	28	50.91	16	
Total Organisms	55			

Lake Monroe Plankton

011793 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	5	9.26	281	1.81
Dinobryon	6	11.11	337	10.28
Fragillaria sp.	1	1.85	56	3.05
Keratella	2	3.70	112	46.89
Oscillatoria	9	16.67	506	0.82
Synedra	12	22.22	675	9.21
Ulothrix	19	35.19	1069	27.94
Total Organisms	54			
Arthropods				
Bosmina	1	2.86	1	
Cyclopoid	1	2.86	1	
Daphnia	1	2.86	1	
Nauplius	32	91.43	30	
Total Organisms	35			

Lake Monroe Plankton

011793 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	1061	82.12	19425	66.31
Chroocococcus	3	0.23	55	0.01
Dinobryon	21	1.63	384	6.21
Euglena	37	2.86	677	0.71
Fragillaria	48	3.72	879	12.90
Keratella	1	0.08	18	2.06
Mallomonus	12	0.93	220	0.22
Monoraphidium Setiforme	1	0.08	18	0.00
Oscillatoria	48	3.72	879	0.38
Polyarthra	1	0.08	18	5.11
Stephanodiscus	1	0.08	18	0.01
Synedra	9	0.70	165	0.22
Tabellaria	7	0.54	128	0.29
Ulothrix	42	3.25	769	5.56
Total Organisms	1292			

Arthropods			
Bosmina	28	19.31	9
Calanoid	4	2.76	1
Cyclopoid	31	21.38	10
Daphnia	4	2.76	1
Diaphanozoma	1	0.69	0
Harpacticoid	1	0.69	0
Nauplius	76	52.41	23
Total Organisms	145		

Lake Monroe Plankton

032793 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Aphanocapsa	3	0.91	154	0.05
Asterionella	119	36.28	6119	8.18
Chrysophaerella	3	0.91	154	13.74
Dinobryon	62	18.90	3188	39.61
Fragillaria	14	4.27	720	8.12
Mallomonus	2	0.61	103	0.08
Oscillatoria	4	1.22	206	0.07
Phormidium	51	15.55	2623	0.20
Synedra	5	1.52	257	0.27
Synura	2	0.61	103	8.74
Tabellaria-sections	51	15.55	2623	4.63
Ulothrix	9	2.74	463	2.57
Tabellaria sp.	3	0.91	154	13.74
Total Organisms	328			
Arthropods				
Nauplius	10	100.00	9	
Total Organisms	10			

Lake Monroe Plankton

0327 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	1151	81.52	55904	53.68
Dinobryon	58	4.11	2817	12.81
Fragillaria	105	7.44	5100	21.05
Melosira	4	0.28	194	0.06
Oscillatoria	9	0.64	437	0.05
Polyarthra	1	0.07	49	3.81
Stephanodiscus	30	2.12	1457	0.26
Synedra	24	1.70	1166	0.44
Synura	4	0.28	194	6.04
Tabellaria-sections	21	1.49	1020	0.66
Trichocerca	1	0.07	49	0.73
Ulothrix	4	0.28	194	0.40
Total Organisms	1412			
Arthropods				
Bosmina	3	10.34	2	
Cyclopoid	5	17.24	4	
Nauplius	21	72.41	17	
Total Organisms	29			

Lake Monroe Plankton

032793 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	1633	75.57	159955	43.99
Dinobryon	46	2.13	4506	5.87
Fragillaria	341	15.78	33401	39.49
Huge Fragillaria??	1	0.05	98	6.29
Melosira	1	0.05	98	0.01
Oscilatoria	6	0.28	588	0.02
Stephanodiscus	69	3.19	6759	0.35
Synedra	27	1.25	2645	0.29
Synura	3	0.14	294	2.62
Tabellaria sections	22	1.02	2155	0.40
Ulothrix	12	0.56	1175	0.68
Total Organisms	2161			
Arthropods				
Bosmina	6	15.00	12	
Cyclopoid	4	10.00	8	
Daphnia	1	2.50	2	
Nauplius	29	72.50	58	
Total Organisms	40			

Lake Monroe Plankton

041893 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	11	14.10	891	5.52
Dinobryon	16	20.51	1296	38.05
Fragillaria sp.	1	1.28	81	2.16
Keratella	2	2.56	162	33.17
Melosira	2	2.56	162	0.32
Oscillatoria	2	2.56	162	0.18
Synedra	6	7.69	486	1.20
Synedra-small	20	25.64	1620	0.25
Ulothrix	18	23.08	1458	19.15
Total Organisms	78			
Arthropods				
Bosmina	1	2.44	1	
Calanoid	4	9.76	5	
Cyclopoid	5	12.20	7	
Nauplius	31	75.61	42	
Total Organisms	41			

Lake Monroe Plankton

041793 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	205	33.28	6852	17.81
Dinobryon	34	5.52	1136	13.98
Keratella	4	0.65	134	11.47

Melosira	3	0.49	100	0.08
Oscillatoria	8	1.30	267	0.09
Polyarthra	3	0.49	100	21.31
Synedra	224	36.36	7487	7.73
Synedra (small)	28	4.55	936	0.06
Ulothrix	94	15.26	3142	17.30
Unknown	13	2.11	435	10.17
Total Organisms	616			
Arthropods				
Bosmina	7	3.23	4	
Calanoid	3	1.38	2	
Cyclopoid	55	25.35	31	
Daphnia	7	3.23	4	
Nauplius	145	66.82	82	
Total Organisms	217			

Lake Monroe Plankton

041793 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Anabaena	3	0.17	83	0.05
Asterionella	477	27.78	13198	17.08
Dinobryon	40	2.33	1107	6.78
Fragillaria	1	0.06	28	0.15
Kellicottia	1	0.06	28	1.49
Keratella	3	0.17	83	3.55
Mallomonus	9	0.52	249	0.09
Melosira	9	0.52	249	0.10
Oscillatoria	3	0.17	83	0.01
Phormidium	11	0.64	304	0.01
Polyarthra	12	0.70	332	35.14
Spirulina	3	0.17	83	0.01
Stephanodiscus	11	0.64	304	0.07
Synedra	802	46.71	22190	11.41
Synedra (small)	61	3.55	1688	0.05
Ulothrix	268	15.61	7415	20.33
Tabellaria sp.	3	0.17	83	3.65
	0	0.00	0	0.00
Total Organisms	1717			
Arthropods				
Bosmina	9	3.44	4	
Calanoid	5	1.91	2	
Cyclopoid	41	15.65	19	
Daphnia	3	1.15	1	
Nauplius	204	77.86	95	
Total Organisms	262			

Lake Monroe Plankton
Bad sample
051893 Upper Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	13	0.84	941	2.29
Chroococcus (cells)	1478	95.97	106983	7.47
Dinobryon	2	0.13	145	1.67
Filinia	29	1.88	2099	22.54

Fragillaria	9	0.58	651	6.82
Oscillatoria	1	0.06	72	0.02
Polyarthra	4	0.26	290	57.68
Ulothrix	4	0.26	290	1.49
Total Organisms	1540			
Arthropods				
Bosmina	42	54.55	51	
Calanoid	3	3.90	4	
Cyclopoid	7	9.09	9	
Daphnia	6	7.79	7	
Diaphanozoma	11	14.29	13	
Nauplius	8	10.39	10	
Total Organisms	77			

Lake Monroe Plankton

051893 Middle Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	324	27.60	53297	17.64
Chroococcus (cells)	512	43.61	84222	0.80
Dinobryon	3	0.26	493	0.77
Fragillaria	316	26.92	51981	73.96
Kellicottia	1	0.09	164	2.27
Keratella	2	0.17	329	3.60
Mallomonus	3	0.26	493	0.05
Melosira	1	0.09	164	0.02
Oscillatoria	1	0.09	164	0.01
Stephanodiscus	1	0.09	164	0.01
Synedra	3	0.26	493	0.06
Ulothrix	7	0.60	1151	0.81
Total Organisms	1174			
Arthropods				
Bosmina	12	50.00	33	
Calanoid	2	8.33	6	
Cyclopoid	2	8.33	6	
Daphnia	5	20.83	14	
Diaphanozoma	2	8.33	6	
Nauplius	1	4.17	3	
Total Organisms	24			

Lake Monroe Plankton

051893 Lower Basin

Plankton Species	Total Count	% of count	Num/L	% of Biomass
Asterionella	621	60.23	152607	26.41
Dinobryon	1	0.10	246	0.20
Fragillaria	399	38.70	98052	72.95
Mallomonus	1	0.10	246	0.01
Stephanodiscus	1	0.10	246	0.01
Stichococcus	1	0.10	246	0.01
Synedra	3	0.29	737	0.05
Ulothrix	4	0.39	983	0.36
Total Organisms	1031			
Arthropods				

Bosmina	3	33.33	12
Cyclopoid	1	11.11	4
Daphnia	2	22.22	8
Nauplius	3	33.33	12
Total Organisms	9		

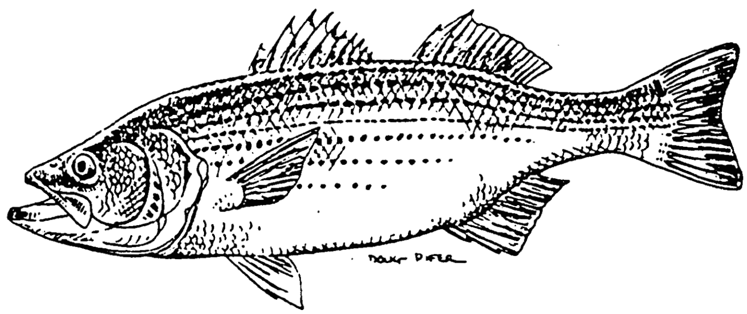
APPENDIX D:

1992 FISH MANAGEMENT REPORT

MONROE RESERVOIR

1992 Fish Management Report

Steven J. Andrews
Fisheries Biologist



FISHERIES SECTION
INDIANA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND WILDLIFE
402 W. Washington Street
Indianapolis, Indiana 46204

1993

MONROE RESERVOIR
Brown and Monroe Counties

Fish Management Report
1992

INTRODUCTION

Lake Monroe is a 10,750 acre flood control reservoir located in Brown and Monroe Counties southeast of Bloomington, Indiana. It is the largest lake in Indiana, and recreational activities such as boating and fishing are very important. Boat access is available at ten publicly-owned ramps located around the lake. In addition, several privately-owned recreational facilities such at boat rentals, sport shops, marinas, and campgrounds are available. Lake Monroe also serves as the primary water supply for the city of Bloomington.

At normal pool, the maximum depth of Lake Monroe is 54 feet with an average depth of 25 feet. The water level is regulated by the Corps of Engineers and is relatively stable, but may fluctuate up to 10 feet depending on water storage needs. The lake is divided into two distinct basins which are separated by the State Road 446 causeway. The upper basin receives 90% of the runoff entering the lake, and is shallower and more turbid than the lower basin. During summer, oxygen concentrations in the lower basin are adequate for fish down to depths of 20 to 25 feet. In the upper basin, adequate oxygen is present down to about 15 feet.

Since impoundment in 1965, Lake Monroe has been managed primarily for largemouth bass and panfish fishing. A 14-inch minimum size limit on largemouth bass has been in effect since 1973. As often occurs at new reservoirs, Monroe provided excellent fishing for several years after impoundment. Fishing quality began to level off as the reservoir aged, accompanied by increases in numbers of less desirable species such as yellow perch, yellow bass, and gizzard shad. Since about 1982, the lake's fish community has been characterized by an overabundance of forage fish and too few predator fish.

Additional fish management practices at Lake Monroe have included several supplemental predator stockings. Early stockings included both northern pike and walleye, but were for the most part unsuccessful. One stocking of 4,500, 10 to 18 inch pike in 1979 did provide moderate success with some returns to the creel. Stockings in the last decade have included both walleye and hybrid striped bass (Table.). The intent of these stockings has been to provide additional fishing opportunities and utilize some of the surplus forage fish, particularly gizzard shad.

Table. Walleye (WAE) and hybrid striped bass (HSB) stockings at Lake Monroe, 1982 through 1992.

Year	Species	Number	No./Acre	Size
1982	WAE	73,700	6.8	1-2"
1985	WAE	8,300	0.8	3"
1986	WAE	48,147	4.5	1-2"
1987	WAE	37,853	3.5	3"
1988	WAE	573,094	53.3	1-2"
1989	WAE	524,362	48.8	1-2"
1990	WAE	642,392	59.8	1-2"
1990	WAE	11,255,325	1,047	Fry
1991	WAE	461,102	42.9	1.5-2.5"
1992	WAE	541,766	50.4	1-2"
1983	HSB	58,282	5.4	1-2"
1984	HSB	100,000	9.3	Fry
1984	HSB	44,540	4.1	2"
1985	HSB	107,000	10.0	1-2"
1986	HSB	53,850	5.0	1-2"
1988	HSB	10,710	1.0	2"
1989	HSB	75,250	7.0	2"
1990	HSB	53,760	5.0	1-2"
1991	HSB	53,750	5.0	1-2"
1992	HSB	54,716	5.1	1-2"

A fisheries survey was conducted at Lake Monroe July 8-28, 1992. The objectives of the survey were to monitor reproduction and growth of largemouth bass and panfish, and to assess any changes in the predator-prey balance. Survey effort consisted of 6.99 hours of D.C. electrofishing, 23 overnight gill net sets, and eight overnight trap net sets. This report presents the results of that survey along with recommendations for future work.

RESULTS AND DISCUSSION

Water chemistry parameters reflected the cool weather which occurred during late spring and early summer of 1992. The lake was beginning to stratify thermally, but the thermocline was still relatively wide and indistinct. At the time of the survey, dissolved oxygen was adequate for game fish survival in the lower basin of the lake to a depth of at least 20 feet. The Secchi disk reading, an index of water transparency, was relatively high for Lake Monroe at 8 feet.

Fish sampling efforts produced 6,963 fish weighing a total of 2,047 pounds. Twenty-four species and one hybrid were represented in the catch. Gizzard shad were most abundant in the sample by number (35%), followed by bluegill (30%), yellow bass (13%), white crappie (6%), largemouth bass (3%), channel catfish (3%), longear sunfish (3%), spotfin shiner (2%), and palmetto bass (hybrid striped bass) at 1%. The remaining species were relatively insignificant in the catch by number, comprising less than 1% of the sample each. By weight, channel catfish were most abundant (20%), followed by gizzard shad (18%), bluegill (13%), largemouth bass (13%), common carp (12%), yellow bass (7%), palmetto bass (6%), walleye (4%), and white crappie (2%). Each of the remaining species comprised 1% or less of the sample by weight.

The gizzard shad sample consisted of 2,421 fish ranging from 2 to 13 1/2 inches in length. Shad abundance was similar both by number and weight to that observed in a 1988 fisheries survey. Reproductive success appeared to be fairly consistent, with all year classes from 1984 through 1992 represented in the catch. Shad growth rates were below average in comparison to shad at other area lakes, with several year classes "piling up" in the 7 1/2 to 8 1/2 inch size range. Shad weights were average in comparison to shad at other lakes.

A total of 2,078 bluegill was collected during the survey. A large number of these fish were captured in trap nets (205 fish/set), possibly due to late spawning activities during the year. The electrofishing catch rate for bluegill was actually about half of the 1988 catch rate. Bluegill collected during the present survey did show a significant improvement in length distribution. They ranged from 2 to 8 inches in length, and 61% were harvestable size, 6 inches or larger. In addition, 18% of the bluegill collected were 7 inches in length or larger as compared to only 1% in 1988. Bluegill growth rates and weights were both average.

The yellow bass sample consisted of 917 fish ranging from 1 1/2 to 9 inches in length. Gill net catch rates for yellow bass declined from 47 fish/set in 1988 to 34 fish/set in the present survey. Yellow bass size distribution improved, with 12% of the fish measuring 8 inches or larger, as compared to only 2% in 1988. Yellow bass growth rates were similar to 1988, while weights improved for 7 inch and larger fish.

A total of 381 white crappie was collected during the survey. They ranged from 2 to 13 1/2 inches in length, and 10% were 8 inches or larger. Crappie reproductive success appeared to be consistent, with all year classes from 1985 through 1992 represented in the catch. During a fall sample conducted as part of another work plan, 379 white crappie were collected in 16 trap net sets. The fall trap net catch rate was 24 fish/set as compared to 6 fish/set in the summer survey. Length distribution of fish in the fall sample was similar to that of the summer survey, except that more young-of-the-year crappie were collected in the fall. Crappie growth rates and weights were average in comparison to white crappie at other area lakes.

The largemouth bass catch was 228 fish ranging from 2 to 20 1/2 inches in length. Legal size bass, those 14 inches or larger, comprised 28% of the catch. Initially, it appeared that the number of small bass had declined since 1988. However, during fall sampling for walleye, largemouth bass were observed at a rate of 103 fish/hour of electrofishing. This included all sizes of bass except for young-of-the-year, but was mostly small to intermediate size fish. During the summer survey, the night electrofishing catch rate was 40 bass/hour.

Reproductive success of largemouth bass appeared to be consistent, with all year classes from 1985 through 1992 represented in the catch. Young-of-the-year bass were also observed to be common during the fall walleye sampling. Bass growth rates were above average after age 3, with most bass reaching 14 inches between ages 3 and 4. Weights were average for bass up to 11 inches, and above average for larger fish. Above average growth and weights of larger bass reflect the abundance of forage available.

A total of 221 channel catfish was collected during the survey. They ranged from 6 to 30 1/2 inches in length, and the largest weighed over 10 pounds. Catfish were well distributed within this size range, and reproductive success appeared to be consistent. Channel catfish weights were average in comparison to channel catfish at other area lakes.

The longear sunfish catch consisted of 185 fish ranging from 2 to 6 inches in length. Electrofishing catch rates declined from 39 fish/hour in 1988 to 23 fish/hour in the present survey. Length distribution improved somewhat, although most longear are still too small to interest anglers.

Eighty-nine hybrid striped bass were collected during the survey. Gill net catch rates increased from two fish/set in 1988 to four fish/set in the current survey. This increase resulted from a more consistent stocking schedule after 1988. Hybrid stripers collected during the present survey ranged from 8 to 22 inches in length. Three year classes (1989-1991) were represented in the catch, and survival appeared to be fairly consistent.

Despite the increase in numbers, growth rates of hybrid stripers have also improved at Lake Monroe. In the present survey, the average length of a hybrid at age 1 was 1 1/2 inches larger than in 1988. As a result, fish are also larger at each succeeding age. The lack of fish over 22 inches in the catch was probably due to size selectivity of the gill nets. Hybrids measuring 23 to 25 inches long were fairly common in a 1991 creel survey. There was also at least one verified fish over 12 pounds caught at Lake Monroe during 1992.

Fifty-two walleye were collected during the survey. They ranged from 8 1/2 to 26 1/2 inches in length, and the largest fish weighed over 7 1/2 pounds. All stockings from 1987 through 1991 were represented in the catch. Almost half (46%) of the walleye were from the 1990 year class and ranged from 13 1/2 to 19 1/2 inches in length. The 1990 stocking was the largest fingerling stocking to date, and included surplus fry as well (Table). No young-of-the-year walleye were collected during the survey, but 347 were captured during fall walleye sampling. The 1992 catch rate for young-of-the-year was approximately three times better than the highest previously recorded catch rate. The reasons for better survival during 1992 are not clear, but may be related to reduced competition and/or predation on stocked walleye.

Other game fish collected during the survey included yellow perch, redear sunfish, black crappie, warmouth, flathead catfish, and brown and yellow bullheads. These species are likely to persist and make occasional contributions to the creel. In particular, yellow perch and redear sunfish seem to be increasing both in numbers and size at present.

Other species of nongame fish collected besides gizzard shad included spotfin shiner, common carp, logperch, brook silverside, shorthead redhorse, golden shiner, white sucker, spotted sucker, and grass pickerel. Carp were insignificant in the sample by number, but ranked fifth by weight. Most carp were large, with the smallest measuring 13 inches in length. Carp are abundant enough to compete with game fish to some extent, but the lack of small carp suggests that predators may be suppressing further expansion of the population. The other nongame fishes do not appear to be detrimental to the fishery at present. Spotfin shiners and brook silversides may be benefiting the fishery by providing additional forage.

CONCLUSIONS AND RECOMMENDATIONS

The Lake Monroe fishery is in better condition than it has been for at least ten years. Increases in the size of bluegill, yellow bass, and longear sunfish, accompanied by decreases in catch rates of yellow bass and longear, suggest that competitive pressures are easing somewhat. Increases in first year growth of hybrid striped bass and increased survival of stocked walleye may indicate that more subtle changes are also occurring in the fish community. While these changes have not produced major shifts in the predator-prey balance, they have led to better fishing opportunities.

Bluegill, yellow bass, and white crappie should provide fair to good fishing opportunities in the near future. Anglers will not find exceptionally large panfish, but they should find more harvestable size fish than in the recent past. Yellow perch are also beginning to get large enough to interest anglers. They will probably make occasional contributions to the panfish catch along with redear sunfish and black crappie.

Predator fishing opportunities should also be relatively good during the next few years. Due to the abundance of forage, growth of adult largemouth bass is above average and legal size bass are relatively abundant. Bass reproductive success appears to be satisfactory which should help maintain good bass fishing opportunities. Channel catfish fishing should be better than at anytime in the lake's history. The 1991 creel survey showed that a significant fishery for hybrid striped bass already exists at Monroe, which should improve with a consistent stocking program. There are also indications that the walleye fishery may improve if increased early survival of walleye translates into more fish in the population.

The changes in the Lake Monroe fishery may represent normal variation, but they also appear to be at least partially related to the predator stocking program. Since the predator stocking program is providing some benefits, and does not appear to be negatively impacting the fishery, it is recommended that the program be expanded. To date, hybrid striped bass have generated the most interest and returns to the creel. It is therefore recommended that the annual hybrid striped bass stocking rate be increased from five to ten fingerlings per acre, provided that the fish are available. Hybrid stripers feed extensively on gizzard shad, and the shad population at Monroe currently appears to be large enough to support an increase in stocking. Increased stocking should provide better fishing for hybrid stripers, and may lead to continued improvements in the fishery as a whole.

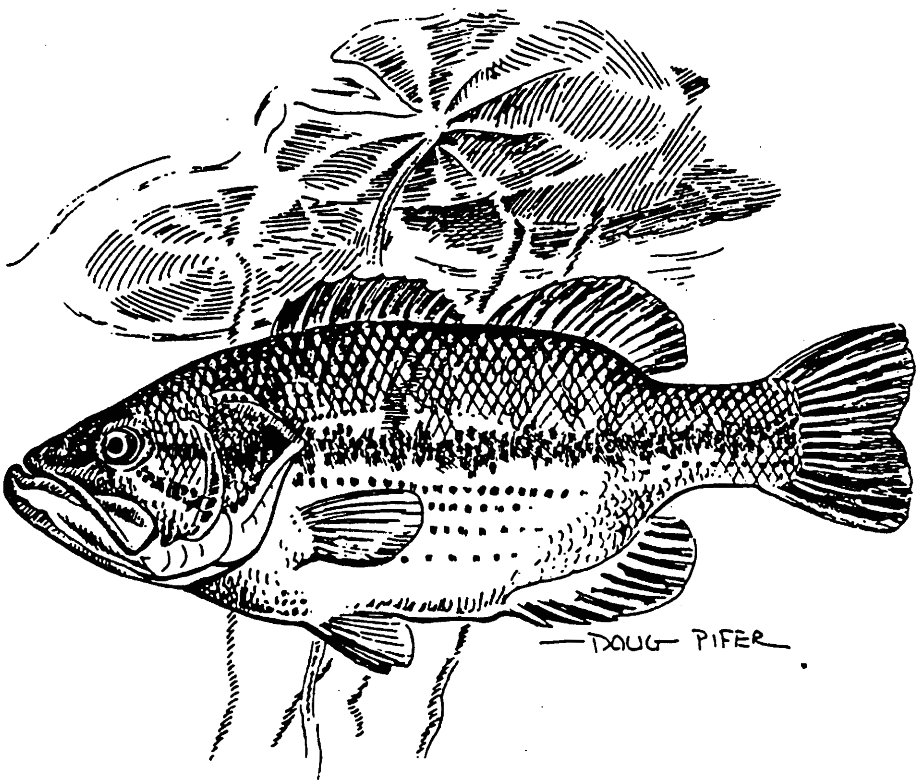
As recommended in the 1991 creel survey report, the walleye stocking program should also be continued through 1994. The annual stocking rate should continue to be 50 fingerlings per acre. If possible, another creel survey should be conducted in 1994, when the current year class (1992) should make its largest contribution to the creel. The objectives of the survey will be to evaluate angler interest and returns to the creel of both walleye and hybrid striped bass, as well as other species.

Although hybrid striped bass and walleye are important, largemouth bass will continue to be the primary predator at Lake Monroe. To protect bass from overharvest, the 14 inch minimum size limit should remain in effect. Lake Monroe should be surveyed every three to five years to monitor reproduction and growth of largemouth bass and panfish, and evaluate any changes in the predator-prey balance. Spot-check surveys should also be conducted each fall to monitor survival of stocked walleye, until a determination is made about the future of this program.

Submitted by: Steven J. Andrews, Fisheries Biologist
Date: November 30, 1992

Approved by: Thomas M. Flatt
Thomas M. Flatt, Fisheries Supervisor

Approved by: William D. James
William D. James, Chief of Fisheries
Date: March 1, 1993



LAKE SURVEY REPORT

State Form 24753R

Type of survey: ☐ Initial survey ☒ Re-survey

Lake name	County	Date of survey (Month, day, year)
Monroe Reservoir	Brown and Monroe	7/8-28/92

Biologist's name	Date of approval (Month, day, year)
Steven J. Andrews	3/1/93

LOCATION

Quadrangle name	Range	Section
Clear Creek, Indiana	1W	27

Township name	Nearest town
7N	Bloomington, Indiana

ACCESSIBILITY

State owned public access site	Privately owned public access site	Other access site
Nine state-owned & 1 federal-owned boat ramp		Two boat liveries

Surface acres	Maximum depth	Average depth	Acre feet	Water level	Extreme fluctuations
10,750	54 Feet	25 Feet	268,750	536 Feet MSL	10 Feet

Location of benchmark: 523

INLETS

Name	Location	Origin
North Fork Salt Creek	Belmont & Nashville Quads	T9N, R4E, S19
Middle Fork Salt Creek	Elkinsville, Story	
South Fork Salt Creek	Elkinsville, Story, Kurtz & Brownstown	

OUTLET

Name	Location
Salt Creek	Two miles east of Harrodsburg, Indiana

Water level control: 3 main gates 2.75' x 12'; 2 low flow 36" gate valves. Low flow valves receive water from multi-level inlets, permitting temperature control.

POOL	ELEVATION (Feet MSL)	ACRES
TOP OF DAM	574	
TOP OF FLOOD CONTROL POOL	556	18,600
TOP OF CONSERVATION POOL	538	10,750
TOP OF MINIMUM POOL	515	3,280
STREAMBED		

Bottom type:
- ☐ Boulder
- ☒ Gravel
- ☒ Sand
- ☒ Muck
- ☒ Clay
- ☐ Marl

Watershed use: Brown County State Park, Yellowwood State Forest, Hoosier National Forest, agricultural.

Development of shoreline: State and private camping areas, bait shops, marinas, sport shops, motels, etc.

Previous surveys and investigations: Fisheries surveys: 1965-1972, 1979, 1980, 1982, 1984-1987, 1988. Embayment sampling: 1967-1969, 1973-1976, 1978. Creel surveys: 1967, 1969, 1970, 1991. IU limnological investigations: 1966-1969 & 1974-1975. IU Food Habits Study: 1970, IU Benthos Study: 1971.

SAMPLING EFFORT

ELECTROFISHING	Day hours 2.99	Night hours 4.00	Total hours 6.99
TRAPS	Number of traps 8	Hours Varied	Total hours 183.75
GILL NETS	Number of nets 23	Hours Varied	Total hours 485.75

PHYSICAL AND CHEMICAL CHARACTERISTICS

Color	Turbidity
Clear green	8 Feet 0 Inches (SECCHI DISK)

TEMPERATURE

DEPTH FEET	DEGREES F°	DEPTH FEET	DEGREES F°	DEPTH FEET	DEGREES F°
SURFACE	79.0	40	62.5	80	
2	78.5	42	61.5	82	
4	78.5	44	61.0	84	
6	78.5	46	61.0	86	
8	78.5	48	60.5	88	
10	78.5	50	60.0	90	
12	78.5	52	60.0	92	
14	78.5	54	59.5	94	
16**	77.0	56		96	
18	76.5	58		98	
20	75.0	60		100	
22	74.0	62			
24	73.5	64			
26	73.0	66			
28	71.5	68			
30	68.0	70			
32 **	66.0	72			
34	65.0	74			
36	64.0	76			
38	63.0	78			

DISSOLVED OXYGEN (D.O.) - TOTAL ALKALINITY - pH

DEPTH FEET	D.O. (ppm)*	ALKALINITY (ppm)*	pH	DEPTH FEET	D.O. (ppm)*	ALKALINITY (ppm)*	pH	Comments:
SURFACE	10.0	51.3	7.5	45				**Limits of thermocline.
5	10.0			50	0.0			
10	9.0			~~55~~ 54	0.0	51.3	7.5	
15	9.0			60				
20	6.0			65				
25	2.0			70				
30	0.2			75				
35	0.0			80				
40	0.0							

*ppm = parts per million

SPECIES AND RELATIVE ABUNDANCE OF FISHES COLLECTED BY NUMBER AND WEIGHT

*COMMON NAME OF FISH	NUMBER	PERCENT	LENGTH RANGE (Inches)	WEIGHT (Pounds)	PERCENT
Gizzard shad	2,421	34.8	1.8-13.6	368.44	18.0
Bluegill	2,078	29.8	2.0- 7.8	270.63	13.2
Yellow bass	917	13.2	1.7- 9.2	149.14	7.3
White crappie	381	5.5	2.1-13.3	49.39	2.4
Largemouth bass	228	3.3	2.0-20.4	268.29	13.1
Channel catfish	221	3.2	5.9-30.5	407.53	19.9
Longear sunfish	185	2.7	2.2- 6.0	16.13	0.8
Spotfin shiner	142	2.0	2.1- 4.0	1.27	0.1
Palmetto bass	89	1.3	8.2-21.9	131.60	6.4
Yellow perch	62	0.9	4.7- 8.5	7.69	0.4
Redear sunfish	55	0.8	5.0- 9.2	18.11	0.9
Walleye	52	0.7	8.7-26.5	78.88	3.9
Black crappie	42	0.6	5.6- 9.6	7.30	0.4
Common carp	37	0.5	13.0-32.0	252.24	12.3
Logperch	12	0.2	4.9- 5.9	0.58	*
Brook silverside	12	0.2	3.2- 4.2	0.14	*
Warmouth	8	0.1	4.2- 7.4	1.39	0.1
Shorthead redhorse	5	0.1	11.5-18.8	8.88	0.4
Brown bullhead	4	0.1	11.0-12.1	2.91	0.1
Flathead catfish	4	0.1	8.8-15.2	1.95	0.1
Golden shiner	3	*	4.2- 8.5	0.32	*
Yellow bullhead	2	*	7.4-11.0	0.91	*
White sucker	1	*	15.8	1.92	0.1
Spotted sucker	1	*	14.8	1.62	0.1
Grass pickerel	1	*	8.9	0.15	*
TOTALS	6,963			2,047.41	
*Less than 0.1%.					

*Common names of fishes recognized by the American Fisheries Society

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Gizzard shad

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0	1	-	*	0+	15.5				
2.5					16.0				
3.0					16.5				
3.5					17.0				
4.0					17.5				
4.5					18.0				
5.0					18.5				
5.5	84	3.5	0.06	1+	19.0				
6.0	193	8.0	0.07	1+	19.5				
6.5	75	3.1	0.09	1+	20.0				
7.0	92	3.8	0.10	2+	TOTAL	2,421			
7.5	517	21.4	0.13	2+					
8.0	606	25.0	0.16	2+,3+					
8.5	397	16.4	0.21	2+,3+,4+					
9.0	262	10.8	0.26	3+,4+					
9.5	77	3.2	0.30	3+,4+,5+					
10.0	41	1.7	0.35	4+,5+					
10.5	60	2.5	0.40	5+,6+					
11.0	11	0.4	0.47	4+,5+,6+					
11.5	2	0.1	0.51	6+					
12.0	1	-	0.60	7+					
12.5									
13.0	1	-	**	7+					
13.5	1	-	0.99	8+					
14.0									

*Less than 0.01 Lb. **Partially consumed by scavengers.

ELECTROFISHING CATCH	Day 92.6/Hr. Night 307.0/Hr.	GILL NET CATCH	36.4/Set	TRAP NET CATCH	9.9/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Bluegill

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0	4	0.2	0.01	1+	15.5				
2.5	9	0.4	0.01	1+	16.0				
3.0	47	2.3	0.02	1+	16.5				
3.5	85	4.1	0.03	1+	17.0				
4.0	112	5.4	0.04	1+,2+	17.5				
4.5	136	6.5	0.06	1+,2+	18.0				
5.0	196	9.4	0.08	2+,3+	18.5				
5.5	223	10.7	0.10	2+,3+	19.0				
6.0	401	19.3	0.14	2+,3+	19.5				
6.5	496	23.9	0.18	3+,4+	20.0				
7.0	331	15.9	0.23	3+,4+,5+	TOTAL	2,078			
7.5	37	1.8	0.26	5+,6+					
8.0	1	-	0.28	6+					
8.5									
9.0									
9.5									
10.0									
10.5									
11.0									
11.5									
12.0									
12.5									
13.0									
13.5									
14.0									

ELECTROFISHING CATCH Day / Night	57.2/Hr. / 57.5/Hr.	GILL NET CATCH	1.5/Set	TRAP NET CATCH	205.3/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Yellow bass

TOTAL LENGTH (Inches)	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT (Pounds)	AGE OF FISH	TOTAL LENGTH (Inches)	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT (Pounds)	AGE OF FISH
1.0					14.5				
1.5	1	0.1	*	0+	15.0				
2.0	7	0.8	*	0+	15.5				
2.5	5	0.5	*	0+	16.0				
3.0					16.5				
3.5					17.0				
4.0					17.5				
4.5					18.0				
5.0	5	0.5	0.07	1+	18.5				
5.5	21	2.3	0.07	1+	19.0				
6.0	37	4.0	0.11	1+,2+	19.5				
6.5	164	17.9	0.13	2+,3+	20.0				
7.0	314	34.2	0.17	2+,3+	TOTAL	917			
7.5	252	27.5	0.19	3+,4+					
8.0	93	10.1	0.24	4+,5+					
8.5	14	1.5	0.28	5+					
9.0	4	0.4	0.33	5+,6+					
9.5									
10.0									
10.5									
11.0									
11.5									
12.0									
12.5									
13.0									
13.5									
14.0									

*Less than 0.01 Lb.

ELECTROFISHING CATCH	Day 0.3/Hr. Night 27.3/Hr.	GILL NET CATCH	33.8/Set	TRAP NET CATCH	3.6/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* White crappie

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0	1	0.3	*	0+	15.5				
2.5					16.0				
3.0					16.5				
3.5					17.0				
4.0					17.5				
4.5					18.0				
5.0	25	6.6	0.06	1+	18.5				
5.5	75	19.7	0.07	1+	19.0				
6.0	40	10.5	0.09	1+,2+	19.5				
6.5	116	30.4	0.11	1+,2+	20.0				
7.0	72	18.9	0.13	2+,3+	TOTAL	381			
7.5	16	4.2	0.16	2+,3+,4+					
8.0	6	1.6	0.20	3+,4+					
8.5	8	2.1	0.24	3+					
9.0	6	1.6	0.29	3+,4+					
9.5	5	1.3	0.35	3+,4+,5+					
10.0	2	0.5	0.36	4+					
10.5	1	0.3	0.47	4+					
11.0	2	0.5	0.64	4+,5+					
11.5	2	0.5	0.68	5+					
12.0									
12.5	2	0.5	0.91	5+					
13.0	1	0.3	0.97	6+					
13.5	1	0.3	1.11	7+					
14.0									

*Less than 0.01 Lb.

ELECTROFISHING CATCH	Day 4.7/Hr. Night 4.8/Hr.	GILL NET CATCH	13.1/Set	TRAP NET CATCH	5.8/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Largemouth bass

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5	7	3.1	1.64	3+,4+
1.5					15.0	7	3.1	1.78	4+
2.0	5	2.2	*	0+	15.5	2	0.9	2.15	4+
2.5	1	0.4	*	0+	16.0	5	2.2	2.28	3+,4+
3.0	1	0.4	0.02	0+	16.5	3	1.3	2.51	4+
3.5					17.0	5	2.2	2.62	4+,5+
4.0					17.5	8	3.5	3.09	4+,5+
4.5					18.0	5	2.2	3.29	4+,5+
5.0					18.5	2	0.9	3.06	5+
5.5					19.0	3	1.3	3.68	5+
6.0	2	0.9	0.10	1+	19.5	7	3.1	4.53	5+,6+
6.5	5	2.2	0.12	1+	20.0	1	0.4	4.08	6+
7.0	8	3.5	0.15	1+	20.5	1	0.4	4.65	7+
7.5	9	3.9	0.18	1+	TOTAL	228			
8.0	11	4.8	0.24	1+					
8.5	9	3.9	0.28	1+					
9.0	3	1.3	0.34	1+,2+					
9.5	5	2.2	0.37	1+,2+					
10.0	12	5.3	0.47	1+,2+					
10.5	13	5.7	0.53	2+					
11.0	20	8.8	0.61	2+					
11.5	12	5.3	0.76	2+,3+					
12.0	17	7.5	0.90	2+,3+					
12.5	15	6.6	1.02	2+,3+					
13.0	5	2.2	1.14	3+,4+					
13.5	11	4.8	1.38	3+					
14.0	8	3.5	1.54	3+,4+					

*Less than 0.01 Lb.

ELECTROFISHING CATCH	Day 20.7/Hr. Night 40.3/Hr.	GILL NET CATCH	0.2/Set	TRAP NET CATCH	0.1/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Channel catfish

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5	9	4.1	0.94	
1.5					15.0	11	5.0	1.01	
2.0					15.5	5	2.3	1.22	
2.5					16.0	6	2.7	1.23	
3.0					16.5	11	5.0	1.31	
3.5					17.0	7	3.2	1.56	
4.0					17.5	12	5.4	1.62	
4.5					18.0	11	5.0	1.71	
5.0					18.5	13	5.9	1.91	
5.5					19.0	10	4.5	1.98	
6.0	3	1.4	0.06	Not aged	19.5	7	3.2	2.21	
6.5	7	3.2	0.08		20.0	3	1.4	2.63	
7.0	9	4.1	0.09		20.5 21.0	9 5	4.1 2.3	2.83 3.22	
7.5	5	2.3	0.12		21.5 22.0	1 3	0.5 1.4	2.68 3.48	
8.0	7	3.2	0.13		22.5 23.0	2 4	0.9 1.8	4.11 4.16	
8.5	2	0.9	0.19		23.5 24.0	3 1	1.4 0.5	4.77 6.06	
9.0					24.5 25.0	1 1	0.5 0.5	5.50 5.25	
9.5					25.5 26.0	2 2	0.9 0.9	6.75 7.75	
10.0	1	0.5	0.27		26.5 27.0	1 1	0.5 0.5	7.31 9.00	
10.5	1	0.5	0.32		27.5 28.0	1 1	0.5 0.5	8.25 8.50	
11.0	3	1.4	0.40		28.5	1	0.5	7.44	
11.5	3	1.4	0.43		29.5	1	0.5	9.63	
12.0	2	0.9	0.49		30.5	2	0.9	10.13	
12.5	4	1.8	0.67		TOTAL	221			
13.0	7	3.2	0.68						
13.5	11	5.0	0.88						
14.0	9	4.1	0.90						

ELECTROFISHING CATCH Day Night	0.3/Hr. 1.3/Hr.	GILL NET CATCH	9.2/Set	TRAP NET CATCH	0.5/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Longear sunfish

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0	1	0.5	0.01	Not aged	15.5				
2.5	3	1.6	0.02		16.0				
3.0	11	5.9	0.02		16.5				
3.5	25	13.5	0.03		17.0				
4.0	14	7.6	0.05		17.5				
4.5	27	14.6	0.07		18.0				
5.0	45	24.3	0.10		18.5				
5.5	50	27.0	0.13		19.0				
6.0	9	4.9	0.16		19.5				
6.5					20.0				
7.0					TOTAL	185			
7.5									
8.0									
8.5									
9.0									
9.5									
10.0									
10.5									
11.0									
11.5									
12.0									
12.5									
13.0									
13.5									
14.0									

ELECTROFISHING CATCH Day / Night	22.1/Hr. / 23.5/Hr.	GILL NET CATCH	0.4/Set	TRAP NET CATCH	2.0/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Palmetto bass

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5				
1.5					15.0				
2.0					15.5				
2.5					16.0	4	4.5	1.98	2+
3.0					16.5	3	3.4	2.11	2+
3.5					17.0	13	14.6	2.39	2+
4.0					17.5	8	9.0	2.58	2+
4.5					18.0	3	3.4	2.82	2+
5.0					18.5				
5.5					19.0	1	1.1	3.70	3+
6.0					19.5	1	1.1	3.62	3+
6.5					20.0	4	4.5	3.71	3+
7.0									
7.5					21.0	1	1.1	4.98	3+
8.0	1	1.1	0.23	1+					
8.5					22.0	1	1.1	5.44	3+
9.0	6	6.7	0.30	1+	TOTAL	89			
9.5	5	5.6	0.35	1+					
10.0	15	16.9	0.40	1+					
10.5	8	9.0	0.48	1+					
11.0	4	4.5	0.57	1+					
11.5	6	6.7	0.61	1+					
12.0	1	1.1	0.70	1+					
12.5	2	2.2	0.91	1+					
13.0									
13.5	1	1.1	1.25	1+					
14.0	1	1.1	1.30	1+					

ELECTROFISHING CATCH Day Night	0.0/Hr. 0.3/Hr.	GILL NET CATCH	3.8/Set	TRAP NET CATCH	0.1/Set

NUMBER, PERCENTAGE, WEIGHT, AND AGE OF: *(species)* Walleye

TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH	TOTAL LENGTH *(Inches)*	NUMBER COLLECTED	PERCENT OF FISH COLLECTED	AVERAGE WEIGHT *(Pounds)*	AGE OF FISH
1.0					14.5	3	5.8	0.93	2+
1.5					15.0	3	5.8	1.05	2+
2.0					15.5	2	3.8	1.14	2+
2.5					16.0	4	7.7	1.32	2+
3.0					16.5	4	7.7	1.45	2+
3.5					17.0	1	1.9	1.55	2+
4.0					17.5	2	3.8	1.74	2+
4.5					18.0	2	3.8	2.11	2+,3+
5.0					18.5	1	1.9	1.95	3+
5.5					19.0	1	1.9	2.29	3+
6.0					19.5	2	3.8	2.83	2+,3+
6.5					20.0	1	1.9	2.70	3+
7.0									
7.5					21.0	1	1.9	3.36	4+
8.0					21.5	1	1.9	3.46	3+
8.5	1	1.9	0.16	1+	22.5	2	3.8	4.63	4+
9.0	1	1.9	0.22	1+					
9.5	1	1.9	0.23	1+	23.5	1	1.9	4.96	4+
10.0	1	1.9	0.30	1+					
10.5	5	9.6	0.32	1+	26.5	1	1.9	7.69	5+
11.0	1	1.9	0.38	1+	TOTAL	52			
11.5	1	1.9	0.46	1+					
12.0	4	7.7	0.49	1+					
12.5									
13.0	1	1.9	0.62	1+					
13.5	2	3.8	0.71	2+					
14.0	2	3.8	0.81	1+,2+					

ELECTROFISHING CATCH	Day 0.0/Hr. Night 1.5/Hr.	GILL NET CATCH	2.0/Set	TRAP NET CATCH	0.0/Set

Species: Gizzard shad	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
Intercept = 0	1991	14	4.7					
	1990	12	4.2	6.6				
	1989	8	4.1	6.6	7.7			
	1988	11	4.6	6.6	7.7	8.6		
	1987	10	4.1	5.9	7.4	8.7	9.7	
	1986	4	3.9	5.6	6.9	8.1	9.2	10.4
	AVERAGE LENGTH		4.3	6.3	7.4	8.5	9.5	10.4
	NUMBER AGED		59	45	33	25	14	4

Species: Bluegill.	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
Intercept = 0.8"	1991	21	2.1					
	1990	13	2.0	3.8				
	1989	10	1.8	3.9	5.5			
	1988	6	1.9	3.6	5.6	6.5		
	1987	5	1.9	3.4	5.0	6.0	7.0	
	1986*	2	1.5	3.3	5.2	6.3	6.9	7.4
	AVERAGE LENGTH		1.9	3.7	5.4	6.3	7.0	
	NUMBER AGED		55	34	21	11	5	

Species: Yellow bass	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
Intercept = 0	1991	7	3.7					
	1990	8	3.4	5.7				
	1989	6	2.9	5.0	6.7			
	1988	8	2.8	5.1	6.3	7.3		
	1987	8	3.0	5.1	6.4	7.3	8.2	
	1986*	1	2.2	4.6	5.8	7.1	7.9	8.9
	AVERAGE LENGTH		3.2	5.2	6.5	7.3	8.2	
	NUMBER AGED		37	30	22	16	8	

Species: White crappie	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
Intercept = 1.4"	1991	11	3.9					
	1990	11	3.5	5.7				
	1989	13	3.7	6.1	7.4			
	1988	11	3.7	5.7	7.1	8.4		
	1987	7	4.0	5.9	7.3	8.9	10.8	
	1986*	1	3.7	6.2	7.1	7.7	8.4	12.2
	AVERAGE LENGTH		3.8	5.9	7.3	8.7	10.8	
	NUMBER AGED		53	42	31	18	7	

NOTE: If not included in average length calculations indicate with a (*)

Species: Largemouth bass	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
Intercept = 0.8"	1991	27	6.0					
	1990	26	4.6	9.6				
	1989	18	4.5	9.1	12.2			
	1988	21	5.1	9.1	12.1	14.4		
	1987	13	4.9	9.3	12.6	16.0	17.9	
	1986	3	4.6	9.6	12.7	16.8	18.3	19.2
	AVERAGE LENGTH		5.0	9.3	12.4	15.7	18.1	19.2
	NUMBER AGED		108	81	55	37	16	3

Species: Palmetto bass	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
Intercept = 0	1991	26	7.2					
	1990	16	5.6	15.5				
	1989	6	4.5	12.7	19.4			
	AVERAGE LENGTH		5.8	14.1	19.4			
	NUMBER AGED		48	22	6			

Species: Walleye	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
Intercept = 2.2"	1991	14	9.3					
	1990	16	9.2	14.3				
	1989	6	8.0	13.7	18.0			
	1988	3	8.8	14.9	19.4	21.9		
	1987*	1	8.6	14.8	21.7	25.0	26.1	
	AVERAGE LENGTH		8.8	14.3	18.7	21.9		
	NUMBER AGED		39	25	9	3		

Species:	YEAR CLASS	NUMBER OF FISH AGED	BACK CALCULATED LENGTH *(Inches)* AT EACH AGE I	II	III	IV	V	VI
	AVERAGE LENGTH							
	NUMBER AGED							

NOTE: *If not included in average length calculations indicate with a (*)*

APPENDIX E:

CURRENT LAKE MONROE WATERSHED JURISDICTIONS

FEDERAL AGENCIES

DEPARTMENT OF DEFENSE:

UNITED STATES ARMY CORPS OF ENGINEERS (ACOE)

Primarily responsible for flood control. They maintain and operate the dam, tailwater, spillway, and control tower.

Responsible for the land under the lake and the shoreline, normally up to 560 feet (mean sea level elevation), and at a higher elevation at some points.

Controls the water above the 538 foot elevation (the flood control pool level) and below the 515 foot elevation. The water between 515'-538' is owned by the Indiana Department of Natural Resources.

Manages and protects the natural resources of the federally owned land around the lake in conjunction with the Department of Natural Resources.

Reviews state and local construction projects under the Clean Water Act, and issues Section 404 permits through the Operations Division, Regulatory Branch. This section of the Act regulates "detrimental" filling or dredging of any area within the floodway.

CONTACTS:

David Cable
Park Manager
Monroe Lake
U.S. Army Corps of Engineers
1620 East Monroe Dam Court
Bloomington, IN 47401
(812) 824-9136

Mike Graham
Area Park Manager
Middle Wabash Area
U.S. Army Corps of Engineers
1620 East Monroe Dam Court
Bloomington, IN 47401
(812) 824-9136

Colonel Herb Harback
District Engineer
U.S. Army Corps of Engineers Louisville District
P.O. Box 59
Louisville, KY 40201-0059
(502) 582-5601

The Middle Wabash Area is composed of four lakes: Cecil M Harden Lake (Raccoon), Cables Mill Lake (Cataract), Patoka Lake, and Monroe Lake.

DEPARTMENT OF AGRICULTURE

FOREST SERVICE (USFS)

Administers and maintains the Hoosier National Forest (HNF), Deam Wilderness Area, the Hardin Ridge Recreation Area and Certain campgrounds. These areas cover 37,000 acres within the lake's watershed, including nine miles of shoreline.

Responsible for the forestry practices and recreation policies of these areas.

CONTACTS:

Bruce Slover
District Ranger
Wayne-Hoosier National Forest
608 West Commerce Street
Brownstown, IN 47220
(812) 358–2675

Les Wadzinski
Assistant District Ranger
Wayne-Hoosier National Forest
608 West Commerce Street
Brownstown, IN 47220
(812) 358–2675

Frank Voytas
Supervisor
Wayne-Hoosier National Forest
811 Constitution Avenue
Bedford, IN 47421
(812) 275–5987

NATURAL RESOURCES CONSERVATION SERVICE (NRCS)

Provides educational and technical assistance in identifying and rectifying soil erosion and sedimentation problems which have water quality impacts.

Its policies are carried out by the local Soil and Water Conservation Districts. These agencies have few regulatory powers and assist, rather than control property owners.

CONTACT:

Monroe County District Conservationist
NCRS
1524 Oakdale Drive
Bloomington, IN 47403
(812) 334-4325

Tom Varns
Brown County District Conservationist
NRCS
P.O. Box 308 Artist Dr.
Nashville, IN 47448-9805
(812) 988-2211

Catrina Motsinger
Jackson County District Conservationist
NRCS
102 E. Commerce St.
Brownstown, IN 47220-2004
(812) 358-3380

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (US EPA) (REGION V)

Responsible for overseeing the enforcement of federal environmental water quality legislation, including the Federal Water Pollution Act (the Clean Water Act) and the Safe Drinking Water Act.

Provides funding and grants for research by state agencies and for state construction programs.

Reviews state standards for water quality and monitors compliance.

CONTACT:

Tom Davenport
U.S. EPA
WQW-16J
77 W. Jackson Blvd.
Chicago, IL 60604
(312) 886-0209

STATE AGENCIES

INDIANA DEPARTMENT OF NATURAL RESOURCES (IDNR)

BUREAU OF LAND, FOREST, AND WILDLIFE RESOURCES

DIVISION OF FORESTRY

Manages thirteen state forests and four state recreation areas on 144,587 acres statewide under a multiple use, multiple benefit philosophy. Yellowwood and Morgan-Monroe State Forests are within the watershed of Lake Monroe.

Manages two state nurseries, producing nine million seedlings annually for reforestation.

Administers Rural Cooperative Fire Program and is responsible for wildfire suppression and control on state lands and adjacent lands.

Provides forest management services and marketing information to private forest land owners in nineteen forestry districts throughout the state. Monroe County lies within the jurisdiction of District 18, which has offices at Owen-Putnam State Forest.

Operates a logger education program in cooperation with Indiana Forest Industry Council (IFIC), to provide timber harvesting operators information on increasing the efficiency of harvesting operations while mitigating the effects on the watershed and protecting water quality.

CONTACTS:

John Friedrich, Property Specialist
IDNR, Division of Forestry
402 West Washington Street, Room 296
Indianapolis, IN 46204
(317) 232-4105

Don Duncan, Property Manager
Yellowwood State Forest
RR #5, Box 390
Nashville, IN 47448
(812) 988-7945

Ralph Unversaw, District Forester
Owen-Putnam State Forest
RR #4, Box 214
Spencer, IN 47460
(812) 829-2462

Bill Hahn, Property Manager
Morgan-Monroe State Forest
6220 Forest Road
Martinsville, IN 46151
(317) 342-4026

DIVISION OF FISH AND WILDLIFE

Manages the fisheries, including surveying fish populations, imposing harvest regulations, and maintaining fish stocking programs.

Responsible for the non-game wildlife fund. Shares management of the Bald Eagle hacking program with the Division of Reservoir Management.

Conducts intermittent water quality monitoring related to fisheries management.

Reviews construction permits within the floodway to determine any effects on water quality, fish, wildlife, and botanical resources.

CONTACTS:

Steve Andrews
Fisheries Biologist
Fish Management District 6
P.O. Box 16
Avoca, IN 47420
(812) 279-1215

DIVISION OF STATE PARKS AND RESERVOIRS

Manages eight large reservoirs built by the U.S. Army Corps of Engineers. Their mandate is to maximize sustained public benefits compatible with authorized purposes.

Currently, their goal is to manage and develop reservoir properties for the enhancement of wildlife and for quality outdoor recreational activities that are compatible with the environment.

They help to maintain the Fairfax beach area, access roads, boat ramps and the surrounding areas. They are also responsible for the management of the North and Middle fork Wildlife Refuge areas. Finally, they monitor and control recreational activities which take place on the lake.

CONTACTS:

Jim Roach
Lake Monroe Property Manager
Wildlife Specialist
Department of Natural Resources
4850 South State Road 446
Bloomington, IN 47401
(812) 837-9546

Randy Roberts
Reservoir Specialist
Recreation Management
Department of Natural Resources
4850 South State Road 446
Bloomington, IN 47401
(812) 837-9546

BUREAU OF WATER AND MINERAL RESOURCES

DIVISION OF WATER

Consists of four branches: Planning, Engineering Services, Regulatory, and Water Management. The Planning Branch works with flood plain management, flood control revolving fund loans and hydroelectric plant permitting. They also address water resource projects including: coordinating federal, state and local flood control projects, conservancy district plans, water supply feasibility studies, and water use inventory.
The Engineering Services Branch performs data collection and analysis on surface and ground water. This includes hydraulic and hydrologic studies, water well driller licensing, and surveying and mapping.

The Regulations Branch reviews construction in the flood way permits, establishes legal lake levels, makes flood plain recommendations, and conducts dam and levee inspections. They issue permits for shoreline and lake bed alterations (sand, gravel and coal removal), public lake water withdrawal, and ditch reconstruction.

The Water Management Branch is involved in water use, basin studies, and water rights. It registers water withdrawal facilities, regulates the sale of water from state funded water supplies, writes statewide water use reports, and issues water withdrawal permits for navigable rivers. This branch also conducts river basin studies, provides technical assistance to prospective water users, and performs groundwater sampling.

CONTACT:

Jim Hebenstreit
Assistant Director
Department of Natural Resources
Division of Water
402 West Washington Street, Room W264
Indianapolis, IN 46204
(317) 232-4160

DIVISION OF SOIL CONSERVATION

Administers Indiana's "T by 2000" erosion reduction program. "T by 2000" refers to the program's goal of reducing soil erosion to a "tolerable" limit by the year 2000. It gives technical and educational assistance on erosion control strategies and soil suitability for development.

The "T by 2000" effort also includes the Lakes Enhancement Program, which provides technical and financial help in evaluating and controlling sediment and nutrient problems in public-access lakes.

CONTACT:

Dale Conard
Chairman of the Area III Association
Soil and Water Conservation District
8550 West Vernal Pike
Bloomington, IN 47404

Harry Nikides
Director
Indiana Government Center South
Room W265
Indianapolis, IN 46204
(317) 233-3870

BUREAU OF LAW ENFORCEMENT AND ADMINISTRATION

LAW ENFORCEMENT DIVISION

Conservation Officers patrol the lake for violators of state hunting, fishing, and boating laws and enforce DNR property laws.

CONTACT:

Lieutenant Dennis Koontz
P.O. Box 266
Nashville, IN 47448
(812) 988-9761

WATER POLLUTION CONTROL BOARD

Promulgates water quality standards.

Designates state waters with an appropriate use designation, such as recreational, exceptional use, etc., and provides criterion to support those uses.

The Indiana Department of Environmental Management provides staff work in support of the Board.

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT (IDEM)

OFFICE OF WATER MANAGEMENT

Responsible for protecting the water quality of the lake and its sources. It has the authority to enforce the Federal and State Water Pollution Control Acts, which limit the discharge of any pollutant into public waters.

Reviews and issues permits for the direct discharge of pollutants into surface waters. These National Pollution Discharge Elimination System (NPDES) permits regulate any facility that discharges waste into surface waters.

Ensures compliance with the laws governing public water systems through surveillance and inspection of public sewage treatment facilities, water quality monitoring, technical assistance programs, construction plan review and water works operator certification.

Conducts water quality monitoring of lakes and rivers to determine if water quality standards are met. Oversees the Indiana Clean Lakes Program. This program provides information, technical assistance and education on lake issues. It conducts a volunteer monitoring program and evaluates trends in water quality throughout the state. It is administered through Indiana University's School of Public and Environmental Affairs.

The Drinking Water Branch of the Office of Water Management enforces federal public health drinking water standards.

CONTACTS:

Dennis Clark
Chief of Special Projects Section
Office of Water Management
Department of Environmental Management
100 N. Senate Ave.
Indianapolis, IN 46206-6015
(317) 223-2482

John Winters
Chief of Assessment Branch
Office of Water Management
Department of Environmental Management
PO Box 6015 (Shade)
Indianapolis, IN 46206-6015
(317) 308-3178

INDIANA STATE DEPARTMENT OF HEALTH (ISDH)

Regulates private sewage disposal systems (septic systems); the permits for these systems are issued by the County Health Departments. Responds to lake and stream pollution problems on a complaint basis. Monitors hazardous radiation spills.

CONTACT:

Michael Brown
Office of External Affairs
State Board of Health
1330 W. Michigan Street
Indianapolis, IN 46206
(317) 633-0100

OFFICE OF THE INDIANA STATE CHEMIST

State lead agency under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and the Indiana Pesticide and Application law regulating pesticide licensing, application, disposal and run off.

CONTACT:

Dave Scott
Pesticides Division
Office of Indiana State Chemist
Department of Biochemistry
1154 Biochemistry Building
West Lafayette, IN 47907-1154
(317) 494-1594

REGIONAL AGENCIES

LAKE MONROE REGIONAL WASTE DISTRICT (LMRWD)

Nine member Board, with membership appointed by the County Commissioners (3), the County Council (1), the Mayor of Bloomington (1), and the Governor (3).

Responsible for planning, organizing, and operating a coordinated waste disposal system which provides for the collection, treatment and disposal of sewage within the district. The district includes all of Monroe County, except those areas serviced by City of Bloomington Utilities, Ellettsville Water Company, Salt Creek Services, and areas served by the Eastern and Northern Richland Township Sewer Corporations.

The district has the authority to issue revenue bonds and establish sewer user rates in the same manner as a municipality.

CONTACTS:

Winfield (Dick) Jacobs
609 South Sale
Ellettsville, IN 47429
(812) 876-1661

Fred St. John
Technician
309 Ridge Springs Lane
Ellettsville, IN 47429
(812) 876-2734
(812) 876-1287 (Ellettsville Waste Water Plant)

John Troter
Technician
519 South Sale
Ellettsville, IN 47429
(812) 876-1875
(812) 876-9311 (Waste Water Treatment Plant)

LOCAL AGENCIES

MONROE, BROWN AND JACKSON COUNTY BOARDS OF HEALTH

The Health Boards are responsible for county policies regarding septic systems, solid waste disposal, pesticide use and wastewater management.

MONROE, BROWN, AND JACKSON COUNTY HEALTH DEPARTMENTS

May intervene in any situation that endangers public health.

Determine the suitability of selected sites for septic systems (for one and two family dwellings only) and issue permits if the sites meet standards.

Investigate water pollution complaints and waste discharge complaints, can order abatement of any polluting activity detrimental to public health.

Issues Municipal Solid Waste Hauler Permits. These permits are required for anyone removing municipal solid waste from establishments or residences other than their own. Vehicles are required to be enclosed and free of leaks. All vehicles are inspected annually.

Inspect the Lake Monroe campgrounds in conjunction with the State Board of Health.

CONTACTS:

Steve Creech
Director
Monroe County Health Department
119 West 7th Street
Bloomington, IN 47404
(812) 333-3543

Warren Henegar
Soils Scientist
Monroe County Health Department
119 West 7th Street
Bloomington, IN 47404
(812) 333-3543

Judy Swift
Brown County Health Department
P.O. Box 281
Nashville, IN 47448
(812) 988-2255

Jim Montgomery
Jackson County Health Department
207 Pine Street
Seymour, IN 47274
(812) 358-6121

MONROE, BROWN, AND JACKSON COUNTY COMMISSIONERS

Approve and enact ordinances for the counties, including zoning ordinances and their amendments, and Comprehensive Plans.

CONTACTS:

Monroe County Commissioners
Courthouse Room 322
Bloomington, IN 47404
(812) 333-3550

Brown County Commissioners
P.O. Box 37
Nashville, IN 47448
(812) 988-2813

Jackson County Commissioners
Courthouse
Brownstown, IN 47220
(812) 358-6121

MONROE, BROWN AND JACKSON COUNTY COUNCILS

County funds are appropriated by the County Councils.

CONTACTS:

Monroe County Council
Courthouse
Bloomington, IN 47404
(812) 333-3510

Brown County Council
P.O. Box 37
Nashville, IN 47448
(812) 988-5485

Jackson County Council
Courthouse
Brownstown, IN 47220
(812) 358-6121

MONROE, BROWN AND JACKSON COUNTY PLANNING COMMISSIONS AND PLANNING DEPARTMENTS

Evaluate petitions for changes in land use, including subdivisions, variances, special exceptions and rezones.

May draft and recommend a zoning ordinance and/or a Comprehensive Plan to the County Commissioners for their adoption.

Implement and enforce adopted plans and ordinances.

CONTACTS:

Monroe County Plan Commission
801 Anita Street
Bloomington, IN 47401
(812) 333-3550

Kevin Buchheit, Director
Monroe County Planning Department
Courthouse Room 306
Bloomington, IN 47404-3900
(812) 333-3560

Brown County Plan Commission
P.O. Box 1665
Nashville, IN 47448-1665
(812) 372-9911

Bonnie Robison, Director
Brown County Planning Department
64 Old School Way
Nashville, IN 47448
(812) 988-5490

Jackson County Plan Commission
2021 East County Road 700 S
Brownstown, IN 47220
(812) 358-6108

Irene McKain, Director
Jackson County Planning & Zoning
c/o Courthouse
111 South Main
Brownstown, IN 47220
(812) 358-6108

MONROE, BROWN AND JACKSON COUNTY BOARD OF ZONING APPEALS (BZA)

Certain planning petitions, specifically Variances and Special Exceptions, must be approved by both the Plan Commission and the Board of Zoning Appeals. The BZA makes the final determination in these decisions.

CONTACT:

Charles Brooker, President
Monroe County Board of Zoning Appeals
Courthouse Room 306
Bloomington, IN 47404-3900
(812) 333-3560

Rex Watters, President
Brown County Board of Zoning Appeals
521 Artist Drive
Nashville, IN 47448
(812) 988-5490

Francis Elliott, Chairman
Jackson County Board of Zoning Appeals
2021 East County Road 700S
Brownstown, IN 47220
(812) 358-6121

CITY OF BLOOMINGTON PLANNING COMMISSION AND PLANNING DEPARTMENT

Same responsibilities as the County Plan Commissions but the city planners are responsible to the City Council.

Public Law 250 gives the city authority to protect its water supply within a ten mile radius of city limits.

CONTACTS:

Director
Bloomington Planning Department
220 East Third Street
Bloomington, IN 47401
(812) 349-3423

CITY OF BLOOMINGTON UTILITIES SERVICE BOARD (USB)

Set policies concerning water and waste water for the Utilities Service Department. Rates are determined by the state regulatory commission.

CONTACT:

Utilities Service Board
1969 South Henderson Street
P.O. Box 1216
Bloomington, IN 47402
(812) 339-1444, extension 204

CITY OF BLOOMINGTON UTILITIES SERVICE DEPARTMENT (CBU)

The Utilities Service Department buys Monroe Reservoir water from DNR for its customers. It owns and maintains Griffy Lake.

Treats the water taken from Lake Monroe and Griffy Lake for distribution in the Bloomington area.

Treated water is also sold by the utility to rural water companies, including: Washington Township Water Company, Ellettsville Water Company, Bloomington and Benton (B&B) Water Company, East Monroe Water Corporation, Southern Monroe Water Corporation, Van Bureau Water Incorporated, Nashville Water Utility, Washington Township Water Company, and Russell Road Water Corporation.

Rhorer, Harrell, Schact Water Corporations, and Shady Side Water Company are also served by the Bloomington Utilities Department at regular residential rates.

CBU monitors the water quality of raw and finished water taken from the lake for public use. They file water quality reports to IDEM and for public record.

CONTACTS:

Mike Phillips, Director
Scott Domke, Assistant Director
City of Bloomington Utilities
P.O. Box 1216
Bloomington, IN 47402
(812) 339-1444

APPENDIX F:

PUBLIC COMMENTS SUMMARY

—Initial Public Meeting
—User Survey

Public Comments on the Lake Monroe Study Voiced at the First Public Meeting, July 16, 1992, Monroe County Courthouse

A. General Concerns Voiced about the Lake

1. Concern about contamination from boating.
2. Concern about sedimentation due to development.
   —desire voiced for caps on development
   —desire voiced for erosion controls
3. Speculation as to whether the lake might provide a future water supply for Indianapolis.
4. Concern that the "natural" look of the lake might be spoiled by development.

B. Questions/Comments on the Study

1. Will the study determine the impact of boating?
   —can we compare solids readings before and after a busy weekend?
2. Can the study determine sources of contamination?
   —how accurately?
3. Will continuous hydrographs be run on the streams?
4. Who is taking the data?
5. Will the Visitors and Conventions Bureau be consulted to determine the value of the lake's "natural" look?

C. Questions/Comments on the Survey

1. Will the surveys be distributed to property owners around the lake?
   —concern voiced that if they are not so distributed commercial issues will be overemphasized.
2. What will happen to the information collected in the survey?
   —how will it be used?
3. Is there any way to identify property owners and send them the results of the survey?

D. Technical Questions

<u>A. Administrative</u>

1. Can this lead to other studies and/or grants?
2. Will the recommendation include only one plan or a set of alternative plans with explanations of each?
   —desire expressed for the latter.
3. Is it feasible to propose a multi-county authority to oversee management (i.e. can the authority be based upon watershed boundaries instead of county lines)?
4. Will the plan address cost sharing?
5. How much attention will state and federal authorities pay to the study?
6. What portions of the funding are being spent on data collection and what portion to developing a management plan?

<u>B. Scientific</u>

1. Define "eutrophy."
2. Define "shoreline."

3. How many years back does the Lake Monroe data go?
   -what will we compare our findings with?
4. How many people are served by the lake as a drinking water source?
5. Does a two foot sedimentation problem which develops over twenty years mean that there will be another two foot sedimentation problem in another two years?

Written public comments received on the lake user's survey, July 25 and August 1, 1992

COMMENTS: MOORES CREEK 8-1-92

Lake Monroe needs planning, but not extreme measures, all have a right to use. Vote majority.

Need more law enforcement on the lake.

Fairfax beach is very dirty.

No dumpsters at ramp.

I support a management plan provided it is done by a non political and a not for profit cause agency—not a profit or non-profit agency or association to make up committees.

This is a nice lake. I appreciate your efforts to keep it this way.

Need more parking area for boats.

Need more handicapped facilities.

COMMENTS: CUTRIGHT 8-1-92

Maximum length of boats should be 25'.

Trash in lake on shore. Too many boats and not enough courtesy shown by boaters.

I *used to* enjoy several of the following (uses) listed in question #3. Lake's dirty, overcrowded.

Everything is affected by people who abuse and do not clean up after themselves.

Something needs to be done to reduce reckless driving and drinking alcoholic beverages while operating boats.

COMMENTS: FAIRFAX 8-1-92

More picnic tables.

[Swimming is adversely affected by seaweed problem. Need to improve: (1) sand in swimming area at Fairfax beach; (2) more lookouts for observing wildlife; (3) more camping areas. There is a bad problem at the beaches with algae blooms (seaweed) and rooted aquatic weeds, and water runoff from paved areas causing lake fill-in with sediments. (ed.) The lake is becoming smaller. It is eroding into itself.

Too many boats of high horsepower. Plans should be made on how to contend with the problems of increased use of the lake due to: (1) increase in population; (2) better economy; (3) more leisure time; (4) better roads to this area; (5) newer technology in boats and motors.

Not enough picnic areas.

Lake is fine. Let some develope (sic).

The lake is wonderful, but we need to be sure it stays that way and isn't too exploited.

Lake Monroe is very beautiful-more efforts should be made to keep it that way.

The areas where you are allowed to swim at like Fairfax beach, is so filthy dirty you don't want to swim.

It's a nice family lake.

Lake Monroe is the county water supply-every action should be taken-when the lake is no more, the entire community and local economy dries up. [There is a bad problem with: (1) unregulated dumping from houseboats and other boats; (2) liquor and unsafe boating. Need to ban motor boats-or charge launch fees. (ed.)

Lake Monroe is *the* source. (for drinking water?? [ed.])

Lake Monroe is source of water for community. Every action should be taken to treat lake as a reservoir, not a recreational lake. Will upset certain groups. When Lake Monroe dies, the entire community and local economy dries up. Motor boats should be banned or launch fees charged. Bad problem with unregulated dumping of sewage from houseboats and others. Unsafe boating by drinkers.

Lake Monroe is *the* source of water for the community. Every action should be taken to treat the lake as a reservoir, not a recreational lake. This will upset small special interest groups, marina owners and owners of property on the lake. But when Lake Monroe dies, the *entire* community and local economy dries up. Bad problem with: (1) unregulated dumping of sewage from houseboats and others; (2) unsafe boaters from drinking. Motor boats should be banned or launch fees charged.

Need more beaches. We always enjoyed the beaches at Fairfax and Paynetown.

Need more beaches.

Too much seaweed growing in swimming area. Witnessed someone taking baby duckling-need tougher enforcement patrolling. Need more trees in Fairfax area.

Need to improve the sand. (in the swim areas. [ed.])

Need to reduce the seaweed in swimming areas.

Need maintenance of weeds. Paynetown needs to be improved.

Restrictions are needed for size of boats and horsepower.

Non-game wildlife (bald eagles, etc) should be a priority concern.

Too many weeds in swimming area. Loud noise from power boating. Messy banks from fishermen. All agency's (sic) need to work together, communicate and NOT duplicate efforts. (i..e. , the DNR does not know what the Corp of Eng is doing/has done.)

Lake Monroe is a beautiful place and should be strongly supported.

Need to improve keeping people off of the load and unloading docks. Such as drinkers, fishing, and partys (sic). I like to be able to get in an (sic) out!

Slower speed for power boats.

Need to improve cleanliness at the lake. Cabin cruisers (boats) should not dump debris into lake. Manage power boats-slower speed. Why charge people to swim and no charge for launching boats? fee of $2.

Control of unsafe boaters -> fishing boats, small boats -> occupants they disregard idle zones -> wonder what other laws they break at the expense of vintage boaters!

Need better policing of the fishing boats and wave runners to observe the rules of using the lake for safety of others. Properly policing the lake is the answer, not lake management.

Need larger area at beach, and special area of lake to ski. Need more camping on Fairfax side. Bad odors at beach.

Need to put in more docks. Not let people tie up to docks to party or fish. Keep docks open for boat loading and unloading.

Need: (1) larger area at Fairfax Beach;(2) special area of the lake to ski; (3) more picnicking area on Fairfax side; (4) need camping area on Fairfax side.

Need more parking at launch ramp. Need more lakefront property for sale.

Quality of water has been adversely affected. Our lakes are a precious natural resource. One must protect them, both for ourselves and for the future.

Need to improve electric hookups at camping.

Boats are too big-horsepower restrictions needed.

Don't know much about the lake.

Bugs on the beach adversely affect the quality of Lake Monroe.

I support whatever it takes to save our lake!

All of the lakes should be managed properly.

Lake rough-boats too big. limit size of boats.

Is a good idea to start a plan now while corrective measures can still be taken.

I feel the DNR (although short funded) could do a better job-I would be willing to pay more in fees.

Too many houses around lake. A plan should be used, but not to the point that it restricts recreation use.

No safe place for scuba diving. At Fairfax, need ski area and camping.

They said when they took the land from the farmers it would never be developed or used commically (sic) for finaital (sic) gain for private development. Housing development should be stoped (sic).

Need more picnicking at Fairfax side, and to be able to use rafts at beach.

Definitely need to patrol what is dumped in the lake from boaters, area residents and other visiters (sic).

Excess speed of boats has adversely affected Lake Monroe. Need wave breaks so people can fish.

Need to improve the beach by Fairfax. Sand on the loop or point would be an improvement.

Overall, I believe this lake is in very good shape considering are (sic) overall polution (sic) intake.

DNR-could provide better lake (launch, dam) supervision.

Water is too dirty for scuba diving. There are no fish to fish.

I am not very familiar with the issues presented here.

Kids and loud music has adversely affected the quality of Lake Monroe. Bad problem with: (1) kids and seadoos; (2) fisherman not idoling (sic) in idol (sic) areas; (3) speeding after dark. Policing in areas where s speed in ???? areas and after dark. Educating boaters to boat rules.

The amount of boats needs to be more limited.

Glad to know some people are taking an interest in environmental issue of recreational area.

Need to improve loading boats.

I'm from Ohio where are (sic) lakes certainly aren't clear either, but this site is discusting (sic).

Need shaded area closer to beach area.