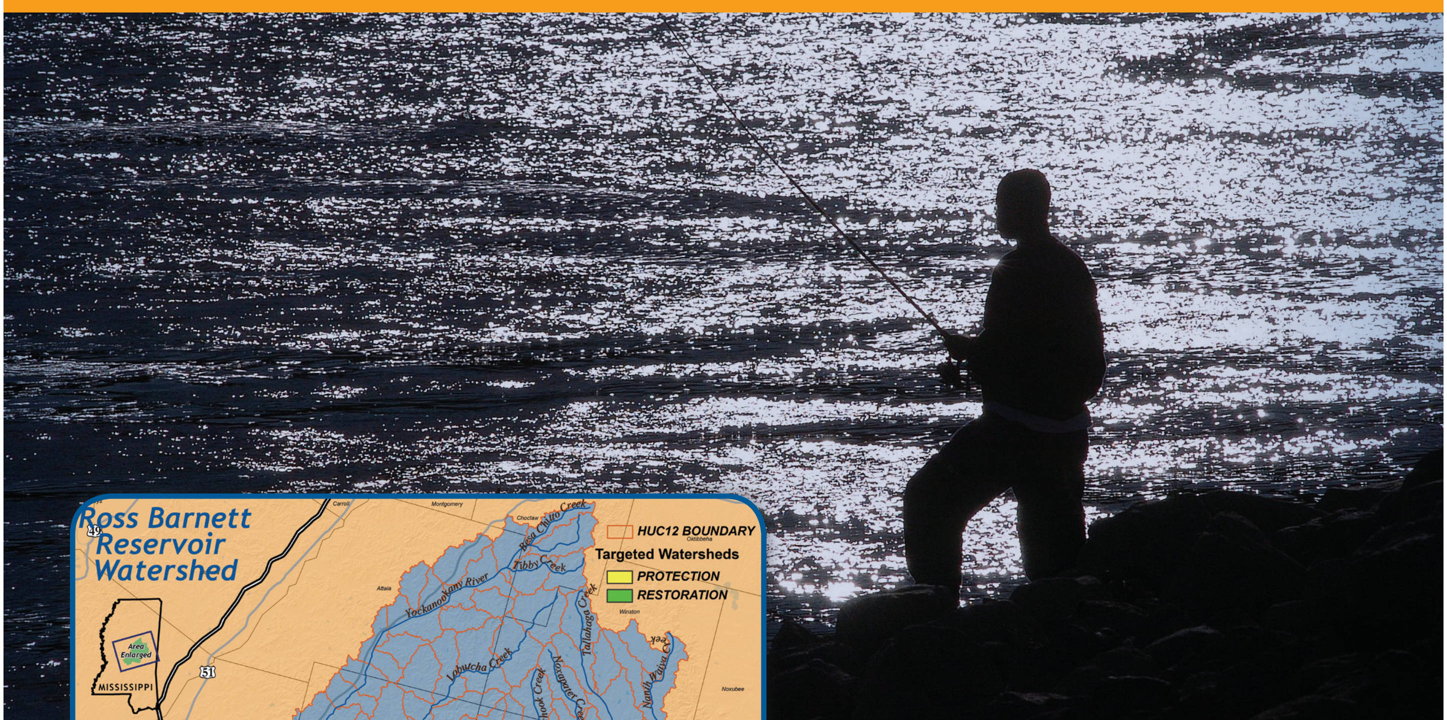
Rezonate!

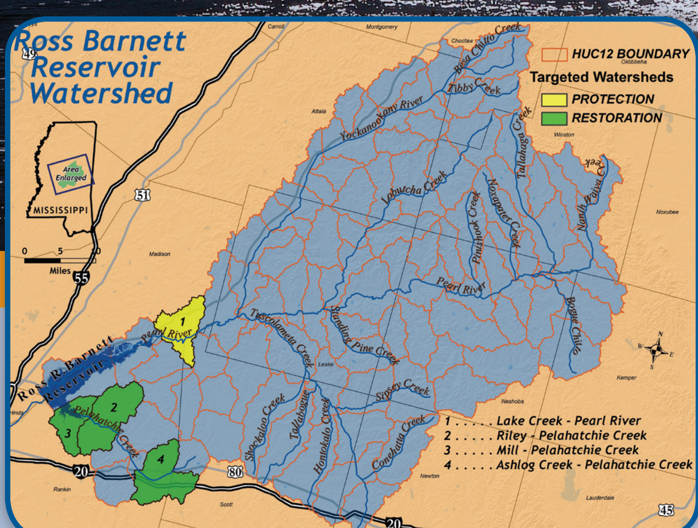
YOUR WATER . . . YOUR LEGACY

COMPREHENSIVE PROTECTION & RESTORATION PLAN

for the

ROSS BARNETT RESERVOIR WATERSHED, MISSISSIPPI





COMPREHENSIVE PROTECTION AND RESTORATION PLAN FOR THE ROSS BARNETT RESERVOIR WATERSHED, MISSISSIPPI

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We have enjoyed working with each of you!

FTN Associates, Ltd., CDM Inc., and The Cirlot Agency

Since its construction in the late 1960s, the Ross Barnett Reservoir has been an irreplaceable resource for central Mississippi. The Reservoir serves as the primary water supply for the City of Jackson, which is located southwest of the Reservoir. As it has done for more than 50 years, this plentiful water resource supports economic growth in central Mississippi and provides outstanding recreational opportunities, scenic beauty, and vital wildlife habitats. Recognizing this, the Mississippi Department of Environmental Quality and the Pearl River Valley Water Supply District jointly developed the Ross Barnett Reservoir Initiative, known as **Rezonate!**.

The Reservoir's watershed includes more than 3,000 square miles of land and over 4,000 miles of flowing rivers and streams. All uses of land within the Reservoir's watershed can potentially impact water quality in its tributaries and ultimately in the Reservoir itself. This ***Comprehensive Protection and Restoration Plan for the Ross Barnett Reservoir Watershed*** will serve as the framework for long-term, coordinated multi agency efforts to protect and restore water quality in the Reservoir and its watershed.

This Comprehensive Watershed Protection and Restoration Plan will serve as the framework for long-term, coordinated multi-agency efforts to protect and restore water quality in the Reservoir and its watershed.

The Reservoir provides many social and economic benefits.
Photo by Brian Albert Broom.

This Plan recognizes six high priority issues in the Reservoir and its watershed, and recommends management measures for reducing and controlling them. The majority of the pollutants originate from diffuse sources throughout the Reservoir watershed, including urban stormwater, stream bank erosion, and runoff from rural and agricultural areas. Since these diffuse pollutant sources cannot be attributed to a single location or regulated entity, they are termed “nonpoint source pollutants.” Specific issues are:

- **Sediments and turbid water,**
- **Nutrient enrichment and algae growth,**
- **Bacteria and other pathogens,**
- **Invasive aquatic plant species,**
- **Pesticides (currently used herbicides and insecticides), and**
- **Trash dumping and littering in and around the Reservoir and its shoreline.**

The Reservoir provides drinking water to citizens of the City of Jackson.
Photo by Shutterstock.

Recreational benefits of the Reservoir.
Photo by Brian Albert Broom.

This Plan is intended to address the entire Reservoir watershed and recommends general management concepts applicable throughout the drainage basin along with specific pollution reduction measures for targeted areas. The use of green infrastructure management practices, a cost-effective, sustainable, and environmentally friendly approach to stormwater management, is the key pollution management concept recommended in this Plan.

Green infrastructure management practices maintain or mimic natural processes by capturing and cleaning stormwater close to its source.

Green infrastructure management practices include streamside buffer zones, bioretention basins, vegetated drainage swales, constructed wetlands, and preserved trees/vegetation. Preserving and restoring natural landscape features (such as forests, stream buffers, and wetlands) are critical components of green infrastructure. Communities in the Reservoir watershed can use green infrastructure to improve water quality and solve stormwater management issues, while providing wildlife habitat and opportunities for outdoor recreation.

The Reservoir supports important fish habitats.
Photo by Brian Albert Broom.

Nine overarching management strategies have been developed for the Reservoir watershed. The strategies incorporate green infrastructure management principles to achieve the goals and realize the **Rez*onate*** vision statement.

Improved water quality, better human health, and increased property values are among the many benefits of green infrastructure.

STRATEGY 1: *Maintain, and restore where possible, the existing riparian buffer zones along the Reservoir shoreline and the banks of tributaries.* Vegetated buffer zones are an effective and low-cost element of green infrastructure that can be used in the Reservoir watershed. Maintaining a vegetated buffer along shorelines and streams provides an attractive landscape and can improve water quality by removing sediment and chemicals before they reach surface waters. In addition, buffers provide flood control, help recharge groundwater, prevent soil erosion, and improve wildlife habitat. When feasible, buffer zones should be restored to a width of at least 50 ft in already-developed areas. Avoid disturbance of buffer zones in undeveloped areas.

Properly managed development using a green infrastructure approach can support sustainable economic growth and maintain the water quality in the Reservoir.

STRATEGY 2: *Do not remove vegetation or disturb soils, if possible. If disturbed, minimize the exposure time of bare soils.* The Reservoir watershed contains some of the most highly erosive soils in the United States, especially in portions of Rankin, Madison, and Leake counties. When bare soils are exposed (due to construction and surface mining) to intense rain they will quickly erode, which eventually leads to large gullies. This eroded soil washes into surface waters, which in turn chokes streams and fills the Reservoir. Retain existing trees and other vegetation where feasible, and quickly replant disturbed sites with native vegetation.

Reservoir shoreline.
Photo by Laura Sheely.

STRATEGY 3: ***Control urban runoff within sites where it is generated, and reduce the quantity of stormwater and pollutants through capture, infiltration, and evapotranspiration.*** Excess stormwater from developed areas can damage stream channels and carry tons of sediment and other pollutants to surface waters. Management measures that remove pollutants close to the source, such as bioretention basins, constructed wetlands, and rain barrels, are much more environmentally effective and cost-effective than attempting to treat the water downstream.

STRATEGY 4: ***Use natural, bioengineering techniques to repair failing stream banks and eroding gullies.*** Preliminary estimates indicate that as much as 65% of the sediments transported to the Reservoir in some areas originate from instream sources (i.e., eroding banks, resuspension from stream beds, and sediments stored in channels from past activities). Bioengineering erosion control techniques combine structural components and native plant material to protect the banks, improve aquatic habitat, and improve the appearance of eroding streams.

STRATEGY 5: ***Adopt new ordinances or expand existing ordinances regulating land development, stormwater management, and landscaping if voluntary measures are shown to be insufficient.*** Review local stormwater management and erosion control policies for stream buffer protection, undisturbed green space, erosion and sediment controls on individual lots within

Bank failures contribute to sediments and turbid water in Reservoir tributaries.
Photos by Laura Sheely.

developments, and post construction stormwater management. If water quality problems persist, zoning policies, and local ordinances will need to be strengthened in order to sustain the long-term health and beneficial uses of the Reservoir and its tributary streams.

STRATEGY 6: *Continue public outreach and education by implementing the activities recommended for each targeted audience in the Comprehensive Education and Outreach Plan.*

Nonpoint source pollution control is a community-based activity. Effective management of nonpoint source pollution requires a long-term commitment to educating the general public, educators and students, civic groups, homeowners, decision-makers, and developers/contractors. Keep the public informed about **Rez*onate*** events, restoration projects, and success stories. Cultivate local champions (individuals, civic groups, or businesses) to take personal ownership and have a leading role in promoting conservation in the Reservoir watershed.

STRATEGY 7: *Work with federal, state, and local agencies to support conservation activities that are in progress on forested and agricultural lands and animal production.*

Many rural landowners in the Reservoir watershed are already participating in programs of the Natural Resources Conservation Service (NRCS) and Mississippi Soil and Water Conservation Commission (MSWCC) to install and maintain best management practices (BMPs) in pastures and row-crop fields and for poultry-growing operations. Look for new opportunities to enhance green infrastructure through practices such as field borders and filter

Mr. Whiskers was created as the **Rez*onate*** mascot.

strips, while taking advantage of cost-sharing programs to fund their installation and maintenance. Work with NRCS to prioritize funding for practices in targeted subwatersheds. Also, participate in forestry stewardship programs and use the technical expertise available from the Mississippi Forestry Commission (MFC) to properly manage logging operations on forest land.

STRATEGY 8: *Develop and implement an incentive program to encourage the voluntary use of green infrastructure management measures.* The successful implementation of this Plan relies heavily on the willingness of landowners to implement measures on their properties and the ability of designers to include them in retrofits and new developments. Incentive programs are creative tools that nonprofit organizations or governments can use to encourage the use of green infrastructure on these private properties. Incentives allow governments to act beyond the confines of their regulatory authority to improve stormwater management and encourage the use of measures not required by local zoning and ordinances. Examples of incentive programs include property tax credits, expedited permit approval, grants, awards, and recognition. Incentive programs must be developed and implemented by local or state governments or non governmental organizations based on available resources.

A constructed wetland is used to treat stormwater from the parking lot of the Mississippi Museum of Natural Science.
Photo by Laura Sheely.

STRATEGY 9: *Focus Phase I restoration and protection efforts on targeted subwatersheds defined by 12-digit hydrologic unit codes (HUC12s).* Develop detailed watershed implementation plans (WIPs) for high priority areas. Use early successes realized in these watersheds to shape future management measures through an adaptive management process.

This Plan recommends specific management measures for targeted subwatersheds. ***Restoration*** measures are recommended for subwatersheds that contain the most significant pollutant sources (i.e., hot spots) or have known water quality issues. ***Protection*** measures are recommended for subwatersheds that have little development and few pollutant sources. Protection measures help preserve the pristine condition of these areas.

In future years, implementation efforts will be extended to other subwatersheds as additional funding, stakeholder interest, and technical resources become available.

Implementation of management measures on a watershed-wide scale (i.e., the entire Ross Barnett Watershed) is not practical or economically feasible. Thus, this Plan recommends focusing the first phase of implementation efforts on three subwatersheds targeted for restoration (Mill-Pelahatchie Creek, Riley-Pelahatchie Creek, and Ashlog-Pelahatchie Creek) and one subwatershed targeted for protection (Lake Creek-Pearl River) (see Figure ES.1).

Pearl River upstream of the Reservoir is largely underdeveloped.
Photo by Brian Albert Broom.

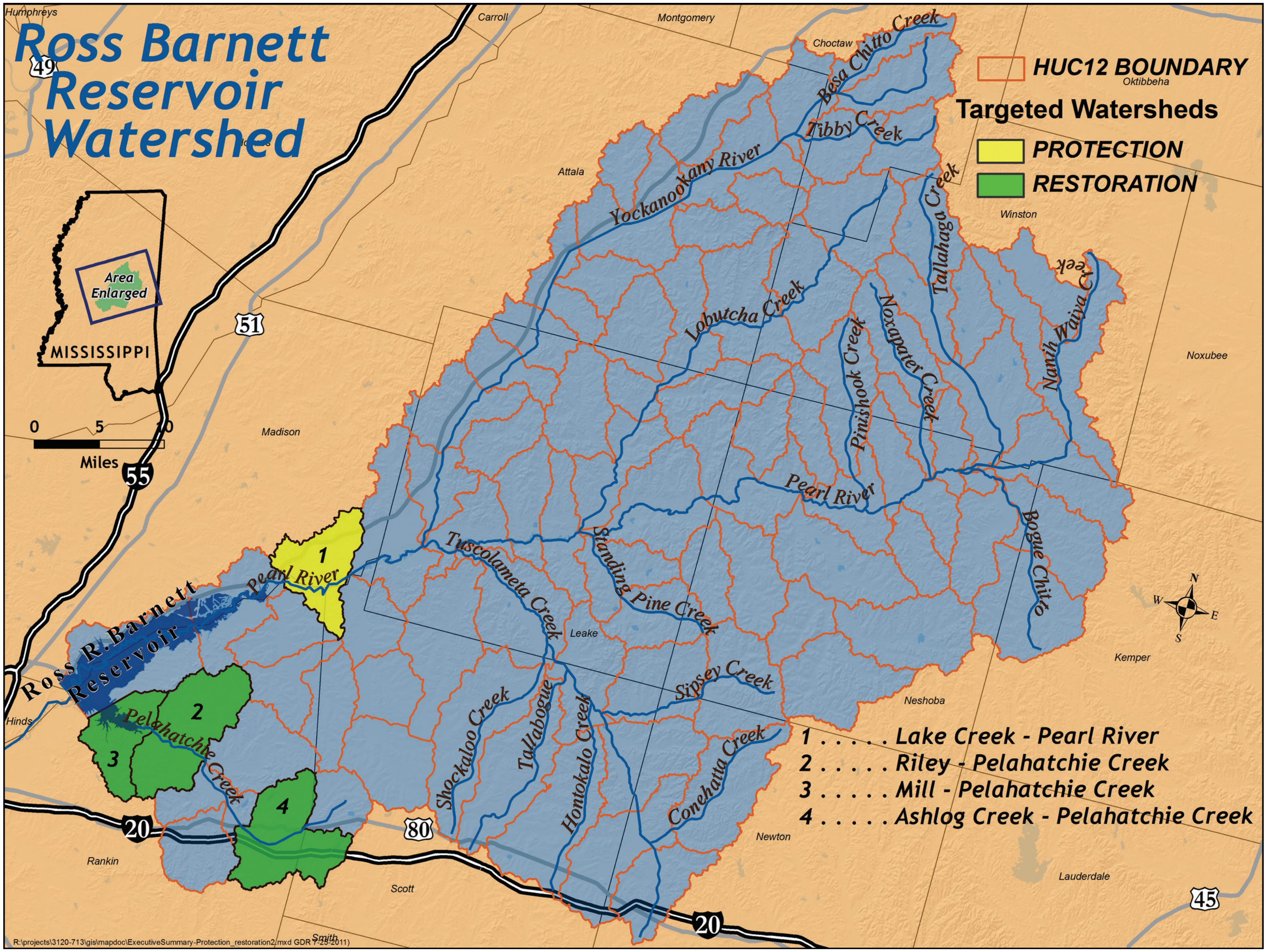

FIGURE ES.1. Targeted subwatersheds.

Restoration: Mill-Pelahatchie Creek

The Mill-Pelahatchie Creek subwatershed is located entirely in Rankin County. It is adjacent to Pelahatchie Bay, an important location for drinking water protection efforts. This watershed contains a high percentage of developed area (Figure ES.2). Thus, urban green infrastructure practices would be effective and highly visible in this area. Restoration measures will reduce pollutants contributed from construction sites and developed areas.

Recommended restoration measures are as follows:

- **Incorporate green infrastructure stormwater management practices in new construction and retrofits,**
- **Coordinate with Rankin County officials in matters related to stormwater management in developed areas,**
- **Improve construction stormwater controls on individual lots that are within a larger common plan of development,**
- **Stabilize disturbed soils on construction sites and surface mines by quickly replanting with native grasses and other vegetation,**
- **Identify and restore shoreline and streamside buffer zones and banks in needed areas, and repair eroding gullies,**
- **Leave undisturbed vegetated areas (i.e., green space) and shoreline/streamside buffer zones within new developments, and**
- **Develop an incentive program to encourage the use of green infrastructure management practices.**

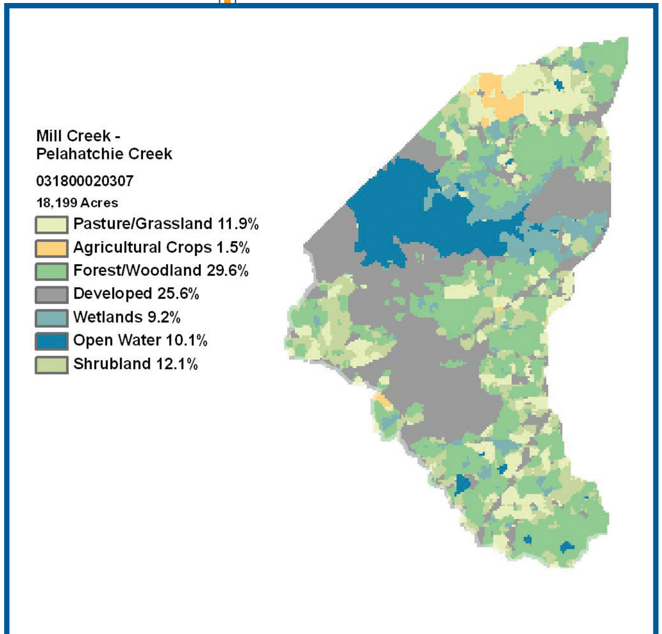

FIGURE ES.2.
Landuse in the Mill Creek-Pelahatchie Creek Watershed.

Restoration: Riley-Pelahatchie Creek

The Riley-Pelahatchie Creek subwatershed is also located in Rankin County and contains some development from the outskirts of Flowood and Fannin. As growth continues, these areas should be managed in the same manner as Mill-Pelahatchie Creek (i.e., construction stormwater control and green infrastructure management measures). This HUC12 also contains extensive pasture and timber areas that should be carefully managed to control nonpoint source pollutants (Figure ES.3).

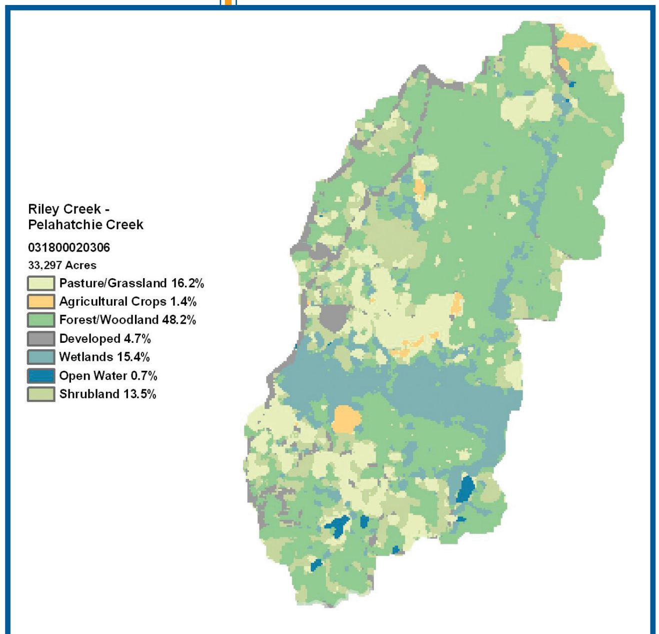

FIGURE ES.3.
Landuse in the Riley Creek-Pelahatchie Creek Watershed.

Recommended restoration measures are as follows:

- **Address compliance issues at a wastewater treatment facility discharging into Pelahatchie Creek (Reservoir East) and encourage all new homes and buildings to connect to a central sewer system because most soils are not suitable for septic tanks,**
- **Incorporate green infrastructure stormwater management measures for new construction,**
- **Preserve streamside buffers and green space as new development expands to this area,**
- **Stabilize disturbed soils on construction and surface mining sites by quickly replanting with native grasses and other vegetation,**
- **Implement pasture management practices on all areas with willing landowners, and**
- **Encourage participation in forestry stewardship programs.**

Restoration: Ashlog-Pelahatchie Creek

The Ashlog-Pelahatchie Creek subwatershed is located in the headwaters of Pelahatchie Creek within Rankin and Scott counties. Headwater systems are generally more responsive to BMPs (i.e., nonpoint source reductions can be detected more quickly in smaller streams). There is some urban development in the City of Pelahatchie. However, the watershed contains mostly forested and pasture land with limited row crop agriculture (Figure ES.4). There are several poultry growing operations located within this HUC12.

Recommended restoration measures are as follows:

- **Incorporate green infrastructure stormwater management measures in new construction and retrofit projects in the City of Pelahatchie,**
- **Preserve streamside buffers and green space as development continues in this area,**
- **Assist poultry growers to ensure that they have access to technical expertise and cost-sharing programs to implement nutrient management plans,**
- **Implement pasture management measures and best management practices for agricultural crops in all areas with willing landowners,**
- **Investigate flooding concerns through evaluation of Pelahatchie Creek's flow capacity, and**
- **Encourage participation in forestry stewardship programs.**

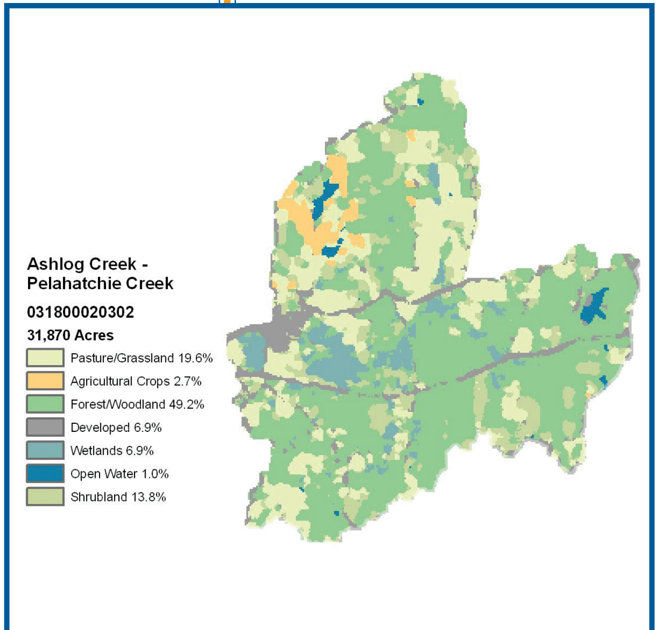

FIGURE ES.4.
Landuse in the Ashlog Creek-Pelahatchie Creek Watershed.

Protection: Lake Creek-Pearl River

The Lake Creek-Pearl River subwatershed is located upstream of the Reservoir in a section of the Pearl River that is used extensively for recreation (between Ratliff Ferry and the Low-Head Dam). There are few roads, making most access by boat. Also, there is little development and almost no croplands in this watershed (Figure ES.5). It is important to protect the wetland areas as they serve important functions for water quality preservation and flood protection for areas downstream.

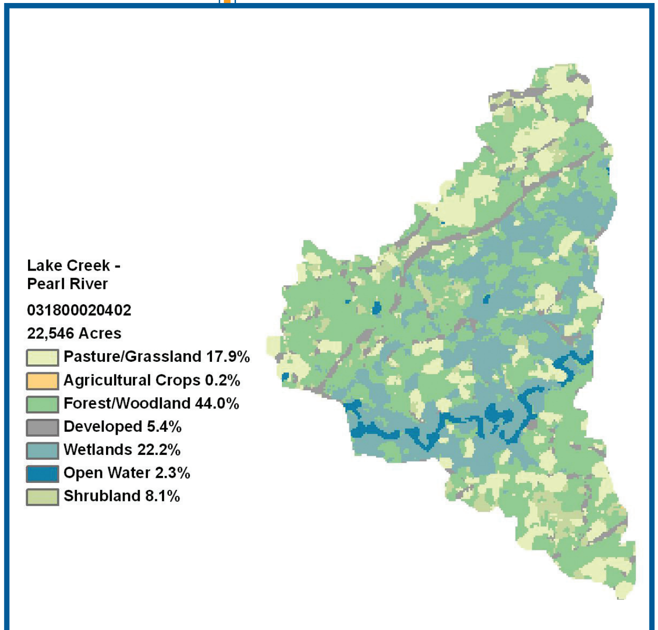

FIGURE ES.5.
Landuse in the Lake Creek-Pearl River Watershed.

Recommendations for protection measures are as follows:

- **Maintain wetlands, streamside buffer zones, and undisturbed green space,**
- **Partner with *Keep the Reservoir Beautiful* to curb littering by recreational boaters,**
- **Use education programs to promote a sense of pride and responsibility for environmental preservation of this area, and**
- **Promote conservation easements through partnerships between non-profit groups and private landowners.**

This ***Comprehensive Watershed Protection and Restoration Plan*** was developed with input from local citizens, resource agency representatives, and technical experts in watershed planning and nonpoint source pollution management. This Plan, the product of almost 2 years of research and collaboration, ties together the following set of comprehensive planning documents.

- **Water Quality Monitoring Plan for the Reservoir and Watershed,**
- **Pathogen Source Assessment and Wastewater Management Plan,**
- **Comprehensive Education and Outreach Plan for Rez*onate!*, and**
- **Source Water Protection Plan for the O.B. Curtis Drinking Water Intake.**

Sunset on the Ross Barnett Reservoir.
Photo by Charles M .Foreman Jr.

Protecting and maintaining clean water in the Reservoir and its watershed is a community-based activity that will require the long-term cooperation and commitment of many individuals. This Comprehensive Watershed Protection and Restoration Plan is intended to sustain these waters as a useful and healthy resource for many years to come.

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1.0 PATH FORWARD – REZ*ONATE* VISION, GOALS, AND PLANS

Recognizing the importance of the Ross Barnett Reservoir, the Mississippi Department of Environmental Quality (MDEQ) and the Pearl River Valley Water Supply District (PRVWSD), along with the National Resources Conservation Service (NRCS) and the Mississippi Soil and Water Conservation Commission (MSWCC), initiated planning to protect and restore water quality in the Ross Barnett Reservoir watershed. This effort, initially called the Ross Barnett Reservoir Initiative, has been branded as Rez*onate!* A set of comprehensive plans based on the vision statement and common goals will guide implementation of the Rez*onate* Plans.

1.1 Vision

A vision statement for the Ross Barnett Reservoir watershed (Figure 1.1) serves as the starting point for developing all aspects of Rez*onate*. The vision for the Ross Barnett Reservoir Initiative was developed by a group of agency representatives and local stakeholders responsible for various resource management activities in the Reservoir and its watershed. Representatives responsible for economic development in the five counties located closest to the Reservoir (Madison, Rankin, Hinds, Scott, and Leake counties) were also invited to participate in an interactive discussion about ways to improve water quality while enhancing the environmental, educational, and recreational value of the Reservoir. Attendees included representatives of PRVWSD, MDEQ, the Mississippi Emergency Management Agency (MEMA), local economic development groups, state and county government, the Rankin County School District, and local real estate developers. The vision statement is an expression of the group’s desires and intentions for the status of the Reservoir in the future. The vision statement is given on Figure 1.1.

Rezonate!

YOUR WATER ... YOUR LEGACY

Born of the aspirations, dreams and desires of visionaries past, the Ross Barnett Reservoir is an interwoven community of residential, commercial, wildlife and ecological systems that coexist to create a source of life, as well as a source of lifestyle.

It is a dichotomy of rural wilderness and the most upscale modern developments. A community in the traditional sense, the Reservoir is also a community in the larger sense ... one where all of Mississippi may take part in camping, boating, hiking, bicycling and a destination for experiential learning, as well as a source for economic development and social interaction.

The common thread to all this activity and community is the unsurpassed water quality management practices performed within the Reservoir's watershed. It is an area vehemently protected by a highly motivated, enlightened citizenry that has a passion for the sustainability of this precious resource.

A source of pride and a wellspring of enjoyment, the Reservoir is a place where all who appreciate its many benefits take personal responsibility for sustaining its unique characteristics for generations to come.

Figure 1.1. Vision statement.

1.2 Goals

Based on the vision statement, there are four goals for the Ross Barnett Reservoir Initiative. The goals are as follows:

- Develop a group of champions that will lead water quality improvements now and will continue the vision into the future.
- Promote a sense of community, citizen pride and involvement, and personal responsibility among residents of central Mississippi.
- Protect and restore water quality and the designated/desired uses in the Reservoir and its tributaries.
- Maintain a healthy balance and diversity in using land and its resources in the Reservoir watershed.

1.3 Rez*onate* Plans

A number of planning documents were developed to guide all future protection and restoration activities in the Reservoir watershed. A list of plans is included below. The content of each plan is described in Appendix A.

- Comprehensive Watershed Protection and Restoration Plan,
- Water Quality Monitoring Plan for the Reservoir and Watershed,
- Pathogen Source Assessment and Wastewater Management Plan,
- Comprehensive Education and Outreach Plan for Rez*onate!*, and
- Source Water Protection Plan for the O.B. Curtis Drinking Water Intake.

MDEQ contracted with FTN Associates, Ltd. (FTN) to provide project management and technical support needed to develop the Rez*onate* plans. The Cirlot Agency joined with FTN to develop education and outreach programs and associated materials. An additional contractor, CDM Inc. (CDM), was responsible for development of the *Pathogen Source Assessment and Wastewater Management Plan*. FTN and CDM coordinated work groups of local stakeholders and agency representatives to give input into all aspects of the planning process.

2.0 WATERSHED DESCRIPTION

2.1 Watershed Size and Location

The Ross Barnett Reservoir is an impoundment of the Pearl River just upstream of Jackson, Mississippi (Figure 2.1).The Reservoir covers approximately 33,000 acres in Madison and Rankin counties. The watershed of the Reservoir covers approximately 3,050 square miles in twelve counties: Attala, Choctaw, Hinds, Kemper, Leake, Madison, Newton, Neshoba, Noxubee, Rankin, Scott, and Winston counties (Figure 2.1). The largest cities in the watershed are Flowood, Ridgeland, Madison, Philadelphia, Kosciusko, and Louisville (Figure 2.1). Interstate 20, US Highway 80, and Mississippi State Highway 25 pass through the watershed, as well as the Natchez Trace Parkway (Figure 2.1).

2.2 Land Use and Land Cover

2.2.1 Current Land Use

The US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) Cropland Data Layer (CDL) is the most recent available land use inventory for the Ross Barnett Reservoir watershed. The CDL is a raster, geo-referenced, crop-specific land cover data layer with a ground resolution of 56 meters. In 2008, land use in the watershed was primarily forested (50%). Watershed land cover from 2008 is shown on Figure 2.2 and summarized in Table 2.1.

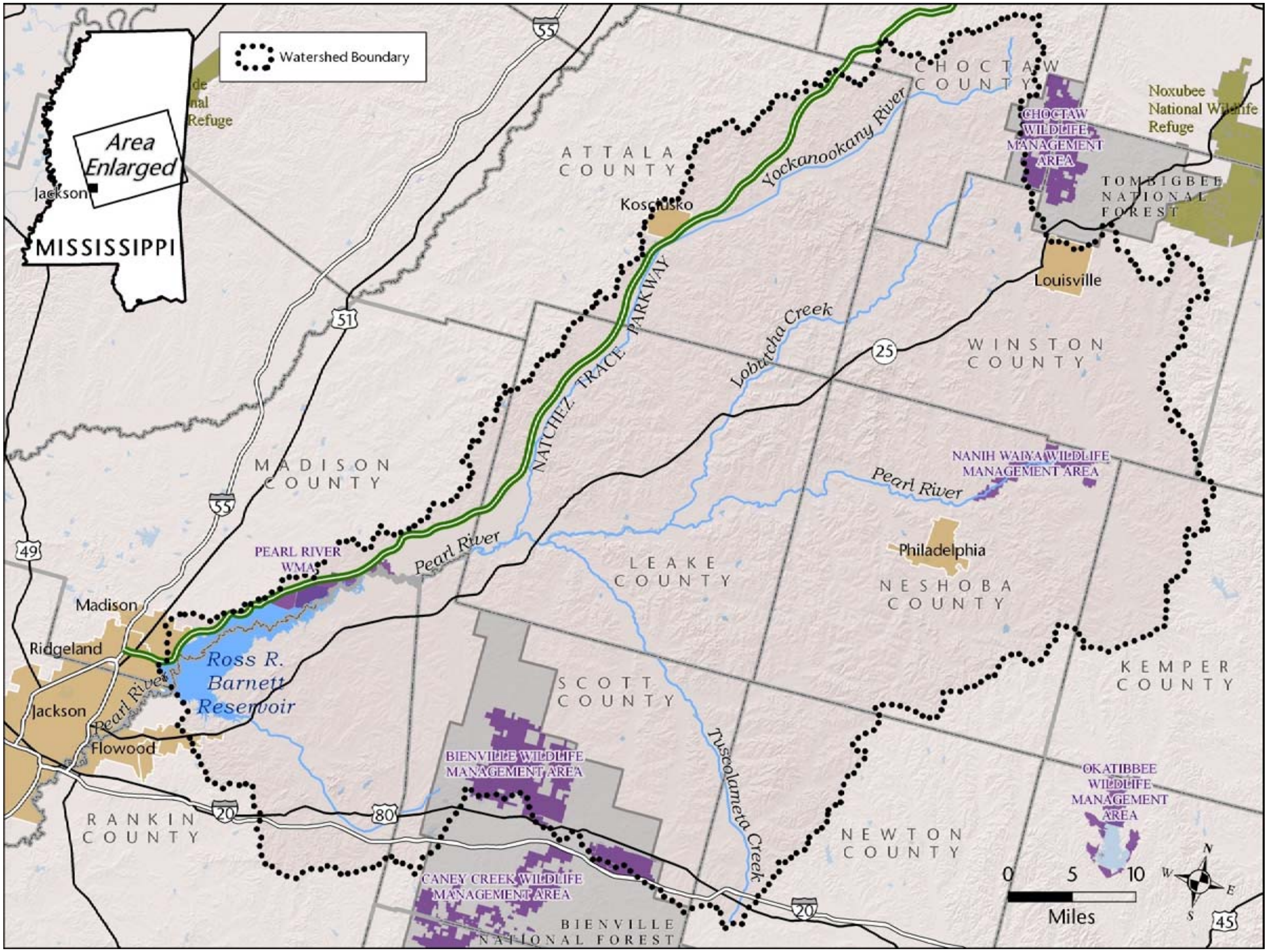

Figure 2.1. Location of Ross Barnett Reservoir and watershed.

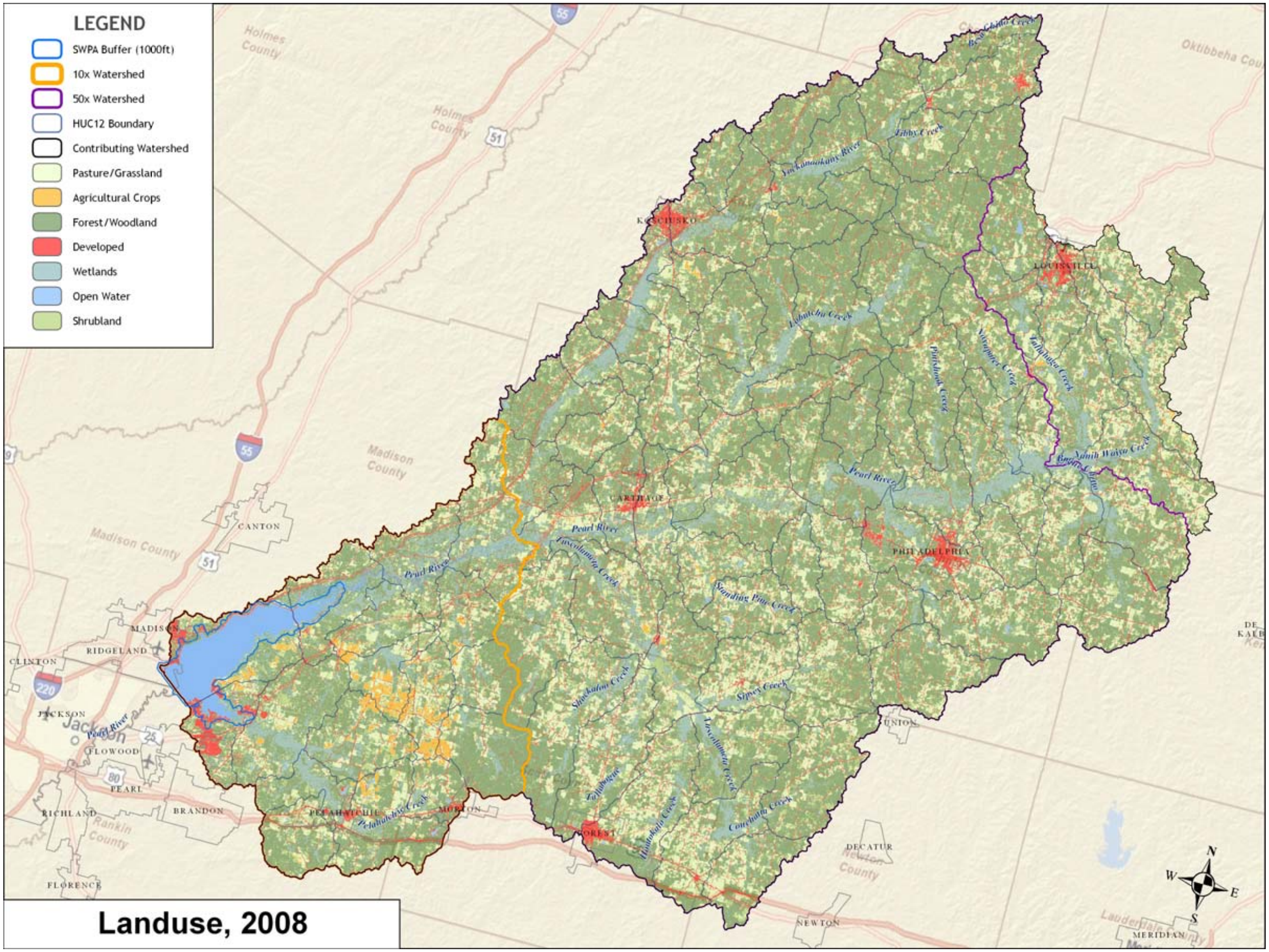

Figure 2.2. Land use/land cover in Ross Barnett watershed in 2008.

Table 2.1. Watershed land use as of 2008.

Land Use/Land Cover	Percent of Watershed
Agricultural Crops	1.1%
Developed	6.3%
Forest/Woodland	50.4%
Open Water	1.8%
Pasture/Grassland	18.9%
Shrubland	12.6%
Wetlands	8.9%
Total	**100.0%**

2.2.2 Areas of Development

Land around the Reservoir is being developed aggressively. The Reservoir shoreline is an area of significant residential and commercial development in Rankin and Madison counties. Residential and commercial developments have lead to economic growth in northwestern Rankin County and southeastern Madison County, which currently experience the second and third highest growth rates in the state. There is additional urban development in upstream watersheds, including the cities of Koscuisko, Philadelphia, and Louisville, and the towns of Forest and Carthage.

2.2.3 Imperviousness

Impervious surfaces are areas that do not allow natural infiltration of rainfall to the underlying soil. In the Ross Barnett Reservoir watershed, these areas include roads, parking lots, and buildings. Yards and landscaped areas are considered somewhat impervious. They soak up some water during rain events, but may generate runoff during intense storms or prolonged rain events.

The most recent information available to quantify impervious surface area for the Reservoir watershed was developed in 2006. This layer was developed by the Multi-Resolution Land Characteristics Consortium (MRLC) in conjunction with the 2006 National Land Cover Dataset (NLCD). The layer classifies the imagery into 101 possible values (0% to 100%) to show the estimated degree of imperviousness.

In 2006, the percent impervious area in each 12-digit hydrologic unit code (HUC12) varied from 7.4% to 0.2%, and averaged 0.3% The HUC12s with highest percentage of impervious area are located near Pelahatchie Bay in Rankin County, and the cities of Philadelphia and Louisville in the upper watershed (Figure 2.3).

2.3 Reservoir and Watershed Characteristics

The Pearl River Valley Water Supply District maintains the Reservoir pool levels between 296 and 297.5 ft mean sea level (msl) during most conditions. The Reservoir's surface area at pool elevation 296 ft msl is approximately 125 square kilometers (Lester Engineering and Harza Engineering 1959). With an average depth of 3 meters, the Reservoir is a shallow body of water. Basic dimensions of the Reservoir are shown in Table 2.2.

Table 2.2. Reservoir dimensions with water level at 296 ft msl.

Parameter	Value	Units
Volume	382,538,243	Cubic Meters
Surface Area	125.4	Square Kilometers
Watershed Area	7,889	Square Kilometers
Length	69.2	Kilometers
Shoreline Length	169	Kilometers
Maximum Depth	15.2	Meters
Mean Width	1.8	Kilometers
Mean Depth	3.0	Meters

In order to fully understand the present condition of the watershed, FTN developed a comprehensive inventory of watershed characteristics (Appendix B), including the history of the Reservoir, socioeconomics, natural resources, fisheries, and species of concern. Appendix B also describes the HUC12 watershed areas along with the physiographic regions, ecoregions, bioregions, wetlands, and aquifers in the Reservoir drainage area. Detailed descriptions of the climate, geology, historical landuse trends, hydrology, and major tributaries are provided.

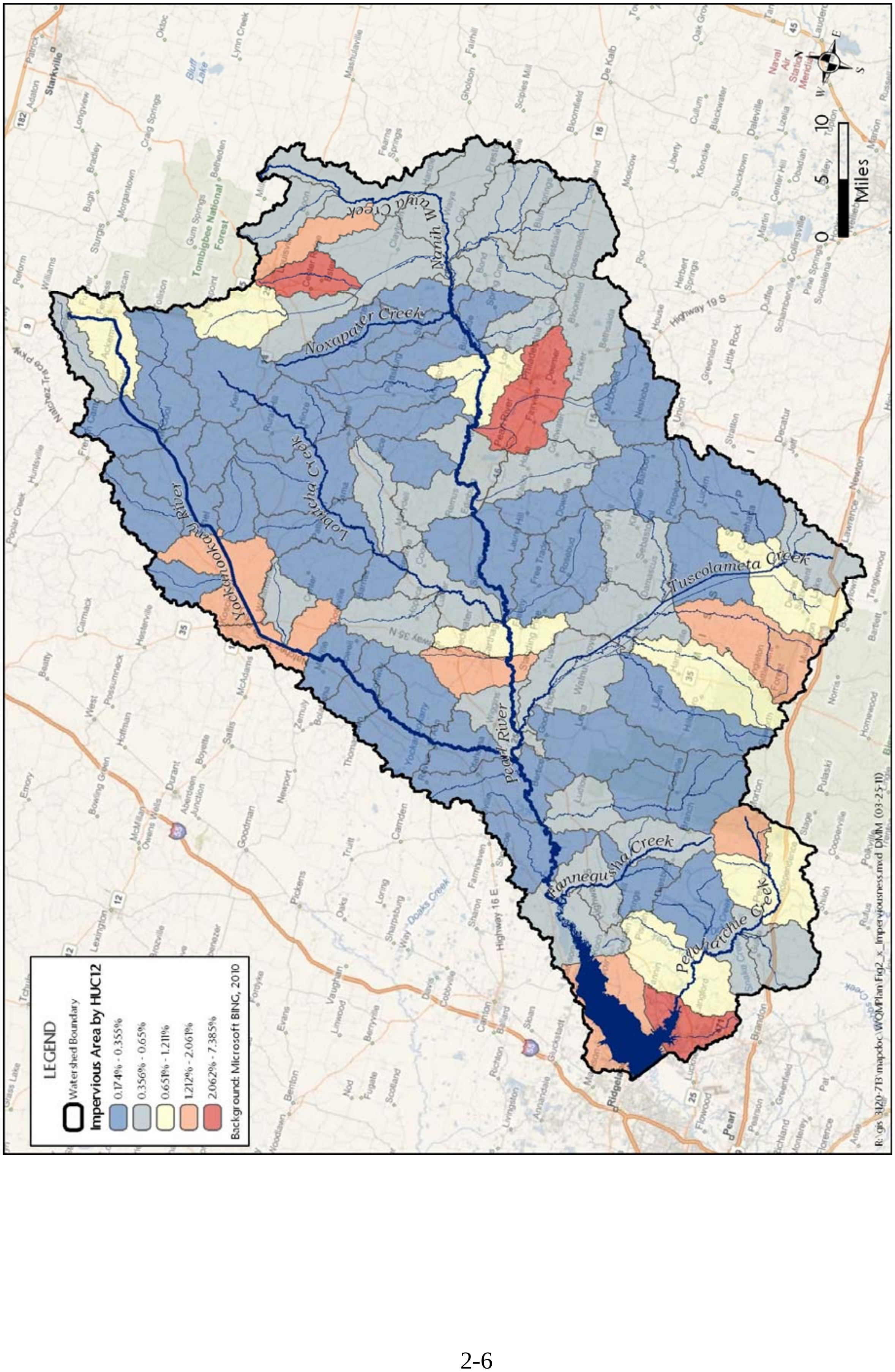

Figure 2.3. Percent impervious surface area by HUC12.

2.4 Water Quality Data

Water quality data for the Reservoir and its watershed have been collected by several agencies including MDEQ; the US Geological Survey (USGS); the US Environmental Protection Agency (EPA); the Mississippi State Department of Health (MSDH); the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP); and the National Park Service. The Water Quality Monitoring Plan includes an inventory of all available data. Appendix C includes an analysis of data for two large rivers in the Reservoir watershed, the Pearl River and the Yockanookany River. Appendix D gives a summary of recent water quality data collected within the Reservoir along with a status and trends analysis. Appendix E summarizes the results of fish tissue samples collected in the Reservoir.

2.5 Regulations Relevant to Restoration and Protection

Appendix F includes descriptions of federal and state regulations that are relevant to restoration and protection of water quality in the Reservoir and its watershed. Many of these regulations include permits issued to regulated facilities. MDEQ issues wastewater and stormwater permits in accordance with federal requirements. Permits include Stormwater Management Plans for designated municipal separate storm sewer system (MS4) areas and Construction Stormwater Permits. Local governments issue ordinances that define stormwater management requirements for counties and cities.

2.6 Water Quality Impairments

Section 303(d) of the Clean Water Act requires states to identify waters that do not support their classified uses and to prioritize the impaired waters. The state then must develop a total maximum daily load (TMDL) for each pollutant causing the impairment. TMDLs are the maximum amount of a given pollutant that a waterbody can assimilate and still maintain its designated uses. The presence of a TMDL for a waterbody is a key factor in selecting watersheds in need of restoration measures. In fact, the management measures recommended in this Plan will share the same goals as TMDL implementation activities for individual waterbodies.

The Mississippi Section 303(d) lists (2008 and 2010) include several stream segments located in the Ross Barnett watershed. Listed causes of impairment include biological impairment, sediment, pathogens, organic enrichment/low dissolved oxygen, and nutrients. Monitored waterbodies in the Ross Barnett watershed included on the draft 2010 303(d) list are listed in Table B.8 in Appendix B. The 2010 list includes only monitored waterbodies. The 2010 list is currently in draft format; however, final approval by the Mississippi Commission on Environmental Quality is anticipated. Table B.9 in Appendix B lists the completed TMDLs for waterbodies within the Reservoir watershed and summarizes recommended pollutant reductions identified in the TMDLs. Appendix G compares monitoring data collected from waterbodies with TMDLs to waterbodies without TMDLs developed as of 2011.

3.0 DESIGNATED USES AND DESIRED USES

3.1 Regulated Designated Uses of Streams

Designated uses for waterbodies are defined by MDEQ in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. This document describes the minimum water quality conditions applicable to all waters as well as specific requirements for particular designated use classifications. MDEQ updates this document on a triennial basis, with the most recent version approved in 2007.

All streams in the Ross Barnett Reservoir watershed have the designated use of Fish and Wildlife Support, with the exception of Warrior Branch, which is designated as an ephemeral stream. All waters of the state, except ephemeral streams, must meet the requirements for Fish and Wildlife criteria in order to support aquatic life. The criteria for Fish and Wildlife include numeric criteria for dissolved oxygen, pH, temperature, and fecal coliform bacteria. The portion of the Pearl River upstream of the Reservoir is also designated for use as Public Water Supply and Recreation (MDEQ 2007).

3.2 Regulated Designated Uses of Reservoir

According to MDEQ standards, the Ross Barnett Reservoir is designated for use as public water supply, fish and wildlife support, and recreation.

MDEQ standards state that waters classified for public water supply will be of sufficient quality that they will meet regulations established by the Safe Drinking Water Act after an approved treatment process. Specific criteria applicable to these waters include bacteria, chloride, specific conductance, dissolved solids, threshold odor, and radioactive substances. MDEQ also specifies maximum allowable levels for several specific chemicals: barium, fluoride, lead, and nitrate (as nitrogen).

Waters classified for use as recreation must be suitable for recreational purposes, including water contact activities such as swimming and waterskiing. MDEQ has established specific criteria for bacteria, specific conductance, and dissolved solids for recreational waters.

3.3 PRVWSD Reservoir Purposes

PRVWSD manages the Ross Barnett Reservoir for several purposes. The most significant purpose is water supply for the City of Jackson. The Reservoir provides raw water to be treated for drinking water to the City of Jackson in accordance with a contract between the City of Jackson and PRVWSD, dated November 18, 1959. Presently, the City of Jackson withdraws water from the Reservoir under the terms and conditions of a water withdrawal permit issued by MDEQ's Office of Land and Water Resources. Permit No. MS-SW-02419 allows the City to withdraw a maximum volume of 30 million gallons per day (MGD) from the Reservoir. PRVWSD also manages the water for several other uses including recreation, residential development, flood mitigation, wildlife habitat, and fishing.

3.4 Desired Uses of Streams and Reservoir

In addition to its regulated and designated uses, the Ross Barnett Reservoir has many desired uses. Desired uses of waters are defined according to the community of stakeholders that live in work in proximity to the waterbody. Although there are no specific criteria for desired uses, it is hoped that waters are maintained at a level of sufficient quality for desired activities. Recreational use of the Reservoir and parts of the Pearl River include boating, swimming, water skiing, fishing, and camping. The recreational opportunities and other amenities that the Reservoir offers significantly increase the quality of life for residents.

The Reservoir offers many desired uses that affect the economy of central Mississippi. In recent years, real estate development in the shoreline areas of the Reservoir has grown at a rapid pace. Property values of area near the shoreline of the Reservoir have generally increased in recent years. Development of businesses that serve the growing community has accompanied the residential growth. Water supply provided by the Reservoir has also allowed the development of industries in central Mississippi. Among these is the Nissan North America, Inc., automotive plant located in Canton, Mississippi.

3.5 Ecosystem Services

Ecosystem services are defined as the benefits that people obtain from ecosystems. While Ross Barnett Reservoir was designed and is managed to achieve the regulatory and designated uses identified above, there are other benefits that are provided to people from this aquatic ecosystem. These ecosystem services include other benefits such as climate regulation, water purification, water regulation, sediment retention, and aesthetic enjoyment. These ecosystem services are typically not included in most management plans because they are considered to be "free" to stakeholders living around and/or using the Reservoir. These ecosystem services and human uses associated with the services are listed in Table 3.1. One of the activities included in implementing the *Comprehensive Watershed Protection and Restoration Plan* will be the quantification and economic valuation of these services so that a more complete estimate of watershed protection and restoration benefits can be obtained.

Table 3.1. Reservoir uses and ecosystem services.

Human Uses	Food Products	Water Storage	Climate Regulation	Water Regulation	Water Purification	Sediment Retention	Natural Hazard Regulation	Spiritual/Inspirational	Recreational	Aesthetic	Educational	Nutrient Cycle	Habitat
Jackson			✔						✔	✔	✔		
• Drinking water supply		✔		✔	✔	✔	✔					✔	
• Flood control				✔			✔						
Area Municipalities		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔
Industry													
• Water supply		✔		✔	✔	✔	✔					✔	
• Cooling water		✔		✔									
• Processing		✔		✔	✔	✔							
Property Owners		✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	
Recreational													
• Boating		✔				✔			✔				
• Swimming		✔			✔				✔				
• Skiing		✔			✔	✔			✔				
• Fishing	✔	✔			✔	✔			✔				✔
• Viewing		✔						✔	✔	✔			✔
Cultural													
• Spiritual								✔		✔			✔
• Ceremonial													
Non-Use													
• Existence/Option/Bequest		✔								✔	✔		✔

4.0 LOCATIONS AND CAUSES OF WATER QUALITY ISSUES

In the Reservoir, as in most aquatic systems, a single pollutant cannot be identified as the cause of current water quality issues of concern. There are multiple issues impacting water quality: *excessive sediment, nutrient enrichment, pathogens, invasive plant species, pesticides, and trash*.

This section separately discusses each of the issues listed above by presenting the impact to water quality, characterizing its interaction with other pollutants, listing the waterbodies impaired by the issue, and noting other locations of concern. Also, this section briefly describes the sources of each issue, including human activities, that contribute pollutants to the Reservoir and its watershed. Appendix H gives a detailed inventory of pollutant sources.

The most prevalent pollutant sources in the Reservoir and its tributaries are widely distributed nonpoint sources originating from its watershed. In most cases, these nonpoint sources of pollutants cannot be easily quantified because information is not readily available to pinpoint their locations or measure their pollutant loads. Consequently, indicators such as land use, information on how various activities (such as urban development or timber harvesting) are managed, and inventories of pollutants typically present on those lands are used to describe the likelihood for discharge of nonpoint source pollutants. Locations of regulated activities such as construction permits and confined animal feeding operations, and management plans for specific land areas (stormwater management plans, for example) are also indicative of actual or potential nonpoint sources of pollution. Regulated point sources of pollutants, although their impact is typically smaller than nonpoint sources, are also included in the pollutant source inventory.

4.1 Sedimentation and Turbidity

Sediment is caused by erosion of soil particles from land surfaces in the watershed and detachment of soil from the banks and beds of tributaries of the Reservoir. The major factors that affect erosion include geology, climate, soil types, topography, vegetation, and land use characteristics. Climate factors include the amount and intensity of rain events and the temperature. Soil characteristics are defined by the soil erodibility, which varies depending on soil characteristics such as composition (percent clay, silt, and sand) and organic composition. Topography describes the slope length, steepness, and shape of the slope. Land use characteristics include management practices such as erosion management practices used at construction sites and sites of land-disturbing activities. Maps describing these characteristics are included in Appendix B.

Excessive sedimentation has been identified as the most significant water quality concern in the Ross Barnett Reservoir by several agencies including MDEQ, PRVWSD, the National Resources Conservation Service (NRCS), and the Mississippi Soil and Water Conservation Commission (MSWCC) (MDEQ 2009). In addition, the Pearl River Basin Team has identified the following issues of concern (MDEQ 2000):

- Sedimentation due to land disturbance adjacent to streams, and
- The impact of turbidity and suspended sediments on water quality.

Sedimentation and turbidity impact water storage capacity, fisheries, water quality, aesthetics, and recreation in the Reservoir. In the watershed streams, sedimentation and turbidity impact fish and other aquatic species, water quality, aesthetics and recreation. Sedimentation is a natural and unavoidable process that occurs in reservoir systems, rivers, and streams. However, in the case of a reservoir, when sediment deposition rates exceed design conditions, the storage volume and useful life of the reservoir are reduced. Due to its large wind fetch, sediments on the Reservoir bottom are often resuspended due to wind and wave action. This concern is discussed in detail in Appendix I.

Suspended sediment in the Reservoir and watershed streams may have a detrimental impact on fish by reducing light penetration needed for growth of aquatic plants beneficial to the fish community, reducing areas for feeding and growth of young insects, and reducing viability of fish eggs. Other aquatic species may also be affected by sedimentation impacts to breeding and feeding habitats. Reduced visibility as a result of turbidity can make it more difficult for predators to locate prey. Sediments may also cover stationary aquatic species, such as clams.

Suspended and deposited sediments are of additional concern because they may carry other chemicals into the water. Phosphorus is often associated with sediments because it readily binds to sediment particles washing from soils. Depending on the chemical properties of soil, other contaminants such as pesticides and metals can become sorbed to sediment particles and transported to waterbodies during the erosion processes.

Sedimentation and turbidity also have aesthetic impacts. Sediment’s impact on water color and clarity can have a significant impact on the public’s perceptions of water quality in the Reservoir and its tributaries. The color of the water in the Reservoir and resulting perceptions about the quality of the water impacts shoreline property values and economic development in the area.

Sediments can also affect recreation and restrict boat access. Navigation of boats in some areas of the Reservoir is currently restricted due to shallow water depths. In addition, as noted previously, turbidity can make it more difficult for fish to locate prey. This may impact recreational fishing success.

4.1.1 Locations

Locations where sedimentation and turbidity are causing water quality issues are summarized in Table 4.1 and on Figure 4.1. Additional detail about these locations and causes is included in Appendix H.

Table 4.1. Locations and causes of concern for sediment and turbidity.

Location	Cause of Concern
Pelahatchie Bay	Identified by stakeholders, significant increase in turbidity following rain events, navigation issues due to sediment deposition.
Mill Creek	Bank failures in several locations – bank failures are a significant concern to adjacent property owners; sedimentation occurring at a rapid rate in lower reaches near Pelahatchie Bay limits boat navigation.
Turtle Creek	Navigation issues due to sediment deposition; site has been frequently dredged.
Hearn Creek near Northbay Subdivision	Dredging is currently underway to restore sediment storage volume in Hearn Creek and prevent sediment from entering the main lake.
Cane Creek, Fannegusha Creek, Hurricane Creek and Red Cane Creek, Coffee Bogue, Eutahatchee Creek, Pearl River	Sediment TMDLs developed; biological monitoring and stressor identification indicates impairment of fish and wildlife use due to sediment; streams are located near the Reservoir (within the 1x:10x watershed).
Pearl River (segment MSUMPRLR2E), Pelahatchie Creek	Sediment TMDLs developed based on evaluated evidence; streams are located near the Reservoir (within the 1x:10x watershed).
Tuscolameta Creek, Tallabogue Creek, Shockaloo Creek, Lobutcha Creek, Pinishook Creek, Tallahaga Creek, Hughes Creek, Conehatta Creek	Sediment TMDLs developed; biological monitoring and stressor identification indicates impairment of fish and wildlife use due to sediment, streams are located within the 10x:50x watershed.
Bogue Chitto Creek, Nanih Waiya Creek, Pearl River (segment MSUPRLRE), Noxapater Creek	Sediment TMDLs developed based on evaluated evidence; streams are located in the above 50x watershed.

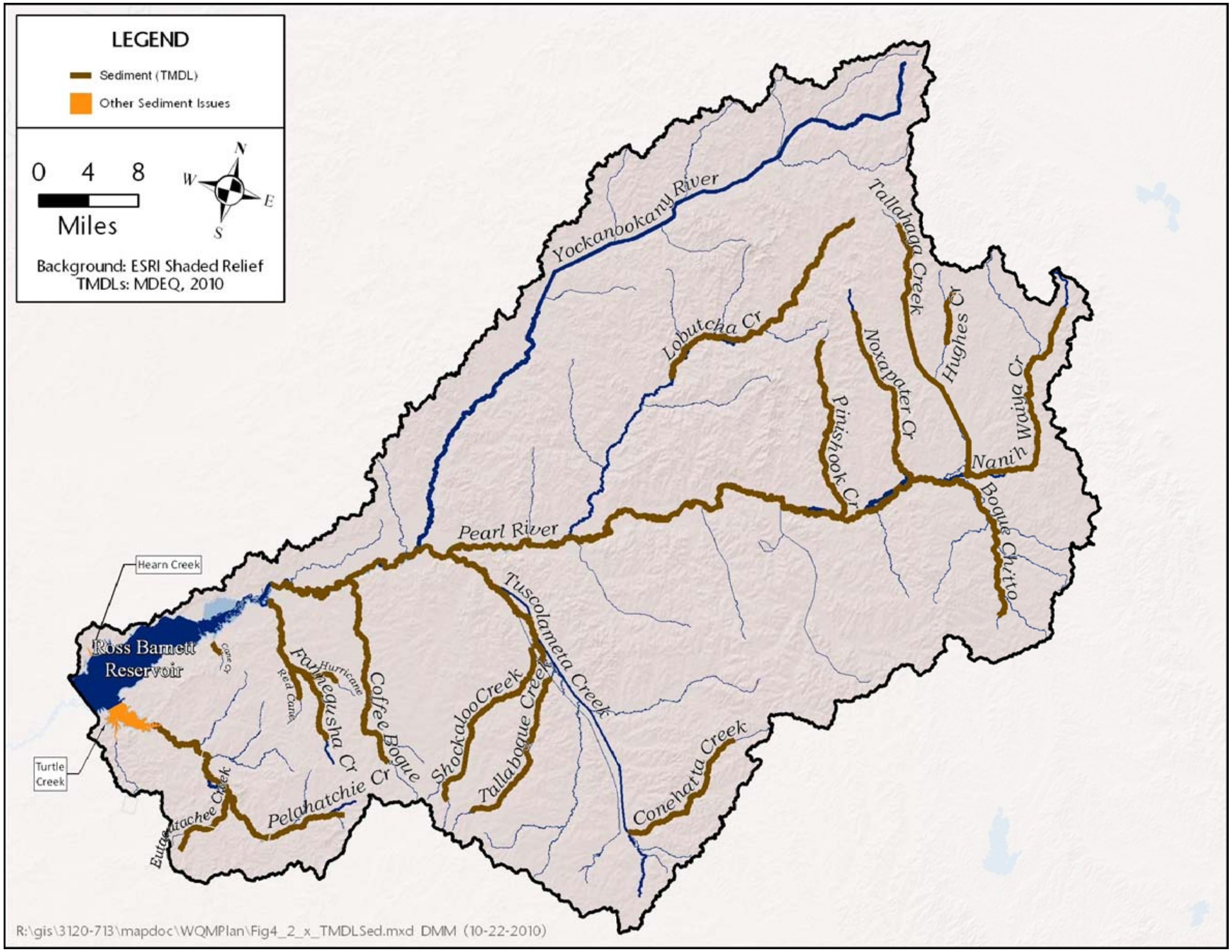

Figure 4.1. Waterbodies in Ross Barnett watershed where sediment issues have been identified.

Records of past dredging activities in the Reservoir indicate the areas where sedimentation is occurring at highest rates (Figure 4.2). An account of PRVWSD dredging activities in the Ross Barnett Reservoir indicates that some areas have been dredged frequently, at a significant cost to PRVWSD. Available information about recent dredging is summarized in Table 4.2.

Table 4.2. Summary of PRVWSD dredging information (PRVWSD, Fritscher 2009 and 2010).

Area	Years Dredged	Dredging Costs
Mill Creek	1997, 2001, 2004	$500,000
Fannin Landing	1990, 1991, 1994	Cost estimate not available
Turtle Creek	2009	$20,000
Northbay Subdivision	2010	$200,000

Figure 4.2. Photo depicting dredging activities in the Reservoir.

4.1.2 Sources

Table 4.3 provides a summary of potential sediment sources present in the watersheds of concern identified in Table 4.1. Each of these potential sediment sources is discussed in greater detail in Appendix H.

Table 4.3. Potential sediment sources in watersheds of concern.

Watershed of Concern	Construction Runoff	Impervious Area	Mining	Forestry	Pasture	Row-Crop Agriculture
Pelahatchie Creek	X	X	X	X	X	X
Pelahatchie Bay	X	X	X	X	X	
Pearl River	X	X	X	X	X	
Mill Creek	X	X				
Turtle Creek	X	X				
Hearn Creek near Northbay Subdivision		X				
Cane Creek	X			X		
Fannegusha Creek, Hurricane Creek, Coffee Bogue						
Red Cane Creek			X	X	X	X
Eutahatchee Creek	X			X	X	
Tuscolameta Creek			X	X	X	X
Pinishook Creek						
Shockaloo Creek			X	X	X	
Tallahaga Creek	X		X	X	X	
Hughes Creek	X			X	X	
Lobutcha Creek				X	X	
Conehatta Creek				X	X	
Bogue Chitto Creek				X	X	
Nanih Waiya Creek				X	X	
Noxapater Creek				X	X	
Tallabogue Creek				X	X	

4.2 Nutrient Enrichment

Nutrient enrichment can lead to a cycle of increased aquatic plant growth followed by low dissolved oxygen, reduced water clarity, and other negative water quality impacts as aquatic plants decay. The water quality impacts of nutrient enrichment are a concern to many agencies and stakeholders involved in management of the Reservoir and its watershed.

Monitoring data show that nitrogen and phosphorus are present in the Reservoir in amounts in excess of what is needed for algae and other plant growth, which indicates that the potential for increased plant growth exists in this system. Data analysis (described in Appendix D) and a water quality model (described in Appendix J) indicate that algae growth in the Reservoir is typically limited by light availability. On a national scale, results of the National Clean Lakes Study showed that lakes with high nutrient levels were two and a half times more likely to have poor biological health (EPA 2009).

Some level of nutrients in the Reservoir is desirable because nitrogen and phosphorus are essential for healthy plant and animal populations, with each waterbody requiring the right balance of nutrients to maintain aquatic life. However, a delicate balance must be maintained when managing the Reservoir for multiple uses. Literature review also shows that there is a clear link between primary productivity and fish production, such that fish production suffers when nutrient levels are low (FTN 2007).

Particular water quality concerns in the Reservoir related to nutrient enrichment and eutrophication are drinking water quality, aquatic vegetation, and low dissolved oxygen conditions. In rivers and streams of the watershed, aquatic vegetation and low dissolved oxygen are the water quality concerns.

High algal production is of concern for drinking water sources because some types of algae cause objectionable taste and odor in drinking water. In addition, organic material resulting from algae present in raw water can form trihalomethanes when chlorine is added during the treatment process. Levels of trihalomethanes are regulated by the Safe Drinking Water Act. These chemicals cause taste and odor issues in treated drinking water and can be harmful to humans in high levels. MSDH routinely measures treated water at the O.B. Curtis plant for trihalomethane levels. Recent measurements show levels are below allowable concentrations. Additional detail is found in the *Source Water Protection Plan*.

High levels of nitrogen and phosphorus in waterbodies can allow excessive growth of aquatic plants to occur under certain conditions. In the Reservoir, these plants can limit navigation and access to shoreline areas. However, from the perspective of local fisherman, the presence of aquatic vegetation is desirable because it provides habitat and a food source for fish. Some local anglers feel that removing aquatic vegetation can have a negative impact on fish populations and fishing success (MDWFP 2009). In rivers and streams, excessive growth of aquatic and semi-aquatic vegetation can slow flow, and potentially aggravate flooding conditions. In addition, some aquatic vegetation, such as stringy, slimy filamentous algae, are considered detrimental to the aesthetics of streams.

Algae and aquatic macrophytes can harm fish and other aquatic organisms as they die, decay, and deplete oxygen levels. In reservoirs, anoxic conditions typically occur in deeper waters of reservoir systems, below the photic zone, and may cause fish and mobile aquatic organisms to leave an area. Organisms that do not or cannot move to another location may die due to lack of oxygen. These conditions also occur in rivers and streams in the watershed. Low dissolved oxygen conditions also trigger the release of chemicals bound to sediments, including phosphorus, manganese, and iron. These chemicals can cause noticeable problems with water taste in waters used for drinking water source.

4.2.1 Locations

Locations of concern for nutrients and eutrophication are shown in Table 4.5 and on Figure 4.3. Additional detail about these locations and causes is included in Appendix H.

Table 4.5 Locations and causes of concern for nutrients and eutrophication.

Location	Cause of Concern
Area within the immediate vicinity of the O.B. Curtis Intake (24-hour time of travel)	Algae present in this area could contribute to odor and taste problems in source water, low hypolimnetic dissolved oxygen levels have been observed during summer time at monitoring station RBR1 (located near the dam).
Pelahatchie Bay	Dense growth of aquatic vegetation.
Reservoir shoreline areas upstream of Highway 43	Dense growth of aquatic vegetation.
Tuscolameta Creek, Tallabogue Creek, Shockaloo Creek	Nutrient and organic enrichment TMDLs have been developed; biological monitoring and stressor identification indicates impairment of fish and wildlife use due to organic enrichment and nutrients
Hughes Creek	Nutrient, organic enrichment, and ammonia nitrogen TMDLs have been developed; biological monitoring and stressor identification indicates impairment of fish and wildlife use due to organic enrichment, low dissolved oxygen, nutrients, and ammonia toxicity
Coffee Bogue, Eutahatchee Creek	Nutrient and organic enrichment TMDLs have been developed; biological monitoring and stressor identification indicates impairment of fish and wildlife use due to organic enrichment, low dissolved oxygen and nutrients; within the 1x:10x watershed
Pearl River	Nutrient TMDL has been developed; evaluated as potentially impaired due to organic enrichment, dissolved oxygen, and nutrients based on activities in the watershed; partly within the 1x:10x watershed
Noxapater Creek, Nanih Waiya Creek, Bogue Chitto Creek	Nutrient and organic enrichment TMDLs have been developed; evaluated as potentially impaired due to organic enrichment, dissolved oxygen, and nutrients based on activities in the watershed
Pelahatchie Creek	Nutrient TMDL has been developed; evaluated as potentially impaired due to nutrients based on activities in the watershed; within the 1x:10x watershed

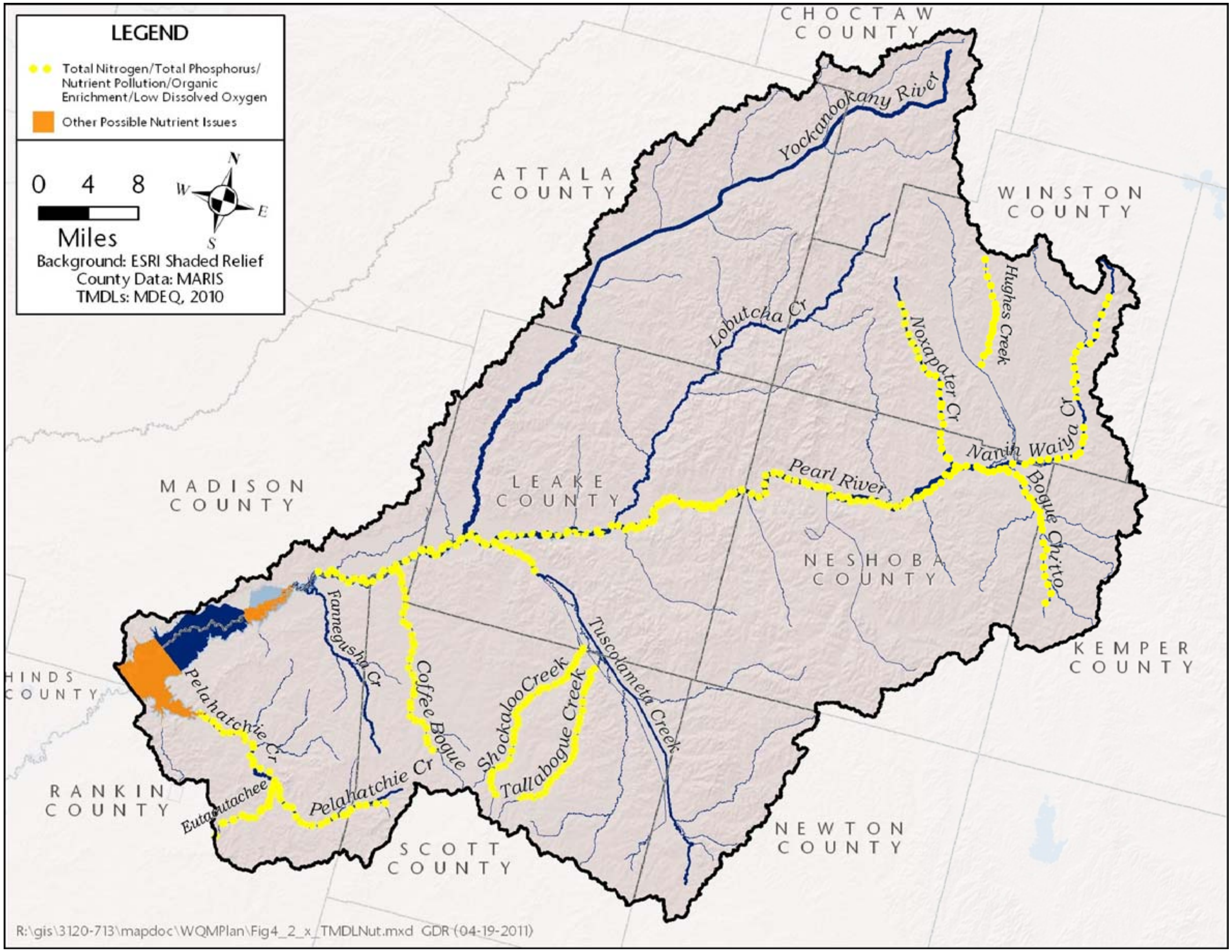

Figure 4.3. Waterbodies in Ross Barnett watershed where nutrient issues have been identified.

4.2.2 Sources

Table 4.6 provides a summary of potential nutrient sources present in the watersheds of concern identified in Table 4.5. Each of these potential nutrient sources is discussed in greater detail in Appendix H.

Table 4.6. Potential nutrient sources present in watersheds of concern.

Watershed of Concern	Animal Feeding Operations	Atmospheric Deposition	Fertilizer	Pasture	Row-Crop Agriculture	Sediment	Soils	Urban Stormwater	Wastewater Discharges
Area within immediate vicinity of O.B. Curtis water intake (24-hour time of travel)		X				X		X	
Pelahatchie Creek	X	X		X	X		X	X	X
Pelahatchie Bay	X	X	X	X	X	X	X	X	X
Reservoir shoreline areas upstream of Highway 43		X	X	X		X	X		
Tuscolameta Creek	X	X	X	X	X		X		
Tallabogue Creek	X	X	X	X			X		X
Shockaloo Creek	X	X	X	X			X		
Hughes Creek	X	X	X	X			X		X
Coffee Bogue	X	X	X	X	X		X		
Eutahatchee Creek	X	X	X	X			X	X	
Pearl River	X	X	X	X			X	X	X
Noxapater Creek	X	X	X	X			X		X
Nanih Waiya Creek	X	X	X	X			X		X
Bogue Chitto Creek	X	X	X	X			X		

4.3 Pathogens

The presence of pathogens in freshwater systems is detected using fecal coliform bacteria, an indicator organism that serves as a surrogate for the presence of other, harmful bacteria. Fecal coliform data available for the Reservoir indicate that levels are typically below Mississippi's water quality criteria. However, the potential for pathogen contamination remains a significant concern due to the Reservoir's extensive use for recreational activities and the large population of people that live and work in close proximity to the Reservoir. A companion plan, titled *Ross Barnett Reservoir Pathogen Source Assessment and Wastewater Management Plan*

(CDM 2010), contains a detailed assessment of the locations of concern and sources of pathogens within the four HUC12s closest to the Reservoir. This Plan describes the potential point and nonpoint sources of fecal coliform in the watershed through review of permitted discharge data and analysis of the unsewered areas identified in the study area. This document also includes a review of available pathogen monitoring data.

4.3.1 Locations

Locations where pathogens are causing water quality issues are summarized in Table 4.7 and on Figure 4.4. Additional detail about these locations and causes is included in Appendix H.

Table 4.7. Locations and causes of concern for pathogens.

Location	Cause of Concern
Locations identified on unsewered area map in the Pathogen Source Assessment and Wastewater Management Plan (CDM 2010). Areas are located in north Rankin County and include 32 subdivisions located along Holly Bush Road, Church Road, and Fannin Landing Circle.	Areas with residents and businesses that are not served by a central sewer system and rely on septic tanks or individual onsite wastewater treatment systems.
Pelahatchie Creek, Coffee Bogue, Fannegusha Creek	Pathogen TMDL developed; assessed as not meeting fecal coliform standard and not achieving secondary contact use based on monitoring data; located within the 1x:10x watershed
Tibby Creek, Shockaloo Creek,	Pathogen TMDL developed; assessed as not meeting fecal coliform standard and not achieving secondary contact use based on monitoring data
Pinishook Creek, Lobutcha Creek, Standing Pine Creek, Pearl River, Tallahaga Creek, Nanih Waiya Creek	Pathogen TMDL developed; assessed as not meeting fecal coliform standard and not achieving secondary contact use based on anecdotal evidence
Unnamed tributary at Holly Bush Road (RBR17) Clark Creek at Clark Creek Road (RBR4) Mill Creek at Castlewoods Road (RBR9) Clear Creek at Lake Road (RBR14) Pelahatchie Creek at Hwy 80 (RBR16) Clear Creek at Haynes Chappel (RBR13)	Areas identified by recent monitoring data as having elevated fecal coliform bacteria level

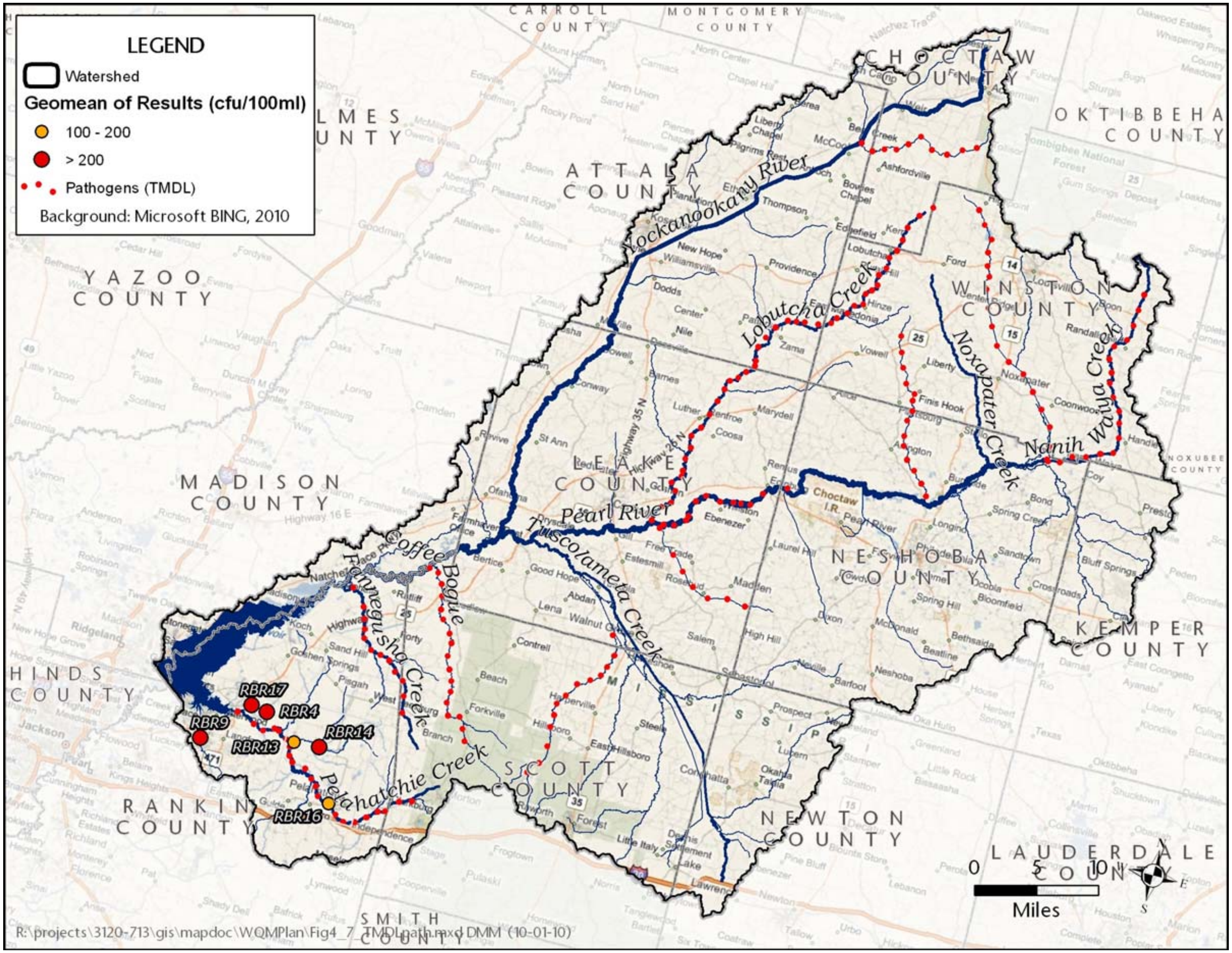

Figure 4.4. Locations in Ross Barnett watershed where fecal coliform issues have been identified.

4.3.2 Sources

Pathogen sources include septic tanks, animals grazing on pasture land, wildlife living near the waterbody, urban stormwater, and effluent from wastewater treatment facilities. Land-applied litter from poultry operations that are concentrated in the southeastern portion of the watershed are also a concern. When litter is applied near streams it may be washed into nearby streams during rain events. Recreational users of the Reservoir may also contribute pathogens due to activities such as illicit discharges of wastewater from boats and marinas and waste from domestic animals.

Table 4.8 summarizes potential pathogen sources known to be present in the watersheds of concern.

Table 4.8. Potential pathogen sources present in watersheds of concern.

Watershed of Concern	**Animal Feeding Operations**	**Pasture**	**Septic Tanks or Onsite WWTPs**	**Urban Stormwater**	**Wastewater Discharges**	**Wildlife**
Locations identified on unsewered area map in *Pathogen Source Assessment and Wastewater Management Plan*			X			
Pelahatchie Creek	X	X		X	X	X
Coffee Bogue	X	X				X
Fannegusha Creek	X	X				X
Tibby Creek	X	X				X
Shockaloo Creek	X	X				X
Pinishook Creek	X	X			X	X
Lobutcha Creek	X	X			X	X
Standing Pine Creek	X	X				X
Tallahaga Creek	X	X			X	X
Nanih Waiya Creek	X	X			X	X
Pearl River	X	X			X	X
Unnamed tributary to Pelahatchie Creek at Holly Bush Road		X			X	X
Clark Creek		X			X	X
Mill Creek				X	X	X
Clear Creek		X			X	X

4.4 Invasive Aquatic Plants

PRVWSD conducts annual surveys to document the location of aquatic invasive plants in the Reservoir and the Pearl River just upstream. PRVWSD has been actively managing alligator weed and water hyacinth for more than 10 years. Hydrilla, another non-native, invasive aquatic plant was found in the Ross Barnett Reservoir for the first time in 2005, and is also under active management. In 2010, these three species accounted for approximately 18% of the aquatic plants in water less than 10 ft deep (alligator weed 11.9%, water hyacinth 5.2%, and hydrilla 0.9%). Active management of these non-native plants has resulted in reduced occurrence and distribution of alligator weed and water hyacinth, and has slowed the spread of hydrilla (Cox et al. 2011). PRVWSD funds the aquatic invasive species program, and recent annual costs are given in Table 4.9.

Table 4.9. Invasive species management costs.

Year	Cost*
2007	202,897
2008	234,550
2009	243,292
As of 9/30/2010	182,711

* Cost reflects only contract costs for aquatic spraying programs. Cost does not include PRVWSD personnel that supervise the program, actual costs are considerably higher.

Invasive plant species are a concern because they grow quickly and out-compete native vegetation. Dense mats of aquatic vegetation can affect water quality by increasing the pH and water temperature and causing decreases in oxygen under the mats. These may also stagnate water, resulting in good breeding grounds for mosquitoes (GRI 2006). Vegetation mats can also block boat navigation in some areas.

4.4.1 Locations

Most aquatic plant species (native and invasive) are found in Pelahatchie Bay and the northern portion of the Reservoir where water levels and environmental conditions favor plant growth (Cox et al. 2011). The areas under active management for invasive aquatic plants include the Reservoir upstream of Highway 43 and Pelahatchie Bay, shown on Figure 4.5 (Wersal et al. 2009).

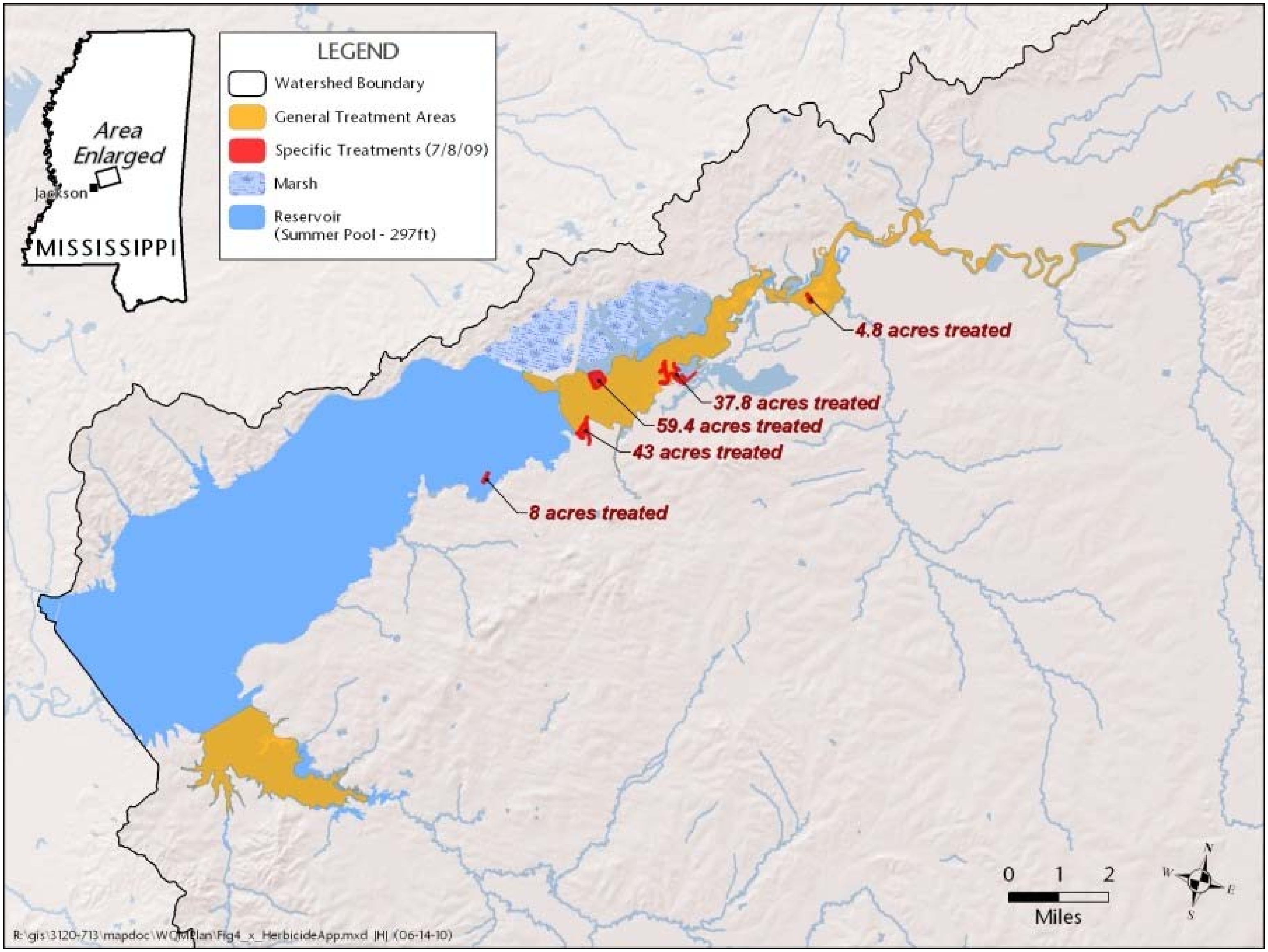

Figure 4.5. Locations in the Reservoir where herbicides are applied for invasive aquatic plant control.

During the plant surveys performed in 2010 and earlier, alligator weed, hydrilla, and water hyacinth were found in the Pearl River in the area from the Low-Head Dam to the Highway 43 Bridge. These upstream river populations can serve as a source for infestation of the Reservoir (Wersal et al. 2009, Cox et al. 2011). It is not known if other streams or lakes in the watershed harbor aquatic invasive species.

4.4.2 Sources

Hydrilla was originally introduced into the United States in the 1960s as a plant for aquariums. The original source of hydrilla and other invasive aquatic plants in the Reservoir is not noted in GRI reports, but may have come from release to the environment of plants used in landscaped areas. Tubers of hydrilla plants, which can remain in the soil layers of the Reservoir, have been found in low densities. These tubers are a cause of re-infestation when the tubers grow into plants. Hydrilla can also be spread by boats chopping up and carrying parts of the plants around the Reservoir (Wersal et al. 2009). Alligator weed and water hyacinth spread by water movement and by humans and animals carrying the plants from one area to another. Any existing individual plant of these species present in the Reservoir can act as a source for continuing infestation.

4.5 Pesticides

There are thousands of commercially available pesticides at the present time. These chemicals are safe and efficient if applied using the correct methods and in the proper amounts. Most currently used pesticides are organic compounds that degrade quickly in the environment. However, pesticides can be toxic to humans, plants, and animals if used improperly (Mississippi State University Extension Service, *Pesticides: Risks and Benefits*). Excess levels of pesticides that are applied to land near the Reservoir can unintentionally harm or kill native aquatic plants and animals.

EPA has established criteria for many pesticides based on protection of aquatic life and human health. MDEQ uses these criteria in its water quality standards (MDEQ 2007). Recent samples of raw water and water treated by the O.B. Curtis Plant showed that levels of

137 compounds classified as either pesticides or pesticide degradates were present at concentrations below the EPA maximum contaminant levels (MCLs) (Rose et al. 2009).

Other than the data collected from the O.B. Curtis Plant, there are no water quality monitoring data for pesticide levels in the Reservoir and very little data for Reservoir tributaries. Tributary data collected in the 1980s show that pesticide levels were less than laboratory detection limits at the time the samples were collected.

Pesticides sold in Mississippi are regulated by the Mississippi Department of Agriculture and Commerce (MDAC), and must be certified by this agency before being sold in Mississippi. The state chemist must also approve all pesticide products. Pesticide products must also be registered and inspected by MDAC, and all dealers selling pesticides must register with the agency. Oversight of pesticides by MDAC is intended to protect the environment and the general public from pesticide contamination and misuse[1].

Pesticides in the Reservoir watershed are commonly applied to landscaped areas on both a large scale (cities, counties, owners of large tracts of land used for forestry or agriculture) and on a small scale (by homeowners on their yards). According to national data compiled by EPA in 2001, approximately 77% of pesticides used in the United States were for agricultural applications and 11% were used for home and garden purposes (Moore et al. 2007).

4.5.1 Locations

Pesticides of concern in the Reservoir include both insecticides and herbicides. Pesticides present in water and sediments are an issue of concern for the entire Reservoir, especially the area near the O.B. Curtis drinking water intake.

4.5.2 Sources

Pesticides in the areas closest to the Reservoir are applied by landowners on lawns, agricultural areas, and some managed forests. Pesticides may also be applied by professionals for termite control in buildings and mosquito control in residential areas. These pesticides can reach water when applied in excess amounts in areas where they may be carried by stormwater runoff.

[1] http://www.mdac.state.ms.us/index.asp, MDAC website, accessed March 22, 2010

The only pesticides known to be applied directly to the Reservoir are the herbicides used to manage aquatic invasive species. These herbicides are applied in areas north of Highway 43 and in Pelahatchie Bay during the growing season months of April through November (Figure 4.9). Herbicide application for invasive species is conducted according to the recommendations of the Geosystems Research Institute at Mississippi State University. Management activities for recent years are described in the report *Littoral Zone Aquatic Plant Community Assessment of the Ross Barnett Reservoir, MS in 2010: A Six-Year Evaluation* (Cox et al. 2011). Additional detail about pesticide sources is included in Appendix H.

4.6 Trash Dumping and Litter

Managing trash dumping and litter is a significant expense for PRVWSD. The district spends approximately $50,000 per year to remove trash from areas under their jurisdiction. According to PRVWSD, trash is a concern because of the potential for contamination of surface water and groundwater, and the potential for insects, snakes, alligators and disease-carrying animals to increase in littered areas. PRVWSD is also concerned that certain materials may be dangerous to recreational users of the Reservoir, including rusted cans, old batteries, rotting carpets, empty coolers, barbeque grills and abandoned appliances.

Trash is a concern for wildlife that lives on or near the Reservoir and its tributaries. Birds, fish, and other mammals can be injured or killed if they ingest or become tangled in trash. Material such as glass and fishing line could cause injury to humans using the area for recreation. Trash such as containers that contain oil or paint or other substances can release chemicals harmful to water quality. In addition, trash directly impacts the aesthetic quality of an area and the perceived value to its users.

PRVWSD provides and maintains containers for trash at sandbar areas, picnic and camping areas, and the surrounding parks, and posts signs to discourage people from littering. A citizen group called *Keep the Reservoir Beautiful* has recently been organized and is working with PRVWSD to combat littering.

4.6.1 Locations

The locations of most concern are sandbars located along the Pearl River between Highway 43 and the Low-Head Dam. These areas are frequently used by recreational boaters for picnicking and camping. A significant amount of trash and litter is often left behind in these areas. Trash that is not properly disposed of and removed from the sand bars is often blown in the Pearl River or washed into it during rain events. This trash has the potential to eventually end up in the Reservoir.

Other locations of concern include several parks located along the Reservoir shoreline, including Old Trace Park, Pelahatchie Shore Park, and Lakeshore Park. Trash that is deposited directly in the Reservoir may eventually end up on the Reservoir shoreline. It is expensive to remove trash from shoreline areas, especially those that are difficult to access.

4.6.2 Sources

Sources of trash from within the Reservoir include recreational users who are boating and fishing or using the parks and other shoreline areas. These users often leave trash behind in recreational areas, which requires expensive cleanup (Figures 4.6 and 4.7). Other direct sources include trash from nearby residential areas and businesses that wind and stormwater carry into the Reservoir.

Figure 4.6. Trash dumping in recreational areas.

Figure 4.7. Trash cleanup efforts.

5.0 PRIORITIZATION AND TARGETING OF PROTECTION AND RESTORATION AREAS

It is not practical or affordable to simultaneously implement management measures in all 87 HUC12s in the Reservoir watershed. The prioritization/targeting process works with manageable-sized catchments (HUC12s) and ranks them as demonstrating high, medium, or low restoration and protection priorities based on a set of characteristics that incorporate data indicative of potential pollution sources and management resources present in each HUC12. This will allow Rez*onate* project managers to first implement restoration and protection measures in areas where they are needed most, and extend the measures to other areas after priority issues are addressed. Prioritization is based on two aspects of the HUC12s.

- The need for **restoration** based on watershed characteristics that indicate the likelihood for high pollutant levels to be contributed from the watershed.
- The need for **protection** activities to conserve existing resources, based on the presence of outstanding features that provide ecosystem services.

Prioritization is the process for identifying the HUC12s that have the greatest need for restoration or protection. Targeting involves collecting additional information about high-priority HUC12s to identify those that have the greatest chance of improvement as management practices are developed and implemented.

Proximity to the Reservoir affects the potential for pollutant sources to directly impact water quality in the Reservoir; areas closer to the Reservoir have increased likelihood of contributing pollutants. Pollutants originating from watersheds farther away from the Reservoir may be removed before they reach the Reservoir through settling or biological transformation processes. Proximity and reduced travel time are considered in the prioritization criteria. In some cases, more stringent criteria were used for the 1x:10 watershed because pollutants originating in these watersheds have a higher probability of reaching the Reservoir.

5.1 Prioritization Method for Restoration

The method for prioritizing HUC12s consists of reviewing data available for a set of watershed characteristics that indicate areas with the highest potential for current or future water quality issues due to the pollutants of concern. Prioritization characteristics have been developed for each issue addressed in this plan: sediment, nutrients and currently used pesticides, pathogens, aquatic weeds, and litter. Nutrients and currently used pesticides are grouped together because the same characteristics indicate the potential presence of these sources.

Data for each of the characteristics were assembled for each HUC12. The characteristics used to prioritize the HUC12s for each issue are listed in Table 5.1. Each HUC12 was assigned an overall restoration priority for each issue based on the number of characteristics classified as having high restoration priority. Appendix K includes a description of the data sources used for each prioritization characteristic.

Table 5.1. Prioritization characteristics for restoration.

Issue	Characteristic
Sediment	• Percent developed areas by HUC12s • Percent of total waters with sediment TMDLs • Slope • Permitted sources most likely to contribute sediment (construction stormwater permits and surface mining permits) • Percent area with cropland landuse
Nutrients and Pesticides	• Percent of total waters with nutrient TMDLs • Percent area with cropland and urban landuses • Percent areas with pasture landuse • Permitted sources most likely to contribute nutrients (animal growing operations and wastewater treatment facilities)
Pathogens	• Percent of total waters with pathogen TMDLs • Percent areas with pasture and urban landuse • Permitted sources most likely to contribute pathogens (animal growing operations and wastewater treatment facilities)
Aquatic Weeds	• Treatment locations • Locations identified during aquatic plant surveys
Trash	• Stakeholder-identified areas of concern

5.2 Prioritization Method for Protection

The protection prioritization identifies HUC12s that have features considered important resource values for people and the environment. Characteristics used for protection prioritization are based on the Mississippi Watershed Characterization and Ranking Tool (MWCRT). MDEQ developed the MWCRT for use in prioritizing watersheds on a statewide basis. The tool uses available geospatial datasets to determine scaled scores for stressors and resource values for HUC12s. Resource value scores developed from the MWCRT were used to identify highest priority HUC12s for protection. This process is described in Appendix K.

5.3 Prioritization Results

The overall prioritization for restoration activities in HUC12 watersheds was developed by overlaying the maps developed for each individual issue. Watersheds in which two or more issues were high priority were considered overall high priority areas for restoration (Table 5.2 and Figure 5.1). This resulted in a high-priority rating being assigned for thirteen HUC12s in the 1x:10x watershed and six HUC12s in the area beyond the 1x:10x. The environmental or human welfare protection scores that indicated high protection values are also noted in Table 5.2.

Table 5.2. Priority watersheds for restoration.

Management Area	HUC12	HUC12 Name	High-Priority Restoration Issues	High Protection Value
1x:10x	031800020301	Upper Pelahatchie Creek	Pathogens, Sediment, Nutrients/Pesticides	
1x:10x	031800020302	Ashlog Creek – Pelahatchie Creek	Pathogens, Sediment	Human Welfare
1x:10x	031800020303	Eutacutachee Creek	Pathogens, Sediment, Nutrients/Pesticides	
1x:10x	031800020305	Snake Creek – Pelahatchie Creek	Pathogens, Sediment, Nutrients/Pesticides	
1x:10x	031800020306	Riley Creek – Pelahatchie Creek	Pathogens, Nutrients/Pesticides	Environmental
1x:10x	031800020307	Mill Creek – Pelahatchie Creek	Pathogens, Sediment, Invasive Species	Human Welfare
1x:10x	031800020201	Hurricane Creek – Fannegusha Creek	Sediment, Nutrients/Pesticides	
1x:10x	031800020202	Red Cane Creek – Fannegusha Creek	Sediment, Nutrients/Pesticides	
1x:10x	031800020102	Beach Creek – Coffee Bogue	Pathogens, Nutrients/Pesticides	
1x:10x	031800020103	Lee Branch – Coffee Bogue	Pathogens, Nutrients/Pesticides	
1x:10x	031800020402	Lake Creek – Pearl River	Pathogens, Trash	Environmental
1x:10x	031800020403	Cane Creek – Pearl River	Nutrients/Pesticides, Pathogens, Invasive Species, Trash	Environmental Human Welfare
1x:10x	03180020404	Mill Creek – Pearl River	Sediment, Invasive Species, Trash	Environmental Human Welfare
Above 1x:10x	031800010303	Upper Nanih Waiya Creek	Nutrients/Pesticides, Pathogens	
Above 1x:10x	031800011403	Rice Creek – Pearl River	Nutrients/Pesticides, Pathogens	Environmental
Above 1x:10x	031800011001	Shockaloo Creek	Nutrients/Pesticides, Pathogens	Environmental
Above 1x:10x	031800010903	Lower Sipsey Creek	Nutrients/Pesticides, Pathogens	
Above 1x:10x	031800010504	Lower Kentawka Canal	Sediment, Nutrients/Pesticides	
Above 1x:10x	031800010103	Hughes Creek	Sediment, Nutrients/Pesticides	

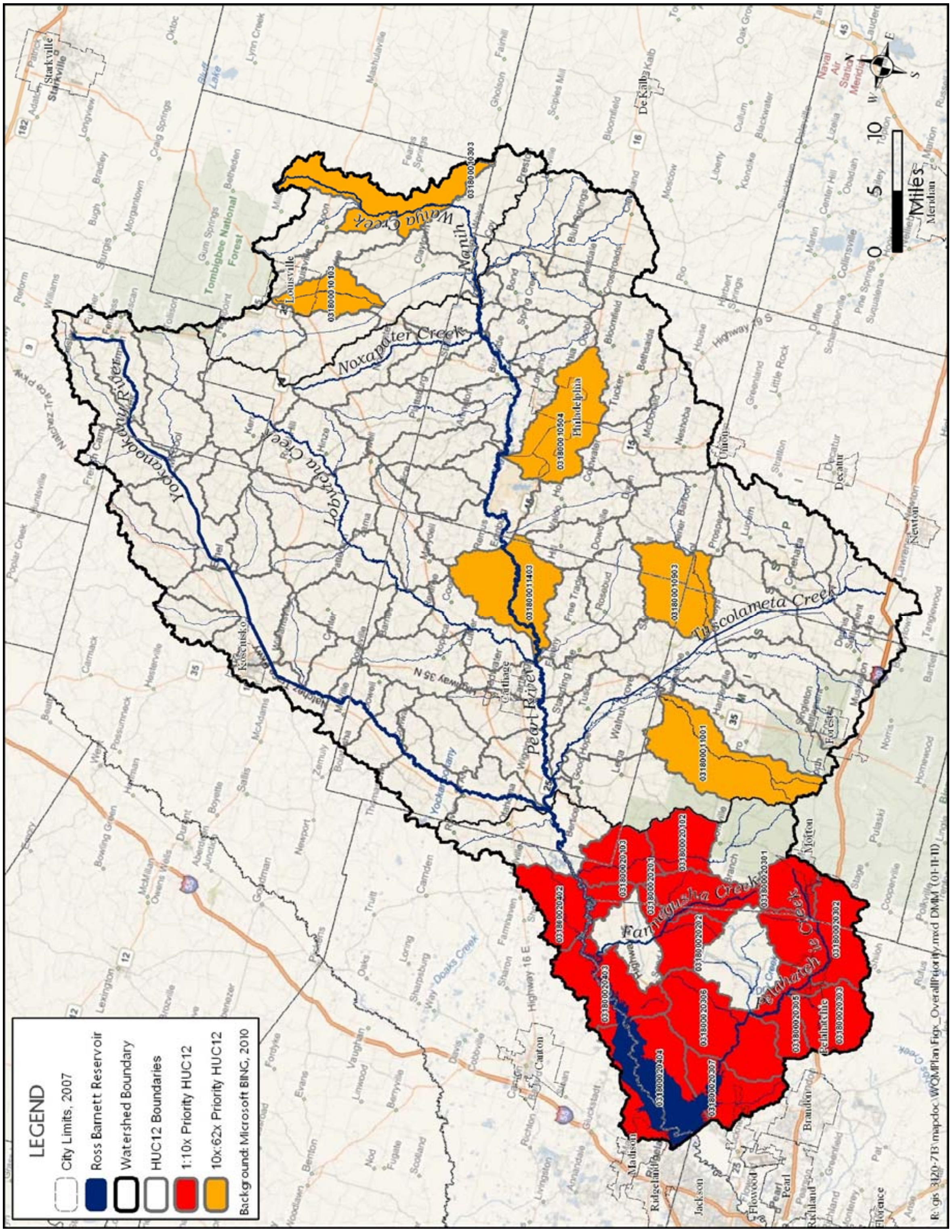

Figure 5.1. Overlay of restoration maps.

5.4 Targeting

Targeting is a common-sense approach used to determine the order in which watershed restoration and protection measures will be implemented for priority HUC12s. The targeting characteristics are factors that cannot be quantified in a mapping exercise. Rather, they indicate the watersheds in which watershed implementation plans would most likely be feasible, cost-effective, and successful. Professional judgment and discussion among the members of the technical advisory group were used to rank HUC12s for targeting based on the characteristics. Targeting characteristics are listed below.

1. Willingness of landowners and local government to participate;
2. Available funding sources (some funding sources have to be allocated to particular landuse types or parts of the state);
3. System responsiveness to management practices (i.e., immediate or quick responsiveness);
4. Pollutant issues that can be effectively addressed with management practices. In comparison, issues such as historical sediment loads cannot be addressed by management practices;
5. Magnitude of the source and likelihood of achieving measurable benefits;
6. Building on locations of past and ongoing management efforts;
7. Public perception of the importance of water quality (i.e., public's primary concerns such as improved water clarity, higher property values, lower water bill, improved recreational opportunities);
8. Expected growth patterns, including areas for new development and retrofitting;
9. Issues with permit compliance status of wastewater treatment facilities, with consideration of the size of these facilities (higher load facilities targeted first); and
10. Presence of septic tanks and onsite wastewater treatment plants in soils with limited adsorption field suitability.

Based on discussion of the above criteria, the Technical Advisory Group selected three high-priority HUC12s for Phase 1 restoration measures (Mill Creek-Pelahatchie Creek HUC12, Riley Creek-Pelahatchie Creek HUC12, and Ashlog Creek-Pelahatchie Creek HUC12). One HUC12 that was not indicated as high priority for restoration, but does have a high value for protection, was targeted for Phase 1 protection measures (Lake Creek-Pearl River HUC12). Information on the targeting criteria for HUC12s in the Pelahatchie Creek watershed is provided in Appendix L. The locations of these HUC12s are shown on Figure ES.2.

6.0 PROTECTION AND RESTORATION GOALS

The protection and restoration goals for Ross Barnett Reservoir and its watershed reflect the six issues driving Rez*onate*. Associated with the overall goals are 10-year goals. Following adaptive management, these 10-year goals will be revised in 10-year increments.

6.1 Sediment Issue Goals

Long Term Goal: All the streams in the watershed have stable sediment regimes.

Ten-Year Goals:

- Twenty-five percent of the streams in the Pelahatchie Creek watershed will have stable sediment regimes in 10 years. Turbidity values in all watershed streams and in the Reservoir are attaining water quality standards. Turbidity criteria will be attained in those streams in the Pelahatchie Creek watershed with stable sediment regimes in 10 years. Reservoir sediments are stabilized and no dredging is required.
- Dredging costs within Pelahatchie Bay will be reduced by 20% in 10 years.

6.2 Nutrient Issue Goals

Long-Term Goal: The Reservoir and watershed streams will attain numeric nutrient criteria.

Ten-Year Goal:

- Pelahatchie Creek will attain numeric total nitrogen and total phosphorus criteria in 10 years.

6.3 Pathogen Issue Goals

Long-Term Goal: The Reservoir and watershed streams will attain primary and secondary contact recreation criteria for pathogens.

Ten-Year Goal:

- Fannegusha Creek and Pelahatchie Creek attain primary and secondary contact recreation criteria for pathogens in 10 years.

6.4 Pesticide Issue Goals

Long-Term Goal: Pesticide and other trace organic compound concentrations, including mixtures, will not exceed human health and aquatic life criteria.

Ten-Year Goal:

- Contaminants of emerging concern (CECs) in the Reservoir, including pesticides, are quantified. Outreach and education programs are developed and implemented to increase awareness and reduce the concentrations of these CECs.

6.5 Litter Issue Goals

Long-Term Goal: Trash index score will be less than 1.5 on a 4-point scale (larger numerical scores mean more trash and litter accumulation) in the Reservoir or along its shoreline from the Low-Head Dam upstream to the downstream dam.

Ten-Year Goal:

- The volume of trash collected and disposed by PRVWSD will decrease by 50% in 10 years.

6.6 Invasive Species Issue Goals

Long-Term Goal: Invasive wetland/aquatic species will account for less than 2% of the aquatic vegetation in the Reservoir and its primary tributaries.

Ten-Year Goal:

- There will be no increase in the incidence of invasive species in the Reservoir, Pelahatchie Bay, and its primary tributaries over the next 10 years.
- Aggressively manage new invasive plant species to prevent their establishment in the context of early detection and rapid response.

7.0 PROTECTION AND RESTORATION MEASURES

7.1 Introduction

Management strategies define the specific activities that must take place in order to move towards meeting watershed restoration and protection goals. The concept of green infrastructure, a cost-effective, sustainable, and environmentally friendly approach to stormwater management, encompasses many of the management strategies recommended for the Reservoir watershed. Green infrastructure has come to refer to stormwater management measures that utilize natural or engineered systems that mimic natural landscapes to capture, clean, and reduce stormwater runoff through plant, soil, and biological processes. These measures may be used for new urban development or retrofits, to enhance existing pasture lands or row-crop fields, and to restore disturbed rural areas.

Green infrastructure measures are designed to treat rain water close to the area where it falls with designs that infiltrate and evaporate stormwater, use plants and soil to remove pollutants, and allow for beneficial uses of excess stormwater. Green infrastructure principles differ from traditional development, which involves “hard infrastructure” such as curbs, gutters, and pipes that capture stormwater from impervious areas and quickly convey it into drainage ditches and stormwater ponds with little treatment. Stormwater ponds control runoff rate, but do little to reduce the total runoff volume produced. In many cases, green infrastructure practices such as bioretention basins and vegetated swales can improve the pollutant removal efficiency and decrease maintenance costs of hard infrastructure.

This Plan includes nine overarching management strategies for the Reservoir watershed. These strategies incorporate green infrastructure management principals to achieve water quality goals. The strategies were introduced in the Executive Summary and are summarized below. This section of the Plan discusses how these strategies can be applied in the Reservoir watershed.

1. Maintain, and restore where possible, the existing riparian buffer zones along the Reservoir shoreline and the banks of tributaries.
2. Do not remove vegetation or disturb soils, if possible. If disturbed, minimize the exposure time of bare soils.

3. Control urban runoff within sites where it is generated, and reduce the quantity of stormwater and pollutants through capture, infiltration, and evapotranspiration.
4. Use natural, bioengineering techniques to repair failing streambanks and eroding gullies.
5. Adopt new ordinances or expand existing ordinances regulating land development, stormwater management, and landscaping if voluntary measures are shown to be insufficient.
6. Continue public outreach and education by implementing the activities recommended in the *Comprehensive Education and Outreach Plan for Rez*onate! for each targeted audience.
7. Work with federal, state, and local agencies to support conservation activities that are in progress on forested and agricultural lands and animal production.
8. Develop and implement an incentive program to encourage the voluntary use of green infrastructure management measures.
9. Focus Phase 1 restoration and protection efforts on targeted HUC12 subwatersheds.

7.1.1 Planning Considerations

There are many factors that need to be considered before selecting green infrastructure measures for specific areas. These include land availability and the acceptability of the measures to landowners. Without the participation of willing landowners, the measures cannot be installed. Installing green infrastructure measures requires specialized planning and consideration of several factors:

- Soil types and infiltration capacity;
- Hydrology, including drainage area, slope, and water table depth;
- Vegetation inhabiting the area in former years; and
- Proper construction sequencing to avoid compacting of the soils.

The installation cost of green infrastructure measures along with annual maintenance costs are important considerations. Developers may consider the initial cost of these measures to be more expensive compared to traditional development methods. However, the use of green infrastructure has been shown to increase property values and decrease the cost of stormwater management and treatment systems[2].

7.1.2 Benefits of Management Measures

The benefits of management measures can be measured in terms of (1) decreased pollutant loads (measured in mass or percentage), (2) reduced stormwater quantity, and (3) fewer pollutant sources such as impervious surfaces, streams without buffer zones, failing septic tanks, etc. The expected load reductions for this Plan will be based primarily on literature values for the percent pollutant reduction expected as a result of management measures.

Although they are based on current science, literature values should be used with caution because the efficiency of management measures is highly dependent on site-specific characteristics including input loads, soil types, existing vegetation, and storm intensity and duration. Often literature values suggest a range of expected pollutant reductions. Studies indicate that the performance of many measures is highly dependent on the influent concentration, such that percent removal is generally greater when influent concentrations are higher (American Society of Civil Engineers [ASCE] and EPA 2000). There are no known studies of best management practice (BMP) efficiencies available for the Reservoir watershed and very few for the southeastern United States. Most BMP performance studies have been conducted in the northeastern United States, concentrated in the Chesapeake Bay region.

There are other benefits of management measures that are not easily calculated, but should be considered in the overall effect. These include indirect benefits associated with business development, increased tax revenues and jobs, recreation and tourism opportunities, and health. Studies have shown that green restoration and protection of the natural environment increases property values, lowers crime through increased community pride and citizen interaction, and fosters healthier communities (Benedict and McMahon 1996).

[2] EPA 2011. Managing Wet Weather with Green Infrastructure. Available online at http://cfpub.epa.gov/npdes/home.cfm?program_id=298

7.2 Existing Measures and Programs

An inventory of management measures and programs currently in place within the Reservoir watershed is needed in order to identify opportunities to build upon ongoing projects and identify pollutant sources or areas where more work is needed. Past activities include improvement projects in two subwatersheds: Mill Creek and Fannegusha Creek. Ongoing activities include stormwater management programs in urban areas, Reservoir management programs conducted by PRVWSD, regulatory management of wastewater, and Farm Bill programs that provide cost-share funds for measures in rural areas. Existing watershed management activities are described in Appendix M.

7.3 Recommended Management Measures for the Watershed

There are many management measures applicable for restoration and protection of the Reservoir watershed. These measures can be categorized according to the land areas where they may be applied, as follows.

1. Upland green infrastructure and urban management measures,
2. Instream management measures,
3. In-Reservoir management measures,
4. Enforceable mechanisms for developed areas,
5. Forest land and timber-harvesting measures, and
6. Conservation measures for lands used for agricultural production (pasture, row crops, and animal growing).

Tables 7.1 through 7.6 list specific measures in each category and indicate the landuses where the measure can be effectively implemented. Appendix N includes Fact Sheets that describe these measures in detail. Fact sheets include design considerations, applicability, pollutant removal efficiency, cost, benefits, limitations, and education needs. MDEQ’s *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater* also contains detailed information on design requirements for many of these measures (MDEQ 2011).

Table 7.1. Upland green infrastructure and urban management measures.

Management Measure	Forest	Developed	Pasture	Shrubland	Cropland	Water	Wetland
Bioretention areas/rain gardens		X					
Stormwater detention/retention basins		X					
Infiltration systems		X					
Constructed stormwater wetlands	X	X					
Pervious pavement		X					
Water quality swales/bioswales		X					
Grassed swales		X	X				
Vegetated filter strips and level spreaders		X	X				
Green roofs		X					
Rain barrels/cisterns		X					
Restored riparian buffer/vegetative buffers	X	X	X	X	X	X	X
Planned Unit Developments (also called cluster developments)	X	X	X	X			
Preservation of vegetation/trees on urban sites	X	X					
BMPs for pesticide and fertilizer application	X	X	X		X		
Disconnected impervious areas		X					

Table 7.2. Instream management measures.

Management Measure	Forest	Developed	Pasture	Shrubland	Cropland	Water	Wetland
Vegetative stream bank protection/stabilization: • Straw matting • Live stakes • Live fascines and poles/posts • Branch packings • Coconut fiber rolls • Live cribwall • Stones/rock armor rip-rap with erosion-control fabric • Dry stone walls • Gabions	X	X	X	X	X		
Gulley stabilization/repair	X	X	X	X	X		

Note: All types of vegetated stream bank stabilization applicable to streams within the indicated landuse types.

Table 7.3. In-Reservoir management measures.

Management Measure	Forest	Developed	Pasture	Shrubland	Cropland	Water	Wetland
Restoration/replanting of reservoir shoreline riparian areas		X				X	X
Disposal methods of dredge material for beneficial use						X	X
Sand bar litter collection						X	X
Herbicide application for aquatic invasive species control						X	X
Artificial wetlands for shoreline protection						X	X
Floating islands (Schwimmkampen islands)						X	

Table 7.4. Enforceable measures for developed areas.

Management Measure	Forest	Developed	Pasture	Shrubland	Cropland	Water	Wetland
Stormwater management plans for cities and counties (MS4)		X					
Improved stormwater pollution prevention plans (SWPPPs) for construction sites and surface mines		X					
Zoning requirements for open space and green space	X	X					
Landscaping ordinances	X	X					
Overlay district		X				X	
Boat holding tank inspections						X	
Litter ordinances	X	X	X	X	X	X	X
Improved wastewater treatment						X	

Table 7.5. Forest land and timber harvesting measures.

Management Measure	Forest	Developed	Pasture	Shrubland	Cropland	Water	Wetland
Properly designed skid trails and landings	X						
Streamside management zones	X					X	X
Forest regeneration	X						
Conservation easements	X			X			

Table 7.6. Conservation measures for lands in agricultural production.

Management Measure	Forest	Developed	Pasture	Shrubland	Cropland	Water	Wetland
Fencing of pastures (interior to facilitate rotational grazing)			X				
Alternative water sources for pasture			X				
Livestock stream crossing			X			X	X
Row-crop residue management					X		
Cover crops					X		
Terraces					X		
Grade stabilization structures		X	X		X		
Riparian buffer zones			X		X		
Field borders			X*		X		
Filter strips					X		
Animal mortality facilities**[3]					X		
Poultry litter transport			X	X	X		
Nutrient management plans[4]			X	X	X		
Integrated pest management[5]	X		X	X	X		

*Pasture areas must be fenced to prevent damage from animal access.
**CAFOs/AFOs

7.3.1 Upland Green Infrastructure and Urban Management Measures

Urban development in the watershed is concentrated near the Reservoir, in Madison and Rankin counties, and a few cities located further upstream (Carthage, Forest, Koscuisko, Louisville, Pelahatchie, and Philadelphia). Conversion of land from undisturbed forest to urban areas results in increased peak flows during storm events and a higher frequency of channel-forming flows. Research has shown that the discharge associated with storm events increases significantly in urban streams. Higher flows in urban streams increase sediment loads, destabilize stream banks, resuspend sediment in stream beds, and increase sediment transport to the Reservoir. Selected upland management measures and their applicability in the Reservoir watershed are described in Appendix O. Local governments in cooperation with resource

[3] Fact Sheet for this practice available from NRCS Conservation Practice Standards http://www.nrcs.usda.gov/technical/standards/nhcp.html
[4] Ibid
[5] Ibid

agencies (NRCS, MSWCC, MDEQ) should strive toward implementing these practices in the Reservoir watershed.

As discussed previously, green infrastructure management measures are designed to treat stormwater in place through infiltration and evapotranspiration. Properly designed measures should be able to meet specific criteria for retention, detention, erosion and sediment control, and water quality planning. The criteria are given in Appendix S.

7.3.2 Local Policy to Promote Green Infrastructure Management Measures

Local ordinances, zoning requirements, stormwater management plans, and comprehensive plans play an important role in the use of green infrastructure in developing urban areas. Local policies can promote use of green infrastructure by treating it as “standard practice” rather than an alternative design. Local governments interested in promoting green infrastructure should begin by reviewing their current policies. As an initial step, governments in the Reservoir watershed can compare their policies to the Checklist of Recommended Elements to Promote Green Infrastructure (Table Q.1 in Appendix O). The checklist contains elements needed in local policies to facilitate an effective green infrastructure program. Additional resources to assist local governments are included in Appendix O.

One highly recommended activity is that local governments form and actively participate in a local consortium of stormwater managers. The consortium would improve communication, collaboration, and shared education programs among governments in the Reservoir watershed. This would result in consistent programs for the watershed and potential cost savings by sharing training events and materials.

7.3.3 Stream Bank Restoration

The recommended approach for restoring eroding and failing stream banks relies heavily on natural stream channel design. This approach, commonly called bioengineering, combines structural components and native plant material to establish a dense living vegetation system in order to protect, as well as stabilize, stream banks and buffer zones. Bioengineering restoration projects use a combination of structural and biological practices integrated with ecological concepts to construct living plant communities that perform erosion, sediment, and flood control when established. These projects use native plant growth to achieve pollutant reduction and bank stability (i.e., they expedite the recovery/restoration process by reestablishing native plant communities and stabilizing damaged banks after structures such as erosion control blankets, log revetments, coconut logs, etc., have decomposed). The costs of installing bioengineering stream bank restoration can be expensive at first if local contractors are not familiar with these methods, but costs are normally much cheaper than traditional erosion control methods. Specific methods of bioengineering are described in the Fact Sheets in Appendix N. Local governments should consider using these methods in place of traditional bank grading and rip-rap. Agencies such as NRCS, the National Sedimentation Laboratory, and MDEQ may be able to provide technical assistance.

7.3.4 In-Reservoir and Shoreline Management

Management measures needed for the Reservoir include reducing wind fetch and stabilizing the lake bottom. In-reservoir structures such as breakwaters or islands can reduce wind fetch and wind-generated waves. In-reservoir structures, however, are not a feasible management option for the Reservoir due to high cost and navigation concerns. Establishment of woody vegetation on the shoreline can stabilize soils and protect the shore from the energy of wind-induced waves, although large trees take many years to become established.

Based on visual analysis of recent aerial photography, approximately 25% of the shoreline has little or no vegetated buffer zone directly adjacent to the shore. However, there are no identified areas with bank failures on the Reservoir shoreline. Much of the shoreline has been stabilized with rip-rap or bulkheads. PRVWSD maintains constant water levels during the winter and summer seasons, which reduces the potential for shoreline erosion.

Replanting shoreline areas with limited riparian vegetation has many benefits: pollutant removal, wave reduction (if wetland vegetation), shoreline protection, and wildlife habitat creation. The shoreline area of the Reservoir is managed by PRVWSD and individual lease holders. Lease holders are responsible for maintaining the shoreline on their individual lots. Rez*onate* project managers can provide education and technical support to help landowners restore and maintain shoreline vegetation.

7.3.5 Education Programs

The common thread in all recommended management measures is stakeholder education. Implementation of many of the recommended management measures will rely on voluntary participation. The *Comprehensive Education and Outreach Plan for Rez*onate includes specific program goals and objectives for targeted audiences. The targeted audiences include the general public, students and educators, civic groups, homeowners, developers/contractors, and decision makers (FTN 2011). The most important actions needed to encourage participation in local participation are summarized below. Additional details are included in the Comprehensive Education and Outreach Plan.

- The public must begin to see the Rez*onate* logo, mascot, and materials on a regular basis. This requires attending local events on a frequent basis. A list of events are attached in the education plan, but some of note are Pepsi Pops, Dragon Boat Races, 5k to10k running races and other sporting events held on or near the Reservoir, and events at the Museum of Natural Science and the Children's Museum.
- The curriculum associated with Rez*onate* should be condensed into a marketable program that can be taken into schools as one-hour programs conducted by outside individuals for teachers and students. This will promote the use of the extended curriculum for Curriculum Challenge for schools in the watershed area. Project managers should partner with *Keep the Reservoir Beautiful* efforts to work local schools to co-promote both efforts.
- Model areas for specific types of management measures need to be established in different areas of the watershed. Measures include rain gardens and rain barrels, streamside buffers, and vegetative stream bank restoration. Demonstration sites will bring awareness of functionality and beauty as well as introduce stakeholders to the concept of green infrastructure.
- Training workshops and/or other educational opportunities need to be held for contractors, developers, and business and government officials. These educational opportunities may be aligned with a certification process for stormwater management and other sediment/ pollution control measures. They may also be used to assist counties and cities meet education requirements for their stormwater management plans.

7.4 Restoration and Protection Measures for Targeted HUC12s

This section describes specific recommendations for management measures needed in subwatersheds selected for the first phase of implementation activities. Members of the

Technical Advisory Group approved the selected subwatersheds based on prioritization and targeting results (Section 5.0). Three subwatersheds are targeted for restoration: Mill-Pelahatchie Creek, Riley-Pelahatchie Creek, and Ashlog-Pelahatchie Creek. One subwatershed is targeted for protection: Lake Creek-Pearl River.

Restoration and protection objectives define the management measures needed in each targeted subwatershed. These measures are considered to be the most critical in order to meet water-quality goals.

7.5 Restoration Measures for Mill-Pelahatchie HUC12

The Mill-Pelahatchie subwatershed is an important location for both watershed restoration and source water protection activities. The restoration objectives for this HUC12 are as follows:

- **Objective 1**: Incorporate green infrastructure stormwater management measures in new construction and retrofits;
- **Objective 2**: Coordinate with Rankin County officials in matters related to stormwater management in developed areas;
- **Objective 3**: Improve stormwater controls for construction on individual lots that are within a larger common plan of development;
- **Objective 4**: Stabilize disturbed soils on construction sites and surface mines by quickly replanting with native grasses and other vegetation;
- **Objective 5**: Identify and restore shoreline and streamside buffer zones and banks in needed areas, and repair eroding gullies; and
- **Objective 6**: Leave undisturbed vegetated areas (green space) and shoreline/streamside buffer zones within new developments.
- **Objective 7**: Develop an incentive program to encourage use of green infrastructure management practices.

The total area of this HUC12 is 18,176 acres (approximately 28 square miles). Hydrologic soil group (HSG) classifications are needed to determine the feasible management measures for a particular area. Infiltration measures will work well on soil types A and B (very well and well-drained soil types). Soil types C and D have low infiltration capacities and will accommodate practices that require holding water. Landuse summary by HSG within the subwatershed is presented in Table 7.7 and on Figures 7.1 and 7.2. There is no type A soil in this subwatershed.

Table 7.7. Landuse and HSG types for the Mill-Pelahatchie HUC12.

Landuse	No Data Available[(1)] (acres)	HSG Type B[(2)] (acres)	HSG Types C[(3)] and D[(4)] (acres)	Total (acres)
Water	1,599	41	207	1,847
Agricultural Crops	5	18	245	268
Pasture/Grassland	52	409	1,681	2,142
Developed	130	814	3,786	4,730
Forest/Woodland	46	1,664	3,777	5,487
Shrubland	66	585	1,465	2,116
Wetlands	278	220	1,088	1,586
Total	**2,176**	**3,751**	**12,249**	**18,176**

Notes:
(1) HSG data are not available for some areas, that are located on or near a waterbody. These areas are shown on Figure 7.2.
(2) Type B soils are well-drained.
(3) Type C soils have moderate infiltration capacity.
(4) Type D soils have little or no infiltration capacity.

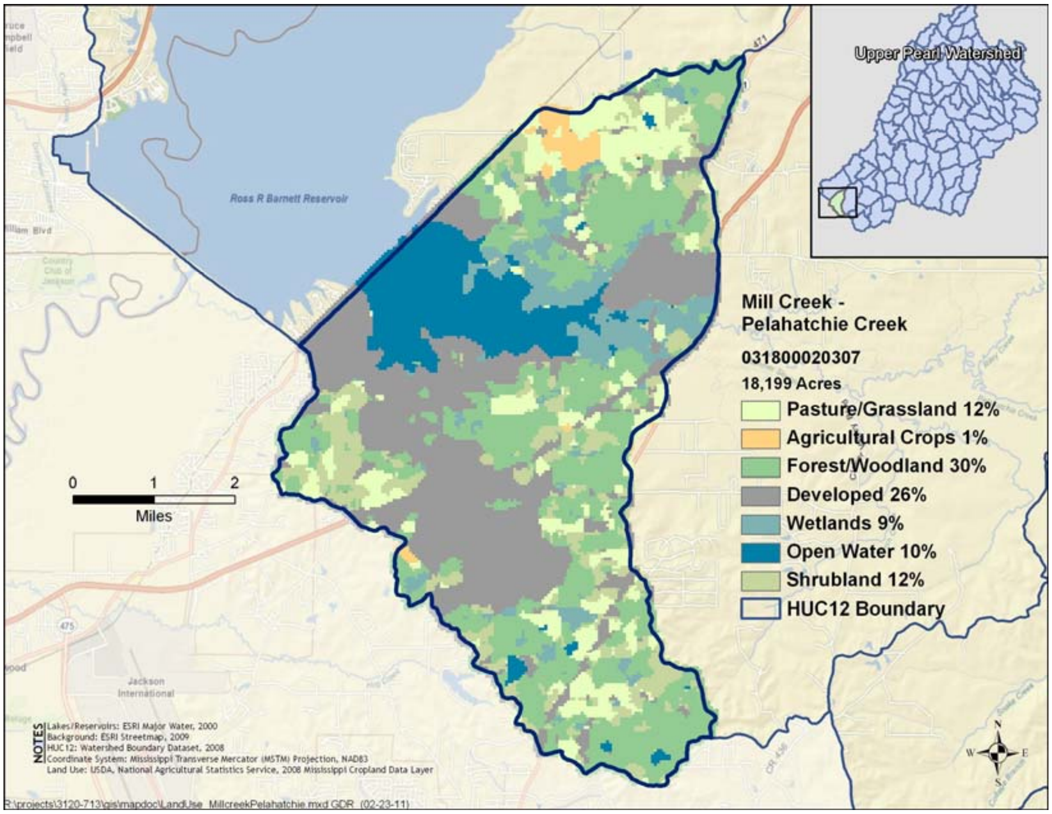

Figure 7.1. Landuse in the Mill-Pelahatchie HUC12.

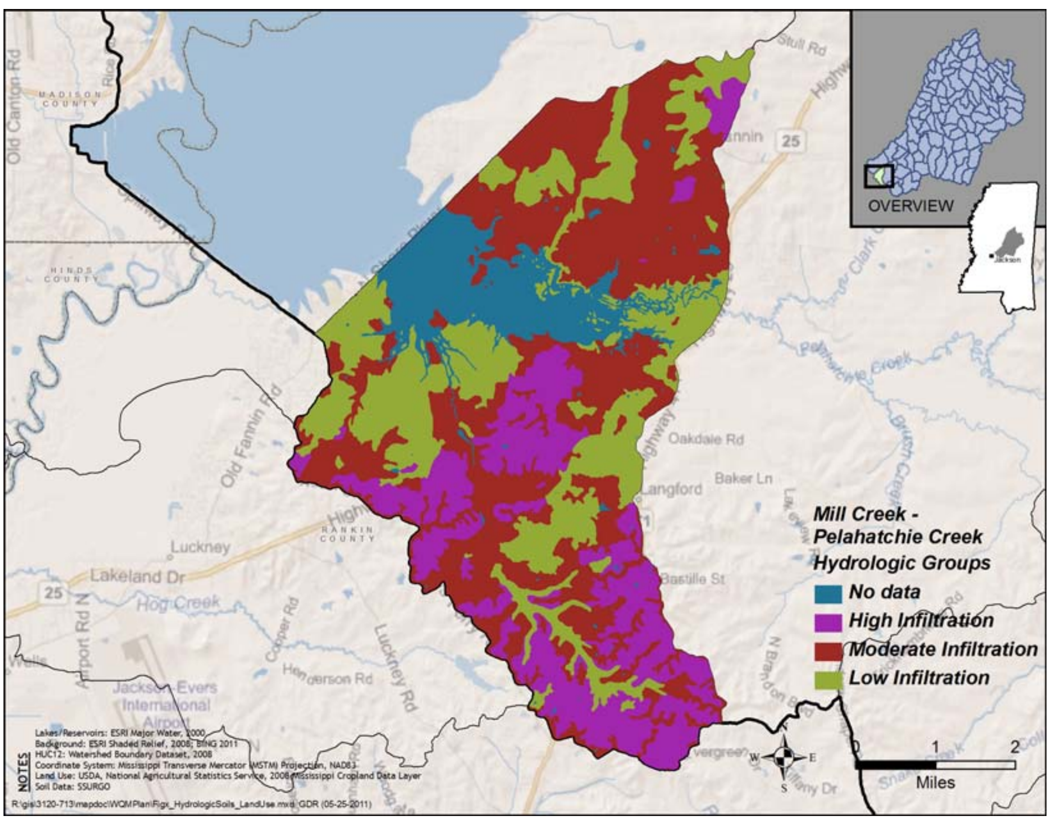

Figure 7.2. HSG types in the Mill-Pelahatchie HUC12.

The Mill Creek-Pelahatchie HUC12 contains the highest percentage of impervious surface area within the Reservoir's drainage area (7.4% based on 2006 NLCD; see Section 2.2.3). Increased erosion is presently occurring on upland areas in Rankin County as well as along the banks and in the beds of Mill Creek and Turtle Creek. Rapid development near these creeks has resulted in the removal of natural vegetation, leaving exposed soils and causing elevated wash loads of sediment from construction sites. Homeowners along the Pelahatchie Bay shoreline have complained of poor water clarity and reduced water depth due to settling of suspended sediments.

It is likely that a significant amount of sediments are presently stored in the channels and floodplains of Mill Creek and other tributaries. These sediments originate from erosion associated with past landuses such as row-crop agriculture and development that occurred prior to regulatory control of construction sites[6]. Modeling estimates indicate that as much as 65% of the sediments in the streams presently in this watershed can be attributed to instream sources (i.e., bank and bed erosion), and the remainder is attributed to land use in the watershed (see Appendix P for explanation of the model).

Sediments from erosion associated with past landuse activities are referred to as "legacy sediments." Legacy sediments can be resuspended and washed towards the Reservoir during high-flow events. Eventually all of the legacy sediments will be washed downstream, but this process may take decades or even hundreds of years (Langland and Cronin 2003).

Sediments have caused high turbidity and navigation problems in Pelahatchie Bay, regardless of whether they are legacy sediments or originate from present-day construction sites and surface mines. A combination of watershed erosion control and vegetative stream bank stabilization is recommended to prevent excessive sediment wash-off into the creeks and to reduce suspended sediment levels.

[6] NPDES stormwater regulations have been implemented in two phases. Phase I (1990) required stormwater permits for construction activities impacting 5 acres or more. Phase II (2003) required stormwater permits for construction activities impacting 1 acre or more.

7.5.1 Implement Urban Green Infrastructure Stormwater Management Measures

Several types of green infrastructure stormwater management measures are recommended for the Mill-Pelahatchie Creek HUC12. Table 7.8 lists recommended management measures and indicates the drainage area or distance in the watershed where each proposed measure could be effectively applied. The areas and distances given in Table 7.8 refer to the drainage area or distance that would generate runoff treated by the measure, not the actual footprint of the treatment measure. Suites of measures can be used in many areas to create a "treatment train" to increase overall pollutant removal. In this case, the areas treated by different management measures will overlap. Table 7.8 is not intended to be an all-inclusive list of management practices, but features green infrastructure measures that are recommended for this subwatershed.

New development area is based on the estimated area with active construction permits (674 acres as of August 2010) and the assumption that growth will continue at 110% of the current rate in this area (712 acres per year)[7]. The areas for urban retrofits are based on the assumption that the measures would be applied to 10% of the developed area with applicable soil types[8]. Additional assumptions are listed in the notes below the table.

The areas/distances given in Table 7.8 should be interpreted as preliminary estimates of areas where management measures may be implemented. They do not refer to specific parcels of land. Rather, they refer to areas with the soil type and landuse where measures are feasible. Figure 7.3 shows developed areas in the HUC12 that contain suitable soil types. Specific parcels will be identified based on landowner willingness and funding sources available when individual watershed implementation plans (WIPs) are developed.

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[7] The assumed growth-rate is an estimate and has not been verified. The growth rate will be adjusted based on local data to be obtained for individual watershed implementation plans and compared with permits issued for new development. Information from the Central Mississippi Planning and Development District may also be used to help refine the growth rate estimate.

[8] The application of management measures to 10% of developed area is an assumption based on professional judgment. Based on review of watershed management plans in other regions, it is reasonable to assume that a maximum of 10% of the drainage area will be treated with green infrastructure measures. Funding resources and landowner willingness are the most common limiting factors.

Table 7.8. Green infrastructure stormwater management measures for Mill-Pelahatchie HUC12.

Management Measure	Drainage Area Served by Management Measure			Estimated Pollutant Percent Reductions			
	Unit	Retrofit (unit)	New Development (unit/yr)	Total Suspended Solids (TSS)	Total Nitrogen (TN)	Total Phosphorus (TP)	Bacteria
Bioretention areas/rain gardens(1)	Acres	271	41	85%	40%	50%	No data
Stormwater detention/retention basins(2)	Acres	132	169	80%	30%	50%	70%
Infiltration systems(3)	Acres	26	4	80%	50%	50%	90%
Constructed stormwater wetlands(4)	Acres	132	20	80%	30%	40%	No data
Pervious pavement(5)	Sq ft	43,560	86,841	80%	70%	60%	No data
Water quality swales/bioswales(6)	LF	10,000	5,000	80%	50%	50%	No data
Grassed swales(7)	LF	5,000	1,000	50%	20%	25%	No data
Vegetated filter strips with level spreaders(8)	LF	5,000	500	40%	25%	25%	No data
Green roof(9)	# of bldgs	N/A	10	Site-specific			
Rain barrels/cisterns(10)	# of bldgs	288	108	Site-specific			
Planned Urban Development (PUD) (11)	Acres	N/A	178	No data	50%	50%	No data
Preservation of vegetation/ trees on urban sites(12)	Acres	N/A	356	Site-specific			
Home and business owner management measures for pesticide and fertilizer application(13)	Acres	4,730	712	Site-specific			
Disconnected impervious areas(14)	Acres	132	40	Site-specific			

Notes:

1. Assume bioretention retrofits applied to 10% of the developed area with type B, and 5% of the developed area with types C and D. Assume 20% of new development will occur on type B soils (20% of the HUC12 is type B soils) and 80% of new development will occur on type C or D soils (80% of the HUC12 is type C or D soils). Then, assume that 10% of newly developed areas with type B and 5% with types C and D will have bioretention systems.
2. Assume that 80% of impervious area drains into stormwater retention/detention basins, and retrofits will be needed at 10%. Existing development is 28% impervious (HUC12 impervious area/HUC12 developed area); assume new development will be the same (199 acres). Assume 85% of new impervious areas will drain into a stormwater detention/retention basin.
3. Assume 28% of developed area (existing and new) on type B soils is impervious (see note 2). Infiltration retrofits applied to 10% of the impervious developed area with type B soils. Assume that 10% of new impervious areas with type B soils will have infiltration systems.
4. Constructed wetlands applied to 10% of existing developed impervious area regardless of soil type. Assume that 10% of new impervious areas will have constructed stormwater wetlands.
5. Two demonstration projects for retrofits of impervious area with pervious pavements are recommended (2 projects at 0.5 acres each). Assume that pervious pavement is applicable for 1% of new impervious areas.
6. Water quality swales distance is assumed and will be refined based on landowner participation.
7. Grassed swales distance is assumed and will be refined based on landowner participation.
8. Vegetated filter strips with level spreader is assumed and will be refined based on landowner participation.
9. Green roofs typically applicable only to new development, 10 demonstration projects recommended.

10. Rain barrels applied to 10% of current rooftops and 25% of new rooftops. Assume rooftops are 10% of impervious area; buildings average 2,000 square feet.
11. PUD management principles used on 25% of new development.
12. 50% of newly developed areas will use tree preservation.
13. Property owners in all developed areas should use pesticide and fertilizer management measures.
14. Approximately 28% of the currently developed area is impervious. Assume that 10% of existing impervious areas and 20% of new developed areas are disconnected.

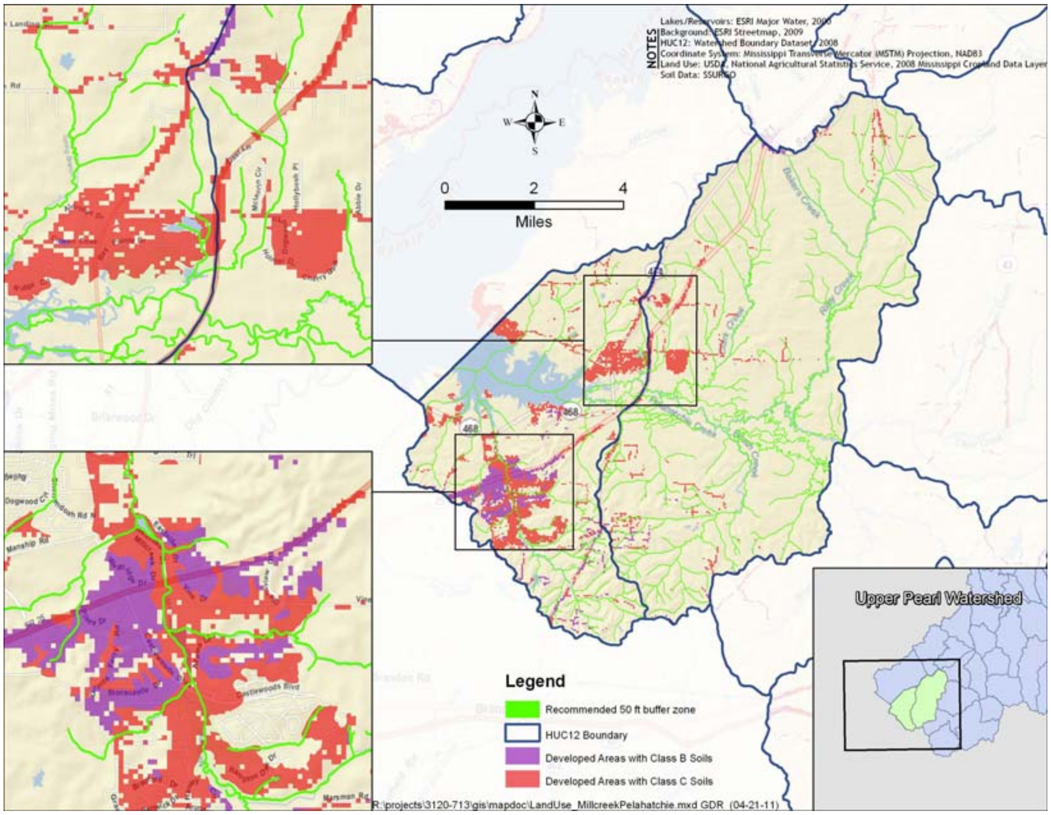

Figure 7.3. HSG type overlay with landuse in the Mill-Pelahatchie HUC12 and Riley-Pelahatchie HUC 12.

The estimated pollutant reductions are based on literature values for the effectiveness of management practices. It is assumed, for example, that bioretention basins will remove 85% of the sediment contained in stormwater treated within the basin.

7.5.2 Coordinate with County Officials

Coordination with local Rankin County officials will be necessary to promote the use of green infrastructure stormwater management measures. Rez*onate* project managers will ensure that the county has access to fact sheets describing green infrastructure management measures and other reference material. The recently updated *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater* (Planning and Design Manual) contains additional information about green infrastructure measures such as open space design, protection of natural features, street design and patterns, and urban forestry (MDEQ 2011).

Project managers will assist county officials with reviewing the Checklist of Recommended Elements to Promote Green Infrastructure (Appendix O) and implementing desired changes. Implementation of the *Comprehensive Education and Outreach Plan for Rez*onate will provide additional training and incentive programs to assist local decision makers and developers/contractors.

7.5.3 Improve Stormwater Controls on Individual Lots

One of the most significant problems within developing areas near the Reservoir is improper installation and maintenance of construction BMPs on individual lots within subdivisions. Education for developers/contractors and increased presence of regulatory authority is needed to improve compliance. The City of Flowood is already working to implement these measures (City of Flowood Public Works Director, February 2011).

Education is needed to promote understanding of the importance of controlling sediments on construction sites. Developers and contractors must take daily responsibility for proper maintenance of construction site BMPs and must be aware that they are working within the Reservoir watershed and that pollutants from construction sites in this watershed negatively impact the quality of its water used for drinking and recreation.

Local governments in this watershed are positioned to provide oversight of installation and maintenance of construction site erosion and sediment control measures through existing local stormwater plans and related ordinances. Local governments in cooperation with staff members involved with MDEQ's Ross Barnett Reservoir Stormwater Compliance Initiative will continue to conduct frequent inspections of construction sites in this subwatershed and issue penalties when needed. The current activities of the Stormwater Compliance Initiative are discussed in Appendix H, Section 1.2.

7.5.4 Stabilize Disturbed Soils

Much of the soil in this subwatershed is silt loam classified by NRCS as "highly erodible." Consequently, it is imperative to stabilize exposed soils on construction sites as soon as possible after clearing and grading. Proper sequencing of activities on construction sites is the method most commonly used to minimize soil exposure. In this method, only areas scheduled for immediate construction activities are cleared, instead of clearing the entire site at one time. A plan for construction sequencing is required in SWPPPs. Specifications for this management practice are included in MDEQ's Planning and Design Manual (MDEQ 2011). Contractors and developers working within the Reservoir watershed must carefully consider their construction sequencing plan and take special precautions to minimize the exposure of highly erosive soils.

The recently proposed Construction General Permit by EPA[9] calls for immediately stabilizing areas where earthwork will stop for more than 7 days, or has been completed. Stabilizing measures (soil conditioning, seeding, mulching or non-vegetative techniques) must be installed within 3 days of stopping or completing work. MDEQ's Large Construction Stormwater Permit[10] allows for a stop-work period of 14 days before stabilization is required, and allows 7 days to install stabilizing measures.

Surface mining sites must fully comply with MDEQ requirements for site stabilization and BMPs for erosion and sediment control. Presently there are three permitted surface mines in this subwatershed. MDEQ's Stormwater Compliance Initiative has issued fines for mines in the Pelahatchie Creek watershed that were operating without proper management practices, and identified several unpermitted surface mines (Appendix H). MDEQ continues to work with existing mine operators to improve stormwater control. In order to reduce sediments originating from erosive soils near the Reservoir, MDEQ might consider limiting future surface mining activities allowed in this HUC12. If the facility is granted a permit, MDEQ should conduct an extensive review of the facility's SWPPP prior to the issuance of permits and perform frequent inspections (at least every other month and following heavy rain events) during operation.

7.5.5 Restore Stream Banks and Buffer Zones and Repair Gullies

Table 7.9 lists management measures for stream banks and gullies in the Mill-Pelahatchie HUC12. The table includes preliminary estimates of stream length where restoration measures may be needed. Specific areas will be identified during the development of WIPs.

[9] http://cfpub.epa.gov/npdes/stormwater/cgp.cfm
[10] http://deq.state.ms.us/MDEQ.nsf/page/epd_epdgeneral?OpenDocument

Table 7.9. Stream-bank and gulley management measures for the Mill-Pelahatchie HUC12.

Management Measure	Length of Management Measures		Pollutant Percent Reductions			
	Unit	Treatment Extent	TSS	TN	TP	Bacteria
Vegetative stream-bank protection/stabilization using bioengineering measures(1)	Linear feet (LF)	2,528	90%	No data	No data	N/A
Gulley stabilization/repair(2)	LF	500	Site-specific			
Restored riparian buffer/vegetative buffers(3)	LF	6,732	60%	30%	35%	No data

Notes:

1. Assume that vegetative stream-bank stabilization measures are needed along 10% of the sediment TMDL segments in the Mill-Pelahatchie HUC12 (528 ft), along with 1,000 ft of Mill Creek and 1,000 ft of Turtle Creek. Bioengineering measures should remove nearly 100% of the TSS at each location.
2. Gullies based on assumed length; will be revised based on field reconnaissance.
3. Assume restored riparian buffer zones needed along 25% of all streams; total stream distance in the Mill-Pelahatchie HUC12 is 5.1 miles. The 25% assumption was chosen because approximately 25% of the watershed is developed. For cost estimates, we assumed that half of the streams would need restoration on both sides and half would need restoration on one side only.

Excessive bank erosion and loss of stream-bank vegetation has been observed in many streams in this HUC12 including Mill Creek (Figures 7.4 and 7.5). As of May 2011, planning is underway for a project to stabilize a 350-ft section of Mill Creek located just south of Spillway Road (depicted on Figure 7.4). This is one of a few sites in the subwatershed being considered for vegetative- and soil-bioengineering stabilization techniques

Vegetative stabilization and soil bioengineering techniques are recommended for streams in this watershed. Based on preliminary analysis, longitudinal rock dikes built parallel to the stream may be needed to prevent further bank scouring and stabilize bank toes. Instream structures (jetties made of posts, logs, or rock) may be needed to protect stream banks in curves by reducing high-velocity currents that occur during peak flows. Soil stabilization (using coir fiber, brush layering, and erosion control matting) may be needed to provide substrate for vegetative stabilization measures and to capture sediment and dissipate energy. Native plant materials and grasses should be planted on the stabilized stream bank. Specific engineering plans will be needed for sites once they are selected. Implementing these techniques will require a coordinated effort between the property owners, technical resource agencies, and entities providing funding.


Figure 7.4. Mill Creek south of Highway 25; right descending bank looking upstream.


Figure 7.5. Mill Creek behind Hidden Hills subdivision, looking upstream.

The Rankin County Board of Supervisors recently completed bank stabilization on portions of Mill Creek near residential areas. The stabilization work consisted of bank grading and placement of rip-rap on the banks. This type of stabilization is effective. However, it often leaves stream channels without riparian zones that regulate temperature (via shading) and provide wildlife habitat (Figure 7.6). Rankin County is planning to work with adjacent property owners to replant vegetation in this section of Mill Creek (George Bobo, Rankin County Road Manager, May 2011, personal communication).

Figure 7.6. Mill Creek stabilized with rip-rap.

Rez*onate* project managers will work with Rankin County officials and local stakeholders to identify additional locations where stream-bank stabilization measures are needed. Field reconnaissance (i.e., visual observation conducted by walking along streams) is the best method to identify locations where stream-bank stabilization is needed. However, field reconnaissance is time-consuming and difficult when streams are not readily accessible. The Rankin County Board of Supervisors conducted low-level aerial photography in portions of Rankin County on two recent occasions[11]. It may be possible to identify stream segments with insufficient riparian vegetation and locations of active bank failures with a close examination of the following sets of high-resolution aerial photographs:

- High-resolution aerial photographs of Mill Creek watershed collected in the fall of 2006,
- High-resolution aerial photographs of Rankin County collected in the fall of 2008, and
- Two-foot topography contours developed using LIDAR data for all of Rankin County based on the 2008 photos.

A sediment budget that delineates upland and instream sources would be helpful to identify specific locations where management measures are needed. However, attributing cumulative sediment loads to individual sources is difficult without detailed information. A literature review (Appendix Q) describes the information and methods used to develop sediment budgets in other parts of Mississippi and other states.

The Technical Advisory Group reviewed a scope of work and cost estimate to develop a sediment budget for the Reservoir watershed (prepared by the Bidenharn Group, Appendix R). This proposal includes collecting a geo-referenced, aerial video and ground-truthing selected areas to pinpoint locations of significant sediment sources in the watershed. At this time, the group has not made a decision on whether to move forward with this work.

Gullies tend to form easily on any area of exposed soil, due to the highly erosive nature of soils in the Reservoir watershed. Once formed, gullies typically grow with time and will continue down-cutting until resistant material is reached. They also expand laterally as they

[11] Photography can be obtained by contacting Lance Cooper, Rankin County Tax Assessor's Office.

deepen, making them a major sediment source. Presently, there is not an inventory of gullies in need of repair in the Reservoir watershed. Rez*onate* project managers will work with county officials and local citizens to identify locations. The fact sheet on gully repair (Appendix N) describes repair methods for gullies of various sizes.

7.5.6 Maintain Green Space and Undisturbed Streamside Buffer Zones

The current zoning ordinance in this watershed includes requirements for open space. The amount of land designated as open space varies within each particular zone, but ranges from 15% to 30%. Open space is defined as "*parcels of land not occupied by dwellings or residential structures, accessory structures and yards … and which is permanently maintained in a suitable state for the shared enjoyment by the owners and/or occupants*."[12]

The undeveloped, "green" portions of the open space (i.e., areas left as natural vegetation and trees) are important for water quality because they reduce and treat stormwater. Structures such as tennis courts and swimming pools may be built in open space and offer valuable recreational and social benefits for residents. However, they reduce the amount of open area that is left as green space.

Current zoning ordinances do not specify the amount of the open area that must be left as green space. Rules to limit impervious area in future developments would reduce the quantity of stormwater generated from future development. Model ordinances suggest that 50% of open area should be preserved as green space[13].

The City of Flowood has zoned some areas as land conservation areas[14]. Zoning ordinances limit certain uses of the conservation areas. The areas are reserved for future growth once the city has established streets and utilities in these areas. This ordinance is intended to encourage development in parts of the city that are already served by streets and utilities. This provision is consistent with green infrastructure principles because it reserves large tracts of undeveloped land and encourages urban growth in an orderly manner. Rankin County has zoned

[12] Zoning Ordinance of Rankin County, Mississippi, Revised December 2010. Available online at http://www.rankincounty.org/
[13] Open Space Model Ordinance. Center for Watershed Protection. http://www.stormwatercenter.net
[14] http://www.ci.flowood.ms.us/ZoningMap.asp

some areas as Planned Urban Developments (PUDs). PUDs preserve open space in subdivisions by allowing smaller lot sizes.

Maintaining vegetated buffer zones along drainage channels and streams is an effective way to remove pollutants from stormwater and protect stream channels from degradation. Buffer zones are highly cost-efficient if disturbance of the buffer zone is initially avoided. Buffer zones for streams have been shown to be one of the most effective methods of reducing water pollution and sedimentation in streams (Department of Defense 2004, Fisher and Fischenich 2000, and Mississippi Forestry Commission [MFC] 2002). Additional regulatory controls to prevent disturbance of riparian buffer zones in new developments is recommended for the Mill-Pelahatchie HUC12. Although they represent an additional level of regulatory control, buffer zone requirements for new developments could be easily incorporated into the review/approval process for site development plans. They could be added as an item for inspections that are already required for sites under construction.

7.5.7 Develop and Implement an Incentive Program

Many of the management measures recommended for this subwatershed will depend on the willingness of individual landowners to implement them on their property, often at their own expense. Cost-sharing programs for urban areas are not widely available. Because of this, it will be important to provide an incentive program to encourage adoption. Possible incentives include tax credits, expedited permit approval, grants, awards, and recognition. There are also many benefits of green infrastructure stormwater management practices, including reduced stormwater treatment costs and community benefits such as increased recreational opportunities and aesthetics.

As a first step, Rez*onate* project managers must work with Rankin County to develop the program. There are several resources available to assist local governments in developing an incentive program, including EPA's *Managing Wet Weather with Green Infrastructure Municipal Handbook: Incentive Mechanisms*. [15]

[15] http://www.epa.gov/npdes/pubs/gi_munichandbook_incentives.pdf

7.5.8 Cost Estimates for Mill-Pelahatchie HUC12 Objectives

Initial estimates of the cost to implement the management measures recommended for this subwatershed have been developed. Table 7.10 includes a summary of costs for implementing the management measures recommended for the Mill-Pelahatchie HUC12. Costs are based on literature-derived values for installation of structural and vegetative management measures, given in Appendix T (Table 7.10). Cost estimates should be considered preliminary, and will be refined within WIPs.

Table 7.10. Preliminary cost estimates for Mill-Pelahatchie HUC12.

Management Measure	Retrofit Cost (implemented over 10 years)	New Development Cost (per year)	Notes
Green infrastructure stormwater management measures	$6,354,485	$3,517,866	Costs calculated from Appendix T and Table 7.8.
Improved stormwater controls on individual lots/stabilize disturbed soils	--	$1,012,820	Cost based on 498 acres per year (712 acres of new development, with 30% reserved for green space) at a cost of $2,000 per acre for improved stormwater controls.
Restored stream banks and buffers	$494,053	--	Estimates for restored banks and buffers are based on Table 7.9 and Appendix T. Cost for gullies not included because repair costs can only be estimated on a site-specific basis.
Maintained green space and buffers	--	$16,020	Cost based on 30% of new development reserved for green space (214 acres) at a cost of $75 per acre per year (see Appendix T).
TOTAL	$6,848,539	$4,546,706	

Notes:
Costs for the coordination with county officials (Section 7.5.2) and an incentive program (Section 7.5.3) are included in the budget for the *Comprehensive Education and Outreach Plan for Rez*onate!.

7.6 Restoration Measures for Riley-Pelahatchie HUC12

The Riley-Pelahatchie subwatershed is located adjacent to the Mill-Pelahatchie subwatershed. It presently contains some development extending from the City of Flowood and the area near Fannin. New development in this HUC12 must be planned and managed in the same manner recommended for the Mill-Pelahatchie HUC12. This HUC12 also contains large forest and pasture areas. The restoration objectives for this HUC12 are as follows:

- **Objective 1**: Address compliance issues at the Reservoir East publicly owned treatment works (POTW) and encourage all new homes and buildings to connect to a central sewer system (most soils are not suitable for septic tanks),
- **Objective 2**: Incorporate green infrastructure stormwater management measures in new construction,
- **Objective 3**: Preserve streamside buffers and green space as new development expands to this area,
- **Objective 4**: Stabilize disturbed soils on construction and surface mining sites by quickly replanting with native grasses and other vegetation,
- **Objective 5**: Implement pasture management measures on all areas with willing landowners, and
- **Objective 6**: Encourage participation in forestry stewardship programs.

The total area of this HUC12 is 33,292 acres (approximately 52 square miles). Land use summary by HSG type within the watershed is presented in Table 7.11 and on Figures 7.7 and 7.8.

Table 7.11. Landuse and HSG type for the Riley-Pelahatchie HUC12.

Landuse	No Data Available (acres)	HSG Type B (acres)	HSG Types C and D (acres)	Total (acres)
Water	10	49	160	219
Agricultural Crops	0	2	444	446
Pasture/Grassland	30	251	5,007	5,288
Developed	2	130	1,402	1,534
Forest/Woodland	40	1,862	14,543	16,445
Shrubland	9	487	3,869	4,365
Wetlands	66	284	4,645	4,995
Total	**157**	**3,065**	**30,070**	**33,292**

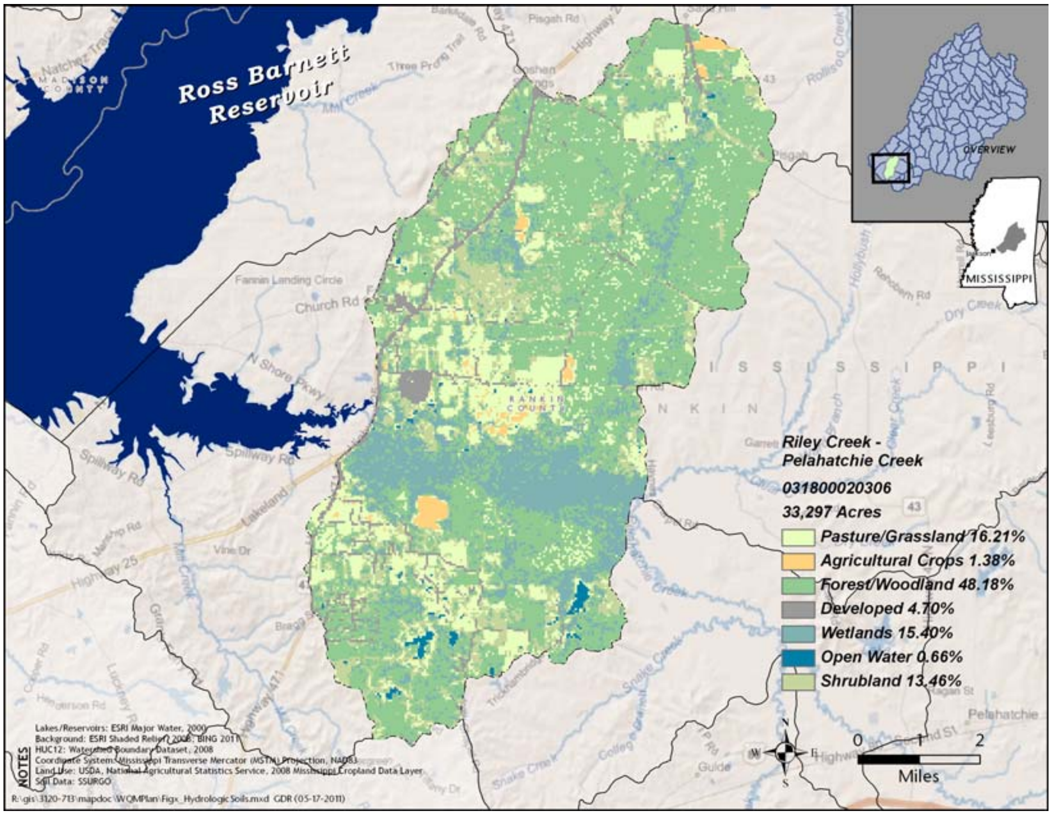

Figure 7.7. Landuse in the Riley-Pelahatchie HUC12.

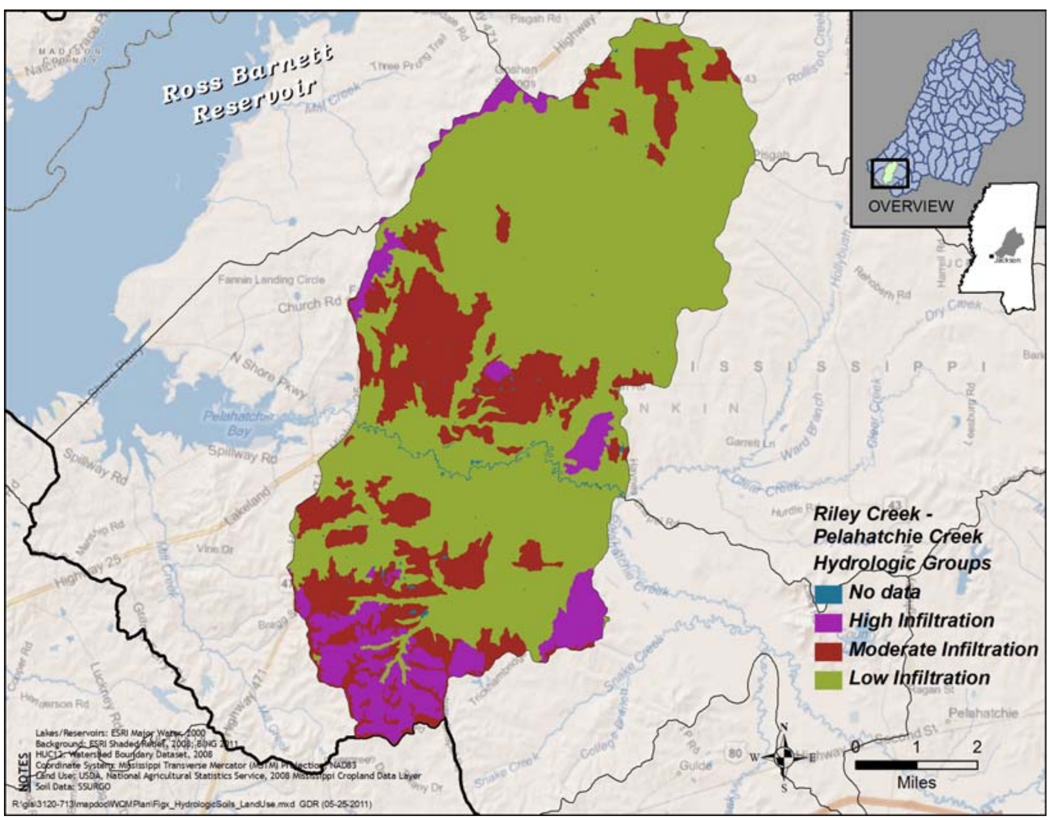

Figure 7.8. HSG types in the Riley-Pelahatchie HUC12.

7.6.1 Address Wastewater Issues

Wastewater issues in the Riley-Pelahatchie subwatershed include both centralized and onsite treatment systems. The Reservoir East Wastewater Treatment Plant (WWTP) has had past permit compliance issues and operational problems and has been the subject of several public complaints (CDM 2010). This facility discharges into Pelahatchie Creek, approximately 4 miles upstream of Pelahatchie Bay. Because it discharges upstream of a waterbody that is used for drinking water supply and contact recreation, MDEQ must quickly move forward to address complaints and compliance issues. The *Ross Barnett Reservoir Pathogen Source Assessment and Wastewater Management Plan* (Wastewater Plan) recommends decommissioning the facility and connecting it to a regional wastewater treatment system when a connection becomes available. Those areas that remain on septic tanks will be targeted for homeowner education programs to teach proper septic tank installation and maintenance.

Opportunities to improve onsite wastewater treatment in this subwatershed include increasing availability of a central wastewater collection system and improving performance of existing onsite treatment systems. A new wastewater collection line is planned for the eastern shore of the Reservoir that will connect to the City of Jackson's WWTP (located in the Pearl River downstream of the Reservoir). The new collection line may allow homes and businesses currently served by onsite wastewater treatment systems to connect to the central collection and treatment system.

Septic systems are viable options for treating wastewater in rural areas as long as they are properly maintained. However, the Wastewater Plan indicated that as many as 65% of the septic tanks in this area may be failing due to poor soil conditions. Decentralized wastewater treatment systems are an option for areas that are currently served by septic tanks (subdivisions, businesses, and schools). Decentralized systems work well in areas that are already served by septic systems and need to improve wastewater treatment. In this case, the septic tank provides primary treatment (solids settling) from individual homes. After primary treatment, water from many systems is collected, treated through additional processes, and disposed of through methods such as underground drip irrigation.

The Wastewater Plan identifies subdivisions located near the Reservoir that are now served by septic systems. Presently, there are 16 subdivions (Baker Lane Farms, Biltmore

Estates, Fox Run, Holly Bush, Kitty Hawk, Lake Harbor Estates, Langford Farms, LeBourgeois Estates, Mellowmeade, North Brandon Ridge, North Brandon Estates, Oak Ridge Estates, Old Fannin, Persimmion Creek, Shenandoah Estates, and Virginia Valley) and several unnamed high-density residential areas that are not served by central sewer systems. Based on current records, these subdivisions contain 625 homes with the potential to contain approximately 1,000 homes when the subdivisions are fully built. These areas would be good candidates for decentralized systems as well as homeowner education programs about properly maintaining septic systems.

7.6.2 Implement Green Infrastructure Stormwater Management Measures

Potential areas for implementation of green infrastructure stormwater management measures in the Riley-Pelahatchie Creek HUC12 were estimated using assumptions similar to those used for the Mill-Pelahatchie Creek HUC12. Table 7.12 lists recommended management measures and indicates the drainage area or distance potentially served by each type of measure.

New development areas are based on the estimated area with active construction permits (240 acres as of August 2010) and the assumption that growth will continue at 110% of the current rate in this area (264 acres per year). The areas for urban retrofits are based on the assumption that measures are applicable to 10% of the developed area with applicable soil types. Additional assumptions are listed in the notes below the table.

The areas/distances given in Table 7.12 are preliminary estimates of areas where management measures may be implemented. They do not refer to specific parcels of land. Rather, they refer to areas with the soil type and landuse where the measure is feasible. Figure 7.3 shows developed areas in the HUC12 that contain suitable soil types. Specific parcels will be identified based on landowner willingness and funding sources available when individual WIPs are developed.

Table 7.12. Green infrastructure stormwater management measures for Riley-Pelahatchie HUC12.

Management Measure	Drainage Area Served by Management Measure			Estimated Pollutant Percent Reductions			
	Unit	Retrofit (unit)	New Development (unit/yr)	TSS	TN	TP	Bacteria
Bioretention areas/rain gardens(1)	Acres	83	1	85%	40%	50%	No data
Stormwater detention/retention basins(2)	Acres	26	34	80%	30%	50%	70%
Infiltration systems(3)	Acres	2	0.4	80%	50%	50%	90%
Constructed stormwater wetlands(4)	Acres	26	4	80%	30%	40%	No data
Pervious pavement(5)	Acres	0.5	0.5	80%	70%	60%	No data
Water quality swales/bioswales(6)	LF	5,000	500	80%	50%	50%	No data
Grassed swales(7)	LF	2,500	250	50%	20%	25%	No data
Vegetated filter strips with level spreaders(8)	LF	2,500	250	40%	25%	25%	No data
Green roof(9)	# of bldg	NA	5	Site-specific			
Rain barrels/cisterns(10)	# of bldg	57	24	Site-specific			
Planned Urban Development (PUD) (11)	Acres	NA	66	No data	50%	50%	No data
Preservation of vegetation/trees on urban sites(12)	Acres	NA	132	Site-specific			
Home and business owner management measures for pesticide and fertilizer application(13)	Acres	1,534	264	Site-specific			
Disconnected impervious area	Acres	25	9	Site-specific			

Notes:

1. Assume bioretention retrofits applied to 10% of the developed area with type B, and 5% of the developed area with types C and D. Assume 9% of new development will occur on type B soils (9% of the HUC12 is type B soils) and 90% of new development will occur on type C or D soils (90% of the HUC12 is type C or D soils). Then, assume that 10% of newly developed areas with type B and 5% with type C and D will have bioretention systems.
2. Assume that 80% of impervious area drains into stormwater retention/detention basins, and retrofits will be needed at 10%. Existing development is 17% impervious (HUC12 impervious area/HUC12 developed area); assume new development will be the same (45 acres). Assume 75% of new impervious areas will drain into a stormwater detention/retention basin.
3. Assume 17% of developed area (existing and new) on type B soils is impervious (see note 2). Infiltration retrofits applied to 10% of the developed impervious area with type B soils. Assume that 10% of new impervious areas with type B soils will have infiltration systems.
4. Constructed wetlands applied to 10% of existing developed impervious area regardless of soil type. Assume that 10% of new impervious areas will have constructed stormwater wetlands.
5. One demonstration project for retrofits of impervious area with pervious pavements is recommended (one project at 0.5 acre). Assume that pervious pavement is applicable for 1% of new impervious areas.
6. Estimated water quality swales distance is based on best professional judgment (BPJ) and will be refined based on landowner participation.
7. Estimated grassed swales distance is based on BPJ and will be refined based on landowner participation.
8. Distance for vegetated filter strips with level spreader is based on BPJ and will be refined based on landowner participation.
9. Green roofs typically applicable only to new development; five demonstration projects recommended.
10. Rain barrels applied to 10% of current rooftops and 25% of new rooftops. Assume rooftop area is 10% of impervious area, and buildings average 2,000 square feet.
11. PUD management principles used on 25% of new development.
12. 50% of newly developed areas will use tree preservation.
13. Property owners in all developed areas should use pesticide and fertilizer management measures.
14. Approximately 17% of the currently developed area is impervious. Assume that 10% of existing impervious areas and 20% of new developed areas are disconnected.

7.6.3 Maintain Undisturbed Streamside Buffer Zones in Developed Areas

Additional controls to prevent disturbance of streamside buffer zones in new developments is highly recommended for the Riley-Pelahatchie HUC12. Although they represent an additional level of regulatory control, buffer zone requirements for new developments could be easily incorporated into the review/approval process for site development as the area continues to grow. Section 7.5.6 of this Plan and Section 4.4 of Appendix O provide additional discussion of the importance of streamside buffer zones and options for implementing them. Table 7.13 provides a preliminary estimate of the stream length where restoration measures may be needed. Specific areas will be identified during the development of WIPs.

Table 7.13. Streamside buffer zones in the Riley-Pelahatchie HUC12.

Management Measure	Length of Management Measure		Pollutant Percent Reductions			
	Unit	Treatment Extent	TSS	TN	TP	Bacteria
Restored riparian buffer/vegetative buffers	LF	6,230	60%	30%	35%	No data

Notes: Assume restored riparian buffer zones needed along 5% of all streams; total stream distance in the Riley-Pelahatchie HUC12 is 23.6 miles. Five percent was selected because approximately 5% of the watershed is developed.

7.6.4 Stabilize Disturbed Soils

As development continues in this watershed, it is imperative to minimize erosion from new construction sites. Also, surface mining sites must fully comply with MDEQ requirements for BMPs for erosion and sediment control and site restoration. Presently there are three permitted surface mines in this subwatershed. The recommendations given in Section 7.5.4 for the Mill-Pelahatchie HUC12 should also be applied in this HUC12 to minimize erosion and transport of sediments from construction sites and surface mines.

7.6.5 Implement Pasture Management Measures

The Riley-Pelahatchie subwatershed includes more than 5,200 acres of pasture land. NRCS and MSWCC have worked extensively with owners of pasture land throughout the Pelahatchie Creek watershed to assist with nutrient management and grazing measures. Many owners of pasture land have already implemented conservation measures on their lands including fencing, rotational grazing, and access control to keep livestock out of streams, coupled with alternative water sources[16].

Although there are no poultry-growing operations located in this HUC12, it is likely that poultry litter from other operations is transported into this subwatershed for use as fertilizer. The use of poultry litter depends on the cost of manufactured fertilizer versus the cost of transporting poultry litter. The NRCS poultry-litter transport cost-sharing program has made the use of poultry litter as a fertilizer cost-effective. Although the exact number is not known, it is reasonable to assume that 15% to 20% of pasture lands and row-crop fields receive poultry litter as a fertilizer (Murray Fulton, February 2011, personal communication). Proper nutrient management is necessary to protect water quality downstream of pastures treated with poultry litter.

MDEQ reports that the most common type of complaint reported for land application of poultry litter is odor (William Ryder, November 2010, personal communication). These complaints are usually due to third-party users applying the litter (i.e., producers who are purchasing the litter from a facility permitted under the National Pollutant Discharge Elimination System (NPDES) program that is located in another subwatershed). Third-party users may be required to develop nutrient management plans and should follow nutrient management guidelines when applying litter to pastures.

Pasture management measures recommended for participating landowners include buffer zones near streams and at the edge of fields. These measures enhance green infrastructure and wildlife habitat while protecting water quality. According to NRCS, some landowners have adopted these measures[17]; however, increasing their use in this subwatershed is recommended (Murray Fulton, NRCS, February 2011, personal communication). A cooperative effort between NRCS and MDEQ will prioritize future projects in this HUC12. Estimated areas are given in Table 7.14.

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[16] EQIP-funded practices in the entire Reservoir watershed totaled 15,542 acres of access control; 258,584 linear feet of fence; three stream crossings; and 85 watering facilities from 2007 to 2010. It is not known how much of these areas are located in the Riley-Pelahatchie HUC12.

[17] EQIP funded 7 acres of field borders and 807 acres of filter strips between 2007 and 2010. These areas apply to the entire Reservoir watershed. Areas within individual HUC12s are not available.

Table 7.14. Pasture management measures for Riley-Pelahatchie HUC12.

Management Measure	Applicability		Pollutant Percent Reductions			
	Unit	Area	TSS	TN	TP	Bacteria
Fencing of pastures (interior to facilitate rotational grazing) (1)	Acres	1,322	Insufficient data available; efficiency of these conservation measures are site-specific.			
Alternative water sources for pasture(1)						
Livestock stream crossing(1)						
Field borders(2)	Acres	106	40%	30%	35%	No data
Filter strips(2)			40%	30%	35%	No data
Preserved/restored riparian buffer zones(3)	LF	18,691	60%	30%	35%	No data
Nutrient management(4)	Acres	1,058	Site-specific			

Notes:

1. Assume that fencing of pastures with alternative water source and stream crossings is needed in 25% of pasture land.
2. Assume field borders/filter strips are applicable to 2% of pasture areas.
3. Riparian buffer zones applicable to 15% of total length of streams. The total length of streams in the Riley-Pelahatchie HUC12 is 23.6 miles. This assumption was selected because pasture land is 15% of the total watershed area.
4. Nutrient management applicable to 20% of pasture area. This is the assumed percentage of pasture land treated with poultry litter.

7.6.6 Promote Forestry Stewardship

There are 16,445 acres of forested land in the Riley-Pelahatchie HUC12. Forested area contributes significantly less runoff and nonpoint source pollutants on a per-acre basis than other landuses. Measures recommended for forest areas will retain the function of green infrastructure near sensitive areas and minimize the impacts of forest harvesting. A recent survey conducted by MFC reported that 93% of the BMPs surveyed on recently harvested forest land were implemented in accordance with the guidelines published in *Mississippi's BMPs – Best Management Practices for Forestry in Mississippi* (MFC 2011).

Conservative management of forested land in the Riley-Pelahatchie HUC12 is important for protecting the overall watershed health and water quality of the Reservoir and its tributaries. MFC has several programs available to assist private landowners manage their land such as the Forest Stewardship Program and the Forest Resources Development Program (see Appendix M). However, data from MFC show that there is very little participation in these programs within the Riley-Pelahatchie HUC12. Increased awareness of these programs among landowners may increase participation in this area.

Specific forestry management measures are included in Table 7.15. Since most forest land in the Reservoir watershed is managed by private landowners, the annual amount of forest land harvested each year is not known. An assumed rate of 4% forest land harvested per year was used to develop this table. This rate is based on information from MFC (MFC 2008).

Table 7.15. Forestry management measures for Riley-Pelahatchie HUC12.

Management Measure	Applicability		Pollutant Percent Reductions			
	Unit	Area	TSS	TN	TP	Bacteria
Properly designed skid trails and landings(1)	Harvested acre	658	52%	70%	52%	n/a
Streamside management zones(2)	LF	2,462	52%	40%	52%	n/a
Forest regeneration(3)	Harvested acre	658	56%	No data	56%	No data
Conservation easements(4)	Acres	Determined at implementation	Insufficient data available; efficiency of these conservation measures are site-specific.			

Notes:

1. Properly designed skid trails and landings applicable to 4% of all forest land.
2. Streamside management zones applicable for 4% of the length of the estimated length of streams in forested areas. Estimated length of streams in forested areas is 11.7 miles (49.4% of the total stream distance; 49.4% of watershed is forested).
3. Forest regeneration area is 4% of all forest land.
4. Participation in conservation easements depends on willingness of private landowners to participate.

7.6.7 Cost Estimates for Riley-Pelahatchie HUC12

Initial estimates of the cost to implement the management measures recommended for this subwatershed have been developed. Table 7.16 includes a summary of costs for implementing the management measures recommended for the Riley-Pelahatchie HUC12. Costs are based on literature values for installation of management measures, provided in Appendix T. Cost estimates will be refined during the development of WIPs.

Table 7.16. Preliminary cost estimates for Riley-Pelahatchie HUC12.

Management Measure	Retrofit Cost (implemented over 10 years)	New Development Cost (per year)	Notes
Green infrastructure stormwater management measures	$1,953,501	$891,591	Costs calculated from Appendix T and Table 7.12.
Improved stormwater controls on individual lots/stabilize disturbed soils	--	$369,600	Cost based on 185 acres per year (264 acres of new development, with 30% reserved for green space) at a cost of $2,000 per acre for improved stormwater controls.
Restored stream banks and buffers	$12,709	--	Estimates for restored banks and buffers are based on Table 7.13 and Appendix T. Cost for gullies not included because repair costs can only be estimated on a site-specific basis.
Conservation practices for forestry and pasture lands	$661,164	--	Costs calculated from Appendix T and Tables 7.14 and 7.15. Does not include costs for streamside management zones and conservation easements.
TOTAL	$2,627,374	$1,261,191	

7.7 Restoration Measures for Ashlog-Pelahatchie HUC12

The Ashlog-Pelahatchie Creek subwatershed is located in the headwaters of Pelahatchie Creek within Rankin and Scott counties. This HUC12 was targeted for restoration because it is located in the headwater region and contains most of the City of Pelahatchie. City leaders have expressed interest in working to implement recommended watershed improvements. There is some urban development in the City of Pelahatchie. However, the watershed is predominantly forested land with some pasture and a small amount of row-crop agriculture. The restoration objectives for this HUC12 are as follows:

- **Objective 1**: Incorporate green infrastructure stormwater management measures in new construction and retrofit projects in the City of Pelahatchie,

- **Objective 2**: Preserve streamside buffers and green space as development continues in this area,
- **Objective 3**: Assist poultry growers to ensure that they have access to technical expertise and cost-sharing programs needed to implement nutrient management plans,
- **Objective 4**: Implement pasture management measures and BMPs for agricultural crops on all areas with willing landowners, and
- **Objective 5**: Address flooding concerns through evaluation of Pelahatchie Creek's flow capacity.

The total area of this HUC12 is 31,817 acres (approximately 50 square miles). Land use summary by HSG type within the watershed is presented in Table 7.17 and on Figures 7.9 and 7.10.

Table 7.17. Landuse and hydrologic soil groups for Ashlog-Pelahatchie HUC12.

Landuse	No Data Available (acres)	HSG Type B (acres)	HSG Types C and D (acres)	Total (acres)
Water	166	68	93	327
Agricultural Crops	5	167	673	845
Pasture/Grassland	40	936	5,272	6,248
Developed	15	217	1,924	2,156
Forest/Woodland	62	3,695	12,196	15,953
Shrubland	38	937	3,240	4,215
Wetlands	19	122	1,932	2,073
Total	**345**	**6,142**	**25,330**	**31,817**

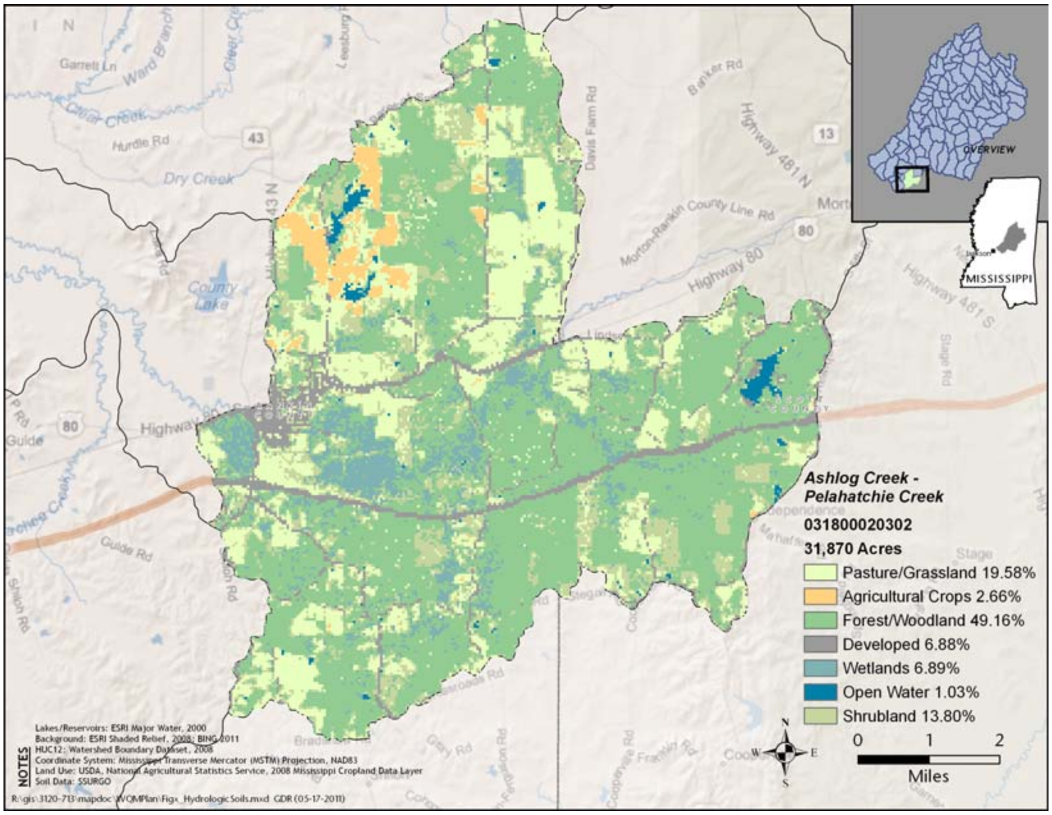

Figure 7.9. Landuse in the Ashlog-Pelahatchie HUC12.

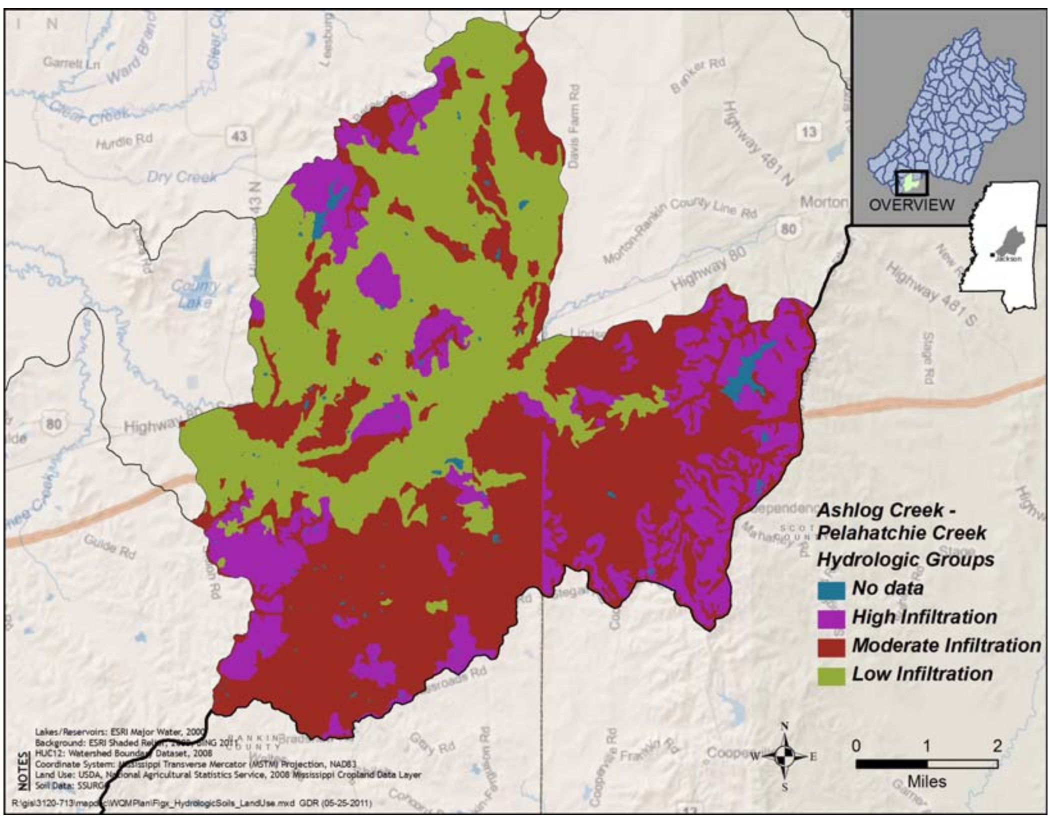

Figure 7.10. HSG types in the Ashlog-Pelahatchie HUC12.

7.7.1 Implement Green Infrastructure Stormwater Management Measures

Potential areas for green infrastructure stormwater management measure implementation in the Ashlog-Pelahatchie HUC12 were estimated using assumptions similar to those used for the Mill-Pelahatchie HUC12. Table 7.18 lists recommended management measures and indicates the drainage area or distance potentially served by each proposed measure.

New development areas are based on the estimated area with active construction permits in August 2010 and the assumption that growth will continue at 110% of that rate in this area (66 acres per year). The areas for urban retrofits are based on the assumption that the measures could be applied to 10% of the developed area with applicable soil types. Additional assumptions are listed in the notes below the table.

The areas/distances given in Table 7.18 are preliminary estimates of areas where management measures may be implemented. They do not refer to specific parcels of land. Rather, they refer to areas with the soil type and landuse where the measure is feasible. Figure 7.11 shows developed areas in the HUC12 that have suitable soil types within developed areas. Specific parcels will be identified based on landowner willingness and funding sources available when individual WIPs are developed.

Table 7.18. Green infrastructure stormwater management measures for the Ashlog-Pelahatchie HUC12.

Management Measure	Drainage Area Served by Management Measure			Estimated Pollutant Percent Reductions			
	Unit	10-year Retrofit (unit)	New Development (unit/yr)	TSS	TN	TP	Bacteria
Bioretention areas/rain gardens[1]	Acres	118	4	85%	40%	50%	No data
Stormwater detention/retention basins[2]	Acres	28	6	80%	30%	50%	70%
Infiltration systems[3]	Acres	3	0.1	80%	50%	50%	90%
Constructed stormwater wetlands[4]	Acres	28	1	80%	30%	40%	No data
Pervious pavement[5]	Acres	0.25	0.1	80%	70%	60%	No data
Water quality swales/bioswales[6]	LF	5,000	500	80%	50%	50%	No data
Grassed swales[7]	LF	2,500	250	50%	20%	25%	No data
Vegetated filter strips with level spreaders[8]	LF	2,500	250	40%	25%	25%	No data
Green roof[9]	# of bldg	NA	5	Site-specific			
Rain barrels/cisterns[10]	# of bldg	61	5	Site-specific			
Planned Urban Development (PUD) [11]	Acres	NA	17	No data	50%	50%	No data
Preservation of vegetation/trees on urban sites[12]	Acres	NA	33	Site-specific			
Homeowner BMPs for pesticide and fertilizer application[13]	Acres	2,156	66	Site-specific			

Notes:

1. Assume bioretention retrofits applied to 10% of the developed area with type B soils, and 5% of the developed area with types C and D. Assume 19% of new development will occur on type B soils (19% of the HUC12 is type B soil), and 80% of new development will occur on type C or D soils (80% of the HUC12 is type C or D). Then, assume that 10% of newly developed areas with type B and 5% with types C and D soils will have bioretention.
2. Assume that 80% of already developed impervious areas drain into a stormwater retention/detention basin; retrofits will be needed at 10%. Existing development is 13% impervious (HUC12 impervious area/HUC12 developed area); assume new development will be the same. Assume that 75% of new impervious areas will drain into a stormwater detention/retention basin.
3. Assume 10% of developed area (existing and new) on type B soils is impervious (see Note 2). Infiltration retrofits applied to 10% of the impervious developed area with type B. Assume that 10% of new impervious areas with type B soil will have infiltration.
4. Constructed wetlands applied to 10% of existing impervious developed area regardless of soil type. Assume that 10% of new impervious areas will have constructed stormwater wetlands.
5. One demonstration project for retrofits of impervious area with pervious pavements is recommended (one project at 0.25 acre). Assume that pervious pavement is applicable for 1% of new impervious areas.
6. Estimated water quality swales distance is based on BPJ and will be refined based on landowner participation.
7. Estimated grassed swales distance is based on BPJ and will be refined based on landowner participation.
8. Distance for vegetated filter strips with level spreader is based on BPJ and will be refined based on landowner participation.
9. Green roofs typically applicable only to new development; five demonstration projects recommended.
10. Rain barrels applied to 10% of current rooftops and 25% of new rooftops. Assume rooftops area is 10% of impervious area, and buildings average 2,000 square feet.
11. PUD management principles used on 25% of new development.
12. 50% of newly developed areas will use tree preservation.
13. Property owners in all developed areas should use pesticide and fertilizer management measures

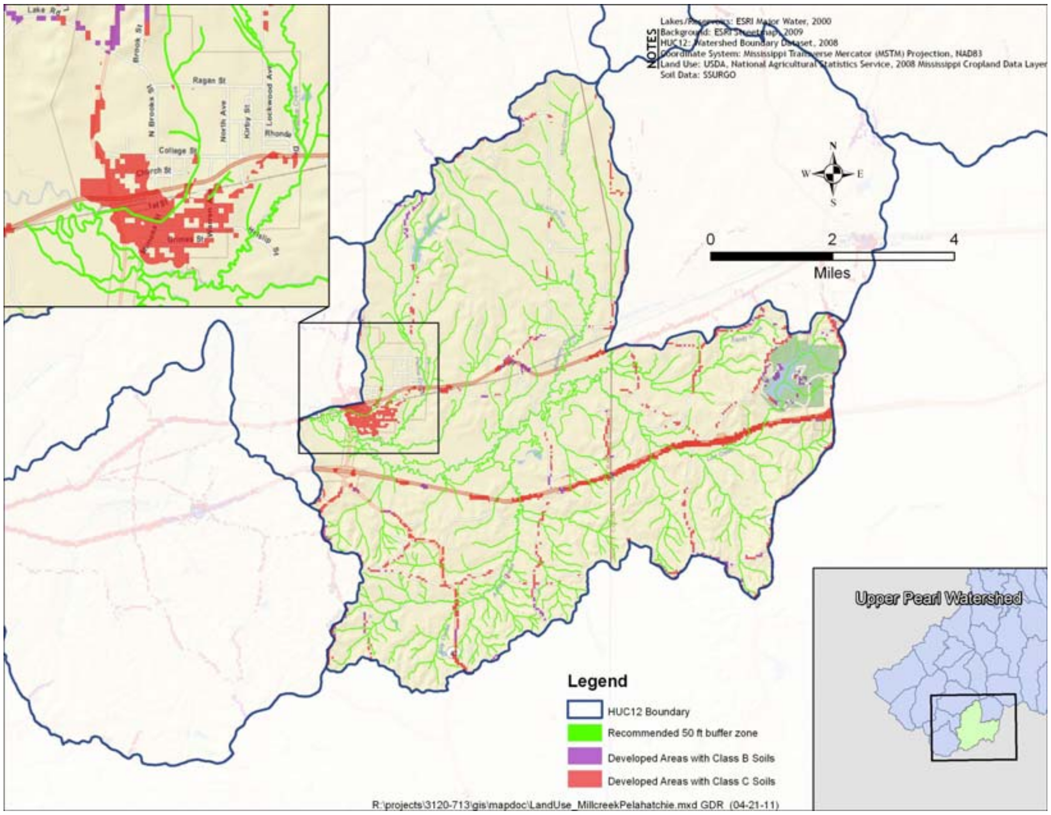

Figure 7.11. HSG type overlay with landuse in Ashlog-Pelahatchie HUC12.

7.7.2 Maintain Undisturbed Streamside Buffer Zones in Developed Areas

Additional controls to prevent disturbance of streamside buffer zones in new developments is highly recommended for the Ashlog-Pelahatchie HUC12. Although they represent an additional level of regulatory control, buffer zone requirements for new developments could be easily incorporated into the review/approval process for site development as the area continues to grow. Section 7.5.6 of this Plan and Section 4.4 of Appendix O provide additional discussion of the importance of streamside buffer zones and options for their implementation. Table 7.19 provides a preliminary estimate of the stream length where restoration measures may be needed. Specific areas will be identified during the development of WIPs.

Table 7.19. Streamside buffers in Ashlog-Pelahatchie HUC12.

Management Measure	Length of Management Measure		Pollutant Percent Reductions			
	Unit	Treatment Extent	TSS	TN	TP	Bacteria
Restored riparian buffer/vegetative buffers	LF	8,686	60%	30%	35%	No data

Notes: Assume restored riparian buffer zones needed along 7% of all streams. Total stream distance in the Ashlog-Pelahatchie HUC12 is 23.5 miles. Seven percent was selected because approximately 7% of the watershed is developed.

7.7.3 Assist Poultry Growing Operations

There are 11 permitted poultry-growing operations in the Ashlog-Pelahatchie Creek subwatershed as of August 2010. According to MDEQ records, these facilities are presently in compliance with their permit requirements. Management measures applicable to poultry production include management of litter, waste storage facilities, and animal mortality facilities. All poultry facilities with NPDES permits must have a comprehensive nutrient management plan. NRCS typically assists producers in the development of these plans. Nutrient management plans are developed on a site-specific basis and include a review of the chemical content of the poultry litter, how and where it is applied, and the soil types on which it will be applied. NRCS leads efforts to assist poultry operations in the state. Rez*onate* project managers will coordinate with NRCS to encourage producers to implement nutrient management and other conservation measures.

7.7.4 Promote Agricultural Management Measures

The Ashlog-Pelahatchie subwatershed includes more than 6,200 acres of pasture land. Because there are several poultry growing operations in this subwatershed, it is likely that poultry litter is used as fertilizer on some pasture areas. Nutrient management is an important factor for improving water quality among owners that apply poultry litter to their fields. Pasture management measures are discussed further in Section 7.5.6. Table 7.20 provides an estimate of the areas where pasture management measures are applicable.

Table 7.20. Agricultural management measures for Ashlog-Pelahatchie HUC12.

Management Measure	Applicability		Pollutant Percent Reductions			
	Unit	Area	TSS	TN	TP	Bacteria
Fencing of pastures (interior to facilitate rotational grazing)(1)	Acres	1,607	Insufficient data			
Alternative water sources for pasture(1)						
Livestock stream crossing(1)						
Field borders(2)	Acres	142	40%	30%	35%	No data
Filter strips(2)			40%	30%	35%	No data
Preserved/restored riparian buffer zones(3)	LF	27,298	60%	30%	35%	No data
Nutrient management(4)	Acres	1,250	Site-specific			

Notes:

1. Assume that fencing of pastures with alternative water source and stream crossings is needed in 25% of pasture land.
2. Field borders/filter strips are applicable to 2% of agricultural land (row crop + pasture areas).
3. Riparian buffer zones applicable to 22% of total length of streams. The total length of streams in the Ashlog-Pelahatchie HUC12 is 23.5 miles. This assumption was selected because agricultural crops + pasture land is 22% of the total watershed area.
4. Nutrient management applicable to 20% of pasture area. This is the assumed percentage of pasture land treated with poultry litter.

Row-crop agriculture accounts for a small percentage of the land in this subwatershed (approximately 845 acres, or 3%). Applicable conservation measures depend on the types of crops that each individual producer is growing. Row-crop production in this watershed is dominated by soybeans, winter wheat, and cotton[18]. However, the crops grown year-to-year change according to market prices. Prices for corn and soybeans have increased recently, and more producers have been growing these crops (Patrick Vowell, MSWCC, personal communication).

Most producers in the Reservoir watershed are already using reduced-till or no-till systems along with residue management. Because herbicide-resistant cotton seeds are now available, no-till systems are frequently used for cotton crops (Murray Fulton, NRCS, February 2011, personal communication). According to NRCS, many producers have also incorporated terraces into their fields to minimize soil and nutrient loss during storm events.

Field borders and filter strips are additional measures recommended for both row-crop agriculture and pasture lands. These measures enhance green infrastructure; provide wildlife habitat; and remove sediment, nutrients, and other pollutants from stormwater runoff. A field

[18] Based on 2009 CDL Landuse Data

border is typically placed around the entire outside edge of a field. Filter strips are placed on the low end of a field, so that they will intercept the stormwater washing off of a field. The area required for both measures is a 35-ft wide strip around the perimeter of the row-crop area or on the low end of the field respectively[19]. To minimize loss due to removing lands from planting or grazing, these measures can be installed in shaded or wet areas that are not usually high production areas.

Field borders and filter strips can be funded through the Conservation Reserve Program (CRP) administered by the Farm Service Agency. It is advantageous for producers to use this program because it allows for annual funding with respective installations on those areas where practices were used[20].

Table 7.20 gives the agricultural measures that are recommended for the Ashlog-Pelahatchie subwatershed. In support of this Plan, NRCS and MDEQ will work to prioritize proposed projects in this HUC12 for cost-sharing funds.

7.7.5 Evaluate Pelahatchie Creek Flow Capacity

A significant concern for the City of Pelahatchie is flooding in some portions of Pelahatchie Creek and its tributaries. A study of the flow capacity of Pelahatchie is needed to evaluate specific causes of flooding and recommend corrective action. The study could also identify actions needed to improve recreational opportunities along Pelahatchie Creek. With proper planning and management, the creek could be developed as a “blue way” to promote use by canoers, kayakers, and hikers.

7.7.6 Cost Estimates for Ashlog-Pelahatchie Creek

Initial estimates of the cost to implement the management measures recommended for this subwatershed have been developed. Table 7.21 includes a summary of costs for implementing the management measures recommended for the Ashlog-Pelahatchie HUC12.

[19] http://www.nrcs.usda.gov/technical/standards/nhcp.html NRCS practice codes 386 (field borders) and 393 (filer strips)

[20] As of March 2010, there were 128,000 acres enrolled in the CRP program in counties within the Reservoir watershed. It is not known how much of this land is within the Ashlog-Pelahatchie HUC12.

Table 7.21. Preliminary cost estimates for Ashlog-Pelahatchie HUC12.

Management Measure	Retrofit Cost (implemented over 10 years)	New Development Cost (per year)	Notes
Green infrastructure stormwater management measures	$2,469,907	$365,106	Costs calculated from Appendix T and Table 7.18.
Restored stream banks and buffers	$17,719	--	Estimates for restored banks and buffers are based on Table 7.19 and Appendix T. Cost for gullies not included because repair costs can only be estimated on a site-specific basis.
Conservation practices for row crop and pasture lands	$303,472	--	Costs calculated from Appendix T and Table 7.20. Does not include costs for streamside management zones and conservation easements.
TOTAL	$2,791,099	$356,106	

7.8 Protection Measures for Lake Creek-Pearl River HUC12

This Plan describes protection measures for the Lake Creek-Pearl River HUC12. This subwatershed is a relatively undisturbed area that contains many ecological features that are important for long-term protection of water quality. Specific protection measures are recommended to maintain the ecological integrity of these areas. The measures recommended for this watershed include education and outreach activities, rather than structural practices. For this reason, the estimate is included in the *Comprehensive Education and Outreach Plan for Rez*onate. The protection objectives for this HUC12 are as follows:

- **Objective 1**: Maintain wetlands, streamside buffer zones, and undisturbed green space,
- **Objective 2**: Partner with *Keep the Reservoir Beautiful* to curb littering by recreational boaters,
- **Objective 3**: Use education programs to promote a sense of pride and responsibility for environmental preservation of this area, and
- **Objective 4**: Promote conservation easements through partnerships with nonprofit land conservation groups.

The total area of this HUC12 is 22,508 acres (approximately 35.17 square miles). The subwatershed is situated in parts of three counties: Madison, Rankin, and Scott. Land use summary by HSG category within the watershed is presented in Table 7.22 and on Figures 7.12 and 7.13.

Table 7.22. Landuse and HSG type for the Lake Creek-Pearl River HUC12.

Landuse	No Data Available (acres)	HSG Type B (acres)	HSG Types C and D (acres)	Total (acres)
Water	274	156	84	514
Agricultural Crops	1	3	28	32
Pasture/Grassland	54	295	3,645	3,994
Developed	6	111	1,071	1,188
Forest/Woodland	101	1,220	8,739	10,060
Shrubland	32	133	1,560	1,725
Wetlands	193	1,397	3,405	4,995
Total	**661**	**3,315**	**18,532**	**22,508**

7.8.1 Maintain Wetlands, Buffers, and Green Space

Natural features of this subwatershed such as undisturbed forest areas, areas of native vegetation, stream corridors, and wetlands serve important water quality functions including pollutant removal, flood control, erosion reduction, and groundwater recharge. Long-term management and protection of the above-mentioned natural features are needed in order to preserve their water quality functions. The Lake Creek-Pearl River HUC12 presently has very little development. The intent of this Plan is not to prevent future development, but rather minimize its impact on the natural features. Future development in this watershed must be carefully planned using Low-Impact Development[21] and Better Site Design[22] principles. Stormwater impacts from development can be mitigated with the use of the many green infrastructure management measures discussed in this Plan.

[21] http://www.epa.gov/owow/NPS/lid/
[22] http://www.cwp.org

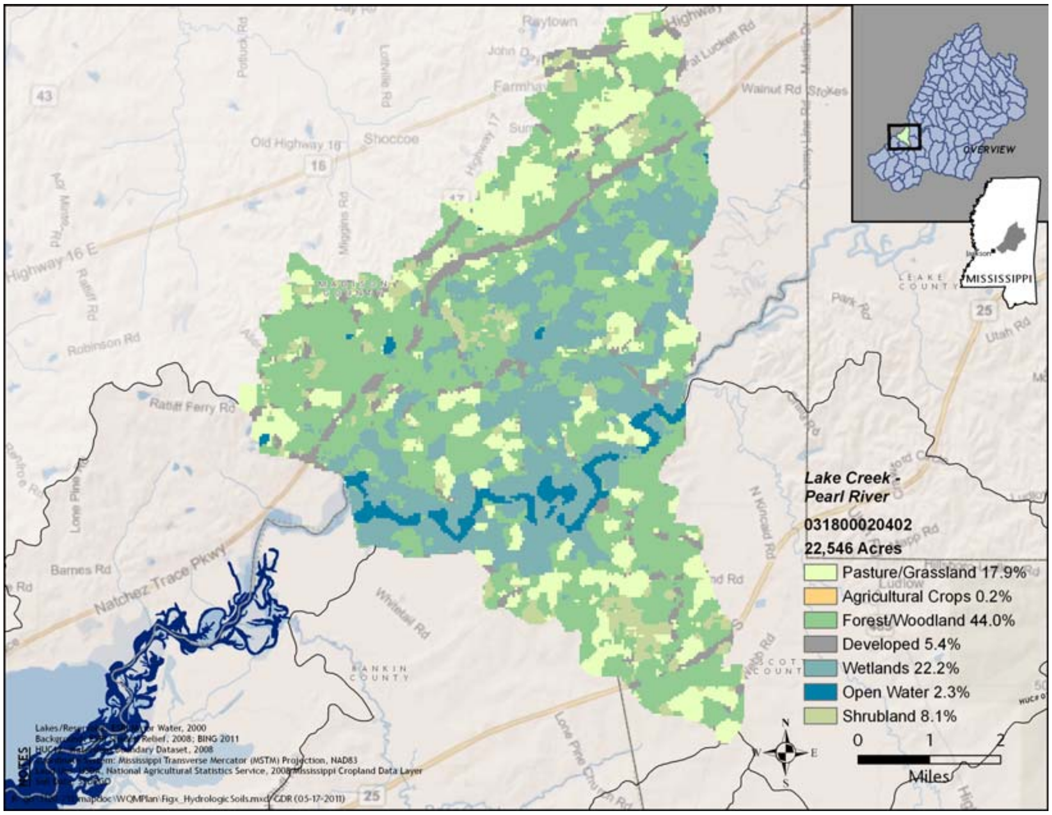

Figure 7.12. Landuse in the Lake Creek-Pearl River HUC12.

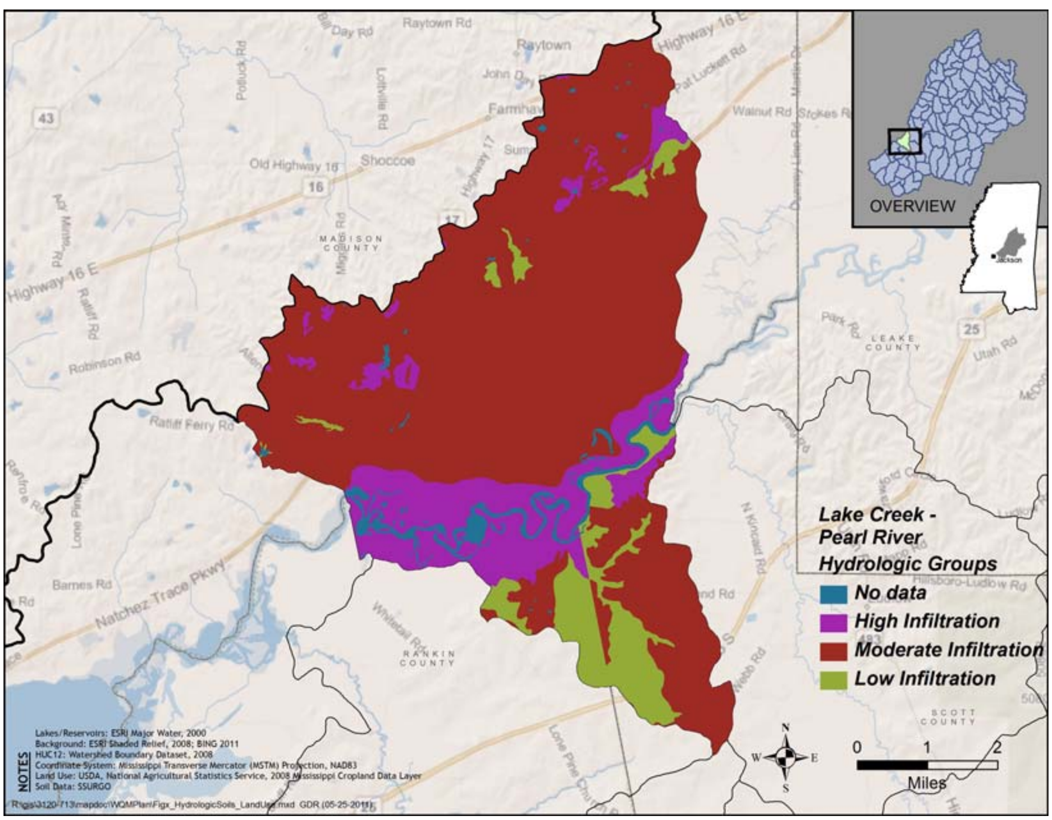

Figure 7.13. HSG types in the Lake Creek-Pearl River HUC12.

Most of the developed areas in the subwatershed are associated with the Natchez Trace near the north boundary, and Highway 25 near the south boundary. The majority of the land is classified as forested land, most of which is managed by private landowners. It is likely that some forest land in this subwatershed is harvested on a regular basis. Rez*onate* project managers should work with MFC to be sure that landowners use proper harvesting measures to manage runoff, and are aware of the opportunities to participate in forestry stewardship programs.

Approximately 22% of this watershed is currently classified as wetlands. It will be of paramount importance to protect these wetland areas from the impacts of development and land disturbance. Recommendations listed below are based on the Center for Watershed Protection's publication *Using Local Watershed Plans to Protect Wetlands* (Cappiella et al. 2007) [23].

- **Use land use planning techniques to redirect development and preserve sensitive areas.** This will require a coordinated effort between Madison, Rankin, and Scott counties. It is unlikely that there will be significant development within this subwatershed in the next 10 years. However, county governments must consider the importance of protecting wetlands in this subwatershed if asked to approve any future development plans. Governments should require the use of environmentally sensitive designs such as "cluster development" if housing developments expand to this area.
- **Identify wetland areas as priority areas for conservation.** Place wetlands in a land trust when feasible. Avoid land-disturbing activities, such as timber harvesting, near wetlands. Use pasture management measures to keep livestock out of sensitive streams and wetland areas.
- **Establish vegetated buffers of at least 50 ft around all wetlands.** This will protect wetlands from negative impacts of development.

Additional provisions to protect wetlands and natural features of this subwatershed include guiding future development with new ordinances, requiring strict erosion and sediment control on any construction sites (including roads), and restricting certain types of land disturbance activities (i.e., surface mining, clear cutting, industrial development). However, these would have to be developed by the county governments with the input of landowners in order to minimize the burden of land use restrictions on private property owners. Detailed

[23] Using Local Watershed Plans to Protect Wetlands (K. Cappiella, A. Kitchell, T. Schueler, 2006). Available online at http://www.cwp.org/documents/cat_view/73-wetlands-and-watersheds-article-series.html

recommendations for long-term land management plans will be included in a WIP for this subwatershed.

7.8.2 Curb Littering

The sand bars located along the Pearl River within this subwatershed are the primary locations of concern for excess trash and littering. The *Keep the Reservoir Beautiful* organization has been formed by citizens in order to help promote voluntary methods for reducing littering and encouraging clean-up of existing trash on these sand bars. PRVWSD is working with the organization to bring the problems with litter to the attention of the public using newspaper articles, volunteer opportunities, clean-up days, and other activities. Public relations activities should continue throughout the recreational season (May through October) each year.

Providing an annual “report card” on littering is an excellent public relations tool to build interest and encourage residents and build support for the *Keep the Reservoir Beautiful* campaign. The *Comprehensive Water Quality Monitoring Plan* describes a monitoring approach for developing and tracking a litter index after holidays when heavy use of the sand bars is expected. Results of litter index monitoring should be shared with the public in conjunction with the organization’s public relations activities.

7.8.3 Implement Educational Programs

Educational programs implemented for protection of this subwatershed should focus on the targeted audiences that most frequently use this area. Many people use the land in this subwatershed for recreational activities such as boating, fishing, water skiing, and hunting. Thus, this group has a vested interest in preserving watershed health and the quality of its water. The *Comprehensive Education and Outreach Plan* includes specific objectives for civic and recreational groups. One objective is to partner with influential boaters and campers who are prominent figures in social outings on the Reservoir (e.g., Flag Island regulars) to encourage clean recreational activities. The bottom-line message for educational programs is that preservation of this subwatershed is necessary for clean water in the Reservoir. In turn, clean water is necessary for continued recreational enjoyment of the Pearl River and waters downstream to the Reservoir. Improved quality of life and higher property values are among the many benefits of clean water.

7.8.4 Promote Conservation Easements and Land Trusts

Conservation easements can be used to protect natural and cultural features of land. Participation in conservation easements is voluntary. Easements typically restrict certain uses of property such as development or significant disturbance of vegetation within the easement area. However, owners retain access and continued ownership of the property. A conservation easement is recorded as a written legal agreement between the landowner and the holder of the easement. The holder may be either a nonprofit conservation organization or government agency.

In Mississippi, conservation easements are usually donated to nonprofit conservation organizations, commonly known as land trusts. A land trust is a local, regional, or national nonprofit organization that protects land for its natural, recreational, scenic, historic or productive value.

There are a number of federal and state programs, particularly agriculture and wildlife programs, that provide incentives and financing to purchase easements and enter into conservation agreements. CRP makes annual lease payments to participating landowners. Participation in CRP requires placing highly erodible crop or pasture land into grasses and woody vegetation. The Wetlands Reserve Program (WRP) applies to lands that have been previously converted from wetlands to crop or pasture land. Other programs include Grasslands Reserve Program (GRP) and Wildlife Habitat Incentives Program (WHIP).

8.0 IMPLEMENTATION

This section provides a schedule and preliminary budget for implementing the *Comprehensive Protection and Restoration Plan* along with the other plans developed as part of the Ross Barnett Reservoir Initiative.

8.1 Schedule

The implementation schedule includes the protection and restoration activities described in Section 7 and the *Comprehensive Education and Outreach Plan for Rez*onate!, the *Source Water Protection Plan for the O.B. Curtis Drinking Water Intake*, and the *Water Quality Monitoring Plan*. For flexibility, schedules were developed based on the amount of time elapsed since the start of implementation (i.e., year 1, year 2) in lieu of specific years. Funding may not be available for all targeted subwatersheds at once; thus, a staggered start-up schedule may be used. This will enable Rez*onate* project managers to track progress based on the start date of implementation activities. The schedule in Table 8.1 specifies the milestones, responsible party, and timeframe for management measures. Watershed Implementation Teams (WITs), along with MDEQ, are the primary responsible parties.

Table 8.1. Implementation schedule.

Management Action	Milestones	Responsible Parties	Timeframe
Restoration Activities in Targeted HUC12s: Mill-Pelahatchie, Riley-Pelahatchie, and Ashlog-Pelahatchie.	Develop WITs. Teams will determine specific areas to begin restoration planning and implementation.	MDEQ	Years 1 to 2
	Refine BMP requirements and budgets. Determine specific locations for implementation.	WITs	Years 1 to 2
	Develop incentive program, and make citizens aware of the incentives for implementing green infrastructure stormwater management practices.	Local governments with support from WITs, PRVWSD, and MDEQ	Middle of Year 3
	Watershed implementation plans completed.	WITs	Year 3
	Watershed implementation plans approved	MDEQ	End of Year 3
	Form local stormwater consortium and begin routine coordination meetings.	MDEQ, county and city stormwater officials	Years 3 to 10
	Implement watershed implementation plans.	WITs	Years 2 to 10
Protection Activities in Targeted HUC12: Lake Creek-Pearl River	Develop WIT. Team will determine specific areas to begin protection planning and implementation	MDEQ and PRVWSD	Years 1 to 2
	Refine BMP requirements and budgets. Determine specific locations for implementation.	WIT	Years 1 to 2
	Watershed implementation plan completed	WIT	Year 3
	Watershed implementation plan approved	MDEQ	End of Year 3
	Implement watershed implementation plan	WIT	Years 3 to 10
Source Water Protection	Continue to facilitate Source Water Protection Work Group	MDEQ and PRVWSD	Years 1 to 10
	Implement Source Water Protection Plan	Source Water Protection Work Group	Years 1 to 10
Education and Outreach	Implement Education and Outreach Plan objectives for selected targeted audiences	Rez*onate* project manager	Years 1 to 5
Monitoring	Select monitoring modules from monitoring plan	MDEQ and PRVWSD	Years 1 to 2
	Implement monitoring program and evaluate data annually	MDEQ and PRVWSD	Years 2 to 10

8.1.1 Watershed Protection and Restoration Plan

The key action for the Protection and Restoration Plan is implementing the recommended management objectives in the targeted HUC12 subwatersheds. These actions include both voluntary and regulatory approaches. Voluntary approaches center around installation of the green infrastructure management measures and improved control of pollutant sources. If needed, regulatory approaches will include modifications of ordinances and stormwater regulations. Following development of WIPs, WIT members should meet on a routine basis to evaluate whether the milestones are being met. The WIPs will include schedules for installing practices on specific parcels of land.

8.1.2 Source Water Protection Plan

Implementation of the Source Water Protection Plan also includes voluntary and regulatory measures. Many of the recommended source water protection measures overlap with measures in the *Comprehensive Protection and Restoration Plan*, especially in the targeted Mill-Pelahatchie Creek subwatershed, which overlaps with the primary protection area.

The Source Water Protection Plan contains a list of recommended actions and a schedule for implementing the actions (see Table 3.1, Action Plan Summary, in the Source Water Protection Plan). The source water protection work group, formed to develop the plan, will continue to oversee implementation of the plan. The group will be lead by MDEQ and include members from MSDH, PRVWSD, and the City of Jackson. At a minimum, this group should meet annually to evaluate yearly progress.

8.1.3 Education and Outreach

Watershed management and nonpoint source pollution reduction in the Reservoir is a community-centered activity that will require voluntary participation and cooperation of many individuals in order to meet goals. Thus, a strong educational component is an important part of the implementation strategy. The Comprehensive Education and Outreach Plan defines the specific actions needed to educate and involve key target audiences.

The plan includes a recommended schedule and budget for implementation over a 5-year period along with evaluation criteria. This schedule complements watershed protection and restoration activities. A review of evaluation criteria should be conducted on a yearly basis to analyze progress, determine if goals are being met, and make needed adjustments. After the first 5-year period, project managers should conduct a comprehensive review of the success of the program and continue with a revised program.

8.1.4 Monitoring Plan

MDEQ will determine the implementation schedule for the monitoring plan based on the funding and personnel available for sampling and laboratory analysis. The monitoring plan was developed as individual modules that specify different types of monitoring. MDEQ can choose to implement all of the modules or only selected modules during specific times. At a minimum, the base monitoring, biology, and pathogen sampling should be conducted to track long-term water quality status and trends. Also, monitoring of priority subwatersheds with WIPs should be conducted to track improvements during pre- and post-implementation.

As management measures are implemented, it will be important to measure water quality improvements and the effectiveness of the measures. Often, long and uncertain lag times occur between implementation and measurable water quality improvements. However, measurable progress is critical to ensuring continued support of watershed projects among local leaders and the general public.

8.2 Budget

The funding for implementation of the Rez*onate* plans will come from several sources. Personnel from agencies participating on implementation teams will be funded by regular agency budgets. Stakeholders from the community may participate on the watershed teams on a voluntary basis. Installation of management measures will be funded through cost-sharing programs such as Section 319(h) and the NRCS EQIP program. Most likely, property owners will be responsible for long-term maintenance of structural management practices. Preliminary budgets for the Rez*onate* plans are summarized below (Table 8.2). It is important to note that there are many benefits that go along with the investment in green infrastructure stormwater management measures and other water quality improvement practices recommended in this plan. These benefits may be quantified when specific implementation sites are selected.

Table 8.2. Budget for implementation of Rez*onate* plans.

Plan	Component	5-Year Budget	Funding Sources
Comprehensive Watershed Protection and Restoration Plan	Restoration measures for Mill-Pelahatchie	$29,582,070	Federal cost-share programs, resource agency funds, individual landowners, green infrastructure grants
	Riley-Pelahatchie	$8,933,328	
	Ashlog-Pelahatchie	$4,616,630	
	Project Management	Not yet determined	MDEQ program funds
	Incentive Program	Not yet determined, depends on the incentive program approved by local governments	County and city government budgets
Source Water Protection Plan	Project Management Management Measures	A budget for this plan was not developed.	Agency program funds for project management. Federal cost-share programs, individual landowners, green infrastructure grants for management measures.
Comprehensive Education and Outreach Plan	Education Activities for Individual Audiences	$945,443	MDEQ 319(h) funds, City and county governments, educational grant programs, and non-profit organizations
Water Quality Monitoring Plan	Project Management Data Collection Data Analysis	Not yet determined, depends on agency budgets	MDEQ, USGS, and PRVWSD program funds

9.0 EVALUATION CRITERIA

Evaluation criteria, which demonstrate progress toward achieving the goals of this Plan, have been established for both programmatic indicators and environmental indicators. Programmatic indicators evaluate activities intended to improve land management and individual behaviors that lead to water quality improvement (i.e., management measures implemented or education information distributed at events and meetings). Environmental indicators are direct measurements of water quality conditions (i.e., reduced sediment and nutrient levels, improved biological health, and fewer stream bank failures). Evaluation criteria are one of the required elements for Section 319(h)-funded watershed plans, summarized in Appendix U.

Management measures recommended in this document will be updated through an adaptive management process as they are implemented and evaluated for performance. This will improve the quality and efficiency of program implementation.

Rez*onate* project managers must track progress based on both programmatic and environmental indicators and compare these to annual project costs. Programmatic evaluation criteria are given in Table 9.1. The criteria include parameters that can be measured with a reasonable level of effort and compared from year to year. If changes are needed, the program managers need to evaluate potential solutions and have the authority to decide which solutions to implement.

Table 9.1. Programmatic indicators.

Indicator	Goals		
	Short-Range (year 1 to 2)	**Mid-Range (year 2 to 10)**	**Long-Range (after year10)**
Awareness of the importance of the Reservoir and the quality of its water *This would be measured by stakeholder surveys. Surveys will measure stakeholder awareness and willingness to change behaviors to improve water quality.	Conduct survey	Show improvement in at least three survey categories	More than 90% of citizens aware
Implementation of homeowner management measures including reduced fertilizer use, rain garden/rain barrel installation, and preserving buffer zones, vegetation, and trees.	Five demonstration projects	Meet goals for targeted HUC12s (see Section 7.0)	Wide acceptance and use
Visits to the Rez*onate* website	100/year	500/year	More than 1,000/year
Participation in Watershed Implementation Teams	One team formed, minimum of seven individuals per team	Two teams formed and functioning	87 teams formed and functioning and coordinating through the Pearl River Basin Team
Funding available for implementation of WIPs	Federal implementation funds	Federal and foundation implementation funds	Federal, foundation, and private implementation funds
Number of schools using the curriculum and participating in WaterFest challenge events	2	10	20
Attendance at WaterFest and sponsorship funding	2,500 attendees, $10,000	3,500 attendees, $25,000	5,000+ attendees, $50,000+
Length of areas with active bank failures	Measure current conditions	30% reduction	50% reduction
Number of construction sites with citations due to inadequate BMPs	Less than 5% of active permits	Less than 2% of active permits	Less than 1% of active permits
Reservoir management costs for removal of litter and dredging	No increase	20% decrease in costs	50% decrease in costs
Cost of drinking water treatment and number of complaints related to drinking water quality	Less than 10% increase in cost; no increase in annual number of complaints		
Implementation of recommended management measures (i.e., bioretention, riparian buffer zones, shoreline protection) for priority HUC12s	Goals will be developed in WIPs.		

Environmental indicators are listed in Table 9.2. Annual evaluation of these indicators will be based on water quality monitoring results. The long-term goal for environmental indicators is to meet the goals defined in Section 6.0. For example, meeting water quality criteria for pollutants with established criteria, and no nuisance conditions caused by pollutants without established criteria. The environmental indicators should also be evaluated on an annual basis and compared with previous year's data.

Table 9.2. Environmental indicators.

Pollutant	Indicators
Sediment	• Measurements of TSS and water clarity (Secchi depth) at base monitoring stations. • Measurements of turbidity at the drinking water intake (measured by the City of Jackson). • Estimates of sedimentation rates in selected parts of the Reservoir (tons/year or inches/year) measured with a bathymetric survey and established sediment ranges OR sediment cores.
Nutrients	• Measurements of nitrogen and phosphorous and chlorophyll-*a* at the base monitoring stations. • Increased dissolved oxygen levels measured in the hypolimnion near the dam and at diel monitoring stations.
Pathogens	• Measurements of fecal coliform bacteria at routine monitoring sites (existing sites and new sites). • Number of water quality standard exceedances measured near recreational areas.
Pesticides	• Measurements of pesticide levels in the water column and fish tissue.
Litter	• Trash index scores measured by *Keep the Reservoir Beautiful*.
Invasive Species	• Annual survey results for aquatic invasive vegetation.

9.1 Annual Review and Adaptive Management

Rez*onate* project managers should review the programmatic and environmental indicators on an annual basis. Programmatic indicators can be compared to the short-, mid-, and long-range goals. Environmental indicators will be compared to water quality criteria and short- and mid-range goals. If indicators fall short of the goals, project managers will need to evaluate the reasons for this and make appropriate changes to the program.

When programmatic indicators are measured at less than 50% of the short- and mid-range goals and environmental indicators do not meet goals or show progress towards meeting goals, project managers should consider making changes to program implementation in order to increase participation. If voluntary measures are lacking, the incentive program should be evaluated and increased as budgets allow. Regulatory mechanisms (stricter ordinances and zoning requirements) should be considered when programmatic indicators are less than 50% of goals and environmental indicators fail to meet goals.

9.2 Program Inputs, Outputs, and Outcomes

Rez*onate* project managers should evaluate the inputs, outputs, and outcomes of the programs related to each area of deficiency. Results of this evaluation will help managers determine ways to improve program implementation. Inputs define the amount of time and resources put into implementation of the *Comprehensive Protection and Restoration Plan*, such as the following:

- What resources are available to implement the program? This includes personnel time and funding for implementation of management measures. If there are specific needs that are not being met, identify these needs and look for resources through grants and cost-share programs. Funding is likely to be a significant limiting factor for implementation of WIPs.
- Are there sufficient experienced staff and technical resources available to properly implement the Plan? Are staff members well trained? If not, identify options for training. Do project managers have the authority to make decisions regarding implementation? If not, some modifications to project management may be needed to ensure timely decision-making.

Outputs refer to administrative accomplishments from implementing the plan. Most outputs can be measured with programmatic indicators (Table 9.1). Examples of outputs are shown below:

- Is the schedule for implementation of management measures (Table 8.1) being met? Because many of the management measures are voluntary, lack of landowner participation may be a limiting factor. If landowners are not willing to finance the cost of installing practices, project managers may need to assist them with finding cost-share programs. Landowners may also be hesitant due to lack of information about management practices. If this is the case, education activities and incentives may improve participation.
- Are goals for number/miles of management practices being met? If not, watershed implementation teams may need encouragement and guidance to increase implementation. Project managers should be aware, however, that the goals

established in this plan are preliminary. Some adjustment may be needed when implementation begins.

Outcomes refer to measurements that show improvements in water quality or fewer pollutant sources. Outcomes are important to track because they document the end result of implementation activities: improved water quality. Even if the outcomes do not show positive results they should be shared with stakeholders because they provide clearly understood feedback about project results. Some outcomes are listed below:

- Have concentrations or loads of the pollutants of concern decreased? This can be determined by comparing monitoring data to past results.
- Do we have less trash accumulating on the Pearl River sandbars? This can be determined by surveys conducted by *Keep the Reservoir Beautiful* Litter Index and by tracking litter clean-up costs.

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APPENDIX A

BACKGROUND AND PLANNING DOCUMENTS

What is Rez*onate*?

Recognizing the importance of the Ross Barnett Reservoir, the Mississippi Department of Environmental Quality (MDEQ) and the Pearl River Valley Water Supply District (PRVWSD), along with the National Resources Conservation Service (NRCS) and the Mississippi Soil and Water Conservation Commission (MSWCC), initiated planning to restore and protect water quality in the Ross Barnett Reservoir watershed. This effort, initially called the Ross Barnett Reservoir Initiative, has been branded as Rez*onate!*.

Several plans have been developed as part of Rez*onate*. What are the plans and why do we need each of them?

The planning stage of the Ross Barnett Reservoir Initiative project included the development of several watershed management planning documents. The documents are listed below and described in this summary. Together, these five documents will lay out a comprehensive approach for managing water quality in the Ross Barnett Reservoir watershed.

- Comprehensive Protection and Restoration Plan,
- Pathogen Source Assessment and Wastewater Management Plan,
- Comprehensive Education and Outreach Plan for Rez*onate!*,
- Water Quality Monitoring Plan, and
- Source Water Protection Plan for the O.B. Curtis Drinking Water Intake.

The **Comprehensive Protection and Restoration Plan** has been developed to provide a coordinated approach for managing the Reservoir and its watershed, specifically addressing issues of greatest concern (sediment, nutrients, pathogens, pesticides, invasive species, and trash). The purpose of the **Comprehensive Protection and Restoration Plan** is to identify strategies for restoration of the Reservoir's impaired tributaries and to promote protection of the Reservoir and its watershed to reduce the potential for future degradation due to other issues of concern. This Plan is a technical document and is intended for use by resource agencies and organizational personnel responsible for administering environmental programs in the watershed.

The Plan is comprehensive in scope and describes the current conditions in the Reservoir and its watershed based on current water quality data and input from resource agencies, local stakeholders, and associated teams. The Plan provides a detailed characterization of the watershed, including geography, climate, geology, soils, land use, and water quality data. The Plan also describes the natural resources present in the watershed and accounts for ongoing water quality management and monitoring activities in the area.

Next, the Plan describes six high-priority issues of concern in the Reservoir and its watershed and recommends management measures for reducing and controlling them. Appendix J of the **Comprehensive Protection and Restoration Plan** describes the locations where these issues are causing or potentially causing water quality problems. The six primary issues of concern are:

- Sediments and turbid water,
- Nutrient enrichment and algae growth,
- Bacteria and other pathogens,
- Invasive aquatic plant species,
- Pesticides (currently used herbicides and insecticides), and
- Trash dumping and littering in and around the Reservoir and its shoreline.

Available information was used to identify the sources of each pollutant. When sufficient data were available, current pollutant loads were also estimated. With the pollutant sources clearly identified, the **Comprehensive Protection and Restoration Plan** identifies priority HUC12 watersheds in need of management measures. The Plan describes the method used to prioritize areas based on their relative risk for impacting the designated/desired uses of the Reservoir and its tributaries, and highlights the priority areas determined from this process. The Plan recommends management practices for reducing the quantity of pollutants entering the Reservoir and tributaries from priority watersheds. Practices include development of watershed implementation plans and teams for priority areas, management measures for urban and rural areas, and additional regulatory controls in some situations. The Plan also identifies watersheds that contain features that provide ecosystem services beneficial to the wellbeing of humans and the environment.

The **Comprehensive Protection and Restoration Plan** includes specific recommendations for voluntary pollutant management measures and a review of current enforceable mechanisms to reduce nonpoint source pollutants. Improved stormwater management in urban areas near the Reservoir is an important component of this. Cost estimates and funding sources for these activities are included. A companion **Water Quality Monitoring Plan** will present a detailed plan to monitor the condition of the Reservoir and its watershed and document success as management measures are implemented. Finally, the Plan includes an implementation schedule and criteria to be used to evaluate the success of the management measures as they are implemented.

The **Pathogen Source Assessment and Wastewater Management Plan** focuses on sources of pathogens within watersheds directly adjacent to the Reservoir and proposes a detailed plan for improving wastewater infrastructure in this area.

The **Comprehensive Education and Outreach Plan for Rez*onate!*** includes a detailed plan for engaging targeted audiences in the protection of the Ross Barnett Reservoir watershed.

The **Source Water Protection Plan for the O.B. Curtis Drinking Water Intake** will guide and shape policy to protect the drinking water source for the City of Jackson. It identifies the required actions for mitigating the identified threats, both existing and future, to the source water along with new and existing programs, projects, and resources, and emergency response protocols.

Who participated in the planning process?

MDEQ contracted with FTN Associates, Ltd. (FTN) to provide project management and technical support needed to develop the Rez*onate* Plans. An additional contractor, CDM Inc. (CDM), was responsible for development of the **Pathogen Source Assessment and Wastewater Management Plan**. FTN and CDM coordinated work groups of local stakeholders and agency representatives to give input into all aspects of the planning process. Work groups developed for each of the Plans are described below. FTN also worked with The Cirlot Agency to develop the

Comprehensive Education and Outreach Plan for Rez*onate!* and materials needed for the public outreach campaign. The Cirlot Agency coordinated WaterFest 2010, an annual family event held at the Reservoir to educate citizens about protecting water quality in the Reservoir. WaterFest will be held each spring using the planning guidance assembled by The Cirlot Agency.

Steering Team

The Steering Team is composed of local leaders and representatives of resource agencies that have direct responsibility for activities effecting water quality in the watershed. Several members are leaders of organizations involved in economic development activities in central Mississippi. Members of the team represent the five counties that are nearest to the Reservoir: Hinds, Leake, Madison, Rankin, and Scott.

Prior to forming the steering team, MDEQ recognized that stakeholder input and involvement are essential for success of the watershed plans. The steering team was envisioned as a method to direct efforts to reach stakeholders who live and work in the watershed, and have an interest in participating in the restoration and protection of this resource. Steering Team members and the agencies or groups they represent are listed in Table A.1. Steering Team members met twice during the initial planning process and had the opportunity to review and provide input into draft plans as they were developed.

Roles and responsibilities of the Steering Team are as follows:

1. Participate in quarterly Steering Team Meetings.
2. Provide oversight and review for all aspects of the project, especially the following:

    - Water Quality Monitoring Plan,
    - Comprehensive Protection and Restoration Plan,
    - Source Water Protection Plan for the O.B. Curtis Drinking Water Intake,
    - Comprehensive Education and Outreach Plan for Rez*onate!*,
    - Building Local Stakeholder Capacity, and
    - Quality Assurance Plans.

3. Assist with collaboration and leveraging opportunities (related to individuals, agencies, expertise, and funding).
4. Serve, or identify others to participate, in technical work groups and education/outreach work groups, as appropriate.
5. Participate and promote public outreach and volunteer activities.

Table A.1. Ross Barnett Reservoir Initiative Steering Team.

Name	Agency/Group
John Sigman, Co-lead	Pearl River Valley Water Supply District, Executive Director
Kay Whittington, Co-lead	Mississippi Department of Environmental Quality, Chief, Basin Management Branch
Jack Winstead	Scott County, President, PRVWSD Board of Directors; Chairman, MDEQ Commission on Environmental Quality
Murray Fulton	Natural Resources Conservation Service, Rankin County
Tom Troxler	Executive Director, Rankin First Economic Development Authority
Tim Coursey	Executive Director, Madison County Economic Development Authority
Ross Tucker	Director of Economic Development at Greater Jackson Alliance
Blake Wallace	Executive Director, Hinds County Economic Development District
Pat Reneger	General Manager, Bass Pro Shop
Mark Frascogona	Neopolis Development
Don Brazil	Mississippi Department of Wildlife, Fisheries, and Parks
Larry Bull	Mississippi Department of Wildlife, Fisheries, and Parks
Keith Allen	Mississippi State Department of Health
Don Underwood	Mississippi Soil and Water Conservation Commission
Patrick Vowell	Mississippi Soil and Water Conservation Commission
Alvin Seaney	Scott County, Mississippi Emergency Management Agency
Kurt Readus	Natural Resources Conservation Service, Area Conservationist
Donetta McCullum-Weatherspoon	Mississippi Department of Environmental Quality, Pearl River Basin Coordinator
Nick Hatten	Mississippi Department of Environmental Quality, Nonpoint Source Section
Paul Chamblee	Leake County, Barnett Reservoir Foundation
Kenneth Dean	US Environmental Protection Agency, Region 4
Homer Burns	Federation of Reservoir Area Homeowner Associations
Jim Phillips	Mississippi Forestry Commission
Larry Cole	US Environmental Protection Agency, Region 4

Project Coordination Team

The project coordination team consisted of representatives from MDEQ, PRVWSD, FTN, CDM, and The Cirlot Agency. The team met on a regular basis (monthly or more often) during the development of this Plan and other plans being developed for the Initiative.

Technical Advisory Group

The technical advisory group met on several occasions to assist in the development of the **Comprehensive Protection and Restoration Plan**. The group provided input and guidance into the technical aspects of the Plan, pollutant causes and sources, prioritization of subwatersheds, and appropriate management measures. Drafts of completed sections of the plan were reviewed and modified according to input from the advisory group. The roles/responsibilities of the Technical Advisory Group included:

- Provide review and oversight for the Watershed Protection and Restoration Plan and the Source Water Protection Plan,
- Ensure plans are technically sound and feasible,
- Identify participants and other resources for implementation of the plans,
- Recommend and review members and agendas for technical work group meetings, and
- Attend meetings as needed.

Members of the Technical Advisory Group are listed in Table A.2.

Water Quality Monitoring Work Group

The water quality monitoring work group met on a routine basis beginning in the fall of 2009 and ending in the fall of 2010. The work group assisted with assembling a comprehensive inventory of water quality data available for the Ross Barnett Reservoir watershed. The group provided recommendations for elements of the water quality monitoring plan. Several versions of the plan were reviewed by the group and revised based on work group input. Participants in the monitoring work group are listed in Table A.3.

Table A.2. Members of the Technical Advisory Group.

Name	Agency/Organization
Larry Bull	Mississippi Department of Wildlife, Fisheries, and Parks
Kristen Sorrell	Mississippi Department of Environmental Quality
Kenneth Dean	US Environmental Protection Agency, Region 4
Larry Cole	US Environmental Protection Agency, Region 4
Paul B. Rodrigue	Natural Resources Conservation Service – Grenada
Kay Whittington	Mississippi Department of Environmental Quality
Zoffee Dahmash	Mississippi Department of Environmental Quality
John Sigman	Pearl River Valley Water Supply District
Greg Burgess	Pearl River Valley Water Supply District
Hollis Allen	Mississippi Department of Environmental Quality
Amy McLeod	Mississippi State Department of Health
Steve Ashby	US Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory
John Madsen	Mississippi State University, Geosystems Research Institute

Table A.3. Participants in the monitoring work group.

Name	Agency
Donetta McCullum-Weatherspoon	Mississippi Department of Environmental Quality
Kay Whittington	Mississippi Department of Environmental Quality
Henry Folmar	Mississippi Department of Environmental Quality
Jackie Key	Mississippi Department of Environmental Quality
Mike Runner	US Geological Survey
Richard Rebich	US Geological Survey
Larry Bull	Mississippi Department of Wildlife, Fisheries, and Parks
John Sigman	Pearl River Valley Water Supply District
Leslie Royals	Mississippi State Department of Health
Matt Hicks	US Geological Survey
Natalie Segrest	Mississippi Department of Environmental Quality
Kenneth Dean	US Environmental Protection Agency, Region 4

Source Water Protection Work Group

The source water protection work group included members from agencies with authority involving protection of the Reservoir and the treatment and distribution of water to the City of Jackson. The work group met on several occasions in 2010. Members of the group developed the vision statement for the **Source Water Protection Plan for the O.B. Curtis Drinking Water**

Intake. Members also provided technical input and review of the Source Water Assessment and Source Water Protection Plan. Table A.4 lists the members of this work group.

Table A.4. Source water protection work group.

Name	Agency
Darion Warren	City of Jackson
Charles Cupit	Mississippi Emergency Management Agency
Dan Gaillet	City of Jackson
David Willis	City of Jackson
Amy McLeod	Mississippi State Department of Health
Donetta McCullum-Weatherspoon	Mississippi Department of Environmental Quality
Kay Whittington	Mississippi Department of Environmental Quality
Jamie Crawford	Mississippi Department of Environmental Quality
Kirsten Sorrell	Mississippi Department of Environmental Quality
Janet Chapman	Mississippi Department of Environmental Quality
Charles Smith	Mississippi Department of Environmental Quality

APPENDIX B

ROSS BARNETT RESERVOIR WATERSHED CHARACTERISTICS

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History

After many years of planning, construction of the Ross Barnett Reservoir began in 1960 and was completed in 1965. The Reservoir was first filled to normal pool elevation in January 1965. The Pearl River Valley Water Supply District (PRVWSD) is the state agency created to construct and manage the Reservoir. PRVWSD is self-supporting and receives no funds from state or local taxes.

Construction of the Reservoir was financed by the City of Jackson and the five member counties: Hinds, Leake, Madison, Rankin, and Scott. The bonds for the construction of the Reservoir were completely retired in 1992. An agreement between the City of Jackson and PRVWSD allows the City to withdraw water from the Ross Barnett Reservoir at no additional charge to the City.

Physiographic Regions

Ross Barnett Reservoir and its watershed are located in the North Central Hills and Jackson Prairie physiographic regions (MARIS online mapping accessed November 2009) of the Gulf Coastal Plain physiographic province of North America (NRCS 2009), shown on Figure B.1. The North Central Hills region, in which the majority of the watershed is located, is an area of high relief, with moderate to steep slopes interspersed with flatter, more rolling hills (NRCS 1999, 2009). The southeastern watershed, around Pelahatchie River, is located in the Jackson Prairie region. This region is characterized by gently rolling hills with slight to moderate slopes (NRCS 1999, 2009; SCS 1987).

Overall, approximately 11% of the watershed is classified as having moderate to steep slopes. Figure B.2 shows the locations of different slope classes in the watershed. The larger rivers in the watershed (i.e., Pearl River, Yockanookany River, Lobutcha Creek, and Tuscolameta Creek) have formed broad valleys with floodplains and local terrace deposits (NRCS 1999).

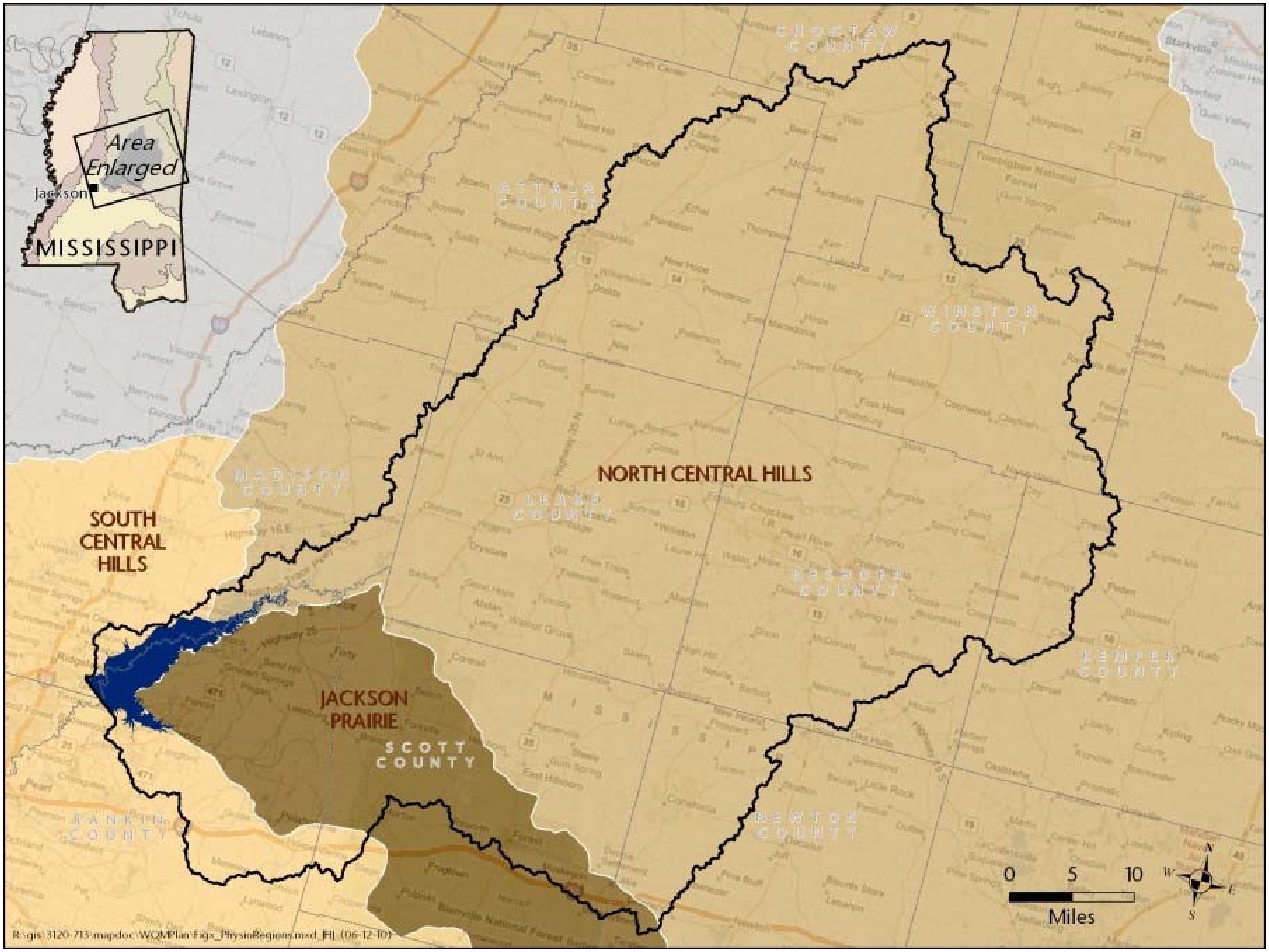

Figure B.1. Physiographic regions present in Ross Barnett Reservoir watershed.

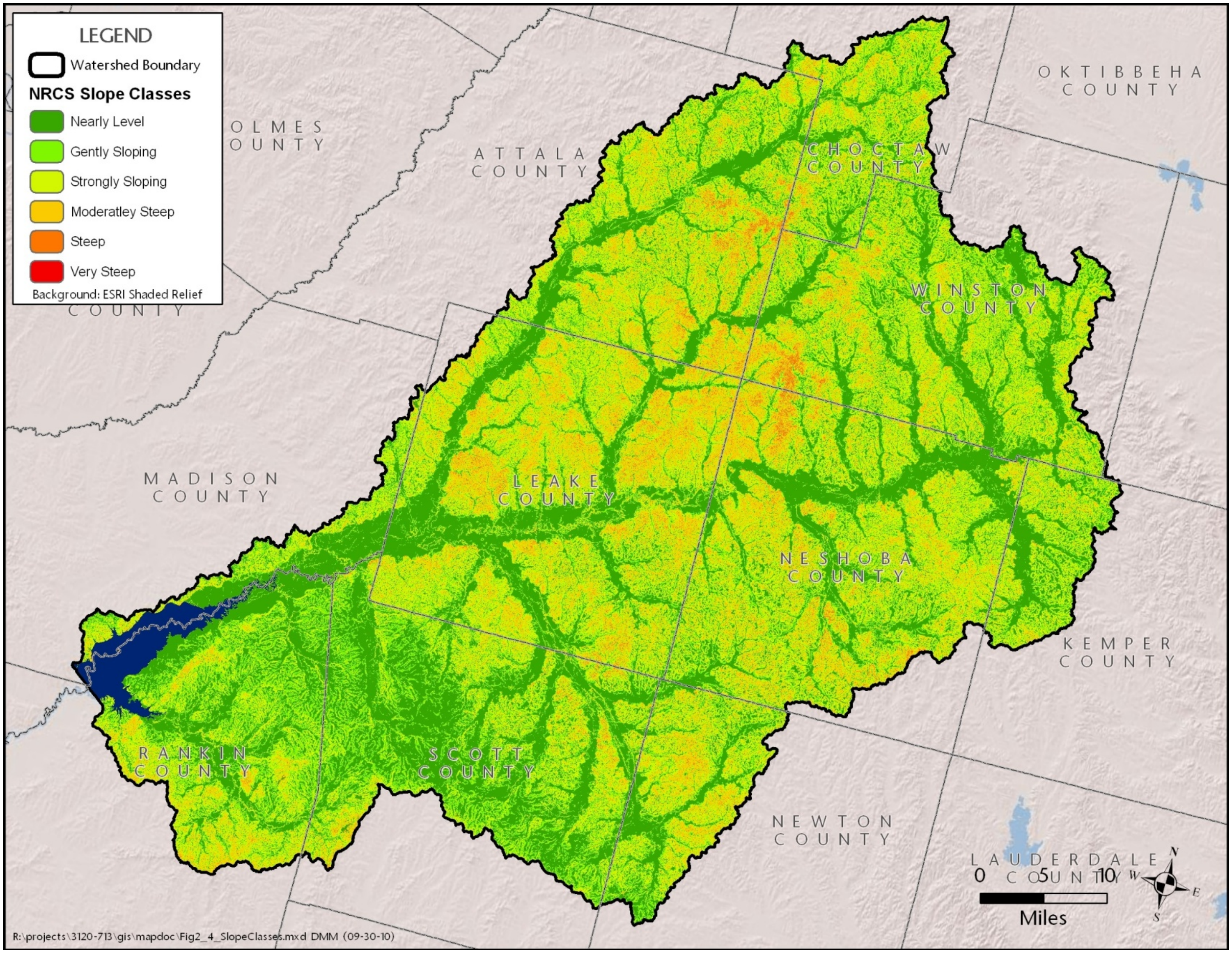

Figure B.2. Classification of slope in the Ross Barnett Reservoir watershed.

Ecoregions and Bioregions

The Ross Barnett watershed includes portions of three Level IV ecoregions, shown on Figure B.3 (Chapman et al. 2004). The Loess Plains and the Jackson Prairie ecoregions are closest to the Reservoir. Upstream of the Reservoir, the majority of the watershed is located in the Southern Hilly Gulf Coastal Plain ecoregion. The Loess Plains ecoregion is characterized by a gently rolling landscape underlain by a relatively thin layer of loess. Streams and rivers in this ecoregion tend to be low gradient with silty and sandy substrate. The Jackson Prairie ecoregion is characterized by irregular plains and low, broad hills. Historic vegetation in this ecoregion was mostly mixed pine and hardwood forest, with prairies interspersed. This area has experienced extensive soil erosion resulting from historical land management. The Southern Hilly Gulf Coastal Plain ecoregion is characterized by dissected irregular plains and gently rolling low hills. Natural vegetation in the portion of this ecoregion where the Ross Barnett watershed is located is mostly oak-hickory-pine forest (Chapman et al. 2004).

As part of the development of the Mississippi Benthic Index of Stream Quality (MBISQ), the state was divided into five bioregions – regions of similar landscape characteristics and stream benthos. Different biological metrics are used to calculate the MBISQ score in each bioregion. The Ross Barnett Reservoir watershed straddles the boundary between the East and West Bioregions (Figure B.4). The majority of the Ross Barnett Reservoir watershed is within the East Bioregion, which includes the Southern Hilly Gulf Coastal Plain and Jackson Prairie ecoregions. Portions of the watershed, including the Reservoir itself, are located in the Loess Plains ecoregion and the West Bioregion.

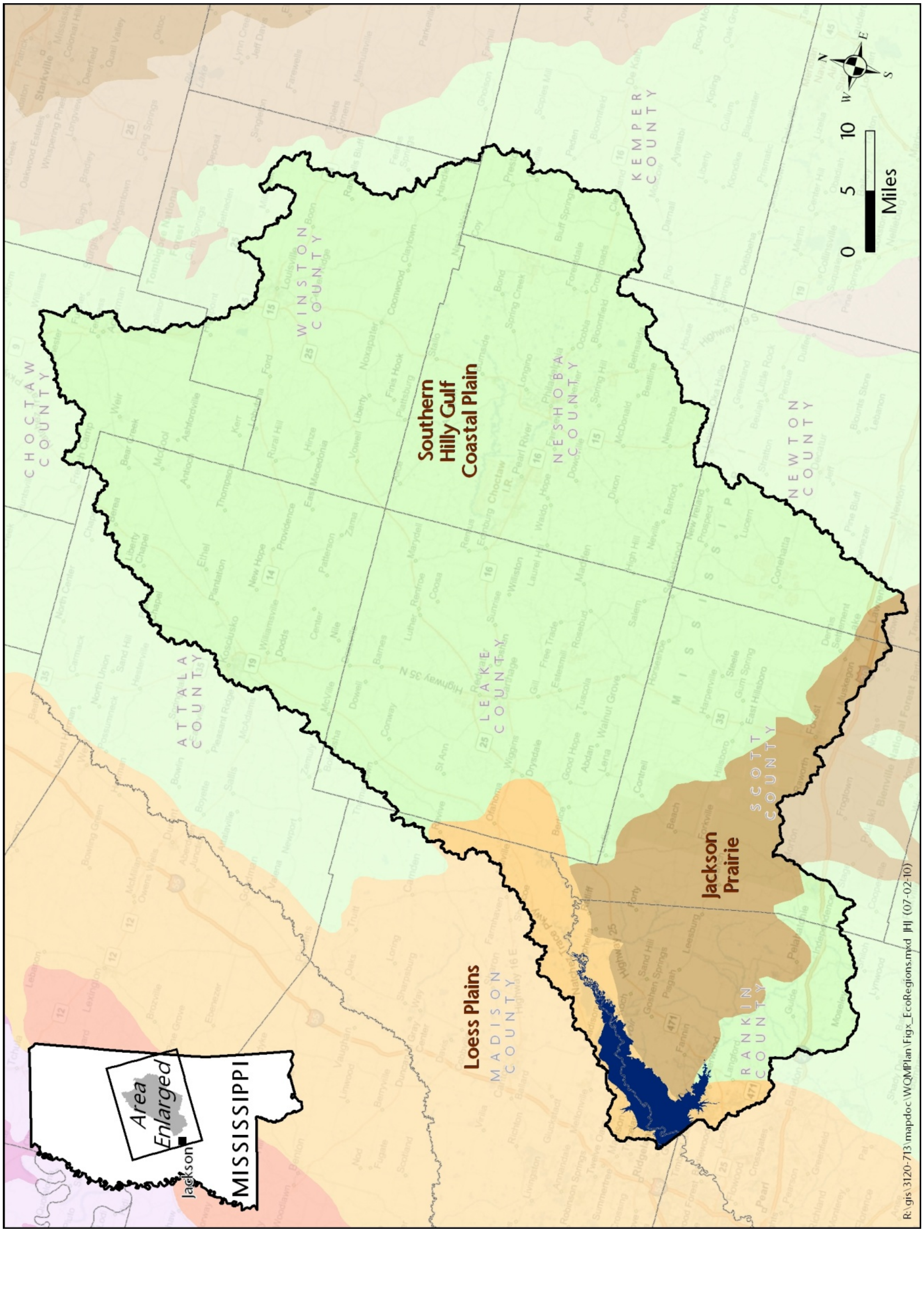

Figure B.3. Ecoregions of the Ross Barnett Reservoir watershed.

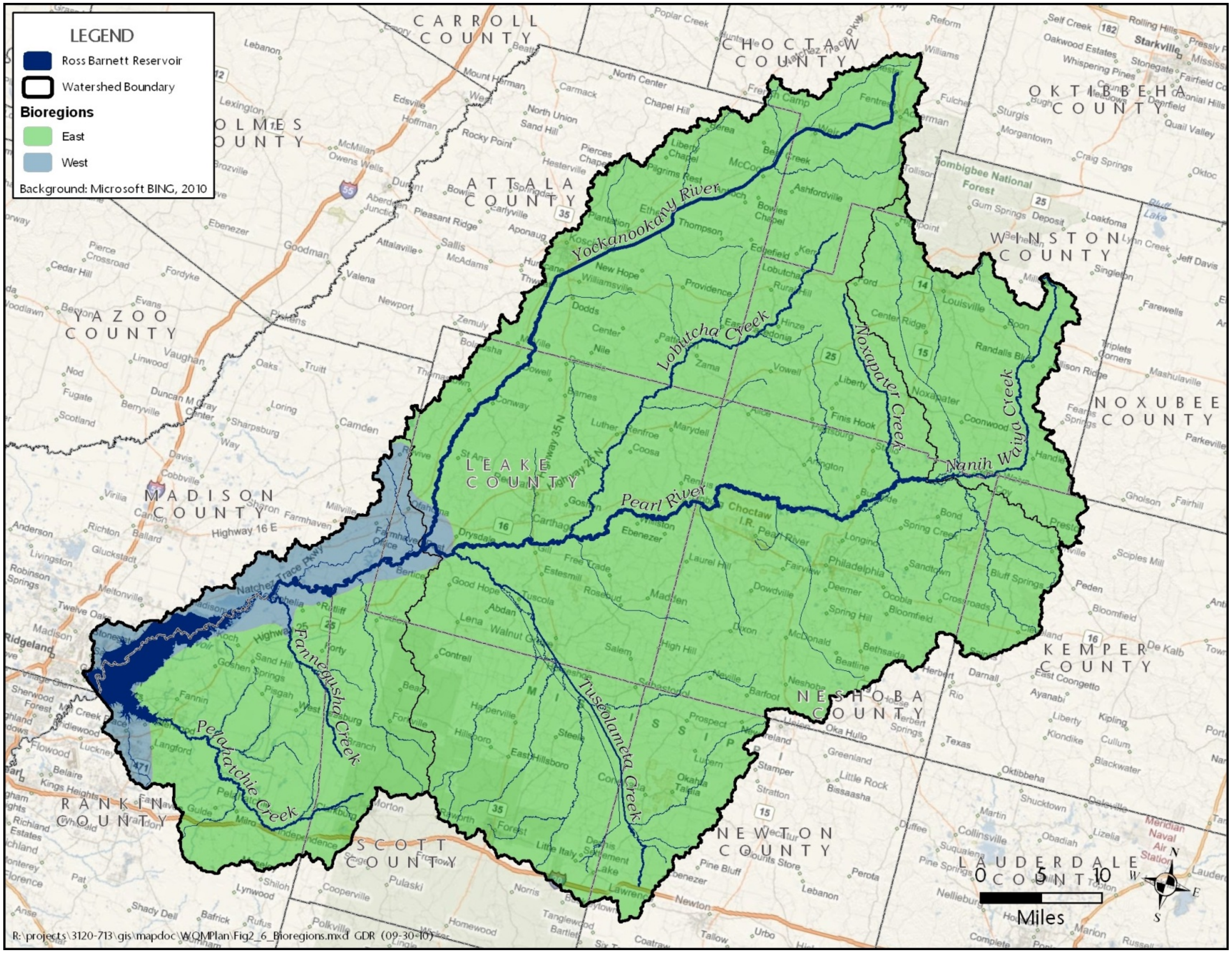

Figure B.4. Bioregions of Ross Barnett Reservoir watershed.

Climate

In general, Mississippi has mild winters and long hot summers, with high humidity between May and September[1]. According to the Mississippi State Climatologist, winter average daily temperatures in central Mississippi typically are in the low- to mid-40s (°F). Summer average daily temperatures in this area are typically in the 80s, with daily maximums over 90°F. Figure B.5 shows the average annual temperature range for Jackson. Average annual precipitation in the watershed is typically around 55 inches. Monthly precipitation averages range from a little over 3 inches to over 5 inches, with September typically being the driest month, and the highest rainfalls occurring during the winter and early spring. Figure B.6 shows monthly average precipitation at Jackson. First frost typically occurs in November, and last frost in March.

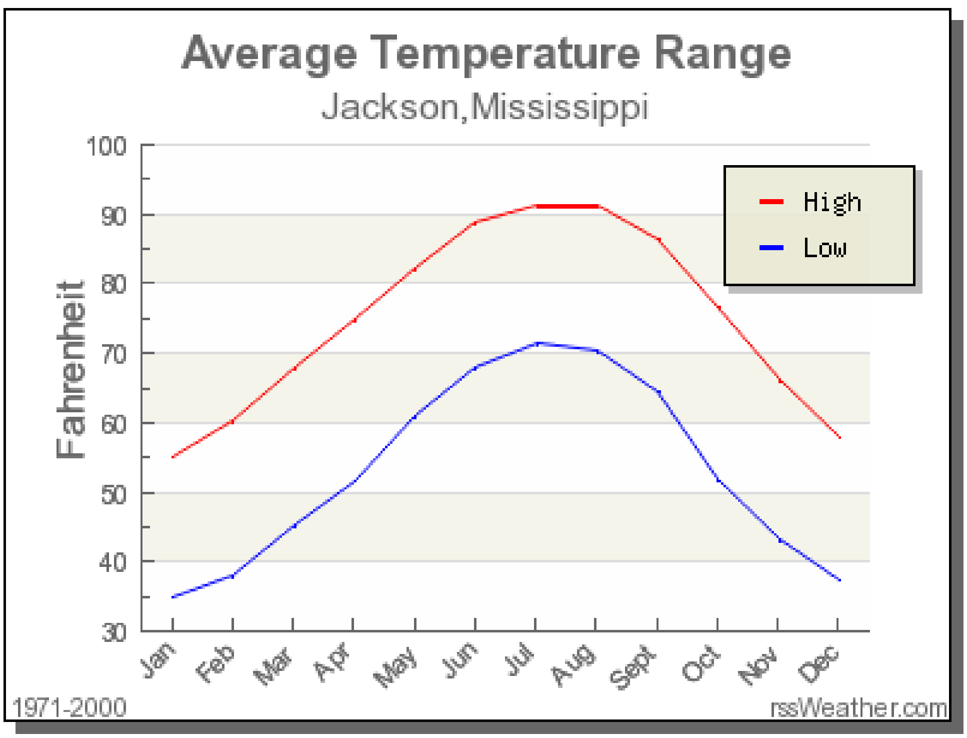

Figure B.5. Average annual temperature range at Jackson, Mississippi.

[1] http://geosciences.msstate.edu/stateclimatologist.htm

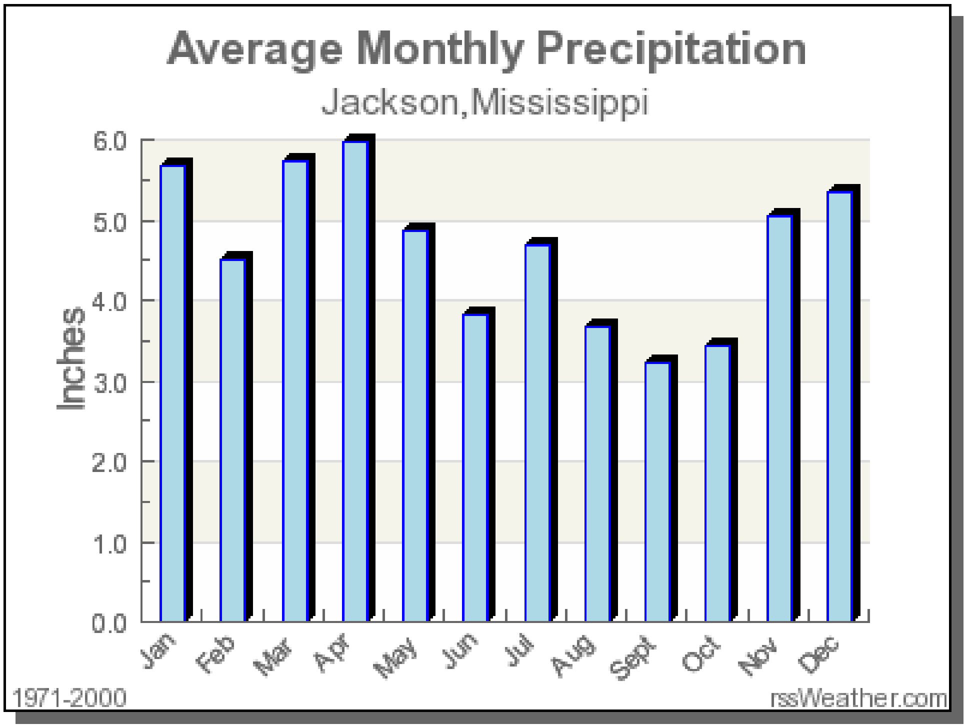

Figure B.6. Average monthly precipitation at Jackson, Mississippi.

Geology

Geologic Elements and Period

The majority of the Ross Barnett watershed is underlain by consolidated clays and muds. An outcrop of sandstone and claystone bisects the watershed running from the northwest to the southeast. All underlying geologic outcrops in the watershed are of the Eocene period (Thompson 2009). A general map of the geology within the Ross Barnett watershed is shown on Figure B.7.

Geologic Faults

The watershed crosses the Pickens-Gilbertown fault systems and the Phillips fault system. It also crosses the Central Mississippi ridge and the Mississippi deformed belt (Figure B.8). The upper watershed is underlain by the buried Appalachian tectonic belt (Thompson 2009).

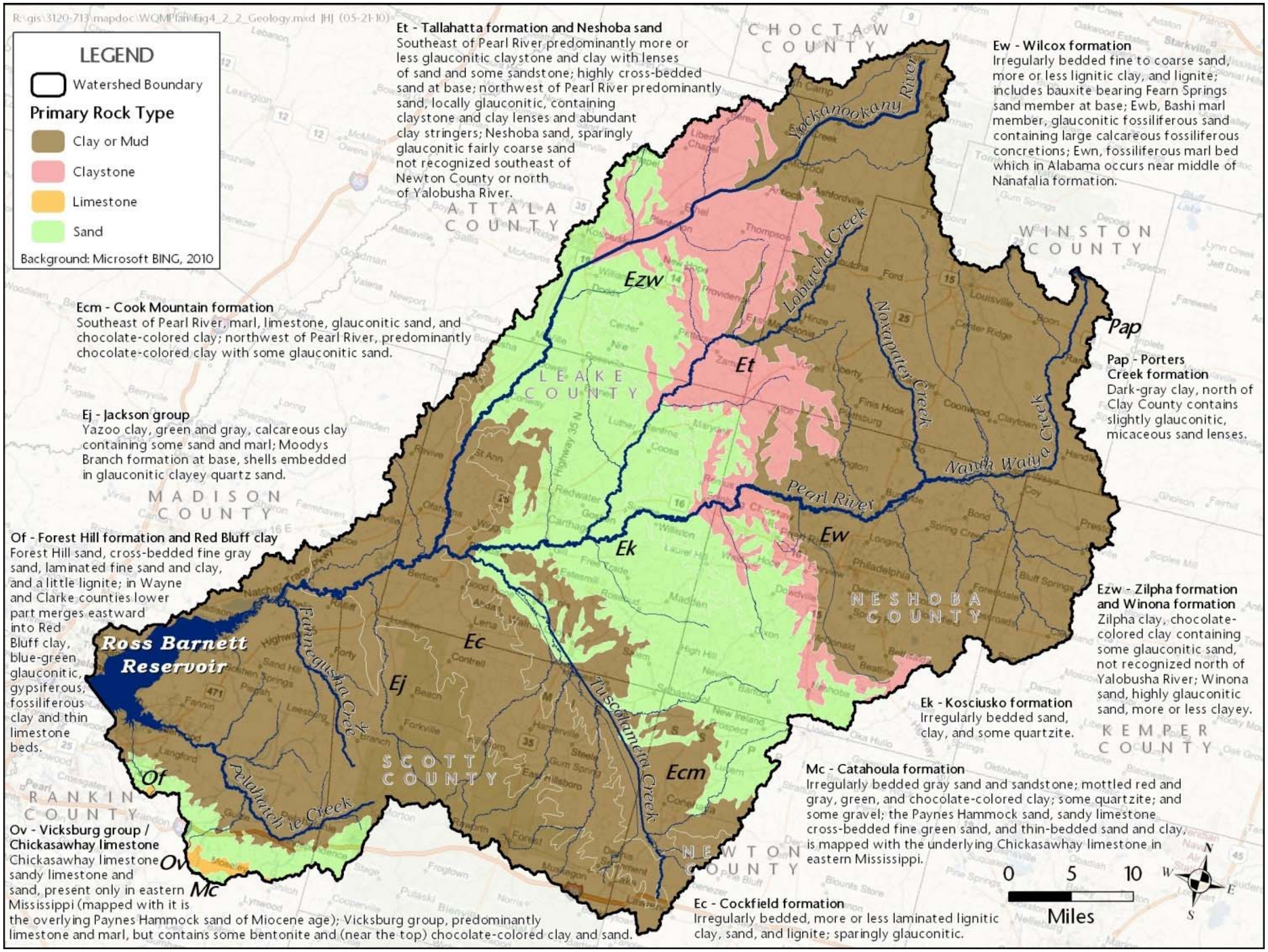

Figure B.7. Geology underlying Ross Barnett Reservoir and its watershed.

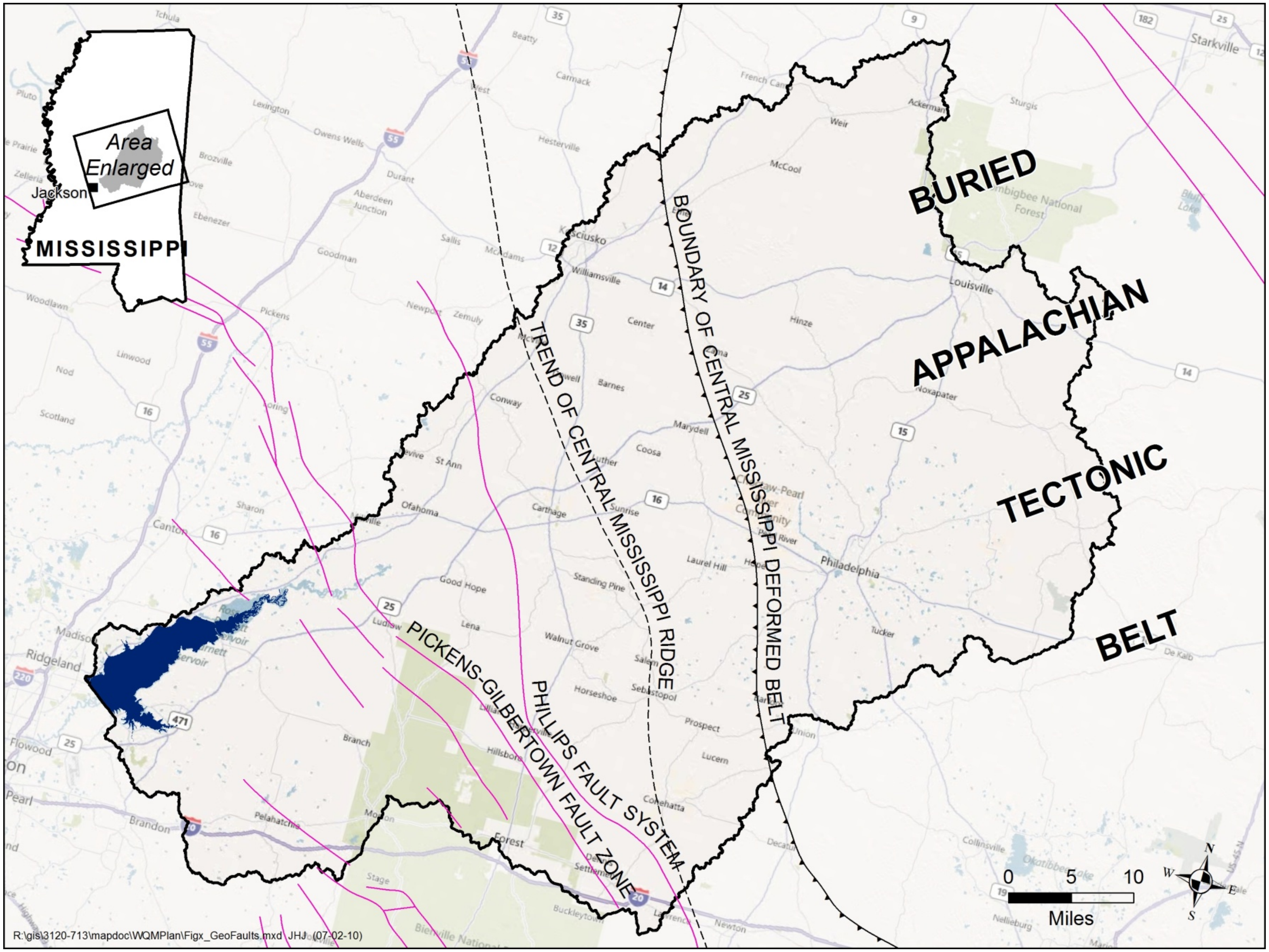

Figure B.8. Geologic structure features within the Ross Barnett Reservoir watershed.

Resource Extraction

There are a number of carbon dioxide wells in the watershed in Rankin and Madison counties[2]. There has been recent activity to extract carbon dioxide deposits from the Jackson Dome, which is partially located under the Reservoir. There are several oil wells in the watershed in Rankin County[3]. Sand and gravel mining activities currently take place in Rankin, Madison, Attala, Leake, and Neshoba counties. Clay mining is conducted in Winston County[4].

Soils

Soil texture is determined by the relative proportions of sand, silt, and clay in the soil. NRCS defines sand, silt, and clay based on particle size, in which sand is the largest and clay the smallest size. Loam is a mixture of all three particle sizes[5]. Soils in the watershed are primarily fine-grained. In the upper watershed, fine sandy loams predominate, with silt loams and loams occurring in the large river valleys, and patches of loamy sand in Leake and Neshoba counties near Lobutcha Creek and Beasha Creek. In the lower watershed and the Reservoir, silt loams predominate, with silty clays and silty clay loams in the major river valleys, and patches of loam, and silty clay loam, and fine sandy loams in the tributary headwaters (Figure B.9).

Hydric soils occur in the watershed along drainageways, in floodplains and depressions[6]. NRCS defines hydric soils as soils that are sufficiently wet in the upper part to develop anaerobic conditions during the growing season[7]. Hydric soils are shown on Figure B.10.

[2] http://gis.ogb.state.ms.us/MSOGBOnline/
[3] *Ibid.*
[4] http://minerals.usgs.gov/minerals/pubs/state/2003/msstmyb03.pdf
[5] https://www.soils.org/publications/soils-glossary
[6] http://soils.usda.gov/use/hydric/lists/state.html
[7] http://soils.usda.gov/use/hydric/overview.html

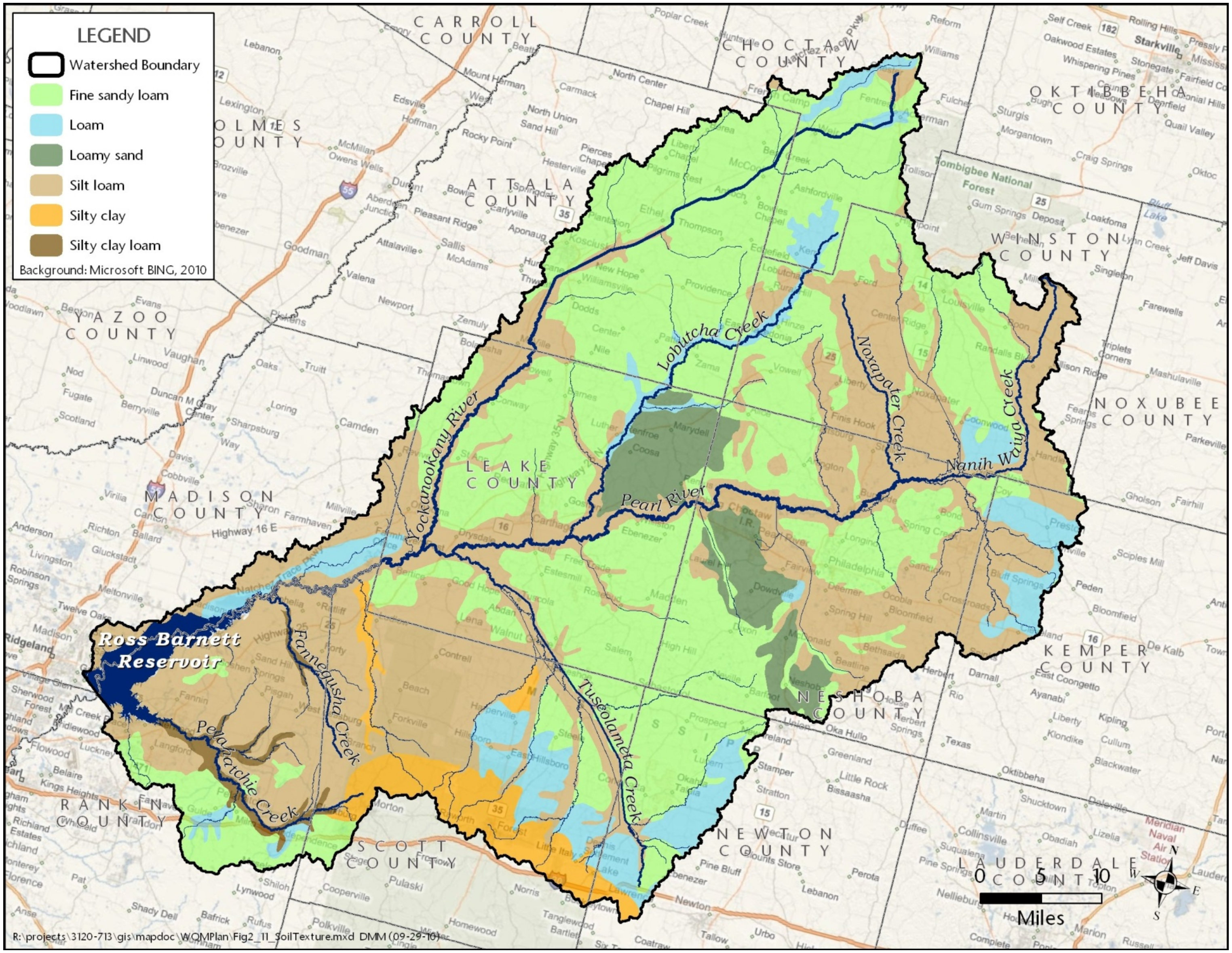

Figure B.9. Soil texture in the Ross Barnett Reservoir watershed.

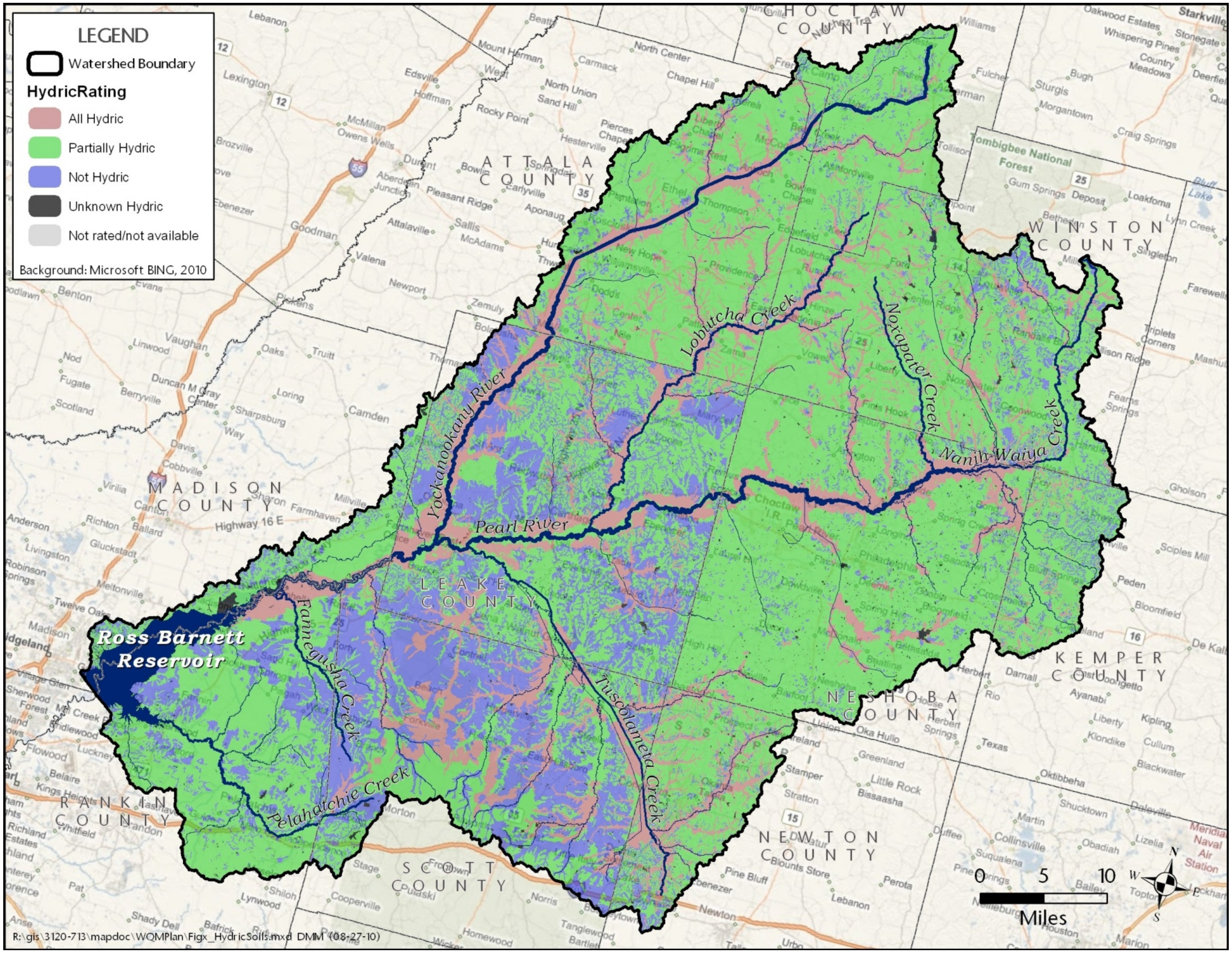

Figure B.10. Hydric soils in the Ross Barnett Reservoir watershed.

Information to describe soil erodibility is available in the state Soil Survey Geographic (SSURGO) database for all the counties included in the Ross Barnett Reservoir watershed. The SSURGO database defines soils as “highly erodible land” or “not highly erodible land.” Areas where erosivity cannot be clearly defined are described as “potentially highly erodible land.” The definition of highly erodible land is based upon the specific variables of the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978). The USLE represents the tons of soil loss by erosion predicted for bare ground divided by the sustainable soil loss (USDA 2000). The overall rating is based on an evaluation of the water erosion hazard and USLE values. If all values in an area are either highly erodible or not highly erodible, then that value is assigned. When values in an area are not consistent, a value of potentially highly erodible is assigned (USDA 1995) (Figure B.11).

Land Use Trends and History

The National Agriculture Statistics Service[8] collects agriculture land use data on a county basis. Data for Scott, Hinds, Rankin, Leake, and Madison counties were reviewed for the period from 1928 to 2008. The data provided by the NASS website included acreage of individual crops planted on a county basis. Data showed that these five counties exhibit similar yearly trends of total crop acreage and percent crop acreage (defined as crop acreage/total county land acreage). While total crop acreage and percent crop acreage amounts vary between counties, the trends remain relatively consistent as a function of time. In all five counties, the percentage of the county in cropland peaked in the early 1980s and then sharply declined. Maximum percentages of cropland in the early 1980s ranged from 7% to 26% (Figure B.12).

[8] www.nass.usda.gov

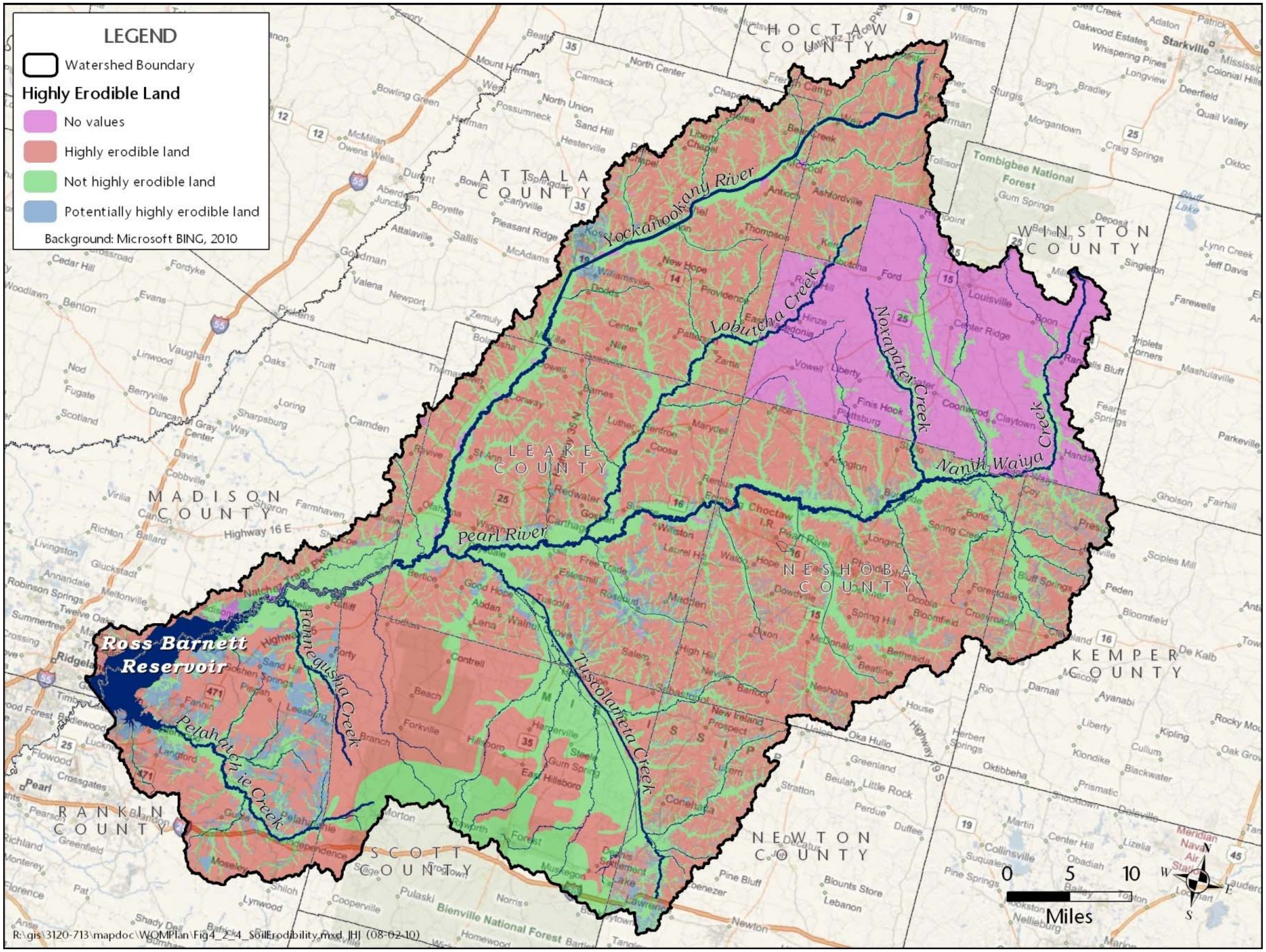

Figure B.11. Soil erodibility in the Ross Barnett Reservoir watershed.

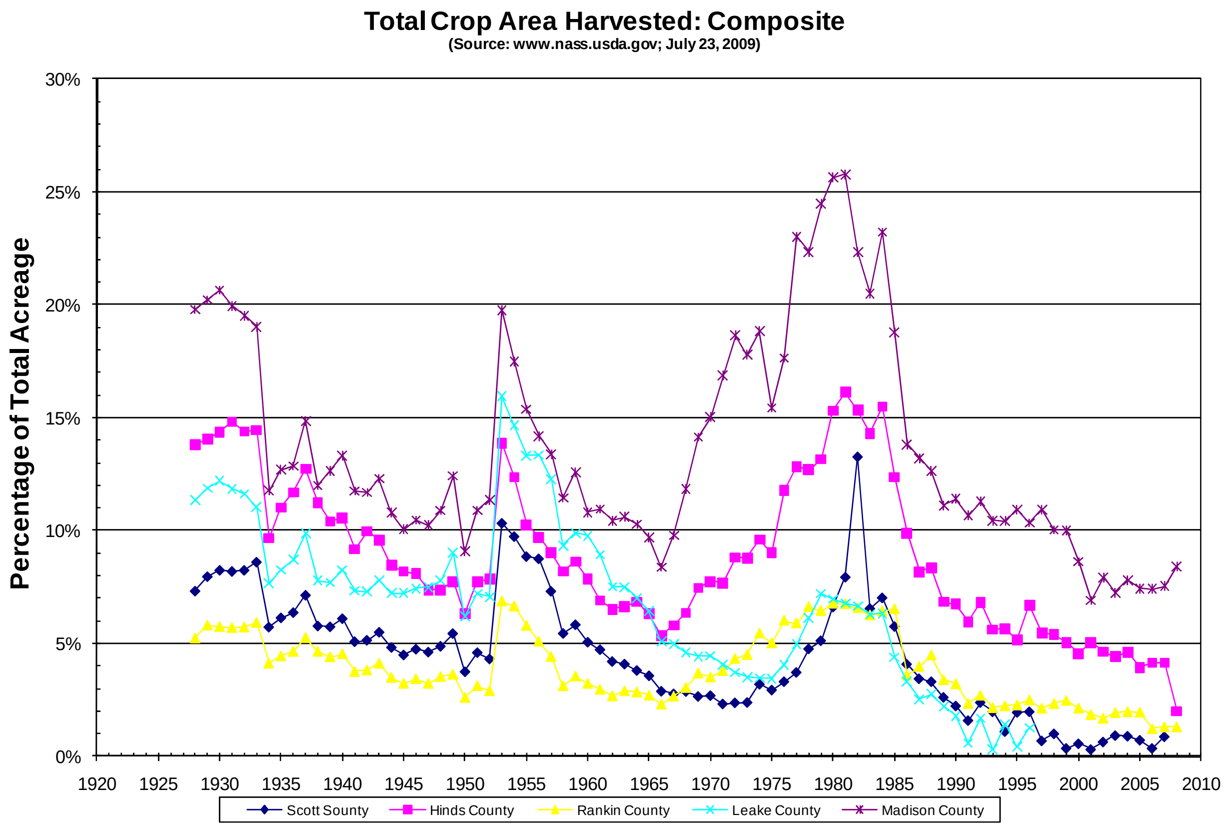

Figure B.12. Percent of counties in crops from 1928 to 2008.

Reservoir Characteristics

Additional characteristics of the Reservoir are shown in Table B.1. The drainage area/surface area ratio value of 61 is relatively high and indicates that BMPs installed closer to the Reservoir will likely have a greater impact on water quality than practices installed in the upper parts of the watershed. The aspect ratio is also relatively high at 38.2. As a rule-of-thumb, an aspect ratio greater than 4 indicates that longitudinal gradients are more important than lateral gradients in water quality. The shoreline development ratio value of 4.3 indicates that the Ross Barnett Reservoir contains a limited number of coves and near-shoreline areas for nursery and spawning of fish. A shoreline development ratio of 1 indicates a perfect circle with very little shoreline area, while a value of 15 indicates a highly dendritic shoreline. The mean depth to maximum depth ratio value for the Reservoir of 0.2 indicates very shallow side slopes with extensive littoral area. A relative depth value of less than 1 indicates greater potential for wind disruption of stratification. The Reservoir shows a very high potential for wind mixing that could cause resuspension of suspended sediment. The areal erosion is an estimate of the percent of lake bed that could be subject to erosion, impacting water quality. This value is relatively high for the Reservoir.

Table B.1. Reservoir characteristics.

Parameter	Value
Drainage Area/Surface Area (DA/SA)	61
Aspect Ratio (Length/Width)	38.2
Shoreline Development Ratio (L/$\sqrt{SA}$)	4.3
Mean Depth/Maximum Depth (Zm/Z)	0.2
Relative Depth	0.12
Residence Time (V/Q) (yr)	0.12 (43 d)
Areal Erosion	76%

The outlet of the Reservoir consists of an earth-fill dam 3 miles wide and approximately 64 ft high. The spillway is approximately 400 ft wide and is controlled by ten gates that are 21 ft tall and 40 ft wide.

The intake for the O.B. Curtis drinking water treatment plant is located on the Reservoir Dam just west of the Madison/Rankin county line. The facility is owned and operated by the City of Jackson. The O.B. Curtis Plant, along with an additional drinking water treatment plant, J.H. Fewel, currently provides water to 175,710 people through 71,788 connections in the city of Jackson. The J.H. Fewel Plant is located on the Pearl River downstream of the Reservoir Dam. After a recent expansion, the O.B. Curtis facility has the capacity to treat 50 MGD of water; however, it presently treats an average of 20 MGD with a peak flow of 35 MGD. The intake structure of the Reservoir allows the city to change the level of withdrawal due to water quality conditions in the Reservoir, primarily to avoid high concentrations of algae and manganese. However, the city does not routinely vary the intake depth (personal communication, Don Bach, City of Jackson). The O.B. Curtis drinking water intake currently operates under Permit No. MS-SW-024419 to divert or withdraw for beneficial use the public waters.

Ross Barnett Reservoir is essentially a flow-through reservoir, with limited flood storage capacity. Reservoir water level is typically maintained between 296 ft msl (winter pool) and 297.5 ft msl (summer pool). Average release flow based on spillway logs from PRVWSD between 1965 and 2005 was 3,718 cfs. PRVWSD has an agreement with the City of Jackson to maintain a minimum flow of 112 MGD in the Pearl River downstream of the Reservoir based on a contract between the City of Jackson and PRVWSD dated November 18, 1959, and a permit by the State of Mississippi Board of Water Commissioners dated December 11, 1959.

Based on flow records from USGS gages at Yockanookany River at Ofahoma, and the Pearl River at Lena, highest inflows to the Reservoir generally occur late December through April, and lowest flows generally occur July through October. Reservoir releases are typically greatest from December through April, and lowest in August.

The flood of record at the Reservoir occurred in April 1979, and resulted in an estimated peak inflow of approximately 160,000 cfs, and peak release of approximately 130,000 cfs (PRVWSD, no date). Flood stage on the Pearl River at Ratliff's Ferry is reported to occur at an elevation of 303.0 ft. This established flood stage elevation can be considered to correspond to a peak flow of approximately 35,000 cfs. NOAA's reported flow exceedance forecast indicates the peak flow of 35,000 cfs has a recurrence interval between the 2-year and 10-year flood events. The Rankin County, Mississippi, Flood Insurance Study (FIS) reports the peak flow for the 10-year flood event on Pelahatchie Creek at State Route 471 as approximately 17,900 cfs (FEMA 2003). The watershed is also subject to flash floods[9].

According to the National Climatic Data Center, between 1950 and 2009, drought events occurred in the watershed only during December 2006 and late spring through early summer of 2007.

Major Tributaries

Table B.2 lists the drainage areas of major tributaries to Ross Barnett Reservoir and Pearl River, along with the percentage of the Ross Barnett watershed. They are shown on Figure B.13.

[9] http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~storms, accessed January 2010.

Table B.2. Drainage areas for major tributaries in the Ross Barnett Reservoir watershed.

Tributary	Drainage Area (square miles)	Percent of Total Watershed
Pearl River upstream of Carthage	1041.4	34.2%
Pearl River downstream of Carthage	240.3	7.9%
Fannegusha Creek	75.6	2.5%
Pelahatchie Creek	237.2	7.8%
Yockanookany River	476.4	15.6%
Tuscolameta Creek	574.1	18.8%
Lobutcha Creek	316.4	10.4%
Coffee Bogue	85.9	2.8%

Wetlands

The majority of wetlands in the watershed are associated with the Pearl River; however, there are some significant functional wetland systems around the Reservoir (wetland areas are shown on Figure B.14). The largest wetland system associated with the Reservoir is located in the Pearl River State Wildlife Management Area along the northwest shore. Additional shoreline wetland systems are located on the eastern shore, just south of Highway 43, parts of the north shore of Pelahatchie Bay, and at the inflow of Pelahatchie Creek.

Aquifers

Aquifer(s) in the Ross Barnett Reservoir watershed are part of the Mississippi embayment aquifer system[10]. The watershed is underlain by five of the principal aquifers in Mississippi: Cockfield, Sparta Sand, Winona-Tallahatta, Meridian-Upper Wilcox, and Lower Wilcox (Wasson 1986, MDEQ 2009). Drinking water in the upper part of the watershed is pumped from groundwater sources.

[10] http://www.nationalatlas.gov

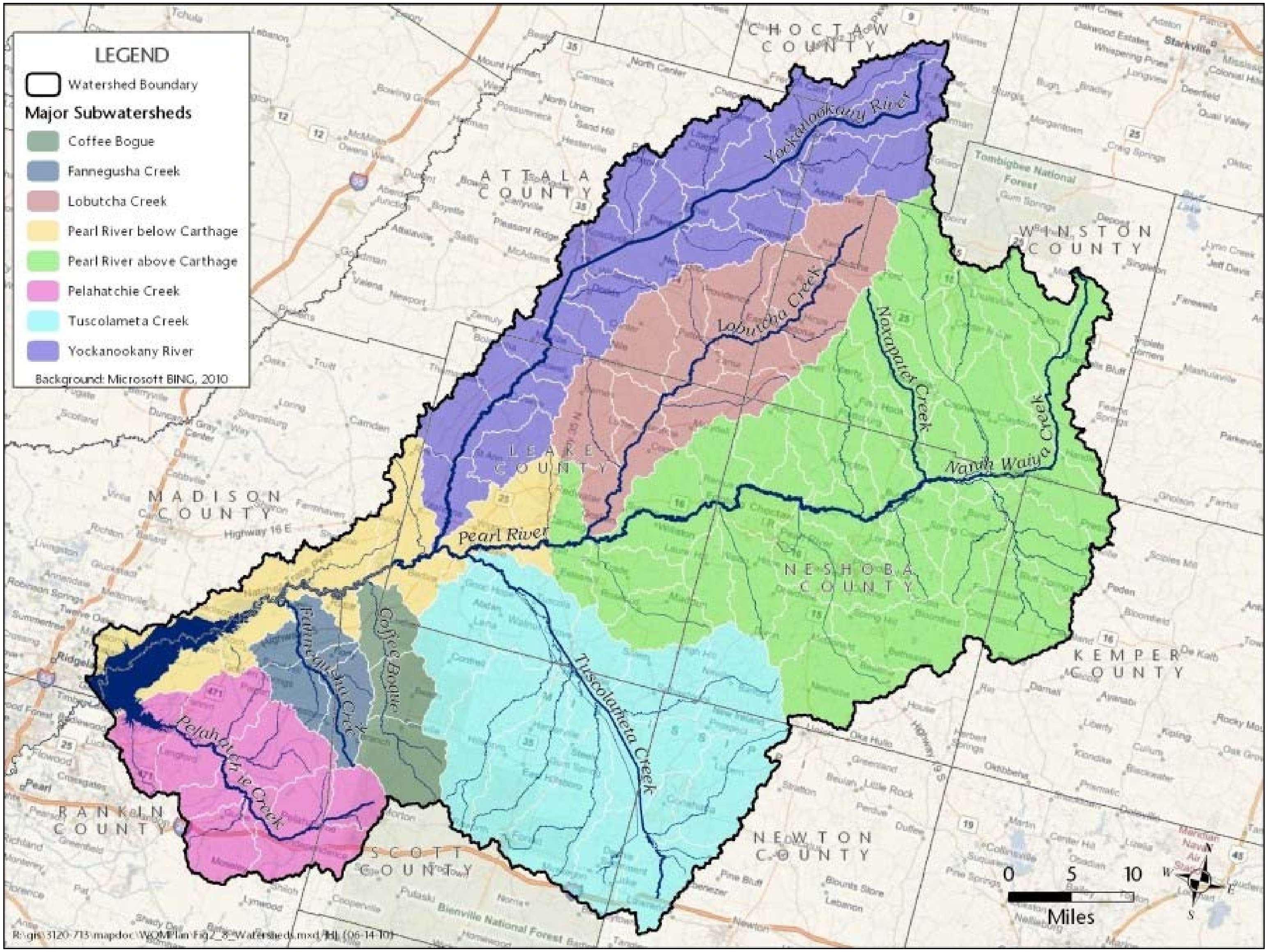

Figure B.13. Major tributaries to the Ross Barnett Reservoir.

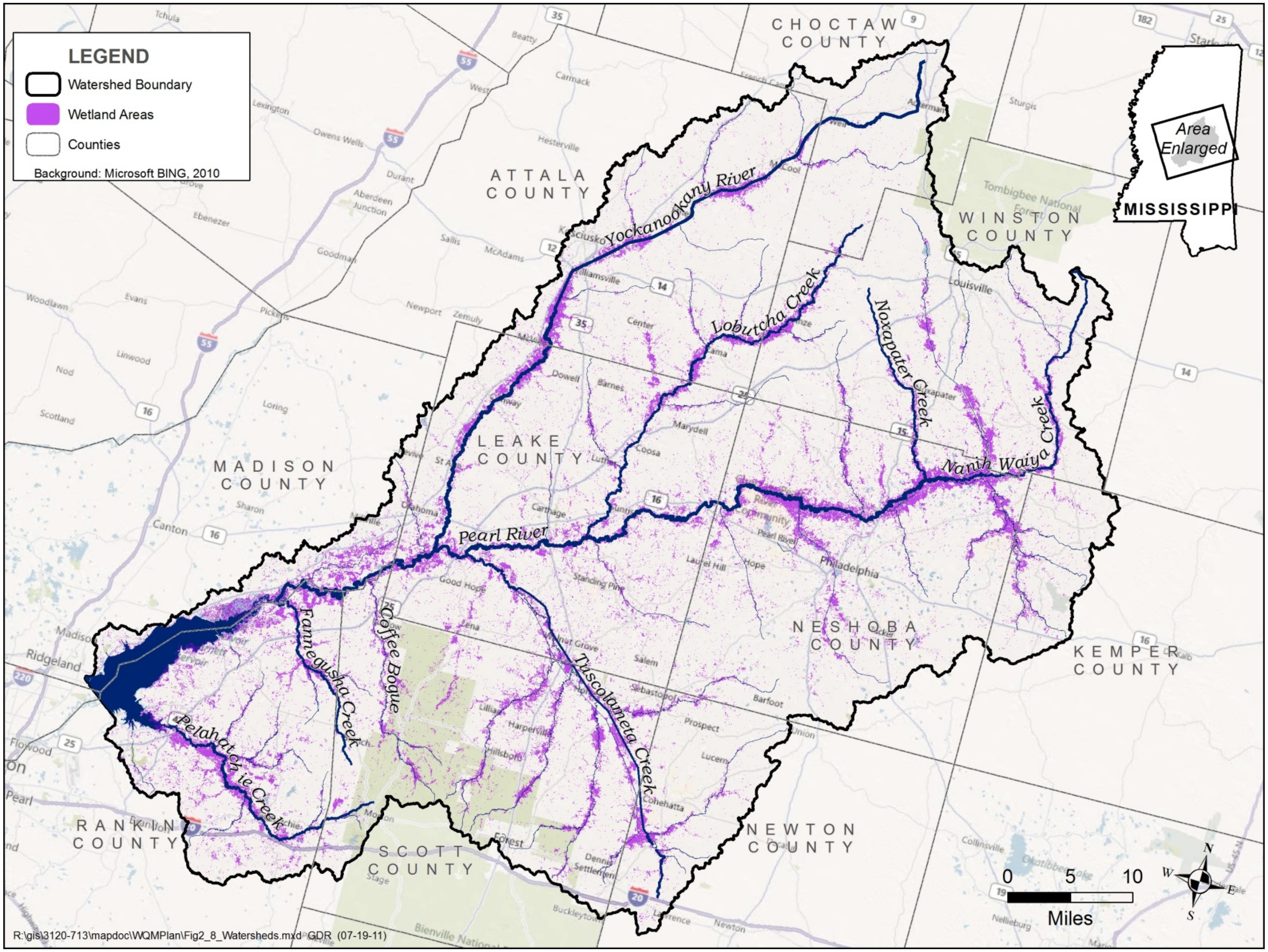

Figure B.14. Wetland areas in the Ross Barnett Reservoir watershed.

Water Use

The Ross Barnett Reservoir is Mississippi's largest source of surface water used for drinking water. Water from the Reservoir and a downstream plant on the Pearl River is used by the City of Jackson to provide water to more than 71,000 connections. The connections include homes, businesses, and the Nissan automotive manufacturing plant in Canton. The treatment capacity of the City of Jackson's O.B. Curtis drinking water treatment plant, which withdraws water from the Ross Barnett Reservoir, has been recently expanded by the installation of a ZeeWeed ultrafiltration system. This type of system was selected for installation based on treatability studies.

Drinking water for the other communities in the watershed is supplied by groundwater. In 2009 there were approximately 240 permitted public water supply wells in the watershed[11].

Natural Resources

The Ross Barnett Reservoir watershed contains an abundance of natural resources. These resources are protected through national forests, state parks, and wildlife refuges. Portions of the Bienville National Forest and the Tombigbee National Forest are located within the watershed. National forest lands are managed by the USDA Forest Service.

Several state parks are located within the watershed. These include Golden Memorial State Park in Leake County, Roosevelt State Park in Morton, and Legion State Park in Louisville. State parks are managed by the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP).

Wildlife refuges located in the watershed include the Pearl River Wildlife Management Area and Waterfowl Refuge, the Bienville Wildlife Management Area, and the Nanih Waiya Wildlife Management Area. Wildlife refuges are also managed by MDWFP.

Species of Concern

There are approximately 36 Mississippi animal species of concern, and 66 Mississippi plant species of concern identified as occurring in the counties within the Ross Barnett Reservoir

[11] http://www.deq.state.ms.us

watershed by the Mississippi Heritage Program[12]. Table B.3 lists the number of these species of concern for specific animal categories. Eight of these species are federally listed as threatened or endangered, and nine are on the Mississippi list of endangered species (Table B.4). The Southeastern Region of the US Fish and Wildlife Service has developed management plans for the federally listed species.

Table B.3. Categories of species of concern for the Ross Barnett Reservoir watershed.

Category	Number of Species of Concern in Watershed
Amphibian	3
Bird	11
Crustacean	3
Fish	4
Insect	2
Mammal	1
Mollusk	7
Reptile	3
Tree/shrub	17
Grass/rush	6
Orchid	11
Other Flower	28
Fern	3
Vine	2

Table B.4. Federal- and state-listed threatened and endangered species for the Ross Barnett Reservoir watershed.

Scientific Name	Common Name	Federal Status	State Status
Falco peregrines	Peregrine Falcon	Endangered	Not Listed
Haliaeetus leucocephalus	Bald Eagle	Threatened	Endangered
Picoides borealis	Red-cockaded Woodpecker	Endangered	Endangered
Thryomanes bewickii	Bewick's Wren	Not Listed	Endangered
Acipenser oxyrinchus desotoi	Gulf Sturgeon	Threatened	Endangered
Ursus americanus luteolus	Louisiana Black Bear	Threatened	Endangered
Elliptio arctata	Delicate Spike	Not Listed	Endangered
Graptemys oculifera	Ringed Map Turtle	Threatened	Endangered
Apios priceana	Price's Potato Bean	Threatened	Endangered

[12] http://mdwfp.com/museum/database/nhp_online_data_animals.html, accessed October 2009

Species of Greatest Conservation Need

The Mississippi Comprehensive Wildlife Conservation Strategy (MDWFP 2005) outlines the conservation value of the Ross Barnett Reservoir watershed with regard to Mississippi animal species (excluding insects) of greatest conservation need. Species of greatest conservation need associated with streams in this watershed are listed in Table B.5. The strategy identifies approximately 18 conservation activities for the streams in the Ross Barnett Reservoir watershed. The strategy also identifies species of greatest conservation need, and recommended conservation activities for all of the land and water habitats that occur in the watershed.

Each species is assigned a tier based on the level of concern. Tier 1 species are in need of immediate conservation action and/or research because of extreme rarity, restricted distribution, unknown or decreasing population trends, specialized habitat needs and/or habitat vulnerability. Some species may be considered critically imperiled and at risk of extinction/extirpation. Tier 2 species are in need of timely conservation action and/or research because of rarity, restricted distribution, unknown or decreasing population trend, specialized habitat needs, or habitat vulnerability or significant threats. Tier 3 species are of less immediate conservation concern, but are in need of planning and effective management due to unknown or decreasing population trends, specialized habitat needs, or habitat vulnerability.

Table B.5. Species of greatest conservation need associated with streams in the Ross Barnett Reservoir watershed (MDWFP 2005).

Scientific Name	Common Name	Tier
Pseudotriton ruber	Red Salamander	3
Hobbseus attenuates	Pearl Rivulet Crayfish	1
Hobbseus valleculus	Choctaw Rivulet Crayfish	1
Procambarus elegans	A Crayfish	2
Fundulus dispar	Northern Starhead Topminnow	2
Elliptio arctata	Delicate Spike	1
Obovaria unicolor	Alabama Hickorynut	1
Anodontoides radiates	Rayed Creekshell	2
Pleurobema beadleianum	Mississippi Pigtoe	2
Lasmigona complanata complanata	White Heelsplitter	3
Macrochelys temminckii	Alligator Snapping Turtle	2
Graptemys oculifera	Ringed Map Turtle	2
Graptemys gibbonsi	Pascagoula Map Turtle	2

Fisheries

Warm-water fish species that make up the typical southeastern reservoir fish population found in the Ross Barnett Reservoir include sport fishes such as crappies, sunfishes, black basses, catfishes, striped bass and hybrid striped bass. Clupeids (shad) are the dominant fish species present. Crappie and black bass anglers are the first and second most numerous angling groups, respectively. In February 2009, the 15-inch minimum size limit on black bass was reduced to a 12-inch minimum length limit. The daily creel limit remained at seven fish. Statewide creel limits apply to other game fish. Commercial fishing is closed, but sport anglers target catfish with trotlines, jugs and handgrabbing (Bull 2009).

Socioeconomics

Jackson MSA

The Ross Barnett Reservoir, and portions of its watershed, are located within the Jackson Metropolitan Statistical Area (MSA), which encompasses Madison, Rankin, Copiah, Hinds, and Simpson counties[13]. The MSA population in 2000 was 497,197. The July 1, 2008, population estimate for this MSA was 537,285 – an increase of 8%. Approximately two thirds of this increase was due to local births, and one third was the result of in-migration[14]. In 2000, the racial makeup of the MSA was primarily white (53.0%) and black (45.3%). The 3-year community survey for 2006 through 2008 indicated that the majority of the population was white (50.1%) or black (46.5%), and that approximately 18% of the population was living on income below the poverty level[15].

County Population Estimates

The area around Ross Barnett Reservoir is relatively heavily populated (Table B.6). The population estimate from the 2009 census for Madison County is 130 people per square mile. For Rankin County, the 2009 population estimate is 185 people per square mile. The average

[13] http://factfinder.census.gov/, accessed September 2010
[14] http://www.census.gov/popest/metro/CBSA-est2008-comp-chg.html, accessed January 2010
[15] http://factfinder.census.gov/servlet/DTGeoSearchByListServlet?_lang=en&_ts=282044753363, accessed January 2010

estimate for the state of Mississippi is 63 people per square mile. According to the US Census Bureau, the populations in Madison and Rankin counties have increased 24% since 2000[16].

The area upstream of the Reservoir is less densely populated (Table B.6). Figure B.15 shows the population data for 2000. Population data from 2009 were compared to 2000 data to review recent changes. The 2009 population estimates for the upstream counties range from 13 to 53 people per square mile. Five of the upstream counties (Scott, Leake, Newton, Neshoba, and Attala) experienced an increase in population since the 2000 Census (0.5% to 10.4%)[17].

Table B.6. Population estimates for counties in the Ross Barnett Reservoir watershed.

County	2009 Estimated Population Per Square Mile	2009 Total Estimated Population	Percent Change From 2000	Percent < 65 From 2009
Rankin	185	143,124	24.1%	89%
Madison	130	93,097	24.7%	89%
Scott	48	29,341	3.2%	88%
Leake	40	23,132	10.4%	87%
Newton	39	22,568	3.3%	84%
Neshoba	53	30,302	5.7%	87%
Winston	32	19,309	-4.2%	87%
Attala	27	19,755	0.5%	83%
Kemper	13	9,090	-6.8%	83%

Regional Economic Base

Economics from Community Survey Fact Sheets from 2006 through 2008 provided by the Census Bureau are listed in Table B.7.

[16] http://factfinder.census.gov/, accessed September 2010
[17] *Ibid.*

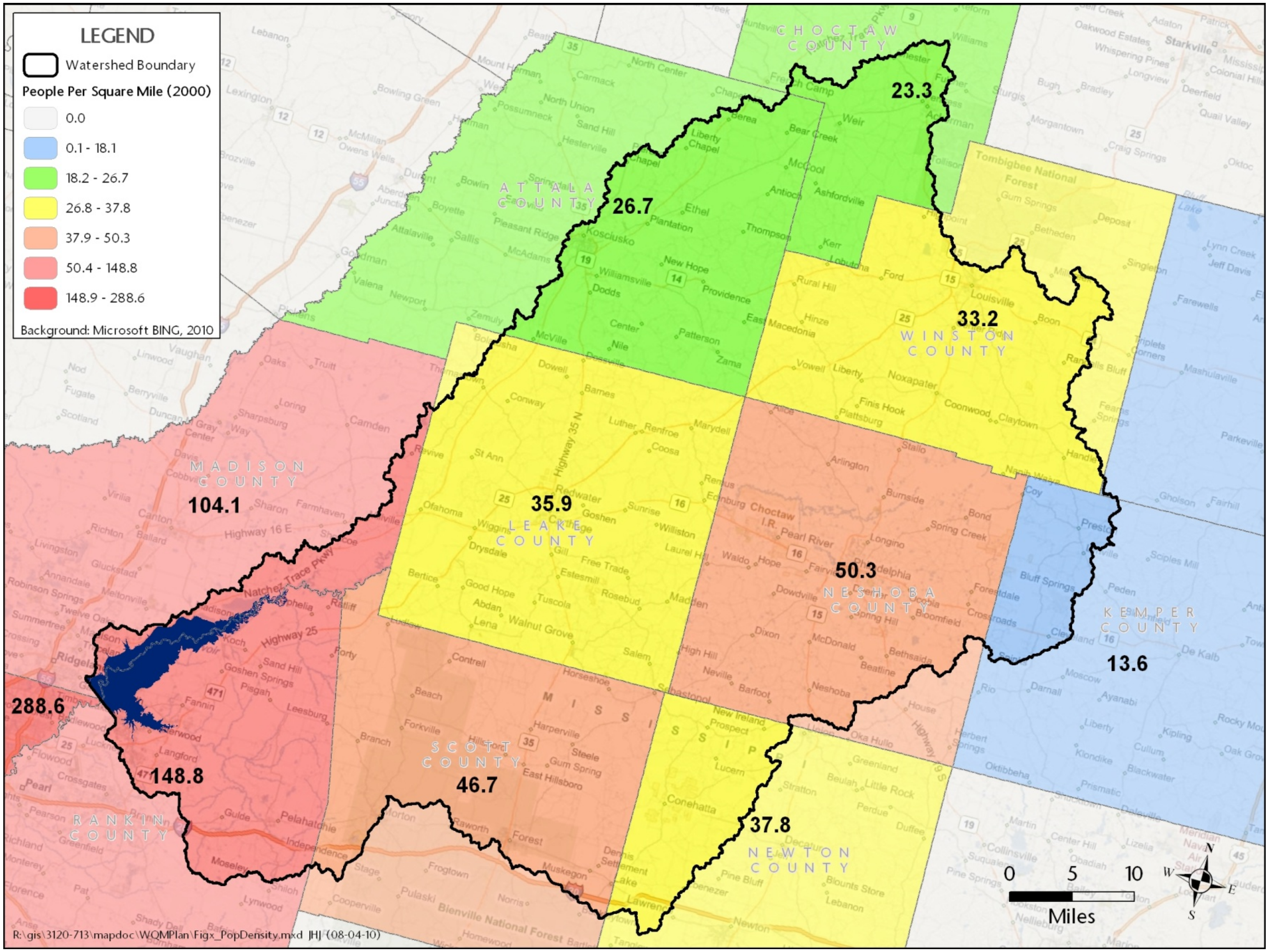

Figure B.15. Population data for counties in the Ross Barnett Reservoir watershed.

Table B.7. Economic information from 2006 through 2008 Community Survey Fact Sheets[18].

County	Estimated Per-Capita Income	Percent Individuals Below Poverty, 2006-2008	Major Employment Industries (> 10%)	Percent Unemployment	Households With Assistance	Households With Social Security or Retirement Income
Rankin	$26,480	10%	Education/health, Retail	4%	9%	42%
Madison	$32,437	13%	Education/health, Prof/admin, Retail, Finance/real estate	6%	16%	47%
Scott	$15,549	23%	Manufacturing, Education/health, Construction	6%	23%	52%
Leake	$16,183	20%	Manufacturing, Education/health, Forestry/Ag, Retail	6%	17%	49%
Neshoba	$16,961	17%	Education/health, Entertainment/ recreation, Retail	8%	26%	45%
Winston	NA	NA	NA	NA	NA	NA
Attala	NA	NA	NA	NA	NA	NA
Kemper	NA	NA	NA	NA	NA	NA
Choctaw	NA	NA	NA	NA	NA	NA

NA=not available

Section 303(d) Listings and Total Maximum Daily Loads

Table B.8 lists monitored waterbodies in the Ross Barnett watershed included on the draft 2010 303(d) List of Impaired Water Bodies[19]. The 2010 list includes only monitored waterbodies. The 2010 list is currently in draft format; however, final approval by the Mississippi Commission on Environmental Quality is anticipated. Table B.9 lists the TMDLs completed by MDEQ[20] and summarizes recommended pollutant reductions identified in the TMDLs.

[18] http://factfinder.census.gov, accessed January 2010
[19] http://www.deq.state.ms.us/MDEQ.nsf/page/TWB_Total_Maximum_Daily_Load_Section?OpenDocument
[20] *Ibid*.

Table B.8. Waterbodies in the watershed included on the 2010 303(d) list.

Stream	Waterbody ID	Impaired Uses	Pollutant
Owl Creek	501111	Fish and Wildlife	Biological impairment
Sugar Bogue	507612	Fish and Wildlife	Biological impairment
Town Creek	503211	Fish and Wildlife	Biological impairment
Unnamed tributary to Tallahaga Creek	500712	Fish and Wildlife	Biological impairment

Table B.9. Completed TMDLs and recommended pollutant reductions for the watershed.

Waterbody and ID	Pollutant	Nonpoint Source Reduction	Point Source Reduction	Approval Date
Bogue Chitto Creek MS121BE	Nutrients, organic enrichment/ low DO	TP – 60%	NA	December 18, 2008
	Sediment	Stable sediment yield	NA	March 25, 2009
	Legacy pesticides	NA	NA	January 4, 2007
Cane Creek MS151E1	Sediment	Stable sediment yield	NA	March 25, 2009
Coffee Bogue Creek MS149E	Pathogens	Summer – 44% Winter – 23%	NA	December 18, 2008
	Nutrients, organic enrichment/ low DO	TP – 60%	NA	March 25, 2009
	Sediment	Stable sediment yield	NA	March 25, 2009
Conehatta Creek MS137CE	Sediment	Stable sediment yield	NA	March 25, 2009
	PCBs	NA	NA	January 13, 2004
Eutacutachee Creek MS152E	Sediment	Stable sediment yield	NA	March 25, 2009
	Nutrients, organic enrichment/ low DO	TP – 60%	NA	June 2009
Fannegusha Creek MS151FE	Sediment	Stable sediment yield	NA	June 28, 2004
	Pathogens	Summer – 73% Winter – 44%		March 2009
Hughes Creek MS122E1	Sediment	Stable sediment yield	NA	March 2009
	Nutrients, ammonia toxicity, organic enrichment/ low DO	TP – 48%	TN – 42% TP-48%	June 2009
Hurricane Creek MS151FM1	Sediment	Stable sediment yield	NA	June 28, 2004

Table B.9. Completed TMDLs and recommended pollutant reductions (continued).

Waterbody and ID	Pollutant	Nonpoint Source Reduction	Point Source Reduction	Approval Date
Lobutcha Creek (Upper and lower) MS132E	Pathogens	Septic tanks – 80% Cattle – 95%	NA	December 15, 1999
Lobutcha Creek MS132E	Sediment	Stable sediment yield	NA	March 25, 2009
Nanih Waiya Creek MS120E	Organic enrichment / low DO and nutrients	TP – 63%	TN – 0 TP – 0 TBODu – 0	December 18, 2008
	Legacy Pesticides	NA	NA	December 18, 2008
	Pathogens	Septic tanks – 80% Cattle – 95%	NA	December 15, 1999
	Sediment	Stable sediment yield	NA	March 25, 2009
Noxapater Creek MS123NE	Organic enrichment / low DO and nutrients	TP – 59%	TN – 0 TP – 0 TBODu – 0	December 18, 2008
	Legacy Pesticides	NA	NA	January 4, 2007
	Sediment	Stable sediment yield	NA	March 25, 2009
Pearl River (Pearl River Basin) MSUMPRLR2E MSUPRLRE	Nutrients	TP – 56%	TN – 0 TP – 56% TBODu – 0	June 29, 2009
	Pathogens	Septic tanks – 80% Cattle – 95%	NA	December 15, 1999
	Sediment	Stable sediment yield	NA	March 25, 2009
Pearl River (Leake and Neshoba) MSLMPRLRE	Legacy Pesticides	NA	NA	January 4, 2007
Pearl River (Leake, Madison, Rankin, and Scott counties) MSUMPRLR2E	Legacy Pesticides	NA	NA	January 4, 2007
Pearl River MSUMPRLR2M	Mercury	NA	None, but monitoring from some point sources is recommended.	January 12, 2004

Table B.9. Completed TMDLs and recommended pollutant reductions (continued).

Waterbody and ID	Pollutant	Nonpoint Source Reduction	Point Source Reduction	Approval Date
Pelahatchie Creek MS153PE	Pathogens	Summer – 30% Winter – 27%		March 2009
	Legacy Pesticides	NA	NA	January 4, 2007
	Sediment	Stable sediment yield	NA	March 25, 2009
	Nutrients	TP – 60%	None	June 2009
Pinishook Creek MS125PE	Pathogens	Septic tanks – 80% Cattle – 95%	NA	December 15, 1999
	Sediment	Stable sediment yield	NA	March 25, 2009
Red Cane Creek MS151FM2	Sediment	Stable sediment yield	NA	June 28, 2004
Shockaloo Creek MS143E	Organic enrichment / low DO and nutrients	TN – 63% TP – 80% TBODu – 29%	TN – 0 TP – 0 TBODu – 22% to 89%	June 29, 2009
	Pathogens	Summer – 14% Winter – 38%		December 18, 2008
	Sediment	Stable sediment yield	NA	March 25, 2009
Standing Pine Creek	Pathogens	Septic tanks – 80% Cattle – 95%	87%	December 15, 1999
Tallabogue Creek MS142E1	Organic enrichment / low DO and nutrients	TN – 63% TP – 80% TBODu – 29%	TN – 0 TP – 0 TBODu – 22% to 89%	June 29, 2009
	Sediment	Stable sediment yield	NA	March 25, 2009
Tallahaga Creek MS122E	Sediment	Stable sediment yield	NA	March 25, 2009
	Pathogens	Septic tanks – 80% Cattle – 95%	92%	December 15, 1999
Tibby Creek MS146TE	Pathogens	Summer – 61% Winter – 94%		December 18, 2008
Tuscolameta Creek MS144E	Organic enrichment / low DO and nutrients	TN – 63% TP – 80% TBODu – 29%	TN – 0 TP – 0 TBODu – 22% to 89%	June 29, 2009
	Sediment	Stable sediment yield	NA	March 25, 2009
Yockanookany River MS146YE and MS147M1	Mercury	NA	Monitoring recommended	January 12, 2004
	PCBs	NA	NA	January 13, 2004

TN = total nitrogen, TP = total phosphorous, NA = not applicable

Fish Consumption Advisories

Fish consumption advisories are active for Yockanookany River, Pearl River upstream of Highway 25, and Little Conehoma Creek, located in Attala and Leake counties. Contaminants of concern for the advisories are polychlorinated biphenyls (PCBs) and mercury. Mercury is the contaminant of concern for Yockanookany River, and Pearl River upstream of Highway 25 (MDEQ 2004a). PCBs are the contaminants of concern for Little Conehoma Creek and Yockanookany River from US Highway 35 to the Pearl River (Figure B.16).

The PCBs in fish in Little Conehoma Creek and the Yockanookany River came from a Texas Eastern Pipeline Compressor Station located near Kosciusko. During the time that PCBs were in use at the compressor station (use of PCBs at this compressor station was discontinued in 1979), waste oil containing PCBs was disposed of in onsite pits. PCBs migrated from these disposal pits to Conehoma Creek and the Yockanookany River. Texas Eastern entered into a consent order with EPA in 1994, and as of 1997, the site was remediated. Fish tissue sampling in 1987 resulted in a fish consumption advisory being issued for Conehoma Creek and the Yockanookany River and the 303(d) listing of these waterbodies. Fish tissues in these stream segments were sampled again in 2003. The 2003 fish tissue data indicate the fish consumption advisory should remain in effect; however, the concentrations of PCBs in the fish tissue have decreased (MDEQ 2004b).

The primary source of mercury to the Yockanookany River and Pearl River is believed to be atmospheric deposition of mercury emitted from regional and global sources. MDEQ has issued a moratorium on additional NPDES-permitted point source discharges containing mercury to the Yockanookany River and Pearl River.

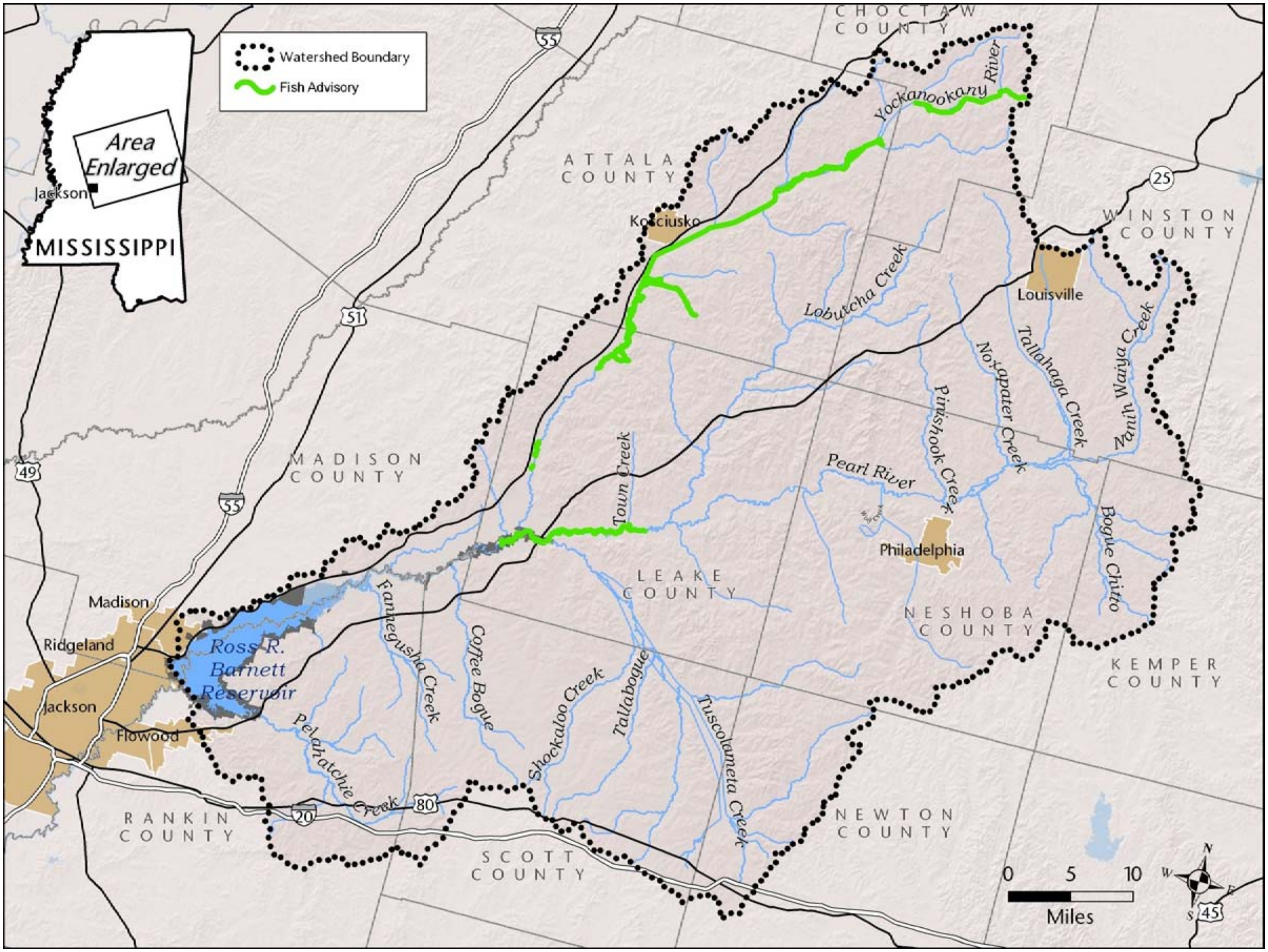

Figure B.16. Fish consumption advisories active in the Ross Barnett Reservoir watershed.

Hydrologic Unit Codes

The US Geological Survey (USGS) delineates watersheds into smaller areas commonly known as 12-digit hydrologic unit codes (HUC12s). There are 87 HUC12s located within the Reservoir watershed. HUC12 boundaries are an important consideration in determining priority watersheds and targeting management practices because they define smaller-sized catchments at a scale on which implementation can be most efficiently managed. The boundary lines for each HUC12 are shown on Figure B.17. The description, identification number, and area of each HUC12 are listed in Table B.10. The plans developed under the Ross Barnett Reservoir Initiative encompass the entire drainage area of the Reservoir, an area of approximately 3,050 square miles. The HUC12s were divided into three major subwatershed groups based on proximity to the Reservoir. The major subwatershed delineations are also shown on Figure B.17. The groups were defined as the area approximately 10 times as large as the size of the Reservoir surface area (1x:10x), the area between 10 and 50 times as large as the reservoir surface area (10x:50x), and the area above the 50x boundary (above 50x).

Proximity to the Reservoir was considered in determining the potential for pollutants originating in the watershed reaching the Reservoir through tributary and overland flow inputs. Areas closer to the Reservoir have increased likelihood of contributing pollutants, whereas pollutants originating from areas located at greater distances from the Reservoir may be removed by biological transformation processes or settling. Thus, focusing resources on areas closer to the Reservoir in the initial phases of implementation of this plan was a reasonable approach for optimizing the cost-benefits of water quality improvements achieved from implementation of management practices.

Major sub-watershed delineations were based on a ratio of the Reservoir surface area relative to the size of the Reservoir drainage area. Three areas were delineated for surface area/drainage area ratios of 1x:10x, 10x:50x, and above 50x the surface area. Boundary lines were drawn based on existing HUC12s within the Reservoir's watershed.

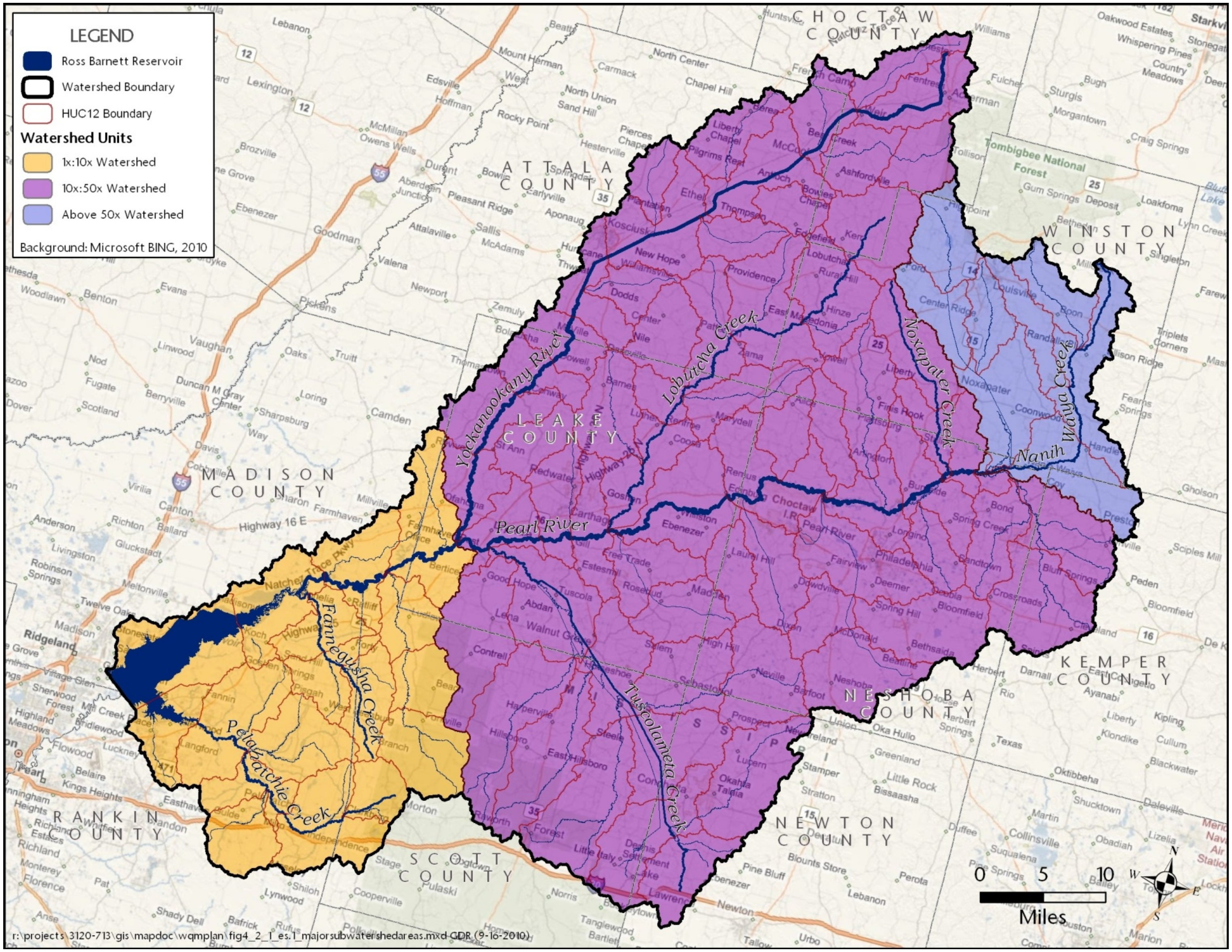

Figure B.17. Boundary lines for 12-digit HUCs in the Ross Barnett Reservoir watershed.

Table B.10. Watershed area, HUC12 ID number, name, and area of each HUC12 in the watershed.

Watershed	HUC12 ID No.	HUC12 Name	Area (acre)s
1x:10x	031800020305	Snake Creek - Pelahatchie Creek	14,179
1x:10x	031800020302	Ashlog Creek - Pelahatchie Creek	31,859
1x:10x	031800020304	Hollybush Creek - Clear Creek	24,167
1x:10x	031800020101	Sugar Bogue - Coffee Bogue	24,143
1x:10x	031800020306	Riley Creek - Pelahatchie Creek	33,296
1x:10x	031800020303	Eutacutachee Creek	17,880
1x:10x	031800020301	Upper Pelahatchie Creek	12,234
1x:10x	031800020307	Mill Creek - Pelahatchie Creek	18,203
1x:10x	031800020201	Hurricane Creek - Fannegusha Creek	17,299
1x:10x	031800020202	Red Cane Creek - Fannegusha Creek	15,027
1x:10x	031800020404	Mill Creek - Pearl River	38,947
1x:10x	031800020102	Beach Creek - Coffee Bogue	15,046
1x:10x	031800020203	Deer Creek - Fannegusha Creek	16,059
1x:10x	031800020403	Cane Creek - Pearl River	25,393
1x:10x	031800020103	Lee Branch - Coffee Bogue	15,796
1x:10x	031800020402	Lake Creek - Pearl River	22,541
1x:10x	031800020401	Pellaphalia Creek - Pearl River	32,702
10x:50x	031800011203	Panther Creek - Yockanookany River	25,521
10x:50x	031800011104	Lower Tibby Creek	16,582
10x:50x	031800011201	Ethel - Hurricane Creek	10,734
10x:50x	031800011206	Leflore Creek - Yockanookany River	30,559
10x:50x	031800010404	Ocobla Creek	12,777
10x:50x	031800011403	Rice Creek - Pearl River	32,090
10x:50x	031800011306	Shiola Creek	14,533
10x:50x	031800010708	Gray Lake - Lobutcha Creek	21,678
10x:50x	031800010801	Upper Tuscolameta Creek	20,971
10x:50x	031800010803	Warrior Creek - Tuscolameta Creek	30,568
10x:50x	031800010904	Hontokalo Creek	37,639
10x:50x	031800010901	Bogue Faliah - Tuscolameta Creek	27,345
10x:50x	031800010905	Tallabogue Creek	33,711
10x:50x	031800011001	Shockaloo Creek	38,638
10x:50x	031800010802	Conehatta Creek	32,708
10x:50x	031800010903	Lower Sipsey Creek	25,201
10x:50x	031800010906	North & South Canals - Tuscolameta Creek	24,257

Table B.10. Watershed area, HUC12 ID number, name, and area of each HUC12 (continued).

Watershed	HUC12 ID No.	HUC12 Name	Area (acre)s
10x:50x	031800011002	Balucta Creek	33,993
10x:50x	031800010902	Upper Sipsey Creek	29,419
10x:50x	031800011003	Lower Tuscolameta Creek	32,963
10x:50x	031800010501	Coonshuck Canal - Fulton Canal	29,235
10x:50x	031800011401	Upper Standing Pine Creek	19,709
10x:50x	031800011402	Lower Standing Pine Creek	18,203
10x:50x	031800010502	Lonsilocher Canal - Kentawka Canal	13,387
10x:50x	031800011406	Yellow Creek - Pearl River	16,437
10x:50x	031800010503	Cushtusia Creek	31,562
10x:50x	031800010605	Luneluah Creek	13,703
10x:50x	031800011307	Lower Yockanookany River	15,884
10x:50x	031800010606	Beasha Creek	20,888
10x:50x	031800011404	Pollard Creek - Pearl River	17,711
10x:50x	031800011405	Pelaphalia Creek - Pearl River	17,790
10x:50x	031800010504	Lower Kentawka Canal	31,666
10x:50x	031800010201	Land Creek - Bogue Chitto	33,136
10x:50x	031800011305	Ninemile Creek - Yockanookany River	22,424
10x:50x	031800010202	Owl Creek	19,517
10x:50x	031800010603	Woodard Creek - Pearl River	18,984
10x:50x	031800010607	Lukfapa Creek	32,008
10x:50x	031800010203	Cow Creek - Bogue Chitto	28,877
10x:50x	031800011304	Merchant Creek - Yockanookany River	13,722
10x:50x	031800010707	Cobbs Creek	21,883
10x:50x	031800010604	Hooper Mill Creek - Pearl River	13,836
10x:50x	031800011303	Socki Creek - Yockanookany River	14,964
10x:50x	031800010405	Hurricane Creek - Pearl River	23,345
10x:50x	031800010602	Jofuska Creek	13,605
10x:50x	031800010705	Bibalucta Creek	19,765
10x:50x	031800010402	Lower Noxapater Creek	10,761
10x:50x	031800010403	Joel Creek - Pearl River	11,424
10x:50x	031800010704	Pailey Creek	19,757
10x:50x	031800011301	Conehoma Creek	11,549
10x:50x	031800010601	Pinishook Creek	27,021
10x:50x	031800010706	Archie Creek - Lobutcha Creek	30,336

Table B.10. Watershed area, HUC12 ID number, name, and area of each HUC12 (continued).

Watershed	HUC12 ID No.	HUC12 Name	Area (acre)s
10x:50x	031800011302	Bokshenya Creek - Yockanookany River	17,790
10x:50x	031800010401	Upper Noxapater Creek	22,606
10x:50x	031800010703	Bear Creek - Lobutcha Creek	33,663
10x:50x	031800011204	Ethel - Turkey Creek	12,614
10x:50x	031800010702	Dry Creek - Lobutcha Creek	28,283
10x:50x	031800011205	Kosciusko - Hurricane Creek	10,788
10x:50x	031800010701	Reedy Creek - Lobutcha Creek	27,158
10x:50x	031800011202	Black Creek - Cole Creek	18,546
10x:50x	031800011103	Upper Tibby Creek	16,129
10x:50x	031800011105	Dry Creek - Yockanookany River	17,839
10x:50x	031800011101	Upper Yockanookany River	21,503
10x:50x	031800011102	Besa Chitto	13,237
Above 50x	031800010103	Hughes Creek	13,915
Above 50x	031800010302	Town Creek	14,665
Above 50x	031800010303	Upper Nanih Waiya Creek	29,080
Above 50x	031800010301	Murphy Creek	15,417
Above 50x	031800010304	Lower Nanih Waiya Creek	30,446
Above 50x	031800010104	Lower Tallahaga Creek	29,361
Above 50x	031800010102	Middle Tallahaga Creek	16,974
Above 50x	031800010101	Upper Tallahaga Creek	20,570

The three major sub-watersheds are described below:

1. The watershed area that is approximately 10 times larger than the Reservoir's surface area (1x:10x subwatershed),
2. The watershed area outside of the 1x:10x area extending to an area approximately 50 times larger than the Reservoir's surface area (10x:50x subwatershed), and
3. The watershed area above the 50x boundary (above 50x subwatershed).

1x:10x Subwatershed

The 1x:10x subwatershed includes areas within Madison, Rankin, Scott, and Leake counties. The area includes portions of the cities of Madison, Ridgeland, Flowood, Pelahatchie, and Morton and the town of Langford (Figure B.18). Forest/woodland is the dominant land use, followed by pasture/grassland (Table B.11). Developed areas are found primarily around Pelahatchie Bay, on some parts of the shoreline areas in Madison and Rankin counties, and near the Reservoir dam. Row-crop agriculture makes up only 4% of the land use in the 1x:10x subwatershed and less than 1% of the remainder of the Reservoir drainage area. The majority of the row-crop farming in the watershed occurs in the northeastern portion of Rankin County and western Scott County. There are also several poultry processing facilities located in this subwatershed.

Table B.11. Land use in the 1x:10x subwatershed.

Land Use	Square Miles	Percentage
Agricultural Crops	22	3.7%
Developed	37	6.3%
Forest/Woodland	248	42.4%
Open Water	42	7.1%
Pasture/Grassland	101	17.2%
Shrubland	66	11.3%
Wetlands	70	12.0%
Total	585	**100.0%**

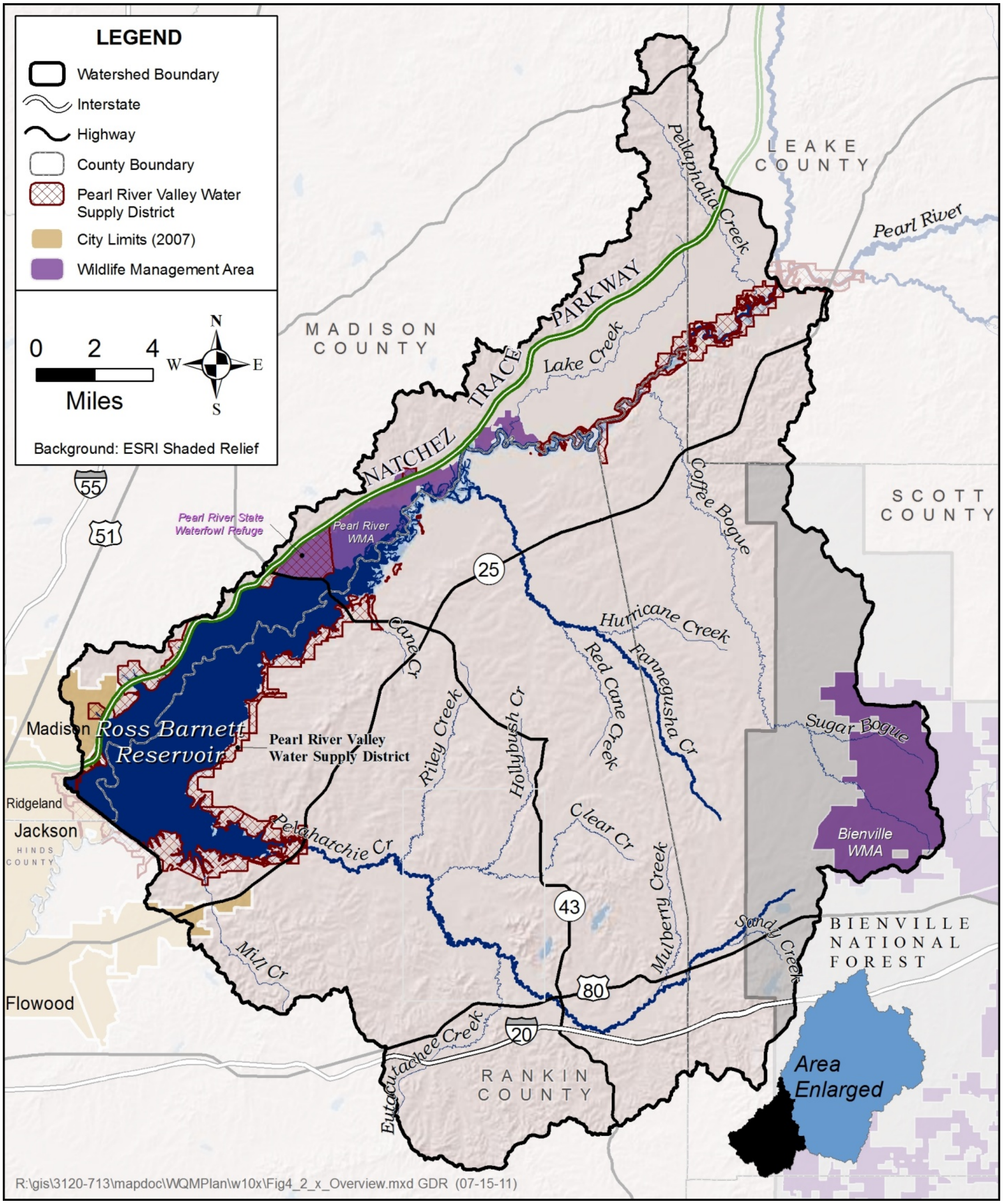

Figure B.18. Ross Barnett Reservoir watershed area within the 1x:10x subwatershed boundary.

Major tributaries of the Reservoir and Pearl River within the 1x:10x subwatershed include Fannegusha Creek, Pelahatchie Creek, and Coffee Bogue. Major roads include parts of Interstate 20 and Highway 25, and the Natchez Trace. The area also contains parts of Bienville National Forest.

The 1x:10x watershed includes 17 HUC12s (Table B.10). The HUC12s located in the 1x:10x subwatershed also coincide with the 17 HUC12s prioritized by the Pearl River Basin Team and EPA Region 4.

10x:50x Subwatershed

Land management activities within the 10x:50x subwatershed are expected to impact water quality in the Reservoir. However, the effects of pollutant pressures originating from this area may be reduced due to the travel time and distance from the Reservoir. The land area in the 1x:50x subwatershed is dominated by forest land use (which covers approximately 53% of the subwatershed) and pasture/grassland (which covers 19% of the subwatershed) (Table B.12).

Major tributaries of the Pearl River within the 10x:50x watershed include Tuscolameta Creek, Lobutcha Creek, and the upper portion of the Yockanookany River. Smaller tributaries include Standing Pine Creek, Noxapater Creek, Bogue Chitto, and Pinishook Creek. Counties include Scott, Newton, Leake, Neshoba, Kemper, Choctaw, Winston, and Attala. The cities of Forest, Philadelphia, Carthage, Kosciusko, Ackerman, and Ethel are located in this subwatershed. Major roads are Natchez Trace, Highway 12, Interstate 20, Highway 43, Highway 482, and Highway 16. Parts of the Choctaw Indian reservation are also contained in this subwatershed.

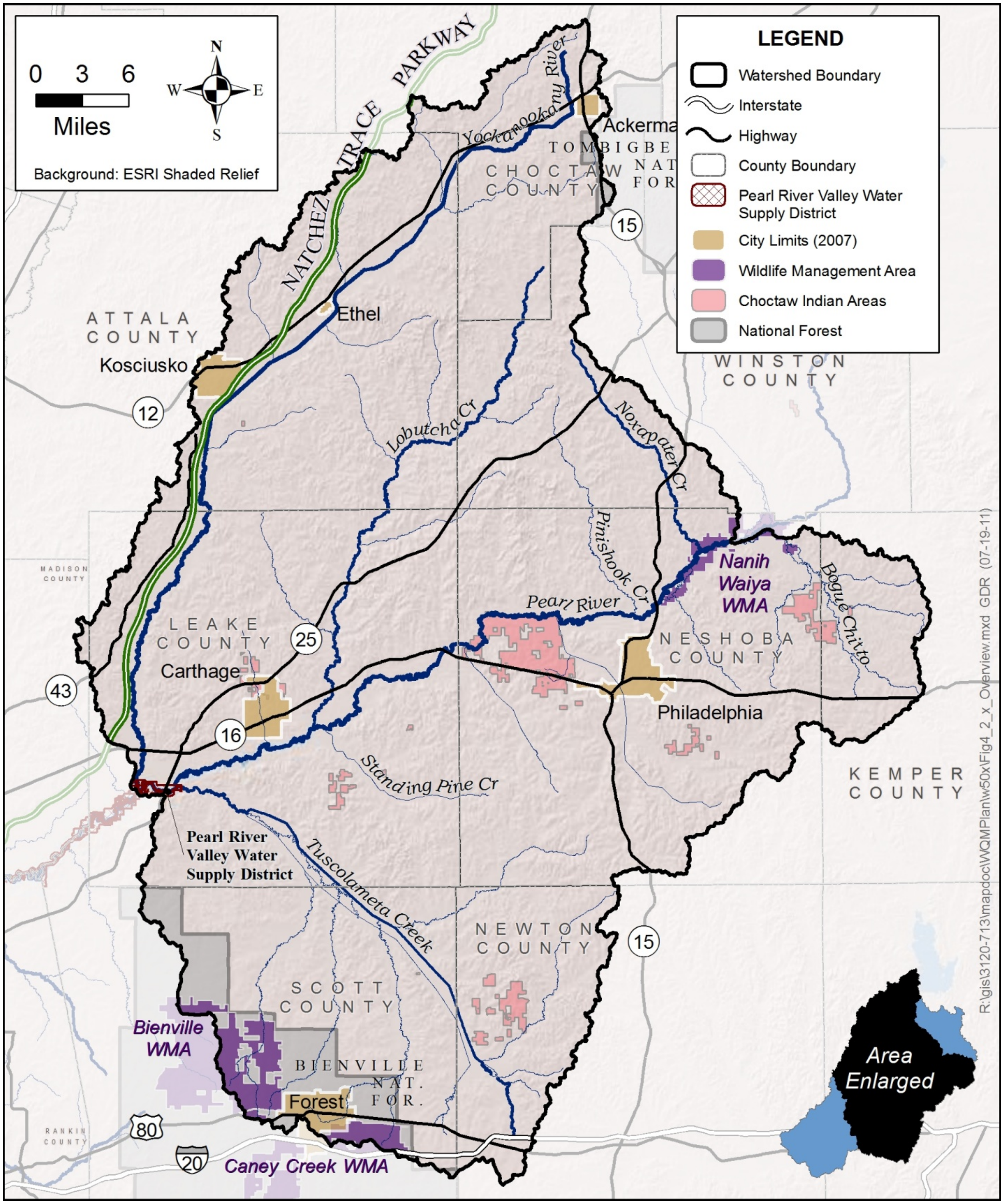

Figure B.19. Ross Barnett Reservoir watershed area within the 10x:50x subwatershed boundary.

Table B.12. Land use in the 10x:50x subwatershed.

Land Use	Square Miles	Percentage
Agricultural Crops	8	0.4%
Developed	135	6.2%
Forest/Woodland	1,167	53.2%
Open Water	11	0.5%
Pasture/Grassland	408	18.6%
Shrubland	285	13.0%
Wetlands	180	8.2%
Total	2,195	**100.0%**

Above 50x Subwatershed

The area beyond the 1x:50x watershed area includes the headwaters of the Pearl River, which forms at the confluence of Nanih Waiya Creek and Tallahaga Creek. Pollutants originating in this portion of the watershed are unlikely to directly impact the Ross Barnett Reservoir; however, they do affect water quality in upper reaches of the Pearl River.

Counties in this subwatershed include Kemper, Noxubee, Winston, and a small part of Choctaw. Nanih Waiya State Park and portion of the Tombigbee National Forest are included in this subwatershed. This area contains the city of Louisville, as well as Highway 14. The dominant land uses in this subwatershed are forest/woodland (45%) and pasture/grassland (26%). Land uses in this subwatershed are shown in Table B.13.

Table B.13. Land use in the above 50x subwatershed.

Land Use	Square Miles	Percentage
Agricultural Crops	2	0.8%
Developed	18	6.9%
Forest/Woodland	120	45.3%
Open Water	3	1.1%
Pasture/Grassland	69	25.9%
Shrubland	32	12.2%
Wetlands	21	7.9%
Total	266	**100.0%**

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ANALYSIS OF WATER QUALITY MONITORING DATA FROM ROSS BARNETT RESERVOIR WATERSHED

OCTOBER 31, 2011

ANALYSIS OF WATER QUALITY MONITORING DATA FROM ROSS BARNETT RESERVOIR WATERSHED

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October 31, 2011

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1.0 INTRODUCTION

Available monitoring data were analyzed to evaluate loading of total phosphorus (TP), total nitrogen (TN), and total suspended solids (TSS) into the Ross Barnett Reservoir. Available data from the majority of the Reservoir tributary sites typically included flows and water chemistry from a single sample, or did not include flows at all. This analysis used only data sets containing flows *and* TP, TN, or TSS for multiple samples. Reasonably complete water quality data sets were available from the Edinburg station on the Pearl River and the Revive station on the Yockanookany River (Figure 1.1). The analysis focuses on these two stations. Flow measurements were also available for the Edinburg station on the Pearl River, but not at the Revive station on the Yockanookany River. For the analyses, Yockanookany River flow measurements collected just downstream of Revive, at Ofahoma, were used with the water quality data from Revive.

These data sets included water quality data from the US Environmental Protection Agency's (EPA) Legacy STORET database, the Mississippi Department of Environmental Quality's (MDEQ) Ambient Monitoring Program, MDEQ's WADES database, and the US Geological Survey (USGS) flow gages. These data sources and periods of record (PORs) are summarized in Table 1.1. Except for flow data, sampling during the time periods indicated in Table 1.1 were either monthly or bimonthly.

Table 1.1. Data sources and POR for analysis of TP, TN, and TSS loadings to Ross Barnett Reservoir.

Location	Data Source	POR	Parameters			
			TN	**TP**	**TSS**	**Flow**
Pearl River at Edinburg	MDEQ WADES	01/2000 – 12/2001	X	X	X	
	USGS Stream Gage	1963 – 2009				X
	Legacy STORET	11/1962 – 03/1967			X	
		08/1975 – 06/1977			X	
		01/1993 – 12/1998	X	X	X	
Yockanookany River near Revive	MDEQ Ambient Monitoring	12/1996 – 02/2001	X	X	X	
	Legacy STORET					
Yockanookany River at Ofahoma	USGS Stream Gage	1943 – 2009				X

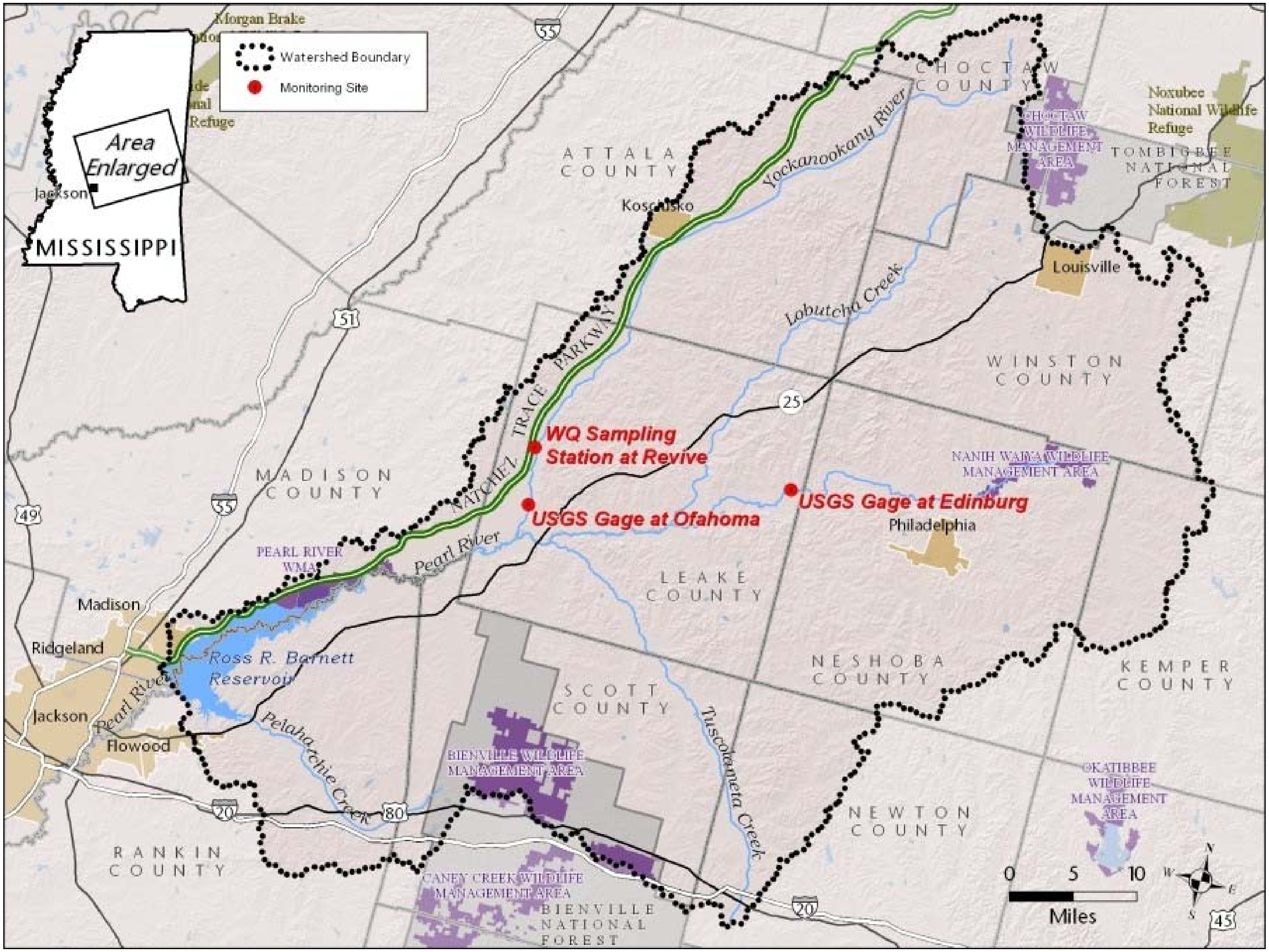


Figure 1.1. Sampling locations on the Pearl River and the Yockanookany River.

The objective of the analysis was to compute daily and annual loads of TN, TP, and TSS, and, where possible, to evaluate:

1. Temporal variation in TP, TN and TSS concentrations and loads:
   a. Annual,
   b. Wet versus dry season, and
   c. Wet versus dry years.

2. Loading differences among watersheds; and
3. Covariation among flow and TN, TP, and TSS.

This summary also discusses additional sampling data collected in the Pearl River and Pelahatchie Creek. There is not a sufficient record of data at these sites to conduct a meaningful analysis of temporal variation or covariation. A complete inventory of water quality monitoring data collected in the Reservoir watershed is available in the *Comprehensive Water Quality Monitoring Plan*.

2.0 DATA ANALYSES

To calculate daily loads for each sampling date, the parameter concentration obtained from grab samples was multiplied by the total discharge on the sampling day, with appropriate unit conversions. Flow data were available as daily mean flows. No formal statistical analyses were performed beyond simple linear regressions. In general, data were evaluated by visual examination of scatter plots and summary tables.

3.0 PEARL RIVER AT EDINBURG

3.1 Flows

A comparison of flows on the sampling days from January 1993 through December 2001 (excluding 1999, when water quality sampling did not occur) with all days during that period is presented in Table 3.1. Table 3.1 indicates that the distribution of flows on sampling days versus all days is comparable with a slight negative bias on sampling days. A plot of average annual flows (Figure 3.1) indicates that average annual flows generally ranged from approximately 600 to 1,800 cubic feet per second (cfs) between 1963 and 2009.

Table 3.1 Pearl River (Edinburg) average daily flow on sampling days versus all days (1993 through 2001, excluding 1999).

Metric		Average Daily Flow (cfs)	
		Sampling Days	**All Days**
Percentile	10th	19	19
	25th	75	57
	50th	206	272
	75th	1,125	1,290
	90th	2,370	3,060
Average		881	1,065
Standard Deviation		1,447	1,820
Maximum		7,280	18,100
Minimum		3	1

3.2 Annual Loadings

A summary of TSS and nutrient concentrations and loading distributions for the Pearl River is presented in Table 3.2. Annual TP, TN, and TSS loadings are summarized in Table 3.3. TP, TN, and TSS concentrations and loadings during 2000 were an order of magnitude below typical values. Low loading values were due to both low concentrations (Table 3.3) and low flows (Figure 3.1) during 2000.

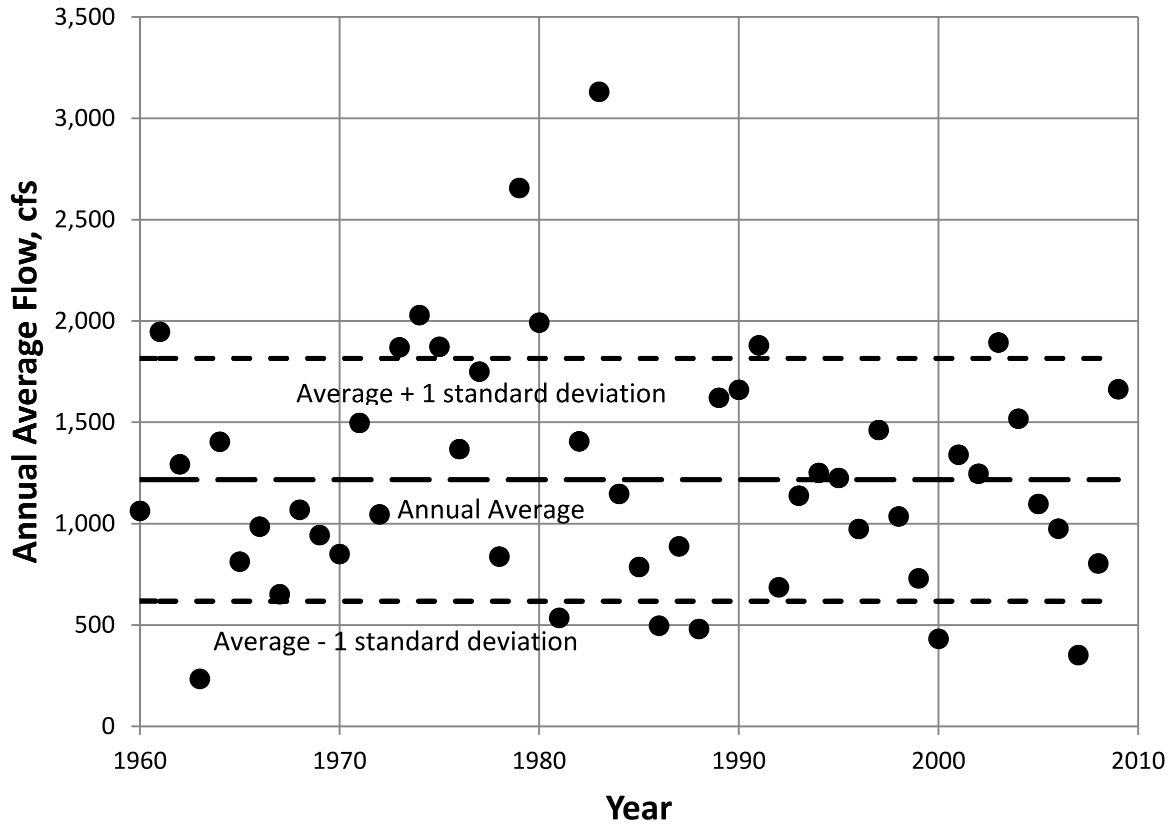


Figure 3.1. Pearl River (Edinburg) annual average flows, 1963 through 2009.

Table 3.2. Summary of Pearl River (Edinburg) nutrient concentration and loading distributions (1993 through 2001, excluding 1999).

Metric		Concentrations (mg/L)			Loadings (kg/day)		
		TP	TN	TSS	TP	TN	TSS
Percentile	25th	0.060	0.655	4.0	14	190	1.09E+03
	50th	0.090	0.950	8.0	48	438	4.11E+03
	75th	0.120	1.240	12.5	165	2,628	3.20E+04
Average		0.100	0.996	15.9	178	1,794	5.38E+04
Standard Deviation		0.077	0.462	37.309	314	2,690	1.79E+05
Maximum		0.440	2.290	286.0	1,562	11,652	1.28E+06
Minimum		0.010	0.170	1.0	0.3	4	2.84E+01

Table 3.3 Pearl River (Edinburg) average annual nutrient loads based on monthly or bimonthly sampling (1993 through 2001, excluding 1999).

Year	Total Phosphorus (kg/day)			Total Nitrogen (kg/day)			Total Suspended Solids (kg/day)		
	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N
1993	279	472	6	3,428	3,828	6	2.32E+5	5.14E+5	6
1994	120	150	6	860	878	6	1.26E+4	1.60E+4	6
1995	369	606	6	2,878	4,401	6	4.48E+4	8.48E+4	6
1996	153	192	6	1,659	1,669	6	2.99E+4	4.44E+4	6
1997	118	125	11	1,975	1,632	11	2.37E+4	3.28E+4	11
1998	316	447	10	2,554	3,714	10	1.04E+5	1.89E+5	10
2000	23	29	9	235	217	9	1.62E+3	1.60E+3	9
2001	113	115	9	1,186	1,274	9	1.68E+4	2.48E+4	9

3.3 Concentrations and Loadings Versus Flows

Table 3.4 summarizes TP, TN and TSS concentrations and loadings at low, intermediate, and high flows. At this scale (i.e., among flow categories), TP and TN concentrations show no correlation with flow at low and intermediate flows and a slight decrease at high flows. In contrast, TSS shows a strong correlation with flow. Loadings for TN, TP and TSS show a strong correlation with flow.

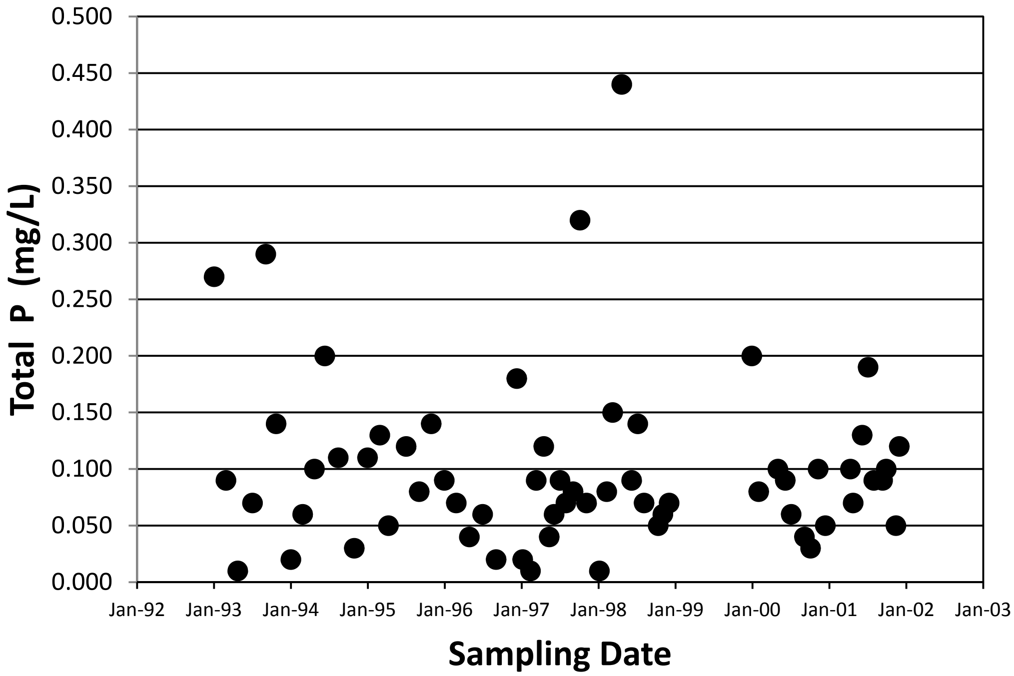
Table 3.4. Pearl River (Edinburg) average daily nutrient loadings and concentrations at base, intermediate, and high flow (1993 through 2001, excluding 1999).

Flow Category	Concentration (mg/L)			Loading (kg/day)		
	TP	TN	TSS	TP	TN	TSS
Base Flow, ≤ 20th percentile; < 50 cfs	0.104	1.012	7	6	55	3.91E+02
Intermediate Flow, 40-60th percentile;189-606 cfs	0.103	1.029	10	82	888	8.80E+03
High flow ≥ 80th percentile; ≥ 1,830 cfs	0.091	0.831	51	635	6,854	2.91E+05

3.3.1 Total Phosphorus Concentrations and Loadings Versus Flows

Scatter plots of TP concentrations versus sampling date and flows are provided on Figure 3.2. TP concentrations varied by an order of magnitude among samples. Interquartile TP concentrations differed by a factor of two (0.06 versus 0.12 mg/L; Table 3.2). TP concentrations are uncorrelated with flow, with some of the lowest TP concentrations occurring at the highest flows (Table 3.4 and Figure 3.2).

Scatter plots of TP loading versus sampling date and flows are provided on Figure 3.3. TP loading varied by nearly two orders of magnitude among samples. Interquartile TP loading values differed by a factor of approximately ten (14 versus 160 kg/day; Table 3.2). TP loading was strongly related to flow (Figure 3.3), with the greatest increase in loading occurring at approximately 1,000 cfs, which is the 67th percentile among all daily flows from 1963 through 2009.



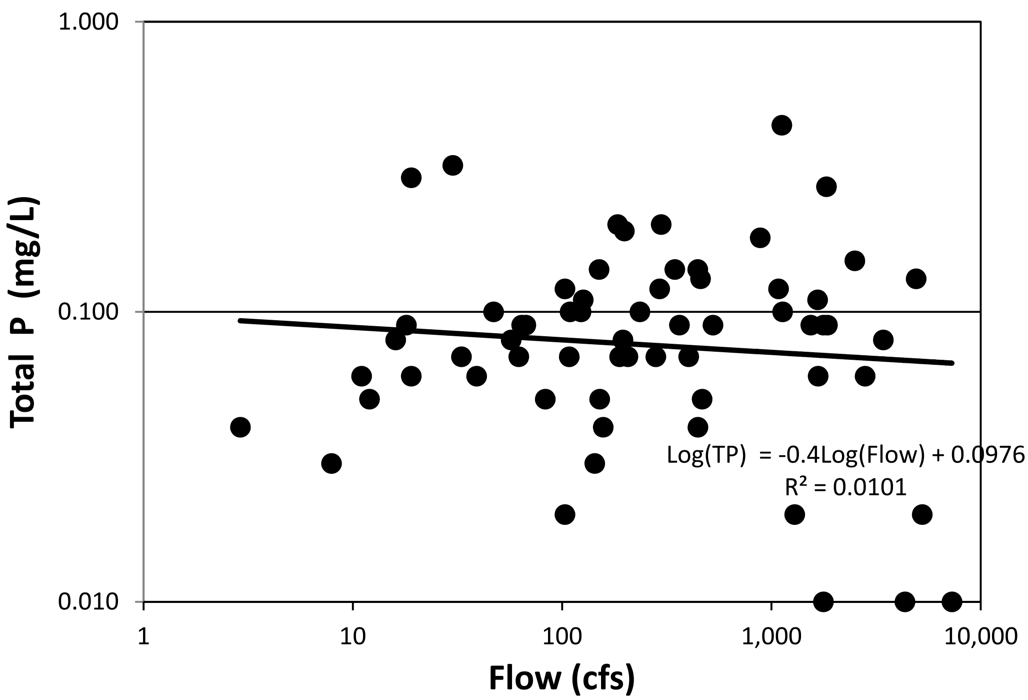


Figure 3.2. Pearl River (Edinburg) total phosphorus concentration versus sampling date (top figure) and flow (bottom figure), 1993 through 2001.

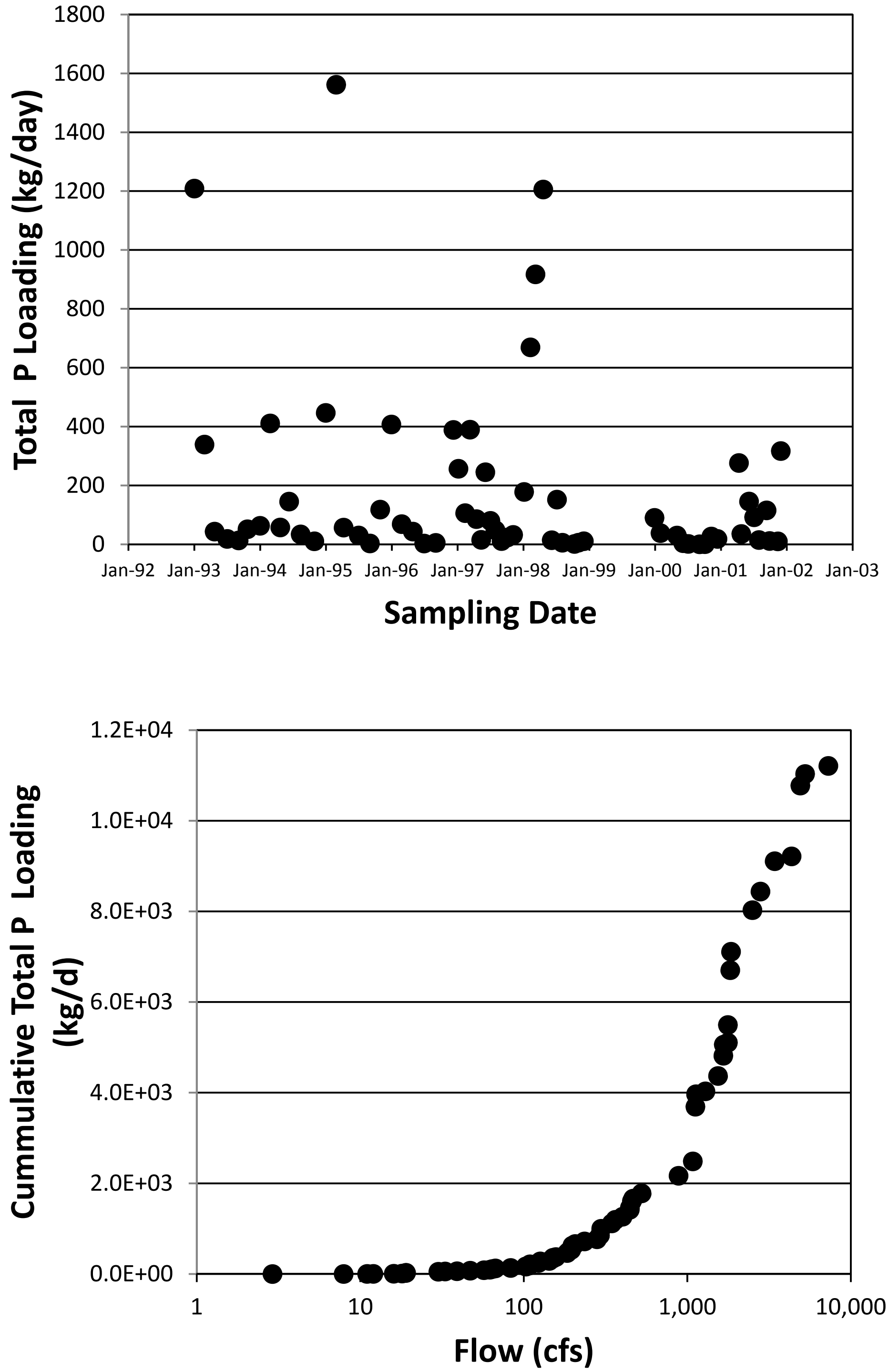


Figure 3.3. Pearl River (Edinburg) total phosphorus loading versus sampling date (top figure) and cumulative loading versus flow (bottom figure), 1993 through 2001.

3.3.2 Total Nitrogen Concentrations and Loadings Versus Flow

Scatter plots of TN concentrations versus sampling date and flows are provided on Figure 3.4. TN concentrations varied by an order of magnitude among samples. Interquartile TP concentrations differed by a factor of two (0.66 versus 1.24 mg/L; Table 3.2). TN concentrations are uncorrelated with flow, with some of the lowest TN concentrations occurring at the highest flows (Table 3.4 and Figure 3.4).

Scatter plots of TN loading versus sampling date and flows are provided on Figure 3.5. TN loading varied by four orders of magnitude among samples. Interquartile TN loading values differed by over a factor of ten (190 versus 2,690 kg/day; Table 3.2). TN loading was strongly related to flow (Figure 3.5), with the greatest increase in loading occurring at approximately 1,000 cfs, which is the 67th percentile among all daily flows from 1963 through 2009.

3.3.3 TSS Concentrations and Loadings Versus Flow

Scatter plots of TSS concentrations versus sampling date and flows are provided on Figure 3.6. TSS concentrations varied by over an order of magnitude among samples. Interquartile TSS concentrations differed by roughly a factor of 3 (5.0 versus 12.5 mg/L; Table 3.2). Examination of Figure 3.6 (top figure) suggests an overall decrease in TSS concentrations between the years of 1962 through 1977 and the years of 1993 through 2001. Because TSS concentrations are correlated with flow (Table 3.4), differences between TSS concentrations in the 1962 through 1977 data set were compared with concentrations from the later data set (1993 through 2001) by examining flow versus TSS for the two time periods (Figure 3.6, bottom figure). Examination of Figure 3.6 indicates a clear difference in TSS concentrations between the two time periods, with the highest concentrations occurring during 1962 through 1977. The regression lines indicate that the greatest average difference (about one order of magnitude) is at the lower flows, while the two time periods differ by approximately a factor of two at higher flows.

Examination of Figure 3.6 shows that TSS concentrations of individual samples are somewhat correlated with flows. However, the correlation is not nearly as strong as when the data are combined into categories (e.g., base, intermediate, and high flows in Table 3.4).

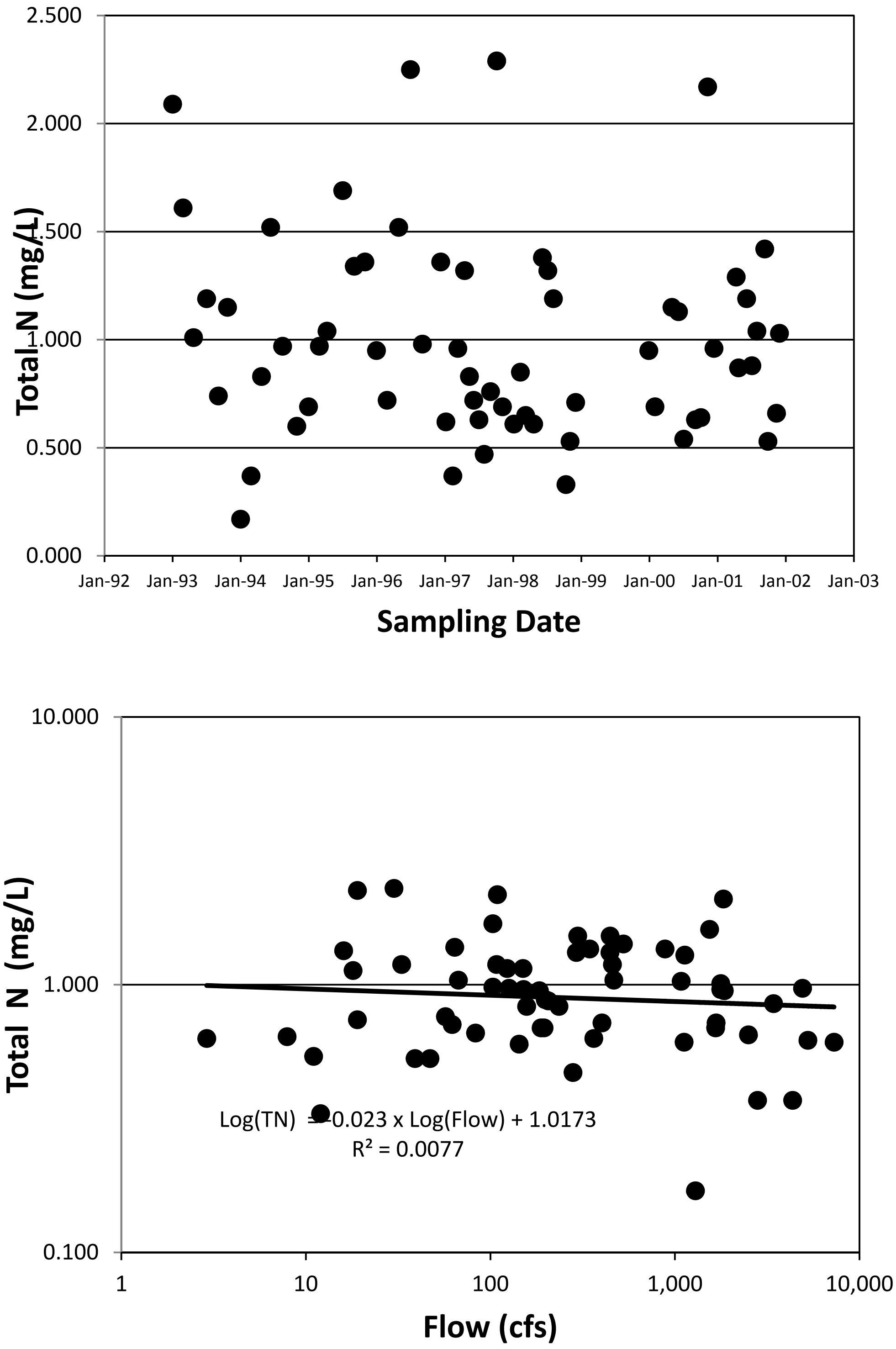


Figure 3.4. Pearl River (Edinburg) total nitrogen concentration versus sampling date (top figure) and flow (bottom figure), 1993 through 2001.

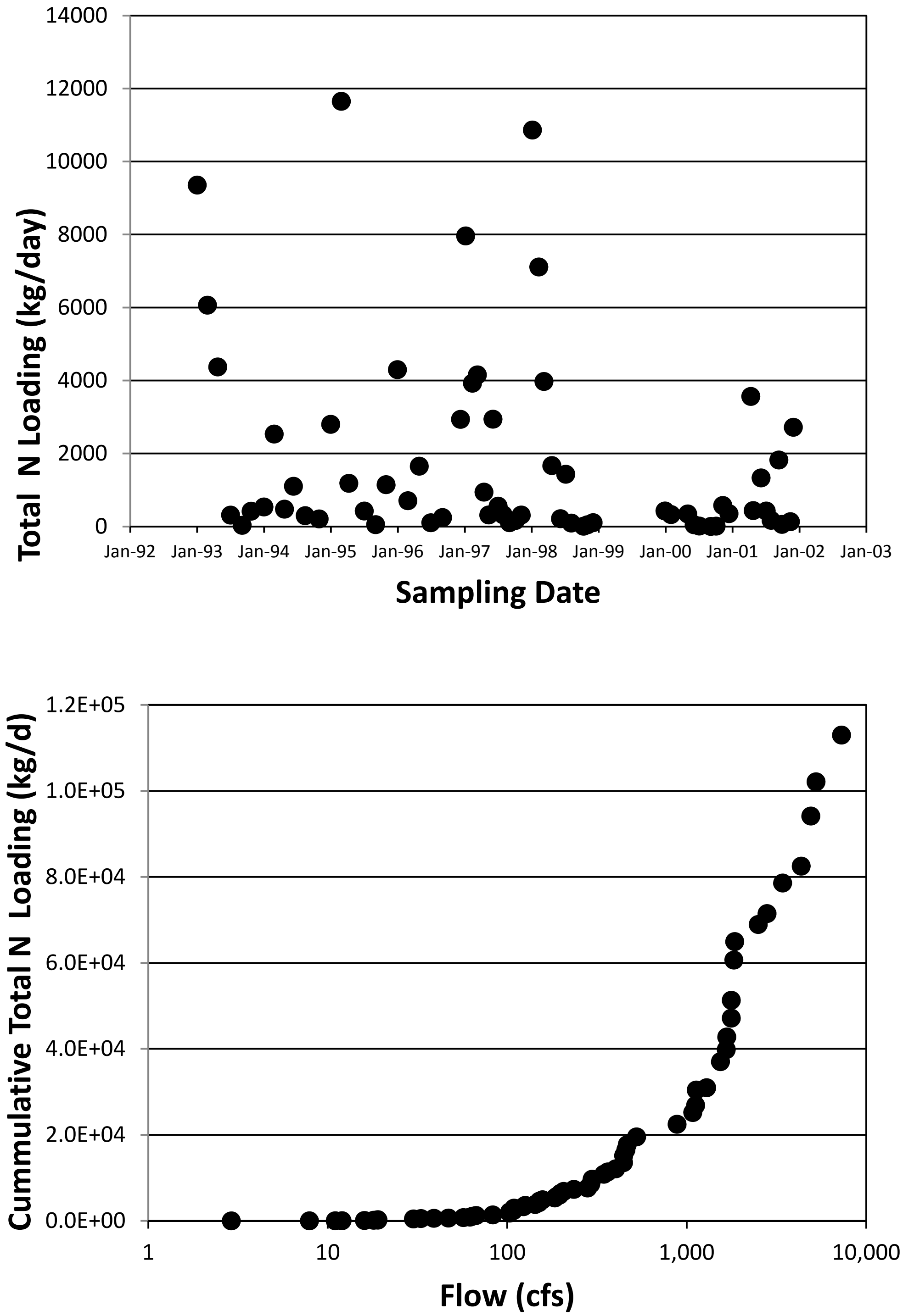
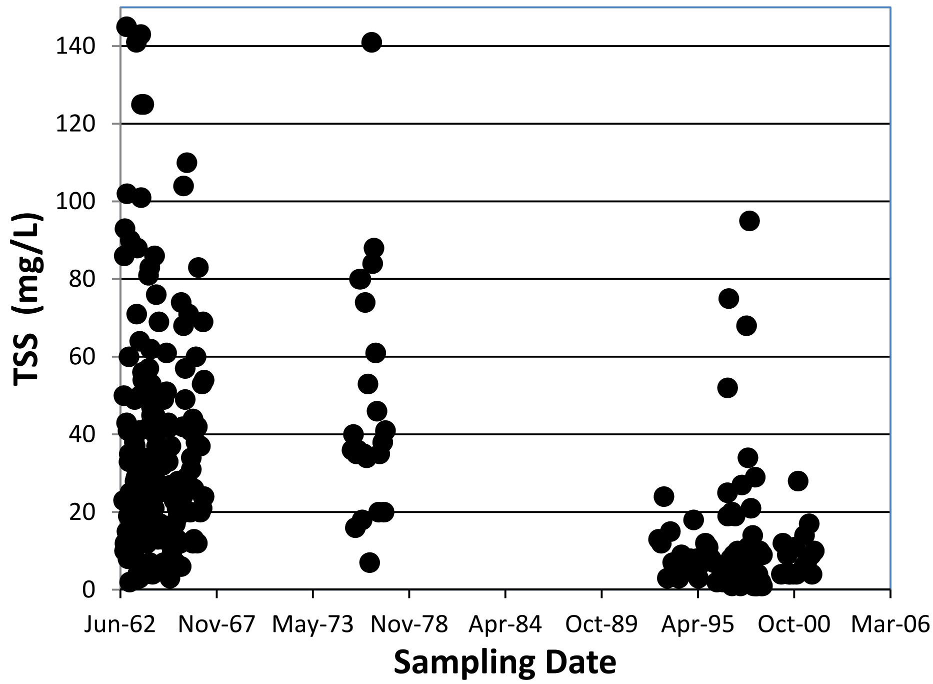


Figure 3.5. Pearl River (Edinburg) total nitrogen loading versus sampling date (top figure) and cumulative loading versus flow (bottom figure), 1993 through 2001.



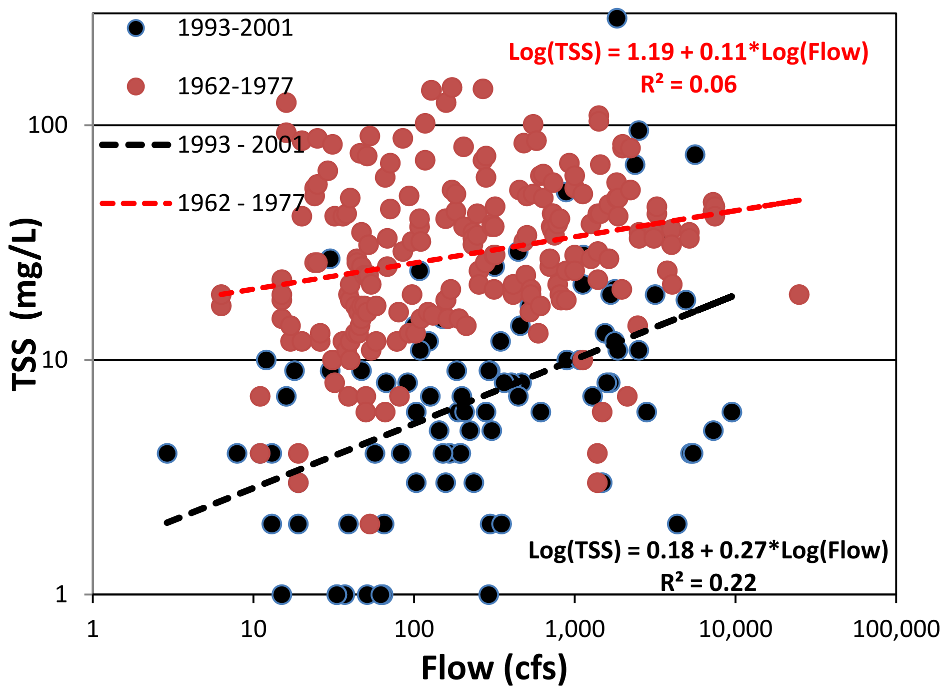


Figure 3.6. Pearl River (Edinburg) total suspended solids concentration versus sampling date (top figure) and flow (bottom figure), 1962 through 2001.

Scatter plots of TSS loadings versus sampling date and flows are provided on Figure 3.7. TSS loadings varied by four orders of magnitude among samples. Interquartile TSS loading values differed by nearly a factor of 30 (1,090 versus 32,000 kg/day; Table 3.2). The same differences between the 1962 through 1977 and 1993 through 2001 time periods were apparent, with higher loading values and a steeper increase with flow apparent in the 1962 through 1977 data set. In the 1993 through 2001 data set, the greatest increase in loading occurs at approximately 2,000 cfs, which is the 82nd percentile among all daily flows from 1963 through 2009.

3.4 Correlations Among Variables

Scatter plots of TN versus TSS, TP versus TSS, and TP versus TN are provided on Figure 3.8. The scatter plots show that, while the relationships are all in the expected direction (i.e., positive correlations among all three variables), the relationships are weak and of little predictive value. These weak relationships might suggest the following:

1. Independent sources of TP, TN, and TSS;
2. Variability in the relative proportions of nitrogen and phosphorus in suspended matter; or
3. A significant and variable inorganic component in the TSS.

3.5 Seasonal and Wet Versus Dry Year Comparisons

Data were classified according to season and wet versus dry hydrological years based on flow records for the Yockanookany River and the Pearl River, as well as precipitation records for Carthage and Philadelphia. Based on these data, the years 1999, 2000, and 2007 were classified as dry and the years 1997 and 2003 were classified as wet. Based on available water quality data, only a single wet year (1997) and a single dry year (2000) could be compared. This comparison is presented in Table 3.5 and indicates that, while average flows during the wet year (1997) were 15 times higher than in the dry year (2000), concentrations of TN, TP and TSS were similar. Differences in loading between years are therefore due to differences in flow.

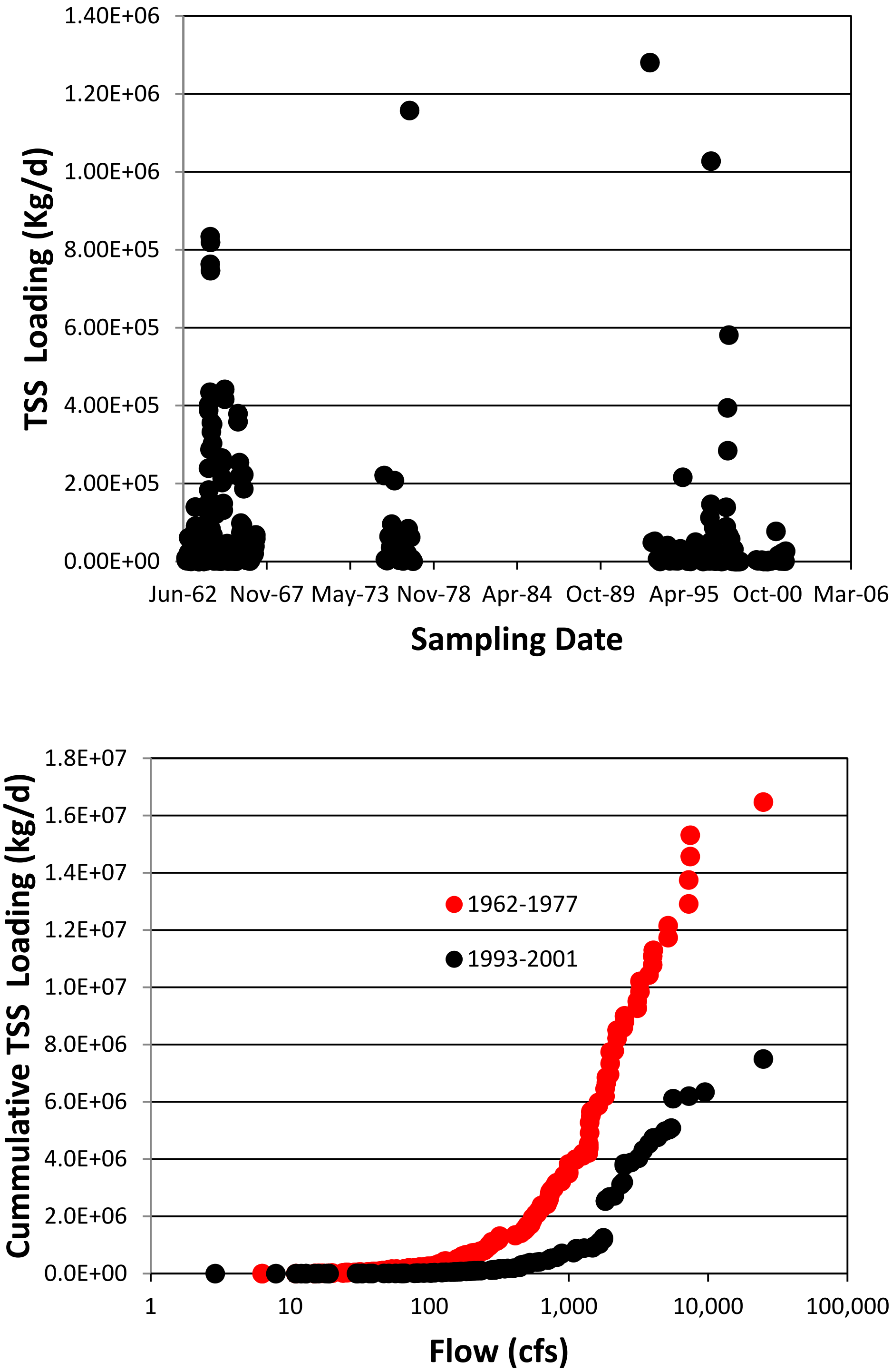


Figure 3.7. Pearl River (Edinburg) total suspended solids loading versus sampling date (top figure) and cumulative loading versus flow (bottom figure), 1962 through 2001.

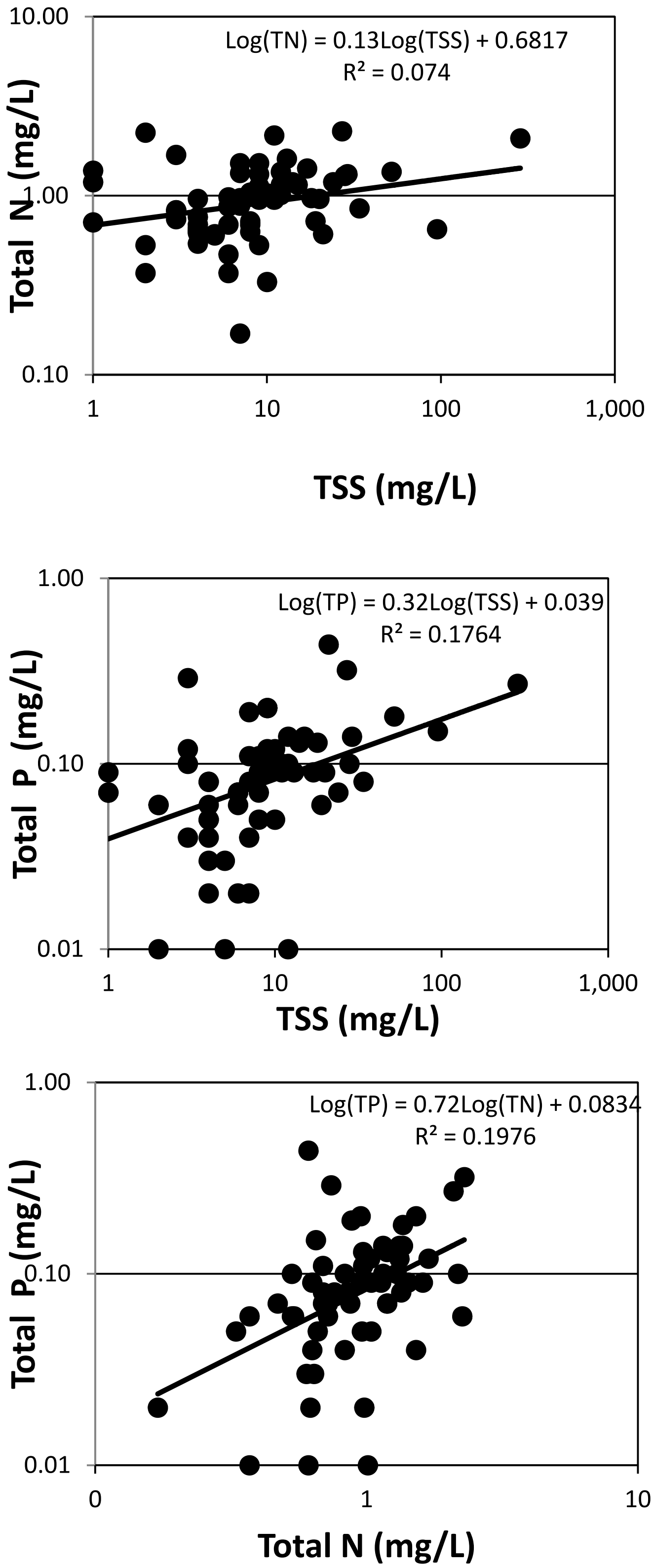


Figure 3.8. Scatter plots of relationships among total phosphorus, total nitrogen, and total suspended solids for the Pearl River (Edinburg), 1993 through 2001.

Table 3.5. Pearl River (Edinburg) wet year (1997) versus dry year (2000) average daily nutrient loadings, concentrations, and flow.

Metric	Dry Year (2000)			Wet Year (1997)		
	TP	TN	TSS	TP	TN	TSS
Loading (kg/day)	23	235	1.62E+03	118	1,975	2.37E+04
Concentration (mg/L)	0.083	0.984	6.8	0.088	0.878	9.8
Flow (cfs)	89			1,309		

For the seasonal analysis, monitoring data were classified as wet season (November through May) and dry season (June through October). The wet versus dry season comparison is provided in Table 3.6. TP and TN concentrations were very similar in wet versus dry seasons while loadings were dramatically higher during wet months. In contrast, TSS concentrations were substantially higher during wet months so that the wet versus dry difference in TSS loading is due to both increased flows and increased TSS concentrations.

Table 3.6. Pearl River (Edinburg) wet (November through May) versus dry (June through October) season average daily nutrient concentrations and loadings (1993 through 2001, excluding 1999).

Metric	Total Phosphorus				Total Nitrogen				Total Suspended Solids			
	Concentration (mg/L)		Loading (kg/day)		Concentration (mg/L)		Loading (kg/day)		Concentration (mg/L)		Loading (kg/day)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Average	0.096	0.105	270	47	0.945	1.068	2721	474	20.6	9.3	8.66E+4	7.12E+3
StdDev	0.080	0.072	387	64	0.431	0.502	3203	703	48.0	7.8	2.29E+5	1.62E+4
N	37	26	37	26	37	26	37	26	37	26	37	26

4.0 YOCKANOOKANY RIVER AT REVIVE AND OFAHOMA

4.1 Flows

A comparison of flows on the sampling days from 1996 through 2001 with all days during that period is presented in Table 4.1. The table indicates that the distribution of flows on sampling days versus all days is comparable with a slight negative bias on sampling days except at the highest flows where there is a substantial negative bias on sampling days. A plot of average annual flows (Figure 4.1) indicates that average annual flows generally ranged from approximately 350 to 950 cfs between 1943 and 2009.

Table 4.1. Yockanookany River (Ofahoma) daily average flows on sampling days versus all days (1996 through 2001).

Metric		Average Daily Flow (cfs)	
		Sampling Days	All Days
Percentile	10^{th}	23	22
	25^{th}	43	40
	50^{th}	91	116
	75^{th}	502	578
	90^{th}	594	1,520
Average		594	524
Standard Deviation		1,443	991
Maximum		8,450	11,000
Minimum		12	6.3

4.2 Annual Loadings

Table 4.2 presents a summary of Yockanookany River nutrient and TSS concentration distributions from the Yockanookany River water quality station at Revive, and distributions of nutrient and TSS loads estimates using water quality data from Revive and flow measurements from Ofahoma. Annual TP, TN and TSS loadings are summarized in Table 4.3. Loadings for all parameters were substantially higher in 2000 than in other years. This is in marked contrast to loadings in the Pearl River during the same time period. At the Pearl River station, loadings for all three parameters were an order of magnitude lower in 2000 compared to other years. At the lower Yockanookany River, loadings of TP, TN, and TSS were lowest in 1999 and highest in 2000. Both 1999 and 2000 were classified as “dry” years (see Section 3.5).

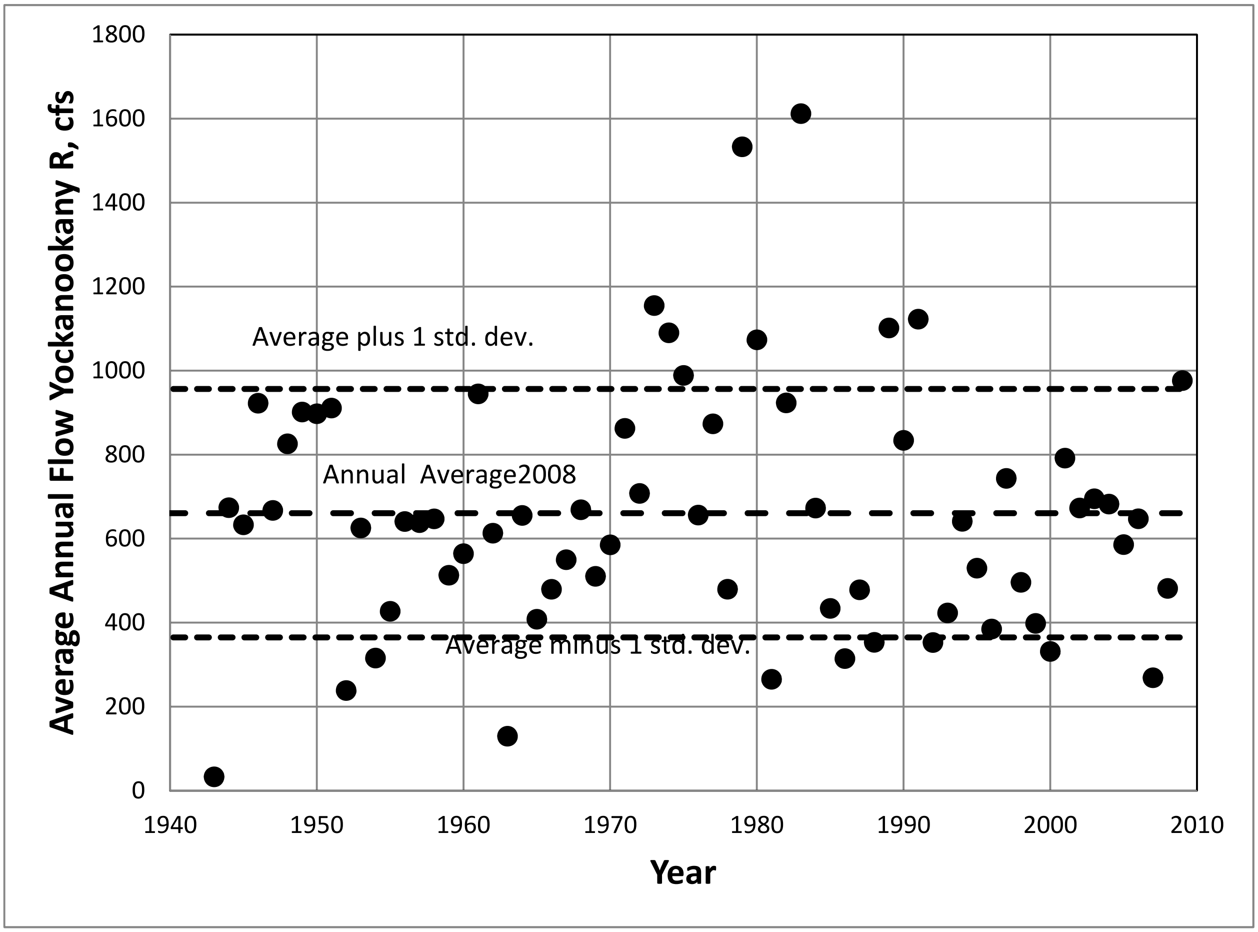


Figure 4.1. Yockanookany River at Ofahoma annual average flows, 1943 through 2009.

Table 4.2. Summary of lower Yockanookany River nutrient concentrations and loading distributions (1996 through 2001).

Metric		Concentrations (mg/L)			Loadings (kg/day)		
		TP	TN	TSS	TP	TN	TSS
Percentile	25th	0.060	0.450	3.0	7	46	2.75E+02
	50th	0.080	0.670	4.5	22	159	1.03E+03
	75th	0.100	0.820	8.0	97	819	9.62E+03
Average		0.098	0.652	7.1	134	1,128	1.73E+04
Standard Deviation		0.094	0.240	10.735	331	3,096	5.26E+04
Maximum		0.580	1.230	68.0	1,861	18,399	2.41E+05
Minimum		0.010	0.230	1.0	1.5	15	6.85E+01

Table 4.3. Lower Yockanookany River average daily nutrient loads based on monthly or bimonthly sampling (1996 through 2001).

Year	Total Phosphorus (kg/day)			Total Nitrogen (kg/day)			Total Suspended Solids (kg/day)		
	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N
1996	18	NA	1	105	NA	0	5.14E+02	NA	1
1997	109	144	8	933	1,161	7	6.72E+03	7.45E+03	8
1998	178	287	10	1,197	2,072	4	3.11E+04	7.50E+04	10
1999	49	73	12	432	566	6	5.08E+03	7.85E+03	12
2000	278	698	7	2,735	6,908	5	3.30E+04	8.57E+04	7
2001	12	NA	1	106	NA	0	NA	NA	0

4.3 Concentrations and Loadings Versus Flows

Table 4.4 summarizes TP, TN and TSS concentrations and loadings at base, intermediate, and high flows. Under this broad classification of flows, concentrations of TP and TN are higher at intermediate flows. In contrast, TSS shows a strong correlation with flow at this scale (i.e., among flow categories) of analysis. Loadings of TN, TP, and TSS all show a strong correlation with flow.

Table 4.4. Lower Yockanookany River average daily nutrient loadings and concentrations at base, intermediate, and high flows (1996 through 2001).

Flow Category	Concentrations (mg/L)			Loadings (kg/day)		
	TP	TN	TSS	TP	TN	TSS
Base Flow, ≤ 20th percentile, ≤ 33 cfs	0.079	0.501	3	4	28	1.84E+02
Intermediate Flow, 40th – 60th percentile, 72-224 cfs	0.148	0.795	5	31	190	1.10E+03
High Flow, ≥ 80th percentile, ≥ 787 cfs	0.090	0.709	15	550	4,694	7.47E+04

4.3.1 Total Phosphorus Concentrations and Loadings Versus Flows

Scatter plots of TP concentrations versus sampling date and flows are provided on Figure 4.2. TP concentrations varied by an order of magnitude among samples. Interquartile TP concentrations differed by a factor of less than two (0.06 versus 0.10 mg/L; Table 4.2). TP concentrations are virtually uncorrelated with flow (Table 4.4 and Figure 4.2).

Scatter plots of TP loading versus sampling date and flows are provided on Figure 4.3. TP loading varied by nearly two orders of magnitude among samples. Interquartile TP loading values differed by a factor of nearly 14 (7 versus 97 kg/day; Table 4.2). Total phosphorus loading was strongly related to flow (Figure 4.3), with the greatest increase in loading occurring at approximately 1,000 cfs, which is the 81st percentile among all daily flows from 1943 through 2009.

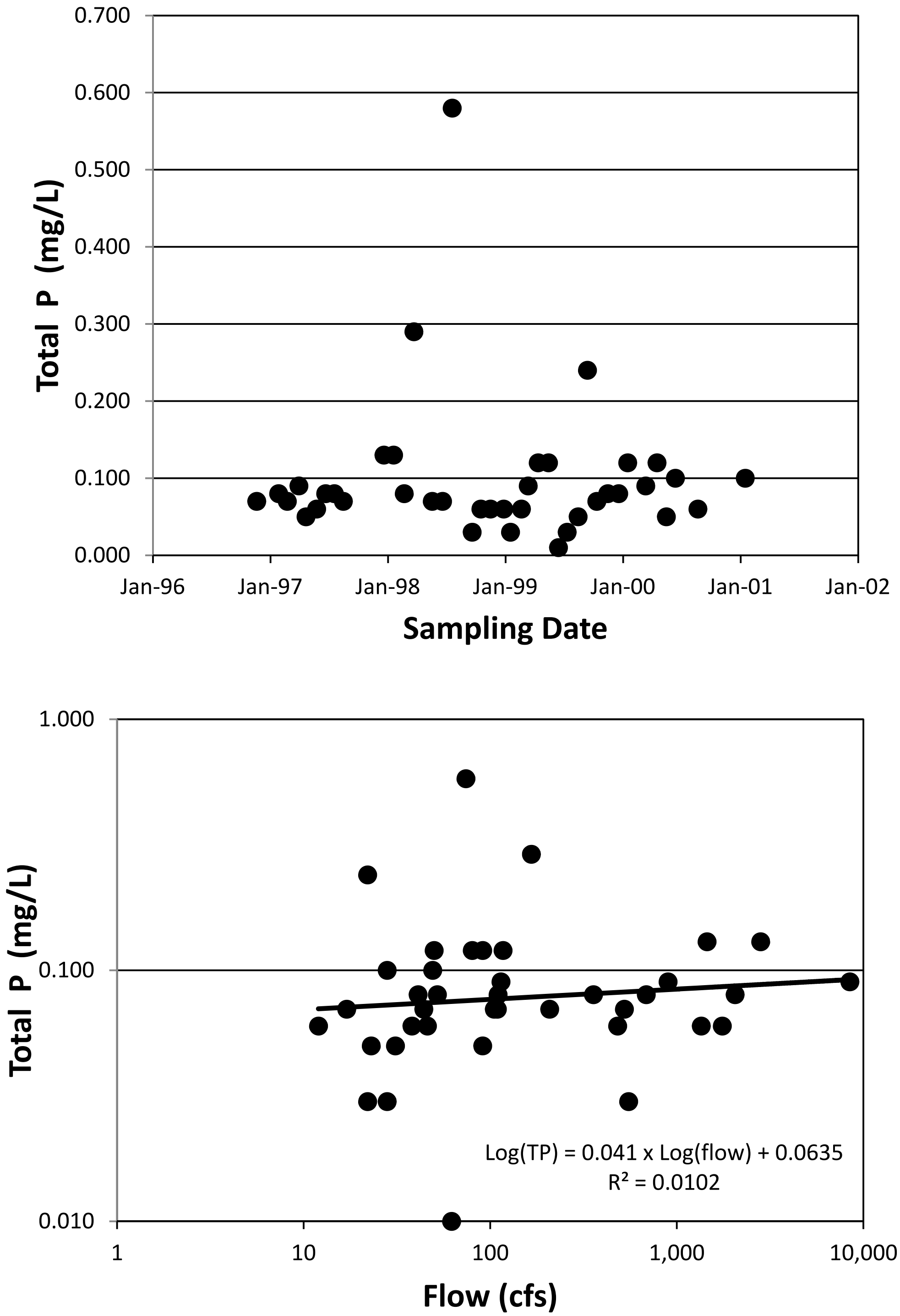
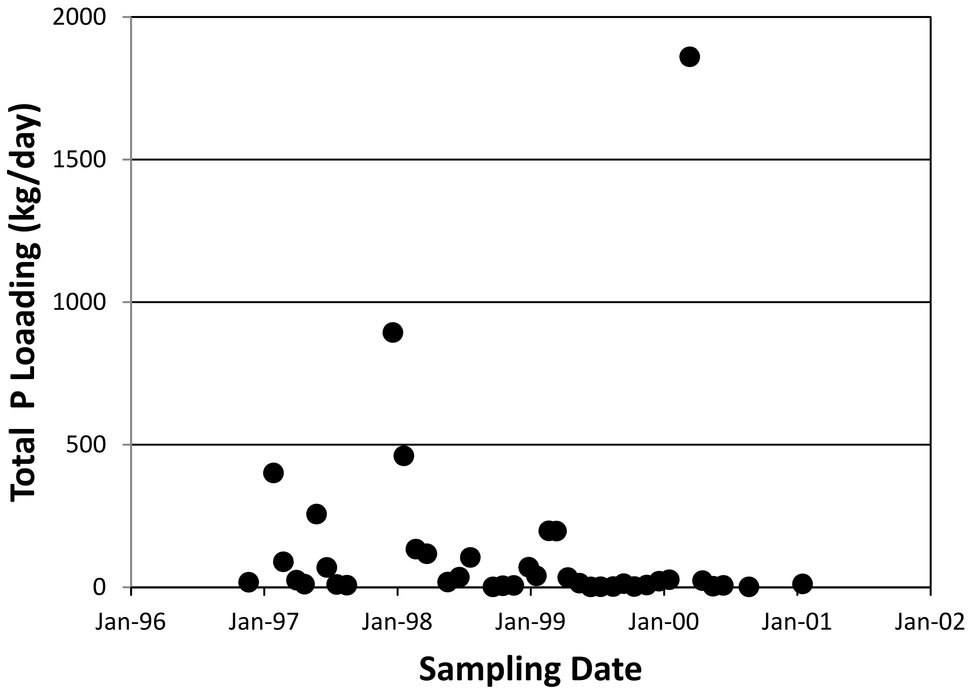


Figure 4.2. Yockanookany River total phosphorus concentrations at Revive versus sampling date (top figure) and flow at Ofahoma (bottom figure), 1996 through 2001.



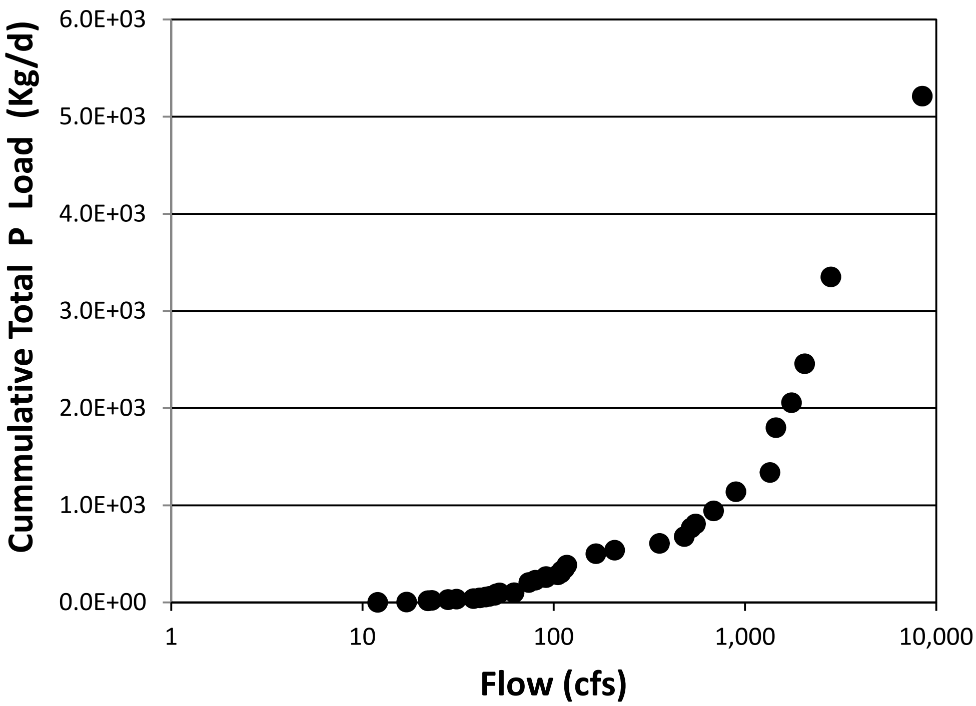


Figure 4.3. Lower Yockanookany River total phosphorus loading versus sampling date (top figure) and cumulative loading versus flow (bottom figure), 1996 through 2001.

4.3.2 Total Nitrogen Concentrations and Loadings Versus Flows

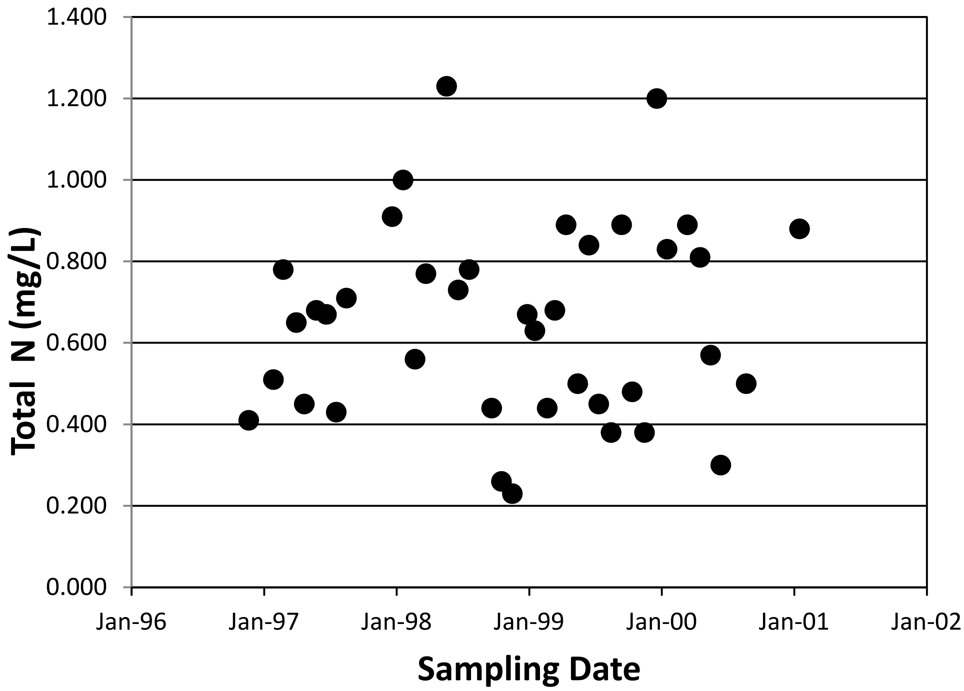
Scatter plots of TN concentrations versus sampling date and flows are provided on Figure 4.4. TN concentrations varied by a factor of six among samples. Interquartile TN concentrations differed by a factor of 1.8 (0.45 versus 0.82 mg/L; Table 4.2). Total nitrogen concentrations are weakly correlated with flows (Table 4.4 and Figure 4.4).

Scatter plots of TN loadings versus sampling date and flows are provided on Figure 4.5. Loadings of TN varied by four orders of magnitude among samples. Interquartile TN loading values differed by roughly a factor of 18 (46 versus 819 kg/day; Table 4.2). Total nitrogen loading was strongly related to flow (Figure 4.5), with the greatest increase in loading occurring at approximately 1,200 cfs, which is the 84th percentile among all daily flows from 1943 through 2009.

4.3.3 TSS Concentrations and Loadings Versus Flows

Scatter plots of TSS concentrations versus sampling date and flows are provided on Figure 4.6. TSS concentrations varied by over an order of magnitude among samples. Interquartile TSS concentrations differed by a factor of nearly three (3 versus 8 mg/L; Table 4.2); as with the Pearl River data, the correlation of individual samples with flow is not as strong as when the data are grouped into categories (e.g., Table 4.4).

Scatter plots of TSS loading versus sampling date and flows are provided on Figure 4.7. TSS loading varied by four orders of magnitude among samples. Interquartile TSS loading values differed by a nearly a factor of 35 (275 versus 9,600 kg/day; Table 4.2). The greatest increase in loading occurs at approximately 1,200 cfs, which is the 84th percentile among all daily flows from 1943 through 2009.



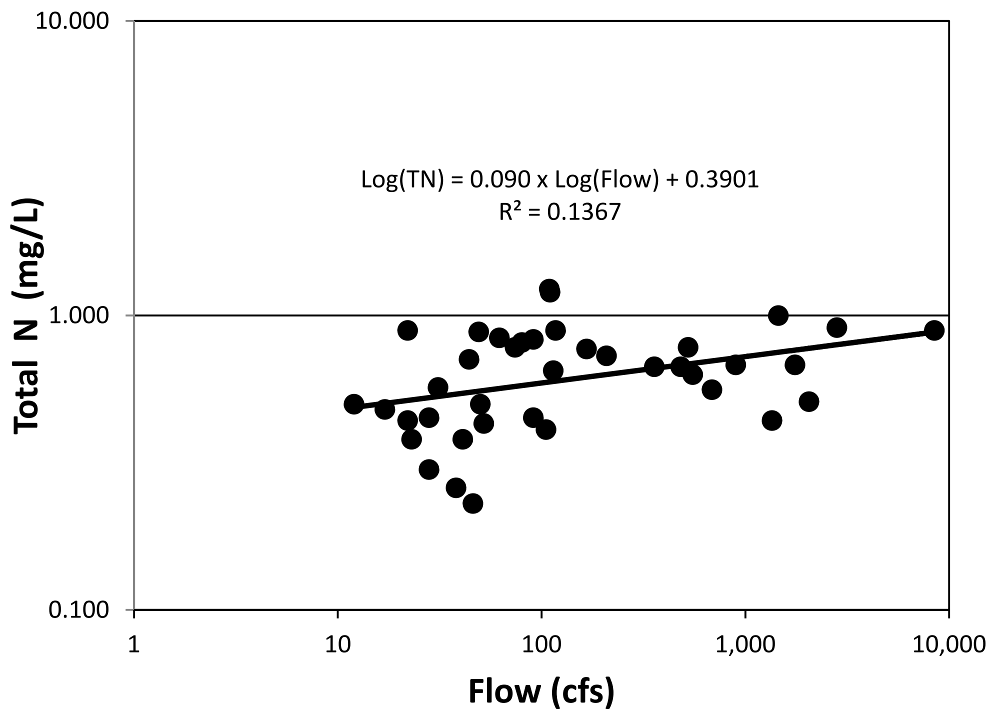
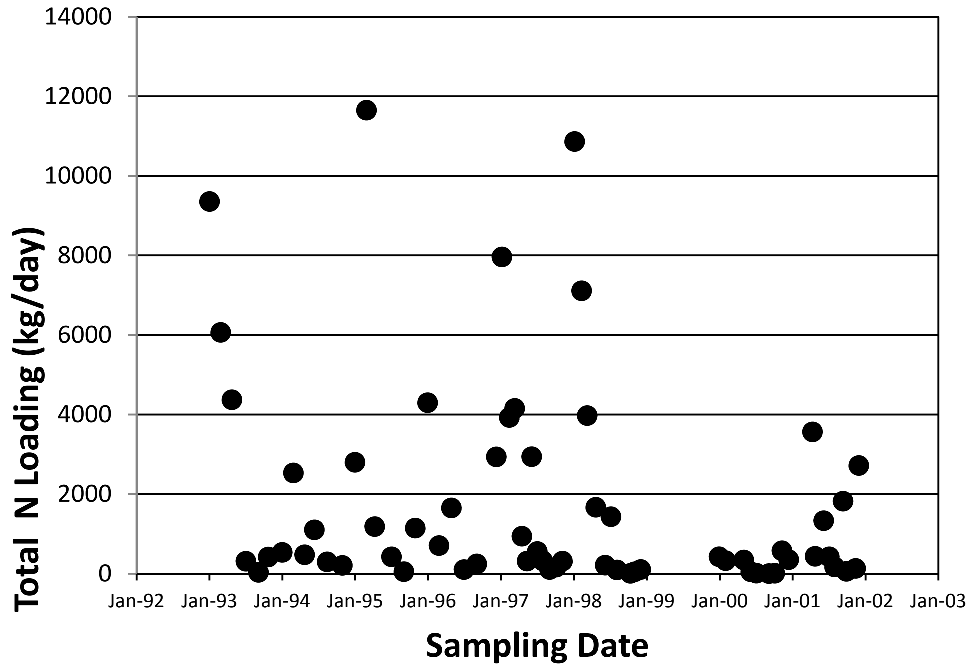


Figure 4.4. Yockanookany River total nitrogen concentrations at Revive versus sampling date (top figure) and flow at Ofahoma (bottom figure), 1996 through 2001.



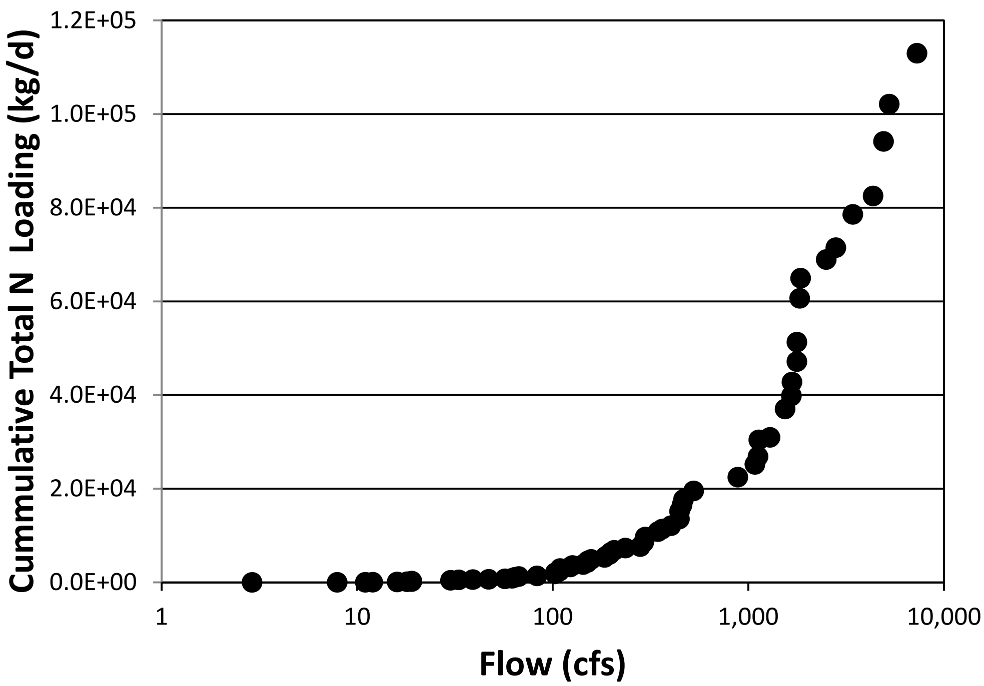


Figure 4.5. Lower Yockanookany River total nitrogen loading versus sampling date (top figure) and cumulative loading versus flow (bottom figure), 1996 through 2001.

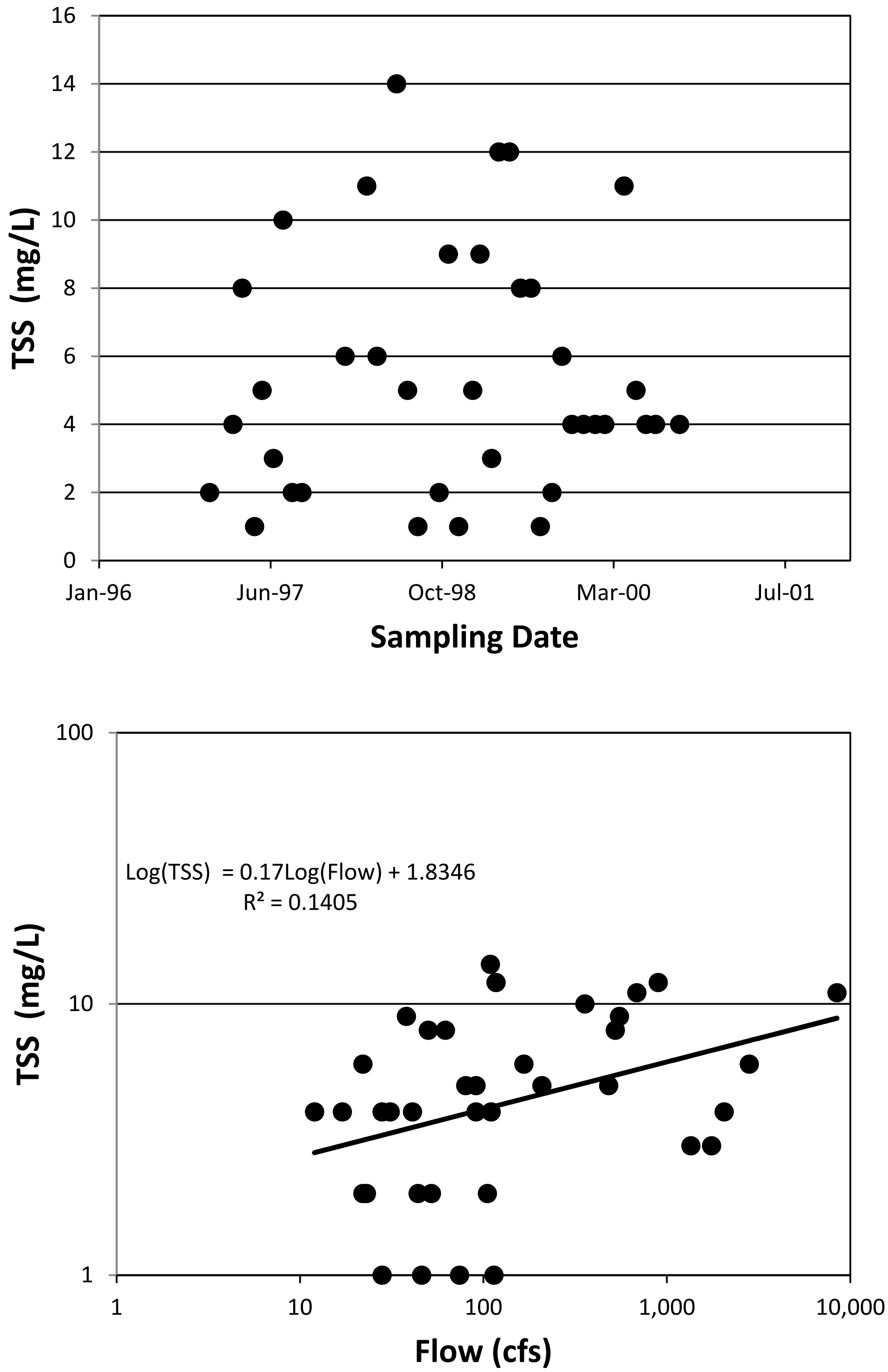


Figure 4.6. Yockanookany River TSS concentrations at Revive versus sampling date (top figure) and flow at Ofahoma (bottom figure), 1996 through 2001.

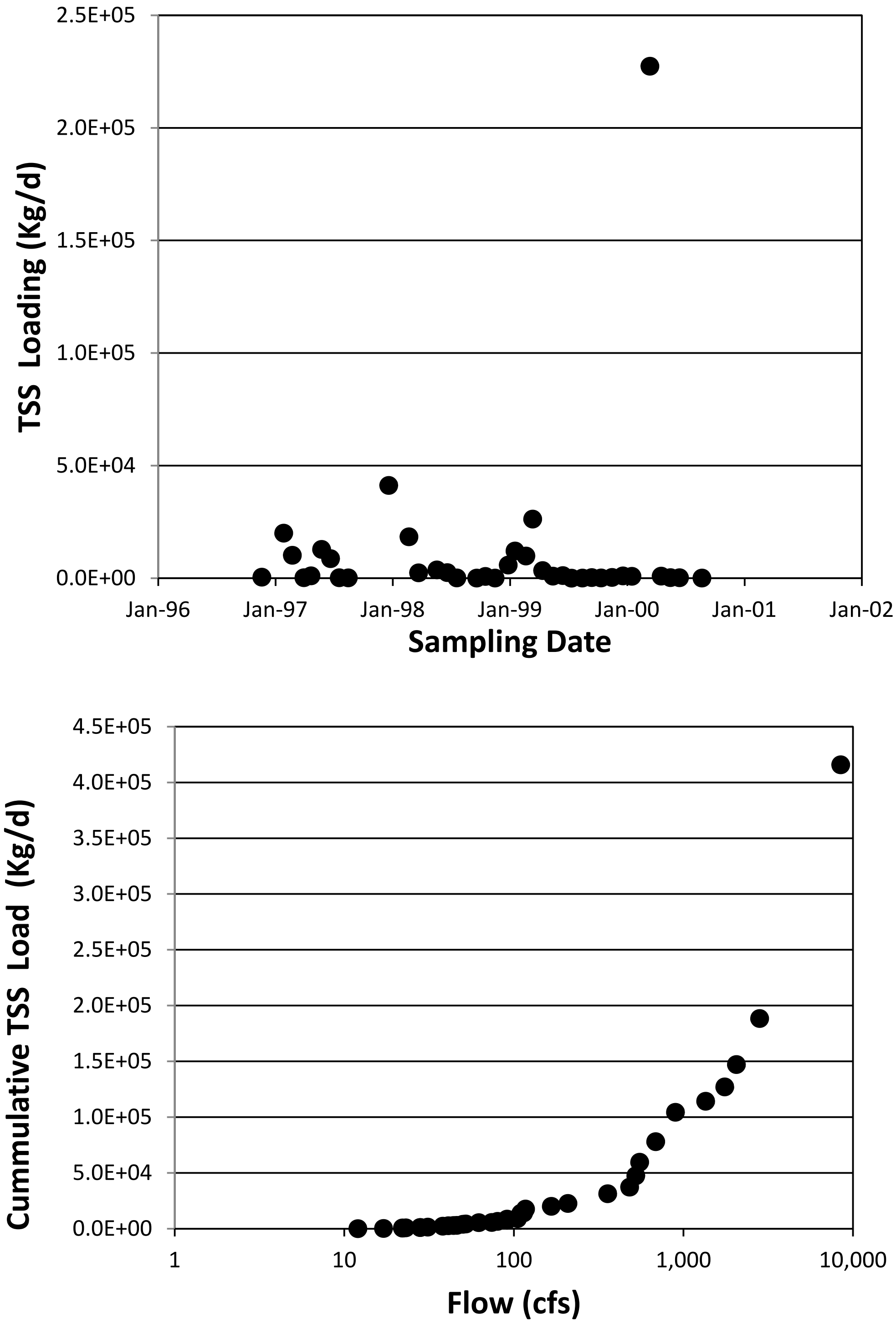


Figure 4.7. Lower Yockanookany River TSS loading versus sampling date (top figure) and cumulative loading versus flow (bottom figure), 1996 through 2001.

4.4 Correlations Among Variables

Scatter plots of TN versus TSS, TP versus TSS, and TP versus TN are provided on Figure 4.8. The scatter plots show that the relationships are weak and of little predictive value. This pattern is similar to that observed at the Pearl River station and might be due to the following:

1. Independent sources of TP, TN, and TSS;
2. Variability in the relative proportions of nitrogen and phosphorus in suspended matter; or
3. A significant and variable inorganic component in the TSS.

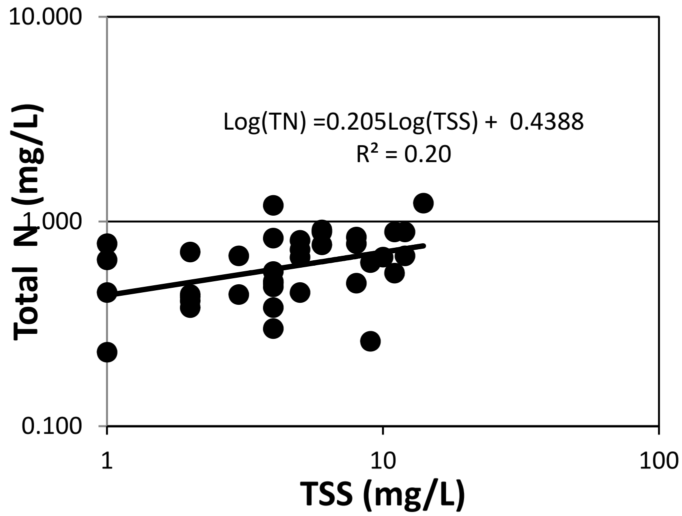
4.5 Seasonal and Wet Year Versus Dry Year Comparisons

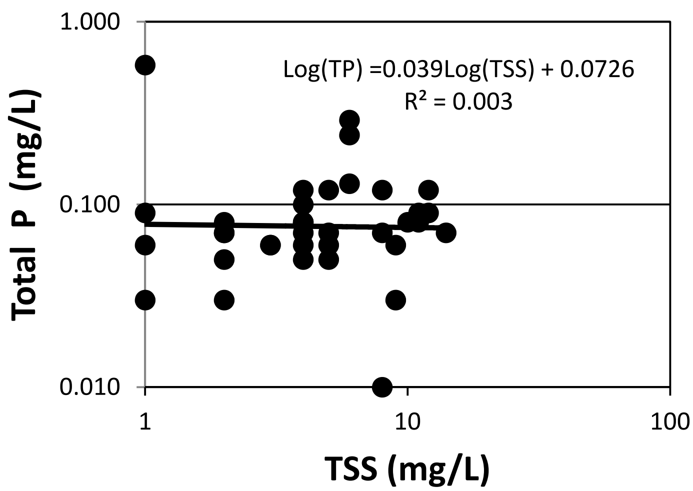
Data were classified according to season and wet versus dry hydrological years based on flow precipitation records as described previously. Based on available water quality data only a single wet year (1997) and a single dry year (2000) could be compared. This comparison is presented in Table 4.5 and indicates that, while average flows during the wet year (1997) were 42 times higher than in the dry year (2000), concentrations of TN, TP, and TSS were similar. Differences in loading between years are therefore due to differences in flow.

Table 4.5. Lower Yockanookany River wet (1997) versus dry (2000) year average daily nutrient loadings, concentrations and flows.

Metric	Dry Year (2000)			Wet Year (1997)		
	TP	TN	TSS	TP	TN	TSS
Loading (kg/day)	14	121	6.07E+02	109	933	6.72E+03
Concentration (mg/L)	0.088	0.727	4.2	0.073	0.610	4.4
Flow (cfs)	59			623		

For the seasonal analysis, monitoring data were classified as described previously. The wet versus dry season comparison is provided in Table 4.6. TP and TN concentrations were very similar in wet versus dry seasons while loadings were dramatically higher during wet months. In contrast, TSS concentrations were higher during wet months so that the wet versus dry difference in TSS loading is due to both increased flows and increased TSS concentrations.





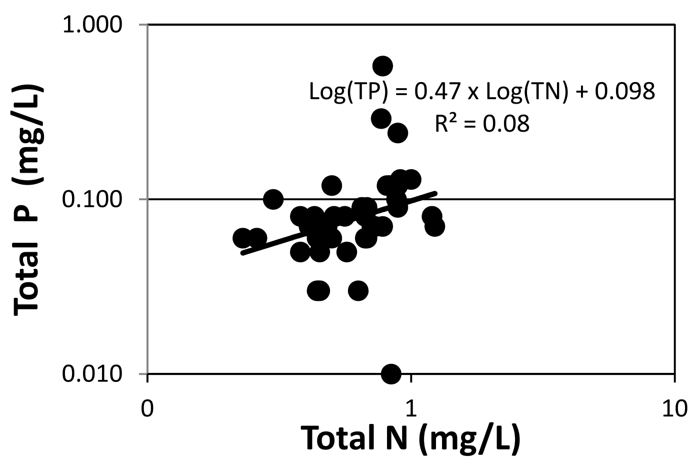


Figure 4.8. Scatter plots of relationships among total phosphorus, total nitrogen, and total suspended solids for the Yockanookany River (Revive), 1996 through 2001.

Table 4.6. Lower Yockanookany River wet (November through May) versus dry (June through October) season average daily nutrient concentrations and loadings.

Metric	Total Phosphorus Concentration (mg/L) Wet	Total Phosphorus Concentration (mg/L) Dry	Total Phosphorus Loading (kg/day) Wet	Total Phosphorus Loading (kg/day) Dry	Total Nitrogen Concentration (mg/L) Wet	Total Nitrogen Concentration (mg/L) Dry	Total Nitrogen Loading (kg/day) Wet	Total Nitrogen Loading (kg/day) Dry	Total Suspended Solids Concentration (mg/L) Wet	Total Suspended Solids Concentration (mg/L) Dry	Total Suspended Solids Loading (kg/day) Wet	Total Suspended Solids Loading (kg/day) Dry
Mean	0.093	0.106	203	34	0.666	0.631	1,701	304	8.8	4.8	2.84E+4	2.00E+3
Std Dev	0.051	0.136	417	66	0.247	0.236	3,921	714	13.6	3.6	6.75E+4	3.66E+3
N	23	16	23	16	23	16	23	16	22	16	22	16

5.0 COMPARISON BETWEEN YOCKANOOKANY RIVER AND PEARL RIVER WATERSHEDS

Comparisons between the Yockanookany River (at Revive) and the Pearl River at Edinburg could be made only for data collected during 1996 through 2001. A direct comparison of loading is not valid because the watershed area of the Pearl River at Edinburg (578,767 acres) is twice as large as the watershed area of the Yockanookany River at Revive (274,502 acres) or Ofahoma (300,160 acres). Therefore, under similar conditions, the Pearl River station should always show about twice the loading. Accordingly, the data were scaled to reflect the yield of TP, TN, or TSS per unit area per sampling day. This variable plotted against flow provides an indication of the amount of TP, TN, or TSS that leaves a unit of the watershed at a given flow rate. The two watersheds can be compared in terms of their TP, TN, and TSS yield per unit area by comparing the slopes and y-intercepts of scatter plots of TP, TN, or TSS versus flow. These plots are provided on Figures 5.1 through 5.3. The slopes of the relationships are very similar across all three parameters, indicating that the relationship between yield and flow is similar between the two watersheds. In all cases, the y-intercept of the Yockanookany River regression line is less than that of the Pearl River line, indicating that the Yockanookany River watershed yields less TP, TN, and TSS per unit area than the Pearl River watershed. This is also confirmed by visual examination of the fitted regression lines. However, the absolute differences between the y-intercepts are very small and amount to only fractions of grams per acre. Therefore, although there are discernable differences between the watersheds, the differences are slight and would not warrant greater attention to one watershed versus the other.

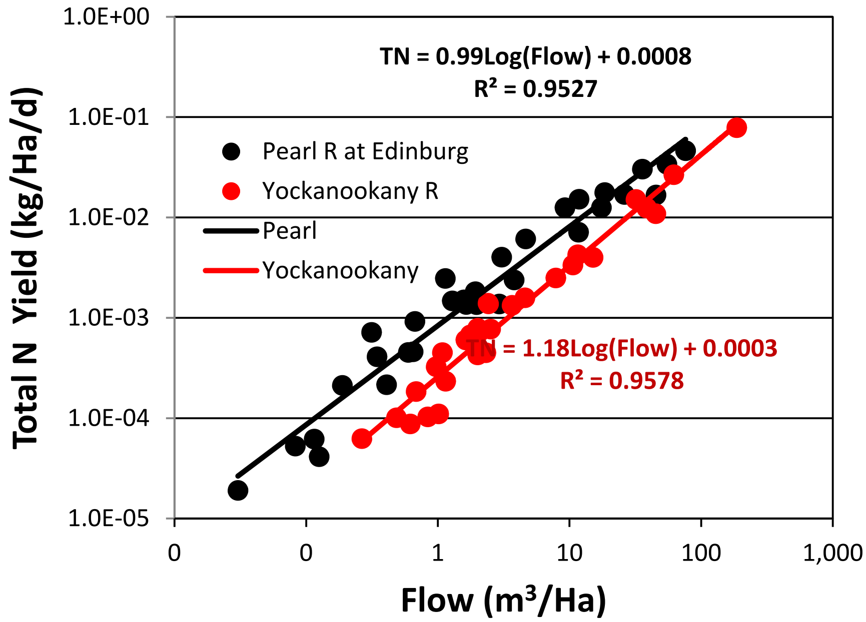


Figure 5.1. Comparison of total nitrogen yield versus water yield relationships for the Pearl River and the Yockanookany River, 1996 through 2001.

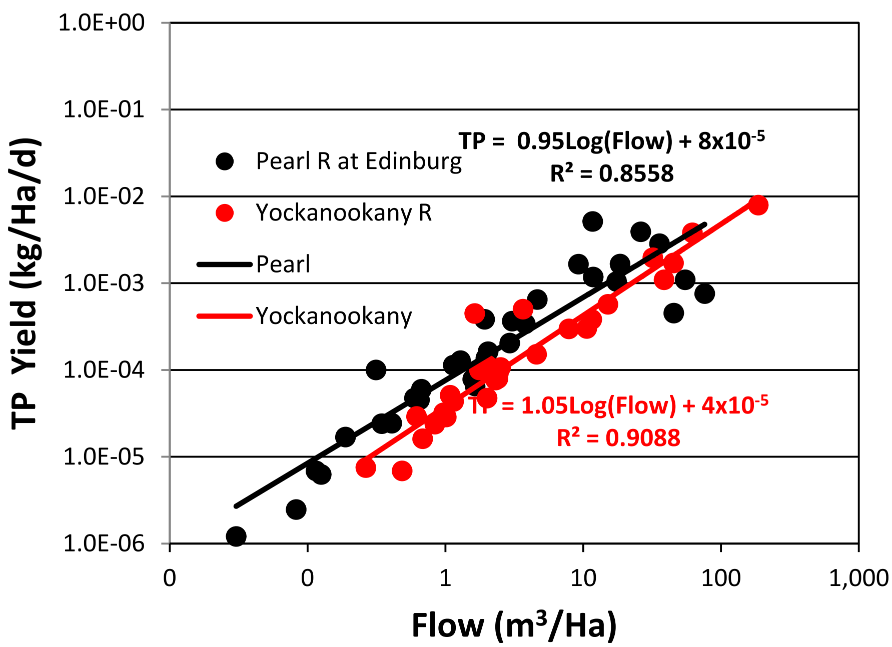


Figure 5.2. Comparison of total phosphorus yield versus water yield relationships for the Pearl River and the Yockanookany River, 1996 through 2001.

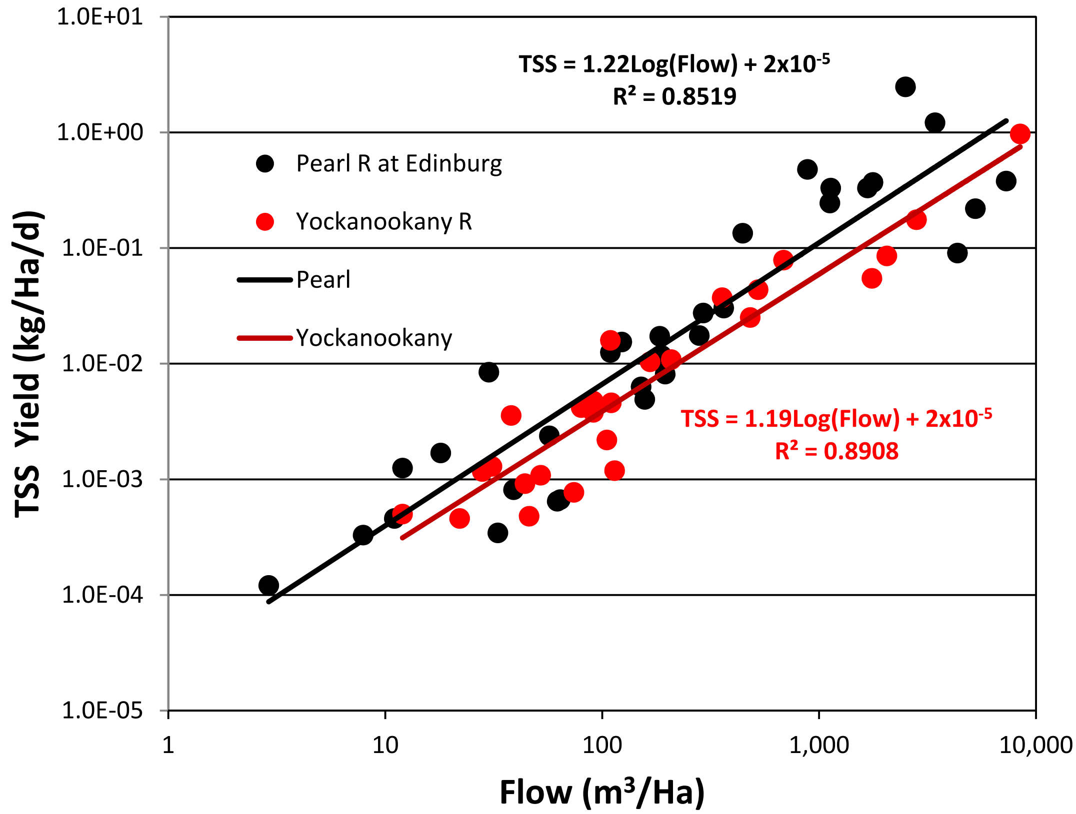


Figure 5.3. Comparison of total suspended solids yield versus water yield relationships for the Pearl River and the Yockanookany River, 1996 through 2001.

6.0 WATER QUALITY DATA FROM OTHER TRIBUTARIES

6.1 Pearl River

Additional water quality data were collected at the Pearl River near the Mississippi Band of Choctaw Indians Reservation. EPA and MDEQ assisted the Mississippi Band of Choctaw Indians with a water quality study on the Pearl River from Burnside to Sunrise, Mississippi. The study was conducted in the summer of 2003 and was designed to assess the effects of several point source discharges of treated wastewater on a section of the Pearl River. Facilities of concern included the Town of Pearl River's wastewater treatment plant (WWTP) and facilities serving Philadelphia and New Harmony.

Results of the study showed that water quality standards for dissolved oxygen were being met in the tributaries (Beesha Creek and Kentawka Creek Canal) and in the portion of the Pearl River included in the study. However, nutrient levels (measured as TN and TP) were considerably higher than the expected background levels for this area based on USGS data. Expected levels based on median data for this area were 0.2 mg/L TN and 0.05 mg/L TP. Measured levels were 0.59 mg/L TN and 0.07 mg/L TP.

This study noted that algae growth was likely limited by nitrogen based on algae growth potential tests. The point source dischargers may be the primary source of nutrients in this part of the Pearl River. Measured concentrations of chlorophyll-a were lower than expected because dense canopy cover in the area limited the amount of light reaching the water surface and high turbidity limited algae growth by reducing light penetration into the water (EPA 2003).

6.2 Pelahatchie Creek

During 2004, MDEQ Field Services Division conducted a field investigation on Pelahatchie Creek to study the impact of the Reservoir East wastewater discharge on Pelahatchie Creek. The study included water chemistry sampling at five stations on Pelahatchie Creek. Samples were analyzed for nutrients, organic material, and fecal coliform bacteria. Biological sampling was also conducted at several sites. Field data collected during this study are not available from MDEQ at this time.

MDEQ uses macroinvertebrates (aquatic insects) to determine general stream conditions. Biological sampling has been conducted on wadeable sections of several tributaries of the Pearl River streams (Figure 6.1). Three stream segments in the immediate vicinity of the Reservoir have been assessed and are considered poor. These are Fannegusha Creek, which enters the Pearl River at the north end of the main lake; Cane Creek, which enters the Reservoir; and an unnamed tributary to Pelahatchie Creek, which enters Pelahatchie Bay (MDEQ 2008).

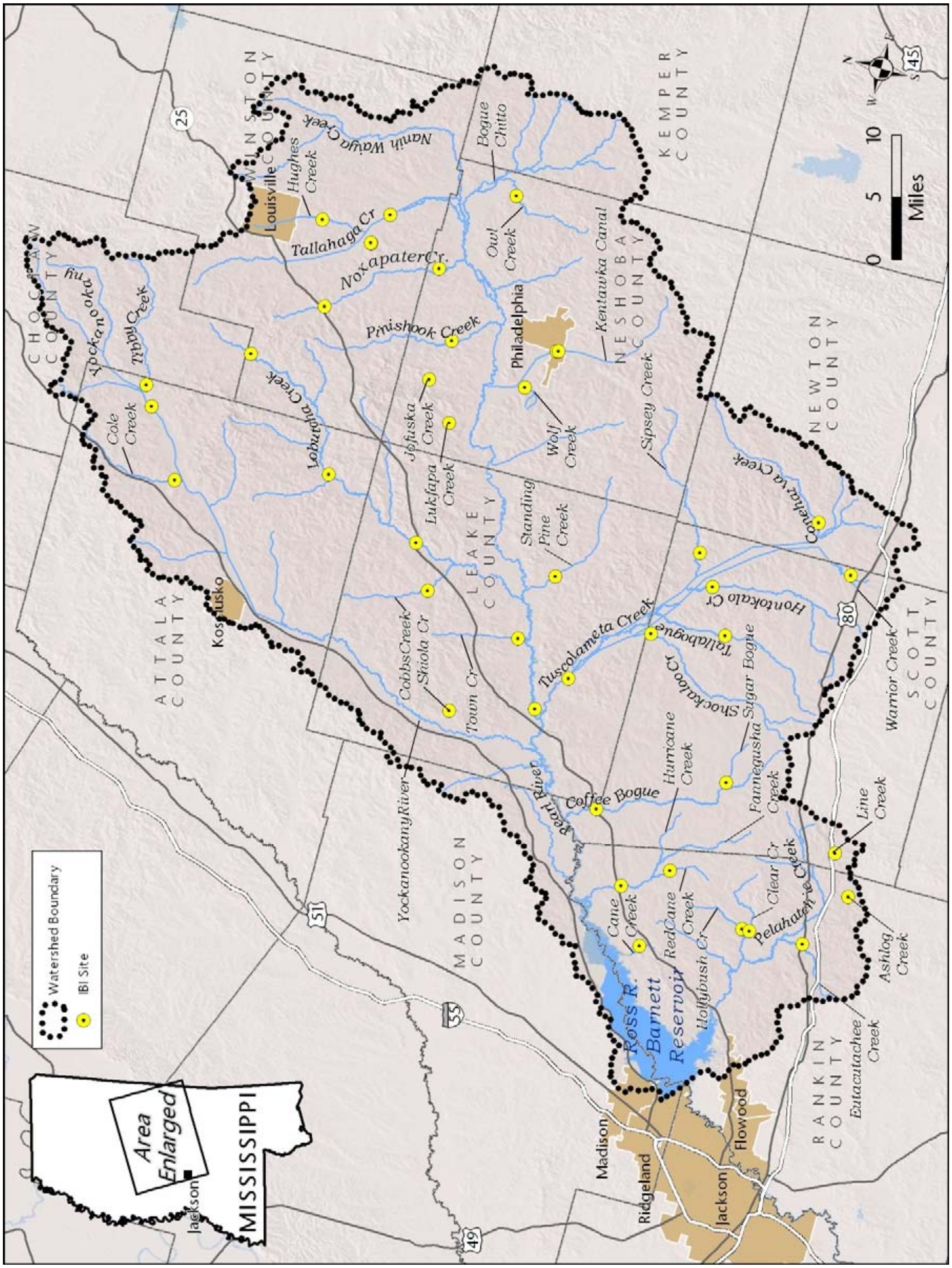


Figure 6.1. Locations of biological sampling in Ross Barnett Reservoir watershed.

7.0 CONCLUSIONS

- Total nitrogen, total phosphorus, and TSS loading values are clearly dominated by flow values.
- Total nitrogen and total phosphorus concentrations are essentially independent of flow such that differences in total nitrogen and total phosphorus loadings (at a station) are due mainly to differences in flow.
- TSS concentrations correlate more strongly with flows, especially when the data are grouped into more inclusive levels (e.g., base, intermediate, and high flows; wet season versus dry season; wet years versus dry years).
- Differences in TSS loadings (at a station) are due to differences in both flow and TSS concentrations.
- Seasons and years with higher flows will show correspondingly higher total phosphorus, total nitrogen, and TSS loadings.
- There has been a dramatic decrease (three- to ten-fold, depending on the flow) in TSS loading in the Pearl River (Edinburg station) since the period of 1963 to 1977.
- The total nitrogen, total phosphorus, and TSS yield on a per unit area basis is slightly lower from the Yockanookany River watershed than from the Pearl River watershed.

8.0 REFERENCES

EPA. 2003. *Pearl River Water Quality Study, Choctaw, MS*. US Environmental Protection Agency in cooperation with the Mississippi Department of Environmental Quality and the Mississippi Band of Choctaw Indians. September 2003.

MDEQ. 2008. *Investigation of Reservoir East*. Available by contacting the Mississippi Department of Environmental Quality, Office of Pollution Control, Surface Water Division.

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water resources / environmental consultants

ANALYSIS OF WATER QUALITY MONITORING DATA FROM 1997 THROUGH 2004 FOR THE ROSS BARNETT RESERVOIR

OCTOBER 31, 2011

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October 31, 2011

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1.0 INTRODUCTION

Available monitoring data were analyzed to evaluate aspects of Ross Barnett Reservoir water quality with special emphasis on total phosphorus, total nitrogen, chlorophyll *a*, and Secchi disc transparency. Data analyzed were collected by several agencies including the Mississippi Department of Environmental Quality (MDEQ), the US Environmental Protection Agency (EPA), the US Geological Survey (USGS), the Mississippi State Department of Health (MSDH), and the City of Jackson. Data from five lake sampling locations (Figure 1.1) were available over various time periods (Table 1.1). Only surface samples (collected at a depth of one meter or less) were used in the analysis.

The following aspects of Reservoir water quality were evaluated:

1. Temporal variation:
   a. Long-term trends,
   b. Seasonal:
      i. Spring, summer, winter, fall; and
      ii. Wet season versus dry season.
   c. Wet versus dry hydrological years.
2. Spatial variation (differences among stations),
3. Covariation among nutrients and endpoints such as chlorophyll *a* and transparency,
4. Seasonal patterns in thermal stratification, and
5. Distribution of fecal coliform bacteria levels.

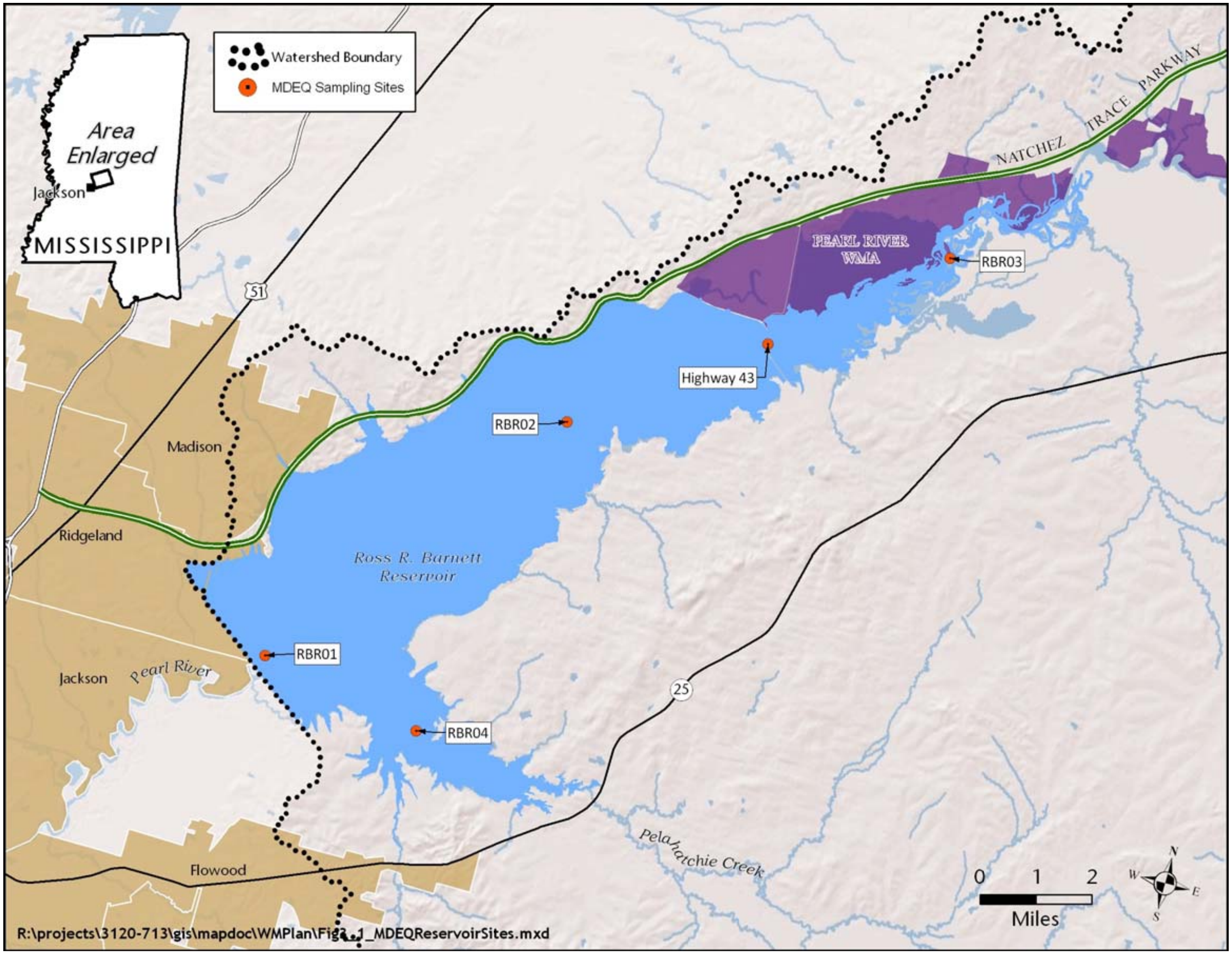


Figure 1.1. Sampling locations in Ross Barnett Reservoir.

Table 1.1. Sampling period of record and frequency at Ross Barnett Reservoir lake locations.

Lake Location	Period of Record	Sampling Frequency	Number of Samples
RBR-1 (Lower Lake)	April 14, 1997, through September 1, 2004	3 to 4 per year	31
RBR-2 (Mid-Lake)	April 14, 1997, through September 9, 2004	3 to 4 per year	31
Highway 43 (Mid-Lake)	April 14, 1997, through September 1, 2004	4 to 10 per year	47
RBR-3 (Upper Lake)	April 14, 1997, through September 9, 2004	1 to 3 per year	17
RBR-4 (Pelahatchie Bay)	April 14, 1997, through September 1, 2004	3 to 4 per year	31

Section 314 of the Clean Water Act directs each state to prepare or establish an identification and classification of the eutrophic conditions of all publicly owned lakes in the state. Eutrophication in surface waters occurs when elevated levels of nutrients lead to changes in the aquatic ecosystem, resulting in increased primary production and decreased dissolved oxygen levels. MDEQ classified the Ross Barnett Reservoir as “eutrophic” using the Carlson Trophic State Index based on Secchi depth. Trophic state is a scale that describes the condition of a waterbody based on its productivity. However, assessments of trophic state index do not reflect whether a waterbody supports its designated use. MDEQ noted that trophic state is not synonymous with water quality. Although trophic state and use support status are related, they should not be used interchangeably. MDEQ also noted that any conclusions drawn from the use of the Carlson Trophic State Index applied to Mississippi lakes should be used with caution, because the index was developed for lakes with little non-algal turbidity (MDEQ 2010).

2.0 DATA ANALYSIS

2.1 Preliminary Data Analysis and Data Classification

To evaluate factors affecting the variation and mean values of total nitrogen, total phosphorus, Secchi disc transparency, and chlorophyll *a*, the data were classified according to season and wet versus dry hydrological years. Wet versus dry years were chosen according to flows records for Yockanookany River and Pearl River, and precipitation records for the cities of Carthage and Philadelphia. Based on these data, the years 1999, 2000, and 2007 were classified as dry years, and the years 1997 and 2003 were classified as wet years.

For the seasonal analysis, monitoring data were first classified as spring (March 21 through June 21), summer (June 22 through September 21), fall (September 22 through January 21) and winter (January 22 through March 20). This analysis showed only weak differences among seasons. This finding was not surprising, because strong seasonality should not be expected at inland latitudes similar to the Reservoir's latitude. Seasons at the Reservoir's latitude might be more accurately characterized as cool and wet (November through May) versus warm and dry (June through October). Accordingly, the data were classified as wet season (November through May) and dry season (June through October). A statistical summary of all data is presented in Table 2.1.

A preliminary evaluation of data from the RBR-2 and Highway 43 locations showed that there were few, if any, differences in total phosphorus, total nitrogen, Secchi disc transparency, and chlorophyll *a* between those stations. Accordingly, the values for those parameters from RBR-2 and Highway 43 were combined for the purposes of this analysis.

Table 2.1. Summary of statistics at the lower (RBR-1), mid (RBR-2+Hwy 43), upper (RBR-3), and Pelahatchie Bay (RBR-4) sampling locations.

Wet Season								
Parameter	**Station**	**Mean**	**Standard Deviation**	**CV [a]**	**Median**	**IQR [b]**	**IQR% [c]**	**N [d]**
Total Phosphorus	Lower Lake	0.112	0.0785	70	0.1	0.032	32	12
	Mid-Lake	0.13	0.0482	37	0.12	0.063	53	65
	Upper Lake	0.107	0.0609	57	0.115	0.088	77	6
	Pelahatchie Bay	0.119	0.0656	55	0.115	0.068	59	12
Total Nitrogen	Lower Lake	0.922	0.2649	29	0.915	0.291	32	12
	Mid-Lake	1.08	0.2477	23	1.07	0.399	37	64
	Upper Lake	1.19	0.3508	29	1.17	0.382	33	6
	Pelahatchie Bay	1.168	0.3371	29	1.205	0.578	48	12
Secchi Disc Transparency	Lower Lake	0.442	0.1701	38	0.435	0.277	64	6
	Mid-Lake	0.443	0.0917	21	0.4	0.058	15	11
	Upper Lake	0.389	0.0723	19	0.35	0.098	28	11
	Pelahatchie Bay	0.377	0.1071	28	0.38	0.138	36	11
Chlorophyll *a*	Mid-Lake	12.7	12.0445	95	5.5	18.07	329	31
Dry Season								
Parameter	**Station**	**Mean**	**Standard Deviation**	**CV [a]**	**Median**	**IQR [b]**	**IQR% [c]**	**N [d]**
Total Phosphorus	Lower Lake	0.075	0.0267	36	0.075	0.03	40	20
	Mid-Lake	0.14	0.0405	29	0.12	0.063	53	51
	Upper Lake	0.141	0.0538	38	0.13	0.077	59	11
	Pelahatchie Bay	0.128	0.1034	81	0.095	0.032	34	18
Total Nitrogen	Lower Lake	0.842	0.2918	35	0.85	0.328	39	20
	Mid-Lake	0.982	0.297	30	1.07	0.339	32	52
	Upper Lake	1.17	0.2614	22	0.93	0.473	51	11
	Pelahatchie Bay	0.969	0.258	27	0.92	0.407	44	19
Secchi Disc Transparency	Lower Lake	0.625	0.3277	52	0.49	0.3	61	11
	Mid-Lake	0.358	0.1491	42	0.325	0.249	77	4
	Upper Lake	0.384	0.0723	19	0.35	0.098	28	11
	Pelahatchie Bay	0.377	0.1071	28	0.38	0.138	36	11
Chlorophyll *a*	Mid-Lake	24.2	9.94	41	22.6	7.73	34	16

Notes:
(a) CV= coefficient of variation.
(b) IQR = interquartile range.
(c) IQR % = interquartile range as percentage of median.
(d) N = number of values.

As a preliminary step to identifying patterns in the data, a three-way analysis of variance (ANOVA) was performed with the data classified according to hydrological year (wet or dry), season (wet or dry), and station (RBR-1, RBR-2+Hwy 43, RBR-3, RBR-4). This analysis was performed to determine if any of the factors (i.e., hydrological years, seasons, stations) accounted for a relatively large portion of the total variance. The analysis was performed only for total phosphorus, total nitrogen, and Secchi disc transparency. For all three analyses, there were no statistically significant effects due to station, season or hydrological year ($P > 0.2$ in all tests). Further analysis of the data involving simple visual evaluations of data plots (scatter plots, box-and-whisker plots) was conducted. These evaluations revealed a number of patterns that might be of management significance even though they are not statistically significant.

2.2 Temporal Variation

2.2.1 Differences Among Years

The approach to evaluate annual variation was to examine time-series plots for evidence of trends, cycles, or differences among years for stations with the most complete time-series data sets. Examination of Figures 2.1 and 2.2 indicates possible weak downward trends in Secchi disc transparency from mid-2003 through July 2006 and in maximum chlorophyll *a* from 2003 through 2005. No similar inter-annual patterns were noted with total nitrogen and total phosphorus.

2.2.2 Seasonal Variation

Seasonal variation (growing season versus winter) is apparent in the time-series plot for chlorophyll *a* from RBR-2+Highway 43 (Figure 2.2). Wet and dry season comparisons are shown for total phosphorus, total nitrogen and Secchi disc transparency at RBR-1, RBR-2 + Hwy 43, RBR-3 and RBR-4 on Figures 2.3 through 2.6, respectively. Figure 2.4 includes a wet versus dry season comparison for Secchi disc transparency at RBR-2+Hwy 43.

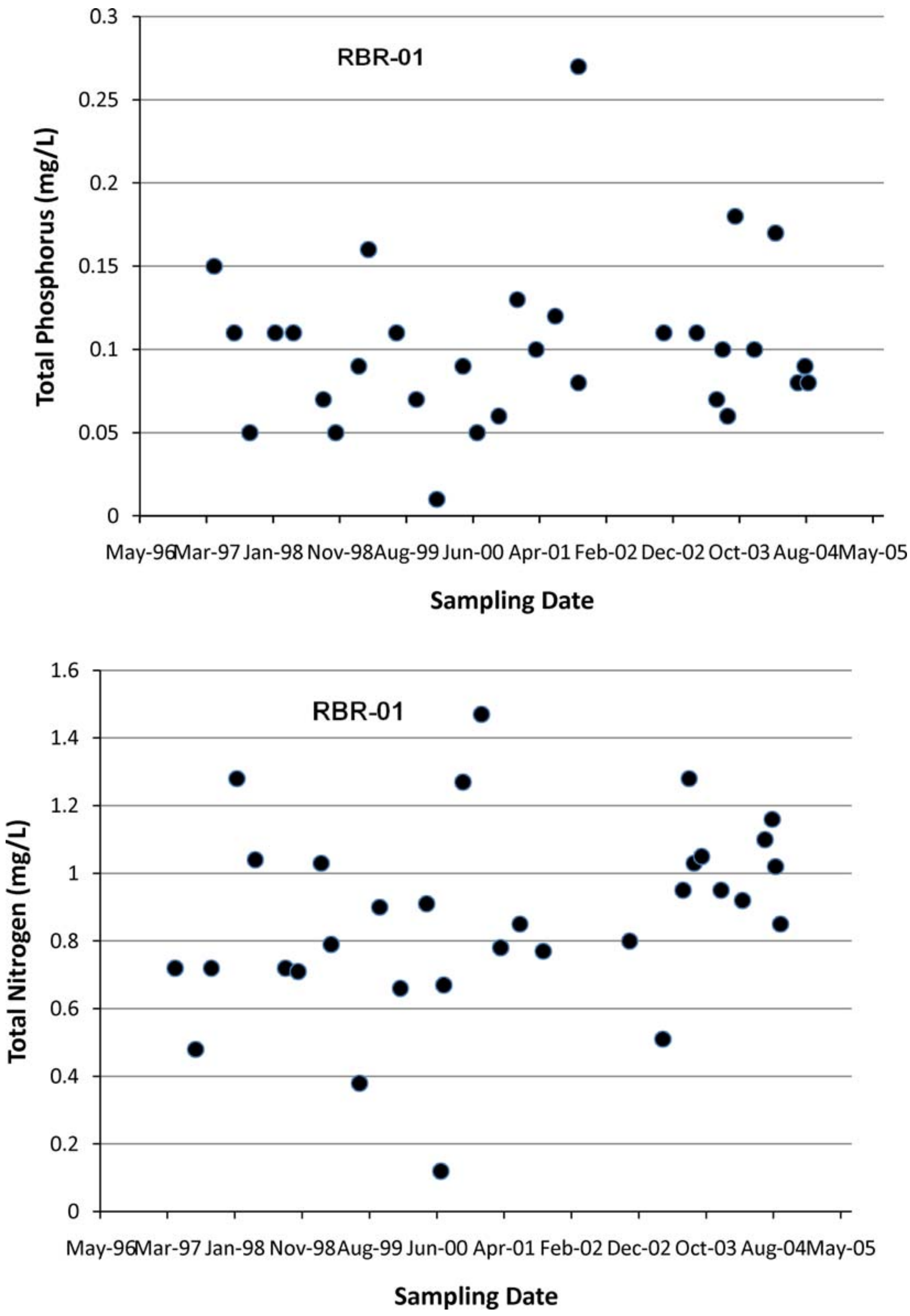


Figure 2.1. Time-series plots of total phosphorus and total nitrogen at RBR-1.

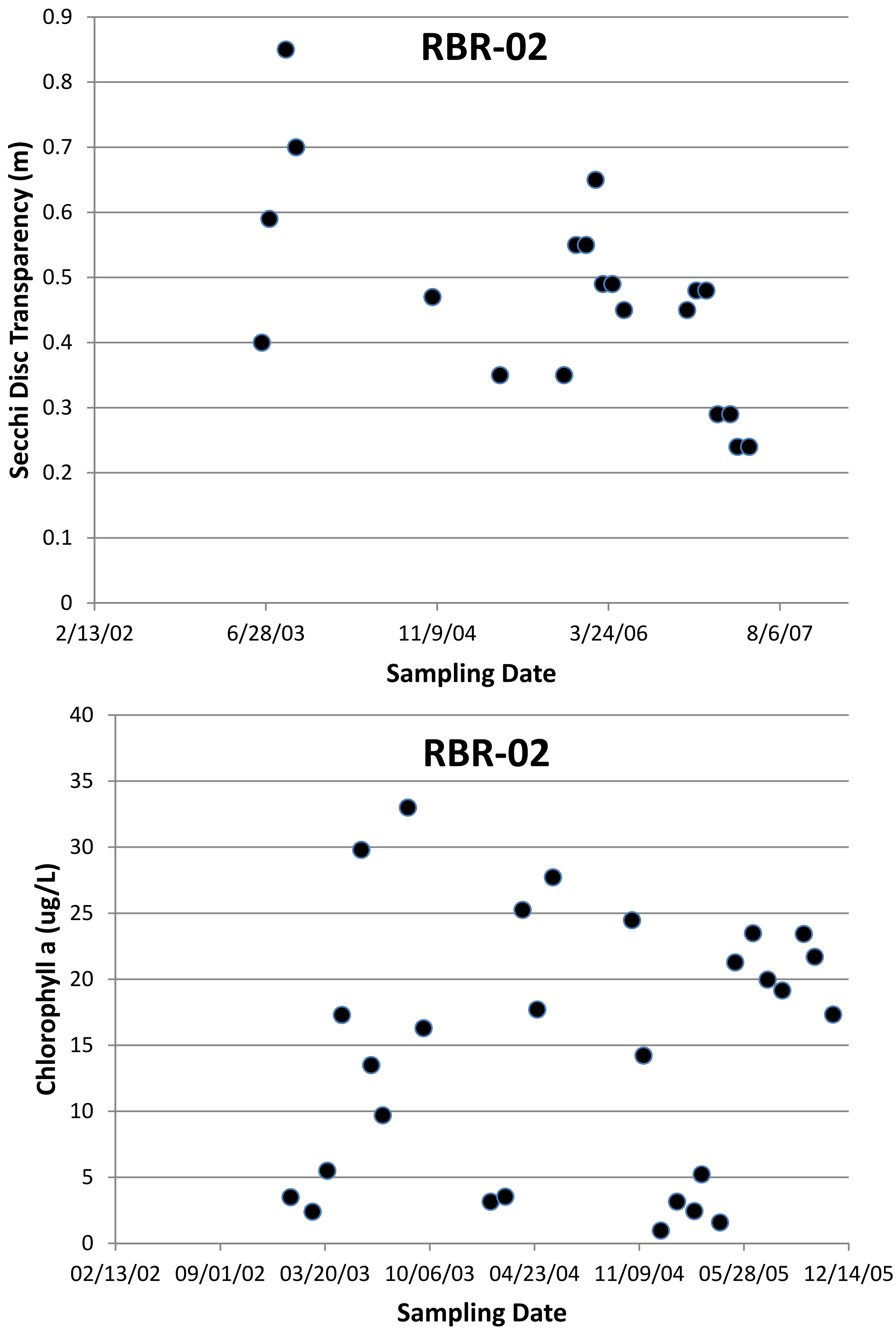


Figure 2.2. Time-series plots of Secchi disc and chlorophyll *a* at RBR-2+Hwy 43.

RBR01

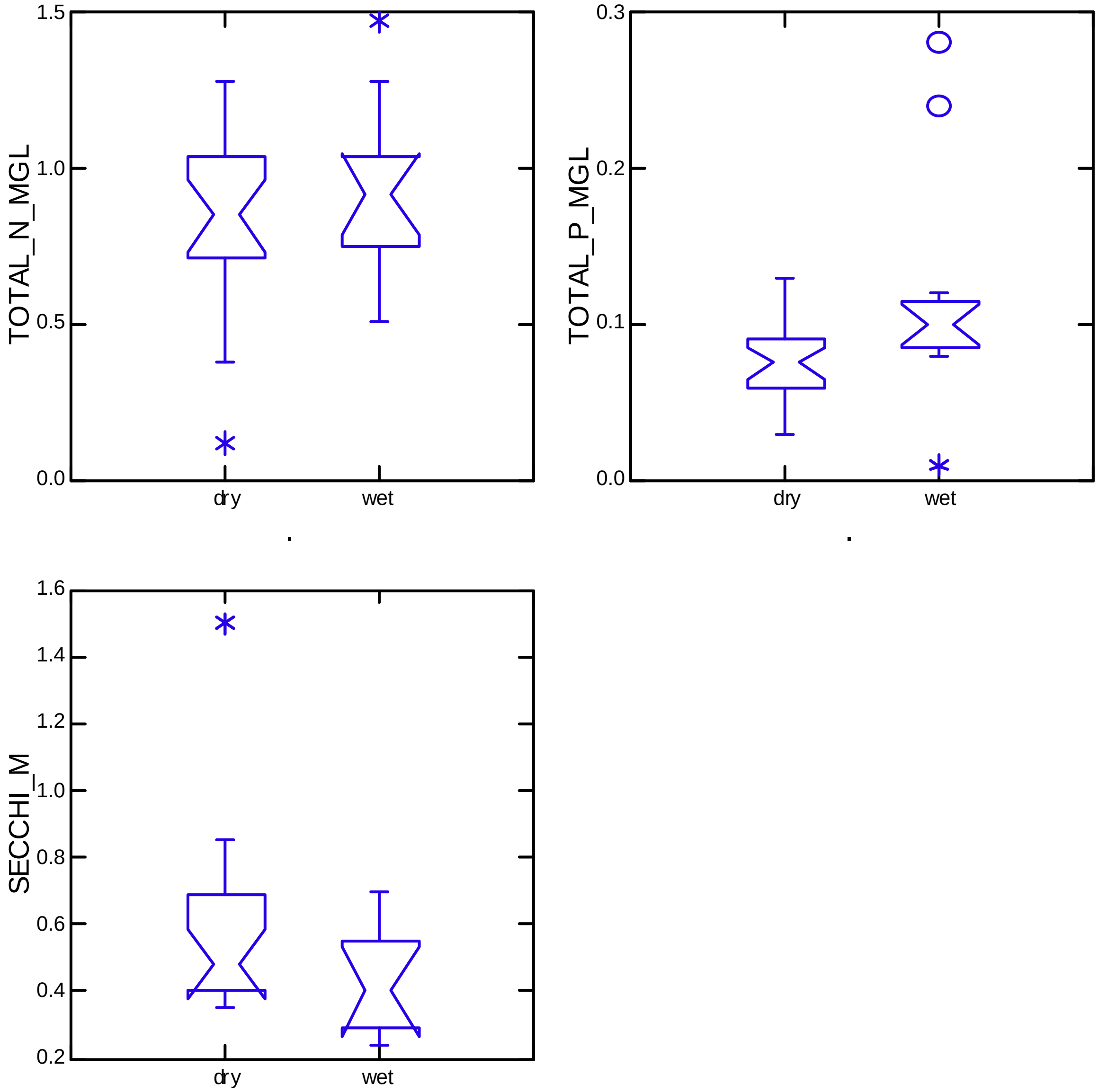


Figure 2.3. Box-and-whisker plots of total nitrogen, total phosphorus, and Secchi disc transparency at RBR-1 during wet (November through May) versus dry (June through October) seasons.

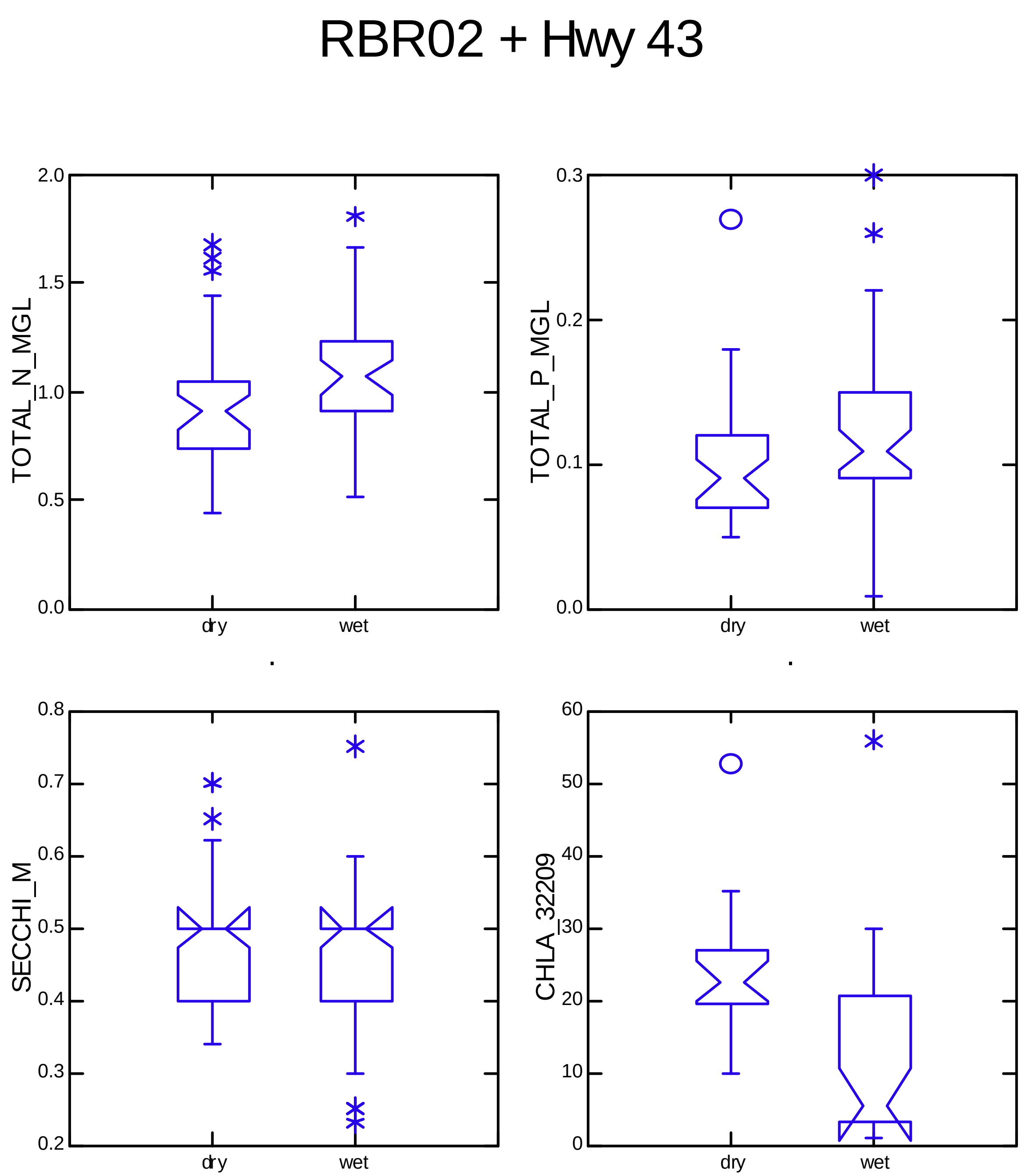


Figure 2.4. Box-and-whisker plots of total nitrogen, total phosphorus, Secchi disc transparency, and chlorophyll *a* at RBR-2+Hwy 43 during wet (November through May) versus dry (June through October) seasons.

RBR03

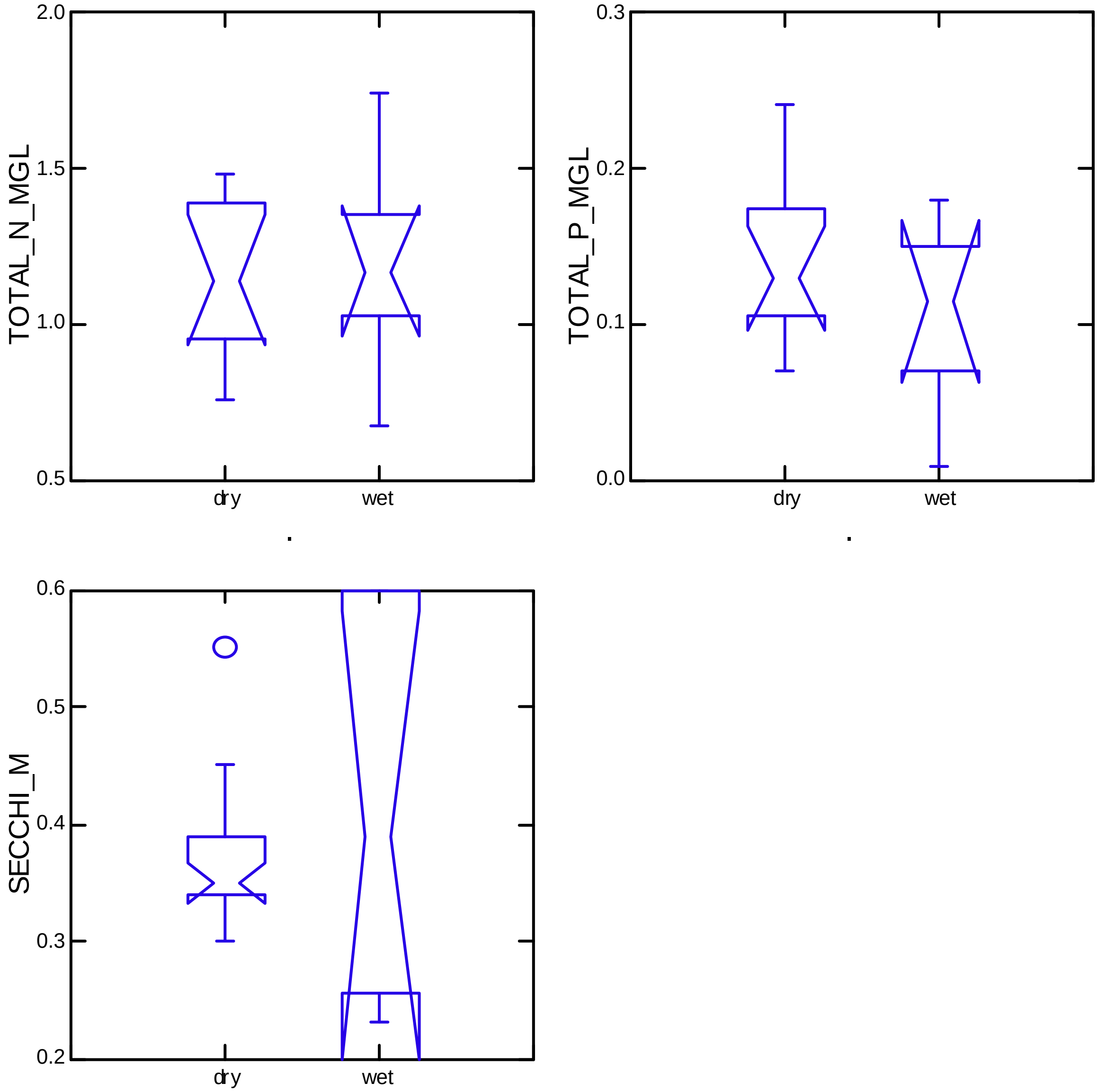


Figure 2.5. Box-and-whisker plots of total nitrogen, total phosphorus, Secchi disc transparency, and chlorophyll *a* at RBR-3 during wet (November through May) versus dry (June through October) seasons.

RBR04

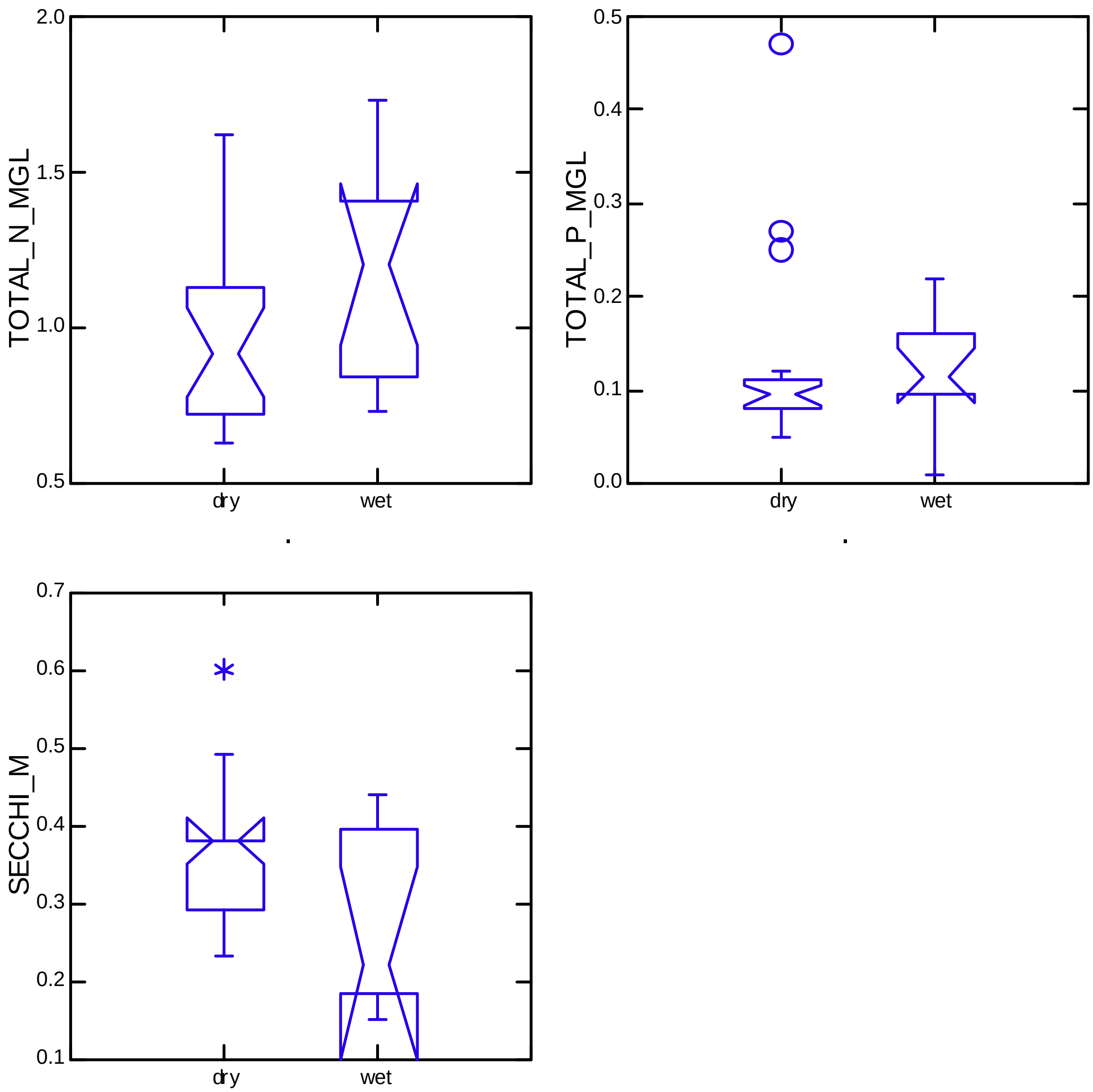


Figure 2.6. Box-and-whisker plots of total nitrogen, total phosphorus, Secchi disc transparency, and chlorophyll *a* at RBR-4 during wet (November through May) versus dry (June through October) seasons.

Although the wet versus dry season differences are not statistically significant, they are generally consistent with expectations for the given parameters. Wet season total phosphorus and total nitrogen should be higher and Secchi disc transparency lower than dry season values. This was generally the case except at RBR-3, where dry season total phosphorus values ranged higher than wet season values and wet season Secchi disc transparency was higher than dry season. Also notable is the higher dry season Secchi disc transparency and chlorophyll *a* at RBR-2 + Hwy 43. This pattern suggests that higher primary productivity in the Reservoir occurs as the water become clearer and suggests that primary production in the Reservoir might be light-limited. This possibility is discussed in further detail later in Sections 3.0 and 4.0.

There was little trend for more variability in total nitrogen, total phosphorus, or Secchi disc transparency in upper versus lower reservoir locations as evidenced by spatial changes in the coefficient of variation (CV) or interquartile range as percentage of the median (IQR%) (Table 2.1).

2.2.1 Wet Versus Dry Hydrological Years

Comparisons of wet versus dry hydrological years for total phosphorus, total nitrogen, and Secchi disc transparency are presented on Figures 2.7 though 2.9, respectively. Although differences are not statistically significant, there appear to be consistent differences among stations in total phosphorus and Secchi disc transparency between wet and dry hydrological years. Figure 2.8 shows a slight increase in total phosphorus at all stations in wet years compared to dry years, while Figure 2.9 shows a slight decrease in Secchi disc transparency at all stations. These changes are consistent with expectations for these parameters. Total nitrogen showed differences between wet and dry years that were not consistent among stations (Figure 2.7).

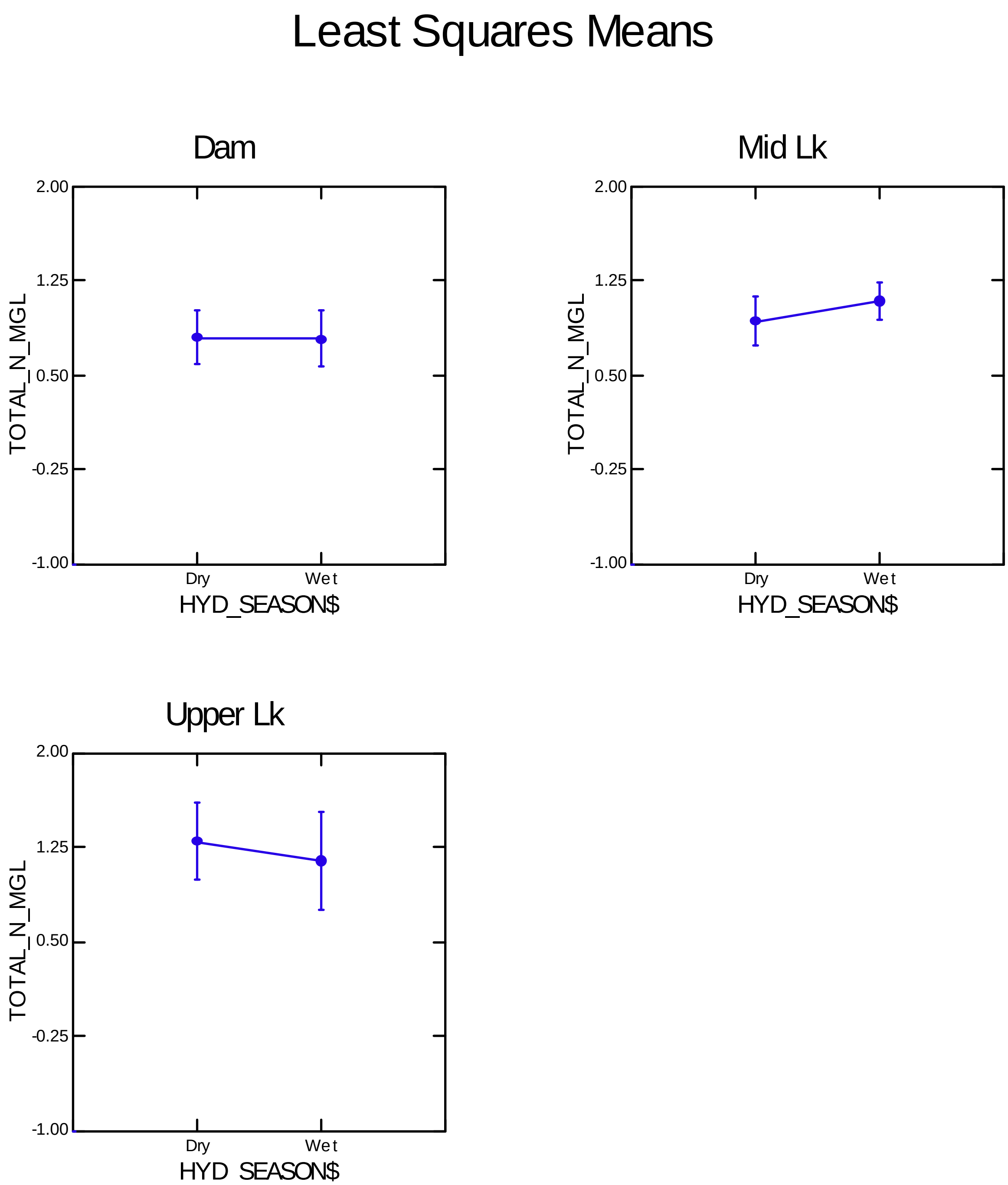


Figure 2.7. Wet and dry hydrological year comparison of total nitrogen among sampling stations.

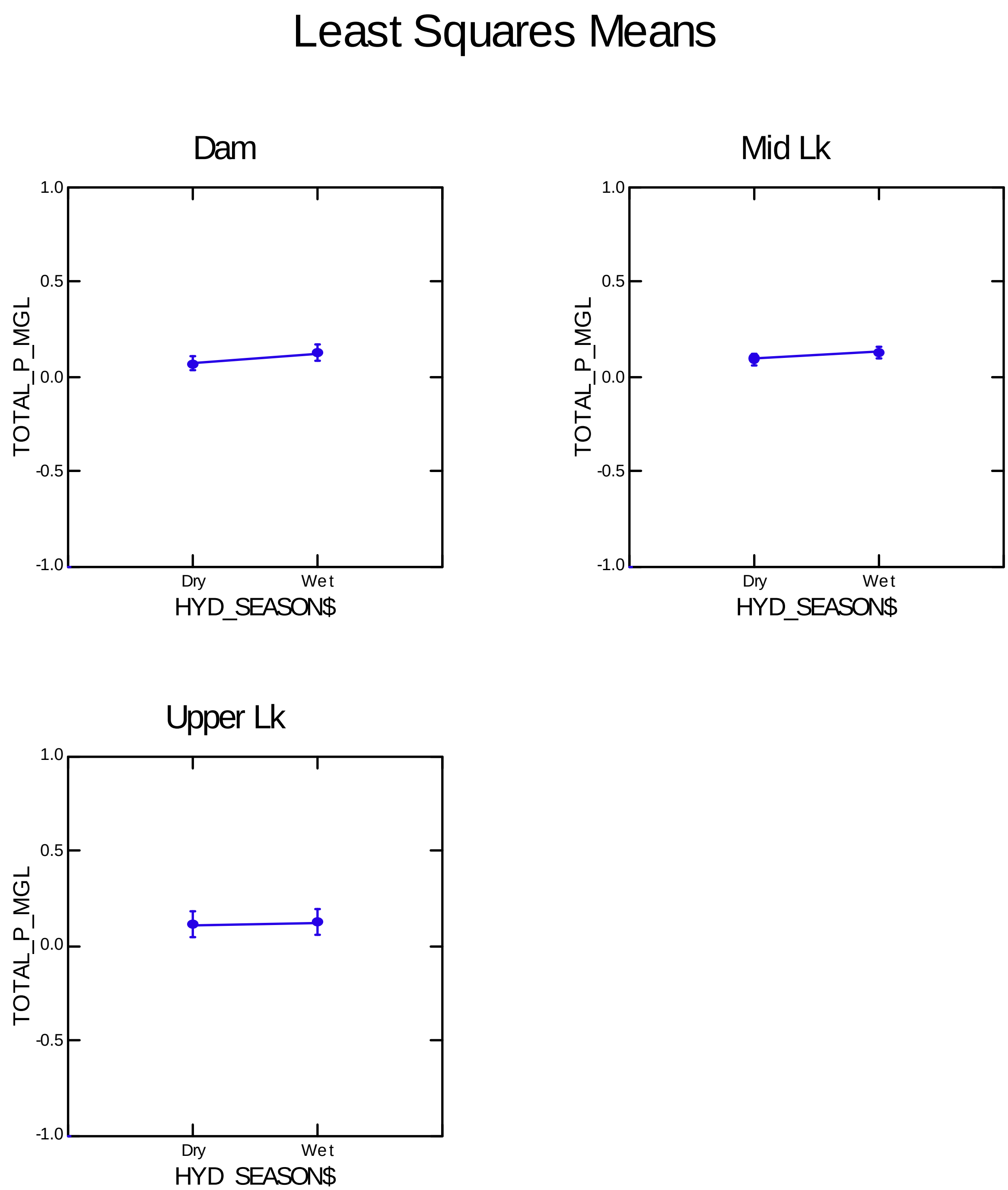


Figure 2.8. Wet and dry hydrological year comparison of total phosphorus among sampling stations.

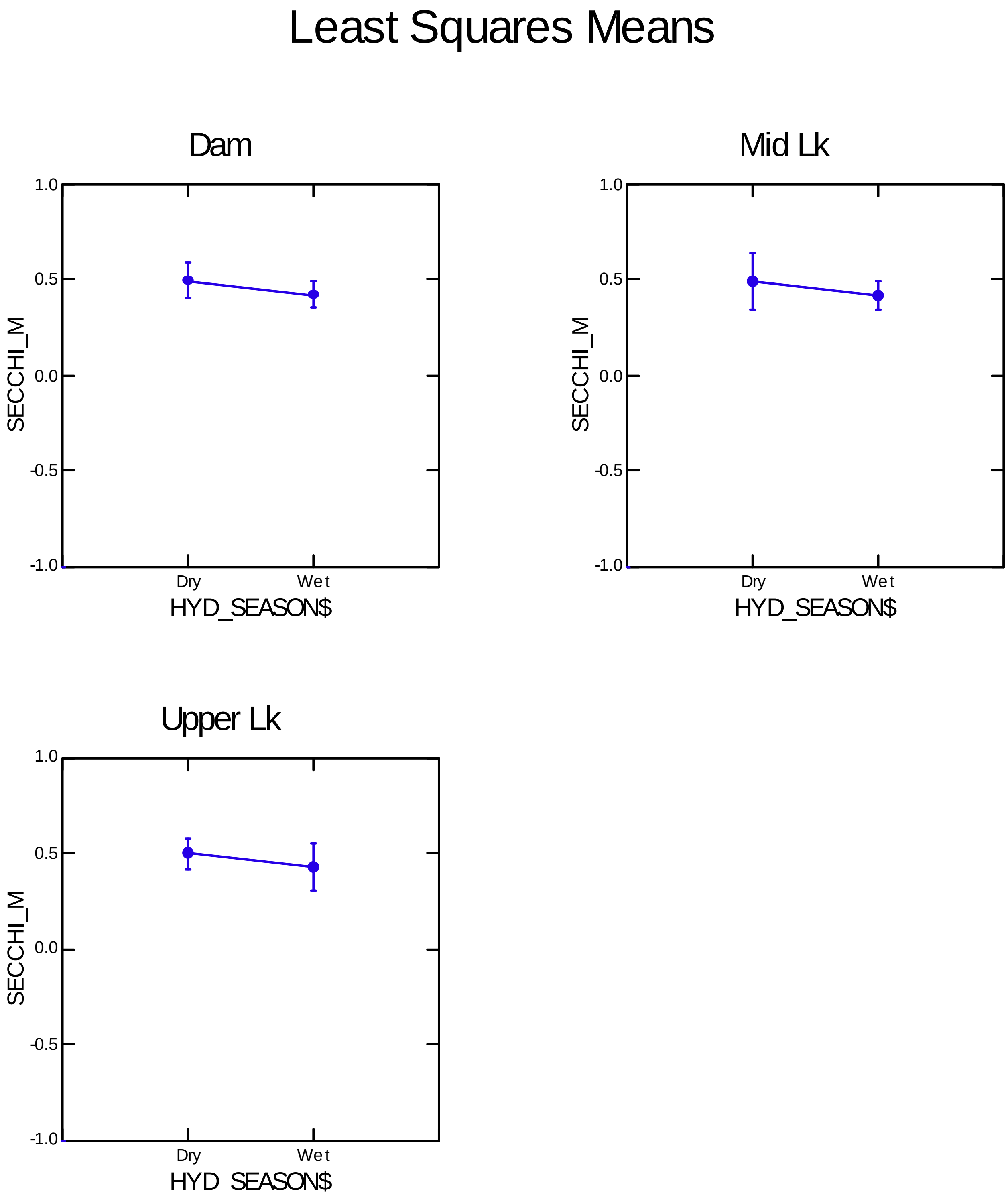


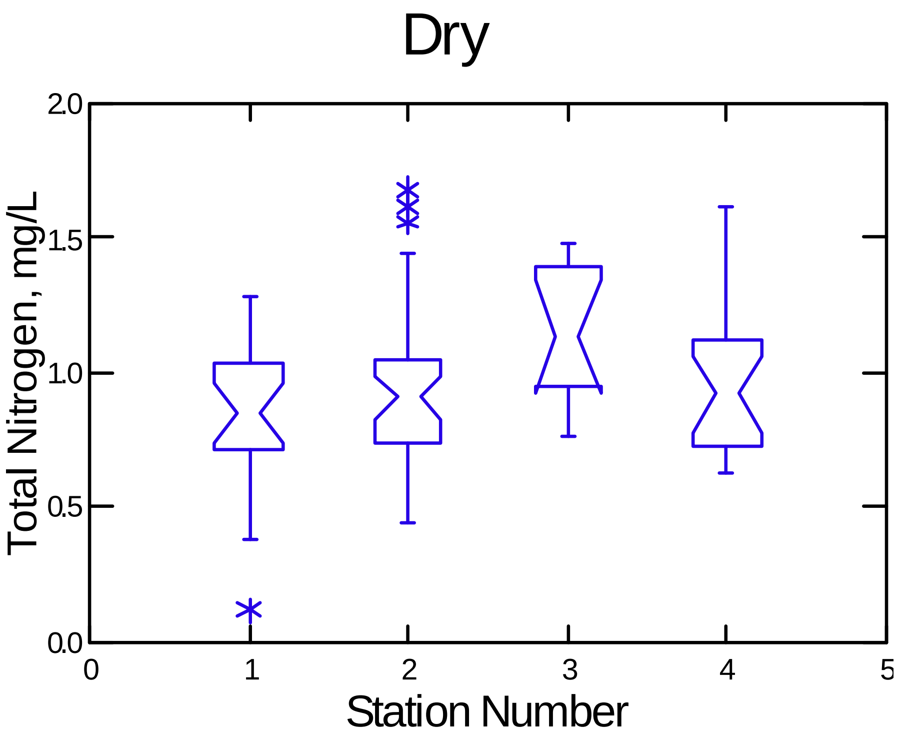
Figure 2.9. Wet and dry hydrological year comparison of Secchi disc transparency among sampling stations.

2.3 Spatial Variation: Differences Among Stations

Spatial variation was evaluated by visually examining box-and-whisker plots of total phosphorus, total nitrogen, Secchi disc transparency, and chlorophyll *a* among stations. As discussed in Section 2.2.2, general differences were observed between wet and dry seasons; therefore, station differences were examined separately for wet and dry seasons. Results of this comparison are presented on Figures 2.10 through 2.12. Figures 2.10 and 2.11 indicate a general pattern of increasing total phosphorus and total nitrogen from the dam station (RBR-1) to the upper reservoir (RBR-3). Total phosphorus and total nitrogen at the Pelahatchie Bay station (RBR-4) more closely resembled the upper reservoir station in the wet season, and the mid-reservoir station in the dry season. A similar spatial trend is evident with dry season Secchi disc transparency (Figure 2.12). Wet season Secchi disc transparency departs somewhat from the pattern with lower values at the Pelahatchie Bay station and similar values among the main reservoir stations (Figure 2.12). These gradients from lower to upper reservoir agree with patterns that are typically seen in reservoirs.

2.4 Covariation Among Nutrients and Nutrient Response Parameters

Adequate chlorophyll *a* data for this analysis were available only for the mid-reservoir location (RBR-2+Hwy 43). Scatter plots showing the relationships between chlorophyll *a* versus nutrients and Secchi disc transparency are provided on Figures 2.13 and 2.14. The scatter plots indicate weak relationships between nutrients and response parameters. Secchi disc transparency shows a weak ($R^2 = 0.19$) positive relationship with chlorophyll *a*, indicating a tendency for higher chlorophyll *a* values in clearer water. Total phosphorus shows a weak ($R^2 = 0.07$) negative relationship with chlorophyll *a*, indicating a tendency for higher chlorophyll *a* values at lower levels of total phosphorus. The total nitrogen versus chlorophyll *a* relationship is essentially flat.



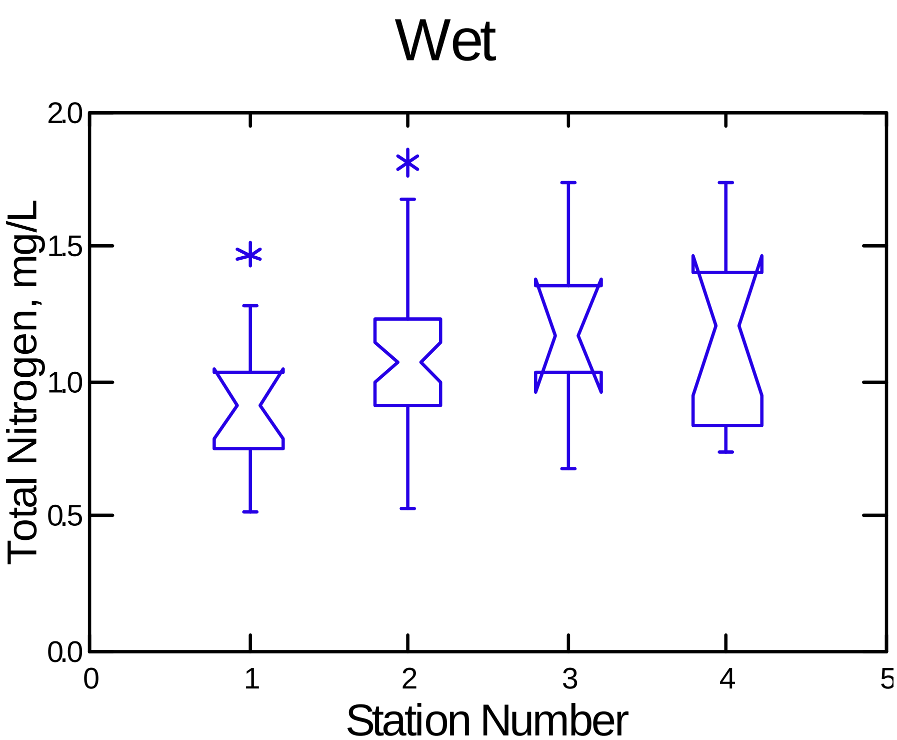


Figure 2.10. Wet and dry season comparison of total nitrogen among sampling stations.

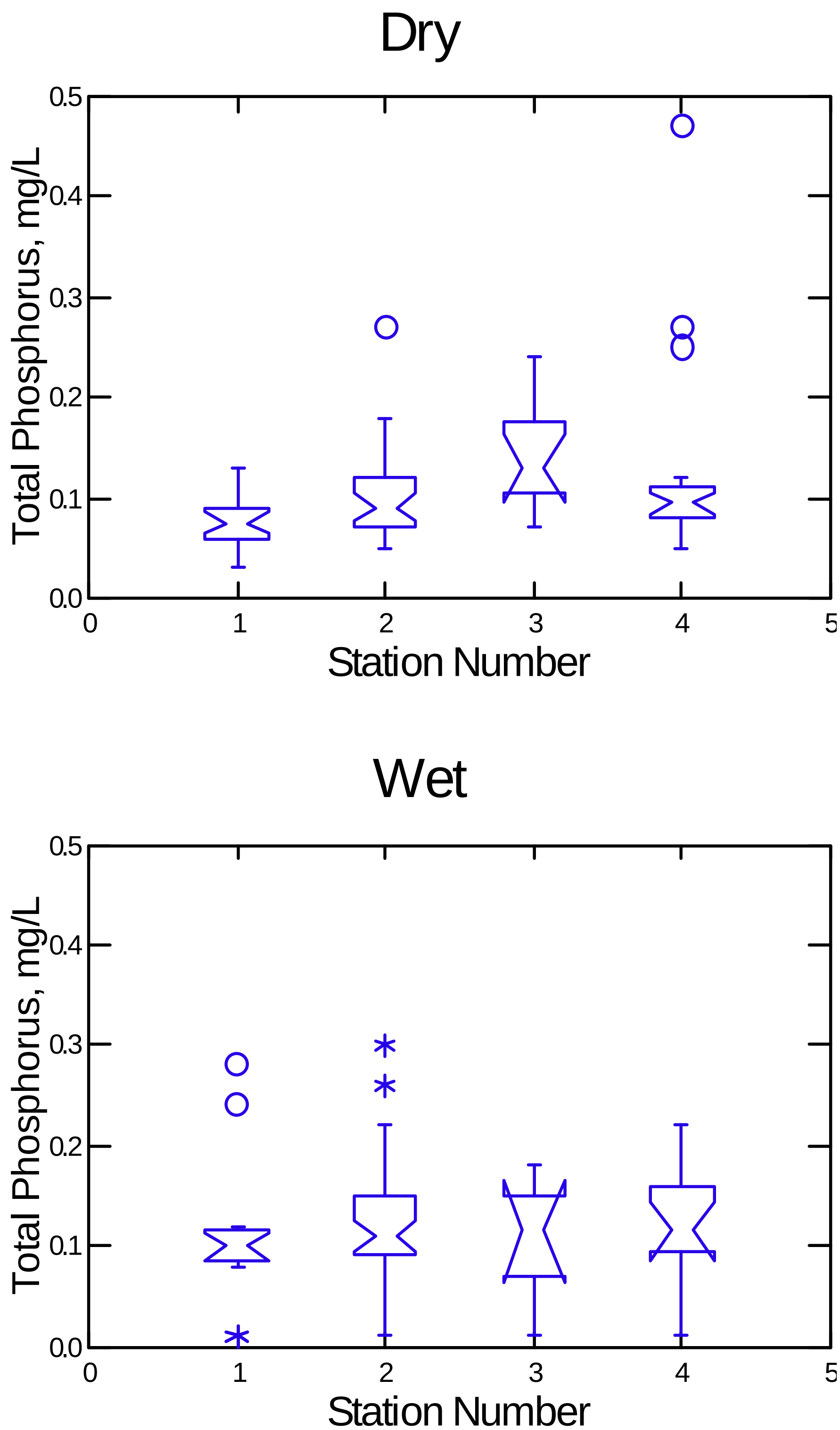


Figure 2.11. Wet and dry season comparison of total phosphorus among sampling stations.

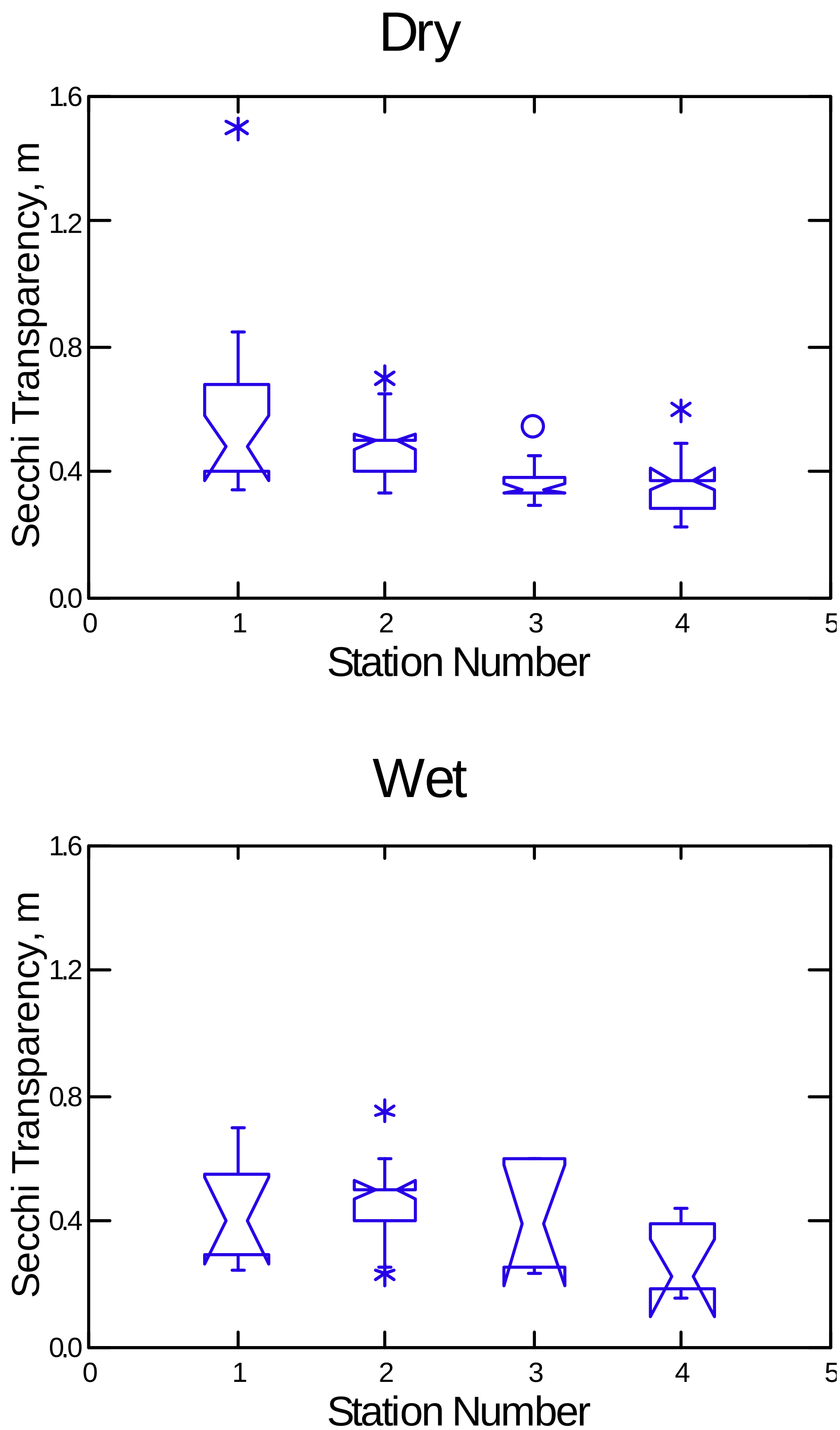
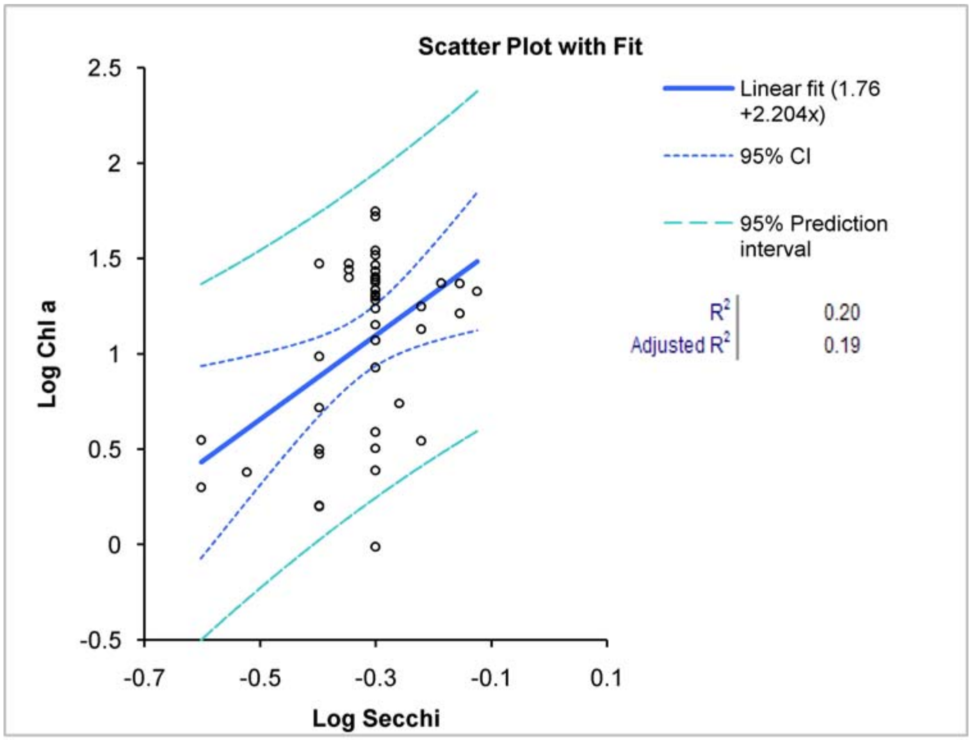


Figure 2.12. Wet and dry season comparison of Secchi disc transparency among sampling stations.



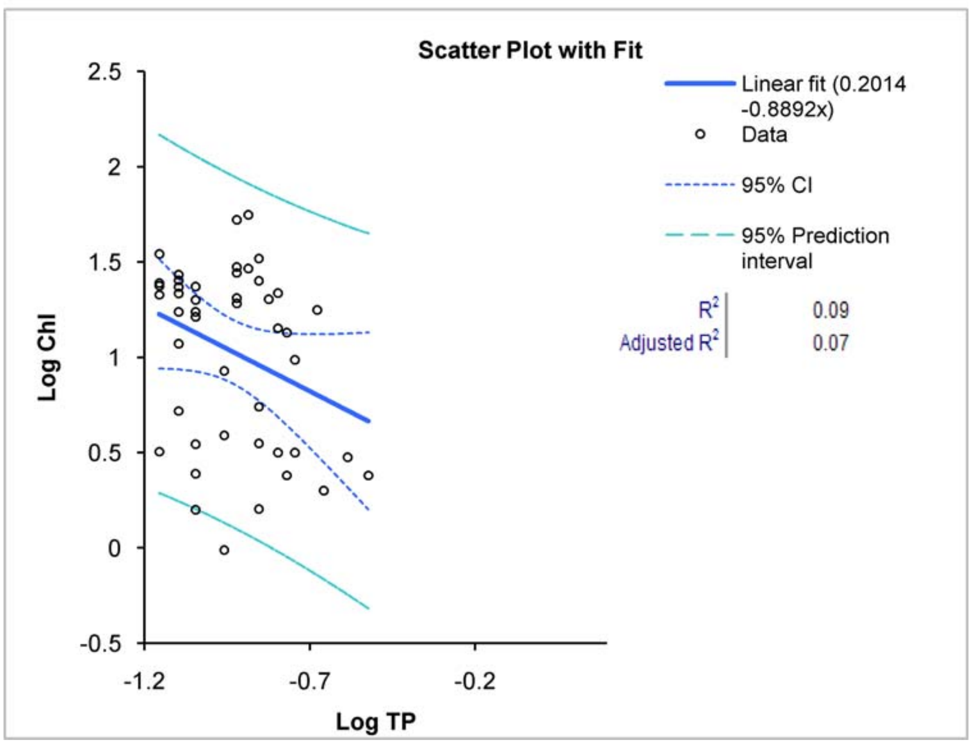


Figure 2.13. Scatter plots of Secchi disc transparency and total phosphorus versus chlorophyll *a* at RBR-2+Hwy 43.

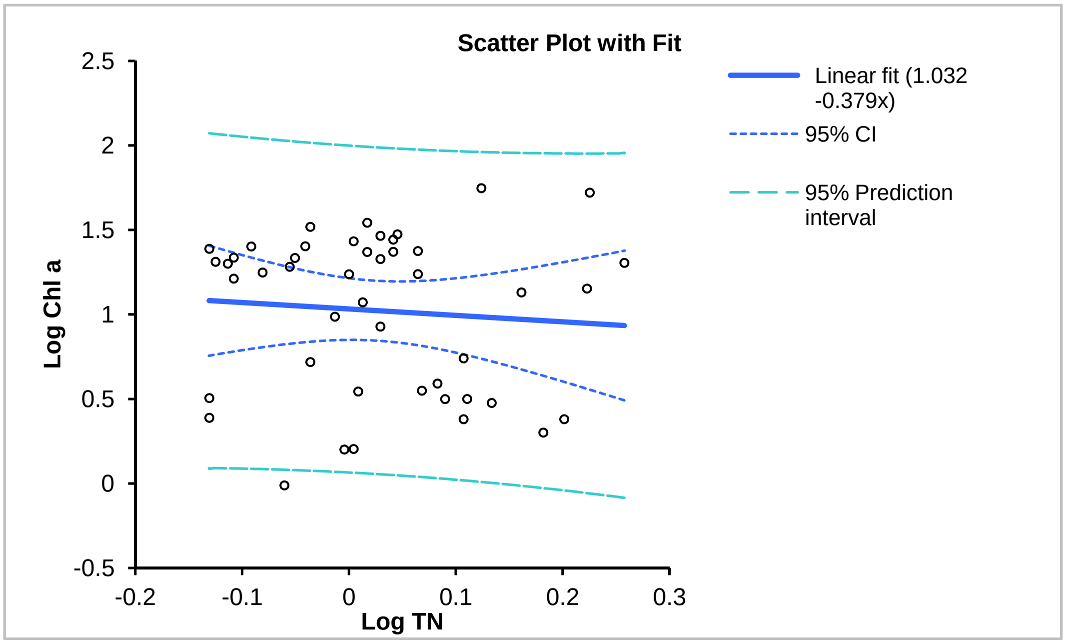
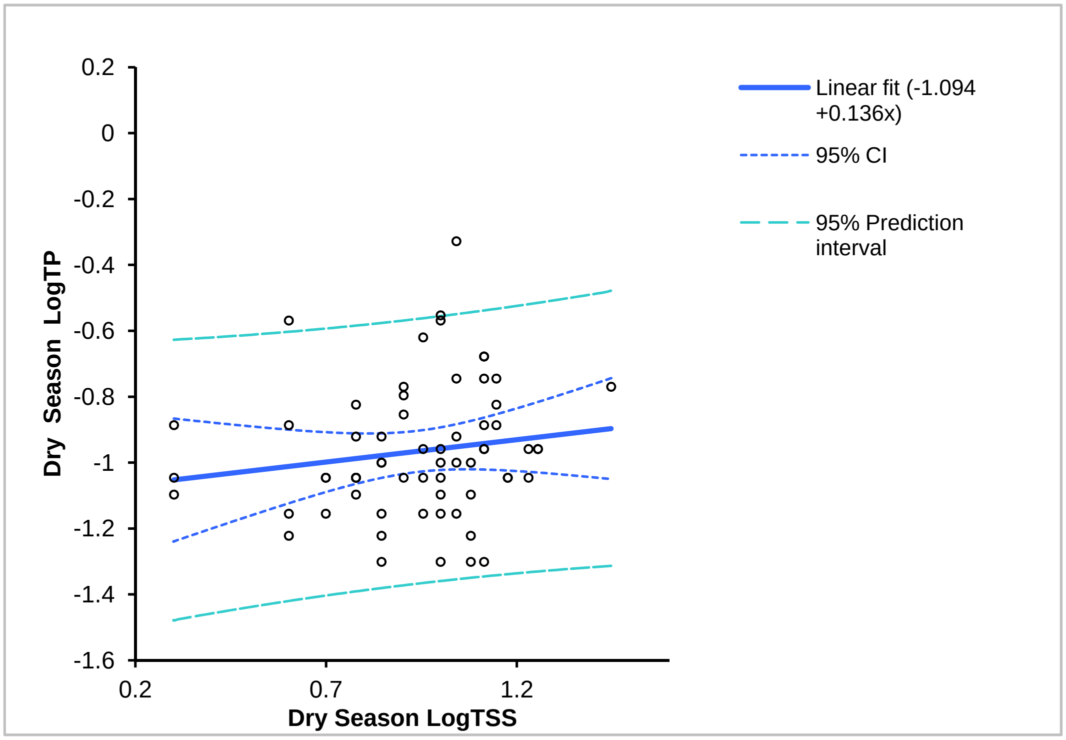


Figure 2.14. Scatter plot of total nitrogen versus chlorophyll *a* at RBR-2+Hwy 43.

In nutrient-limited aquatic systems, nutrients (total phosphorus and total nitrogen) tend to show a positive correlation with chlorophyll *a*. In these systems, chlorophyll *a* will tend to show a negative relationship with Secchi disc transparency to the extent that water clarity is controlled by algal biomass. As non-algal turbidity increases, an aquatic system will tend to become less nutrient-limited and more light-limited and the correlation between Secchi disc transparency and chlorophyll *a* decreases. The scatter plots presented on Figures 2.13 through 2.15 indicate that primary production in the reservoir is typically light-limited.

2.5 Thermal Stratification and Dissolved Oxygen

Figure 2.16 provides temperature and dissolved oxygen profiles from the dam station during the summer months of 2003 and 2004. The vertical temperature profiles indicate that the Reservoir is typically only weakly stratified during much of the summer, with the strongest stratification possibly occurring during early to mid-summer. The July profiles for both years indicate that dissolved oxygen decreases to very low levels or to anoxia during periods of strong stratification. During these periods of anoxia, phosphorus is likely released from the sediments and subsequently transferred into the water column upon lake mixing.



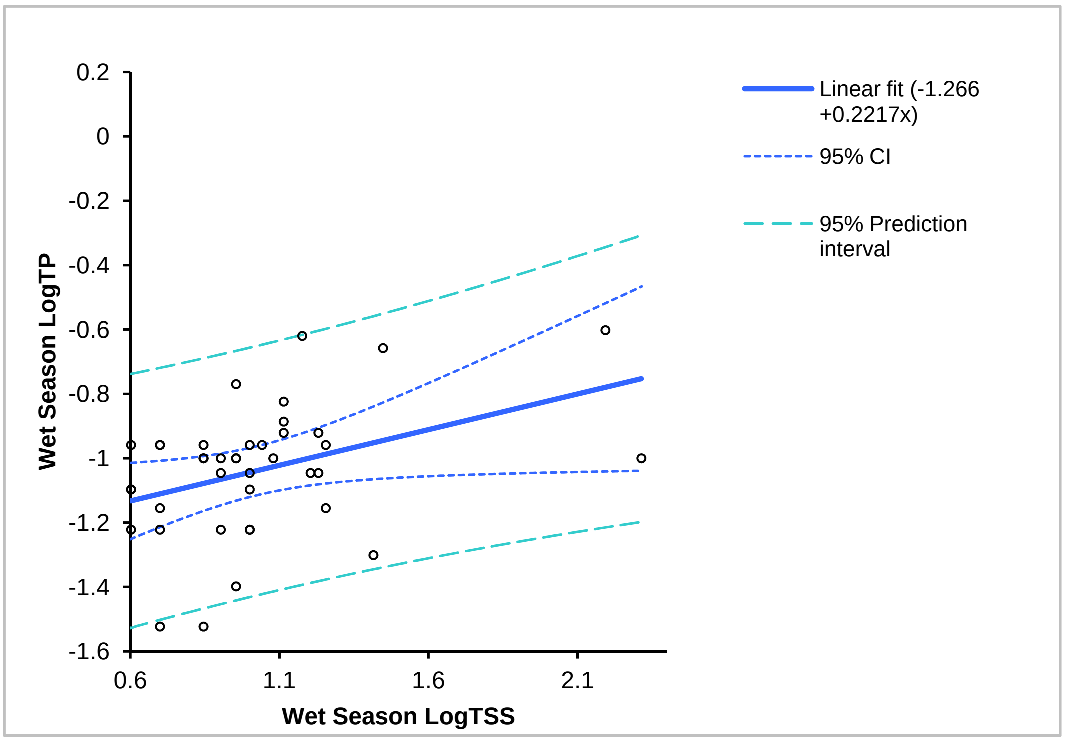


Figure 2.15. Scatter plots of total phosphorus versus total suspended solids (all stations) during wet and dry seasons.

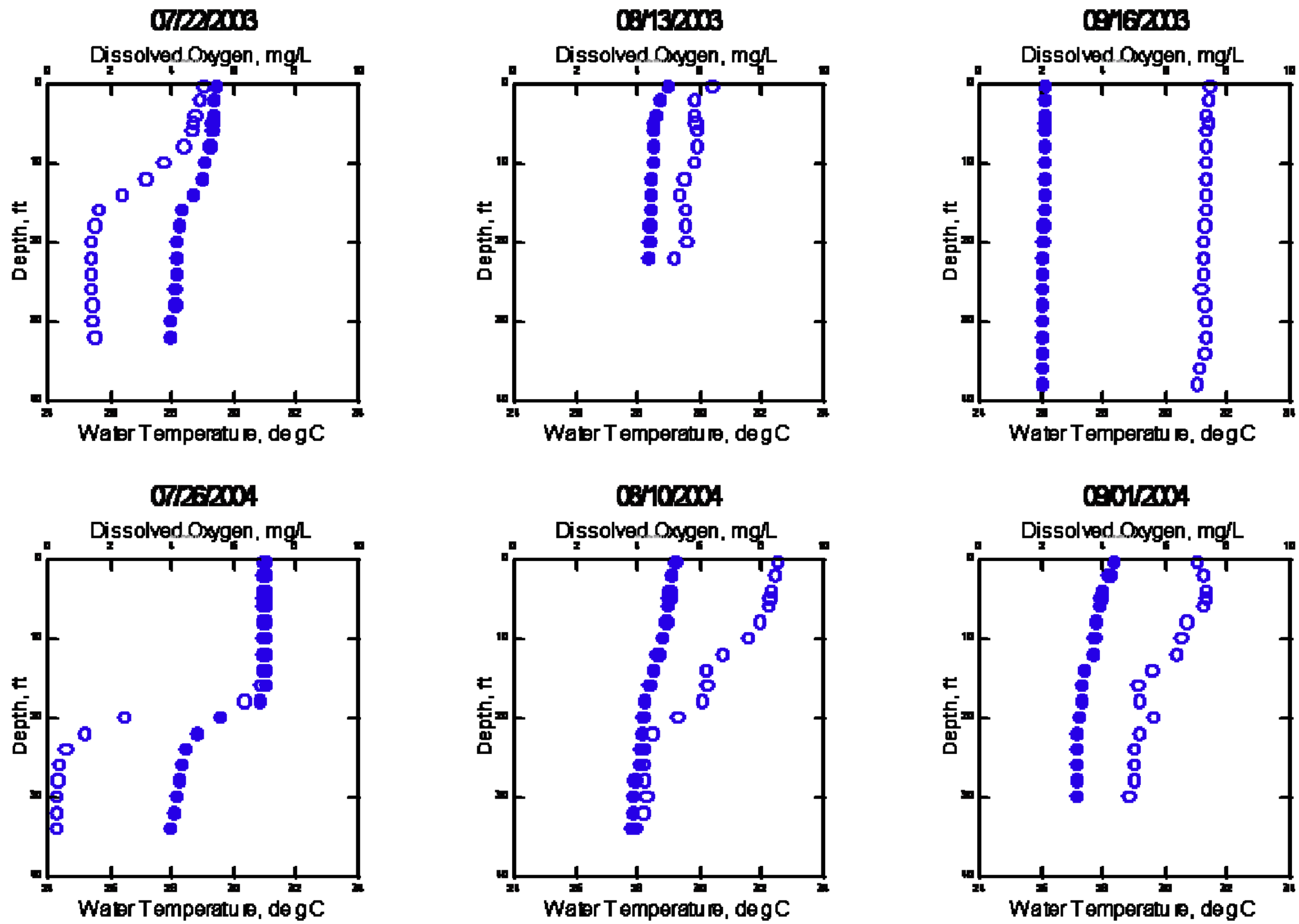


Figure 2.16. Temperature (closed circles) and dissolved oxygen (open circles) depth profiles at the dam station (RBR-1) during the summer months of 2003 and 2004.

2.6 Distribution of Fecal Coliform Values

Fecal coliform bacteria measurements were available from the RBR-1, RBR-2, RBR-3, and RBR-4 locations. Samples were collected during wet and dry seasons from 1997 through August 2001. A summary of the combined data from all sampling locations is provided in Table 2.2. The *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters* (MDEQ 2007) states that:

> "For the months of May through October, when water contact recreation activities may be expected to occur, fecal coliform shall not exceed a geometric mean of 200 per 100 mL based on a minimum of 5 samples taken over a 30-day period with no less than 12 hours between individual samples, nor shall the samples examined during a 30-day period exceed 400 per 100 mL more than 10% of the time."

It was not practical, given the available data, to reproduce the MDEQ assessment method for evaluating compliance with the state water quality criteria for fecal coliform bacteria. However, the summary presented in Table 2.2 indicates that the geometric mean of bacteria counts is well below 200 colony-forming units (CFU) per 100 mL and that over 90% of dry season values are less than 400 CFU per 100 mL. This analysis indicates that Ross Barnett Reservoir is in general compliance with primary contact-based water quality criteria for fecal coliform bacteria.

Table 2.2. Summary of fecal coliform measurements (CFU/100 mL) from all sampling locations during 1997 through 2001.

Percentile	Season: Dry (CFU/100 mL)	Season: Wet (CFU/100 mL)	Combined Seasons (CFU/100 mL)
10	8	9.1	9.1
20	11	20.6	14
30	20	24.4	23
40	23	46.6	30
50	30	80	50
60	50	107.8	93
70	93	150	145
80	230	326	230
90	300	930	900
95	465	1,250.3	1,057.5
Maximum	4,600	11,000	11,000
Geometric Mean	41.3	81.1	61.7
Percent Rank of 400	0.915	0.807	0.846

3.0 DISCUSSION

Total nitrogen, total phosphorus, Secchi disc transparency and chlorophyll *a* levels show weak seasonality with generally higher nutrients and lower water clarity during the wet season. Similarly, there is a weak response to wet versus dry hydrologic years.

The pattern of covariance between nutrient and response parameters suggests a light-limited, as opposed to nutrient-limited, system. In addition, as shown on Figure 2.12, it does not appear that total phosphorus is closely related to total suspended solids (TSS). This result suggests that management efforts that reduce non-algal turbidity might not result in a concomitant reduction in total phosphorus. Increased water clarity without a corresponding decrease in total phosphorus might lead to extremely high levels of algal production and biomass.

The Reservoir appears to be thermally stratified for only a relatively short period of time in the early summer. During this time, the hypolimnion can become anoxic, which typically results in nutrient release from the lake sediments. These nutrients can be then incorporated into the water column upon destratification. In the case of the Ross Barnett Reservoir, this period of internal loading would occur in the middle of the algal growing season. This could further increase the potential for algal blooms. Internal loading due to mid-summer destratification might also account for the poor correlation between total phosphorus and TSS. It could also represent a cause of early summer algal blooms that would not be affected by watershed-based management activities.

4.0 CONCLUSIONS

- The lack of strong seasonality in nutrient conditions suggests that wet weather events might not strongly control potential primary production in the Reservoir.
- Management of suspended solids in the Reservoir might not simultaneously reduce nutrient, thereby creating the potential for significant increases in algal production and biomass.
- Internal loading as a result of mid-summer episodes of lake destratification might be a significant source of nutrients to the Reservoir.
- The Ross Barnett Reservoir is in general compliance with the primary contact-based water quality criteria for fecal coliform.

5.0 REFERENCES

MDEQ. 2007. *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters*. Mississippi Department of Environmental Quality, Office of Pollution Control. Jackson, MS.

MDEQ. 2010. *State of Mississippi Water Quality Assessment 2010, Section 305(b) Report*. Prepared by the Mississippi Department of Environmental Quality, Office of Pollution Control, Field Services Division, Water Quality Assessment Section. April 1, 2010.

APPENDIX E

FISH TISSUE DATA ANALYSIS

OCTOBER 31, 2011

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1.0 INTRODUCTION

Fish tissue analyses were performed on edible portions (filets) of largemouth bass (*Micropterus salmoides*) and flathead catfish (*Pylodictis olivaris*) sampled annually from 2004 to 2007 during the summer months (June through August). These species are typically the top predators in aquatic systems and are most likely to show the highest concentrations of bioaccumulative pollutants (e.g., mercury and some pesticides), particularly with larger, older individuals. These species are also important sport/game fish and are often highly sought by anglers.

Four composite samples of three to four fish were analyzed for each species. Weights and lengths of fish included in each composite are summarized in Table E.1. Fish weights ranged from 1 lb to 1.6 lb for largemouth bass and 5.2 lb to 7.8 lb for flathead catfish. Samples were analyzed for the analytes listed in Table E.2. Analysis of all metals except mercury followed US Environmental Protection Agency (EPA) Method 200.7. Mercury analysis followed EPA Method 245.1. Analysis of organic contaminants followed EPA Method 8081.

2.0 RESULTS

Analytical results are summarized in Tables E.3, E.4 and E.5. No organic analytes, including toxaphene or DDT, were detected above their respective minimum quantitation levels (MQLs) (Table E.3). Metal concentrations, as indicated by the average and maximum concentrations as well as the number of samples exceeding the MQL, were similar in both species (Table E.4). Of the metals detected in excess of the MQL, only arsenic and mercury have fish tissue-based warning limits associated with human health protection (Table E.4). Of these two, only mercury was detected in any of the eight samples (six of eight samples; three samples each for largemouth bass and flathead catfish).

Results of mercury analyses on largemouth bass and flathead catfish are presented in Table E.5. The average and range of mercury concentrations in largemouth bass (excluding the single value less than the MQL) were 0.25 μg/g and 0.08 to 0.36 μg/g, respectively. The average and range of mercury concentrations in flathead catfish (excluding the single value less than the MQL) were 0.25 µg/g and 0.14 to 0.33 µg/g, respectively (Table E.5).

3.0 DISCUSSION

The maximum mercury concentrations (Tables E.4 and E.5) are near the EPA warning limit of 0.3 µg/g and below the Food and Drug Administration warning limit of 0.5 µg/g. Based on this finding, consumption advisories or institutional controls to manage human health risks from mercury or other fish tissue contaminants common in Mississippi waters (e.g., toxaphene and DDT) are not warranted.

Table E.1. Summary of weights and lengths (total length) of largemouth bass and flathead catfish sampled from 2004 to 2007 from Ross Barnett Reservoir.

	M. salmoides		***P. olivaris***	
Sampling Date	**Length (mm)**	**Weight (g)**	**Length (mm)**	**Weight (g)**
06/29/2004 07/21/2004	426 370 375	894 748 757	570 562 582	2,427 2,265 2,430
08/08/2005	347 357 327	644 762 535	680 667 631	3,543 3,607 3,446
07/11/2006	320 310 306 323	499 413 456 464	615 645 604	2,877 2,975 2,676
07/17/2007	360 318 294	538 414 353	626 624 617 605	3,025 2,805 3,036 2,680

Each cell in the table indicates fish that were included in the same composite of edible portions.

Table E.2. Analytes and MQLs for analysis of largemouth bass and flathead catfish edible portions collected from Ross Barnett Reservoir from 2004 to 2007.

Analyte	MQL*	Analyte	MQL	Analyte	MQL
Aluminum	10.2	4,4' – DDE	34	Endrin	26
Antimony	0.73	4,4 – DDT	34	Endrin aldehyde	34
Arsenic	0.18	Aldrin	23	Endrin Ketone	40
Cadmium	0.05	α-BHC	23	γ-Chloradane	25
Chromium	0.05	α-Chlordane	5.4	Lindane	17
Copper	0.42	Atrazine	200	Guthion	272
Iron	0.67	β-BHC	15	Heptachlor	27
Lead	0.22	Choradane Tech	67	Heptachlor epoxide	21
Manganese	0.06	Chlorpyrifos	23	Hexachlorobenzene	10
Nickel	0.11	Cis-Permethrin	250	Methoxychlor	58
Selenium	0.52	δ-BHC	16	Mirex	23
Silver	0.10	Dicofol	27	Pendimethalin	80
Tin	0.18	Dieldrin	29	Simazine	200
Zinc	0.87	Endosulfan I	20	Toxaphene	58
Mercury	0.05	Endosulfan II	27	Trans-Permethrin	64
4,4' – DDD	34	Endosulfan sulfate	23	Trifluralin	23

* MQL units: µg/g for metals, µg/Kg for organic contaminants.

Table E.3. Summary of combined analytical results for largemouth bass and flathead catfish edible portions (eight samples total) collected from Ross Barnett Reservoir from 2004 to 2007.

Analyte	Average	Maximum	Number Greater than MQL	Analyte	Average	Maximum	Number Greater than MQL
Aluminum	4.66	28.10	3	Chlorpyrifos	< MQL	< MQL	0
Antimony	< MQL	< MQL	0	Cis-Permethrin	< MQL	< MQL	0
Arsenic	< MQL	< MQL	0	δ-BHC	< MQL	< MQL	0
Cadmium	0.25	0.90	2	Dicofol	< MQL	< MQL	0
Chromium	1.00	3.82	4	Dieldrin	< MQL	< MQL	0
Copper	0.11	0.55	1	Endosulfan I	< MQL	< MQL	0
Iron	1.27	5.23	3	Endosulfan II	< MQL	< MQL	0
Lead	0.54	3.94	1	Endosulfan sulfate	< MQL	< MQL	0
Manganese	1.07	4.67	3	Endrin	< MQL	< MQL	0
Nickel	< MQL	< MQL	0	Endrin aldehyde	< MQL	< MQL	0
Selenium	0.19	1.18	1	Endrin Ketone	< MQL	< MQL	0
Silver	0.58	2.37	2	γ-Chloradane	< MQL	< MQL	0
Tin	0.71	2.78	2	Lindane	< MQL	< MQL	0
Zinc	5.22	18.00	4	Guthion	< MQL	< MQL	0
Mercury	0.20	0.36	6	Heptachlor	< MQL	< MQL	0
4,4' - DDD	< MQL	< MQL	0	Heptachlor-epoxide	< MQL	< MQL	0
4,4' - DDE	< MQL	< MQL	0	Hexachloro-benzene	< MQL	< MQL	0
4,4 - DDT	< MQL	< MQL	0	Methoxychlor	< MQL	< MQL	0
Aldrin	< MQL	< MQL	0	Mirex	< MQL	< MQL	0
α-BHC	< MQL	< MQL	0	Pendimethalin	< MQL	< MQL	0
α-Chlordane	< MQL	< MQL	0	Simazine	< MQL	< MQL	0
Atrazine	< MQL	< MQL	0	Toxaphene	< MQL	< MQL	0
β-BHC	< MQL	< MQL	0	Trans-Permethrin	< MQL	< MQL	0
Chlordane Tech	< MQL	< MQL	0	Trifluralin	< MQL	< MQL	0

All values greater than the MQL are in µg/g dry weight. For purposes of computing averages, analyte measurements less than the MQL were assigned a default value of 0.05 µg/g.

Table E.4. Summary of analytical results for metals in for largemouth bass and flathead catfish edible portions (four samples per species) collected from Ross Barnett Reservoir from 2004 to 2007.

Analyte	*M. salmoides*			*P. olivaris*		
	Average	# > MQL	Max	Average	# > MQL	Max
Aluminum	16	2	28	4.27	1	4.3
Antimony	NA	0	NA	NA	0	NA
Arsenic	NA	0	NA	NA	0	NA
Cadmium	0.90	1	0.90	0.79	1	0.79
Chromium	1.8	2	3.5	2.1	2	3.8
Copper	0.55	1	0.55	NA	0	NA
Iron	2.0	1	2.0	4.0	2	5.2
Lead	3.9	1	3.9	NA	0	NA
Manganese	4.7	1	4.7	1.8	2	3.6
Nickel	NA	0	NA	NA	0	NA
Selenium	NA	0	NA	1.2	1	1.2
Silver	1.9	1	1.9	2.4	1	2.4
Tin	2.8	1	2.8	2.6	1	2.6
Zinc	8.6	2	12	12	2	18
Mercury	0.25	3	0.36	0.25	3	0.33

Table E.5. Summary of mercury concentrations in individual samples of largemouth bass and flathead catfish from Ross Barnett Reservoir.

Largemouth Bass (µg/g, dry weight)	Flathead Catfish (µg/g, dry weight)
0.36	0.29
0.31	0.33
0.08	0.14
< MQL	< MQL
Average of samples > MQL = 0.25	Average of samples > MQL = 0.25

APPENDIX F

FEDERAL AND STATE REGULATIONS RELEVANT TO RESTORATION & PROTECTION

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1.0 INTRODUCTION

This appendix describes federal and state regulations that are relevant to restoration and protection of water quality in the Reservoir and its watershed. Included in these descriptions are the agencies responsible for implementing these regulations and their associated programs, and the entities that are regulated. There are a number of federal regulations that are implemented by state agencies. Many of these regulations require permits to be issued.

2.0 FEDERAL REGULATIONS ADMINISTERED BY FEDERAL AGENCIES

This section describes federal regulations that apply to the Reservoir and its watershed, and that are implemented by federal agencies. This includes regulation of dredge and fill activities, flood insurance, hazardous waste disposal, and clean-up of contaminated sites, as well as programs to reduce erosion and nonpoint source pollution, and track releases of toxic materials.

2.1 Clean Water Act Section 404 – Dredge and Fill Permits, and Section 401 – Water Quality Certification

Several sections of the Clean Water Act deal with controlling impacts to navigable waters. Section 404 of the Clean Water Act controls the placement of dredge or fill materials into wetlands and other waters of the US. Section 10 of the Rivers and Harbors Act regulates impacts to navigable waters of the US. Section 401 of the Clean Water Act requires MDEQ to certify that a project requiring a Section 10 or Section 404 permit will not violate the state water quality standards.

Sections 401 and 404 of the Clean Water Act require that impacts to qualifying waterbodies be avoided or minimized. Where impacts are unavoidable, mitigation may be required. Qualifying waterbodies include wetlands and "other waters of the US." The basic definition for other waters of the US, for the purpose of Section 404, is any waterbody that displays an ordinary high water mark (OHWM). This includes lakes and ponds that have a hydrologic connection to a qualifying waterbody; perennial and intermittent channels; and ephemeral stream channels that exhibit an OHWM. The US Army Corps of Engineers (USACE) administers the regulations associated with both of these sections.

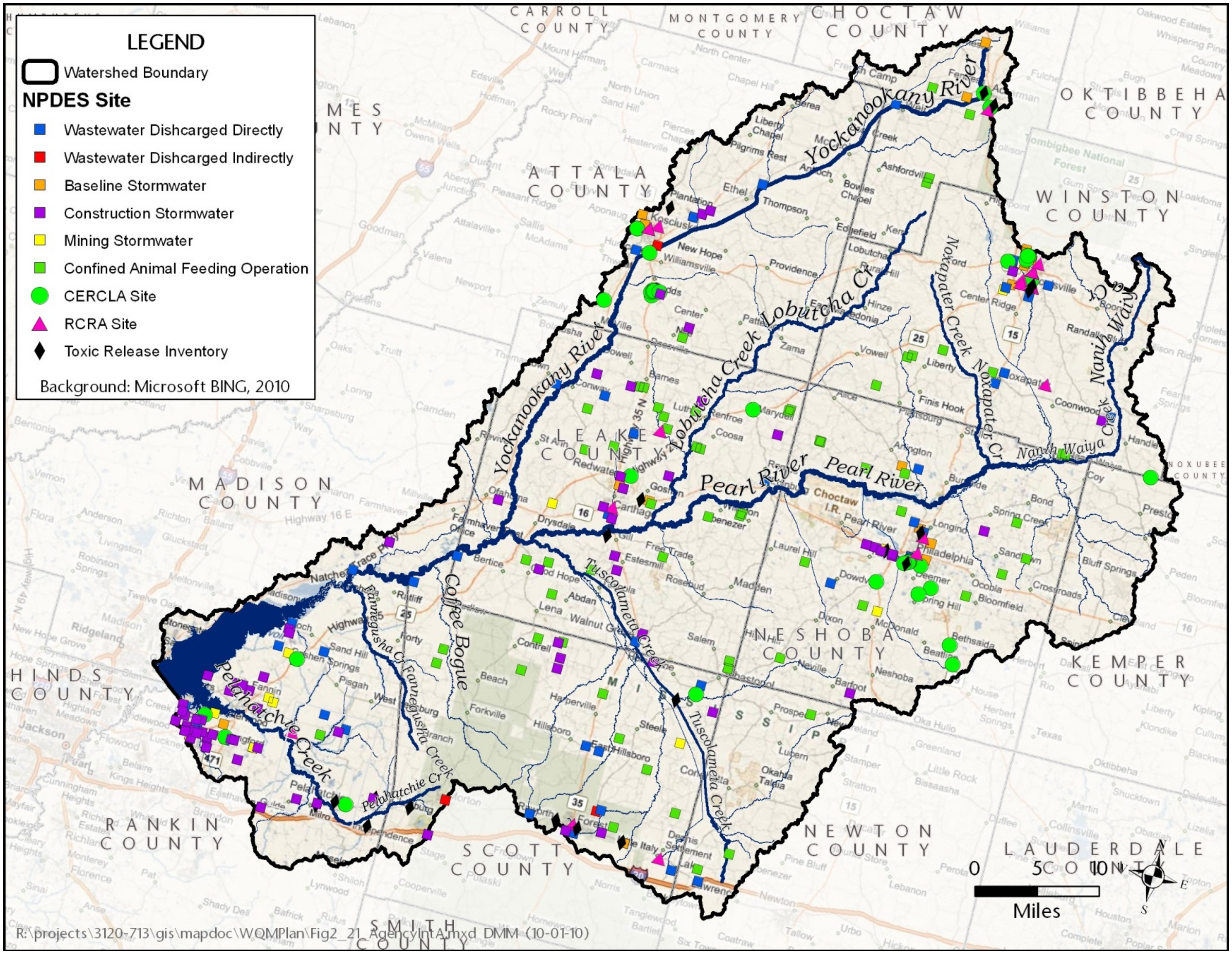

Figure F.1. Locations of facilities in Ross Barnett Reservoir watershed under federal regulation.

USACE commonly issues two types of permits under Section 404: Individual Permits and Nationwide Permits (NWPs). Individual permits are required when 1) impacts to wetlands exceed 0.5 acre, and/or 2) impacts to a qualifying waterbody are greater than 300 linear feet. The individual permit includes a period of public review, and processing generally takes between 60 and 120 days. The processing time can be greater if public hearings or environmental statements are required, or if all required information on the permit application form is not provided. NWPs are general permits typically used when minor impacts are necessary to wetlands (less than 0.5 acre) or a qualifying waterbody (any impacts less than 300 linear feet). Processing time is generally less and no public review period is necessary.

Mitigation for both wetland losses or stream function and value losses may be required by USACE for a project authorized under either an individual or nationwide permit. The extent of the mitigation is dependent upon the size, quality, and functionality of the wetland or waterbody to be impacted.

The Ross Barnett Reservoir is considered a navigable body of water by USACE and is subject to regulations under Section 10 of the Rivers and Harbor Act of 1889 and Section 404 of the Clean Water Act. Any work on, in, or over water or wetlands requires a Section 10 permit and any deposition of dredged or fill material into waters or wetlands of the US requires a Section 404 permit, both issued by USACE.

A general permit for Section 10 activities associated with construction of L- and T-shaped piers, boathouses, and gazebos on the Reservoir has been issued by USACE. A copy of this permit is on file in the PRVWSD office. Certain limitations intended to protect the environment and natural and cultural resources are placed on these activities. This permit does not authorize any activities resulting in the discharge of dredged or fill material. Any work requiring deposition of dredged or fill material in waters or wetlands of the US will require an individual permit from USACE.

PRVWSD maintains navigational channels throughout the Reservoir. The deposition of the dredged material requires an individual permit from USACE. The deposition site chosen for the dredged material will be located in the least environmentally damaging location.

2.2 Clean Water Act Section 319

Section 319 of the Clean Water Act provides funding for projects that reduce nonpoint source water pollution. EPA provides grants to states to use for implementing nonpoint source pollution control programs. MDEQ receives Section 319 grant monies, some of which is distributed to nonpoint source pollution control projects implemented by other agencies or interest groups. A 40% non-federal match is required when using Section 319 grant money. Nonpoint source pollution control projects in the Ross Barnett Reservoir watershed that have been funded using Section 319 grant money are described in Appendix M of the *Comprehensive Protection and Restoration Plan*.

2.3 Federal Food Security Act (Farm Bill)

Under the Federal Food Security Act (Farm Bill), initially passed in 1985, all US farm operators are required to meet soil erosion control standards specified in the law. Compliance with these standards is a prerequisite for participation in most federal farm programs. Subsequent amendments to the Farm Bill have added programs that provide incentives to farm operators for enhancing water quality through such actions as taking highly erodible lands out of production, and restoring wetlands. The US Department of Agriculture (USDA) administers the Farm Bill. Many of the incentive programs are administered through the USDA National Resources Conservation Service, e.g., Conservation Reserve Program (CRP and CREP), Environmental Quality Incentives Program (EQIP), and Wetlands Reserve Program (WRP).

2.4 National Flood Insurance Program

The National Flood Insurance Program (NFIP) is a non-regulatory federal program administered by the Federal Emergency Management Agency (FEMA). However, this program provides mechanisms that can be used to restrict development in floodplains, which can have beneficial effects on water quality. The NFIP supports development and enforcement of floodplain management plans and ordinances. Covered communities in the watershed are Attala County, the city of Kosciusko, the town of Ackerman, Leake County, the city of Carthage, Neshoba County, the city of Philadelphia, Newton County, the town of Lake, Scott County, the city of Forest, the city of Morton, the town of Sebastopol, Winston County, and the city of

Louisville. Although participation in the NFIP is not required, if a community agrees to participate, they are required to adopt and enforce floodplain management regulations (floodplain ordinances) with minimum standards as required by federal regulations.

2.5 Hazardous Waste Regulations

Facilities that generate, store, or transport wastes containing materials identified by EPA as a hazardous waste (40 CFR Part 261) are regulated under the Resource Conservation and Recovery Act of 1976 (RCRA). The purpose of RCRA is to track hazardous wastes, ensuring that they are disposed of properly. There are a number of facilities subject to RCRA located in the Ross Barnett Reservoir watershed (Figure F.1).

2.6 Superfund

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Superfund Amendments and Reauthorization Act (SARA) provide funding for cleanup of abandoned sites where hazardous waste is located. Superfund was established by CERCLA and allows EPA to clean up such sites and to compel responsible parties to perform cleanups or reimburse EPA for cleanups. Contaminated sites are listed on the National Priorities List (NPL) upon completion of Hazard Ranking System (HRS) screening, public solicitation of comments about the proposed site, and response to all comments. The CERCLA regulations require reporting of releases of toxic substances that could pose a health threat. There are a number of sites in the Ross Barnett watershed where releases and cleanups have occurred. Locations of these sites are indicated on Figure F.1.

2.7 Toxics Release Inventory

The Toxics Release Inventory (TRI) is authorized by the Emergency Planning and Community Right-to-Know Act (EPCRA) and the Pollution Prevention Act (PPA). EPCRA Section 313 requires EPA and states to collect data annually on releases and transfers of certain toxic chemicals from industrial facilities and make the data available to the public via the TRI. The goal of TRI is to provide communities with information about toxic chemical releases and waste management activities and to support informed decision-making. There are a number of sites in the Ross Barnett watershed included in the Toxics Release Inventory (Figure F.1).

3.0 FEDERAL REGULATIONS ADMINISTERED BY STATE AGENCIES

For some federal regulations that apply to the Reservoir and its watershed, authority for implementation of the regulatory programs has been delegated to state agencies.

3.1 National Pollutant Discharge Elimination System Program

3.1.1 Wastewater Discharged Directly to Surface Water

The Clean Water Act requires the control of wastewater discharges to surface waters under the National Pollutant Discharge Elimination System (NPDES) program. MDEQ has the delegated authority to administer the NPDES program in Mississippi. The Mississippi Commission on Environmental Quality (MCEQ) oversees MDEQ's administration of the NPDES program on the state level, while EPA provides oversight at the federal level.

Under the delegated authority, MDEQ issues NPDES permits to facilities that discharge or have the potential to discharge to waters of the state. These permits are typically issued with an effective term of 5 years and contain limitations on wastewater flow and/or pollutants that may be discharged, as well as other conditions and/or restrictions on the discharge. Typically, permit limitations are based on effluent guidelines (i.e., technology-based) or state water quality standards (water quality-based). NPDES permit writers also have the discretion to impose limitations based on best professional judgment (BPJ) for any parameters that may pose a threat to the waters of the state, but for which no established effluent guideline or specific state water quality standard exists. The permit writer is required to provide appropriate justification for any BPJ limitation.

Effluent guidelines for categorical industries have been promulgated in 40 CFR Parts 400 through 699. These limitations represent the type and quantity of pollutants expected to be discharged from a particular industry after the wastewater has received a specified degree of treatment. MDEQ is prohibited from issuing NPDES permits with limitations that are less stringent than the effluent guidelines, but may require more stringent limitations if deemed necessary to protect the water quality and beneficial uses of the receiving stream.

In addition to pollutant limitations, major dischargers and select minor discharges will have biomonitoring requirements included in the NPDES permit. Biomonitoring tests involve the placement of test organisms in varying concentrations of effluent to evaluate toxicity. Based on the ratio of effluent to receiving stream flow at critical conditions (7Q10), a critical dilution will be determined that represents the minimum concentration at which no toxicity must be observed.

Permittees are required to perform self-monitoring through routine effluent sampling. Sampling results are reported to MDEQ regularly on discharge monitoring reports (DMRs). In addition to self-monitoring, MDEQ inspectors perform routine compliance inspections of permitted facilities. Enforcement measures, including fines and permit revocation, are available to MDEQ when addressing noncompliance by dischargers.

As of October 2009, there were approximately 45 sites in the Ross Barnett watershed with active individual NPDES permits for discharge of wastewater to surface waters.[1] Eleven of these sites were classified as municipal wastewater dischargers. The remainder of the sites were classified as industrial or commercial wastewater dischargers. There are also several ready-mix (concrete and asphalt) operations in the watershed that are covered by a general NPDES wastewater discharge permit. Discharges of wastewater from wet decks at sawmills are also covered by a general NPDES wastewater discharge permit. The locations of facilities with NPDES wastewater permits are indicated on Figure F.1.

3.1.2 Wastewater Discharged Indirectly to Surface Water

The Clean Water Act effluent limitations guidelines (40 CFR 400 through 699) also specify discharge limitations for categorical industries discharging to collection systems for municipal wastewater treatment facilities. Unlike most states, the federal pretreatment program in Mississippi is run at the state level, as opposed to the city level. Therefore, those industries seeking to discharge to municipal systems must obtain a pretreatment permit from the state. As of October 2009, there were four pretreatment permits active for industries that discharge pretreated wastewater into a municipal wastewater treatment system. The locations of these facilities are indicated on Figure F.1.

[1] http://opc.deq.state.ms.us/default.aspx

3.1.3 Industrial Stormwater Permits

Industrial stormwater is permitted through a state general permit. As of October 2009, approximately 30 industrial sites in the Ross Barnett Reservoir watershed were under the Mississippi baseline stormwater general permit.[2] Locations of these sites are indicated on Figure F.1 as “baseline stormwater.”

3.1.4 Construction Stormwater Permits

Construction stormwater is covered under a state general permit. In October 2009, 37 sites in the Ross Barnett Reservoir watershed had coverage under the large construction stormwater general permit, which applies to sites where more than 5 acres of land are disturbed.[3] Locations of these sites are indicated on Figure F.1.

3.1.5 Mining Stormwater Permits

There are several sand and gravel mines located in Rankin County near Highway 25, Highway 471, and Wirtz Road. Mining activities cause significant disturbance of land surfaces, which may contribute to sediment pollution in nearby waters if not properly controlled. MDEQ requires mining facilities to obtain coverage under a general stormwater permit and develop a stormwater pollution prevention plan. Facilities receiving coverage under the mining general permit must implement erosion and sediment controls during mining activities, maintain erosion and sediment controls after mining until the site is stabilized, and conduct regular inspections to ensure the controls are adequate and working. Mining sites greater than 4 acres are also required to obtain a mining permit from the office of geology and must have a plan for reclamation of the site. Additional information on mining sites in the watershed is included in Appendix H to the *Comprehensive Protection and Restoration Plan*.

3.1.6 Municipal Storm Sewer Systems Permits

There are several areas within the Ross Barnett watershed that are required to develop Stormwater Management Plans required under the Clean Water Act Storm Water Phase II Rule

[2] http://opc.deq.state.ms.us/default.aspx
[3] *Ibid*.

for municipal separate storm sewer systems (MS4s). These areas are Rankin County, the City of Flowood, Madison County, the City of Madison, and the City of Ridgeland. The Mississippi Department of Transportation (MDOT) also has a Stormwater Management Plan (SWMP) that applies to road construction and maintenance in Rankin and Madison counties.

Each stormwater management plan must include six control measures. The control measures are as follows:

1. Public education and outreach,
2. Public participation and involvement,
3. Illicit discharge detection and elimination,
4. Construction site stormwater controls,
5. Post construction stormwater controls, and
6. Pollution prevention and good housekeeping.

3.1.7 Concentrated Animal Feeding Operations

Concentrated animal feeding operations (CAFOs) of greater than 1,000 animal units, or that are determined to be a threat to water quality, are required to obtain a federal CAFO permit under the NPDES program administered by MDEQ. In Mississippi, these facilities are covered under a state general permit. There are currently six permitted CAFO facilities located in the Ross Barnett Reservoir watershed. All of these facilities are swine operations located in Winston and Choctaw counties in the upper part of the watershed. The locations of these sites are indicated on Figure F.1.

All CAFOs are required to develop a nutrient management program. NRCS typically provides guidance to individual growers for developing these programs. These programs describe manure management practices to ensure no runoff is generated that could potentially transport manure to nearby waterbodies during rain events. Nutrient management programs must also be submitted to MDEQ and approved before coverage under a CAFO general permit is issued. Animal feeding operations that meet the CAFO criteria, as defined by the Clean Water Act, are permitted for water discharges through general permits administered by MDEQ.

3.2 Safe Drinking Water Act

All drinking water systems serving 25 people or more are considered public drinking water systems and are subject to EPA regulation through the Safe Drinking Water Act (SDWA). Elements of the SDWA include the Enhanced Surface Water Treatment Rule, Disinfection Byproducts Rule, the requirement for Source Water Assessment and Protection, and the Underground Injection Control (UIC) Program. In Mississippi, the SDWA is administered by the Mississippi State Department of Health (MSDH). The exception to this is the requirement for Source Water Assessment and Protection. In 1998, MSDH contracted with MDEQ to develop and administer the Source Water Assessment Program (SWAP). MDEQ received EPA approval of the SWAP Plan in November 1999 (MDEQ 1999) before initiating efforts to implement the program.

MDEQ administers the UIC program in Mississippi. The UIC program is responsible for regulating the construction, operation, permitting, and closure of injection wells that place fluids underground for storage or disposal. This program provides permitting and guidance to allow the safe operation of injection wells to prevent contamination of underground drinking water resources.

3.3 Underground Storage Tank Regulations

Underground storage tanks (USTs) are regulated under federal programs. EPA has delegated to the state of Mississippi the authority to implement this program in Mississippi. USTs that contain hazardous substances and/or petroleum are regulated under Subtitle I of RCRA. USTs containing hazardous wastes are regulated under Subtitle C of RCRA.

Under the Mississippi Underground Storage Tank Regulations, owners are required to notify MDEQ of installation, replacement, closure, or transfer of ownership. In these notifications, owners must certify that they are compliant with the requirements of the regulations, including those for installation, cathodic protection of steel components, financial responsibility, and leak detection. As of October 2009, there were approximately

670 underground storage tanks registered with MDEQ in the Ross Barnett Reservoir watershed.[4] Locations of these storage tanks are indicated on Figure F.1.

[4] http://opc.deq.state.ms.us/default.aspx

4.0 STATE REGULATIONS

There are also state regulations that apply to the Reservoir and its watershed.

4.1 Onsite Wastewater Treatment Regulations

State regulations addressing onsite wastewater treatment systems are administered through MSDH. Regulations are in place to address single-family residence onsite wastewater treatment systems, as well as onsite systems serving recreational vehicle campgrounds, developments, and multi-family dwellings. These regulations require approval and certification of all new installations of onsite wastewater treatment systems, including replacement of old systems. Certification is not required for systems in use prior to enactment of the regulations, providing they meet criteria specified in the regulations.[5]

4.2 Surface Mining Regulations

The Mississippi Surface Mining and Reclamation Rules and Regulations[6] are administered by MDEQ. These regulations require surface mining operations to obtain a permit to operate from MDEQ and provide for reclamation of the mine site when operations cease. The regulations also provide a mechanism for prohibiting surface mining in areas by designating them as land unsuitable for mining. Environmentally sensitive areas can be designated as land unsuitable for mining.[7] Surface mines that disturb an area 4 acres or larger must also obtain a permit from the MDEQ Office of Geology. Locations of sites in the Ross Barnett Reservoir watershed that hold a surface mining permit are shown on Figure F.2.

[5] http://www.msdh.ms.gov/msdhsite/_static/30,0,78.html, accessed June 2010
[6] http://www.deq.state.ms.us/newweb/mdeqregulations.nsf/f75488ee863070bd86256df300511acf/12629755e7eda67e8625765e004ba561/$FILE/GEO-1%20Proposed%20amendment%202009.pdf
[7] *Ibid*.

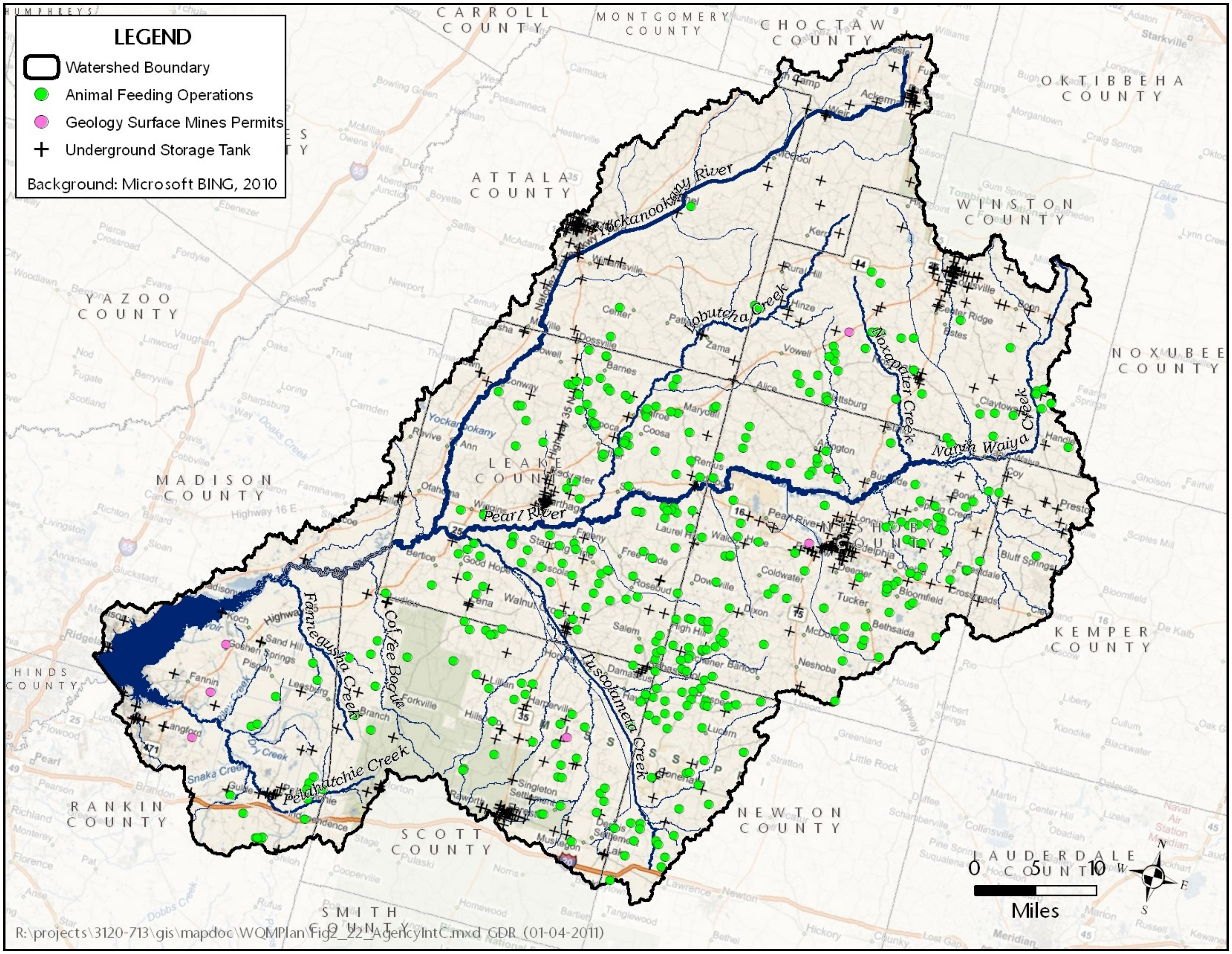

Figure F.2. Locations in Ross Barnett Reservoir watershed under state regulation.

4.3 MDOT Construction Projects and Completed Facilities

The Mississippi Department of Transportation (MDOT) is responsible for implementation of erosion and sediment control practices on highway construction. MDOT is required to apply to MDEQ for a Certificate of Permit Coverage for construction projects to be permitted through the state construction stormwater general permit.

4.4 Surface Water Quality Regulations and/or Criteria

The state water quality standards (WQS) adopted by MDEQ are published in the *State of Mississippi Water Quality Criteria for Intrastate, Interstate, and Coastal Waters.*[8] The WQS include designated uses for waterbodies and numeric and narrative criteria to protect these uses. Designated uses for Ross Barnett Reservoir include Fish and Wildlife Support (aquatic life support), Public Water Supply, and Recreation. All other waterbodies in the watershed have the WQS designated use of Fish and Wildlife Support. Numeric and narrative criteria for selected parameters are summarized in Table F.1.

4.5 Public Waterways

State regulations[9] designate all sections of natural flowing streams with mean annual flow of at least 100 cfs as public waterways. These are waterways where the public has the "right of free transport in the stream and its bed, and the right to fish and engage in water sports." However, access to public waters is generally restricted to developed public access points. The designated Public Waterways in Ross Barnett watershed are as follows:

1. Ross Barnett Reservoir,
2. Pearl River,
3. Pelahatchie Creek downstream of Eutacutachee Creek,
4. Coffee Bogue downstream of Lee Branch,
5. Yockanookany River downstream of Tibby Creek,

[8] http://www.deq.state.ms.us/mdeq.nsf/0/E12C3B35E44CBFBC862574670051589E/$file/WQS_std_adpt_aug07.pdf?OpenElement
[9] Public Waterways of the State of Mississippi. Accessed online at http://deq.state.ms.us/MDEQ.nsf/page/L&W_pub_waterways?OpenDocument

6. Lobutcha Creek downstream of Dry Creek,
7. Tuscolameta Creek downstream of Connehatta Creek,
8. Nanih Waiya Creek downstream of State Highway 490,
9. Tallahaga Creek downstream of State Highway 490,
10. Bogue Chitto downstream of State Highway 21, and
11. Kentawka Canal downstream of Cushtusia Canal.

Table F.1. Numeric and narrative water quality criteria for Ross Barnett Reservoir and its tributaries.

Parameter	Waterbody	Criteria
Dissolved Oxygen	All	Daily average of 5 mg/L, Instantaneous value of 4 mg/L
pH	All	6 – 9 su
Temperature	All	Maximum of 90ºF, < 5ºF change in temperature from heated discharges
Fecal Coliform	Ross Barnett Reservoir	30-day geometric mean of 200 colony-forming units (CFUs) per 100 mL and no more than 10% of the samples collected in a 30-day period greater than 400 CFUs per 100 mL
	Other waterbodies in watershed	May – Oct: 30-day geometric mean of 200 CFUs per 100 mL and no more than 10% of the samples collected in a 30-day period greater than 400 CFUs per 100 mL Nov – Apr: 30-day geometric mean of 2,000 CFUs per 100 mL and no more than 10% of the samples collected in a 30-day period greater than 4,000 CFUs per 100 mL
Specific Conductance	Ross Barnett Reservoir	500 µmhos/cm
	Other waterbodies in watershed	1,000 µmhos/cm
Chlorides	Ross Barnett Reservoir	230 mg/L
Dissolved Solids	Ross Barnett Reservoir	500 mg/L
	Other waterbodies in watershed	750 mg/L
Nitrate	Ross Barnett Reservoir	10 mg/L
Turbidity	All	Turbidity outside the limits of a 750-ft mixing zone shall not shall not exceed the background turbidity at the time of discharge by more than 50 Nephelometric turbidity units (NTUs).

4.6 Animal Feeding Operations

Poultry operations that are not required to obtain NPDES permits are still permitted for water discharge by MDEQ. Poultry operations serving fewer than 1,000 animal units and utilizing dry litter disposal are required to submit a Notice of Intent to MDEQ for coverage under an animal feeding operation (AFO) multimedia discharge general permit. As of August 2010, there were 334 sites in the Ross Barnett Reservoir watershed covered by the AFO dry litter multimedia discharge general permit.[10] All poultry operations that serve fewer than 1,000 animal units and do not use dry litter disposal are required to apply to MDEQ for an individual waste disposal operating permit. As of October 2009, there were approximately 40 sites in the Ross Barnett watershed with individual animal feeding operation waste disposal system operating permits.[11] Locations of the sites with state AFO permits are indicated on Figure F.2.

[10] Data provided by MDEQ Office of Pollution Control.
[11] http://opc.deq.state.ms.us/default.aspx

5.0 REFERENCES

MDEQ. 1999. Mississippi Source Water Assessment Program. Mississippi Source Water Environmental Quality, Office of Pollution Control. Jackson, MS.

APPENDIX G

DATA COMPARISON FOR TMDL VERSUS NON-TMDL STREAMS

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1.0 INTRODUCTION

Recent data for total suspended solids (TSS), turbidity, total phosphorus, and total nitrogen were summarized for streams in the Ross Barnett Reservoir watershed with and without applicable total maximum daily loads (TMDLs) for sediment and nutrients. These data are summarized based on whether the stream was impaired, whether the stream is supporting its designated uses, and/or whether the stream was assessed.

2.0 TOTAL SUSPENDED SOLIDS AND TURBIDITY DATA

Box-and-whisker plots of the TSS measurements from streams supporting and not supporting designated uses appear to be statistically different (Table G.1, Figure G.1). However, plots of turbidity measurements from streams supporting and not supporting designated uses do not show significant differences (Table G.2, Figure G.2).

3.0 TOTAL NITROGEN AND TOTAL PHOSPHORUS DATA

The plot of total phosphorus measurements from streams supporting and not supporting designated uses appears to indicate a statistical difference (Table G.3, Figure G.3). The same is not true for total nitrogen; plots of total nitrogen measurements do not show significant differences between those streams supporting designated uses and those not supporting their designated uses. However, few total nitrogen measurements (only 23 samples) were available for statistical analysis (Table G.4, Figure G.4).

Table G.1. Sediment TMDLs and TSS concentrations.

Statistic	Not Addressed in a Sediment TMDL[1]	Assessed as Supporting Designated Uses[2]	Assessed as Not Supporting Designated Uses and Addressed in a Sediment TMDL[1,2]	Assessed as Not Supporting Designated Uses[2]	Not Assessed[2]
Number of Stations	10	9	14	15	1
Number of Measurements	182	170	241	245	12
Minimum TSS Value (mg/L)	1	1	1	1	4
Maximum TSS Value (mg/L)	206	68	286	286	206
Mean TSS Value (mg/L)	9.368	7.476	18.278	18.102	36.167
Standard Deviation	18.845	10.824	37.850	37.566	56.613

Notes:
1. MDEQ 2009.
2. Alley and Segrest 2008 [Mississippi 2008 305(b) report].

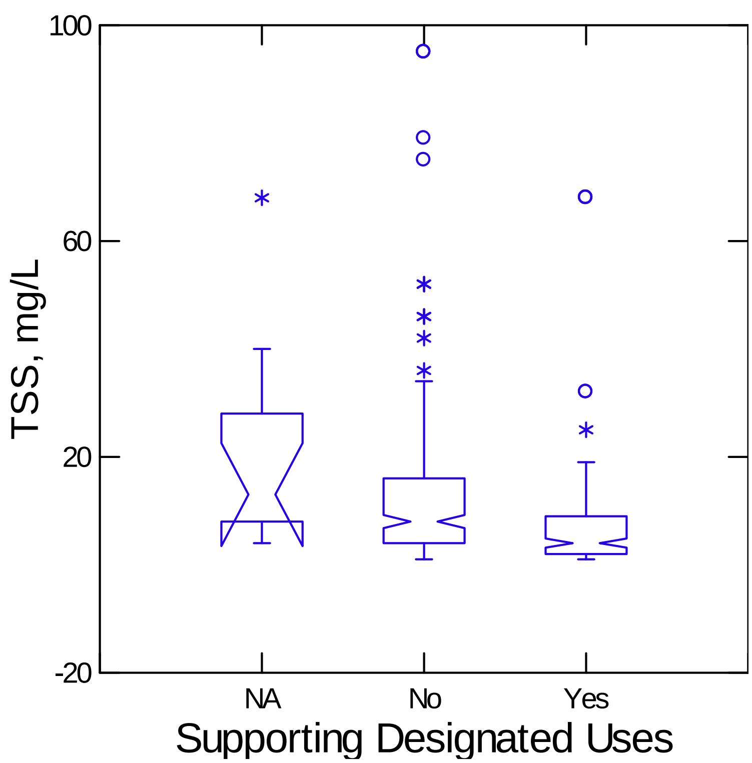

Figure G.1. Box-and-whisker plot of TSS measurements from streams supporting designated uses, not supporting designated uses, and those not assessed (NA).

Table G.2. Sediment TMDLs and turbidity measurements.

Statistic	Not Addressed in a Sediment TMDL[1]	Assessed as Supporting Designated Uses[2]	Assessed as Not Supporting Designated Uses and Addressed in a Sediment TMDL[1,2]	Assessed as Not Supporting Designated Uses[2]	Not Assessed[2]
Number of Stations	26	18	22	25	10
Number of Measurements	199	182	247	254	19
Minimum Turbidity Value (NTU)	2.5	5	4	4	2.5
Maximum Turbidity Value (NTU)	190	52	252	252	190
Mean Turbidity Value (NTU)	20.978	19.6	20.098	28.194	32.474
Median Turbidity Value (NTU)	18	18	20	20	18
Standard Deviation	16.709	9.63	30.588	30.358	43.8

Notes:
1. MDEQ 2009.
2. Alley and Segrest 2008 [Mississippi 2008 305(b) report].

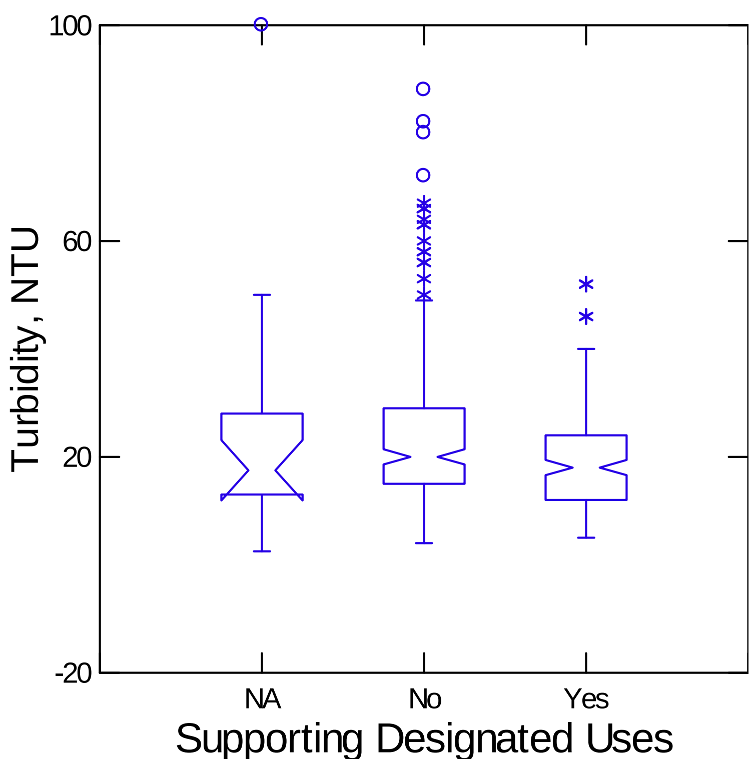

Figure G.2. Box-and-whisker plot of turbidity measurements from streams supporting designated uses, not supporting designated uses, and those not assessed (NA).

Table G.3. Nutrient TMDLs and total phosphorus concentrations.

Statistic	Not Addressed in a Nutrient TMDL[1]	Assessed as Supporting Designated Uses[2]	Assessed as Not Supporting Designated Uses and Addressed in a Nutrient TMDL[1,2]	Assessed as Not Supporting Designated Uses[2]	Not Assessed[2]
Number of Stations	18	13	23	28	2
Number of Measurements	235	169	990	1054	2
Minimum Total Phosphorus Value (mg/L)	0.010	0.010	0.010	0.010	0.021
Maximum Total Phosphorus Value (mg/L)	0.640	0.616	4.530	4.530	0.055
Mean Total Phosphorus Value (mg/L)	0.128	0.128	0.126	0.126	--
Median Total Phosphorus Value (mg/L)	0.080	0.080	0.090	0.090	--
Standard Deviation	0.135	0.144	0.261	0.255	--

Notes:
1. MDEQ 2009.
2. Alley and Segrest 2008 [Mississippi 2008 305(b) report].

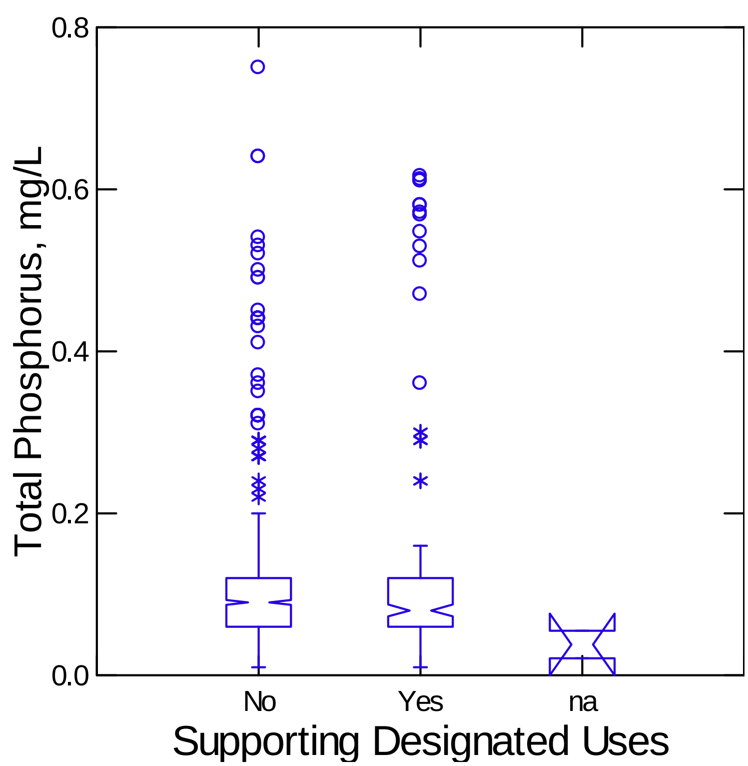

Figure G.3. Box-and-whisker plot of total phosphorus measurements from streams supporting designated uses, not supporting designated uses, and those not assessed (NA).

Table G.4. Nutrient TMDLs and total nitrogen concentrations.

Statistic	Not Addressed in a Nutrient TMDL[1]	Assessed as Supporting Designated Uses[2]	Assessed as Not Supporting Designated Uses and Addressed in a Nutrient TMDL[1,2]	Assessed as Not Supporting Designated Uses[2]	Not Assessed[2]
Number of Stations	5	2	2	4	1
Number of Measurements	20	12	3	6	5
Minimum Total Nitrogen Value (mg/L)	0	0	1.3	0.6	0
Maximum Total Nitrogen Value (mg/L)	1.204	0.39	3.6	3.6	1.204
Mean Total Nitrogen Value (mg/L)	0.229	0.095	2.833	1.783	0.246
Median Total Nitrogen Value (mg/L)	0.049	0.049	3.6	1.05	0.011
Standard Deviation	0.349	0.122	1.328	1.426	0.535

Notes:
1. MDEQ 2009.
2. Alley and Segrest 2008 [Mississippi 2008 305(b) report].

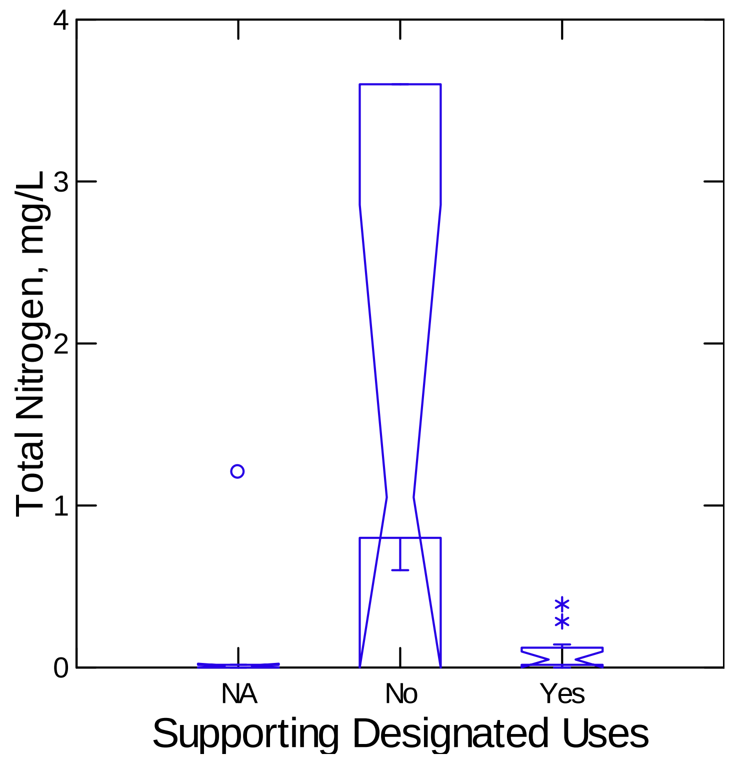

Figure G.4. Box-and-whisker plot of total nitrogen measurements from streams supporting designated uses, not supporting designated uses, and those not assessed (NA).

4.0 REFERENCES

Alley, V.E., and N.G. Segrest. 2008. *State of Mississippi Water Quality Assessment, 2008 Section 305(b) Report*. Mississippi Department of Environmental Quality. Jackson, MS.

MDEQ. 2009. Shapefile of stream reaches with completed TMDLs as of 06/10/2009. Mississippi Department of Environmental Quality.

APPENDIX H

POLLUTANT SOURCE INVENTORY

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1.0 SEDIMENT

1.1 Locations of Concern for Sediment

Locations of both monitored and evaluated waterbody segments were identified based on Mississippi's 303(d) list. Biological sampling of stream benthic communities was conducted in the monitored waterbody segments using the Mississippi Benthic Index of Stream Quality. Through a stressor identification process, MDEQ has determined that sediment is the probable primary cause of biological impairment in many of the monitored waterbodies (MDEQ and Ray Montgomery Associates 2009). TMDLs have been completed for the majority of these impairments. Cane Creek, Pelahatchie Creek, Fannegusha Creek, and sections of the Pearl River are of particular concern because they are located in the 1x:10x watershed and flow directly to the Reservoir. Hurricane Creek, Red Cane Creek, Coffee Bogue, and Eutahatchee Creek and are also located in the 1x:10x watershed. Other locations with sediment issues were identified based on stakeholder input. These include Mill Creek, Turtle Creek, and tributaries to Pelahatchie Bay.

There are three major sedimentation zones in the Ross Barnett Reservoir: upstream of the Highway 43 Bridge, upstream of the Northshore Parkway Bridge (over the mouth of Pelahatchie Bay), and in front of the dam. In all reservoirs, sedimentation occurs in front of the dam. Both the Highway 43 Bridge and the Northshore Parkway have only one relatively narrow opening through which water can flow. This situation effectively creates sedimentation basins in the upper Reservoir and Pelahatchie Bay.

1.2 Sediment Sources

Most of the sediment in the Reservoir comes from erosion sites in the watershed, and is transported by the Reservoir's tributaries. Tributaries to Pelahatchie Bay in particular have high sediment loads. NRCS has noted that visual observation shows water flowing into Pelahatchie Bay from tributaries has extremely high turbidity after storm events (MDEQ et al. 2008). MDEQ considers sediment contributions from disturbed land areas (e.g., construction areas) near the Reservoir to be one of the most significant issues impacting Reservoir water quality. The Mill Creek watershed on the eastern side of the Reservoir in Rankin County is an area of specific concern.

1.2.1 In-Reservoir Sediment Sources

There are multiple sources of sediment from within the Reservoir itself. These include erosion of the lake bed and banks and resuspension of sediment due to wave action. The Ross Barnett Reservoir is an extremely shallow system (average depth of 10 ft), making it susceptible for resuspended sediment due to wind/wave effects. Resuspension indices indicate that the Reservoir is likely to have a significant amount of resuspended sediments (Table H.1). Additional information regarding the potential for wind effects on the Reservoir is included in Appendix I of the *Comprehensive Protection and Restoration Plan*.

Table H.1. Resuspension indices for the Reservoir.

Index	Result	Indications
Dynamic Ratio	Greater than 3	"Lakes with values greater than 0.8 are most likely to have problems with sediment resuspension" (Bachmann et al. 2000).
Areal Erosion	75.7%	Indicates the percentage of the lake bed likely to be subject to erosion process and sediment transport, including those resulting from wave action.

1.2.2 Upland Sediment Sources

Upland activities that may contribute to increased sediment loads in streams include construction, surface mining, land clearing for residential and commercial development, increased impervious surface area, harvesting of forested areas, row crop agriculture, and disturbance of stream banks by grazing animals. Alteration of stream channels (straightening and widening) and removing vegetation in the riparian area near stream banks make streams much more likely to have higher sediment loads. In addition, developed areas of the Reservoir shoreline can contribute sediments to the Reservoir, as removal/alteration of the natural vegetation and other features of the shoreline can diminish the natural ability of riparian areas to filter and remove sediment from water draining into the Reservoir. Presently, vegetation has been removed from approximately 25% of the Reservoir shoreline for development[1].

[1] Based on examination of aerial photographs.

Permitted activities that contribute to sediment loads include construction and surface mining. The locations of current mining stormwater and construction stormwater permits in the Reservoir watershed are shown on Figure H.1.

Due to rapid development along the Highway 25 corridor, runoff from construction sites has become an important issue. A recent study conducted by Millsaps College included an analysis of the bed material found in Mill Creek along its entire length (headwaters near Brandon from its mouth in Pelahatchie Bay). This study provided some evidence that development and alteration of the land use is directly impacting Mill Creek (Killcreas and Musselman 2009). The study divided Mill Creek into three zones for analysis of bed material.

- Zone 1, small upstream tributaries – dominated by medium and fine sands;
- Zone 2, along the main stem of Mill creek for a distance of 5 km – grain size varied greatly; and
- Zone 3, lower 0.5-km reach to confluence with Pelahatchie Bay: 50 to 70% medium sands with less than 10% fines. This was unexpected since the geologic formation of this area is dominated by silts and clays. Author concluded that Zone 1 was that the sediment source, and increased discharge due to development transported the larger particles to Zone 3.

The report also discusses anthropogenic modifications such as straightening, residential development including Castlewoods golf course, channel protection with rip-rap, and a low head dam on Mill Creek located approximately 1 kilometer south of spillway road. The report also present evidence of significant increases in stream flow (Killcreas and Musselman 2009). The increased flow is likely the result of recent increased development and impervious area in the watershed.

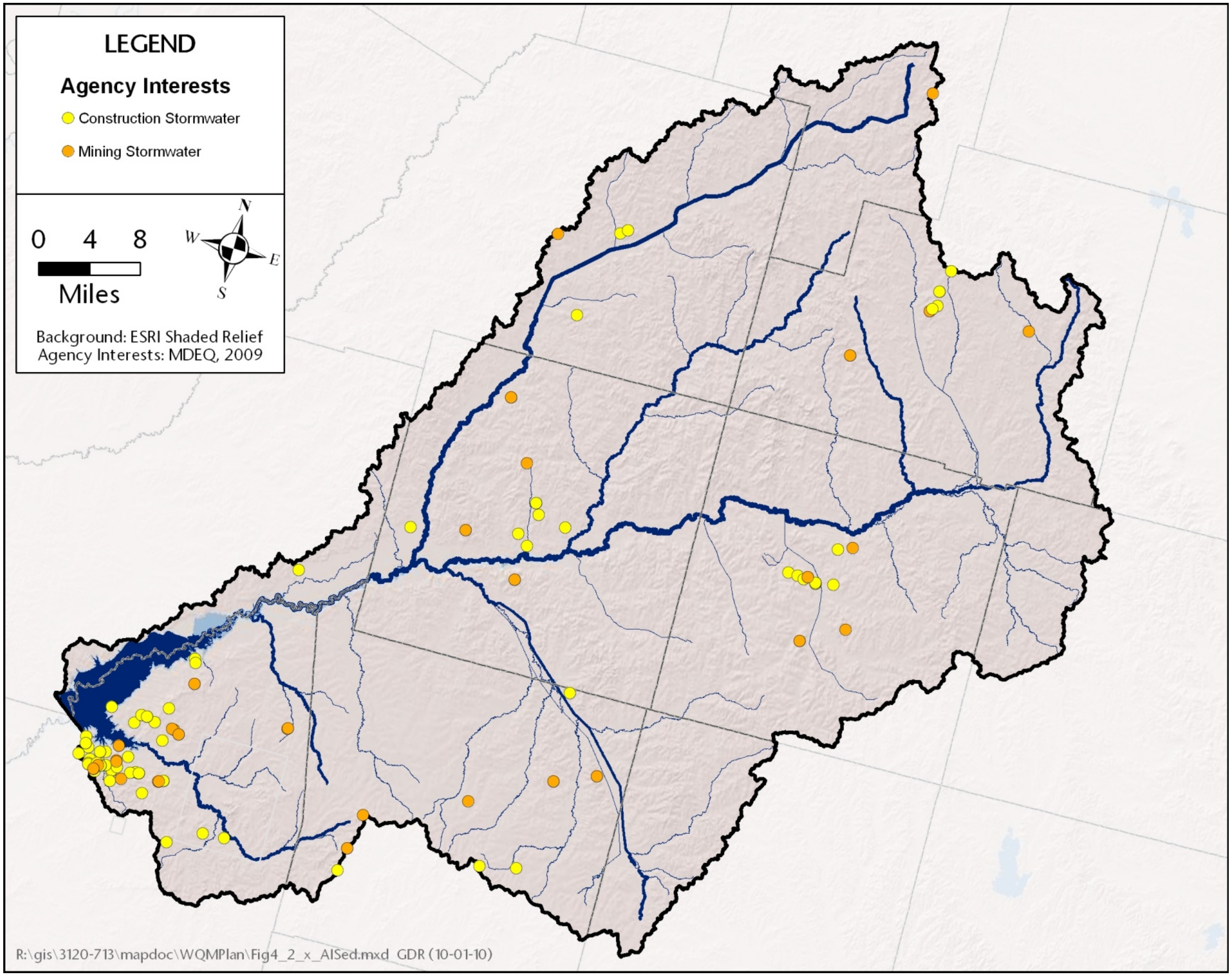

Figure H.1. Agency interests that are potential sediment sources.

Sediment releases from construction sites are regulated through stormwater pollution prevention plans (SWPPPs) and local ordinances. MDEQ issues Large (disturbance of 5 acres or greater) and Small (disturbance of one acre to less than 5 acres) Construction Storm Water General Permits. MDEQ requires that all construction sites that are one acre or larger develop an SWPPP that contains measures to reduce soil erosion and control sediments and describes how and when these measures will be implemented on the construction site. Developers of sites 5 acres or larger must submit a notice of intent (NOI) and SWPPP to MDEQ for approval prior to starting construction. Construction sites smaller than one acre are permitted by local government and managed through ordinances and inspections administered by the county or city government in authority over each particular area. PRVWSD also has requirements for specific sediment control practices on individual lots specified in their building permit requirements. Silt fences must be properly installed, inspected, and maintained during construction[2].

Watersheds that contain a significant portion of impervious area are at risk for excessive erosion and sediment contribution to the Reservoir. Research has shown that runoff is directly correlated to the amount of impervious surface area in a watershed. Increased imperviousness leads to increased amounts of water flowing in stream channels during rain events, resulting in flooding, habitat loss, erosion and widening of the stream channel. Physical changes to the stream channel occur as stream channels seek a new equilibrium. The time of concentration, or amount of time that it takes water to travel from land surfaces to receiving streams, also decreases in highly impervious watersheds causing higher peak flows (D'Ambrosio et al. 2004). Negative impacts due to impervious surfaces can occur in areas with as little as 5% impervious areas. Streams in parts of the watershed with a high percentage of impervious area are more likely to be impacted by channel erosion and downstream sedimentation issues. The percentages of impervious area in each of the HUC12s in the Ross Barnett watershed are shown on Figure H.2.

[2] http://www.therez.ms/residential1.html

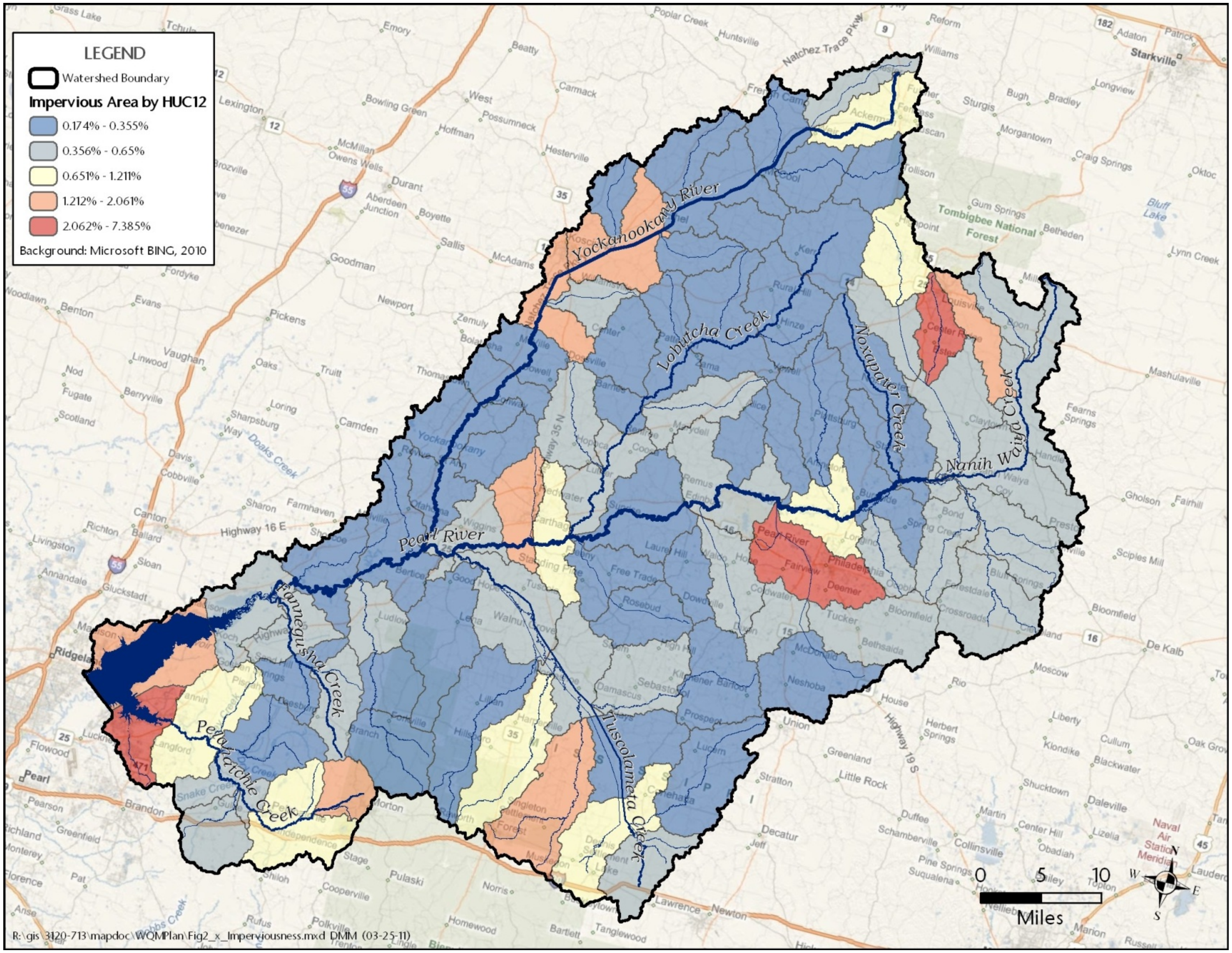

Figure H.2. Impervious area in each HUC12 in the Ross Barnett watershed.

The HUC12 that contains Pelahatchie Bay (Mill Creek – Pelahatchie Creek, HUC12 No. 031800020307) is approximately 7.4% impervious based on 2006 land use data. The HUC12 adjacent to the lower part of the Reservoir (No. 031800020401) contains 4.4% impervious area. Other subwatersheds with 8% to 10% impervious surfaces include the HUC12s that contain the cities of Morton, Philadelphia, Koscuisko, and Louisville.

1.2.3 Sediment Sources from Forested Lands

Almost 50% of the watershed is forested land (Figure H.3). Most forested areas in the Reservoir watershed are loblolly/shortleaf pine and hardwood timberlands. Forest lands in the Reservoir watershed are managed by private landowners, businesses, or government agencies. Approximately 12,455 acres of the land that borders the Reservoir is currently managed as forest land by PRVWSD. PRVWSD has developed a 10-year forestry management plan that supports multiple forest uses and includes plans for managing and harvesting timber in each parcel. Timber harvesting activities are aimed at harvesting mature timber and improving timber stands in other areas. The plan allows forest harvest near recreational areas of the Reservoir only when it is necessary to improve overall forest health. There are several areas adjacent to the upper Reservoir that PRVWSD has set aside as streamside management zones. Some of the timber land is in a wildlife management area managed by MDWFP. Timber harvesting in this area is limited and done in accordance with MDWFP objectives (PRVWSD, no date).

The Mississippi Forestry Commission (MFC) conducts a survey every 3 years of BMP implementation on randomly selected areas. The results of this survey are available to the public. The most recent survey was conducted on 237 randomly selected sites in 2010. This survey concluded that statewide, 93% of BMPs installed at the survey sites were implemented in accordance with guidelines of the state forestry agencies. Areas where forestry management practices are not properly implemented can contribute significant amounts of sediment.

Forest lands that have been harvested in recent years are more likely to contribute sediment to streams draining into the Reservoir. Harvested areas where the vegetative cover and canopy are removed are significantly more susceptible to erosion. Harvest records for privately owned forest lands are not available; however, MFC reports that approximately 4% of forest lands in Mississippi have activities each year (MFC 2008).

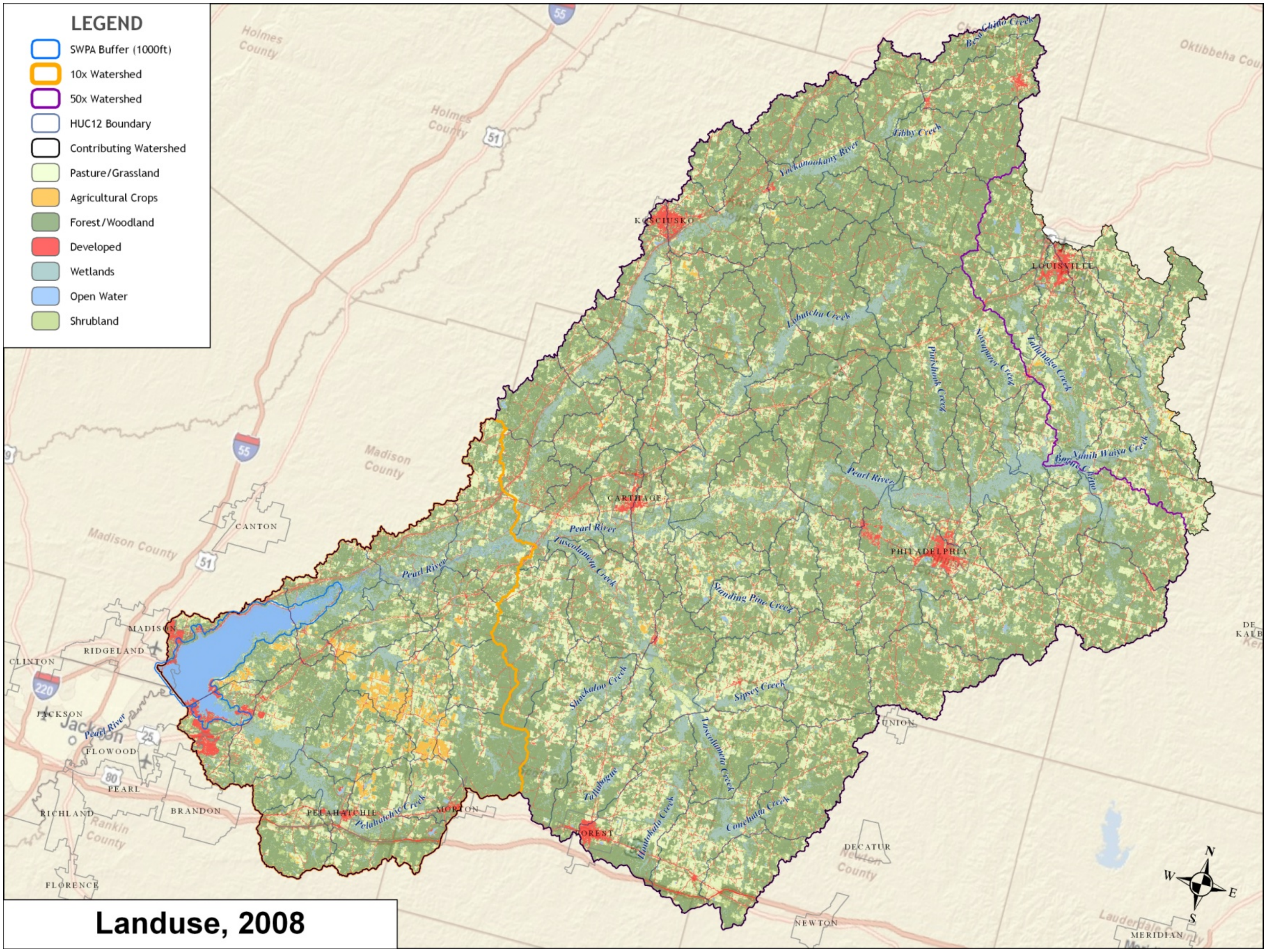

Figure H.3. Landuses in the Reservoir watershed.

MFC tracks timber inventory, growth, drain and growth to drain ratio for pine and hardwood forests. Information is available by county. The timber inventory is based on surveys conducted in 2004 and 2006. Growth represents the amount of timber growth on forestland since the inventory measured in tons. Drain is an estimate of timber harvested, based on the Timber Severance Tax.

The timber industry often uses a ratio of growth/drain to estimate sustainability of forest resources. Growth/drain ratio greater than 1 indicates an increase in forest resources. The average ratio for counties in the reservoir watershed is 2.5 for softwoods and 4.1 for hardwoods. The total amount of removal in Reservoir counties during the inventory period until 2009 was 17% for softwoods and 4% of the hardwoods.

1.2.4 Sediment Sources from Construction Sites and Surface Mines

Proper use of BMPs at construction sites is vital to improved water quality in the Reservoir watershed. The Reservoir and much of its surrounding land in Rankin County are located in the Loess Plains Ecoregion, which contains the most highly erosive soil in the state (ecoregions are shown on Figure H.4). Removal of natural vegetative cover will lead to significant erosion if the soil surface is left unprotected. Because of this, management of construction sites and surface mines is extremely important. Disturbed soils in this area should be replanted with vegetative cover as soon as possible.

Specifications for the design of BMPs are given in the recently updated *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater* (Planning and Design Manual) (MDEQ 2011). The Planning and Design Manual describes BMPs for use during and after construction to prevent erosion and treat stormwater. The Large and Small Construction Storm Water General Permits, as well as most stormwater management plans and local ordinances, require that practices be designed according to the specifications in the Planning and Design Manual.

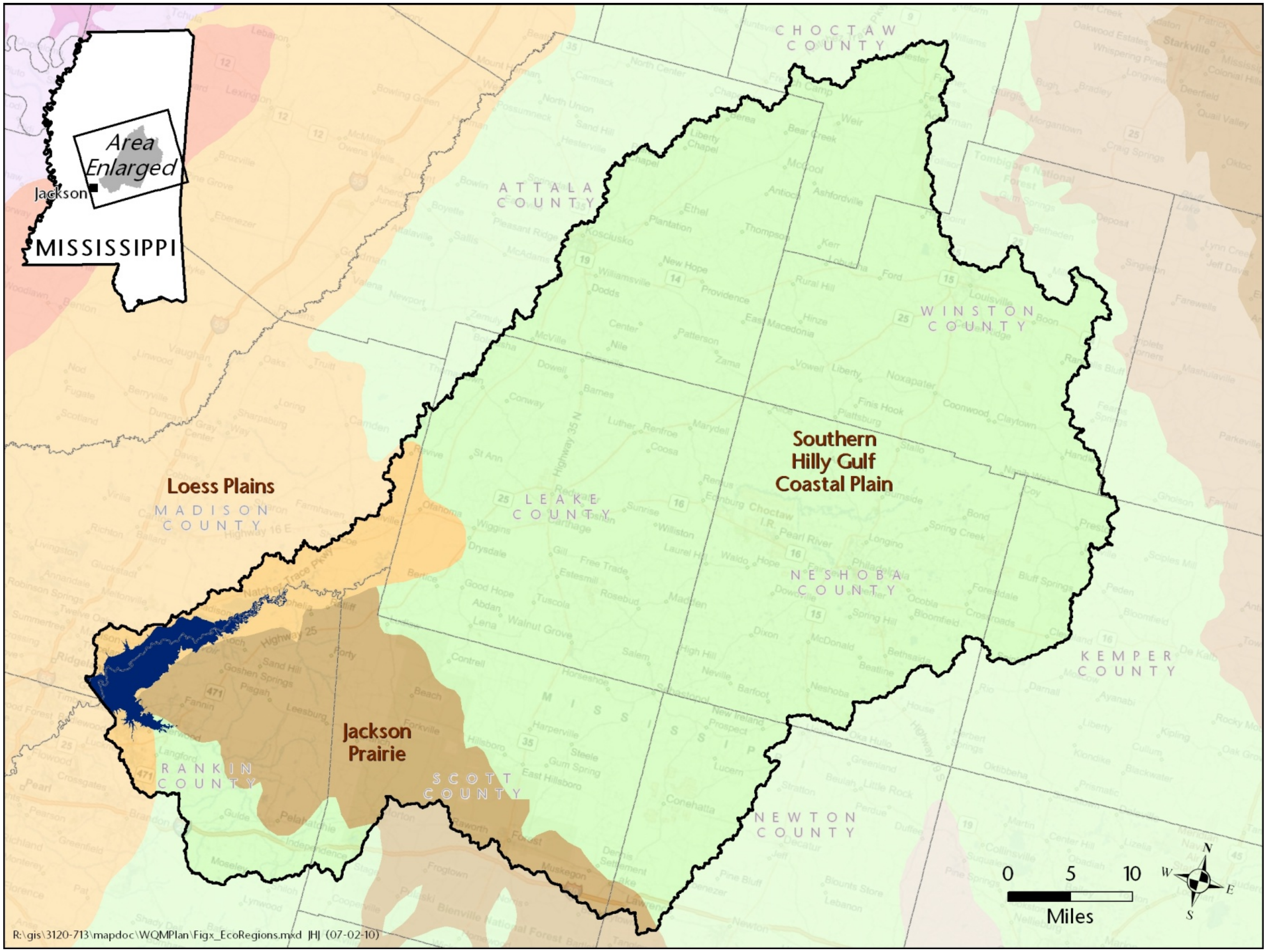

Figure H.4. Ecoregions in the Ross Barnett Reservoir watershed.

MDEQ's Environmental Compliance and Enforcement Division (ECED) leads the Ross Barnett Reservoir Stormwater Compliance Initiative. The Initiative, which began in 2007, is working to improve stormwater management at construction sites and surface mines located in the Reservoir watershed, particularly in areas rapid commercial and residential development. The Initiative has included the following activities:

- Frequent informal surveys of the area and increased compliance evaluation inspections at facilities with coverage under the large construction stormwater and surface mining general permits, along with frequent informal "windshield surveys" of the area;
- Increased enforcement actions;
- Additional review of SWPPPs for new developments (MDEQ's ECED reviews SWPPPs to ensure adequate design of construction/mining BMPs. This review will be in addition to the review typically conducted by the Environmental Permitting Division);
- Improved communication with local authorities; and
- Enhanced stormwater management plans in MS4 areas.

MDEQ inspectors have conducted "windshield surveys" to document the condition and effectiveness of management practices before, during, and after storm events. Photographs taken by MDEQ personnel during rain events in 2009 show insufficient BMPs in several newly developed subdivisions near the Reservoir including Lost Rabbit, Latter Rayne, Gardens of Mansdale, Hidden Hills, and Arbor Landing. Photographs show turbid water draining from construction sites in improperly stabilized ditches. Increased turbidity was visible in the Reservoir near construction sites in Lost Rabbit and Arbor Landing developments. Subsequent visits to these sites have shown improvements including the establishment of vegetation and rip-rap stabilization along drainage ditches, properly installed silt fences, and improved function of stormwater detention ponds.

Results of inspections over recent years are summarized in Table H.2. Lack of education among contractors and a reluctance to fund the cost of installing and maintaining BMPs are the most common reasons for regulation violations. Activities in 2009 show a decrease in fines from previous years. MDEQ cited the reasons for the decrease as a slower economy resulting in a decrease in large construction projects. MDEQ also noted that recent inspections showed that stormwater rules have been more strictly enforced and projects are being more closely managed.

Table H.2. MDEQ inspections of construction sites in Ross Barnett watershed (personal communication, Donetta McCullum-Weatherspoon, MDEQ, December 2009).

Year	Inspections	Notices of Violations (NOVs) Issued	Fines collected
2007	7	2*	$40,000*
2008	10	7	$69,600
2009	14	4	$35,200
2010	24	1	5,000

*NOVs and fines issued by EPA Region 4

MDEQ has conducted a significant number compliance evaluation inspections (CEIs) in 2008, 2009, and 2010 and intends to continue conducting inspections of large construction sites two to three times yearly and during rain events. CEIs have resulted in a significant number of NOVs and monetary fines. Active large construction sites that have been issued NOVs in 2008, 2009, or 2010 are included in Table H.3. The locations of these facilities are shown on Figure H.5.

Table H.3. Active large construction sites receiving NOVs in 2008, 2009, or 2010.

Facility Name	NPDES Permit No.
Pinelands LLC	MSR102072
Pinebrook Subdivision	MSR102343
Arbor Landing	MSR104194
Flowood Fire Station Numbers 1 and 2	MSR105379
Hidden Hills Inc	MSR101669
Bonne Vei	MSR104728
Lakeland Heights Subdivision	MSR103711
Garner Lake and Residence	MSR105639

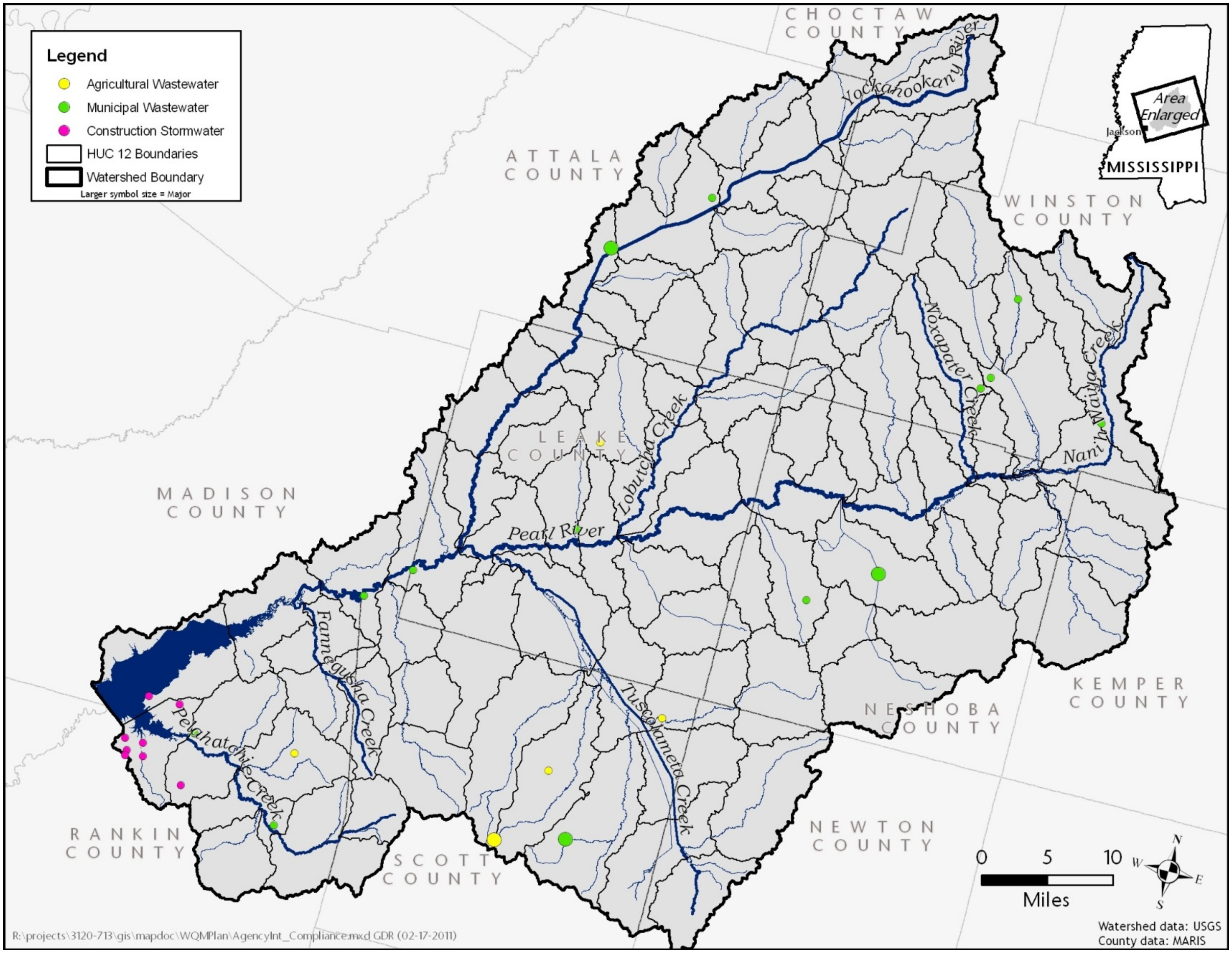

Figure H.5. Locations of construction stormwater sites, wastewater treatment facilities, and poultry processing wastewater treatment facilities with permit violations in the Ross Barnett watershed.

The reasons for NOVs at these sites include incorrect installation and lack of maintenance of the BMPs. According to MDEQ personnel, the majority of violations in the Reservoir watershed have been corrected, and developers and contractors have improved performance on installing and maintaining BMPs. However, the pace of development has decreased significantly due to the recent economic downturn. It will be important to for developers to continue their efforts when development increases in future years (personal communication, Steve Bailey, MDEQ, December 2010).

Finally, MDEQ is working to improve coordination with the local authorities regulating small construction general permit sites. When violations at small construction sites are noted, MDEQ first works with the local authorities to resolve problems. Working at the local level is the most efficient way to improve enforcement. Local authorities are responsible for enforcement of SWPPPs on individual lots in developments that are covered under the large construction stormwater general permit. Local stormwater managers have noted that stormwater and sediment control on individual lots are often the most neglected. The City of Flowood is currently working with the local developers, contractors, and inspectors to improve this issue (personal communication, Garry Miller, City of Flowood Public Works Director, February 2011).

Local governments conduct the majority of inspections on small construction sites. The number of sites, inspections, and enforcement actions are reported to MDEQ in annual MS4 reports. Table H.4 shows the number of sites for each MS4 entity as of December 2010.

Table H.4. MS4 sites per county and number of inspections and enforcement actions per site.

MS4 Entity	Small Construction Site Permitted	Number of Inspections*	Number of Enforcement Actions*
Rankin County	249	693	38
City of Madison	8	Not available	-
City of Ridgeland	10	90	0
City of Flowood	120	daily	30
Madison County	Not available	-	-

* January – December 2010

MDEQ is also conducting inspections at all surface mines in the Reservoir watershed. Previous inspections have noted violations at two surface mines in the Pelahatchie Bay watershed and resulted in monetary fines of up to $30,000. MDEQ has identified three sites with non-permitted surface mining activities located in the Pelahatchie Bay watershed and has worked with these facilities to obtain permits and install proper BMPs. Inspections after rain events are also used to visually identify areas with elevated turbidity and high amounts of suspended sediments, which can sometimes be traced back to source areas.

1.2.5 Sediment Sources from Grazing Lands

Approximately 16% of the land in the watershed is classified as pasture/grassland, and may be used for grazing animals. Grazing animals on pasture lands are often allowed to enter streams in order to access water and cooler, shaded areas. Animal access to streams, however, can damage stream beds and banks and may cause erosion. There is no specific information available to locate areas in the watershed where animal access occurs. However, because there are cattle located in the watershed, pastures are a potential source of sediment loads to streams.

2.0 NUTRIENTS

2.1 Locations of Concern for Nutrients

Excess nutrients and subsequent growth of algae and other aquatic plants may occur in any area of the Reservoir within the depth of the photic zone. Excessive algae would be of concern at any location in the Reservoir, since this water may potentially flow to the drinking water intake. The area of the Reservoir of greatest concern, however, is in the area in the vicinity of the O.B. Curtis drinking water treatment plant intake.

In near-shore areas of the Reservoir, nutrients can contribute to excessive growth of aquatic macrophytes. MDWFP has observed thick mats of aquatic vegetation in parts of Pelahatchie Bay and the upper Reservoir upstream of Highway 43 (Bull 2010).

Low dissolved oxygen conditions have been observed at monitoring station RBR1, located near the Reservoir dam. Low dissolved oxygen levels were measured in the hypolimnion during the summer when increased algae growth (and death) rates occurred during temperature stratification, preventing transfer of oxygen to the bottom water.

2.2 Nutrient Sources

The primary types of nutrient sources in the Reservoir watershed are nutrients naturally present in the soil and nutrients applied to the landscape for land management activities. Nutrients are carried to the Reservoir through surface water flow, either dissolved in the water (typically nitrogen) or sorbed to suspended sediment particles (typically phosphorus). Nutrient sources in the watershed include stormwater from urban areas, failing septic systems, permitted discharge of treated wastewater, atmospheric deposition, and agricultural activities.

Nutrients are naturally present in the watershed because they are contained in soils. The quantity of nitrogen found in Mississippi soils is closely related to levels of organic matter and typically ranges from 500 to 2,000 lbs/acre (Oldham 2003). According to research conducted by MSU, more than 90% of the nitrogen in soils is associated with organic matter. Phosphorus is typically present in low levels in soils in central Mississippi, but can vary significantly from place to place due to current and historical land management practices. Most soils in Mississippi are slightly acidic, which causes inorganic phosphorus to bind with cations and form insoluble precipitates that are not available for plant uptake (Oldham 2008).

Atmospheric deposition is another known source of nitrogen in surface waters. USGS quantified the contribution of atmospheric nitrogen along with four other nitrogen sources: wastewater, fertilizer, livestock manure, and urban areas. According to output from the USGS model, Spatially Referenced Regression on Watersheds (SPARROW), atmospheric deposition is the most significant incremental yield of nitrogen in watersheds contributing to the Ross Barnett Reservoir (Hoos and McMahon 2009).

The SPARROW model results show that manure from livestock production, and to a lesser extent, nitrogen from commercial fertilizer applied to agricultural land contribute to instream nitrogen yield. Figure H.6 shows the nitrogen yields for the Reservoir watershed and the relative contribution of each source category (Hoos and McMahon 2009). These results indicate that nitrogen yields (kilograms per hectare) were highest in the Hontokalo Creek and Cobbs Creek watersheds. These two watersheds contain the towns of Forest and Koscuicko, respectively. These towns have major (greater than 1 MGD) NPDES-permitted wastewater treatment facilities, which are the largest nitrogen sources in these subwatersheds. Model output for phosphorus is not yet available.

Denitrification, the conversion of ammonia nitrogen to nitrogen gas, is an important removal process that should be considered in the nitrogen balance. Nitrogen gas is produced through denitrification and released to the atmosphere, removing it from the water. Denitrification occurs under anoxic conditions and may be a significant pathway of nitrogen removal in the Reservoir and its tributaries.

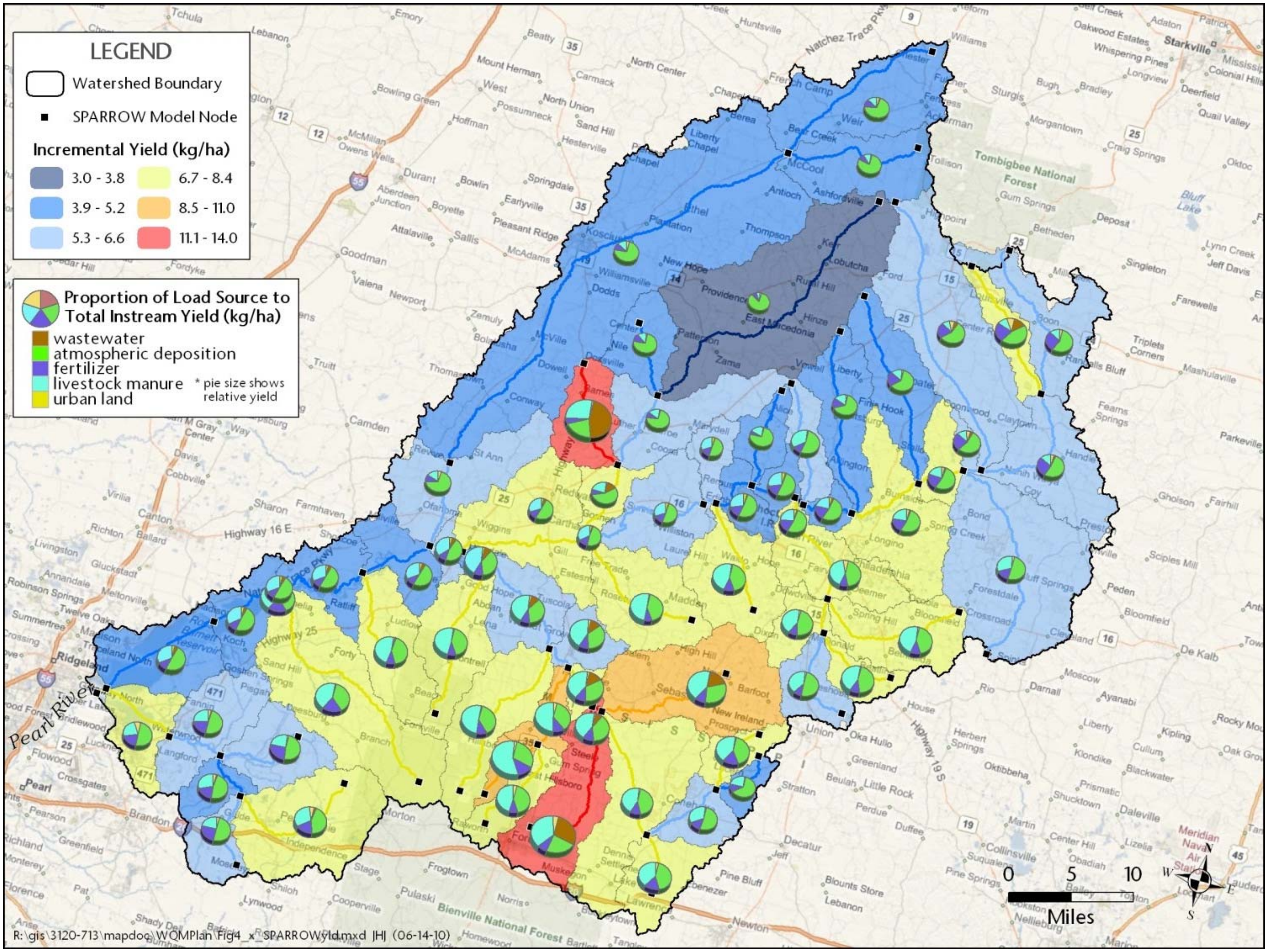

Figure H.6. Modeled nitrogen yields for 12-digit HUCs in the Ross Barnett watershed.

Phosphorus in Reservoir sediments can also be a significant contributor to nutrient enrichment and eutrophication, particularly in shallow lakes (Wetzel 1983, Cole 1983, Cooke et al. 1977). Phosphorus in reservoir sediments comes from tributary inputs of phosphorus-rich sediment, and dead algae, plants, and animals. When phosphorus-rich sediments in lakes and reservoirs are exposed to anoxic (low dissolved oxygen) conditions, the phosphorus is released from the sediment into the water column (Wetzel 1983, Cole 1983, Correll 1998, Carpenter 2005). In addition, phosphorus in sediment can become available in the water column when the sediments are resuspended by waves, boats, dredging, etc (Wetzel 1983). High phosphorus levels in sediments in shallower areas of the Reservoir can support abundant growth of aquatic and semi-aquatic plants (macrophytes) (Wetzel 1983). There are instances where phosphorus from lake and reservoir sediments has been found to contribute significantly to eutrophic conditions in the waterbody (Cooke et al. 1977, Cole 1983, Wetzel 1983, Carpenter 2005).

2.2.1 Nutrient Sources from Urban and Landscaped Areas

Application of fertilizers by homeowners is a significant source of nutrients in the Reservoir. There are many residential subdivisions directly adjacent to the Reservoir. Nitrogen fertilizer is often applied by homeowners in excessive amounts, sometimes much greater than the amount actually needed based on plant needs (personal communication, Houston Therrell. Rankin County Extension Service, March 2010). Nitrogen fertilizers are often applied in the form of ammonia, which can be readily used by plants once it reaches aquatic systems. Sediments washing from landscaped urban areas can also carry phosphorus into the Reservoir. Research has shown that 50% to 90% of phosphorus movement within the landscape is attached to sediment particles (Oldham 2008).

Stormwater from urban areas may also contribute significant nutrients to the Reservoir and its tributaries. Urban areas near the Reservoir include Madison, Ridgeland, and Flowood. Although there are no data currently available to quantify the amount of nutrients contributed by these areas, research has shown that nutrients from urban areas can be significantly elevated. Research conducted by Beaulac and Reckhow found that phosphorus contributions from urban land can be as much as ten times higher than from forested land (1982). Sources of nutrients in urban stormwater include fertilizer applied to landscaped areas, failing septic systems, and pet waste.

2.2.2 Nutrient Sources from Wastewater Treatment

Septic systems are located throughout the watershed. These systems are a potential nutrient source if they are not properly maintained. Additional detail on the location and condition of failing septic systems in the four HUCs that are closest to the Reservoir can be found in the *Ross Barnett Reservoir Pathogen Source Assessment and Wastewater Management Plan* (CDM 2010).Point source discharges, particularly those from wastewater treatment plants (WWTPs), contain high levels of nitrogen and phosphorous.

There are currently 31 municipal and private facilities in the Reservoir watershed permitted to discharge treated wastewater. Most of the facilities use conventional or aerated lagoons and disinfection to treat wastewater. The facilities are required to submit monthly or annual monitoring reports to MDEQ to ensure that they are meeting permit limits for flow, temperature, pH, and turbidity and loads of organic material, bacteria, and nutrients.

There are three major municipal NPDES-permitted facilities in the watershed, the Forest POTW (MS0020362), Kosciusko POTW South (MS0027774), and Philadelphia POTW (MS0021156). Major municipal facilities are those with flows of 1.0 MGD or greater. These facilities' permits require them to monitor their effluent for total nitrogen levels. Municipal WWTPs with minor NPDES permits (i.e., flows less than 1 MGD) discharge treated wastewater from the towns of Forest, Walnut Grove, Carthage, Noxapater, Kosciusko, Weir, and Louisville. The POTW for the town of Carthage has a maximum permitted flow of 0.95 MGD and discharges treated effluent into Town Creek, a tributary of the Pearl River. Table H.5 includes a list of NPDES permits that would be considered nutrient sources. This list includes municipal and commercial wastewater treatment and selected industrial facilities. The locations of these point source facilities are shown on Figure H.7.

Table H.5. Point sources that are potential nutrient sources.

NPDES Permit Number	Name	County	Facility Type
MS0002615	Peco Foods Inc	Scott	Agricultural
MS0052582	Boswell Meat Processing	Neshoba	Agricultural
MS0026140	Tyson Foods Inc, Carthage Processing Plant	Leake	Agricultural
MS0060275	Mississippi Poultry Corporation	Rankin	Agricultural
MS0046931	Tyson Foods Inc, River Valley Animal Foods, Forest	Scott	Agricultural
MS0056103	Lady Forest Farms Inc, Forest Hatchery	Scott	Agricultural
MS0020575	Ackerman POTW	Choctaw	Municipal and Private Facilities
MS0020061	Carthage POTW	Leake	Municipal and Private Facilities
MS0024791	Ethel POTW	Attala	Municipal and Private Facilities
MS0020362	Forest POTW	Scott	Municipal and Private Facilities
MS0027774	Kosciusko POTW, South	Attala	Municipal and Private Facilities
MS0025194	Lake POTW	Scott	Municipal and Private Facilities
MS0025640	Louisville POTW, East	Winston	Municipal and Private Facilities
MS0025836	Louisville POTW, South	Winston	Municipal and Private Facilities
MS0025241	Noxapater POTW, North	Winston	Municipal and Private Facilities
MS0021628	Noxapater POTW, South	Winston	Municipal and Private Facilities
MS0025003	Pearl River Valley Water Supply District, Lake Harbor	Rankin	Municipal and Private Facilities
MS0021008	Pelahatchie POTW, West	Rankin	Municipal and Private Facilities
MS0021156	Philadelphia POTW	Neshoba	Municipal and Private Facilities
MS0026727	Sebastopol Water Association	Scott	Municipal and Private Facilities
MS0020982	Walnut Grove POTW	Leake	Municipal and Private Facilities
MS0020435	Weir POTW	Choctaw	Municipal and Private Facilities
MS0028347	MDOT, Interstate 20 West, Rest Area, Scott	Scott	Municipal and Private Facilities
MS0028398	Mississippi Department of Wildlife Fisheries and Parks, Roosevelt State Park	Scott	Municipal and Private Facilities
MS0029777	Leake County Board of Education, Edinburg Attendance Center	Leake	Municipal and Private Facilities
MS0030066	Leake County Board of Education, Thomastown Attendance Center	Leake	Municipal and Private Facilities
MS0032158	Attala County Schools, Greenlee Elementary School	Attala	Municipal and Private Facilities
MS0034185	Rankin County School District, Pisgah High School	Rankin	Municipal and Private Facilities
MS0035327	Reservoir East Subdivision	Rankin	Municipal and Private Facilities

Table H.5. Point sources that are potential nutrient sources (continued).

NPDES Permit Number	Name	County	Facility Type
MS0038393	Scott County Schools, Scott Central Attendance Center	Scott	Municipal and Private Facilities
MS0038768	Louisville Municipal School District, Nanih Waiya School	Winston	Municipal and Private Facilities
MS0040622	Natchez Trace Parkway, River Bend Comfort Station	Madison	Municipal and Private Facilities
MS0044113	Pearl River Water Supply District, Leake County Water Park	Leake	Municipal and Private Facilities
MS0044920	Neshoba County Fair Association, Neshoba County Fairgrounds	Neshoba	Municipal and Private Facilities
MS0048194	Lees Steakhouse	Scott	Municipal and Private Facilities
MS0054925	Pearl River Water Supply District, Coal Bluff Water Park	Scott	Municipal and Private Facilities
MS0061107	Renfroe Country Store	Leake	Municipal and Private Facilities

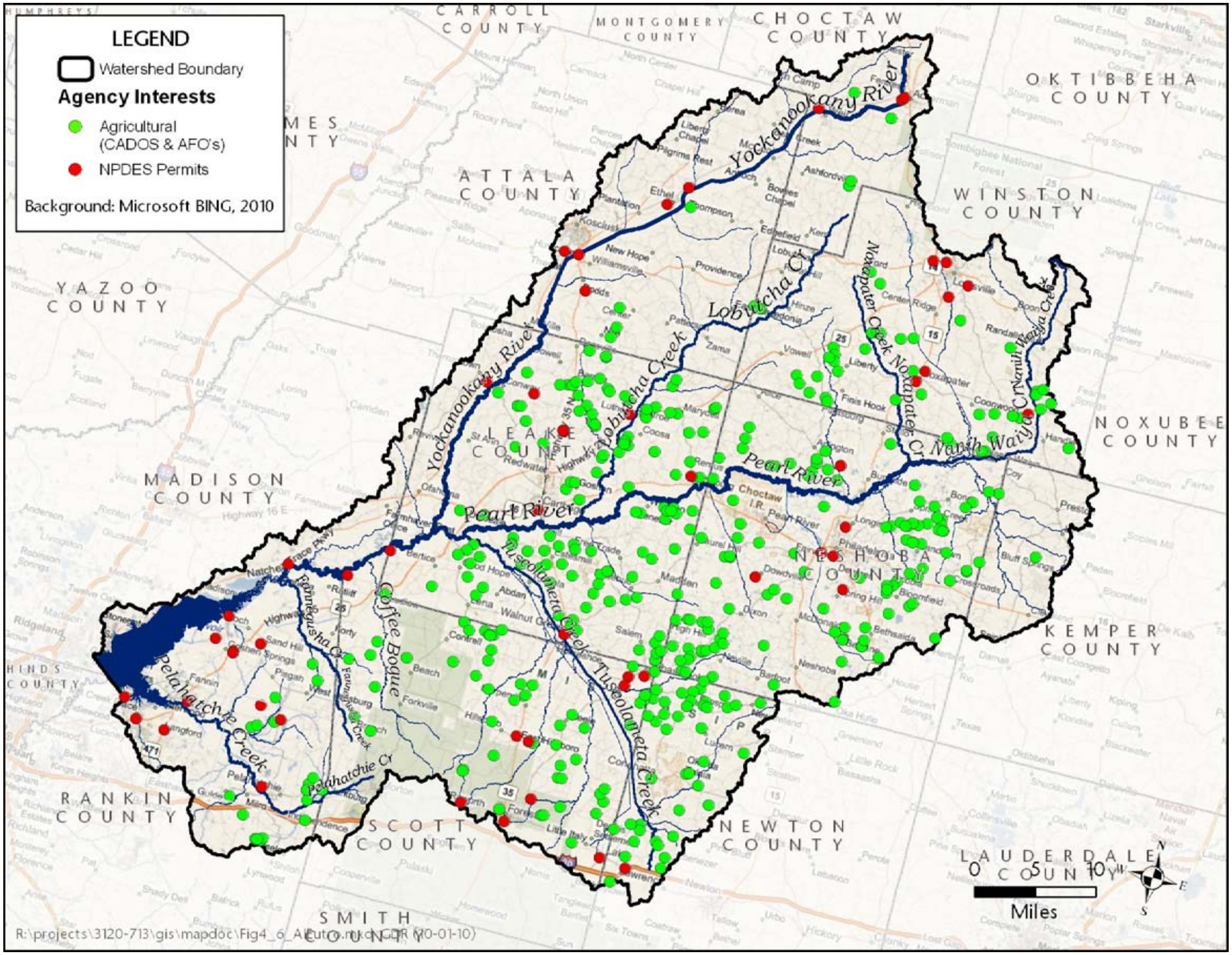

Figure H.7. Locations of point source facilities that are nutrient sources.

MDEQ has noted permit violations at 15 of the facilities in recent years. The violations are summarized in Table H.6. Locations of the facilities are shown on Figure H.5.There are two facilities with compliance issues located within the direct tributaries of the Reservoir: Reservoir East Subdivision and Pelahatchie publicly owned treatment works (POTW), West. There are currently no enforcement actions against these facilities. However, MDEQ is reviewing discharge monitoring data for these facilities and may proceed with enforcement actions if permit violations continue.

There is currently one facility classified as a major industrial NPDES permit, Tyson Foods Inc., River Valley Animal Foods, Forest (Permit No. MS0046931). This facility currently has a maximum permitted flow of 0.95 MGD and discharges treated wastewater into an unnamed tributary of Tallabogue Creek. This facility has had no recent significant permit compliance issues. There were minor exceedances of permitted levels of total suspended solids (TSS) reported in June 2008; however, the difference between the reported value and permit limit was less than 4%.

2.2.3 Nutrient Sources from Agricultural Operations

Agricultural facilities include animal growing operations that generate animal manure and treated wastewater from poultry processing facilities. There are 334 facilities that have dry poultry AFO permits in the Reservoir watershed. MDEQ requires operators to develop nutrient management plans for their facilities that specify methods for disposing of poultry litter. Poultry litter is either applied to the operator’s land according to the management plan or sold to third parties who use the litter for fertilizer. According to MDEQ, the most common issues from these facilities are due to complaints due to odor from land application of manure. Often the complaints are due to application by a third party, so the complaints can’t be tracked to a particular permit holder.

Table H.6. Permit violations from wastewater treatment facilities in the Ross Barnett watershed.

Facility Name and Permit Number	County	Issues
Ethel POTW MS0024791	Attala	Significant violations occurred in 2009 for biochemical oxygen demand (BOD), fecal coliform and dissolved oxygen. The NPDES permit also has phased limits that will require a facility upgrade.
Kosciusko POTW, South MS0027774	Scott	Significant violations occurred for BOD in September and December of 2009.
Pelahatchie POTW, West MS0021008	Rankin	Annual average BOD concentration was exceeded by 49% (as reported in quarterly monitoring reports).
Reservoir East Subdivision MS0035327	Rankin	Fecal coliform bacteria limits exceeded by 50% for the second half of 2009.
Philadelphia POTW MS0021156	Neshoba	This facility has exceeded its permitted flow over the past few years. The NPDES permit has phased limits that increase the permitted flow once modifications are completed.
Neshoba County Fair Association, Neshoba County Fairgrounds MS0044920	Neshoba	Fecal coliform bacteria (annual average) was exceeded by more than 100% in 2009.
Noxapater POTW, North MS0025241	Winston	Required to install disinfection; will be in place by June 2011.
Noxapater POTW, South MS0021628	Winston	Required to install disinfection; will be in place by June 2011.
Louisville POTW, East MS0025640	Winston	Required to install disinfection; was installed as of December 2010.
Louisville POTW, South MS0025836	Winston	Required to install disinfection; was installed as of December 2010.
Louisville Municipal School District, Nanih Waiya School MS0038768	Winston	Facility has not submitted 2009 DMR.
Carthage POTW MS0020061	Leake	Fecal coliform limit was exceeded by 63% in 2009.
Forest POTW MS0020362	Scott	Significant violations in 2010 for mercury and cyanide (monthly averages).
PRVWSD, Leake County Water Park MS0044113	Leake	Significant violations in 2009 of BOD, TSS, and fecal coliform (annual averages) due to flooding problems at the facility.
PRVWSD, Coal Bluff Water Park MS0054925	Scott	Annual average BOD limit was exceeded by >100% in 2009.

Six swine facilities with Combined Animal Feeding Operation (CAFO) permits are located in Winston and Choctaw counties, which are in the upper part of the watershed. All of these facilities have lagoons and land application areas to treat and dispose of wastewater. They are all permitted for no discharge of wastewater, but have outfalls to sample stormwater runoff once per quarter. There are no compliance issues with these facilities other than the occasional odor compliant.

Six industrial facilities in the watershed treat wastewater from poultry processing. The majority of these facilities have had recent compliance problems. Based on MDEQ records, many of these issues have been resolved. The facilities are listed in Table H.7 and their locations shown on Figure H.7.

Table H.7. Poultry processing wastewater treatment facilities in the Ross Barnett watershed.

Facility Name and Permit Number	County	Issues
Peco Foods Inc, MS0002615	Scott	Pathogen violations in January and December 2009; TSS violations in 2006.
Tyson Foods Inc, Carthage Processing Plant MS0026140	Leake	Pathogen violations in February 2007; oil and grease in August 2008. Enforcement action in 2009 issued a monetary fine due to failure to monitor and report chlorine levels.
Mississippi Poultry Corporation, MS0037486	Rankin	Compliance inspection reports noted deficiencies in monitoring and DMRs; significant exceedances of permit limits for organic material, nutrients, and pathogens in December 2009 and January through March of 2010. Enforcement action issued in July 2010.
Lady Forest Farms Inc., Forest Hatchery, MS0056103	Scott	Compliance inspection report and NOVs issued in 2007 noted permit exceedances in nutrients, pathogens, and organic material in 2006 and 2007. NOVs reported exceedances of TSS limits in 2009.
Tyson Foods Inc., River Valley Animal Foods, Forest, MS0046931	Scott	Slight exceedance of TSS in 2008.

The Census of Agriculture conducted by the United States Department of Agriculture, National Agricultural Statistics Service (NASS) contains data that can be used to characterize agricultural activities in the Reservoir watershed. The most recent census was conducted in 2007, issued in February 2009, and updated December 2009. Census data from 2002 were also reviewed in order to assess the changes in agricultural lands that have occurred within a 5-year period. It should be noted that agricultural census data are available only on a county basis, so the county information given cannot be compared directly with watershed boundaries.

According to Census of Agriculture data, the total amount of land in farms in counties located within the Ross Barnett watershed has increased between the years 2002 and 2007. Land in farms consists of agricultural land used for crops, pasture, or grazing as well as woodland that is not used for cultivation or grazing it is considered part of the operations of a farm owner. In the 11 counties within the watershed, the increase in total land in farms ranged from 11% to 16%. However the increase in land in farms may be due to an increase in the area categorized as total woodland. Total woodland includes natural and planted woodlots or timber tracts, cutover and deforested land with young growth. The area of farms categorized as total woodland has shown an increase ranging from 15% to 56% in the counties within the watershed. The acreage used for crops and pasture has either decreased or shown an increase nominal to the percent of land in farms increase.

Dominant crops in the four counties located closest to the Reservoir are shown in Table H.8. In Rankin County, cotton production has decreased significantly and there has been an increase in the number of acres of soybeans. Similarly, there has also been an increase in soybean production in Madison County and a decrease in other crops including hay, cotton, and wheat. Landuse data from the NASS Cropland Data layer in 2008 indicates the locations where particular crops are grown within the 1x:10x watershed (Figure H.8).

Table H.8. Dominant crop types based on Census of Agriculture data.

County	Dominant Crop Types
Leake	Corn
Madison	Corn, Soybeans, Cotton, Wheat
Rankin	Corn, Soybeans, Cotton, Wheat
Scott	Corn

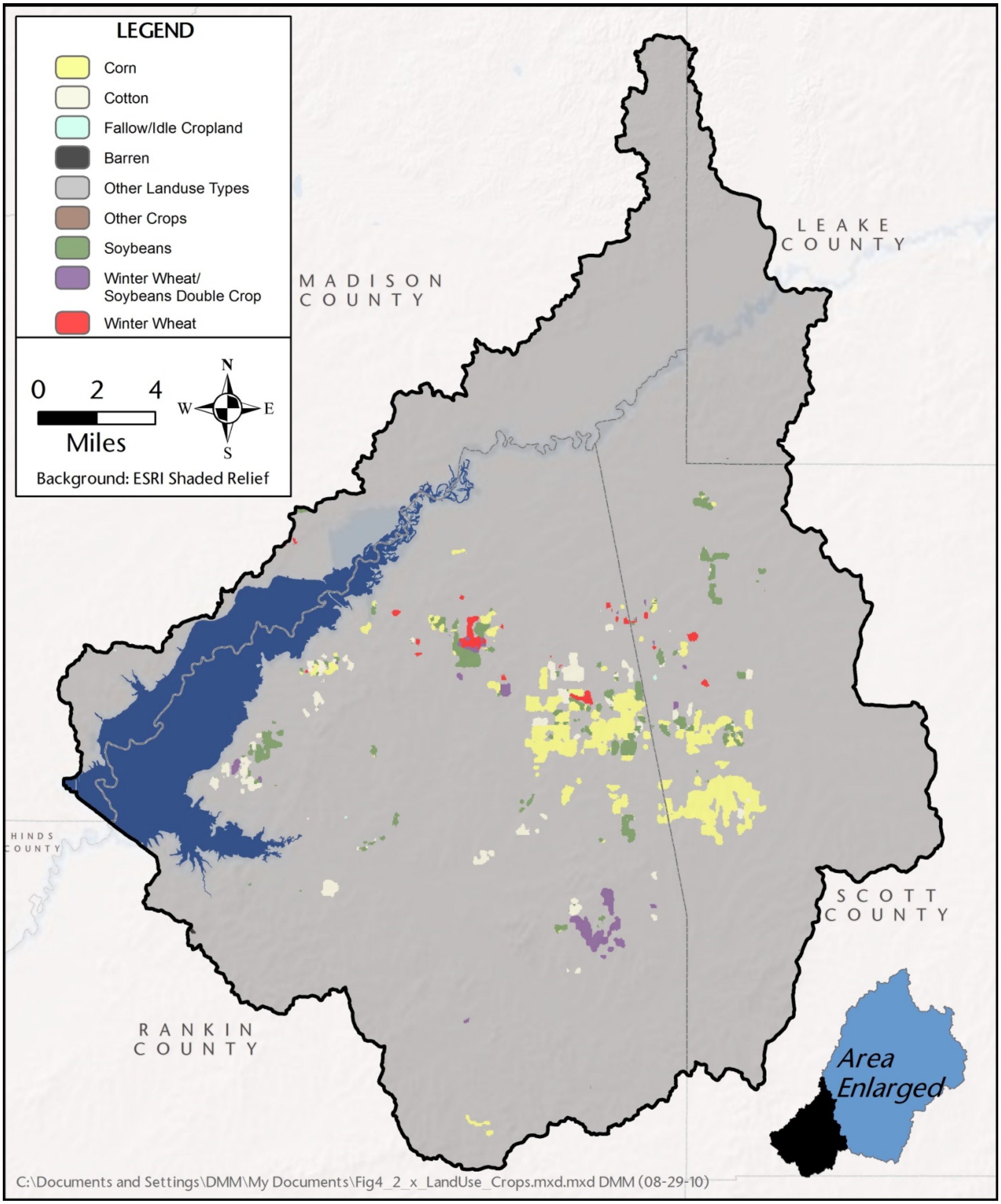

Figure H.8. Crop types in the Reservoir watershed.

Additional Census of Agriculture data for Scott and Rankin counties are shown in Table H.9. Only Rankin and Scott counties are included in Table H.9 because they are the only counties with a discernable amount of agricultural crop areas in the watershed. Rankin and Scott counties have experienced decreases in total cropland of 4% and 17%, respectively. The total cropland category includes all harvested cropland as well as cropland used only for pasture and grazing and land where crops were planted but not harvested.

Table H.9. Selected agricultural statistics for Rankin and Scott counties (USDA 2009).

Agricultural Census County Statistics	**Percent Change from 2002 to 2007**	
	Rankin	**Scott**
Land in Farms	7%	11%
Total Cropland	-4%	-17%

Census of Agriculture - County Data – Mississippi, + means increase in area and – means decrease in area

The Census of Agriculture contains additional information related to fertilizer use. According to the NASS, there has been an increase in the acreage treated with commercial fertilizer since 2002, with the exception of Rankin County. In the four counties closest to the Reservoir (Madison, Rankin, Leake, and Scott), the land areas treated are less than 10% of county areas.

Animal manures are a potential source of nutrients in streams in the watershed, due to the number of poultry-growing and other animal operations in the area. Scott County is among the counties with highest concentration of poultry growing facilities in the state (personal communication, Kurt Readus, March 19, 2010). Information available from the Census of Agriculture can be used to estimate the current number of farms with agricultural operations involving animals. The number of farms is available on a county basis (Table H.10). Table H.11 shows the percent change in farm types from 2002 to 2007 for the four counties closest to the Reservoir. In most cases, the number of farms has decreased from 2002 to 2007. The exception to this is the number of swine farms in Scott and Rankin counties. The significant increase in the number of swine farms in Scott County (233%) does not necessarily indicate an increase in the number of animals. This is because NASS does not track the number of animals on each farm.

Table H.10. Number of farms for the four counties closest to the Reservoir (USDA 2009).

Farm Type	Leake	Madison	Rankin	Scott
Any Poultry	130	20	81	146
Cattle and Calves	344	263	355	423
Hogs and Pigs	4	9	8	10

Census of Agriculture – County Data – Mississippi

Table H.11. Percent change in farm types from 2002 to 2007 (USDA 2009).

Farm Type	Leake	Madison	Rankin	Scott
Any Poultry	-32%	-13%	-10%	-25%
Cattle and Calves	-20%	-16%	-12%	-8%
Hogs and Pigs	-50%	-10%	+14%	+233%

Census of Agriculture – County Data – Mississippi, + means increase in area and – means decrease in area

Farmers typically store poultry litter in containment areas located near poultry houses. Stored litter can be land-applied as a fertilizer on nearby pasture lands or sold for use in other areas. Poultry litter is typically applied to pasture land at appropriate times in order to supplement nitrogen needs. NRCS recommends applying poultry litter only after testing has been conducted to determine the nutrient content in the litter. When these recommendations are not followed, poultry litter can be a significant source of excess nutrients and pathogens.

NRCS provides cost-sharing assistance to businesses that transport poultry litter through their poultry litter distribution program. The decision to use or sell litter is often based on current market and the profitability selling fertilizer after transportation costs. Currently, the price of commercial fertilizers is high and many farmers are able to sell litter to other areas. In Scott and Newton counties, for example, about half the litter is applied to land within the area where it is generated. The remaining litter is transported and sold to other areas outside of the county (personal communication, Joe Addy, District Conservationist for Scott County, March 22, 2010).

Approximately 19% of the land in the Ross Barnett watershed is classified as pasture/grassland based on the NASS landuse data for 2008 (see Figure H.3). As noted previously, poultry litter applied to pasture can be a potential source of nutrients. Pasture can also be a source of nutrient loads to surface waters through cattle use of streams (depositing manure in streams), manure deposited on pasture land, and fertilizers applied to pastures.

The amount of cropland used for pasture or grazing is given on a county basis in the Census of Agriculture. The number of acres for the four counties closest to the Reservoir are given below. The areas given in Table H.12 are based on county boundaries, not watershed boundaries.

Table H.12. Cropland used for pasture or grazing based on 2007 Census of Agriculture data.

County	Number of Acres	Percent of County
Leake	10,434	2.8
Madison	18,534	4.0
Rankin	9,596	1.9
Scott	10,786	2.8

3.0 PATHOGENS

3.1 Locations of Concern for Pathogens

Streams where fecal coliform water quality criteria were exceeded were included on the Mississippi's 303(d) list of impaired waters, and fecal coliform TMDLs have been prepared for these listed streams. Pelahatchie Creek, Fannegusha Creek, and Coffee Bogue are of particular concern because these streams drain directly to the Reservoir.

Recreational users of the Reservoir commonly swim, water ski, and fish from boats in the main lake, near the dam, in Pelahatchie Bay, and along Roses Bluff (near the shoreline in Madison County). There are several locations where public access to swimming areas is allowed. These include public parks in Rankin County (Pelahatchie Shore Park, Lakeshore Park) and Madison County (Old Trace Park and Brown's Landing). It is important to prevent bacterial contamination in these areas to protect public health. Boaters also swim near sand bars upstream of Ratliff Ferry. Areas with residential developments that are not served by a central sewer system also have a higher potential for pathogen issues in nearby waters. These areas are primarily located along the eastern shoreline of the Reservoir and north of Pelahatchie Bay.

3.2 Pathogen Sources

Stormwater management plans developed for Rankin County, Madison County, and the cities of Flowood, Madison, and Ridgeland have provisions to conduct surveys of the stormwater conveyances in their areas to detect potential illicit discharges. These are typically conducted during dry weather. At this time, these programs have not identified any illicit discharges that are pathogen sources.

There are two NPDES-permitted point sources in the watershed that are currently under an agreement to install disinfection systems. These facilities are Noxapater POTW South (MS0021628) and Noxapater POTW North (MS0025241). These facilities are permitted to discharge treated effluent into Gum Branch and Talladega Creek. Installation of disinfection systems is expected to reduce bacteria in the receiving streams (personal communication, Rusty Lyons, MDEQ, May 2010).

4.0 PESTICIDES

The types of pesticides present in the Reservoir watershed can be categorized by their intended use. The uses of the pesticides most commonly sold in central Mississippi (per the Mississippi Department of Agriculture and Commerce) are described in Table H.13. Pesticides applied to land surfaces draining to the Reservoir have the potential to reach the Reservoir during rain events, especially from developed areas located closest to the Reservoir. This includes pesticides used near homes and other buildings and pest and weed control chemicals used in landscaped areas.

Table H.13. Intended uses of common pesticide chemicals.

Application	Chemicals
Pest control industry (termite treatments to homes)	Pyrethroids (i.e., cypermethrin), Bifenthrin, Fipronil
Lawns (herbicides and insecticides applied to lawns by homeowners/ businesses or companies hired by them)	MSMA (monosodium methanearsonate), no additional product will be sold with a turf label after December 31, 2010; Pendimethalin; Atrazine; 2,4-D; Glyphosate; Dicamba; Malathion; Carbaryl; Bifenthrin
Mosquito control done in cities/counties	Permethrin; Resmethrin
Agricultural areas	Glyphosate; 2,4-D; Acephate; Dicrotophos; Flumioxazin
Forest areas	Glyphosate; Imazapyr; Metasulfuron methyl

Pesticides applied to landscaped areas near the Reservoir shoreline are an important source to consider. On a national scale, EPA calculates approximately70 million pounds of active pesticide constituents are applied to lawns each year. Pesticides can leave the surface area of the lawn by several different means such as; runoff, leaching into groundwater or by volatizing into the air. Pesticides that are applied to turf areas have some runoff, but usually the highest level is during significant storm events and usually if pesticide has been applied recently. Leaching into the groundwater is another way that the pesticide can be moved through a watershed. Leaching occurs when a soluble pesticide moves through the soil into the watershed. Generally only trace amounts are lost to groundwater.

Pesticides that are allowed to reach impervious surfaces are quickly washed into the watershed by rain events. Lastly, pesticides can be allowed in the watershed by improper disposal and applicator cleaning. Many homeowners wash applicators on grass, sidewalks or directly into gutter or storm drains (Schueler 1995).

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APPENDIX I

ANALYSIS OF WIND/WAVE EFFECTS ON THE ROSS BARNETT RESERVOIR

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1.0 INTRODUCTION

Identifying areas of a shallow lake likely to experience sediment resuspension due to a wind of a specific speed from a specific direction can be performed using fetch, wind speed, and water depth to calculate wave-based shear stress forces acting on bottom sediments. Fetch is a function of wind direction relative to the lake shore. Fetch, wind speed, and water depth are used to calculate wave period, wave length, and wave height. Wave period, wave length, and wave height are then used to calculate the “maximum bottom boundary velocity”, which is used to calculate the bottom shear stress (Laenen and LeTourneau 1996).

In general, sediment resuspension due to wave action is most likely when water depth is less than half of the wave length (Carper and Bachman 1984). Bachman et al. (2000) and Carper and Bachman (1984) solved wave equations to determine the minimum wind velocity that would result in a wave length greater than two times the water depth for multiple locations within lakes and for 36 wind directions. They were able to compare these results to historical wind data from nearby weather stations to get an idea of the frequency of sediment resuspension at specific locations within the lakes.

2.0 DETERMINING FETCH

A program has been developed to calculate effective fetch for the surface area of Mississippi River pools using Geographical Information System (GIS) data (Rogala 1997). The most effective method used the raster-based Global Resource Information Database (GRID) module to divide the pool surface into 20-meter cells and calculate effective fetch for each cell. The program requires a significant amount of time to perform the calculations; running the calculation for one pool for one wind direction took approximately 5 hours.

3.0 INDICES

Hakanson (1982) developed an indicator called the dynamic ratio, calculated by taking the square root of the lake surface area in square kilometers and dividing that by the average lake depth in meters. Bachmann et al. (2000) found the dynamic ratio to be well-correlated to bottom sediment disturbance frequency. They found that in lakes with dynamic ratios of 0.8 or higher, almost the entire lake bottom can be subject to sediment resuspension due to wave action. They concluded that these lakes would be most likely to have problems with sediment resuspension. <u>The dynamic ratio for the Ross Barnett Reservoir is greater than 3.</u>

Hakanson (1982) also developed an equation for estimating the percentage of a lake bed likely to be subject to erosion process and sediment transport, including those resulting from wave action. He termed this value the “areal erosion estimate.” <u>Areal erosion has been calculated to be 75.7% for the Ross Barnett Reservoir.</u>

4.0 ESTIMATING AMOUNT OF SUSPENDED MATERIAL

Sheng and Lick (1979) developed empirical relationships between shear stress and suspended sediment for shallow areas of Lake Erie. Laenen and LeTourneau (1996) used these empirical equations to estimate probable suspended sediment concentrations in Upper Klamath Basin in Oregon.

A study of sediment resuspension in seven shallow lakes in New Zealand (Hamilton and Mitchell 1996) found bottom shear stress to be a better predictor of suspended solids concentrations than equations using wind speed, wave height, water depth, and wave length. Including measures of the sediment settling velocity and macrophyte biomass improved the regression relationship.

5.0 ROSS BARNETT RESERVOIR

The dynamic ratio and estimate of areal erosion indicate that Ross Barnett Reservoir will be affected by resuspension of sediments from wave action.

One element of wave sediment resuspension to consider is wind direction and speed. Figure I.1 shows a wind rose developed from data from the weather station at the Jackson airport (located east of the dam). This wind rose indicates that at the airport, wind blows most frequently from the south to southeast (approximately 26% of the time) and from the north to north-northwest (approximately 14% of the time). The long axis of Ross Barnett Reservoir runs primarily from southwest to northeast (Figure I.2), which is nearly perpendicular to the prevailing winds. Winds parallel to the long axis of the Reservoir (south-southwest to west-southwest and north-northeast to east-northeast) occur approximately 25% of the time (Figure I.1). Winds blowing parallel to the long axis of the Reservoir have longer fetch, and can build larger waves that would be more likely to resuspend sediments. Monthly wind roses for the Jackson airport (provided in Attachment I.1) indicate that these winds occur most frequently during the summer months.

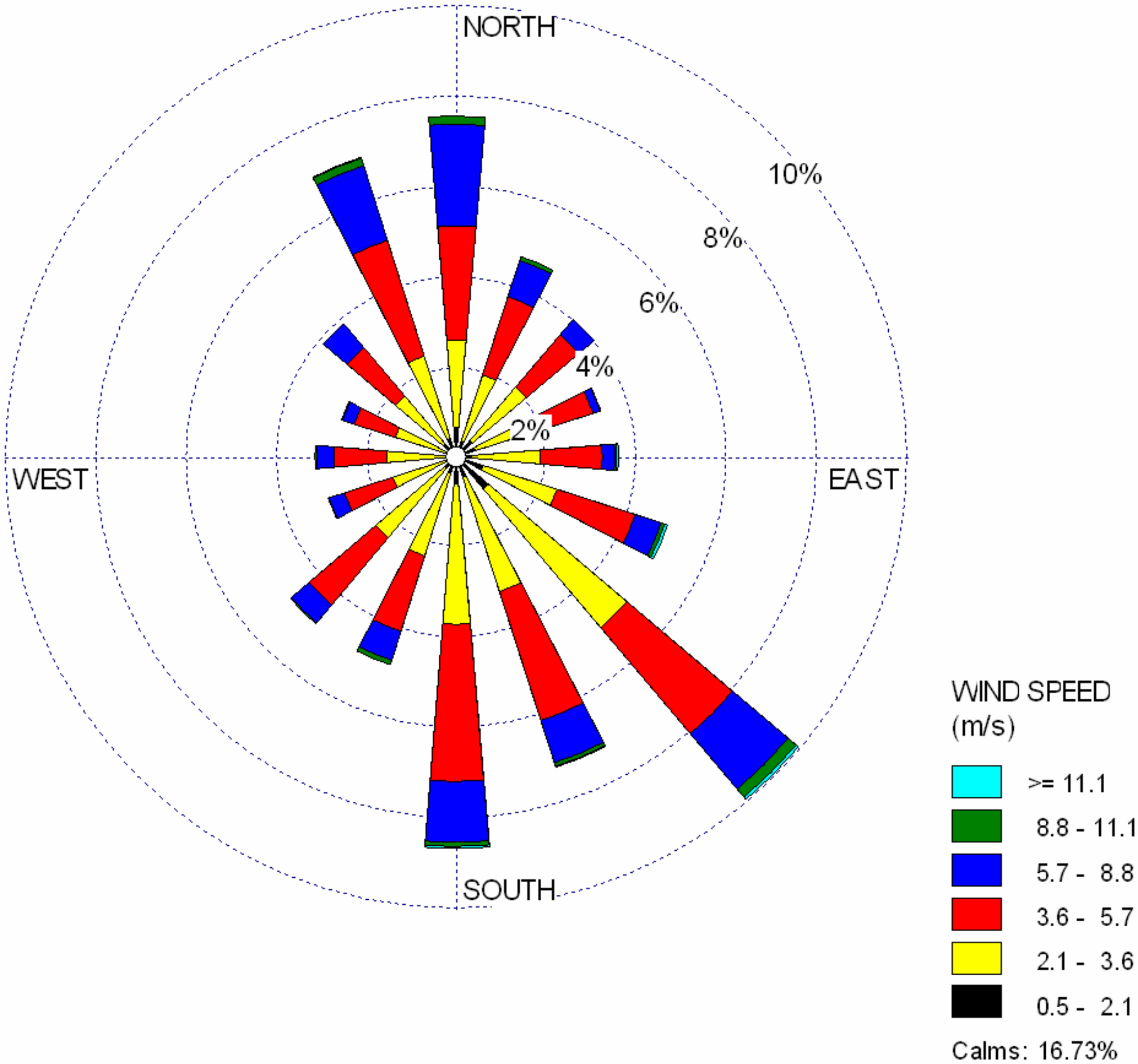

Figure I.1. Wind rose for Jackson airport (from MDEQ Air Quality Monitoring Network Review[1]).

[1] http://www.deq.state.ms.us/MDEQ.nsf/pdf/Air_2010AQNetwork/$FILE/AQ%20Monitoring%20Network%202010.pdf?OpenElement

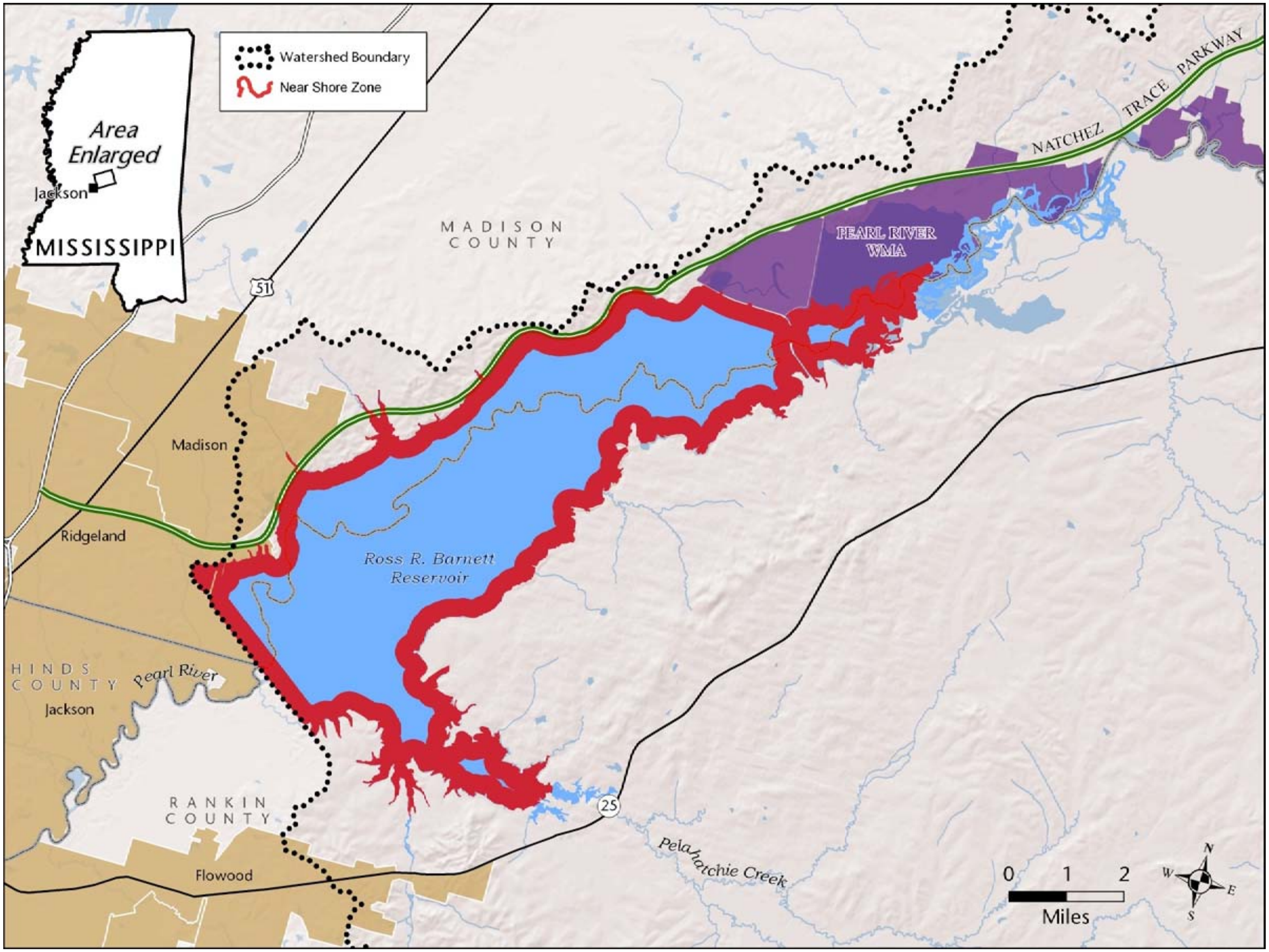

Figure I.2. Orientation of Ross Barnett Reservoir.

6.0 MANAGEMENT OPTIONS

Studies have determined that aquatic plants can play an important role in improving water quality in shallow systems by stabilizing sediment and preventing sediment resuspension due to wave action (James and Barko 1990, 1994; Dieter 1990; Barko and James 1998, Horppila and Nurminen 2003). Therefore, establishment and maintenance of submersed aquatic plants is an option for reducing turbidity in shallow systems where wind and wave action contribute significantly to the turbid conditions (James et al. 2001a). Studies have shown that both meadow-forming submersed aquatic plants, such as Chara and Vallisneria species, and canopy-forming submersed aquatic plants, such as Nympha species, can significantly reduce sediment resuspension (Van den Berg et al. 1998, James et al. 2001b). James et al. (2001b) suggest that establishing meadow-forming aquatic plants can stabilize sediments with minimal interference with boating and other open-water recreation.

Osmon (2008) identifies promotion of aquatic plant growth as the essential task of a comprehensive strategy to make turbid, shallow lakes clearer through biomanipulation. The benefits of aquatic plants include stabilization of sediments, competition with algae (which contribute to turbidity) for nutrients, providing refuge for zooplankton (which feed on algae), and encouraging predatory fish populations (including sport fish). Potential elements of a shallow lake turbidity management program include:

- Water level management to encourage aquatic plant growth,
- Developing “no wake” zones to reduce waves from boating activities that resuspend sediment,
- Establishing breakwater areas to reduce fetch length,
- Naturalizing shorelines to absorb wave energy,
- Controlling external nutrient loading,
- Stocking of predatory fish species, and
- Removing carp, which resuspend sediment during feeding (Osmon 2008).

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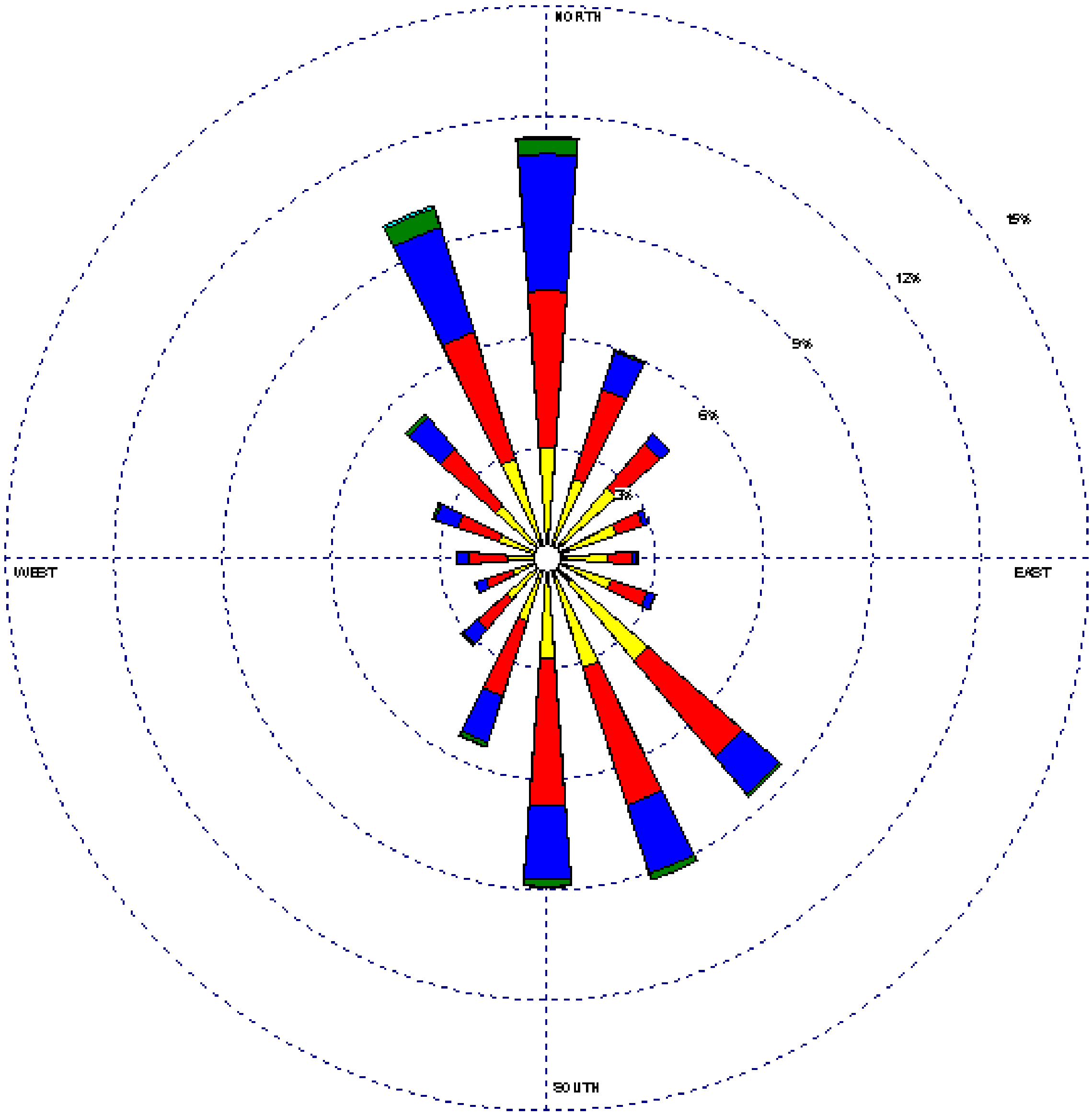
ATTACHMENT I.1

Monthly Wind Rose Plots from the Jackson Airport Weather Station

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS

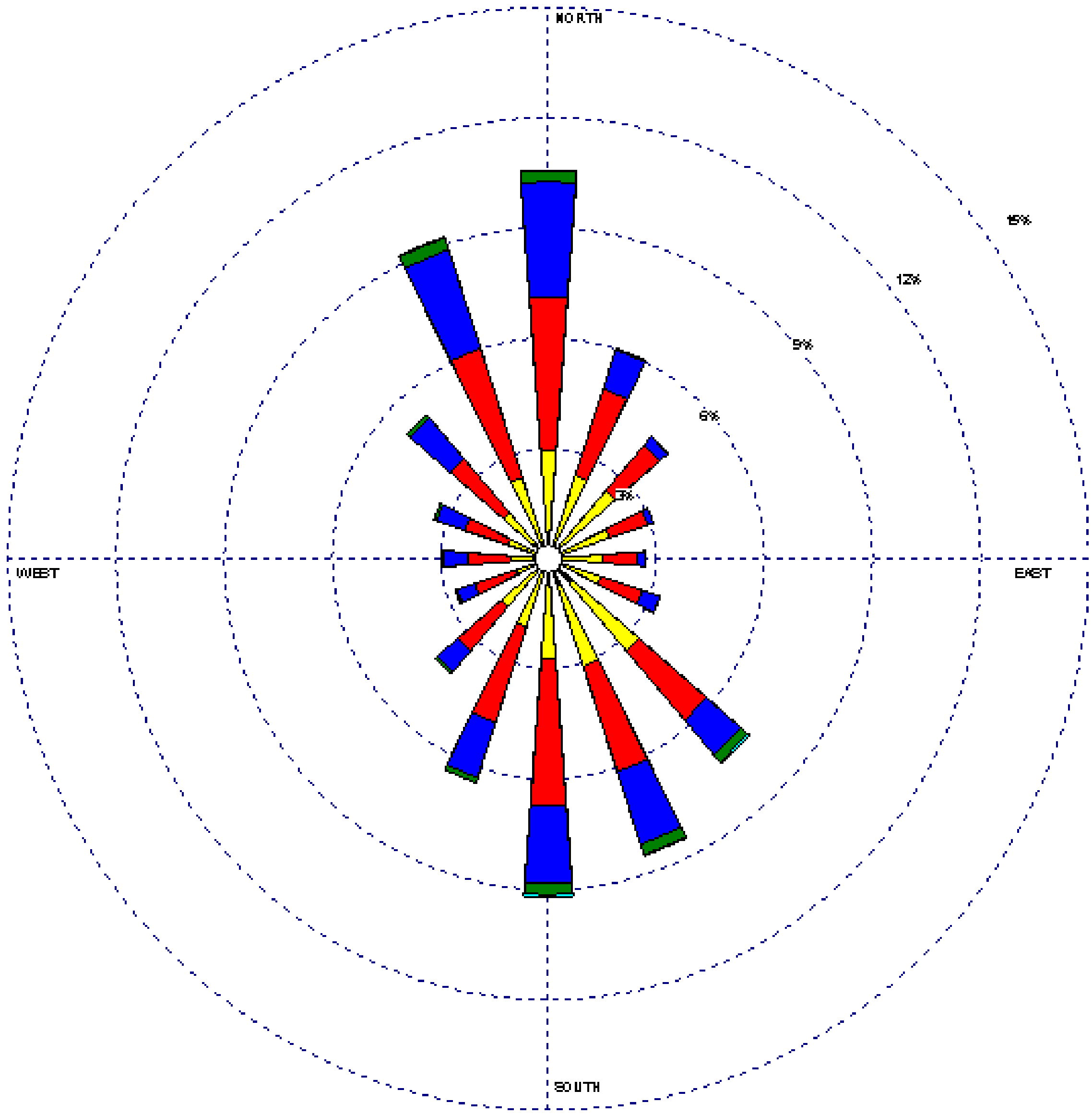


Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	DISPLAY: Wind Speed	UNIT: m/s	COMMENTS
5.40 - 8.49	AVG. WIND SPEED: 4.16 m/s	CALM WINDS: 11.02%	
3.34 - 5.40	ORIENTATION: Direction (blowing from)	PLOT YEAR-DATE-TIME: 1961 Jan 1 - Jan 31 Midnight - 11 PM	
1.80 - 3.34			
0.51 - 1.80			

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS



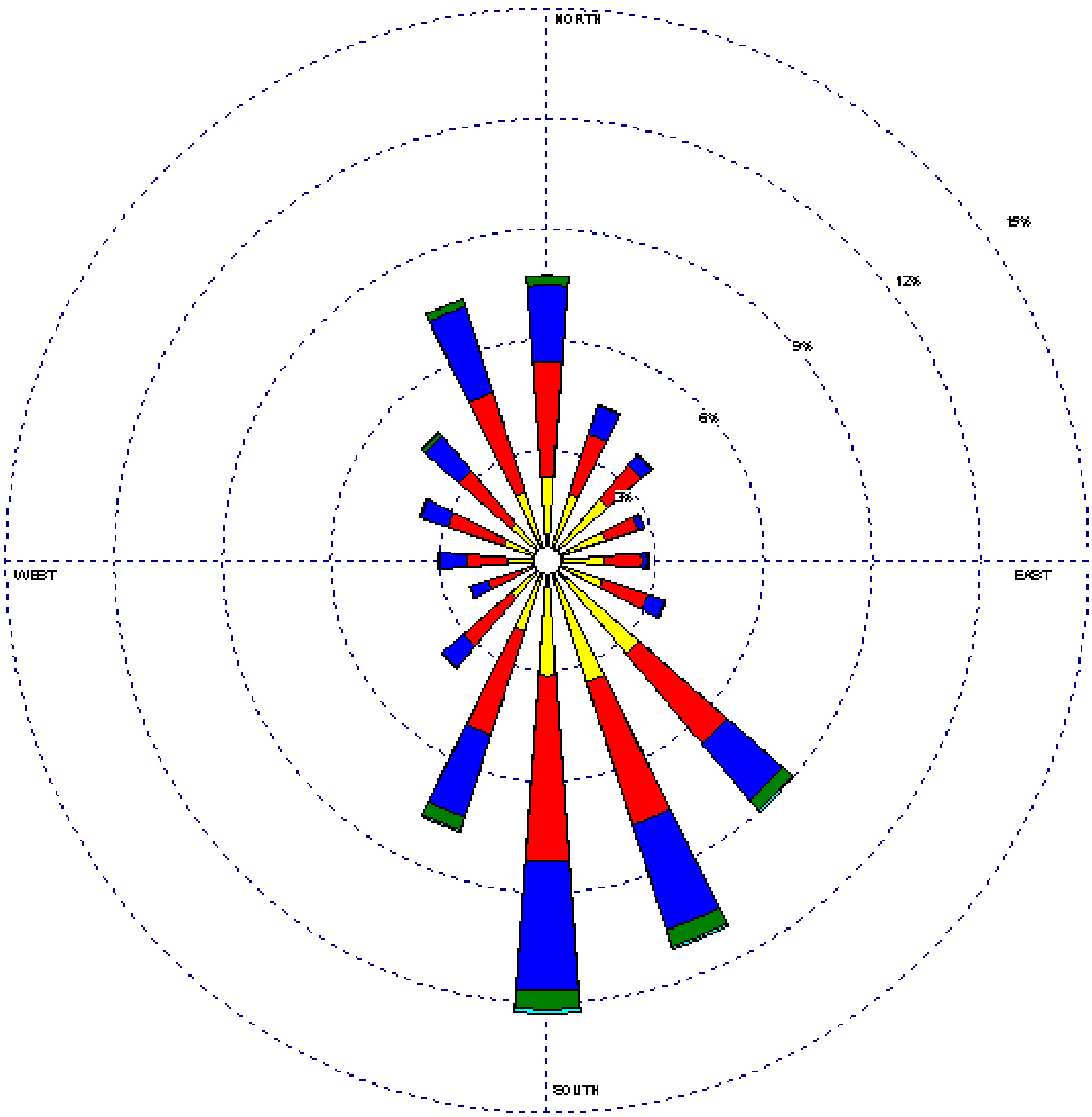
Wind Speed (m/s)

- > 11.06
- 8.49 - 11.06
- 5.40 - 8.49
- 3.34 - 5.40
- 1.80 - 3.34
- 0.51 - 1.80

MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
DISPLAY Wind Speed	UNIT m/s	COMMENTS
AVG. WIND SPEED 4.27 m/s	CALM WINDS 10.85%	
ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Feb 1 - Feb 29 Midnight - 11 PM	

WIND ROSE PLOT

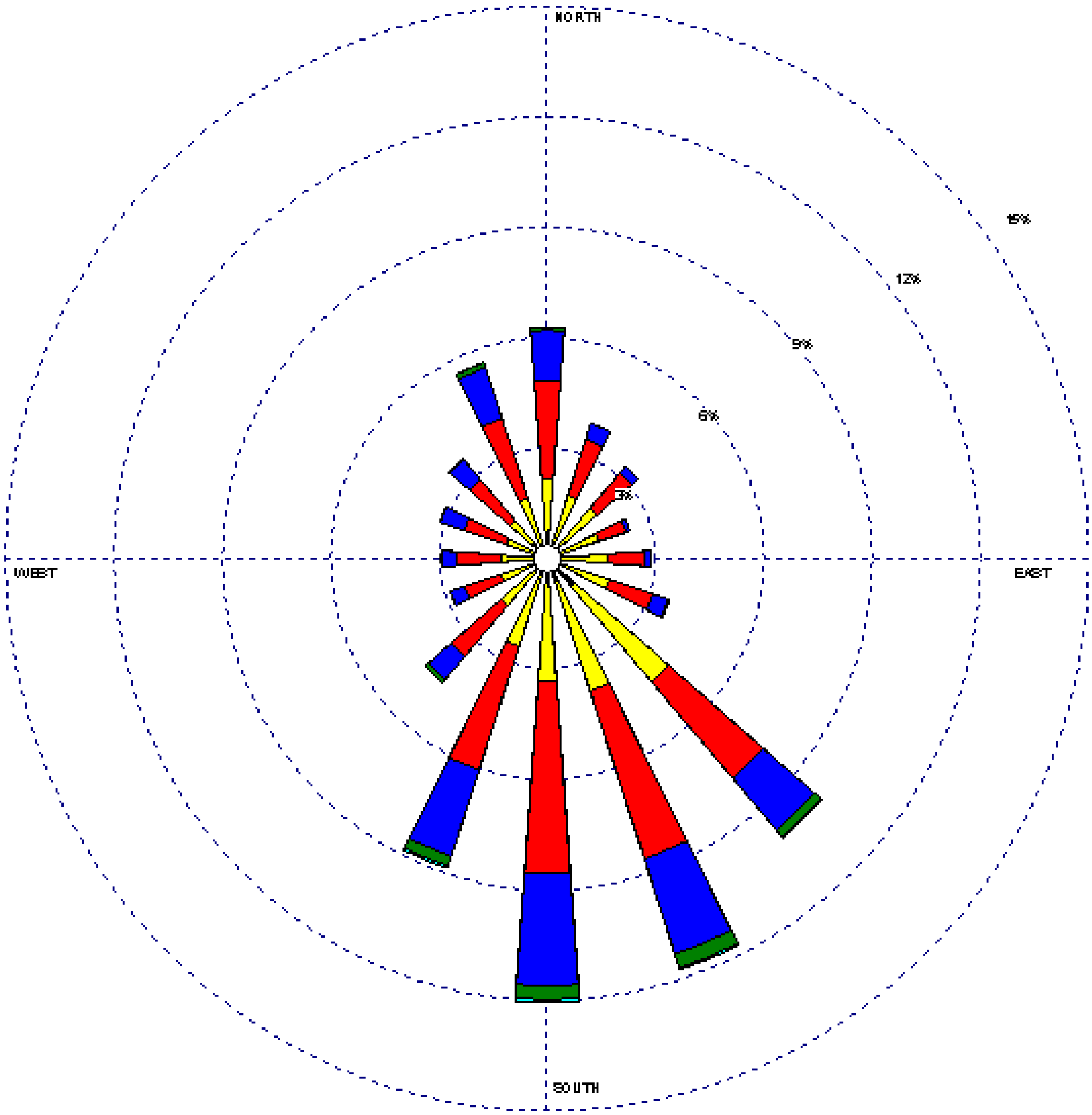
Station #03940 - JACKSON/THOMPSON FIELD, MS



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	DISPLAY: Wind Speed	UNIT: m/s	COMMENTS
5.40 - 8.49	AVG. WIND SPEED: 4.43 m/s	CALM WINDS: 9.57%	
3.34 - 5.40	ORIENTATION: Direction (blowing from)	PLOT YEAR-DATE-TIME: 1961 Mar 1 - Mar 31 Midnight - 11 PM	
1.80 - 3.34			
0.51 - 1.80			

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS

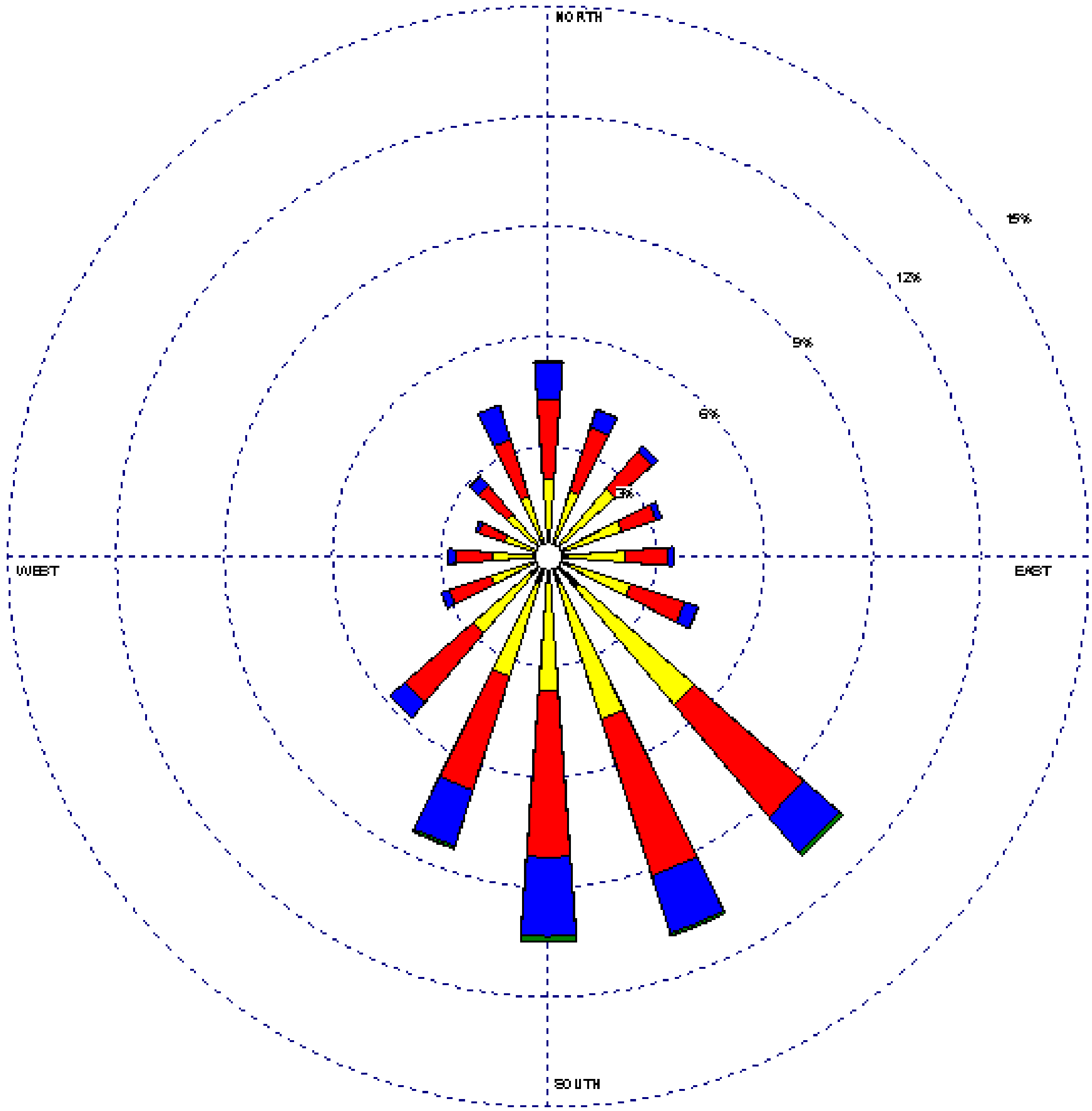


Wind Speed (m/s) > 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
	DISPLAY Wind Speed	UNIT m/s	COMMENTS
	AVG. WIND SPEED 4.18 m/s	CALM WINDS 12.34%	
	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Apr 1 - Apr 30 Midnight - 11 PM	

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS



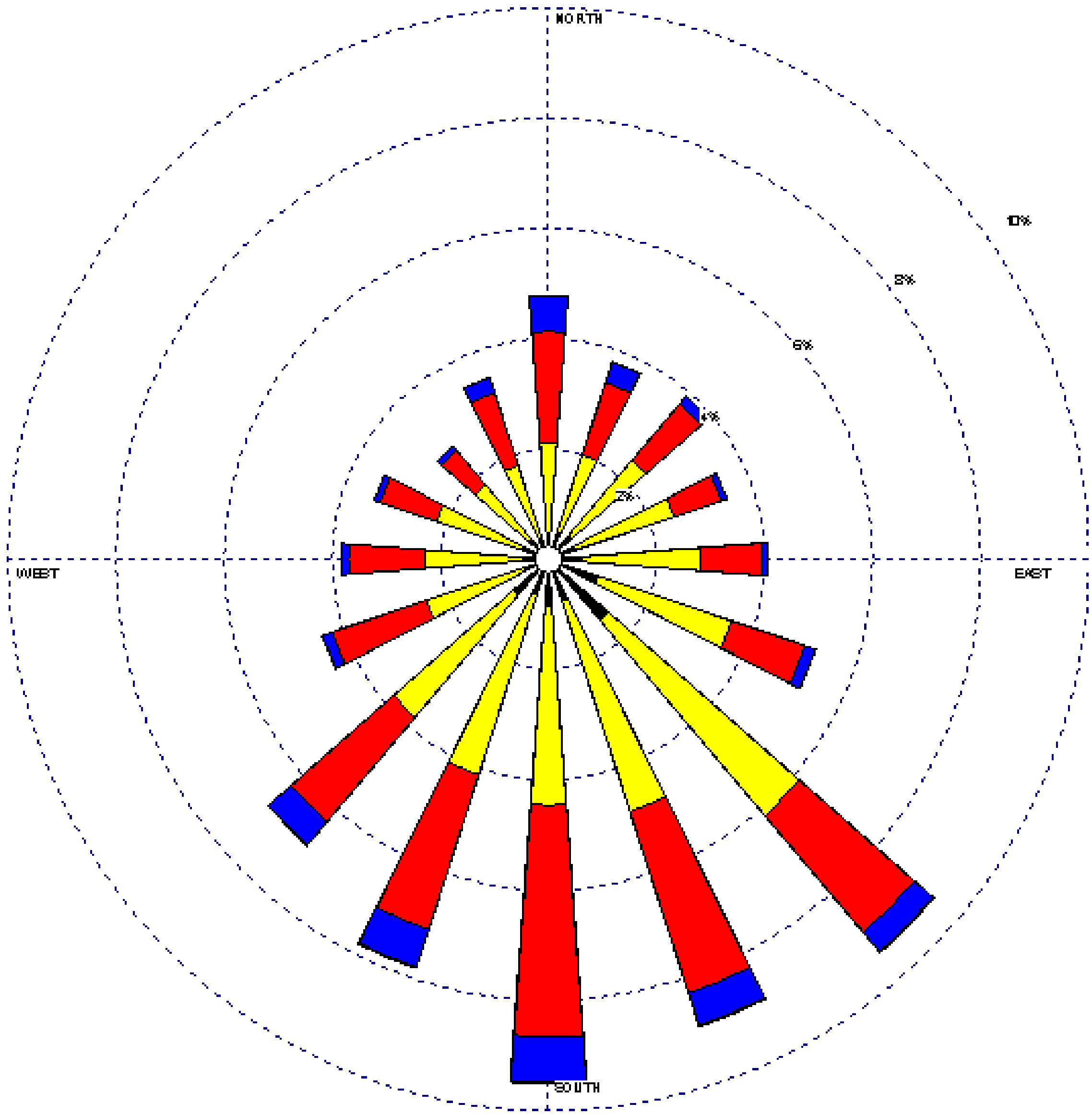
Wind Speed (m/s)

- > 11.06
- 8.49 - 11.06
- 5.40 - 8.49
- 3.34 - 5.40
- 1.80 - 3.34
- 0.51 - 1.80

MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
DISPLAY Wind Speed	UNIT m/s	COMMENTS
AVG. WIND SPEED 3.71 m/s	CALM WINDS 13.53%	
ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 May 1 - May 31 Midnight - 11 PM	

WIND ROSE PLOT

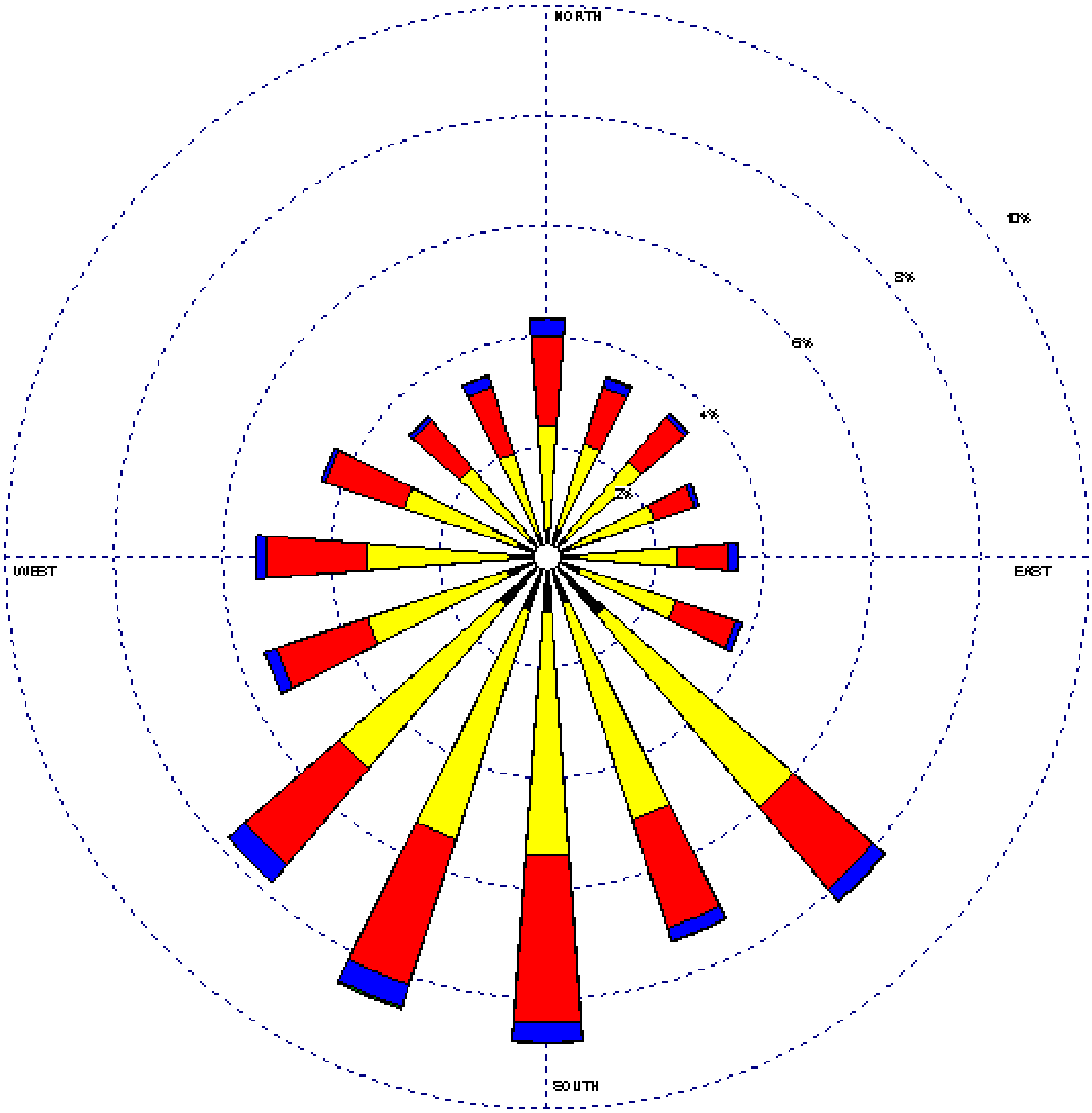
Station #03940 - JACKSON/THOMPSON FIELD, MS



Wind Speed (m/s)	MODELER	DATE	COMPANY NAME
> 11.06	Sara West	10/29/2002	USDA-ARS
8.49 - 11.06	**DISPLAY**	**UNIT**	**COMMENTS**
5.40 - 8.49	Wind Speed	m/s	
3.34 - 5.40	**AVG. WIND SPEED**	**CALM WINDS**	
1.80 - 3.34	3.30 m/s	14.40%	
0.51 - 1.80	**ORIENTATION**	**PLOT YEAR-DATE-TIME**	
	Direction (blowing from)	1961 Jun 1 - Jun 30 Midnight - 11 PM	

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS

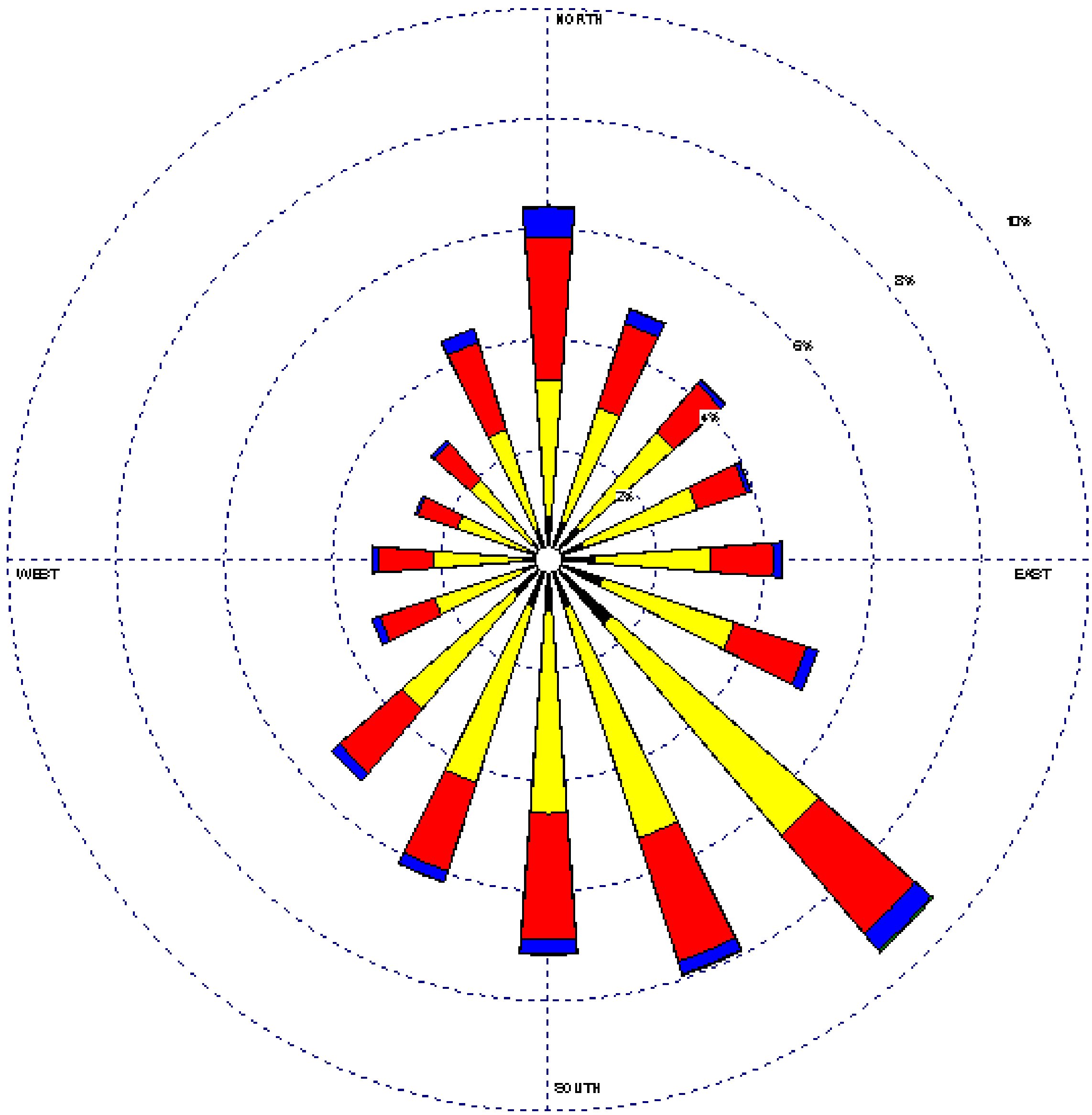


Wind Speed (m/s)			
> 11.06	MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
8.49 - 11.06	DISPLAY Wind Speed	UNIT m/s	COMMENTS
5.40 - 8.49	AVG. WIND SPEED 3.10 m/s	CALM WINDS 15.55%	
3.34 - 5.40	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Jul 1 - Jul 31 Midnight - 11 PM	
1.80 - 3.34			
0.51 - 1.80			

WRPLOT View 3.5 by Lakes Environmental Software - www.lakes-environmental.com

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS



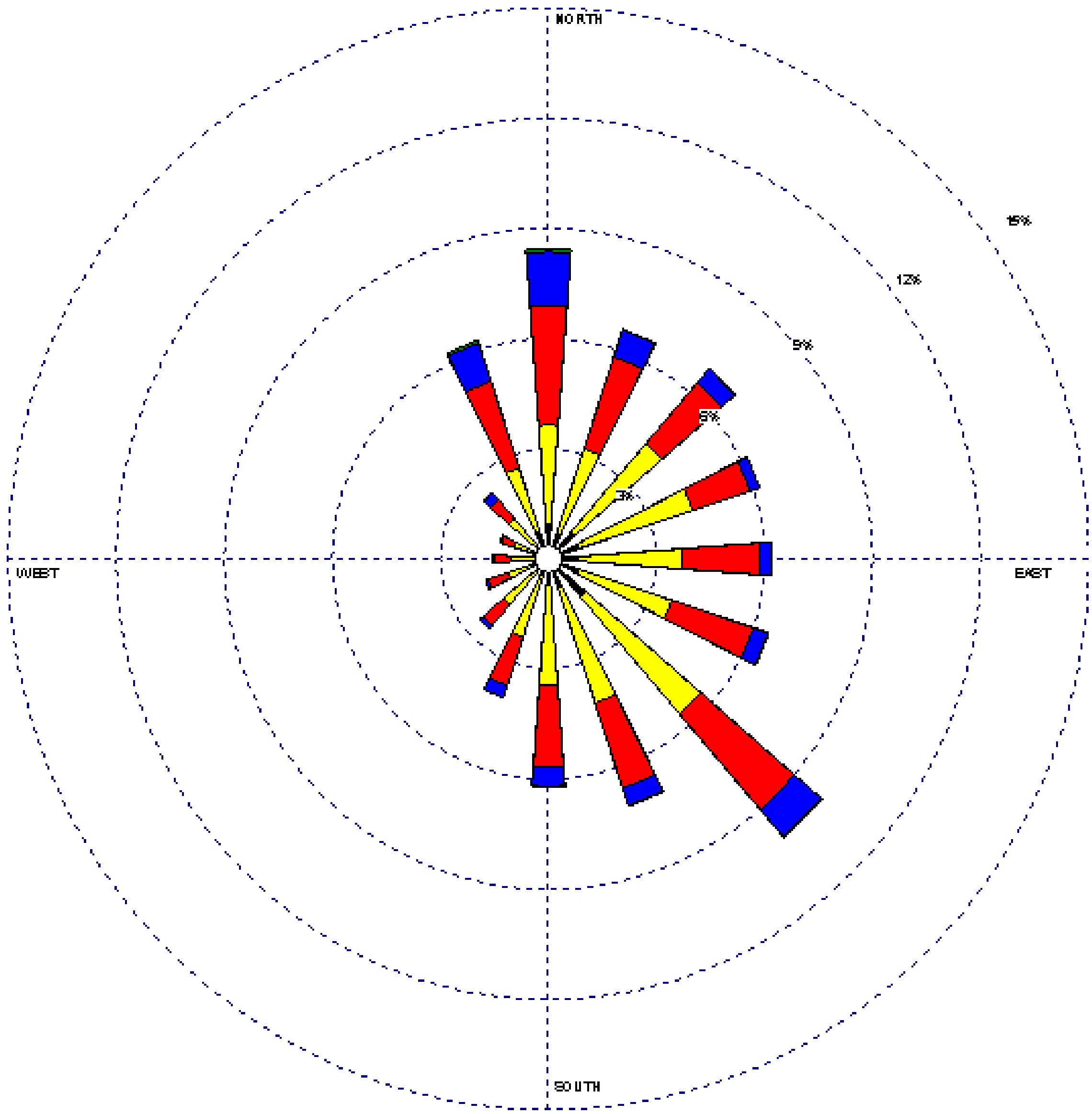
Wind Speed (m/s)

- > 11.06
- 8.49 - 11.06
- 5.40 - 8.49
- 3.34 - 5.40
- 1.80 - 3.34
- 0.51 - 1.80

MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
DISPLAY Wind Speed	UNIT m/s	COMMENTS
AVG. WIND SPEED 3.06 m/s	CALM WINDS 18.31%	
ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Aug 1 - Aug 31 Midnight - 11 PM	

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS



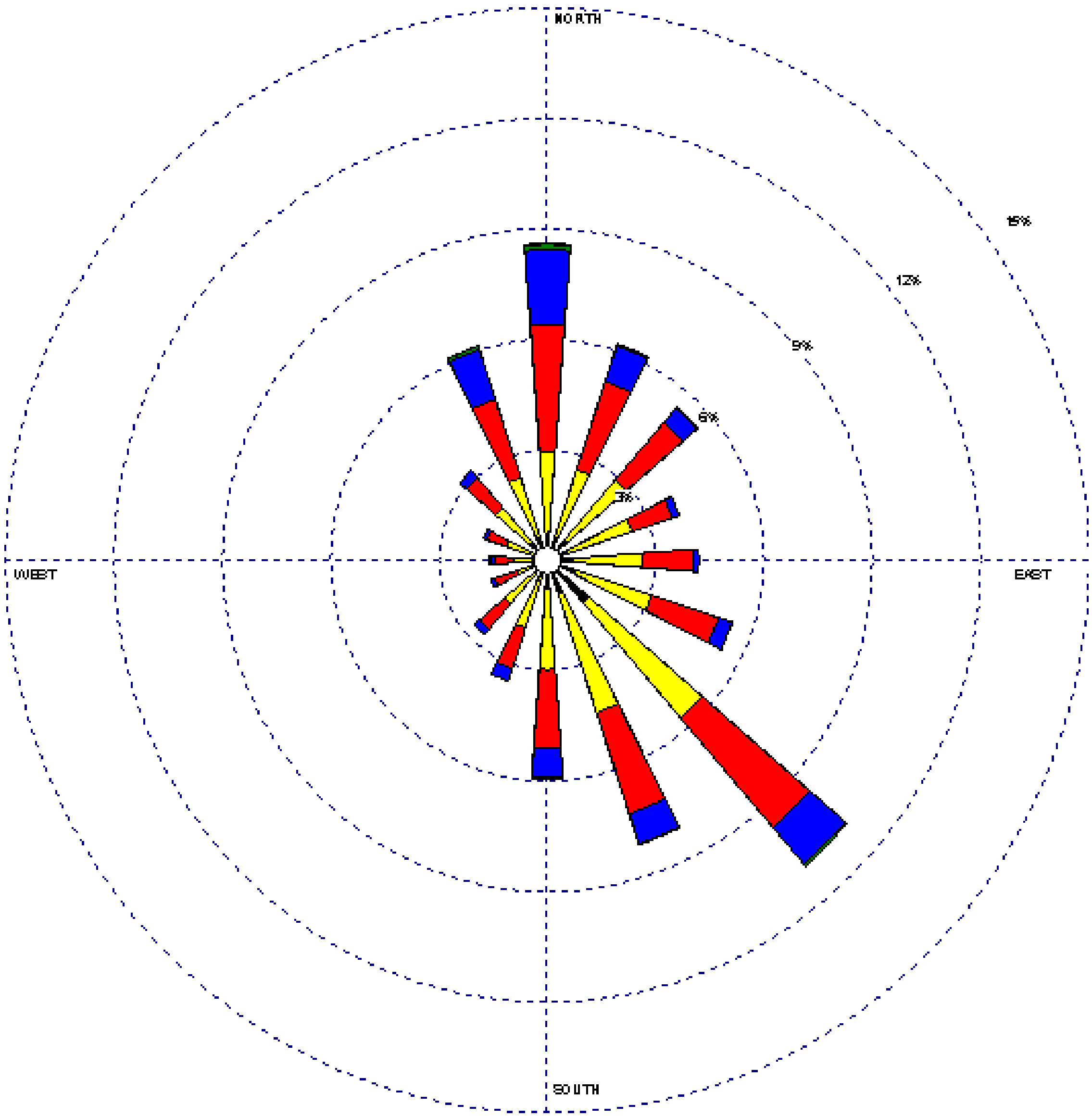
Wind Speed (m/s)

- > 11.06
- 8.49 - 11.06
- 5.40 - 8.49
- 3.34 - 5.40
- 1.80 - 3.34
- 0.51 - 1.80

MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
DISPLAY Wind Speed	UNIT m/s	COMMENTS
AVG. WIND SPEED 3.39 m/s	CALM WINDS 16.01%	
ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Sep 1 - Sep 30 Midnight - 11 PM	

WIND ROSE PLOT

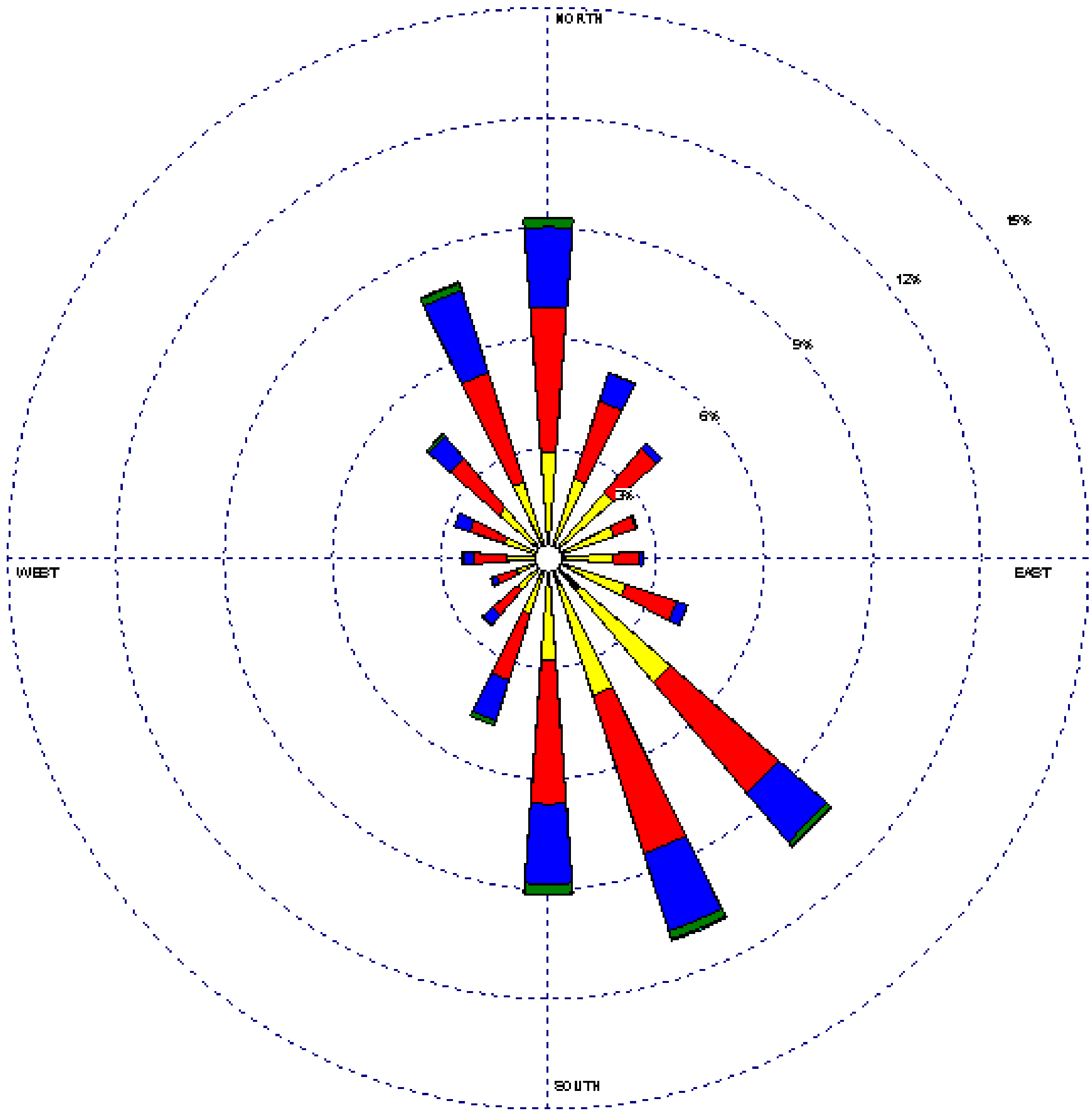
Station #03940 - JACKSON/THOMPSON FIELD, MS



Wind Speed (m/s)	MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
> 11.06 8.49 - 11.06 5.40 - 8.49 3.34 - 5.40 1.80 - 3.34 0.51 - 1.80	DISPLAY Wind Speed	UNIT m/s	COMMENTS
	AVG. WIND SPEED 3.58 m/s	CALM WINDS 20.63%	
	ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Oct 1 - Oct 31 Midnight - 11 PM	

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS



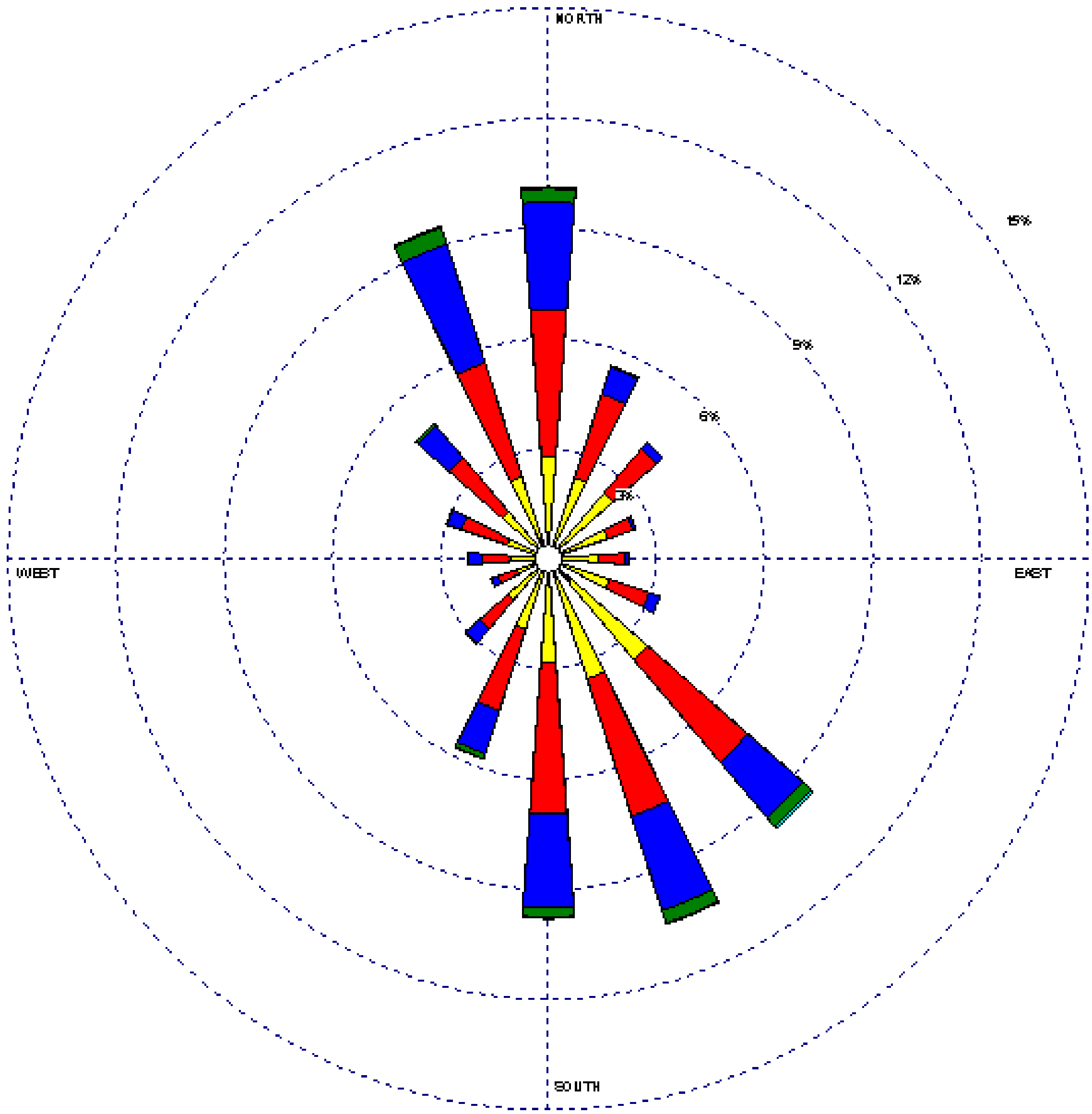
Wind Speed (m/s)

- > 11.06
- 8.49 - 11.06
- 5.40 - 8.49
- 3.34 - 5.40
- 1.80 - 3.34
- 0.51 - 1.80

MODELER Sara West	DATE 10/29/2002	COMPANY NAME USDA-ARS
DISPLAY Wind Speed	UNIT m/s	COMMENTS
AVG. WIND SPEED 4.03 m/s	CALM WINDS 14.93%	
ORIENTATION Direction (blowing from)	PLOT YEAR-DATE-TIME 1961 Nov 1 - Nov 30 Midnight - 11 PM	

WIND ROSE PLOT

Station #03940 - JACKSON/THOMPSON FIELD, MS



Wind Speed (m/s)

- > 11.06
- 8.49 - 11.06
- 5.40 - 8.49
- 3.34 - 5.40
- 1.80 - 3.34
- 0.51 - 1.80

MODELER	DATE	COMPANY NAME
Sara West	10/29/2002	USDA-ARS

DISPLAY	UNIT	COMMENTS
Wind Speed	m/s	

AVG. WIND SPEED	CALM WINDS
4.25 m/s	11.96%

ORIENTATION	PLOT YEAR-DATE-TIME
Direction (blowing from)	1961 Dec 1 - Dec 31 Midnight - 11 PM

ftn Associates Ltd.
water resources / environmental consultants

ROSS BARNETT RESERVOIR
BATHTUB MODEL STATUS REPORT

OCTOBER 31, 2011

ROSS BARNETT RESERVOIR BATHTUB MODEL STATUS REPORT

Prepared for

Mississippi Department of Environmental Quality
PO Box 2261
Jackson, MS 39225-2261

Prepared by

FTN Associates, Ltd.
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Little Rock, AR 72211

FTN No. 3120-713

October 31, 2011

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1.0 INTRODUCTION

A water quality model was configured for Ross Barnett Reservoir using the US Army Corps of Engineers (USACE) BATHTUB model. The model performs water and nutrient balance calculations in a steady-state, spatially segmented hydraulic network that accounts for advective and diffusive transport, and nutrient sedimentation. BATHTUB utilizes empirical models of reservoir nutrient balance and eutrophic response to predict reservoir water quality (Walker 1987). Required model inputs include annual average inflows and outflows, with annual average phosphorus concentrations, and reservoir water quality profiles, Secchi depths, and chlorophyll-*a* concentrations. Nitrogen data can also be incorporated into the model. The purpose for this modeling effort is to evaluate reservoir productivity responses to changes in nutrient and sediment inputs.

2.0 MODEL CONFIGURATION

2.1 Geometry

The Ross Barnett Reservoir was represented in the model using segmented geometry, as shown on Figure J.1. Each segment was described in the model using the surface area, length, and average depth dimensions. In addition, the mixed layer depth and hypolimnetic depth of each reservoir segment was specified, as well as the downstream segment. Model inputs are summarized in Table J.1. Surface area was measured from the reservoir extent when the water level was at the normal pool elevation of 90.5 meters (297 ft). Segment lengths were measured as straight-line distances, rather than along the thalweg. Mean depth was calculated by dividing estimated segment volume by the segment surface area. To estimate segment volumes, the proportion of volume in each segment was estimated based on data from the 2007 depth survey of the Reservoir performed by the Mississippi Department of Wildlife, Fisheries, and Parks; then this proportion was multiplied by the volume from the Reservoir elevation-capacity curve for elevation 90.5 meters (297 ft) (Lester and Harza Engineering 1959). Note that the mixed layer depths[1] are currently all set to the mean depth. No value has been specified for the hypolimnetic depth. These values have not yet been determined from the available water quality profile data for the Reservoir.

[1] Mixed layer depth is defined as the depth at which light penetration is 1% of light on the water surface.

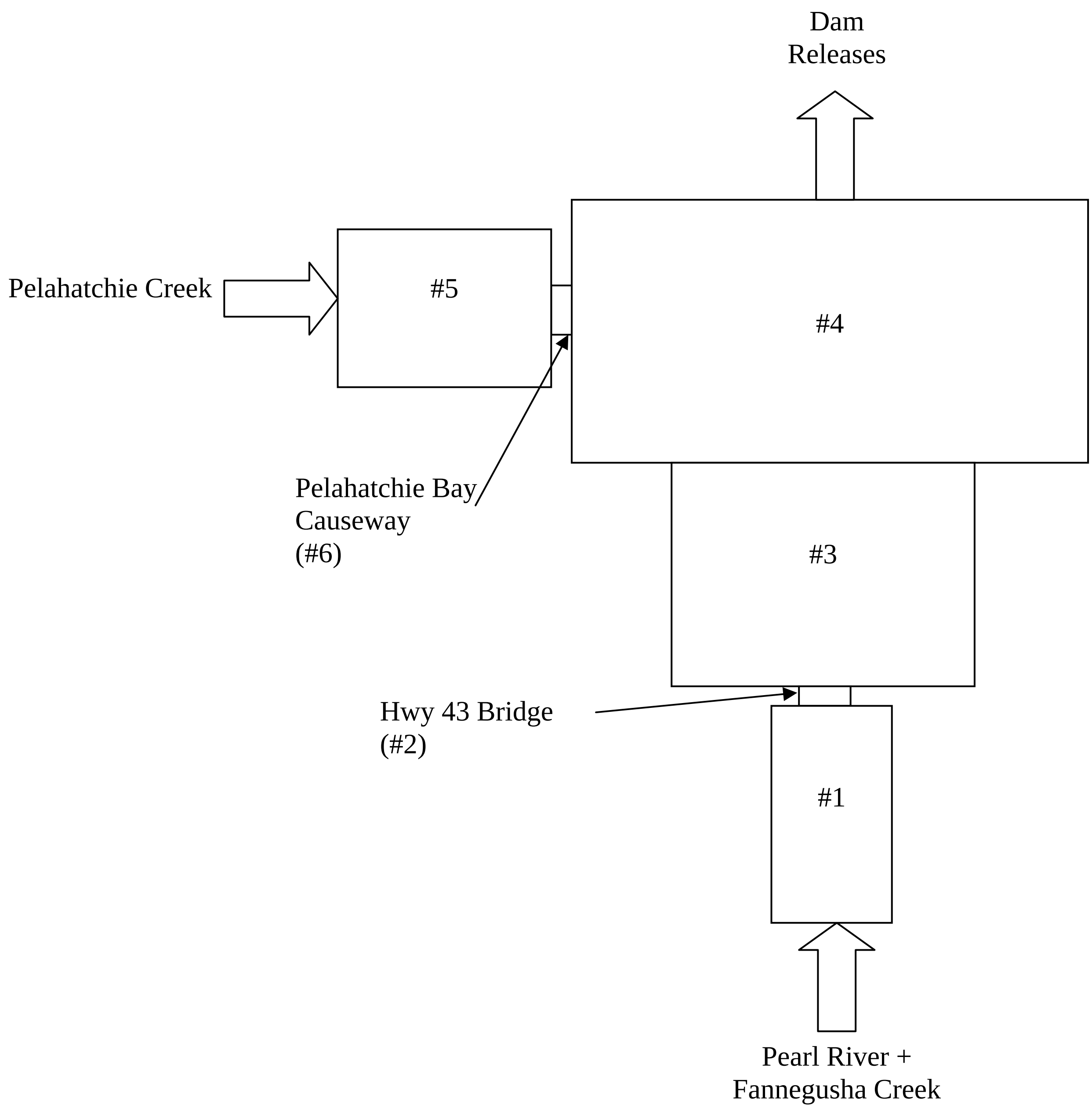

Figure J.1. Schematic of BATHTUB geometry for the Ross Barnett Reservoir.

Table J.1. BATHTUB geometry inputs for the Ross Barnett Reservoir.

Segment	Surface Area (km^2)	Mean Depth (m)	Length (km)	Outlet Segment	Mixed Layer Depth (m)	Hypolimnetic Depth (m)
1	10.5	2.38	11.6	2	2.38	0
2	0.03	5.25	0.067	3	5.24	0
3	49.5	3.44	11.5	4	3.44	0
4	36.0	5.85	6.2	0	1.75	0
5	9.2	1.79	6.0	6	1.79	0
6	0.005	6.23	0.034	4	6.23	0

2.2 Inflows

Inflows were specified for the headwaters of Ross Barnett Reservoir, and Pelahatchie Bay. For each inflow, the drainage area and annual flow are specified. The model inputs for the inflows are shown in Table J.2. Annual flow for the Pearl River was estimated based on annual flows reported at US Geological Survey (USGS) gages on the Pearl and Yockanookany Rivers. The average of the annual flows over the period of record at each gage was divided by the drainage area for the gage to calculate the flow per area: 0.015 cubic meters per second (cms) per square kilometer for Pearl River at Edinburgh, 0.013 cms/km^2 for Pearl River at Lena, and 0.006 cms/km^2 for Yockanookany River at Revive. Based on these values, a flow per area of 0.014 cms/km^2 was selected to estimate the inflows. Annual flow for the Pearl River was estimated by multiplying 0.014 cms/km^2 by the upstream drainage area of the headwaters. Since recent flow data were not available for Pelahatchie Creek (the current Pelahatchie Creek gage measures stage only), the Pearl River flow per area was also used to estimate annual flow into Pelahatchie Bay. Therefore, Pelahatchie Creek annual flow was estimated by multiplying the drainage area to Pelahatchie Bay by 0.014 cms/km^2.

Table J.2. BATHTUB tributary inputs for the Ross Barnett Reservoir.

Inflow	Drainage Area (km^2)	Flow (cubic hm/yr)
Headwaters	7,278	3,250
Pelahatchie Bay	614	274

2.3 Outflow

Annual flow was also specified for the Reservoir releases. The average annual outflow was calculated from the midnight readings from the spillway logs for the period from 1979 through 2004, approximately 4,300 cubic feet per second (cfs) (3,840 cubic hm/yr).

2.4 Observed Reservoir Water Quality

Observed Reservoir water quality data are input with the Reservoir geometry. Data were selected from the Mississippi Department of Environmental Quality (MDEQ) reservoir monitoring program at Ross Barnett from 1997 through 2004 to calibrate the model. A spreadsheet was used to calculate average total phosphorus, total nitrogen, chlorophyll-*a*, Secchi depth, and organic nitrogen. The input values for each segment are shown in Table J.3. Non-algal turbidity was calculated from Secchi depth and chlorophyll-*a* using the following equation (Walker 1987):

Non-algal turbidity = (1/Secchi) – (0.25*chlorophyll-*a*)

Orthophosphorus can also be input to the model, but these data were not available. Since there is no water quality monitoring station on the Pelahatchie causeway, observed water quality data for Segment 6 were set to the values used in Segment 5.

Table J.3. BATHTUB observed water quality inputs for the Ross Barnett Reservoir.

Segment	WQ Station ID	Non-algal Turbidity (1/m)	Total Phosphorus (ppb)	Total Nitrogen (ppb)	Chlorophyll-*a* (ppb)	Secchi Depth (m)	Organic Nitrogen (ppb)
1	RBR03	2.27	134	1136	8.9	0.4	885
2	2485000	1.69	166	990		0.5	720
3	RBR02	2.16	107	916	10.5	0.4	658
4	RBR01	1.49	97	910	9.0	0.6	665
5	RBR04	2.60	269	1098	9.1	0.4	854

2.5 Inflow Water Quality

Measured water quality data for the inflows were incomplete for this time period (see Table J.4); thus, some assumptions were required to specify inflow water quality data.

BATHTUB is designed to determine reservoir water quality based on inflow water quality. However, as we worked to calibrate the model, it provided insight into the inflow water quality. This will be described in Section 4.0. For the initial model run, inflow water quality concentrations were set to the concentrations observed in the upstream Reservoir segment (i.e., headwaters/Pearl River inflow water quality was set to observed water quality in Segment 1, and Pelahatchie Bay inflow water quality was set to observed water quality for Segment 5).

Table J.4. Summary of available water quality data for model inflows from model period.

Station	Parameter	1997	1998	1999	2000	2001	2002	2003	2004
2488250 – Pearl River near Wanilla	Total Phosphorus	X							
	Total Kjeldahl Nitrogen (TKN)	X							
2482000 – Pearl River near Edinburgh	Total Phosphorus	X	X	X	X	X			
	TKN	X	X	X	X	X			
	Ammonia	X	X	X	X	X			
	Nitrate + Nitrite Nitrogen (NO_2+NO_3)	X	X	X	X	X			
MDEQ 310 – Fannegusha Creek near Sand Hill	Total Phosphorus					X			
	TKN					X			
	Ammonia					X			
	NO_2+NO_3					X			
2484480 – Yockanookany near Revive	Total Phosphorus	X	X			X			
	TKN	X	X			X			
	Ammonia	X	X			X			
	NO_2+NO_3	X	X			X			
MDEQ 259 – Tuscolemeta Creek near Piggtown	Total Phosphorus					X			X
	TKN					X			X
	Ammonia					X			X
	NO_2+NO_3					X			X
	Orthophosphate								X

2.6 Outflow Water Quality

Water quality data were not available for the Pearl River at Ross Barnett Reservoir dam for the period 1997 through 2004. For initial runs, the outflow water quality was set to the water quality observed in the Reservoir at the dam (RBR-01).

2.7 Model Options

The model options selected for the initial BATHTUB run are summarized in Table J.5.

Table J.5. Model options selected for modeling.

Model Option	**Selection**
Conservative substance	Not computed
P balance	Canfield & Bachman (1981)
N balance	Not computed
Chlorophyll-*a*	P, N, light, T
Secchi depth	Not computed
Dispersion	Fischer-numeric (Fischer et al 1979)
P calibration	Decay rates
N calibration	Decay rates
Availability factors	Ignore
Mass-balance tables	Use estimated concentrations

3.0 INITIAL MODEL RESULTS

Plots of the output from the initial model run are included on Figures J.2 through J.4. Modeled phosphorus concentrations were lower than observed, and only roughly followed the longitudinal pattern of total phosphorus concentrations in the reservoir. Modeled chlorophyll-*a* concentrations were similar only in the mid-lake segment (Segment 3 on Figure J.1). With the selected model options, total nitrogen was set to the observed values.

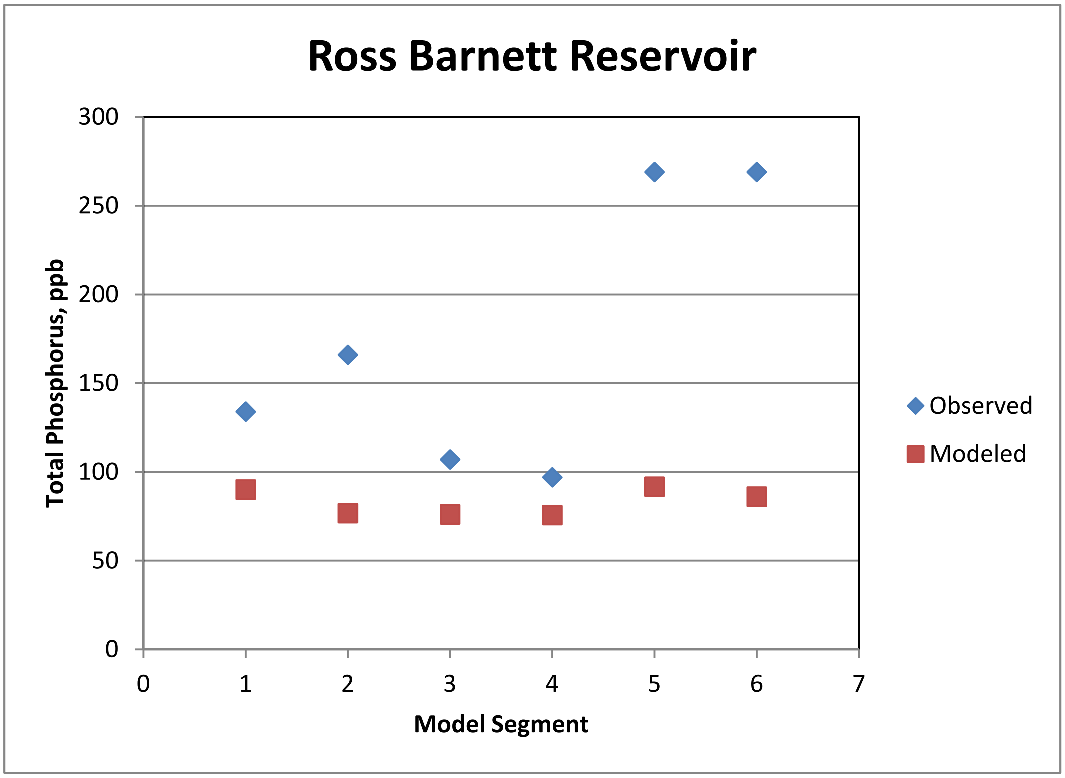

Figure J.2. Comparison of observed phosphorus in the Reservoir with BATHTUB model output.

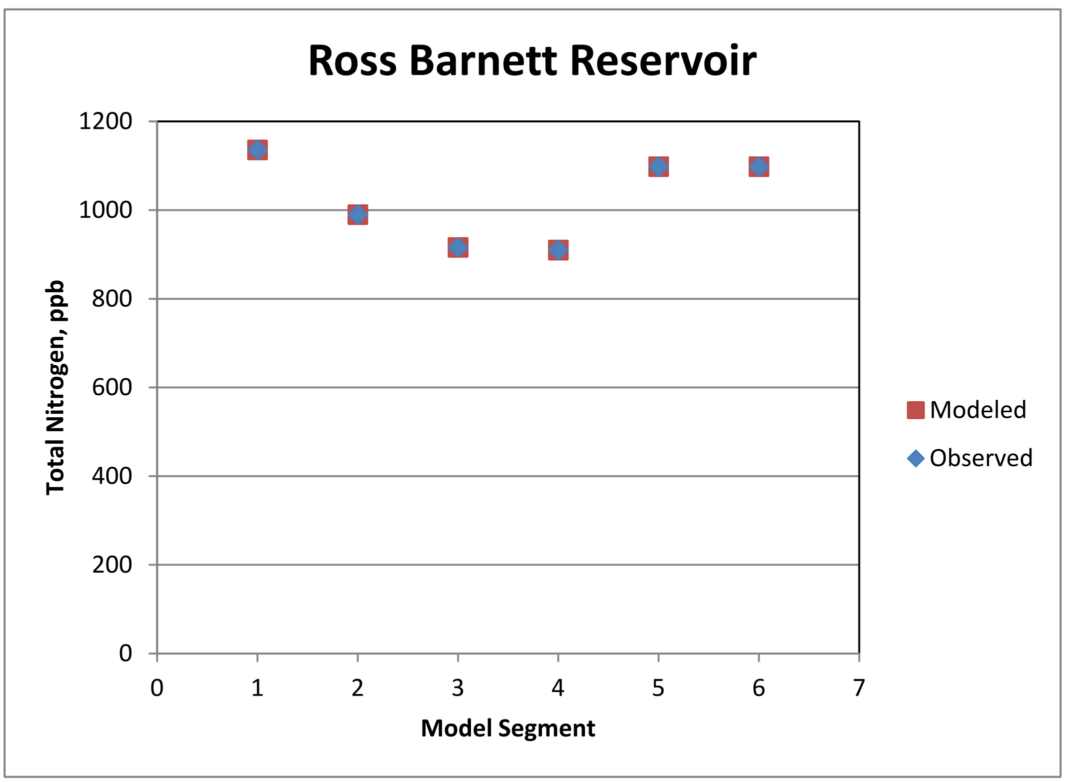

Figure J.3. Comparison of observed nitrogen in the Reservoir with BATHTUB model output.

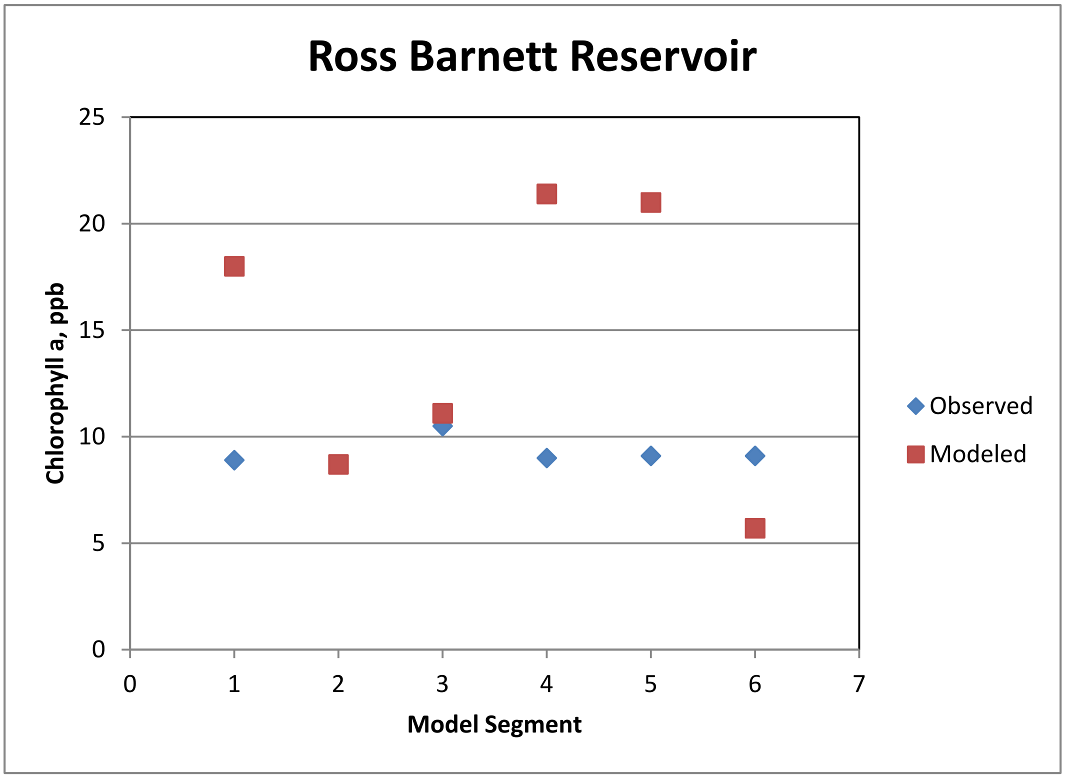

Figure J.4. Comparison of observed chlorophyll-*a* in the Reservoir with BATHTUB model output.

4.0 MODEL CALIBRATION

4.1 Total Phosphorus

Initially, the focus was on calibrating the model-predicted Reservoir total phosphorus concentrations. After evaluating several model options, the second order available phosphorus model gave the best results for the phosphorus balance (Walker 1987). An additional phosphorus balance model from Higgins and Kim (1981) was examined.

Regardless of the choice for the phosphorus balance model, the model estimated phosphorus concentrations in the inflow segments (1 and 5) that were much lower than observed. This may have been due to low inflow concentrations of phosphorous. To compensate for this, the inflow phosphorus concentrations were arbitrarily increased until the modeled phosphorus concentrations in the inflow segments were similar to the observed Reservoir total phosphorus concentrations. Using this backwards method, the Pearl River total phosphorus concentration at the inflow would need to be around 200 ppb, and that the Pelahatchie Bay inflow concentration would need to be around 2,000 ppb. Based on this finding, the water quality data for the Ross Barnett tributaries were reexamined.

Initially, total phosphorus concentrations in the inflow were based on data for the Pearl River at Edinburgh, and the Yockanookany River at Revive. This is because these monitoring stations accounted for two of the largest tributary watersheds. Data from these sites have been analyzed in detail in Appendix C of the *Comprehensive Watershed Protection and Restoration Plan*. Total phosphorus concentrations at the Pearl River monitoring site averaged 100 ppb, and at the Yockanookany site they averaged 98 ppb. Since this was only about half the Pearl River inflow concentration needed to match the Reservoir total phosphorus concentration, water quality data from other tributary watersheds were reviewed. The one total phosphorus measurement available from Fannegusha Creek was 140 ppb, which is less than 200 ppb. However, when data from Tuscolameta Creek were reviewed, total phosphorus concentrations ranged from 360 ppb to 1,270 ppb. Given these high total phosphorus concentrations, it is possible that the average total phosphorus concentration of the Pearl River at the headwaters could be in the range of 200 ppb.

Total phosphorus data from special studies of Pelahatchie Creek are available. These data indicate that total phosphorus concentrations in lower Pelahatchie Creek tend to be around 200 ppb. This is an order of magnitude less than the concentration suggested by the modeling exercise. However, a few samples collected as part of a special study during low-flow, high-temperature conditions indicated total phosphorus concentrations as high as 1,200 ppb below a municipal wastewater facility's discharge point. At this point, it cannot be confirmed that total phosphorus concentrations in Pelahatchie Bay inflows average around 2,000 ppb. Internal loading of total phosphorus from sediments within Pelahatchie Bay may account for the additional phosphorous load.

4.2 Chlorophyll-*a*

Calibration for the chlorophyll-*a* model was attempted next. Because algae growth in the Reservoir is light-limited, a chlorophyll-*a* model that considers non-algal turbidity would be most appropriate. However, neither of the BATHTUB models that use non-algal turbidity provided results similar to the observed chlorophyll-*a*. Based on examination of the chlorophyll-*a* models and their inputs to determine why the model results are so disparate, it appears that the BATHTUB chlorophyll-*a* models are not applicable to a light-limited system like the Ross Barnett Reservoir. It is possible that BATHTUB will not be useful for estimating changes in Ross Barnett Reservoir water quality until sediment inputs are reduced and water clarity improves.

5.0 CONCLUSIONS

There are several issues associated with the modeling effort to date. First, it is apparent that the measured water quality data necessary to adequately characterize nutrient inputs to the Reservoir are not available. Second, it is unclear whether BATHTUB will be able to provide useful insight into potential changes in Ross Barnett Reservoir water quality when nutrient and sediment inputs to the Reservoir are reduced through watershed management.

6.0 REFERENCES

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APPENDIX K

PRIORITIZATION OF HUC12 WATERSHEDS FOR PROTECTION AND RESTORATION

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1.0 RESTORATION

Section 5.0 of the *Comprehensive Protection and Restoration Plan* presents the characteristics used for prioritizing watersheds delineated by US Geological Survey (USGS) 12-digit hydrologic unit codes (HUC12s) for restoration measures. For clarity, the characteristics are repeated below in Table K.1. This appendix explains how data for each of the characteristics were analyzed to develop a ranking system for HUC12 watersheds.

Table K.1. Prioritization characteristics for restoration.

Issue	Characteristic
Sediment	• Percent developed areas by HUC12 • Percent of total waters with sediment total maximum daily loads (TMDLs) • Slope • Permitted sources most likely to contribute sediment (construction stormwater permits and surface mining permits) • Percent area with crop land use
Nutrients and Pesticides	• Percent of total waters with nutrient TMDLs • Percent area with crop and urban land uses • Percent areas with pasture land use • Permitted sources most likely to contribute nutrients (animal growing operations and wastewater treatment facilities)
Pathogens	• Percent of total waters with pathogen TMDLs • Percent areas with pasture and urban landuse • Permitted sources most likely to contribute pathogens (animal growing operations and wastewater treatment facilities)
Aquatic Weeds	• Treatment locations • Locations identified during aquatic plant surveys
Trash	• Stakeholder-identified areas of concern

Criteria were developed for each characteristic to classify the HUC12s as having “high,” “medium,” or “low” restoration priority. These criteria were based on analysis of the values of the characteristics for all of the HUC12s. For example, the percent developed area was calculated for each HUC12. Developed area was used as a surrogate for impervious area. Values of percent developed area ranged from 2.8% to 25.6%. A plot of the cumulative distribution for developed area was created and visually inspected for “break points” in the values. Break points were assigned at points on the cumulative distribution that showed a visible change in slope (Figure K.1). Break points for the criteria were also compared to known literature values for the expected effect of watershed characteristics on downstream water quality. Impervious surface area is known to have some effect on channel condition and loads of sediment and other nonpoint source pollutants at 5% and a much greater effect at 10% (D'Ambrosio et al. 2004; Schueler 1995).

The prioritization characteristics include potential sources of pollutants due to both nonpoint sources and point sources. Waters for which TMDLs have been developed for sediment, nutrients, and pathogens indicate areas with recognized pollutant issues. Watersheds with a higher percent of developed area, higher slopes, and land uses that are indicative of land modification and anthropogenic activities have a greater potential for pollutants to be generated in the watershed and contributed to nearby waters. The characteristics that refer to point sources (i.e., sources likely to contribute to sediment, nutrients, and pathogens) are subject to regulatory programs described in Appendix F of the *Comprehensive Protection and Restoration Plan*.

1.1 Sediment

As shown in Table K.1, the characteristics used to prioritize HUC12s for sediment issues are 1) percent impervious cover, 2) percent streams with TMDLs, 3) slope, 4) construction and mining permits, and 5) percent crop land use. The criteria for classifying the sediment prioritization characteristics are summarized in Tables K.2 and K.3. The percent developed area characteristic was described in Section 1.0. The remaining characteristics are discussed in this section.

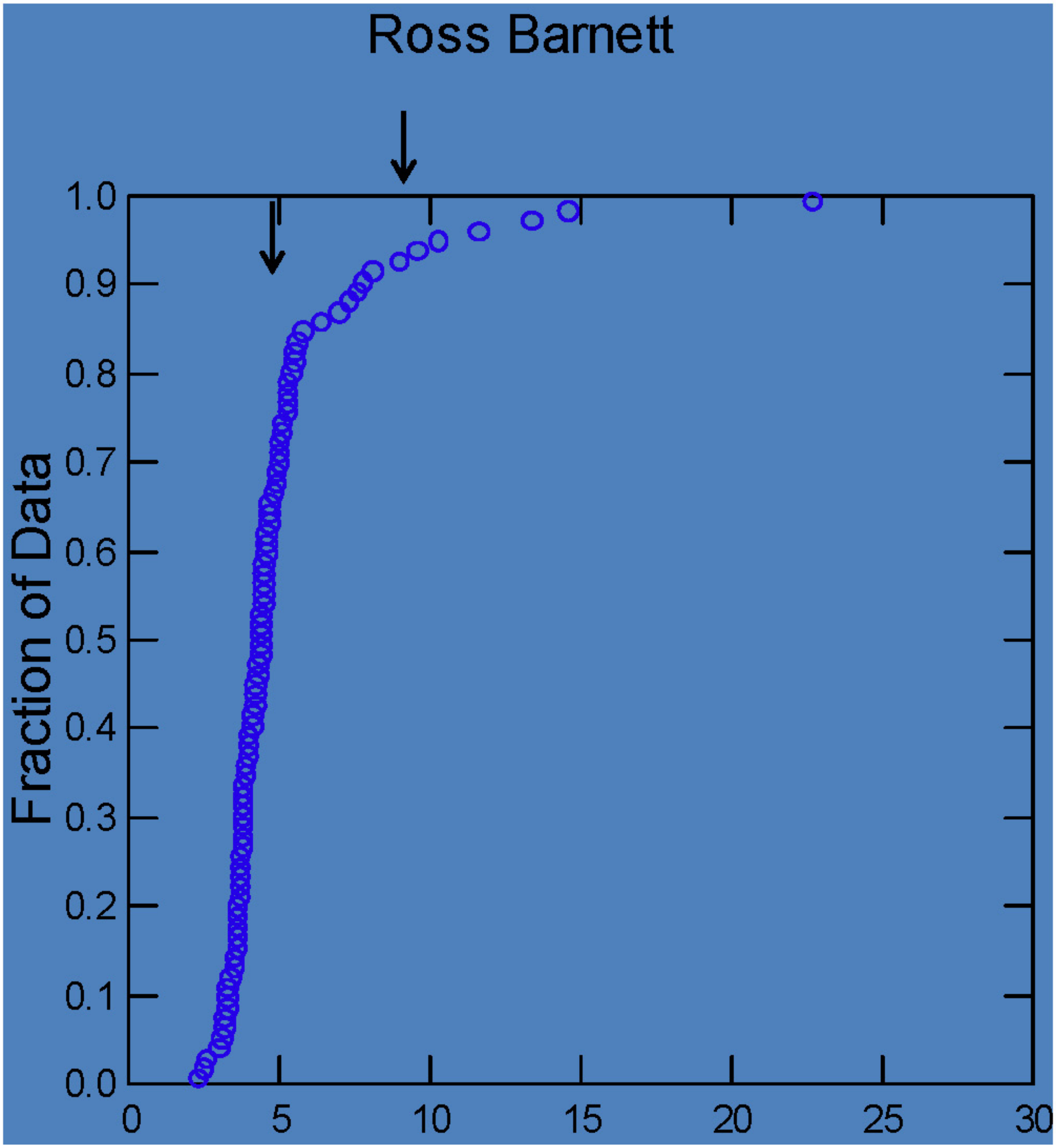

Figure K.1. Cumulative distribution for developed surface area.

Table K.2. Criteria for classifying sediment prioritization characteristics for HUC12s in the 1x:10x watershed.

Characteristic	Criteria for:		
	High Priority	**Medium Priority**	**Low Priority**
Percent Impervious Cover	≥5%	n/a	< 5%
Percent Streams in TMDLs: Initial	>60%	30% – 60%	< 30%
Percent Streams in TMDLs: Revised	>50%	30% – 50%	<30%
Percent High Slope	>4%	1.5% – 4%	< 1.5%
Percent Medium Slope	>60%	30% – 60%	< 30%
Presence of Construction and Mining Permits	1 or more	NA	None present
Percent Crop Land Use	>3.5%	1.4% – 3.5%	< 1.4%

Table K.3. Criteria for classifying sediment prioritization characteristics for HUC12s above the 1x:10x watershed.

Characteristic	Criteria for:		
	High Priority	**Medium Priority**	**Low Priority**
Percent Developed Area	>10%	5% – 10%	< 5%
Percent Streams in TMDLs: Initial	>60%	30% – 60%	< 30%
Percent Streams in TMDLs: Revised	>50%	30% – 50%	<30%
Percent High Slope	>4%	1.5% – 4%	< 1.5%
Percent Medium Slope	>60%	30% – 60%	< 30%
Presence of Construction and Mining Permits	1 or more	NA	None present
Percent Crop Land Use	>3.5%	1.4% – 3.5%	< 1.4%

1.1.1 Sediment TMDLs

The presence of sediment TMDLs was quantified by comparing the sum of the lengths of all stream reaches in a HUC12 with the sum of the lengths of stream reaches for which TMDLs have been developed. Length of all stream reaches was calculated using the National Hydrography Dataset (NHD) for medium resolution streams. The NHD includes a total of 1,954 miles of stream in the Ross Barnett Reservoir watershed. Sediment TMDLs have been developed for 395 miles of stream in the watershed. The criteria shown in Tables K.2 and K.3 for classifying the HUC12s were set based on the cumulative distribution of percent streams with sediment TMDLs. More stringent criteria for developed area was used for HUC12s in the 1x:10x watershed. The cumulative distribution plot for sediment TMDLs is shown on Figure K.2.

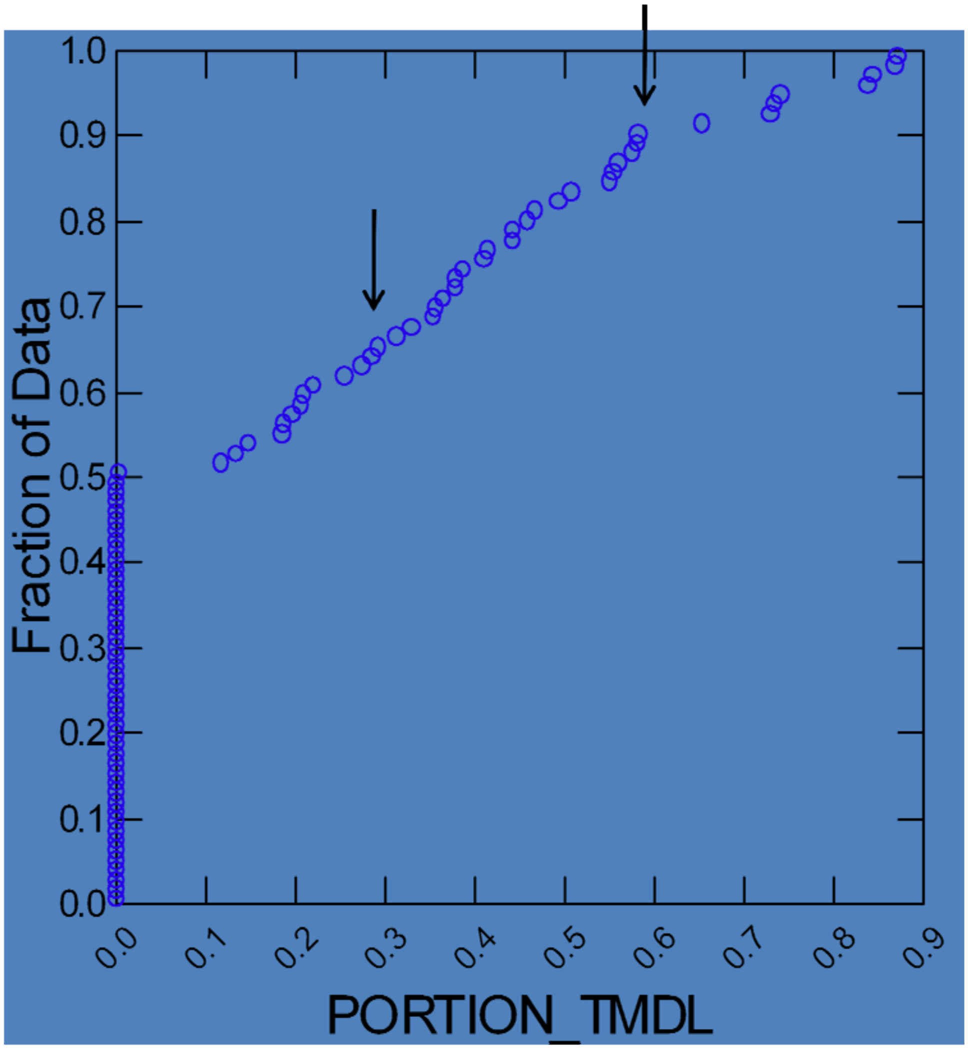

Figure K.2. Cumulative distribution for sediment TMDLs.

Slope classes defined by the Natural Resources Conservation Service (NRCS) were used to characterize slopes in each HUC12. Table K.4 includes the NRCS terms for both simple and complex slopes. For prioritization, areas with the NRCS simple slope classifications of "nearly level" or "gently sloping" were classified as "low slopes;" areas with the NRCS simple slope classifications of "strongly sloping" to "moderately steep" were classified as "medium slopes;" and areas with the NRCS simple slope classification of "steep to very steep" were classified as "high slopes." Complex slopes are groups of slopes that have definite breaks in several different directions and in most cases markedly different slope gradients within the areas delineated. Slope complexity has an important influence on the amount and rate of runoff and on sedimentation associated with runoff.

The percentages of each HUC12 categorized as medium slopes and high slopes were plotted as cumulative distributions (Figures K.3 and K.4, respectively). Break points for prioritization based on percent high slopes and percent medium slopes were set based on these distributions. The classifications for medium and high slopes were then combined into one prioritization factor. For the combined slope factor, all HUC12s with an overall high priority for high slopes were given a high priority. In addition, all HUC12s where either the high or the medium slope had an overall high priority and the other had an overall medium priority were also assigned a high priority. All HUC12s with a low priority for both medium and high slopes were given a low priority. The remaining HUC12s were given a medium priority.

Table K.4. NRCS slope classes.

Classes		**Slope Gradient Limits**	
Simple Slopes	**Complex Slopes**	**Lower Percent**	**Upper Percent**
Nearly level	Nearly level	0	3
Gently sloping	Undulating	1	8
Strongly sloping	Rolling	4	16
Moderately steep	Hilly	10	30
Steep	Steep	20	60
Very steep	Very steep	>45	

From http://soils.usda.gov/technical/manual/contents/chapter3.html#table3-1

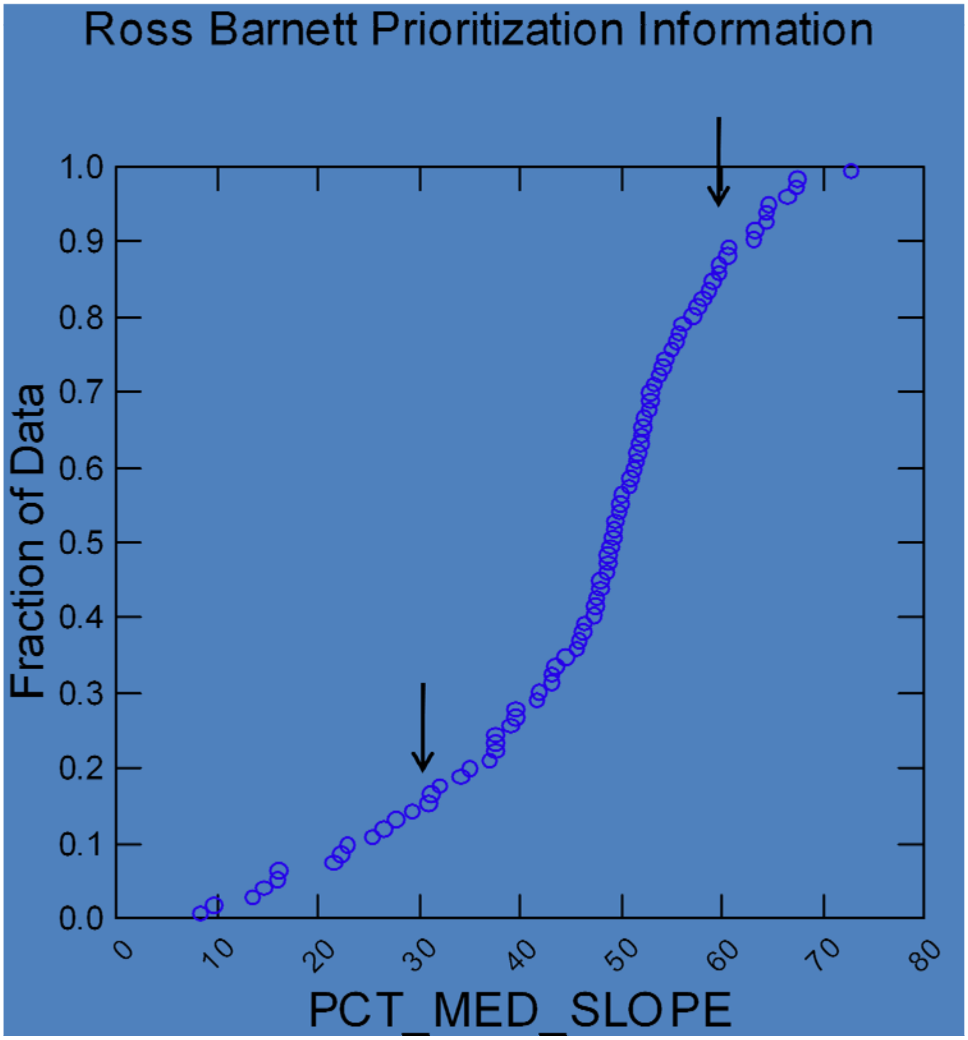

Figure K.3. Cumulative distribution for percent medium slope.

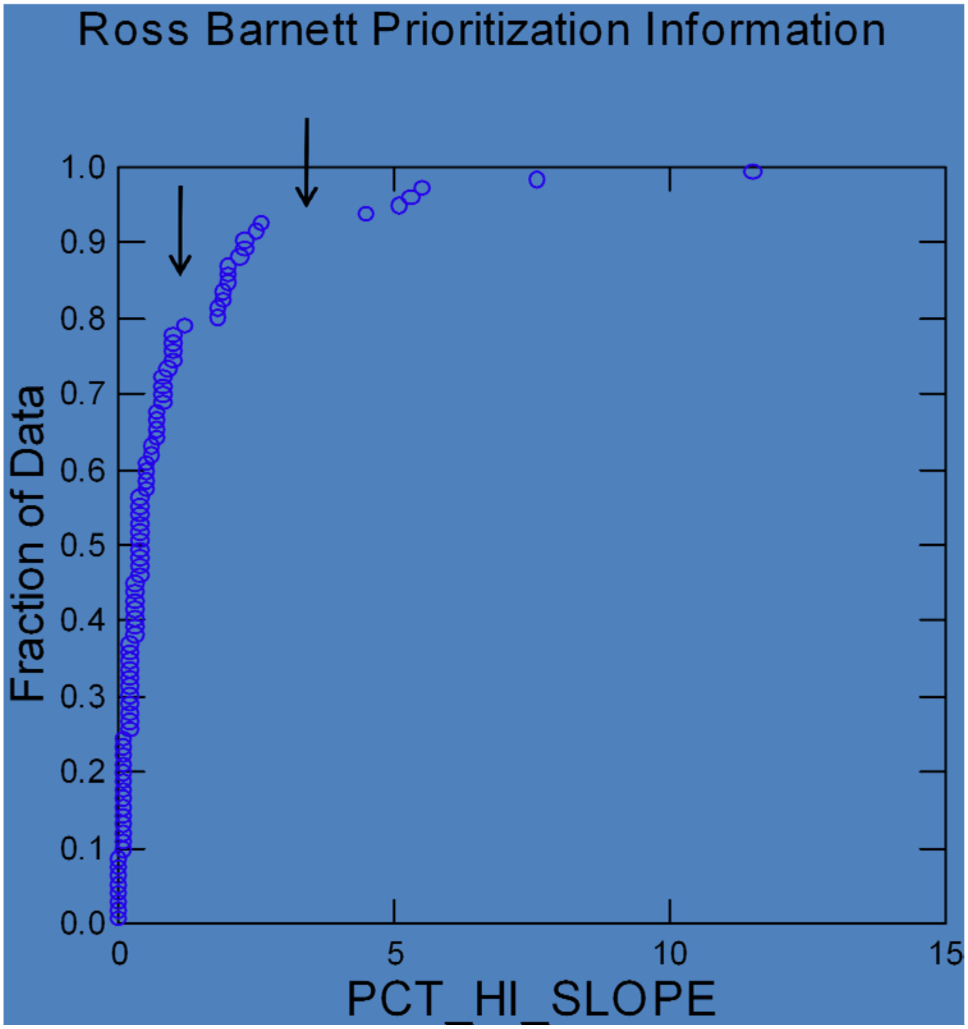

Figure K.4. Cumulative distribution for percent high slope.

1.1.2 Permitted Sediment Sources

Permitted sources likely to contribute sediments include construction stormwater and surface mining stormwater. The locations of permitted construction and mining stormwater discharges were obtained from the Mississippi Department of Environmental Quality (MDEQ). The coverage of construction stormwater permits was restricted to only sites covered under the large construction stormwater permit, which applies to construction activities that disturb 5 acres or greater. Each HUC12 was assigned a rating of “high” if any construction or mining stormwater permits were present in the HUC12 and “low” if there were none.

1.1.3 Crop Land Use

The percentage of crop land use in a few HUC12s was as high as 25%; however, the majority of HUC12s contain less than 1%. The criteria for prioritization based on percent crop land use were determined from the cumulative distribution of percentages for each HUC12 (Figure K.5).

1.1.4 Overall Sediment Restoration Priority

The priority watersheds for sediment were identified based on the ratings for five characteristics. Results are shown on Figure K.6. HUC12s with two characteristics rated as high priority were assigned an overall high priority. This resulted in nine first-tier priority HUC12s (highlighted in red on Figure K.6). The TMDL rating was reviewed with a change in the high break point. When the breakpoint was reduced to 50%, four additional second-tier HUC12s were prioritized (highlighted in yellow on Figure K.6). High priority was assigned to 13 out of 87 HUC12s (11%).

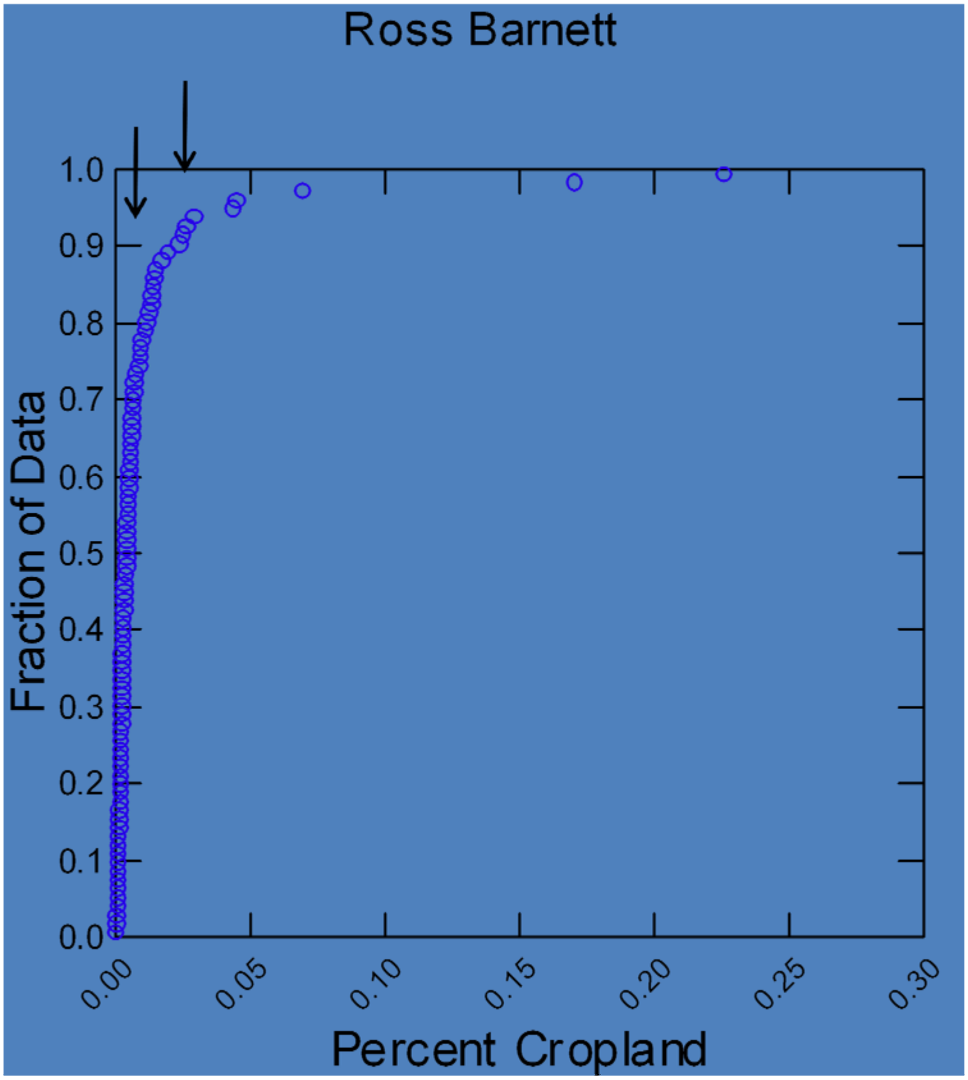

Figure K.5. Cumulative distribution for percent crop land use.

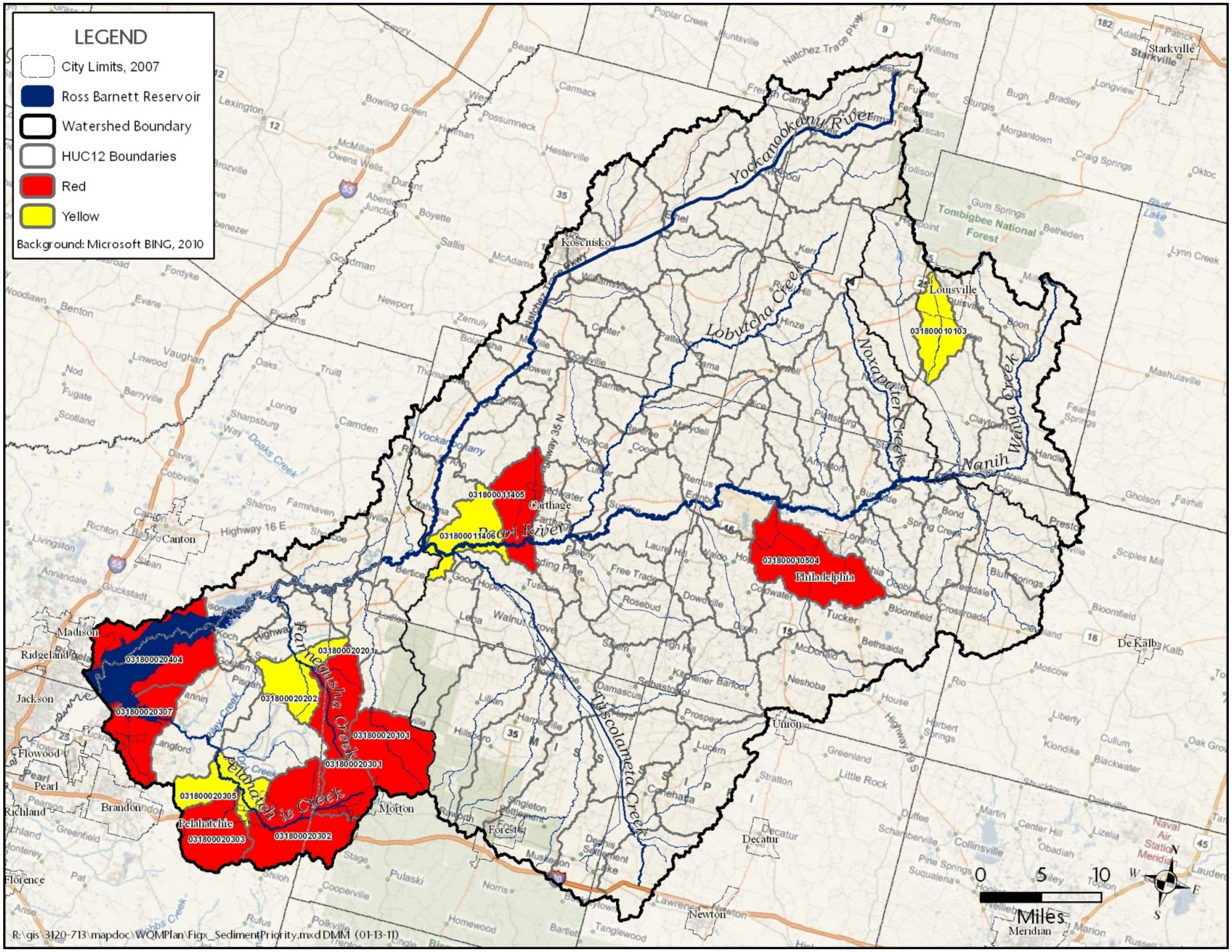

Figure K.6. Priority map for sediments.

1.2 Nutrients/Pesticides

The characteristics used to prioritize HUC12s for nutrient/pesticide issues are 1) percent of streams with TMDLs, 2) percent urban and crop land uses, 3) percent pasture land use, 4) the presence of wastewater treatment facilities, and 5) animal growing operations. The criteria for classifying the nutrient/pesticide prioritization characteristics are summarized in Tables K.5 and K.6.

Table K.5. Criteria for classifying nutrient/pesticide prioritization characteristics for HUC12s in the 1x:10x watershed.

Characteristic	Criteria for:		
	High Priority	**Medium Priority**	**Low Priority**
Percent streams in TMDLs	>60%	30% – 60%	< 30%
Percent urban and crop land use	>15%	6.5% – 15%	Less than 6.5%
Percent pasture land use	>14%	NA	< 14%
Presence of wastewater treatment facilities	1 or more	NA	None present
Presence of animal growing operations	≥12	5 – 11	< 5

Table K.6. Criteria for classifying nutrient/pesticide prioritization characteristics for HUC12s above the 1x:10x watershed.

Characteristic	Criteria for:		
	High Priority	**Medium Priority**	**Low Priority**
Percent streams in TMDLs	>60%	30% – 60%	<30%
Percent urban and cropland landuse	>15%	6.5% – 15%	Less than 6.5%
Percent pasture landuse	>14%	NA	<14%
Presence of wastewater treatment facilities	>3	2	1
Presence of animal growing operations	≥12	5 – 11	<5

1.2.1 Nutrient TMDLs

The presence of nutrient TMDLs was quantified by comparing the length of all stream reaches in each HUC12 with the sum of the length of streams for which TMDLs have been developed. Nutrient TMDLs have been developed for 257 miles of stream. The criteria shown in Tables K.5 and K.6 for classifying the HUC12s were set based on the cumulative distribution of percent streams with nutrient TMDLs.

1.2.2 Urban, Crop, and Pasture Land Uses

Several types of land uses were considered in the prioritization for nutrients and pesticides. These include urban land use, crop land use, and pasture land use. Urban area accounts for a small percentage of most HUC12s and tends to be concentrated in areas near the Reservoir and several municipalities in the upper watershed. As previously discussed, crop land is a small percentage of most HUC12s. Pasture land accounts for approximately 14% of the Reservoir drainage area, and ranges from 6% to 36% in individual HUC12s.

Urban lands and crop lands were considered together. The criteria for prioritization based on percent urban and crop lands were determined from the cumulative distribution of percentages for each HUC12 (Figure K.7).

Pasture land was considered separately so that its relationship with the presence of animal operations that apply poultry litter to pasture land could be evaluated. The cumulative distribution for pasture land showed a single inflection point at approximately 14%, and high and low ratings were assigned based on this value (Figure K.8).

1.2.3 Permitted Nutrient Sources

Permitted sources likely to contribute nutrients include wastewater treatment facilities and animal growing operations. These two types of permits were considered separately for prioritization. The locations of permitted wastewater treatment facilities were obtained from MDEQ. Facilities included are those that treat domestic and industrial wastewater prior to discharge using technologies such conventional lagoons, aerated lagoons, and activated sludge. All of these facilities have specific permit limits for organic material. Some facilities also have monitoring requirements for nutrients (typically total nitrogen and total phosphorous). All of these facilities are considered potential nutrient contributors.

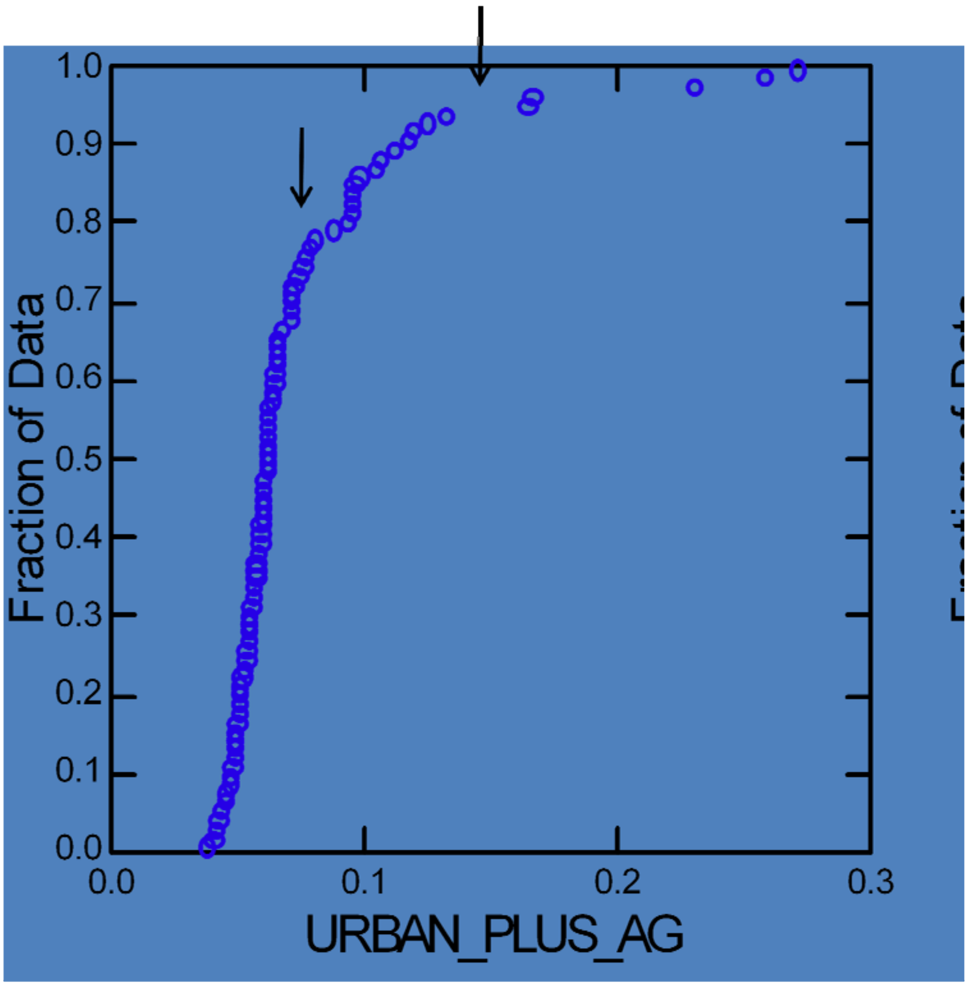

Figure K.7. Cumulative distribution for percent crop and urban land uses.

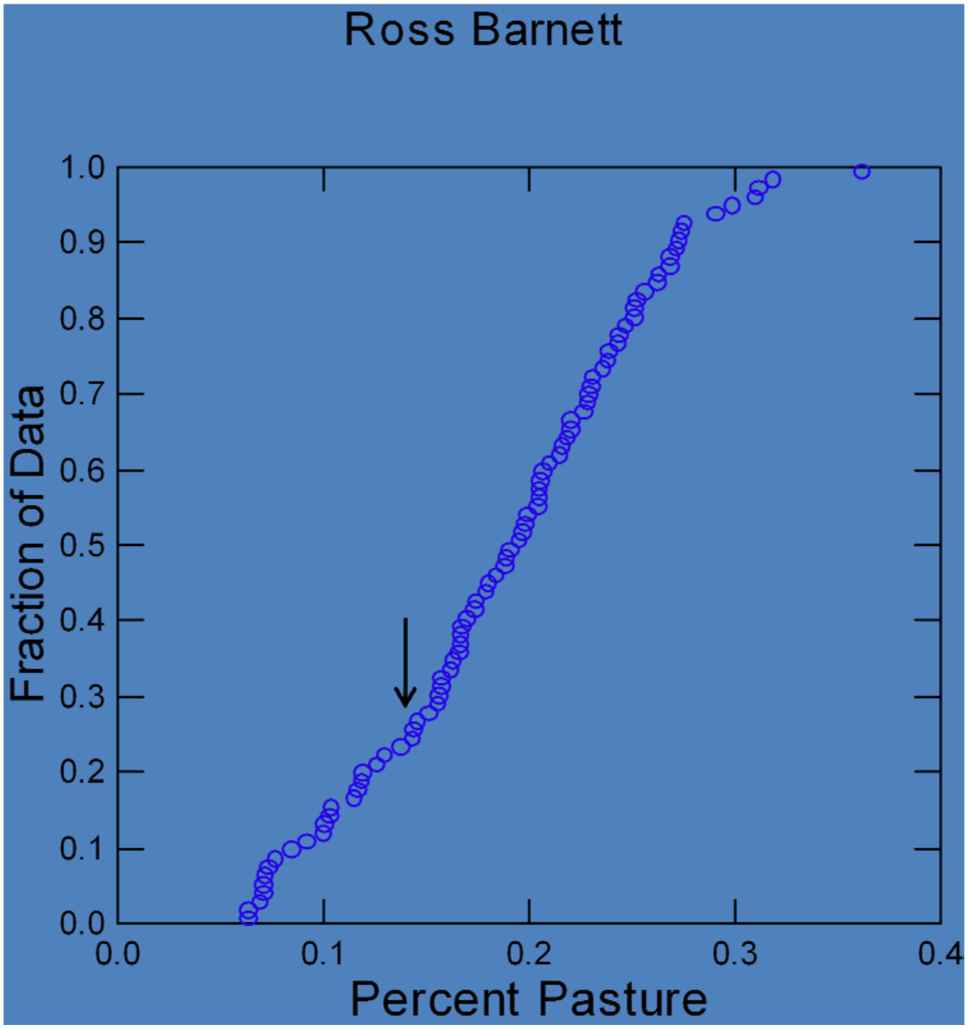

Figure K.8. Cumulative distribution for percent pasture land use.

In the 1x:10x watershed, ratings for wastewater treatment facilities were assigned as "high" if one or more facilities were present in each HUC12 and "low" if no facilities were present. In the remainder of the watershed, ratings for the wastewater treatment facilities were assigned as "high" if three or more facilities were present in each HUC12, "medium" if two facilities were present, and "low" if there was one or none. Facility size (permitted flow and effluent limits for organic material) was not considered in the prioritization.

The Ross Barnett Reservoir watershed contains numerous permitted animal growing operations for poultry and swine operations, with the majority being poultry. Records obtained from MDEQ contain locations of permits for confined animal feeding operations (CAFOs) and locations of state operating permits for animal feeding operations (AFOs). There are six CAFO permits in the watershed for swine operations. These facilities have lagoons and land application areas to treat and dispose of wastewater. Poultry operations that serve fewer than 1,000 animal units and utilize dry litter disposal are required to submit a Notice of Intent to MDEQ for coverage under a multimedia discharge general permit. There are 326 sites in the Ross Barnett Reservoir watershed covered by the AFO dry litter multimedia discharge general permit as of August 2010. The number of CAFO and AFO facilities in each HUC12 was determined based on the current permit locations. Ratings for the animal growing operations were assigned as "high" if 12 or more facilities were present in each HUC12, "medium" if 5 to 11 facilities were present, and "low" if less than five were present. Figure K.9 shows the frequency distribution curve for number of CAFO/AFO facilities.

1.2.4 Overall Nutrient Priority

The priority watersheds for nutrients/pesticides were identified based on the ratings for five characteristics. Results are shown on Figure K.10. HUC12s with two characteristics rated as high priority were assigned an overall high priority. A high-priority rating was assigned to 20 out of 87 HUC12s (23%).

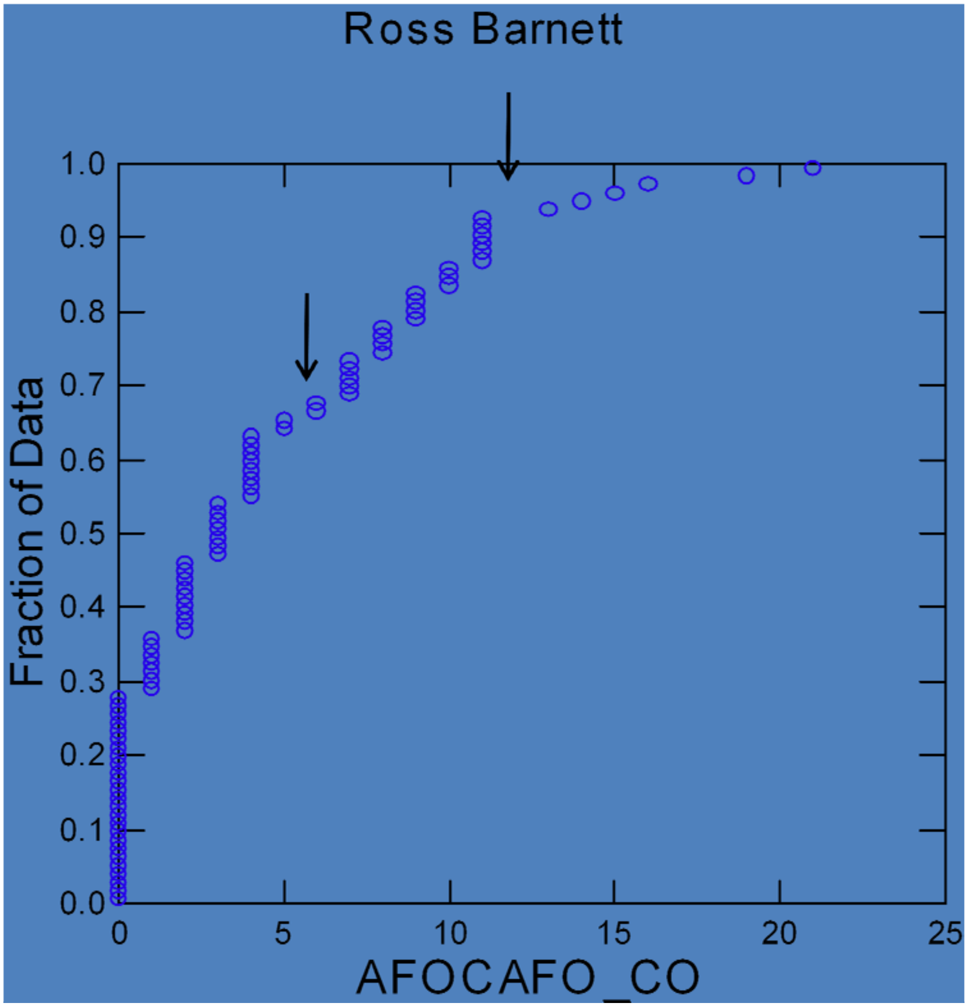

Figure K.9. Frequency distribution curve for number of CAFOs/AFOs.

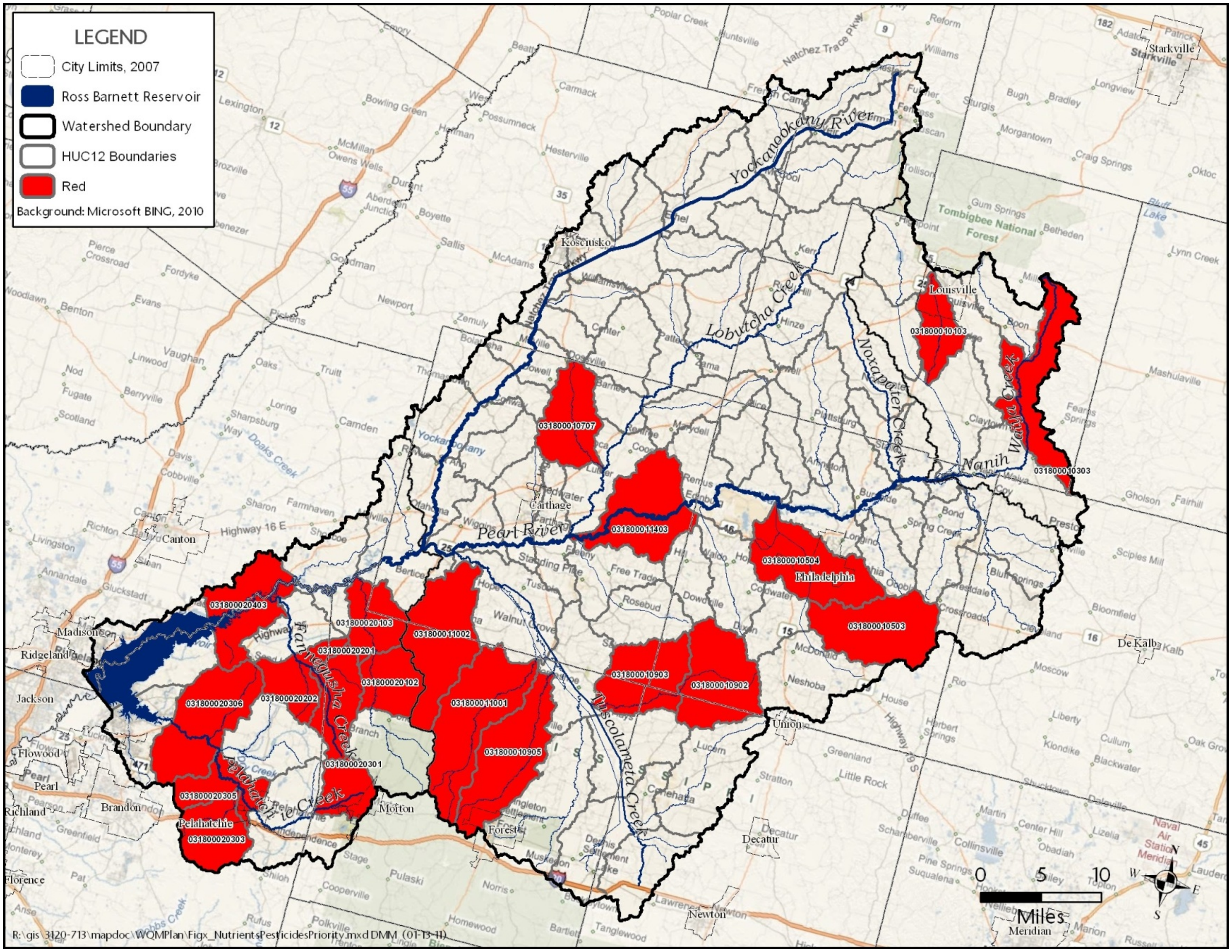

Figure K.10. Priority map for nutrients and pesticides.

1.3 Pathogens

The characteristics used to prioritize HUC12s for pathogen issues were percent of streams with TMDLs, percent urban and pasture land use, and the presence of wastewater treatment facilities and animal growing operations. The criteria for classifying the pathogen prioritization characteristics are summarized in Tables K.7 and K.8.

Table K.7. Criteria for classifying pathogen prioritization characteristics for HUC12s in the 1x:10x watershed.

Characteristic	Criteria for:		
	High Priority	**Medium Priority**	**Low Priority**
Percent streams in TMDLs	>35%	NA	<35%
Percent urban and pasture land use	>20%	14% – 20%	Less than 14%
Presence of wastewater treatment facilities	1 or more	NA	None present
Presence of animal growing operations	≥12	5 – 11	<5

Table K.8. Criteria for classifying pathogen prioritization characteristics for HUC12s above the 1x:10x watershed.

Characteristic	Criteria for:		
	High Priority	**Medium Priority**	**Low Priority**
Percent streams in TMDLs	>35%	NA	< 35%
Percent urban and pasture land use	>36%	20% – 36%	Less than 20%
Presence of wastewater treatment facilities	≥3	2	1
Presence of animal growing operations	≥12	5 – 11	< 5

1.3.1 Pathogen TMDLs

The presence of pathogen TMDLs was quantified by comparing the length of all stream reaches in each HUC12 with the sum of the length of streams for which TMDLs have been developed. Pathogen TMDLs have been developed for 279 miles of stream. The criteria shown in Tables K.7 and K.8 for classifying the HUC12s were set based on the cumulative distribution of percent streams with pathogen TMDLs.

1.3.2 Pasture and Urban Land Uses

Pasture and urban land uses were considered in the prioritization for pathogens. Pasture lands are typically used for grazing animals (i.e., cattle, horses, and other animals). Grazing animals may deposit manure near streams and within streams when fencing is not in place. As previously discussed, litter from poultry operations is also routinely applied to pasture lands. Although nutrient management plans limit the application of litter near stream buffer zones and prior to storm events, litter remains a potential pathogen source during wet-weather conditions.

Urban areas contain sources such as pet waste and failing septic systems. The criteria for prioritization based on percent pasture land and urban land were determined from the cumulative distribution of percentages for each HUC12 (Figure K.11). As shown in Table K.7, more stringent criteria were used for the 1x:10x watershed because pathogens originating in these watersheds have less travel time prior to reaching the Reservoir.

1.3.3 Permitted Pathogen Sources

Permitted sources likely to contribute pathogens to nearby streams include wastewater treatment facilities and animal feeding operations. HUC12 watersheds were rated as "low," "medium," and "high" using the same method for nutrient sources described in Section 1.2.3.

1.3.4 Overall Pathogen Priority

The priority watersheds for pathogens were identified based on the ratings for four characteristics. Results are shown on Figure K.12. HUC12s with two characteristics rated as high priority were assigned an overall high priority. This resulted in five first-tier high-priority HUC12s (highlighted in red on Figure K.12). Because only five HUC12s were indicated, the medium ratings were reviewed. HUC12s with two characteristics rated as medium and one characteristic rated as high were also considered high priority. With this modification, 17 additional second-tier HUC12s were prioritized (highlighted in yellow on Figure K.12). High priority was assigned to 22 out of 87 HUC12s (25%).

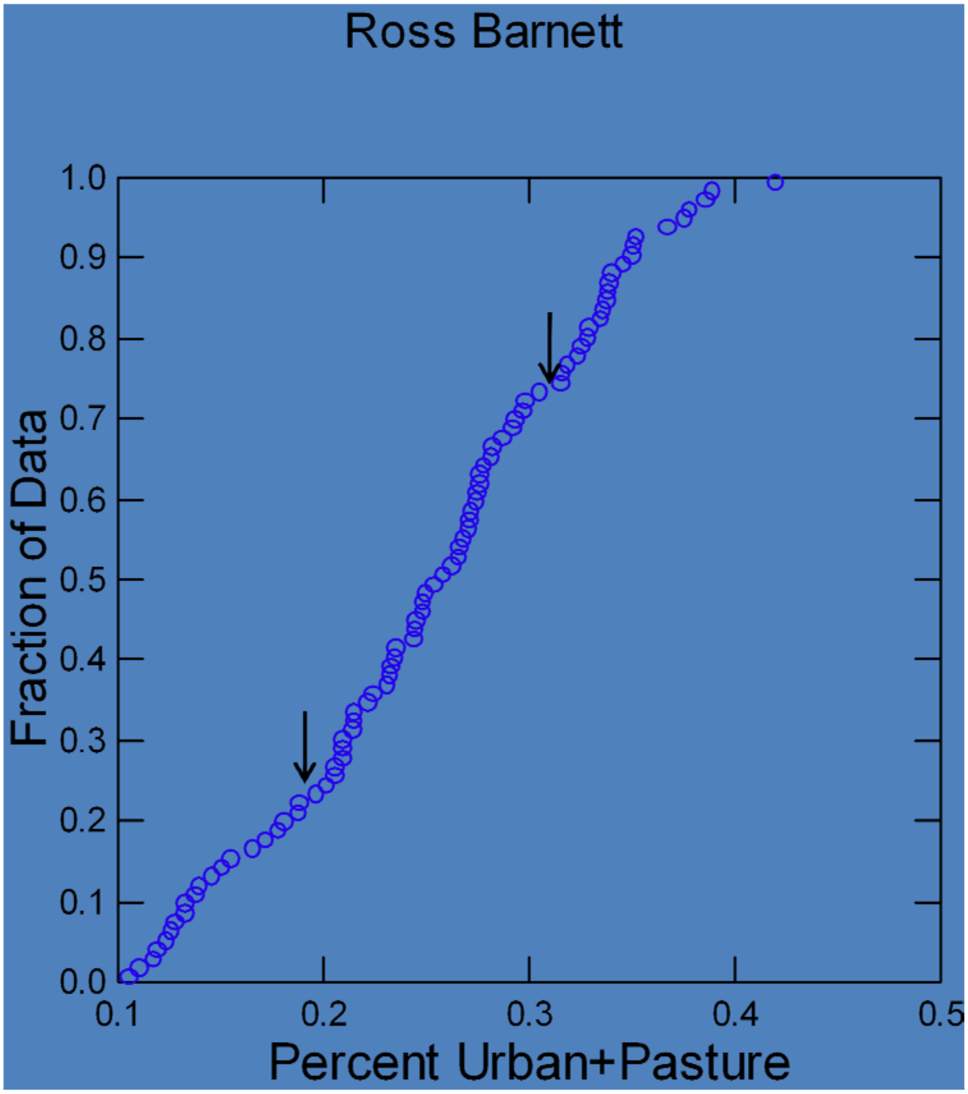

Figure K.11. Cumulative distribution for percent pasture and urban land use.

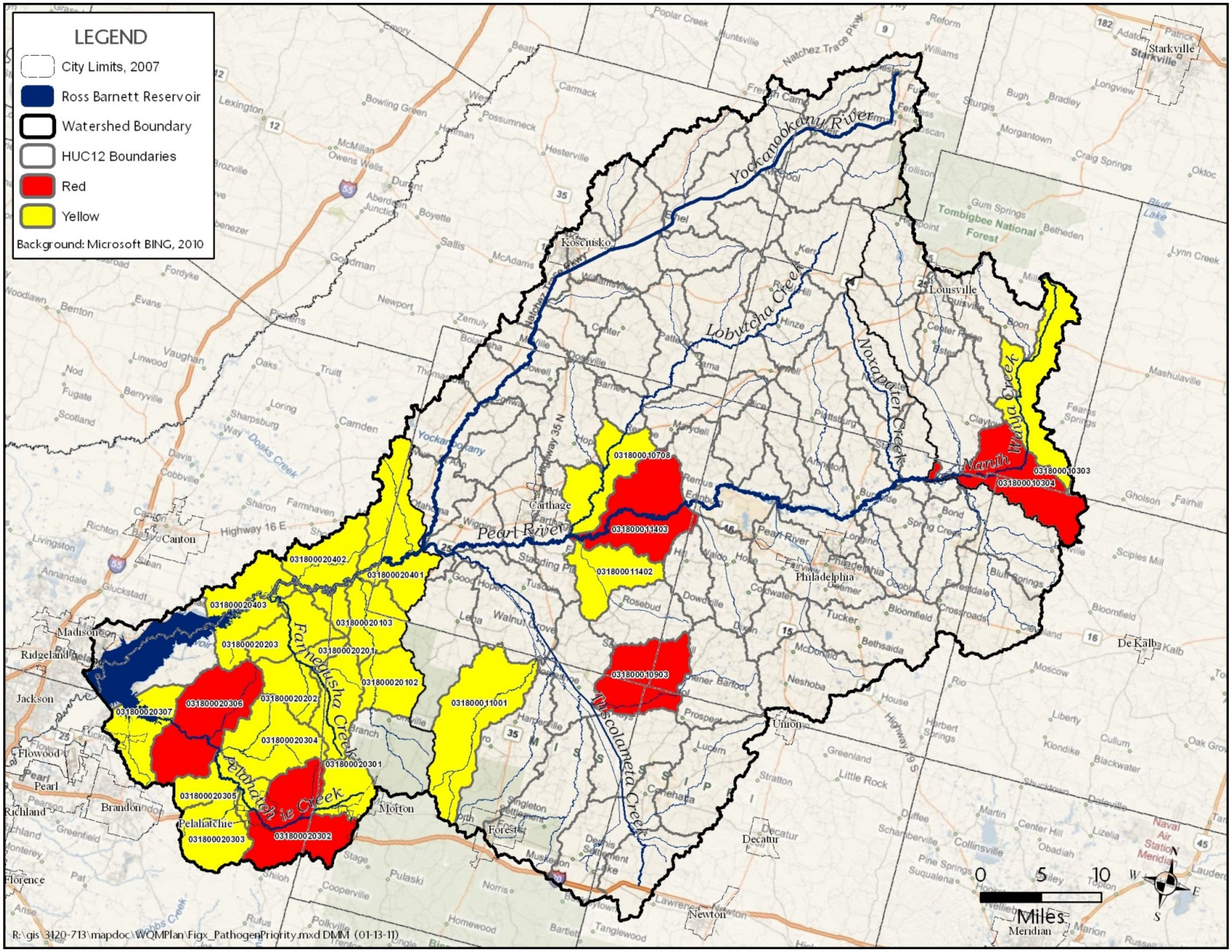

Figure K.12. Priority map for pathogens.

1.4 Aquatic Weeds

The characteristics used to prioritize HUC12s for aquatic invasive weeds included locations that are currently treated with herbicides to control plant growth and locations that have been identified during annual surveys conducted by the Geo-Resources Institute at Mississippi State University. This information indicates that aquatic weeds are currently a concern within the three HUC12 watersheds where the Reservoir is located: HUC12 ID Nos. 0318000020-301, 0318000020-404, and 0318000020-403.

1.5 Trash

The characteristics used to prioritize HUC12s for trash were limited to specific areas of concern noted by PRVWSD and other stakeholders. These areas are the sandbars located along the section of the Pearl River extending from the upper end of the Reservoir to the Low-Head Dam (HUC12 ID Nos. 0318000020-403, 0318000020-402, and 0318000020-401).

2.0 PROTECTION

Section 5.0 of the *Comprehensive Protection and Restoration Plan* presents the characteristics used for prioritizing HUC12 watersheds for protection measures. Characteristics used for protection prioritization are based on the Mississippi Watershed Characterization and Ranking Tool (MWCRT). The MWCRT was used to develop resource values for each HUC12. The resource values are based on features that affect the human welfare and environmental wellbeing of areas of the state (Storelli 2006). A resource, within the scope of this tool, is defined as an environmental parameter that is considered to be beneficial and worthy of protection.

2.1 Human Welfare Protection

The MWCRT assigns a score for the presence of features that affect human welfare. Scores depend on the perceived importance of each feature to human welfare. Detailed information about the methods used to develop the scores is given in Storelli (2006). Features that affect human welfare are listed below. The MWCRT scores for human welfare are shown on Figure K.13. HUC12s with a score greater than 1.4 were considered “high value” for human welfare. Features that were considered to affect human welfare are as follows:

- Public waterways,
- Drinking water supply,
  - Water supply intakes.
  - Source Water Protection Areas.
- Water quality standards for recreation (streams),
- Water quality standards for recreation (lakes),
- Recreational locations,
- State parks, and
- National parks.

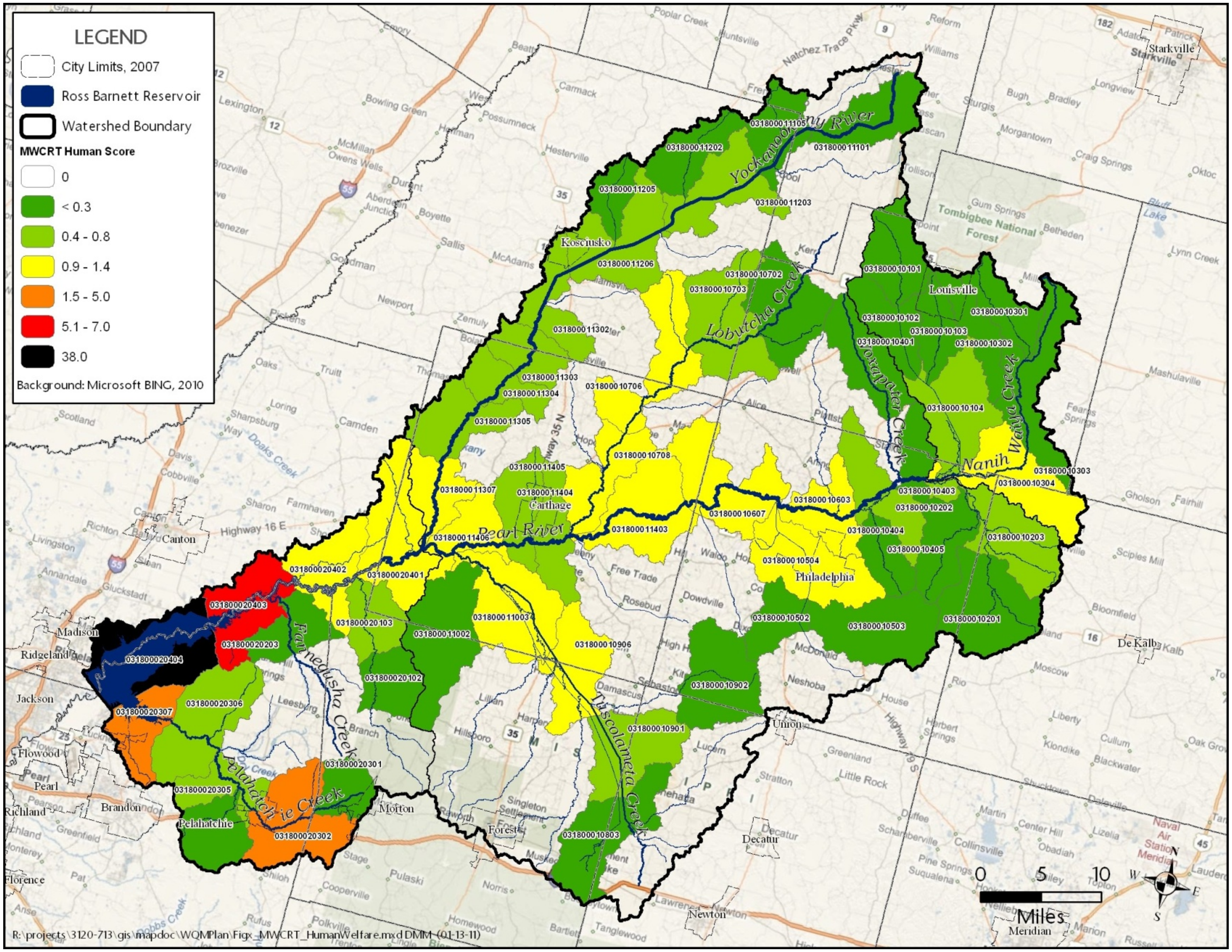

Figure K.13. MWCRT scores for human welfare.

2.2 Environmental Protection

The MWCRT also assigns a score for the presence of features that are considered to benefit the wellbeing of the environment. The loss or corruption of these features would be a detriment and could adversely affect the ecology of the local area. The characteristics for environmental resources include the presence of the following land uses or attributes. The MWCRT scores for environmental resources are shown on Figure K.14. HUC12s with a score greater than 8.8 were considered “high value” for environmental protection. Features considered to benefit the wellbeing of the environment are as follows:

- Endangered species,
- Wetlands,
- Wildlife Management Areas (WMAs),
- National Wildlife Refuges (NWRs),
- National forests,
- Lakes, and
- Perennial streams.

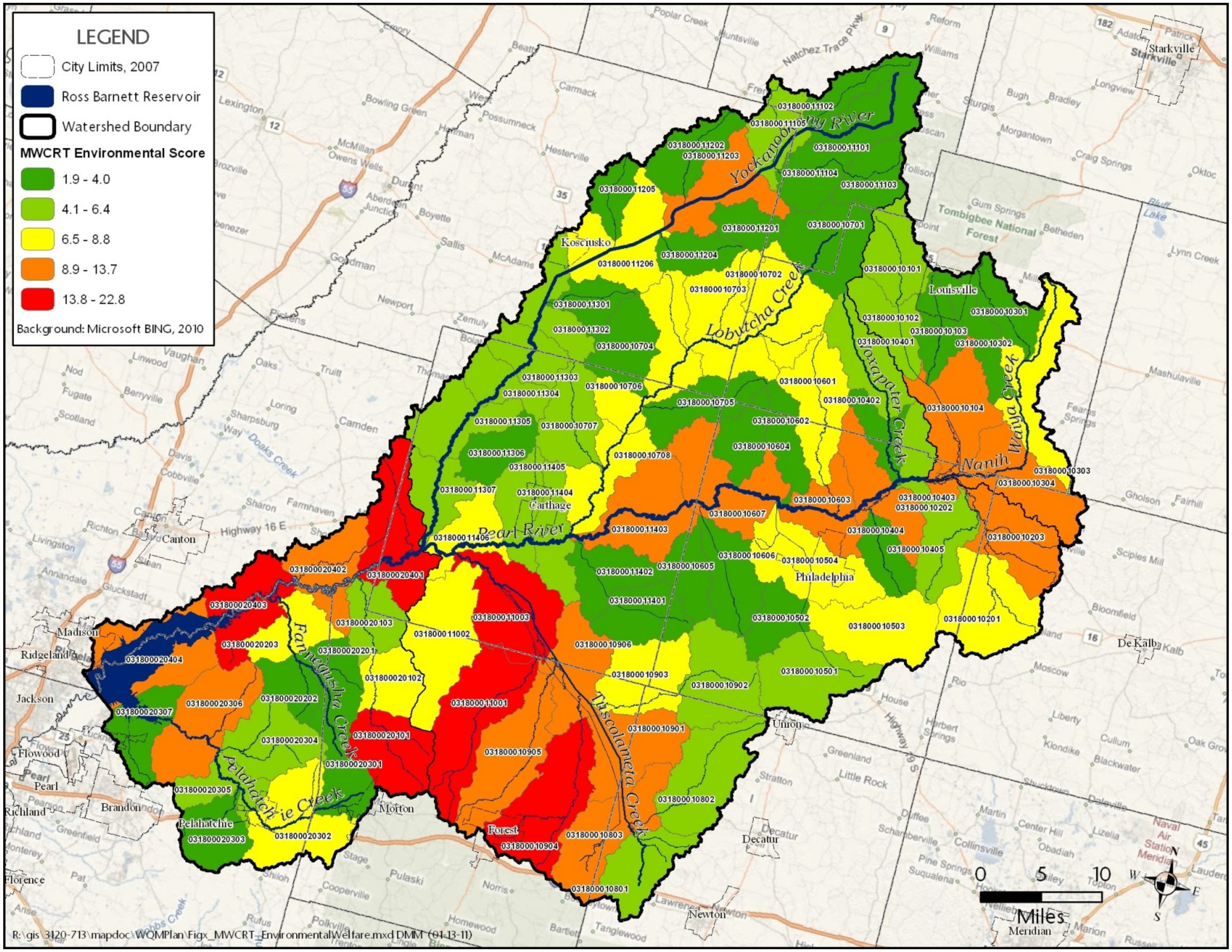

Figure K.14. MWCRT scores for environmental resources.

3.0 REFERENCES

D'Ambrosio, J., T. Lawrence, and L.C. Brown. 2004. "A Basic Primer on Nonpoint Source Pollution and Impervious Surface." Ohio State University Extension Fact Sheet. Food, Agricultural, and Biological Engineering Department, Ohio State University. Available online at http://ohioline.osu.edu/aex-fact/0444.html.

Schueler, T. 1995. Site Planning for Urban Stream Protection. Metropolitan Washington Council of Governments, Washington, DC.

Storelli, John. 2006. Mississippi Watershed Characterization & Ranking Tool, Descriptive Report. Mississippi Department of Environmental Quality. June 14, 2006.

APPENDIX L

TARGETING INFORMATION FOR SELECTED HUC12 WATERSHEDS

TARGETING CRITERIA

1. Willingness of landowners and local government to participate;
2. Available funding sources (some funding sources have to be allocated to particular landuse types or parts of the state);
3. System responsiveness to management practices (i.e., immediate or quick responsiveness);
4. Pollutant issues that can be effectively addressed with management practices. In comparison, issues such as historical sediment loads cannot be addressed by management practices;
5. Magnitude of the source and likelihood of achieving measurable benefits;
6. Building on locations of past and ongoing management efforts;
7. Public perception of the importance of water quality (i.e., public's primary concerns such as improved water clarity, lower water bill, improved recreational opportunities);
8. Expected growth patterns, including areas for new development and retrofitting;
9. Issues with permit compliance status of wastewater treatment facilities, with consideration of the size of these facilities (higher load facilities targeted first); and
10. Presence of septic tanks and onsite wastewater treatment plants in soils with limited adsorption field suitability.

Prioritization results and information for each targeting characteristic in the Pelahatchie Creek watershed is summarized in the following table.

Table L.1. Prioritization results and information for each targeting characteristic in the Pelahatchie Creek watershed.

<table>
<tr><th colspan="2">031800020</th><th>-301
Upper</th><th>-302
Ashlog</th><th>-303
Eutacut.</th><th>-304
Hollybush</th><th>-305
Snake</th><th>-306
Riley</th><th>-307
Mill</th></tr>
<tr><td colspan="9">Prioritization Results</td></tr>
<tr><td colspan="2">Restoration Priority</td><td>Pathogens, Sediment, Nutrients/Pesticides</td><td>Pathogens, Sediment</td><td>Pathogens, Sediment, Nutrients/Pesticides</td><td>--</td><td>Pathogens, Sediment, Nutrients/Pesticides</td><td>Pathogens, Nutrients/Pesticides</td><td>Pathogens, Sediment, Invasive Species</td></tr>
<tr><td colspan="2">Protection Priority</td><td>--</td><td>Human Welfare</td><td>--</td><td>--</td><td>--</td><td>Environmental</td><td>Human Welfare</td></tr>
<tr><td colspan="9">Targeting Criteria</td></tr>
<tr><td rowspan="3">Willingness (need to gage this by talking with local government and stakeholders)</td><td>Incorporated/ Developed Areas</td><td></td><td>Talked with mayor of City of Pelahatchie about potential green infrastructure incorporated into plan for Mill Park.</td><td></td><td></td><td>Small part of the City of Pelahatchie also located in this HUC12 (see -302).</td><td></td><td>Hidden Hills subdivision interested in riparian area restoration project, contains possible demolition sites for green infrastructure BMPs.</td></tr>
<tr><td>Unincorporated Areas</td><td>Would need to discuss with Scott County</td><td colspan="6">Rankin County – willing to promote the use of green infrastructure in new developments and retrofits. Citizens group is looking into overlay zoning for some areas. Keep the Reservoir Beautiful group formed.</td></tr>
<tr><td>Agricultural Areas</td><td colspan="7">• Some best management practices (BMPs) already installed in pasture lands are fencing (interior cross-fencing to facilitate rotational grazing) and watering areas (trough with heavy use area).
• Cropland: types of crops in the order of most prevalent to least are corn, cotton, soybeans, winter wheat.
• According to the Natural Resources Conservation Service (NRCS), almost all farmers are using reduced till systems for cotton crops.
• NRCS has already worked with many livestock growers, but not all of them.
• Field borders and filter strips recommended for pastureland and row crops.
• Riparian buffer preservation recommended for all streams.</td></tr>
<tr><td rowspan="2">Funding</td><td>Active</td><td>Bienville National Forest Programs (US Department of Agriculture [USDA] Forest Service).</td><td></td><td></td><td></td><td></td><td></td><td>Emergency Watershed Protection project for Mill Creek stabilization.</td></tr>
<tr><td>Potential</td><td colspan="7">Cost-sharing programs through the NRCS Environmental Quality Incentives Program (EQIP), the Mississippi Department of Environmental Quality (MDEQ) Section 319 Program, the Farm Service Agency (FSA) Conservation Reserve Program (CRP), the Mississippi Forestry Commission Forest Research Development Program (FRDP) and the Forest Legacy Program, and the Mississippi Conservation Initiative program.</td></tr>
</table>

Table L.1. Prioritization results and information for each targeting characteristic in the Pelahatchie Creek watershed (continued).

031800020		-301 Upper	-302 Ashlog	-303 Eutacut.	-304 Hollybush	-305 Snake	-306 Riley	-307 Mill
Responsiveness (will depend on projects)		Very little soil suitable for infiltration (most soils are type D).	Headwater systems are generally more responsive to BMPs (i.e., results show up faster in a smaller drainage area).	Headwater systems are generally more responsive to BMPs (i.e., results show up faster in a smaller drainage area).	Very little soil suitable for infiltration (most soils are type D).			Construction site BMP enforcement is likely effective at reducing sediments in Mill Creek.
Pollutant issues that can be addressed with management measures	Individual	Sediment and nutrients from agriculture and pastureland.	Sediment and nutrients from agriculture, pastureland, and urban areas; 11 animal feeding operations (AFOs), two dischargers with National Pollutant Discharge Elimination System (NPDES) permits.	Sediment and nutrients from pastureland and some urban areas; two AFOs.	Sediment and nutrients from agriculture (winter wheat and soybeans) and pastureland; four AFOs; one NPDES discharger.	Sediment and nutrients from pastureland; one NPDES discharger.	Sediment and nutrients from pastureland; one NPDES discharger; sediment from surface mines.	Sediment and nutrients from agriculture (cotton); sediments from construction sites and surface mines.
	All	All areas are potentially affected by historical sediments from past agricultural land use; Rankin County (7% agricultural land use in 1960; currently 1%) and Scott County (16% agricultural land use in 1981, currently 2%).						
Magnitude and likelihood of achieving benefits: <u>Pelahatchie Creek TMDLs</u> • Nutrients: 60% reduction in total phosphorus; • Fecal coliform: 30% to 70% reduction; • Sediment: stable sediment condition		Depends on the individual location and sources –ties back to specific sources of concern. Individual locations of concern can be identified with stakeholder input or specialized activities such as aerial photography. Need baseline data to quantify measureable benefits.						
Ongoing efforts		NRCS is working with landowners enrolled in FSA programs.						Mill Creek stabilization.
Public perception (from local stakeholders)		Water quality is extremely important to economic development in the area; retrofitting of new areas is more important that new development; new growth should be carefully controlled.						
Growth		Low – one construction site	Low – two construction sites	Low	Low – one construction site	Medium – eight construction sites	High – 20 construction sites	Low – one construction site
Permit compliance (identified facilities with issues are listed)					MS Poultry	Pelahatchie POTW West	Reservoir East	Construction stormwater Notices of Violations (NOVs)
Septic tanks (HSG included on attached maps, HSG type D is not suitable)								Identified on the Northern Shore of Pelahatchie Bay

APPENDIX M

EXISTING MANAGEMENT AND RESTORATION

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1.0 INTRODUCTION

There are several resource agencies and organizations with management responsibilities in the Ross Barnett Reservoir watershed. Some have developed management plans that apply to the watershed. In addition, several organizations are leading restoration projects in the Ross Barnet Reservoir watershed. The *Comprehensive Protection and Restoration Plan* has been developed with consideration of these management activities and restoration projects.

2.0 MANAGEMENT PROGRAMS

Organizations and resource agencies with resource management responsibilities in the Ross Barnett Reservoir and its watershed include the Pearl River Valley Water Supply District (PRVWSD), neighborhood associations, developers, the Mississippi Department of Environmental Quality (MDEQ), the US Department of Agriculture (USDA) Forest Service, the Mississippi Department of Wildlife Fisheries and Parks (MDWFP), the USDA Natural Resources Conservation Service (NRCS), the Mississippi Soil and Water Conservation Commission (MSWCC), the Mississippi Forestry Commission (MFC), the Mississippi Band of Choctaw Indians, and the National Park Service. PRVWSD is primarily responsible for management of the Reservoir and their property around it.

2.1 Pearl River Valley Water Supply District

Current in-reservoir management practices include dredging, enforcement of boating rules/litter collection, shoreline maintenance, and herbicide application for control of aquatic invasive species. In addition, PRVWSD manages approximately 17,000 acres of land around the Reservoir. PRVWSD oversees developed lands around the Reservoir and manages over 12,400 acres of timberland around the Reservoir. The PRVWSD forestry management plan is described in Section 3.1.

2.1.1 Dredging

Dredging represents a significant expense and is a result of sediment loads transported to the Reservoir from its tributaries. Annual dredging costs for PRVWSD are approximately $500,000. This figure includes fuel, personal costs, and equipment depreciation (personal communication, PRVWSD, November 2010). PRVWSD uses management practices to minimize unintended release of sediment during dredging.

Locating appropriate disposal sites for dredging material is a concern. Current disposal methods include 1) upland areas near dredge sites, 2) marginal wetland areas, and 3) in-reservoir disposal to create small islands and wildlife habitat. Disposal in marginal wetland areas is intended to improve habitat and create additional opportunity for growth of plant species. The

Ross Barnett Reservoir Monitoring Plan includes recommendations for additional record keeping, monitoring of the amount of sediment removed, and particle size of sediment. Also, the monitoring plan recommends a sediment survey to estimate the volume of sediment in the Reservoir.

2.1.2 Enforcement of Boating Rules

PRVWSD maintains the Reservoir Patrol to enforce boating laws. Although the primary function of the Patrol is to maintain safety, officers monitor for environmental problems such as littering or release of septic tank waste. The officers have the ability to issue citations to boaters who are littering and disposing of septic tank waste improperly if they directly observe these activities. All boats with septic holding tanks must register with PRVWSD and have an annual inspection of their holding tanks. No-wake zones are required near boat launches and areas. The primary purpose of no-wake zones is boater safety, but they also reduce waves generated by boat traffic from impacting sensitive shoreline areas.

2.1.3 Shoreline Maintenance

PRVWSD reports that shoreline stabilization is not a significant concern. Currently, no areas with eroding shoreline have been identified. PRVWSD manages the Reservoir to have minimal elevation changes, which helps protect shorelines from erosion. Except in severe drought conditions, the water level remains between 296 ft and 297.5 ft mean sea level (msl). Reduced water level fluctuation minimizes the potential for failure of the banks due to alternating periods of wet/dry conditions. Structural stabilization measures (rip rap and metal bulkheads) have been installed along much of the shoreline to protect it from erosion.

2.1.4 Aquatic Invasive Species Management Program

PRVWSD currently manages several species of invasive aquatic plants in the Reservoir, including alligator weed, water hyacinth, and hydrilla. The management program includes annual surveys of the locations of these aquatic plants. Herbicides are applied to targeted areas during the summer growing season to prevent growth and further spread. Costs for herbicide application in recent years are summarized in Table M.1. The management program has been successful in reducing these species in the Reservoir (Wersal et al. 2009). The Geosystems Research Institute recommends continued herbicide application along with intensive surveying and regular assessments of invasive species populations.

Table M.1. Cost of aquatic invasive species spraying programs (PRVWSD 2010).

Year	Cost
2007	$202,897
2008	$234,550
2009	$243,292
As of 09/30/2010	$182,711

Note: Cost reflects only contract costs for aquatic spraying programs. Cost does not include PRVWSD personnel that supervise the program; actual costs are considerably higher.

2.2 USDA Forest Service

The USDA Forest Service manages two national forests located in the Ross Barnett Reservoir watershed, the Bienville National Forest and the Tombigbee National Forest.

2.3 Mississippi Department of Wildlife Fisheries and Parks

MDWFP manages the Ross Barnett Reservoir fishery (see Section 3.2 for discussion of the fishery management plan) and several properties in the watershed. These include the Pearl River Wildlife Management Area, the Pearl River Wildlife Management Area Waterfowl Refuge, the Bienville Wildlife Management Area, the Nanih Waiya Wildlife Management Area, the Roosevelt State Park, and the Golden Memorial State Park.

2.4 USDA Natural Resources Conservation Service

Under the Federal Food Security Act (Farm Bill), initially passed in 1985, all US farm operators are required to meet soil erosion control standards specified in the law. Compliance with these standards is a prerequisite for participation in most federal farm programs. Subsequent amendments to the Farm Bill have added programs that provide incentives to farm operators for enhancing water quality through such actions as taking highly erodible lands out of production and restoring wetlands. These programs are implemented through NRCS by county. All counties in the Ross Barnett Reservoir watershed are eligible for participation in some or all NRCS programs.

2.5 Mississippi Soil & Water Conservation Commission

MSWCC was established by the legislature in 1938 after recognizing the need to protect the soil and water resources of the state. Their mission is to effectively guide, promote, and demonstrate the conservation, development, protection, and proper utilization of the soil, water, and related resources of Mississippi. MSWCC works in cooperation with NRCS to provide assistance to landowners who participate in conservation projects or educational opportunities related to conservation.

2.6 Mississippi Forestry Commission

MFC provides information and assistance to owners of public and private landowners in the state, and has developed a Best Management Practices Handbook (MFC 2008) describing recommended best management practices (BMPs) for forest lands in Mississippi. In addition, the Mississippi Forestry Commission administers several management programs, including the State Forest Stewardship Program, Forest Resource Development Program, and Forest Legacy Program.

2.6.1 State Forest Stewardship Program

The State Forest Stewardship Program provides assistance to private landowners of nonindustrial lands to manage natural resources on forest land to improve water quality, air quality, wildlife, and recreational benefits of forest lands. Landowners enrolled in the forest stewardship program must meet certain criteria to participate in the program and must develop and implement a forest stewardship plan. As of November 2010, there were approximately 5,800 acres of forest land within the Reservoir watershed enrolled in the Forest Stewardship Program (Figure M.1).

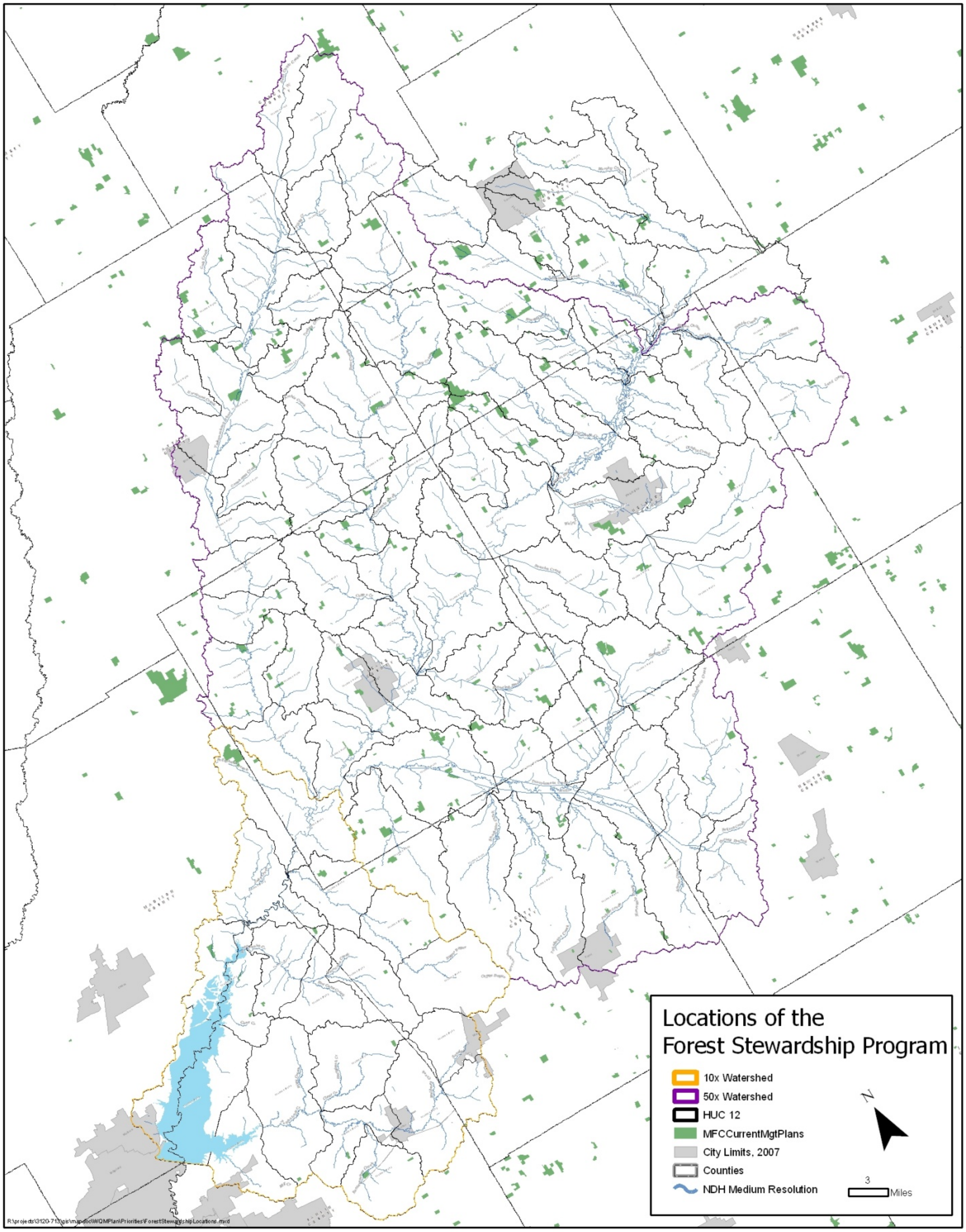

Figure M.1. Forest conservation program areas in the Ross Barnett watershed.

2.6.2 Forest Resource Development Program

Through Forest Resource Development Program (FRDP), resource development plans can be developed at the request of private landowners. In addition, this program provides assistance with tree planting and forest improvement practices for the purpose of long-term timber production. This program facilitates implementation of forestry practices designed to produce timber and enhance wildlife development. Participating landowners agree to protect the area receiving FRDP assistance from fire and grazing, and to properly manage the area for a minimum of 10 years. As of November 2010, there were approximately 25,121 acres of forest land within the Reservoir watershed enrolled in the FRDP.

2.6.3 Forest Legacy Program

The Forest Legacy Program (FLP) was established by Congress in 1990 to ascertain and protect environmentally important forest areas. Water supply protection is identified as an attribute of one of the four core national criteria used to score and rank FLP projects. MFC identified three Forest Legacy Areas (FLAs) in the state that are experiencing, or previously have experienced, population growth that could result in forest conversion to non-forest use. The Central Mississippi FLA includes the Ross Barnett Reservoir and a significant portion of the watershed that drains to the Reservoir (MFC 2007).

2.7 Mississippi Band of Choctaw Indians

The Mississippi Band of Choctaw Indians is responsible for natural resources management on their tribal lands in the Ross Barnett Reservoir watershed. This includes real estate transfers, forestry management, and environmental protection.

2.8 National Park Service

The National Park Service is responsible for management of the lands associated with the Natchez Trace Parkway, which runs through the Ross Barnett Reservoir watershed.

3.0 MANAGEMENT PLANS

Administration of some public lands in the Ross Barnett Reservoir watershed is led by a formal planning process. Management plans that address lands in the watershed are discussed below.

3.1 PRVWSD Forestry Management Plan

PRVWSD manages the forest areas in their lease land according to a forestry management plan. The current plan was developed for the years 2000 through 2010. A new plan is currently in development. The forestry management plan includes detailed descriptions of each compartment of forest land. Management practices are prescribed for each compartment in order to maintain healthy forest areas. Timber harvesting is conducted according the management plan upon approval from the PRVWSD Board of Directors.

3.2 Ross Barnett Reservoir Fishery Management Plan

MDWFP maintains a fishery management plan for the Ross Barnett Reservoir. The management goal is to promote, conserve and enhance the fisheries resources in Ross Barnett Reservoir so that fishing is accessible to a majority of the anglers under existing and future fishing pressure.

The objectives of the fishery management plan are as follows:

1. Control exotic plants to not exceed current levels
2. Stay informed of issues within the Pearl River watershed that may be detrimental to wildlife and fisheries habitat.
3. Evaluate the existing minimum length limit (15 inches) on black bass.
4. Maintain the mean weight of angler harvested crappie at $\geq$0.6 lbs, and the targeted angler catch rate at $\geq$1.9 crappie/hour (75th percentile for reservoirs).
5. Maintain the mean “lunker” weight of largemouth bass caught by tournament anglers at $\geq$5 pounds.
6. Maintain the Ross Barnett tailwater fishery for hybrid striped bass.

7. Determine fishing effort and harvest of catfish species by hand grabbers in the Reservoir area south of Highway 43 and Pelahatchie Bay.

3.3 USDA Forest Service Land and Resource Management Plan for National Forests in Mississippi

The National Forest Management Act requires the development of a Land and Resource Management Plan, a document that sets the broad framework for activities on National Forest Lands. A broad, strategic direction for managing all National Forest lands within each state is documented in a statewide Land and Resource Management Plan. The Land and Resource Management Plan addresses the uses and services associated with National Forest lands, including timber harvesting, mineral extraction, hunting, recreation, range, water quality, fishing, and wildlife. This plan is currently being revised.

3.4 Stormwater Management Plans and Ordinances

Cities and counties regulated under the Municipal Separate Storm Sewer System (MS4) program must develop and implement a stormwater management program. Stormwater management programs specify management practices that will be used to address six elements of stormwater management:

1. Public education and outreach,
2. Public participation and involvement,
3. Illicit discharge detection and elimination,
4. Construction site stormwater controls,
5. Post-construction stormwater controls, and
6. Pollution prevention and good housekeeping.

Regulated entities are required to submit annual reports to MDEQ that summarize actions taken under each of the six elements. All entities in the Ross Barnett Reservoir watershed are currently in compliance with MS4 requirements.

As a requirement of the MS4 permit, regulated cities and counties must develop and enforce stormwater ordinances to regulate development. MDEQ has reviewed and approved the ordinances in effect in Rankin and Madison counties and in the cities of Madison, Flowood, and Ridgeland as meeting US Environmental Protection Agency (EPA) criteria (personal communication, Jim Morris, MDEQ, December 2010). The applicable ordinances in these areas include stormwater management and subdivision ordinances. The cities of Madison, Flowood, and Ridgeland also have grading and landscape ordinances. The specific design criteria vary for each area, but generally require that post-development flows are less than or equal to pre-development flows generated during specific rain events, typically a 2-year, 24-hour storm. The landscaping ordinances in Madison and Flowood restrict the removal of trees on development sites outside of the building footprint and paved areas. The city of Madison requires developers to maintain a 20-ft buffer zone along drainage channels and a 30-ft buffer along stream tributaries.

4.0 CONSERVATION PLANS

Some conservation activities in the Ross Barnett Reservoir watershed are led by a formal planning process. Conservation plans that address lands in the watershed are discussed below.

4.1 Mississippi Comprehensive Wildlife Conservation Strategy

The streams of the Pearl River drainage upstream of Ross Barnett Reservoir were identified as one of the top five high-priority freshwater habitat systems in Mississippi for Species of Greatest Conservation Need (see Appendix B of the *Comprehensive Protection and Restoration Plan* for discussion of these species) (MDWFP 2005). This system was classified as vulnerable to degradation. Priority conservation actions identified for this area include habitat restoration and protection, BMPs to address nonpoint source pollution, prohibiting gravel mining in streams, control of exotic species, public education, and landowner incentive and assistance programs.

Priority conservation actions are also identified for other habitat systems in the watershed, including reservoirs, artificial ponds, bottomland hardwood forests (which are one of the top five high-priority terrestrial habitat systems in Mississippi), Jackson Prairie, marshes, urban and suburban lands, and pine plantations.

4.2 The Nature Conservancy High Priority Conservation Areas

The Nature Conservancy has identified several areas in the watershed as high-priority conservation areas: North Bienville National Forest, Noxapater Creek, Pearl River, Tallahaga Creek, and upper Yockanookany River[1].

[1] http://www.nature.org/wherewework/northamerica/states/mississippi/preserves/art17303.html

5.0 RESTORATION PROJECTS

Several restoration projects have been implemented, or are currently being implemented, in the Ross Barnett Reservoir watershed. These projects are described below.

5.1 Jackson Prairie Restoration Project

The Nature Conservancy is partnering with the USDA Forest Service to restore 66 acres of Jackson Prairie in Bienville National Forest[2]. As part of this project, the Nature Conservancy will also partner with Mississippi State University to research management methods, historic extent of the Jackson Prairie, and land use in the project area. Restoration will include use of herbicides to control woody vegetation.

5.2 Mill Creek Restoration Project

The Mill Creek watershed encompasses approximately 6,250 acres on the south side of Pelahatchie Bay. It is located within the fastest growing area of Rankin County. Construction and development activities in the watershed were thought to contribute the majority of sediment pollution. There have been several recent projects in the Mill Creek watershed: a stabilization project in 2010 and a project involving upland management practices and stream stabilization in 2007 through 2009.

The Rankin County Board of Supervisors worked with NRCS in 2010 to stabilize 1,600 linear feet of Mill Creek using conventional practices and an additional 1,600 ft with natural practices such as root wads and geotextile fabrics. The total cost of the project was $250,000, and was partially funded by NRCS through a Mississippi Conservation Initiative (MCI) cost-share program. The recently completed project is part of a large-scale stabilization project proposed for Mill Creek.

The Mill Creek Watershed Implementation Team, led by the Rankin County Board of Supervisors, completed installation of upland management practices in 2009. The project also included practices to stabilize a section of Mill Creek. The project focused primarily on sediment

[2] http://www.nature.org/wherewework/northamerica/states/mississippi/news/news2389.html

as a pollutant. This project has consisted of education and outreach activities, implementation of BMPs for erosion and sedimentation control, and flow and water quality monitoring. The total budgeted amount for the work described below was $1,087,447. Sixty percent of this budget was paid by MDEQ using Section 319 funds, and 40% was paid by Rankin County.

- Bank stabilization of 850-ft section of Mill Creek in a residential area upstream of Highway 25 using riprap (estimated sediment savings of 1,564 tons/year);
- Installation of rock dam at the upstream end of the stabilized section of a tributary of Mill Creek to control flow;
- Grading and stabilization of drainage swale near entrance to Northwest Rankin High School using concrete pavers and underground slope drain;
- Grading and stabilization of gulley on a sloped property near the Northwest Rankin school complex;
- Grading and stabilization of a gulley on another sloped property near the Northwest Rankin school complex, including installation of check dams;
- Installation of a rain garden in a drainage swale near an entrance to the Northwest Rankin school complex; and
- Grading and stabilization of a drainage ditch near the entrance to the Northwest Rankin Elementary School.

Installation of these BMPs is expected to reduce erosion by over 8,700 tons of sediment per year. The Rankin County Board of Supervisors will be responsible for maintaining these BMPs. Education and outreach efforts have involved local students and builders, and included:

- Development of factsheets, brochures, billboards, logos, and web pages by students with support of teachers and agencies;
- WaterFest, a free annual social event;
- Land Development Stormwater Management Workshop attended by licensed builders, engineers, architects, and planning officials;
- Stakeholder meetings;
- Presentations; and
- Newspaper and radio ads.

The US Geological Survey (USGS) has conducted extensive monitoring in the Mill Creek watershed. Six USGS monitoring sites collected flow and suspended sediment data to characterize the discharge-sediment load relationships in the watershed, and to monitor the effect of erosion control projects in the watershed. Only two of the monitoring sites were activated prior to 2000. Water-level data are also being collected to develop stage-flow relationships. (Rankin County Board of Supervisors et al. 2009). As of December 2010, monitoring has continued at Mill Creek at Highway 25 and a tributary to Mill Creek.

5.3 Fannegusha Creek Restoration Project

The Fannegusha Creek watershed is a 46,943-acre watershed located in Rankin and Scott counties in central Mississippi. The drainage area of this watershed is comprised of approximately 46% agricultural lands. This project identified sediment as the primary pollution problem in Fannegusha Creek. The overall goal of the project was to implement best management practices on targeted areas in the Fannegusha Creek watershed to reduce pollutant loadings from agricultural nonpoint sources. The project funds were used to install 101 practices affecting 5,307 acres of land. The BMPs included the installation of terraces in row-crop fields, grade stabilization structures at selected streams, and agricultural management practices such as pasture and hayland planting, nutrient management, and fencing. MSWCC calculated that 189,283 tons of soil were saved through installation of BMPs in the watershed. The total budgeted amount for the work described above was $946,152. Sixty percent of this budget was paid by MDEQ using Section 319 funds, and 40% was contributed by local landowners (MSWCC 2009).

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APPENDIX N

FACT SHEETS FOR RECOMMENDED MANAGEMENT PRACTICES

Bioretention Basins/ Rain Gardens

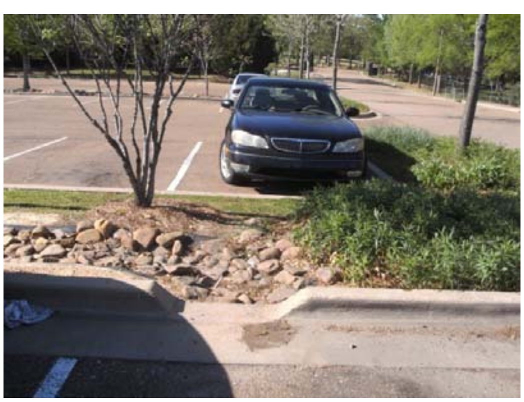
Description

Source: Mississippi Museum of Natural Science

A bioretention system (sometimes referred to as a "rain garden") is a type of filtration best management practice (BMP) designed to collect and filter moderate amounts of stormwater runoff using conditioned planting soil beds, gravel beds and vegetation within shallow depressions. The bioretention system may be designed with an underdrain to collect treated water and convey it to discharge, or it may be designed to infiltrate the treated water directly to the subsoil. Bioretention cells are capable of reducing sediment, nutrients, oil and grease, and trace metals.

Design Considerations

- Maximum contributing drainage area of 5 acres.
- Can be integrated with site landscaping.
- Depending on the soil type and depth to water table, the bioretention area can be designed to infiltrate into the underlying soil.
- Should be located close to the source of runoff to limit the amount of concentrated flow to the basin.
- Not recommended in areas with steep slopes.
- Detailed design information and requirements for bioretention basins/rain gardens are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This publication is available from the Mississippi Department of Environmental Quality (MDEQ) and online at http://www.deq.state.ms.us.



Source: Mississippi Museum of Natural Science

Implementation

- Urban retrofit.
- New development.

Bioretention basins can be installed in existing landscaped areas and designed to connect to existing stormwater infrastructure systems within the developed and urbanized area of the watershed. In addition to retrofitting, they can be incorporated into the design of the stormwater management system of proposed developments. They can be installed in any soil type; however, if installed in a low-permeability soil, the bioretention basins shall be designed to not infiltrate into the ground. Non-infiltrating bioretention basins treat the stormwater by removing suspended solids, nutrients, and pollutants and then discharging the stormwater into the stormwater conveyance system.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	80% to 90% (with pre-treatment)
Total Nitrogen	30% to 50% (if soil media is at least 30 inches)
Total Phosphorus	30% to 90%
Metals	40% to 90%
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Bioretention Basin Vegetation

Link: http://msucares.com/lawn/landscape/sustainable/rain.html

Cost

While this practice may create additional site work costs as compared to conventional practices, it can be offset by reduced infrastructure such as stormwater pipes, storm drains, and stormwater ponds. Costs per acre of development range from $5,000 to $10,000 for larger areas and costs per square foot range from $3 to $15. In some cases, it has been found that bioretention can yield a 50% savings over conventional systems for overall site drainage. In most cases, the area would have been landscaped, so the cost of installing and maintaining a bioretention area should be compared to the cost of otherwise landscaping the area.

Benefits

- Applicable to small drainage areas.
- Good for highly impervious areas, particularly parking lots.
- Good retrofit capability.
- Relatively low maintenance requirements.
- Can be planned as an aesthetic feature.
- Efficient pollutant removal method.
- Can provide reduction in peak runoff rates for relatively frequent storms.
- Can provide runoff volume reduction.

Limitations

- Requires careful landscaping and maintenance.
- Not suitable for large drainage areas.
- Surface soil layer may clog over time (though it can be restored).

- Frequent trash removal may be required, especially in high-traffic areas.
- Vigilance in protecting the bioretention area during construction is essential.
- Required frequent maintenance of plant material and mulch layer.

Maintenance

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24-hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Trash and debris should be removed at each inspection.
- Vegetation should be inspected at least annually, and maintained in healthy condition.

Education and Outreach

The target audience for this practice is developers and decision-makers. Developers should be encouraged to include bioretention in the design for retrofit and new projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about bioretention basins through participation in the watershed team and stormwater management training. Education of officials is vital to preventing delays or difficulties in the permit approval process that may occur when GI practices are used in place of conventional practices. Property owners will be encouraged to use bioretention in model retrofit projects.

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Stormwater Retention/ Detention Ponds

Description

Stormwater ponds (also referred to as retention ponds, wet ponds, or wet extended detention ponds) are constructed stormwater retention basins that have a permanent (dead storage) pool of water throughout the year. They can be created by excavating an already existing natural depression or through the construction of embankments. These should not be confused with conventional dry detention basins that do not provide a permanent pool. Dry detention basins fail to demonstrate an ability to meet the majority of water quality goals, are prone to clogging and resuspension of previously settled solids, and require a higher frequency of maintenance than wet ponds.

In a stormwater pond, runoff from each rain event is detained and treated in the pool through gravitational settling and biological uptake until it is displaced by runoff from the next storm. The permanent pool also serves to protect deposited sediments from resuspension. Above the permanent pool level, additional temporary storage (live storage) is provided for runoff quantity control.

There are several different variants of stormwater pond design, the most common of which include the wet pond, the wet extended detention (ED) pond, and the micropool ED pond. In addition, multiple stormwater ponds can be placed in series or parallel to increase performance or meet site design constraints.

Design Considerations

Source: Georgia Stormwater Management Manual

- Minimum contributing drainage area of 25 acres; 10 acres for micropool ED pond.
- A sediment forebay or equivalent upstream pretreatment must be provided.
- Minimum length to width ration for the pond is 1.5:1.
- Maximum depth of the permanent pool should not exceed 8 feet.
- Side slopes to the pond should not exceed 3:1 (horizontal:vertical).
- Use may be limited by depth to bedrock.
- Use may be limited by soil permeability or groundwater levels, or require special design measures to control exfiltration of retained water or inflow of groundwater.
- Detailed design information and requirements for stormwater retention/detention ponds are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual.

This publication is available from the Mississippi Department of Environmental Quality (MDEQ) and online at http://www.deq.state.ms.us.

Implementation

- Urban retrofit.
- New development.

Stormwater ponds are generally applicable to most types of new development and redevelopment, and can be used in both residential and nonresidential areas. Ponds can also be used in retrofit situations.

Generally, dry weather base flow and/or large contributing drainage areas are required to maintain pool elevations. Because wet basins remove soluble pollutants, they are ideal for sites where nutrient loadings are expected to be high. In such instances, source controls must also be implemented to further reduce nutrient loadings. The site soils, depth to bedrock, and depth to water table are additional site constraints that should be assessed prior to designing a stormwater pond.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	80%
Total Nitrogen	30%
Total Phosphorus	50%
Metals	50%
Pathogens (coliform, *E. coli*)	70% (if no resident waterfowl population is present)

Cost

The construction costs associated with wet ponds range considerably. A recent study (Brown and Schueler 1997) estimated the cost of a variety of stormwater management practices. The study resulted in the following cost equation, adjusting for inflation:

$$C = 24.5V^{0.705}$$

Where:

C = Construction, design and permitting cost;

V = Volume in the pond to include the 10-year storm (ft^3).

Using this equation, typical construction costs are:

- $45,700 for a 1 acre-foot facility.
- $232,000 for a 10 acre-foot facility.
- $1,170,000 for a 100 acre-foot facility.

Ponds do not consume a large area relative to the drainage size of the watershed (typically 2.3% of the contributing drainage area). It is important to note, however, that these facilities are generally large and require a relatively large contiguous area. Other practices, such as filters or swales, may be "squeezed" into relatively unusable land, but ponds need a relatively large continuous area.

For ponds, the annual cost of routine maintenance is typically estimated at about 3% to 5% of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Ponds are long-lived facilities (typically longer than 20 years). Thus, the initial investment into pond systems may be spread over a relatively long time period.

In addition to the water resource protection benefits of wet ponds, there is some evidence to suggest that wet ponds may provide an economic benefit by increasing property values. The results of one study suggest that "pond front" property can increase the selling price of new properties by about 10% (EPA 1995). Another study reported that the perceived value (i.e., the value estimated by residents of a community) of homes was increased by about 15% to 25% when located near a wet pond (Emmerling-DiNovo 1995).

Benefits

- Moderate to high removal rate of urban pollutants.
- High community acceptance.
- Opportunity for wildlife habitat.
- Can increase adjacent property values when properly planned and sited.
- Sediment generally needs to be removed less frequently than for other best management practices (BMPs).
- Can be used in retrofits.
- Provides good water quantity control for reducing the frequency of flooding events that cause bank erosion.

Limitations

- Potential for thermal impacts/downstream warming.
- More costly than extended dry detention basins.
- Larger storage volumes for the permanent pool and flood control require more land area.
- Infiltration and groundwater recharge is minimal, so runoff volume control is negligible.
- Moderate to high maintenance requirements.
- Can be used to treat runoff from land uses with higher pollutant loads if bottom is lined and sealed.
- Invasive species control required.
- Sometimes can create problems such as nuisance odors, algae blooms, and rotting debris when not properly maintained.
- May attract excessive waterfowl, which can be a nuisance and can increase fecal coliform levels.

Maintenance

- Remove debris from inlet and outlet structures.
- Maintain side slopes/remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.
- Inspect wet basins to ensure they are operating as designed at least once a year.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include improved designs for stormwater ponds in new and retrofit projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about stormwater ponds through participation in the watershed team and stormwater management training.

References

Information in the factsheet is adapted from:

AMEC Earth & Environmental, the Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, and the Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook (first edition)*. Atlanta Regional Commission. Accessed September 2011 at http://www.georgiastormwater.com/GSMMVol2.pdf.

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Infiltration Devices

Infiltration devices are trenches or basins that fill with stormwater runoff and allow the water to exfiltrate, i.e., exit the device by infiltrating into the soil. There are four major types of infiltration devices: infiltration trenches, infiltration basins, dry wells, and subsurface structures.

Infiltration Trenches

Infiltration trenches are shallow excavations filled with stone. The stone provides underground storage for stormwater runoff. The stored runoff gradually exfiltrates through the bottom and/or sides of the trench into the subsoil, and eventually into the water table.

Infiltration Basins

Infiltration basins are stormwater runoff impoundments that are constructed over permeable soils. Runoff from the design storm is stored until it exfiltrates through the soil of the basin floor.

Dry Wells

Dry wells consist of small excavated pit filled with stone, or a small structure surrounded by stone, used to temporarily store and infiltrate runoff from a very limited contributing area. Runoff enters the structure through an inflow pipe, inlet grate, or through surface infiltration. The runoff is stored in the structure and/or void spaces in the stone fill. Dry wells are well-suited to receive roof runoff via building gutter and downspout systems.

Subsurface Structures

Subsurface structures are underground systems that capture runoff, and gradually infiltrate it into the groundwater through rock and gravel. There are a number of underground infiltration systems that can be installed to enhance groundwater recharge. The most common types include pre-cast concrete or plastic pits, chambers (manufactured pipes), perforated pipes, and galleys.

Infiltration basin.
Source: Massachusetts Stormwater Handbook

Infiltration practices differ from filtering practices in that stormwater is infiltrated through native soil and allowed to recharge groundwater, while filtration practices typically employ non-native soil materials or other media, and may use underdrains to convey the filtered water to discharge.

Design Considerations

- Pretreatment must be provided if the infiltration BMP will receive stormwater other than roof runoff.
- The underlying soils should have an infiltration rate of 0.5 inch per hour or greater.
- An observation well should be installed to monitor percolation.
- Careful consideration during construction is required to prevent sediment from clogging the underlying soils.
- Infiltration devices transfer more stormwater to the soil than any other type of best management practice (BMP), and they more closely mimic the natural hydrology of the area by taking a portion of concentrated flow and allowing it to infiltrate into the soil.
- Detailed design information and requirements for infiltration devices are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This publication is available from MDEQ and online at http://www.deq.state.ms.us.

Implementation

- Urban retrofit.
- New development.

Infiltration BMPs can be suitable for treating runoff from drainage areas (ranging up to 50 acres in size for infiltration basins) where subsoil, groundwater conditions, and depth to bedrock are appropriate. Infiltration BMPs can be used for a wide range of land uses, including commercial, residential, industrial, and gravel mining sites. However, some industrial and commercial areas have contaminants that may pose a risk of groundwater contamination. In this case, infiltration should not be used without adequate treatment of runoff prior to entering the device. In some cases, infiltration measures should be avoided in favor of other BMPs.

Infiltration devices work best in relatively small drainage areas that are completely impervious or stabilized. Infiltration devices are frequently used to infiltrate runoff from adjacent impervious surfaces, such as parking lots and roof tops.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	80% to 85%
Total Nitrogen	30% to 60%
Total Phosphorus	35% to 60%
Metals	90%
Pathogens (coliform, *E. coli*)	90%

Cost

Infiltration trenches are slightly expensive when compared to other stormwater practices, in terms of cost per area treated. Typical construction costs, including contingency and design costs, are about $5 per cubic foot of treated stormwater (Southeastern Wisconsin Regional Planning Commission [SWRPC] 1991; Brown and Schueler 1997). Infiltration trenches typically consume a relatively small 2% to 3% of the drainage site. In addition, infiltration trenches can fit into thin, linear areas. Thus, they can generally fit into relatively unusable portions of a site.

Infiltration basins are relatively cost-effective practices, because little infrastructure is needed when constructing them. One study estimated the total construction cost at about $2 per cubic foot (adjusted for inflation) of storage for a 0.25-acre basin (SWRPC 1991). Infiltration basins typically consume about 2% to 3% of the site draining to them, which is relatively small. Maintenance costs are estimated at approximately 5% to 10% of construction costs.

The construction cost of a dry well can vary greatly depending on design variability, configuration, location, site-specific conditions, etc. Typical construction costs in 2003 dollars range from $4 to $9 per cubic foot of storage volume provided. Annual maintenance costs have been reported to be approximately 5% to 10% of the capital costs (Cahill Associates, Inc., and the Stormwater Manual Oversight Committee 2006).

The construction cost of subsurface infiltration structures can vary greatly depending on design variations, configuration, location, desired storage volume, and site-specific conditions, among other factors. Typical construction costs are about $5.70 per square foot, which includes excavation, aggregate (2.0 feet assumed), non-woven geotextile, pipes and plantings.

One cost concern associated with infiltration practices is the maintenance burden and longevity. If improperly maintained, infiltration basins have a high failure rate. Thus, it may be necessary to replace the basin after a relatively short period of time.

Benefits

- Helps recharge groundwater, which supports dry-weather flows in streams.
- Helps reduce frequency of flooding by reducing the amount of water flowing to surface waters.
- Pollutant removal efficiencies are generally as good as other BMPs.
- Preserves the natural water balance of the site.
- Good for small sites with porous soils.

Limitations

- Potential for groundwater contamination.
- High failure rates due to improper siting, inadequate pretreatment, poor design, and lack of maintenance.
- Restricted to fairly small drainage areas.
- Not appropriate for treating significant loads of sediment and other pollutants.

- Requires frequent maintenance.
- May cause undesirable groundwater seepage into basements and foundations if not properly sited.

Maintenance

- Systems should be inspected at least twice annually, and following any rainfall event exceeding 2.5 inches in a 24-hour period, with maintenance or rehabilitation conducted as warranted by such inspection.
- Pretreatment measures should be inspected at least twice annually, and cleaned of accumulated sediment as warranted by inspection, but no less than once annually.
- If an infiltration system does not drain within 72 hours following a rainfall event, then a qualified professional should assess the condition of the facility to determine measures required to restore infiltration function, including but not limited to removal of accumulated sediments or reconstruction of the infiltration device.
- Debris should be removed from inlet and outlet structures.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include infiltration devices in the design for new and retrofit projects on sites with appropriate soils. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about infiltration devices through participation in the watershed team and stormwater management training.

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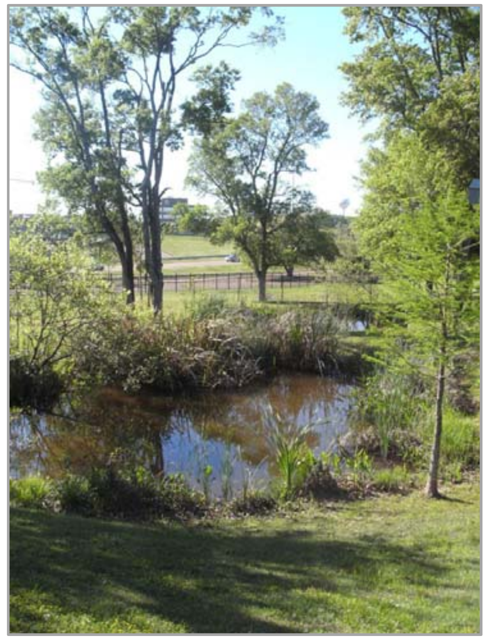
Constructed Stormwater Wetlands

Description

Constructed stormwater wetlands are constructed shallow marsh systems that are designed to treat urban stormwater runoff and control runoff volumes. As stormwater flows through the wetland facility, pollutant removal is achieved through settling and uptake by marsh vegetation.

Wetlands are among the most effective stormwater practices in terms of pollutant removal and also offer aesthetic value and wildlife habitat. Constructed stormwater wetlands differ from natural wetland systems in that they are engineered facilities designed specifically for the purpose of treating stormwater runoff and typically have less biodiversity than natural wetlands both in terms of plant and animal life. However, as with natural wetlands, stormwater wetlands require a continuous base flow or a high water table to support aquatic vegetation. There are several design variations of the stormwater wetland, each differing in the relative amounts of shallow and deepwater, and dry storage above the wetland. These include the shallow wetland, the extended detention shallow wetland, pond/wetland system, and the pocket wetland.



Source: Mississippi Museum of Natural Science

Design Considerations

- Requires sufficient contributing area and/or groundwater elevation to maintain a permanent pool.
- The use of stormwater wetlands may be limited by the depth to bedrock.
- May increase water temperature, which may affect use in watersheds of cold water fisheries.
- Minimum contributing drainage area of 25 acres; 5 acres for pocket wetland.
- Detailed design information and requirements for constructed stormwater wetlands are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This publication is available from the Mississippi Department of Environmental Quality (MDEQ) and online at http://www.deq.state.ms.us.

Implementation

- Urban retrofit.
- New development.

Stormwater wetlands are generally applicable to most types of new development and redevelopment, and can be utilized in both residential and non-residential areas. However, due to the large land requirements, wetlands may not be practical in higher-density areas.

Site constraints that can limit the suitability of constructed stormwater wetlands include inappropriate soil types, depth to groundwater, contributing drainage area, and available land area. Soils consisting entirely of sands are inappropriate unless the groundwater table intersects the bottom of the constructed wetland, or the constructed stormwater wetland is installed above the sand to hold water.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	80%
Total Nitrogen	30%
Total Phosphorus	40%
Metals	50%
Pathogens (coliform, *E. coli*)	Insufficient data

Cost

Wetlands are relatively inexpensive stormwater practices. Construction cost data for wetlands are rare, but one simplifying assumption is that they are typically about 25 percent more expensive than stormwater ponds of an equivalent volume. Using this assumption, an equation developed by Brown and Schueler (1997) to estimate the cost of wet ponds can be modified to estimate the cost of stormwater wetlands using the equation:

$$C = 30.6V^{0.705}$$

Where:
C = Construction, design, and permitting cost; and
V = Wetland volume needed to control the 10-year storm (ft^3).

Using this equation, typical construction costs are the following:

- $57,100 for a 1 acre-foot facility.
- $289,000 for a 10 acre-foot facility.
- $1,470,000 for a 100 acre-foot facility.

Wetlands consume about 3% to 5% of the land that drains to them, which is relatively high compared with other stormwater management practices.

For wetlands, the annual cost of routine maintenance is typically estimated at about 3% to 5% of the construction cost. Alternatively, a community can estimate the cost of the maintenance activities outlined in the maintenance section. Wetlands are long-lived facilities (typically longer than 20 years). Thus, the initial investment into these systems may be spread over a relatively long time period.

Although no studies are available on wetlands in particular, there is some evidence to suggest that wet ponds may provide an economic benefit by increasing property values. The results of one study suggest that "pond frontage" property can increase the selling price of new properties by about 10% (US Environmental Protection Agency [EPA] 1995). Another study reported that the perceived value (i.e., the value estimated by residents of a community) of homes was increased by about 15% to 25% when located near a wet pond (Emmerling-DiNovo 1995). It is anticipated that well-designed wetlands, which incorporate additional aesthetic features, would have the same benefit.

Benefits

- Relatively low maintenance costs.
- Best BMP for maximum TSS, nitrogen, and phosphorus removal while also providing stormwater volume control.
- Aesthetically pleasing when properly maintained and can be sited in both low-and high-visibility areas.
- Can provide excellent habitat for wildlife and waterfowl.

Limitations

- Depending upon design, may require more land than other BMPs.
- Until vegetation is well established, pollutant removal efficiencies may be lower than anticipated.
- Relatively high construction costs compared to other BMPs.
- Needs continuous base flow for viable wetlands.
- Poorly maintained stormwater wetlands can be colonized by invasive species that out-compete native wetland plants.
- Creates potential breeding habitat for mosquitoes.
- May present a safety issue for nearby pedestrians.
- Can serve as decoy wetlands, intercepting breeding amphibians moving toward vernal pools.

Maintenance

- Inspect wetland during both the growing and non-growing seasons twice a year for the first 3 years after construction.
- Replace wetland vegetation to maintain at least 50% surface area coverage.
- Remove invasive vegetation.
- Monitor sediment accumulation and remove periodically.
- Periodic mowing of embankments.
- Removal of woody vegetation from embankments.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include constructed stormwater wetlands in the design for new and retrofit projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about stormwater wetlands through participation in the watershed team and stormwater management training.

References

Information in the factsheet is adapted from:

Alabama Soil and Water Conservation Committee. 2009. *Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Volume 1: Developing Plans and Designing Best Management Practices*. Montgomery, AL. March 2009. Accessed September 2011 at http://swcc.alabama.gov/pages/erosion_handbook.aspx.

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Porous Pavement/Pavers

Description

Porous pavement is a paved surface with a higher than normal percentage of air voids to allow water to pass through it and infiltrate into the subsoil. This porous surface replaces traditional pavement, allowing parking lot, driveway, and roadway runoff to infiltrate directly into the soil and receive water quality treatment. All permeable paving systems consist of a durable, load-bearing, pervious surface overlying a stone bed that stores rainwater before it infiltrates into the underlying soil. Permeable paving techniques include porous asphalt, pervious concrete, paving stones, and manufactured "grass pavers" made of concrete or plastic. Permeable paving may be used for walkways, patios, plazas, driveways, parking stalls, and overflow parking areas.

Design Considerations

Source: *Georgia Stormwater Management Manual*

- Soil infiltration rate of 0.3 inch per hour or greater required.
- Generally, porous pavements should not be used on slopes greater than 5%.
- A 3-foot buffer between the bottom of the stone bed and the seasonal high groundwater elevation and a 2-foot buffer for bedrock should be maintained.
- Particular care must be taken during construction to assure preparation of subgrade, placement of aggregates, and installation of pavements meets design specifications.
- System should not be placed on compacted fill.
- Permeable pavements are generally applicable to low-traffic access ways, residential drives, overflow or low-use parking areas, pedestrian access ways, alleys, bike paths, and patios. Because of the reduced strength of pavement associated with permeable pavement surfaces such as porous asphalt and concrete, these surfaces are not typically appropriate for high-traffic or heavy vehicle loads.
- Detailed design information and requirements for porous pavement/pavers are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This publication is available from the Mississippi Department of Environmental Quality (MDEQ) and online at http://www.deq.state.ms.us.

Implementation

- Urban retrofit.
- New development.

Porous paving is an excellent technique for dense urban areas, because it does not require any additional land.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	80% (if storage bed is sized to hold water quality volume and designed to drain within 72 hours)
Total Nitrogen	65% to 80%
Total Phosphorus	50% to 80%
Metals	60% to 90%
Pathogens (coliform, *E. coli*)	Insufficient data

Cost

Permeable asphalt costs range from $5 to $11 per square meter ($0.50 to $1.00 per square foot), while permeable concrete costs between $22 and $70 per square meter ($2.00 and $6.50 per square foot). Interlocking concrete paving blocks cost $54 to $108 per square meter ($5.00 to $10.00 per square foot). In addition, permeable pavements may reduce or eliminate the need for additional stormwater infrastructure, so a more accurate price comparison would involve the costs of the full stormwater management paving system. For example, a grass/gravel paver and porous concrete representative stated that when impervious paving costs for drains, reinforced concrete pipes, catch basins, outfalls and storm drain connections are included, an asphalt or conventional concrete stormwater management paving system costs between $102 and $125 per square meter ($9.50 and $11.50 per square foot), compared to a permeable pavement stormwater management system at $50 to $70 per square meter ($4.50 to $6.50 per square foot) (Department of Defense 2004). The savings are considered to be even greater when permeable paving systems are calculated for their stormwater storage; if designed properly, they can eliminate retention pond requirements.

Benefits

- Reduces runoff from paved surfaces.
- Reduces peak discharge rates.
- Increases recharge through infiltration.
- Reduces pollutant transport through direct infiltration.
- Can be used as a retrofit when parking lots are replaced.
- Reduces stormwater infrastructure (piping, catch basins, ponds, curbing, etc.)

Limitations

- Application limited to areas with soil with higher infiltration rates greater than 0.3 inch per hour.
- Prone to clogging, so aggressive maintenance with jet washing and vacuum street sweepers is required.
- Special care is needed to avoid compacting underlying parent soils.
- Not applicable for high-traffic areas or for use by heavy vehicles.
- Potential for high failure rate if not adequately maintained or used in unstabilized areas.
- Potential for groundwater contamination if proper buffer is not maintained between the system and the water table.
- Special attention to design and construction needed.

Maintenance

- Inspect the porous pavement after each storm event. Inspectors should check for ponding on the surface which might indicate local or widespread clogging.
- The porous pavement site should be posted with signs indicating the nature of the surface, and warning against resurfacing the site with conventional pavement or the use of materials which could affect the infiltration capacity of the surface.
- No winter sanding of permeable pavements is permitted.
- Minimize application of salt for ice control.
- Inspect annually for pavement deterioration or spalling.
- For porous asphalt and concrete, clean periodically (two to four times per year) using a vacuum sweeper. Power washing may be required prior to vacuum sweeping, to dislodge trapped particles.
- For interlocking paving stones, periodically add joint material to replace lost material.
- For seeded grid systems, periodic reseeding of grass pavers to fill in bare spots.
- Major clogging may necessitate replacement of pavement surface, and possibly filter course and sub-base course.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include pervious pavement in appropriate areas for new and retrofit projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about pervious pavement through participation in the watershed team and stormwater management training.

References

Information in the factsheet is adapted from:

Alabama Soil and Water Conservation Committee. 2009. *Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Volume 1: Developing Plans and Designing Best Management Practices*. Montgomery, AL. March 2009. Accessed September 2011 at http://swcc.alabama.gov/pages/erosion_handbook.aspx.

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Water Quality Swales

Description

Water quality swales are vegetated open channels that are explicitly designed and constructed to capture and treat stormwater runoff within dry or wet cells formed by check dams or other means. They are designed to treat the required water quality volume (WQv) and to convey runoff from the 10-year storm without causing erosion. There are two primary water quality swales, the dry swale and wet swale (or wetland channel). Dry and wet swales are not to be confused with a filter strip or grassed channel. The water quality swales are engineered to provide a higher level of pollutant removal than the grassed channel.

Dry Swale

The dry swale is a vegetated conveyance channel designed to include a filter bed of prepared soil that overlays an underdrain system. Dry swales are sized to allow the entire WQv to be filtered or infiltrated through the bottom of the swale. Because they are dry most of the time, they are often the preferred option in residential settings.

Wet Swale (Wetland Channel)

The wet swale is a vegetated channel designed to retain water or marshy conditions that support wetland vegetation. A high water table or poorly drained soils are necessary to retain water. The wet swale essentially acts as a linear shallow wetland treatment system, where the WQv is retained.

Dry Swale
Source: *Georgia Stormwater Management Manual*

Wet Swale
Source: *Georgia Stormwater Management Manual*

Design Considerations

- Longitudinal slopes must be less than 4%.
- Bottom width should be 2 to 8 feet.
- Side slopes of 2:1 or flatter; side slopes of 4:1 recommended.
- Should convey the 25-year storm event with a minimum of 6 inches of freeboard.
- Detailed design information and requirements for water quality swales are available in Section 3.2.6, Enhanced Swales, of the *Georgia Stormwater Management Manual, Volume 2: Technical Handbook (first edition)*. This publication is available from the Georgia Environmental Protection Division and online at http://www.georgiastormwater.com/vol2/3-2-6.pdf.

Implementation

- Urban retrofit.
- New development.

Water quality swales have many uses. Dry swales are most applicable to residential and institutional land uses of low to moderate density where the percentage of impervious cover in the contributing areas is relatively low. Wet swales may not be appropriate for some residential applications, such as frontage lots, because they contain standing water and may attract mosquitoes.

Water quality swales may also be used in parking lots to break up areas of impervious cover. Along the edge of small roadways, use water quality swales in place of curb and gutter systems. Water quality swales may not be suitable for sites with many driveway culverts or extensive sidewalk systems.

The topography and soils on the site will determine what is appropriate. The topography should provide sufficient slope and cross-sectional area to maintain non-erosive flow velocities. Porous soils are best suited to dry swales, while soils with poor drainage or high groundwater conditions are more suited to wet swales. The primary factors to consider when designing water quality swales are soil characteristics, flow capacity, erosion resistance, and vegetation.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	80%
Total Nitrogen	Dry Swale: 50% / Wet Swale: 40%
Total Phosphorus	Dry Swale: 50% / Wet Swale: 25%
Metals	Dry Swale: 40% / Wet Swale: 20%
Pathogens (coliform, *E. coli*)	Insufficient data

Cost

Limited data exist on the cost to implement water quality swales, although they are relatively inexpensive to construct compared to other stormwater treatment practices. The cost to design and construct most water quality swales can be estimated as $0.50 per square foot of swale surface area, based on 1997 prices. These costs should be adjusted for inflation to reflect current costs.

Benefits

- Combines stormwater treatment with runoff conveyance system.
- May be used to replace more expensive curb and gutter systems.
- Roadside swales provide water quality and quantity control benefits, while reducing driving hazards by keeping stormwater flows away from street surfaces.
- Accents natural landscape.
- Compatible with low-impact design (LID).
- Can be used to retrofit drainage channels and grass channels.
- Little or no entrapment hazard for amphibians or other small animals.

Limitations

- Higher degree of maintenance required than for curb and gutter systems.
- Subject to erosion during large storms.
- Individual dry swales treat a relatively small area.
- Impractical in areas with very flat grades, steep topography or poorly drained soils.
- Wet swales can produce mosquito breeding habitat.
- Should be set back from shellfish growing areas and bathing beaches.

Maintenance

- Inspect swales to make sure vegetation is adequate and slopes are not eroding. Check for rilling and gullying. Repair eroded areas and revegetate. Perform within the first few months after construction and twice a year thereafter.
- Maintain grass heights of approximately 4 to 6 inches (dry swale). Wet swales may not need to be mowed depending on vegetation.
- Remove sediment and debris manually at least once a year.
- Re-seed as necessary.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include water quality swales in appropriate locations in new and retrofit projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about water quality swales through participation in the watershed team and stormwater management training.

References

Information in the factsheet is adapted from:

AMEC Earth & Environmental, the Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, and the Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook (first edition)*. Atlanta Regional Commission. Accessed September 2011 at http://www.georgiastormwater.com/GSMMVol2.pdf.

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Grassed Treatment Swale

Description

A water quality grassed swale is a shallow open-channel drainageway, stabilized with grass or other herbaceous vegetation that is designed to filter pollutants. Grassed treatment swales are designed to promote sedimentation by providing a minimum hydraulic residence time within the channel under design flow conditions (water quality flow). This best management practice (BMP) may also provide some infiltration, vegetative filtration, and vegetative uptake. Conventional grass channels and ditches are primarily designed for conveyance. Treatment swales, in contrast are designed for hydraulic residence time and shallow depths under water quality flow conditions. As a result, treatment swales provide higher pollutant removal efficiencies. Pollutants are removed through sedimentation, adsorption, biological uptake, and microbial breakdown.

Design Considerations

- Grassed treatment swales should be designed so that the flow travels the full length to receive adequate treatment.
- All channels should be designed for capacity and stability.
- Vegetation should be select based on site soils conditions, planned mowing requirements (height, frequency), and design flow velocities.
- Should not be used on slopes greater than 4%; slopes between 1% and 2% recommended.

Source: Georgia Stormwater Management Manual.

- Ineffective unless carefully designed to achieve low velocity rates in the channel (less than 1.0 foot per second).
- Swale shape should be trapezoidal or parabolic.
- Swale must have greater than 85% vegetated growth prior to receiving runoff.
- Bottom of swale must be above seasonal high water table.
- Detailed design information and requirements for "the management practice" are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Implementation

- Urban retrofit.
- New development.

Grass channels are well suited to a number of applications and land uses, including treating runoff from roads and highways and pervious surfaces. The suitability of grassed swales depends on land use, soil type, slope, imperviousness of the contributing watershed, and dimensions and slope of grassed swale system. Typical situations where grass swales can be used include roadside ditches, channels at property boundaries, outlets for diversions and other concentrated flow areas subject to channel erosion.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	50%
Total Nitrogen	20%
Total Phosphorus	25%
Metals	30%
Pathogens (coliform, e coli)	Insufficient data

Cost

Grassed swale construction costs are estimated at approximately $2.70 per square meter ($0.25 per square foot.) These costs, however, do not include design costs, raising the total cost to approximately $5.40 per square meter ($0.50 per square foot.) Grassed swale costs compare favorably with other stormwater management practices.

Benefits

- Can be used as part of the runoff conveyance system to provide pretreatment.
- Grass channels can act to partially infiltrate runoff from small storm events if underlying soils are pervious.
- Less expensive than curb and gutter systems.
- Open drainage system aids maintenance.
- Accepts sheet flow or pipe flow.
- Compatible with low-impact design (LID) measures.
- Little or no entrapment hazard for amphibians or other small animals.

Limitations

- Potential for bottom erosion and resuspension.
- Short retention time does not allow for full gravity separation.
- Limited biofiltration provided by grass lining.
- Must be designed carefully to achieve low flow rates for water quality volume purposes (less than 1.0 foot per second).
- Mosquito control considerations.

Maintenance

- Inspect annually for erosion, sediment accumulation, vegetation loss, and presence of invasive species.
- Perform periodic mowing; frequency depends on location and the type of grass. Do not cut shorter than water quality flow depth (maximum 4 inches).
- Remove debris and accumulated sediment, based on inspection.
- Repair eroded areas, remove invasive species and dead vegetation, and reseed with applicable grass mix as warranted by inspection.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include grassed swales in the design for new and retrofit projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about grassed swales through participation in the watershed team and stormwater management training.

References

Information in the factsheet is adapted from:

Alabama Soil and Water Conservation Committee. 2009. Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Volume 1: Developing Plans and Designing Best Management Practices. Montgomery, AL. March 2009. Accessed September 2011 at http://swcc.alabama.gov/pages/erosion_handbook.aspx.

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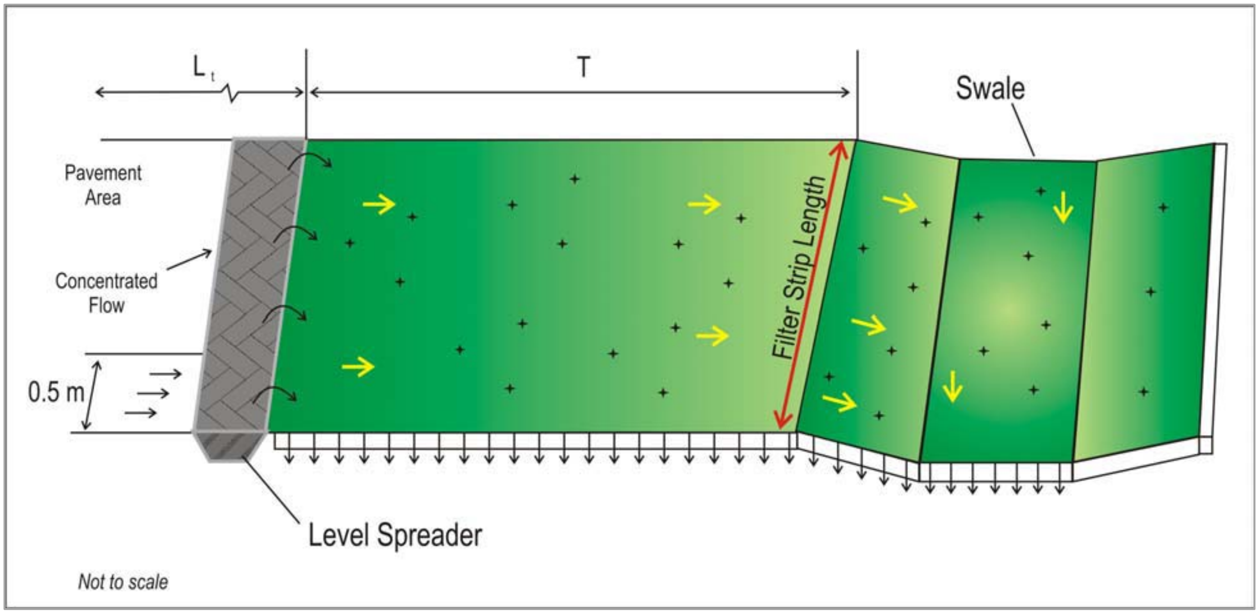
Vegetated Filters Strips with Level Spreaders

Description

Vegetated filter strips, also known as filter strips, grass buffer strips, and grass filters, are uniformly graded vegetated surfaces (i.e., grass or close-growing native vegetation) that receive runoff from adjacent impervious areas. Filter strips are uniformly graded and densely vegetated sections of land engineered and designed to treat runoff from and remove pollutants through vegetative filtering infiltration. Vegetated filter strips are designed to slow runoff velocities, trap sediment, and promote infiltration, thereby reducing runoff volumes. Vegetated filter strips typically treat sheet flow or small concentrated flows that can be distributed along the width of the strip using a level spreader.



A level spreader is constructed at a virtually zero (0%) grade across the slope consisting of a permanent linear structure used to disperse or "spread" concentrated flow thinly over a vegetated or forested riparian buffer or filter strip. Its purpose is to spread concentrated water over a wide enough area so that erosion of vegetated buffers or filter strips does not result (Van Der Wiele 2007).

Design Considerations

- Runoff from an adjacent impervious area must be evenly distributed across the filter strip as sheet flow.
- Filter strips can be used as part of the runoff conveyance system to provide pretreatment.

- Can provide groundwater recharge.
- Reasonably low construction cost, but has a relatively large land requirement.
- Detailed design information and requirements for vegetated filter strips with level spreaders are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual, available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us, as well as in the *Level Spreader Design Guidelines*, available from the North Carolina Division of Water Quality and online at http://h2o.enr.state.nc.us/su/documents/LevelSpreaderGuidance_Final_-3.pdf.

Implementation

- Urban retrofit (in limited applications).
- New development.

Typical application will be new development due to the land required, but they can be installed as a retrofit if there is enough space. Filter strips are effective for residential settings and small impervious areas. They are also effective as a pre-treatment device prior to other treatment best management practices (BMPs).

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	40%
Total Nitrogen	20% to 30%
Total Phosphorus	20% to 35%
Metals	Insufficient data
Pathogens (coliform, *E. coli*)	Insufficient data

Cost

A rough estimate of filter strip construction costs includes the cost of seed or sod, approximately $0.30 per square foot for seed or $0.70 per square foot for sod. This amounts to a cost between $32,000 and $74,000 per hectare ($13,000 and $30,000 per acre) for filter strips. The cost of filter strip construction may be higher than other stormwater management practices, but the construction costs are offset by low maintenance costs, roughly $865 per hectare ($350 per acre) per year. Additionally, maintenance costs might overlap with regular landscape maintenance costs.

Benefits

- Reduces runoff volumes and peak flows.
- Slows runoff velocities and removes sediment.
- Low maintenance requirements.
- Serves as an effective pretreatment for bioretention cells.
- Can mimic natural hydrology.

- Small filter strips may be used in certain urban settings.
- Ideal for residential settings and to treat runoff from small parking lots and roads.
- Can be used as part of runoff conveyance system in combination with other BMPs.
- Little or no entrapment hazard for amphibians or other small creatures.

Limitations

- Variability in removal efficiencies, depending on design.
- Little or no treatment is provided if the filter strip is short-circuited by concentrated flows.
- Does not provide a significant amount of runoff storage to significantly reduce peak discharge.
- Often poor retrofit option due to large land requirements.
- Effective only on drainage areas with gentle slopes (less than 6%).
- Improper grading can greatly diminish pollutant removal.

Maintenance

- Inspect filter strip at least annually for signs of erosion, sediment buildup, or vegetation loss.
- Along the upper edge of the filter strip, the deposition of sediment may form a "berm" that obstructs flow into the filter area or concentrates flow. The filter strip should be inspected at least annually to detect this condition, and accumulated sediment removed to restore sheet flow into the filter area.
- In meadows, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- Remove debris and accumulated sediment, based on inspection.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include vegetated filter strips and level spreaders in the design for new and retrofit projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about vegetated filter strips and level spreaders through participation in the watershed team and stormwater management training.

References

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Green Roofs

Description

Green roofs are vegetative alternatives to traditional roofing materials. Instead of having asphalt, gravel, or shingles on a roof, live plants and growing media are placed.

Sod-covered houses were common throughout much of Europe and western North America, yet new technologies are allowing for their use on modern residential, commercial, and industrial buildings. A green roof typically consists of vegetation, a growing medium, impermeable membranes, drainage, and sometimes supplemental irrigation. Green roofs help to mitigate the effects of urbanization on water quality by filtering, absorbing, or detaining rainfall.

Green roofs are either intensive or extensive, referring to the soil media depth and ultimate weight upon the roof.

Source: Mississippi State University

Intensive green roofs have growing media ranging from 8 inches to 24 inches in depth, which allow for the inclusion of larger shrubs and even trees, with weight loads ranging from 60 to 200 pounds per square foot. Intensive roofs require more regular maintenance and are suited to structures that can support heavier loads.

Extensive green roofs have shallower soils ranging from 2 inches to 7 inches in depth, typically allowing for herbaceous plants and groundcovers, and weight loads ranging from 16 to 35 pounds per square foot. This is usually more suitable for existing roof types as it is lighter in weight. Maintenance considerations are generally lower for extensive types.

With any green roof project, an architect or structural engineer should determine the weight loads that the roof will support.

Design Considerations

- The location of the green roof is very important in the design, which is influenced by factors such as height above ground, wind exposure, and sunlight and shade by surrounding buildings.
- A building must be able to support the loading of green roof materials under fully saturated conditions.

- Detailed design information and requirements for green roofs are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Implementation

- Urban retrofit.
- New development.

Green roofs can be applied to new construction or retrofitted to existing construction. They are applicable on residential, commercial, and industrial buildings and are easily constructed on roofs with up to a 20% slope. Many cities such as Chicago and Washington, DC, are actively encouraging green roof construction as a means to reduce stormwater runoff and combined sewer overflows. Other municipalities are encouraging green roof development with tax credits or density credits, or by allowing a small impervious credit to be applied to other structural best management practice (BMP) requirements.

Green roofs are applicable in all parts of the country. In climates with extreme temperatures, green roofs provide additional building insulation, which makes them more financially justifiable for many facility operators.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	Insufficient data
Total Nitrogen	Insufficient data
Total Phosphorus	Insufficient data
Metals	Insufficient data
Pathogens (coliform, *E. coli*)	Insufficient data

Cost

Extensive green roofs range in price from approximately $5 per square foot to $20 per square foot. However, there are significant cost savings associated with reducing energy consumption and longer roof lifespan. For instance, the green roof on the Gap building in San Bruno, California, more than covered the additional cost associated with its construction through energy savings within a few years. Annualized costs should be lowered considerably by the roof's increased lifespan. Furthermore, some municipalities offer incentives to help defray the higher up-front costs of green roof construction.

Intensive green roofs can be considerably more expensive than extensive green roofs. Estimates range from $20 to $80 per square foot. Other benefits should be taken into account, however, such as recreational space provided and costs relative to the price of land in an area.

Benefits

- Reduces volume and peak rate of runoff from more frequent storms.
- Reduces heating and cooling costs for the buildings.
- May extend life expectancy of the roof by shielding the roof from ultraviolet rays and temperature.
- Provides sound insulation.
- Ideal for redevelopment or in the ultra-urban setting.

Limitations

- Precipitation captured by green roofs (through interception, storage, plant uptake, evapotranspiration) is not recharged to groundwater.
- If green roofs require irrigation to maintain plans, they may reduce the volume of water available for other purposes.
- May require additional structural strengthening if used for retrofit.

Maintenance

Immediately after construction, green roofs need to be monitored regularly to ensure the vegetation thrives. During the first season, green roofs may need to be watered periodically if there is not sufficient precipitation. After the first season, extensive green roofs may only need to be inspected and lightly fertilized approximately once per year. The roofs may need occasional weeding and may require some watering during exceptionally dry periods. If leaks should occur in the roof, they are relatively easy to detect and fix. Intensive green roofs need to be maintained as any other landscaped area. This can involve gardening and irrigation, in addition to other roof maintenance. Green roofs are less prone to leaking than conventional roofs. In most cases, detecting and fixing a leak under a green roof is no more difficult than doing the same for a conventional roof.

Education and Outreach

Implementation of this practice is voluntary and would be applied on individual lots and homes. For these reasons, the target audience for this practice is the general public.

References

Information in the factsheet is adapted from:

Brzuszek, R.F. 2010. “Green Roofs for Southern Landscapes” (fact sheet). Published by the Mississippi Agricultural and Forestry Experiment Station and the Mississippi State University Extension Service. Accessed October 2011 at http://msucares.com/lawn/landscape/sustainable/greenroofs.html.

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Rain Barrels/Cisterns

Description

Rain barrels and cisterns are structures that store rooftop runoff and reuse it for landscaping and other non-potable uses. Rain barrels and cisterns are low-cost water-conservation devices that reduce runoff volume and, for very small storm events, delay and reduce the peak runoff flow rates. Cisterns are essentially large-scale rain barrels.

Design Considerations

Source: Massachusetts Stormwater Handbook

- Cisterns or rain barrels can be applied across various site conditions.
- Rain barrels and cisterns can be implemented without the use of pumping devices, instead relying on gravity flow.
- Sizing is based on expected water demands, rainfall patterns, and cistern system costs.
- Detailed design information and requirements for rain barrels/cisterns are available in the "Cisterns/Rain Barrels" section of the *Florida Field Guide to Low Impact Development*. This publication is available from the University of Florida IFAS Extension, and online at http://buildgreen.ufl.edu/Fact_%20sheet_Cisterns_Rain_Barrels.pdf.

Implementation

- Urban retrofit.
- New development.

Cisterns and rain barrels are applicable to most commercial and residential properties where there is a gutter and downspout system to direct roof runoff to the storage tank. They take up little room and can be used in dense urban areas. Rain barrels and cisterns are excellent retrofit techniques for almost any circumstance.

Pollutant Removal Efficiency

Rain barrels and cisterns do not provide primary pollutant removal benefits. However, similar to the benefits of green roofs, rainwater harvesting with cisterns reduces stormwater runoff through interception, reducing stress of downstream management and treatment systems.

Cost

Materials and installation costs vary substantially across cistern applications, depending on the source (e.g., manufactured or pre-fabricated versus constructed onsite), storage capacity (size), location (above- or below-ground), and structural material. A single residential rain barrel with typical attachments and accessories costs around $50 for the parts for self-assembly and $200 assembled, whereas cistern costs can start at about $1,500 and a large commercial cistern can cost thousands or tens of thousands of dollars. These upfront costs can be partially offset by reduced demand for potable water, but they do not directly offset regularly incurred materials and installation costs of conventional stormwater system components.

Benefits

- Can reduce water demand for irrigation or other non-potable uses.
- Property owners save money on water bills by using stored water for landscape purposes.
- Public water systems may experience lower peak demand in summer.
- When properly installed, rain barrels and cisterns reduce stormwater runoff volume for small storms.

Limitations

- Provides mosquito-breeding habitat unless properly sealed.
- May need to be disconnected and drained in winter to avoid cracking of storage structure.

Maintenance

Rain barrels and cisterns require minimal maintenance. The tank should be cleaned out about once a year if debris is present. Gutters and downspouts should be inspected regularly and kept clear. If a first-flush bypass system is used, remove debris from the bypass and make sure drain holes are kept open so that the system functions properly. No maintenance is required to prevent mosquito breeding in a rain barrel if all surfaces at the downspout entrance are sealed. However, the seals should be inspected periodically, and if mosquitoes become a problem, mosquito dunks (floating, donut-shaped briquettes containing the biological insecticide *Bacillus thuringiensis*) should be used.

Education and Outreach

Implementation of this practice is voluntary and would be applied on individual lots and homes. For these reasons, the target audience for this practice is the general public.

References

Information in the factsheet is adapted from:

Clark, M., and G. Acomb. 2008. "Cisterns/Rain Barrels." In *Florida Field Guide to Low Impact Development: Stormwater Management Practices for Application in Master Planned Community Development.* Program for Resource Efficient Communities, University of Florida. Accessed October 2011 at http://buildgreen.ufl.edu/Fact_%20sheet_Cisterns_Rain_Barrels.pdf.

EPA. 2008. "On-Lot Treatment Fact Sheet." National Menu of Stormwater Best Management Practices. US Environmental Protection Agency, Office of Water. Accessed September 2011 at http://www.epa.gov/npdes/stormwater/menuofbmps.

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US Department of Defense. 2010. "Low Impact Development" [UFC 3-210-10]. Series 3-200: Civil/Geotechnical/Landscape Architecture in *Unified Facilities Criteria*. Administered by the US Army Corps of Engineers, the Naval Facilities Engineering Command, and the Office of the Air Force Civil Engineer. 15 November 2010. Accessed September 2011 at http://www.wbdg.org/ccb/DOD/UFC/ufc_3_210_10.pdf

Planned Unit Development

Description

Planned unit development, also called "cluster development" or "open space development," is an alternative site planning technique that concentrates development in a compact area to reserve undeveloped space elsewhere on the site. In this technique, lot sizes, setbacks, and frontage distances are minimized to allow for open space. Open space areas are often used for neighborhood recreation, stormwater management facilities, or conservation purposes. Open space that is preserved in a natural condition needs little maintenance and helps to reduce and sometimes treat stormwater runoff from development. Open space design is most applicable in areas with moderate base zoning density requirements (less than six dwelling units per acre).

Design Considerations

Open space development is allowed in zoning ordinances in Rankin and Madison counties in areas designated as Planned Urban Development (PUD) districts. PUD districts are superimposed over residential developments. They must maintain the density requirements over the residential zone over which they are imposed. However, minimum lot size and width can be reduced and remaining land reserved in contiguous tracts of common open space for use by residents.

Photo by Angie Tornes, National Park Service.
Source: Milwaukee River Basin Partnership (2003).

Detailed design information and requirements for planned unit developments are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This publication is available from the Mississippi Department of Environmental Quality (MDEQ) and online at http://www.deq.state.ms.us.

Implementation

- New development.

Pollutant Removal Efficiency

Open space developments can reduce impervious surfaces from 40% to 60% when compared to conventional subdivision designs.

Pollutant/Parameter	Efficiency
Annual Runoff Volume	20% to 60%
Total Suspended Solids (TSS)	Not measured
Total Nitrogen	40% to 60%
Total Phosphorus	40% to 60%
Metals	Not measured
Pathogens (coliform, *E. coli*)	Not measured

Benefits

- Decreased development costs due to less road building and construction of structural stormwater management practices.
- Maintenance costs are low as long as land is kept in its natural state (approximately $75 per acre per year).
- Can provide affordable housing to residents.
- Enhanced quality of life and recreational opportunities for residents.

Limitations

- Smaller lots may be perceived as less marketable.
- Delays in the review of plans for cluster development are expected since they require a special exemption from current zoning requirements.
- Open space must be managed by a homeowner association or separate entity.

References

Information in this factsheet is adapted from:

Center for Watershed Protection. 1998. *Better Site Design: A Handbook for Changing Development Rules in Your Community.* Prepared for the Site Planning Roundtable. With assistance from the Morris and Gwendolyn Cafritz Foundation; the US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds; Chesapeake Bay Trust; Turner Foundation; and Chesapeake Bay Program. Ellicott City, MD. 100 pp. Accessed October 2011 at http://www.cwp.org/store/publications.html.

Central Mississippi Planning and Development District. 2010 (revised). Zoning Ordinance of Rankin County, Mississippi. Jackson, MS. 147 pp. Accessed October 2011 at http://www.rankincounty.org/CD/images/Rankin%20Co%20Zoning%20Ord%202010.pdf.

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Fertilizer and Herbicide Application

Description

Urban landscape maintenance activities include vegetation removal, herbicide and insecticide application, fertilizer application, and watering. All of these maintenance practices have the potential to contribute pollutants to the storm drain system. The major objective of this best management practice (BMP) is to minimize the discharge of pesticides, herbicides, and fertilizers to the storm drain system and receiving waters in urban areas.

Integrated pest management (IPM), a sustainable approach to managing pests by combining biological, cultural, physical, and chemical tools, is described in more detail in a separate Fact Sheet.

Design Considerations

This design for this BMP includes a set of recommendations that apply to homeowners and professionals engaged in landscape maintenance activities. Fertilizers and pesticides should be used on lawns and gardens only when necessary. Use can be minimized by selecting hearty plants that are native to the area (see Table 1 and http://www.msucares.com for lists of native plants and shrubs). If it is necessary to use chemical pesticides, the least toxic pesticide that targets the specific pest in question should be chosen. Particular attention should be paid to areas of high-intensity management, such as cemeteries and golf courses, which may contribute large amounts of excess fertilizer and pesticides to runoff.

Planting of native vegetation in Jackson, Mississippi.
Source: Mississippi Museum of Natural Science

Planting of native vegetation in Jackson, Mississippi.
Source: Mississippi Museum of Natural Science

Table 1. Native plant and shrub species.

Plant Type	Recommended Species	
Groundcovers	• Liriope • Monkey grass • Asian jasmine • Ardisia • Aspidistra • Dwarf bamboo	• Holly leaf fern • Indigo bush • Sword fern • Sedum • Setcreasea
Perennials	• Daylily • Stokes aster • Lantana • Verbena • Black-eye Susan • Purple coneflower	• Evening primrose • Louisiana phlox • Narrow leaf sunflower • Rain lily • Louisiana iris • Wild petunia
Shrubs	• Butterfly bush • American beautyberry • Flowering quince • Forsythia • Holly • Virginia willow • Summersweet	• Spirea • Vitex • Oleander • Elaeagnus • Wax myrtle • Yaupon holly
Trees	• Ironwood • Parsley hawthorne • Live oak • Southern magnolia • American holly • Red maple	• Sweetgum • Black gum • Willow oak • Winged sumac • Bald cypress

Source: http://msucares.com/lawn/landscape/sustainable/maintenance.html

- Follow all federal, state, and local laws and regulations governing the use, storage, and disposal of fertilizers and pesticides and training of applicators and pest control advisors.
- Use pesticides only if there is an actual pest problem (not on a regular preventative schedule).
- Do not use pesticides if rain is expected. Apply pesticides only when wind speeds are low (less than 5 mph).
- Do not mix or prepare pesticides for application near storm drains.
- Prepare the minimum amount of pesticide needed for the job and use the lowest rate that will effectively control the pest.
- Employ techniques to minimize off-target application (e.g., spray drift) of pesticides, including consideration of alternative application techniques.
- Calibrate fertilizer and pesticide application equipment to avoid excessive application.
- Periodically test soils for determining proper fertilizer use.

- Sweep pavement and sidewalk if fertilizer is spilled on these surfaces before applying irrigation water.
- Purchase only the amount of pesticide that you can reasonably use in a given time period (monthly or annually, depending on the product).
- Dispose of empty pesticide containers according to the instructions on the container label.
- Detailed design information and requirements for pesticide and fertilizer BMPs are available in *Conservation Practice Standard Code 595: Integrated Pest Management*. This publication is available from the Natural Resources Conservation Service and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

This practice can be practiced by homeowners and professional landscaping crews in any maintained area of vegetation.

Pollutant Removal Efficiency

Pollutant removal efficiency depends on the actual practices used by the individuals. Overuse and misuse of fertilizers and pesticides are common in urban areas. Proper use could significantly reduce fertilizers and pesticides transported in urban stormwater.

Cost

Proper landscape activities are very cost effective. Promoting the growth of healthy plants that require less fertilizer and pesticide applications minimizes labor and maintenance costs of lawn and garden care. Using water, pesticides, and fertilizers only when necessary and replacing store-bought fertilizers with compost material can increase the savings for a property owner as well as benefit the environment.

Benefits

- Proper landscaping techniques can effectively increase the value of a property. Attractive, water-efficient, low maintenance landscapes can increase property values between 7% and 14% (US Environmental Protection Agency [EPA] 1993).
- Reduced landscape maintenances costs for homeowners.

Limitations

- Due to the extremely hot summers experienced in central Mississippi, some irrigation may be needed during dry periods.
- Mississippi soils contain low levels of organic material and may need additional nutrients to support plant growth.
- Compliance is voluntary. It is not practical to monitor landscaping practices on residential properties.

Education and Outreach

The target audience for this BMP includes homeowners and professional lawn services. Professional service suppliers might over apply fertilizers and pesticides to better please customers, and homeowners may not know the proper amounts of fertilizer and pesticides to use. Both groups might apply lawn-care chemicals too close to waterbodies. Local governments conduct education programs for local citizens. If funding is available, local governments can start programs for area-wide composting using yard waste picked up at the curb. The compost could be sold, given to local gardeners, or used in municipal management.

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Information in the factsheet is adapted from:

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City of Miami Beach Public Services. (no date.) *Landscape Maintenance, Pesticide, Herbicide, and Fertilizer Best Management Practices (BMPs)*. Accessed October 2011 at http://www.nmbworks.com/publications/stormwater/Landscape%20Maintenance%20SC.pdf.

EPA. 1993. *Xeriscape Landscaping: Preventing Pollution and Using Resources Efficiently* [EPA-840-B-93-001]. US Environmental Protection Agency, Office of Water. Washington, DC. 16 pp.

Natural Resources Conservation Service. 2010. Integrated Pest Management [Conservation Practice Standard Code 595]. *National Handbook of Conservation Practices*. US Department of Agriculture, Natural Resources Conservation Service. Accessed October 2011 at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025930.pdf.

Disconnected Impervious Areas

Description

Runoff from connected impervious surfaces commonly flows directly to a stormwater collection system with no possibility for infiltration into the soil. For example, roofs and sidewalks commonly drain onto roads, and the runoff is conveyed by the roadway curb and gutter to the nearest storm inlet. Runoff from numerous impervious drainage areas may converge, combining their volumes, peak runoff rates, and pollutant loads. Disconnection decouples roofs, roadways and other impervious areas from stormwater conveyance systems, allowing runoff to be collected and managed on site or dispersed into the landscape. Runoff is redirected onto pervious surfaces such as vegetated areas, reducing the amount of directly connected impervious area and potentially reducing the runoff volume and filtering out pollutants.

Most impervious area in the Florence Gardens subdivision in Gulfport, Mississippi, drains into vegetated areas. Homes are clustered close together and rooftops drain into landscaped areas (upper left). Meadow areas and native vegetation treat runoff from walking trails (upper right). Grassed swales carry stormwater from sidewalks and roads. Sidewalks are built only on one side of the street, and curb and gutter systems are not needed. All photos by Laura Sheely.

Design Considerations

- Disconnected areas should be graded so that stormwater runoff becomes sheet flow and is directed to a vegetated filter strip, bioretention basin, or pervious landscaped areas for treatment.
- Disconnection can also reduce the calculated peak discharge rate by increasing the time of concentration.
- Lower runoff velocities will result in greater contact time with the soil, potentially increasing the runoff volume lost to infiltration.
- Factors influencing runoff velocity include slope and surface roughness. Decreasing the slope and increasing surface roughness will reduce the runoff velocity. The time of concentration can also be increased by increasing the length of the flow paths, (for instance, by increasing circuitousness).

Implementation

- Urban retrofit.
- New development.

Disconnection practices may be applied in almost any location, but impervious surfaces must discharge into a suitable receiving area for the practices to be effective. Runoff must not flow toward building foundations or onto adjacent private property. Typical receiving areas for disconnected impervious runoff include vegetated best management practices (BMPs) (e.g., filter strips or bioretention) and other existing landscaping such as shrubs.

Pollutant Removal Efficiency

Water quality benefits are gained from disconnection practices because a percentage of the overall stormwater volume infiltrates into pervious areas or is lost through evapotranspiration. Pollutant load from impervious areas is a product of pollutant concentration and the stormwater volume. Disconnection practices decrease the total volume of stormwater discharged to receiving waterbodies. Therefore, the reduction in pollutant and nutrient loading attributed to disconnection is dependent upon the reduction in stormwater volume.

The pollutant removal efficiency is also dependent on the type of area to which the stormwater is diverted. For example, if stormwater is diverted to a properly designed bioretention basin, the pollutant removal should be equivalent to the levels expected for bioretention. Pollutant removal rates for various bioretention, filtering, and vegetative BMPs are included in their respective fact sheets.

Cost

There is generally assumed to be little cost associated with implementing a disconnection program. Disconnecting roofs requires simple modifications typically costing $100 or less. However, there will likely be costs associated with maintaining the areas where stormwater is directed. Bioretention basins, vegetated swales, or other vegetative areas may need to be constructed if they are not already present.

Benefits

Routing runoff to vegetated areas will reduce the peak discharge and stormwater volume by providing an opportunity for infiltration and evapotranspiration. The potential exists for runoff to be completely taken "out of the system" by spreading it out and infiltrating it over pervious surfaces and BMPs. The impact of disconnection on stormwater volume and peak discharge is dependent upon the area to which the stormwater is directed.

Limitations

- Most disconnection systems can handle stormwater from only a small amount of impervious surface area. Most design manuals recommend a maximum area of 500 square feet per system. Thus, applications are limited to residential or small commercial areas. Multiple treatment areas for larger disconnected areas are required.
- Rain gardens and other BMPs can create flooding and visual nuisance if not properly designed and maintained

Maintenance

Related maintenance activities are primarily focused on the areas designated to receive stormwater runoff. Infiltration areas should be routinely checked to ensure that they are free of debris and trash. Both vegetated and constructed infiltration areas should be inspected for sediment accumulation. Additionally, receiving areas should be inspected for signs of channelized flow and signs of compaction.

Education and Outreach

The target audience for this practice is developers and decision makers. Developers should be encouraged to include bioretention in the design for retrofit and new projects. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure incentive program. Decision makers include city and county government officials who approve stormwater management plans. This group will be educated about bioretention basins through participation in the watershed team and stormwater management training. Education of officials is vital to preventing delays or difficulties in the permit approval process that may occur when GI practices are used in place of conventional practices. Property owners will be encouraged to use bioretention in model retrofit projects.

References

Information in the fact sheet is adapted from:

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Riparian Buffer/ Vegetated Buffer

Description

Riparian buffers are natural or constructed low-maintenance ecosystems adjacent to surface waterbodies, where trees, grasses, shrubs, and herbaceous plants function as a filter to remove pollutants from overland stormwater flow and shallow groundwater flow prior to discharge to receiving waters. Maintaining a vegetated buffer along creeks, streams, and rivers provides an attractive landscape and can improve water quality by removing sediment and chemicals before they reach the waterway. In addition, buffers provide flood control, help recharge groundwater, prevent soil erosion, and preserve or improve certain types of wildlife habitat.

The primary objective of the buffer strip should be determined prior to design. Various objectives might include protection of water quality, streambank stabilization, downstream flood attenuation, or provision of wildlife habitat or movement corridors.

Design Considerations

Source: Paxton Creek Watershed & Education Association

- The width, length, and plant composition of a buffer will determine its effectiveness, and should be based on the objective of the buffer strip.
- Stormwater flow to buffer should generally enter as sheet flow.
- Slope of buffer should not be greater than 6%.
- Level spreaders are required if flow to buffer is concentrated.
- An effective urban riparian buffer design consists of three preservation zones. Zone 1 is on the stream or shoreline side and includes undisturbed forest to provide shade and stabilize banks. Zone 2 is the middle zone and should also be forested, but limited clearing is acceptable as well as passive recreational uses. Zone 3 is the outer zone, which is the buffer between the forested zones and development. This zone provides initial removal of pollutants.
- Establishing continuous riparian forest buffers in the landscape should be given a higher priority than establishing fragmented buffers. Continuous buffers provide better stream shading and water quality protection, as well as corridors for the movement of wildlife.
- Detailed design information and requirements for riparian/vegetated buffers are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 2: Stormwater Runoff Management Manual. This

publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Implementation

- Urban retrofit.
- New development (preservation of existing buffers).
- Pasture and row-crop areas that boarder perennial streams or drainage channels.

Revegetated riparian buffers can be installed along the bank of any stream, creek, or waterbody within the watershed. The plantings should be native species that will thrive in the local climate where installed.

Pollutant Removal Efficiency

Placement of the buffer strip within the watershed will determine its effectiveness. Buffers installed higher within the watershed are more effective at removing pollutants. The efficiencies given in the table are considered “average” values of efficiency.

Pollutant	Efficiency
Total Suspended Solids (TSS)	60%
Total Nitrogen	30%
Total Phosphorus	35%

Riparian Vegetation for the Reservoir Watershed

Native species of shrubs, trees, and grasses should be used for revegetation of riparian buffers. Native vegetation is adapted to survive in the climate and soil conditions of Mississippi and requires less maintenance (fertilizer, watering, etc). Recommended vegetative plantings for the areas nearest to streams (Zone 1) include the following non-woody species: switchgrass (*Panicum virgatum*), soft rush (*Juncus effusus* and *Juncus* spp.), soft stem bulrush (*Scirpus validus*), maidencane (*Panicum hemitomon*), and water willow (*Dianthera americana*). Suitable woody trees and shrubs are numerous and include willow (*Salix* spp.), cypress (*Taxodium distichum*), overcup oak (*Quercus lyrata*), pin oak (*Quercus palustris*), Nuttall oak (*Quercus texana*), red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), water tupelo (*Nyssa aquatica*), green ash (*Fraxinus pennsylvanica*), and sweetbay magnolia (*Magnolia virginiana*). Suitable shrub species include buttonbush (*Cephalanthus occidentalis*), common alder (*Alnus serrulata*), elderberry (*Sambucus canadensis*), red chokeberry (*Aronia arbutifolia*), Virginia sweetspire (*Itea virginica*), deciduous holly (*Ilex decidua*), and nonflowering dogwood (*Cornus amomum* and *C. foemina*). Rose mallow (*Hibiscus moscheutos*) is a non-woody perennial that is shrub-like in appearance and provides large colorful flowers. Trees for areas farther away from the shoreline include all of those listed above; these tree species are especially tolerant of root flooding for long periods but will also thrive further from the shoreline. The Mississippi State University Extension Service has developed the following excellent guides for selecting appropriate native vegetation: *Native Trees for Mississippi Landscapes* and *Native Shrubs for Mississippi Landscapes* (Brzuszek 2007a, 2007b). The University of Georgia

Marine Extension Service has developed a list of plants appropriate for riparian buffer restoration. Many of the trees, shrubs, and grasses listed in this publication (University of Georgia Marine Extension Service, no date) will most likely be effective for the Reservoir watershed.

Whether riparian buffers should be revegetated with trees or grasses is a question of ongoing discussion. Both grass and forest buffers can reduce levels of nutrients and sediments from surface runoff, and reduce levels of nitrates from subsurface flows. Grass buffers are more quickly established, and in terms of sediment removal, may offer greater stem density to decrease the velocity of water flow and provide greater surface area for sediments to be deposited. Forested buffers, though, offer the advantage that the woody debris and stems may offer greater resistance and are not as easily inundated, especially during heavy floods (US Environmental Protection Agency [EPA] Chesapeake Bay Program Forestry Work Group 1993). Higher rates of denitrification are often observed in forested buffers, presumably due to the greater availability of organic carbon and interactions which occur between the forest vegetation and the soil environment (Lowrance et al. 1995; Correll 1997).

Cost

Planting costs depend on geographic location, number of acres planted, number of trees planted per acre, species of trees, and whether or not the trees are from bare root or container stock. Grass buffers tend to cost less than forest buffers to plant and maintain.

Cost-share and incentive programs exist for the preservation of riparian buffers, for the removal of riparian areas from agriculture production, and for riparian restoration. The US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) is usually the lead federal agency. The programs are typically available in agricultural areas; there are no known cost-share programs in urban areas. Known cost-share/incentive programs include Conservation Reserve Program, the Wetland Reserve Program, and the US Fish and Wildlife Service's Partners for Fish and Wildlife Program.

Benefits

- Offers numerous aesthetic and passive recreational benefits.
- Provides water quality treatment, erosion control, and water temperature benefits.
- Builds support for greenways within riparian buffers in urban and suburban watersheds by maintenance of trails that are well-constructed, well-marked, and well-signed.
- Creates shade, which improves the habitat for aquatic organisms.
- Stabilizes the shoreline and eroding stream banks.
- Has low maintenance requirements once established.
- Can increase property values.
- Provides food and habitat for wildlife.

Limitations

- Sometimes seen as unkempt public areas.
- Can be perceived as interfering with views of streams, especially with shrubby bank-side vegetation.
- In the worst cases, can be abused as places for dumping trash and litter.
- May require development and adoption of an ordinance for urban application.
- Will not repair damaged shorelines.
- May obstruct views of the Reservoir.
- Urban runoff can concentrate rapidly from paved areas and cut across the buffer as channel flow, eliminating the intended function of passing through the buffer.

Maintenance

- Inspect buffer at least annually for signs of erosion, sediment buildup, or vegetation loss.
- If a meadow buffer, provide periodic mowing as needed to maintain a healthy stand of herbaceous vegetation.
- If a forested buffer, then the buffer should be maintained in an undisturbed condition, unless erosion occurs.
- If erosion of the buffer occurs, eroded areas should be repaired and replanted with vegetation similar to the remaining buffer. Corrective action should include eliminating the source of the erosion problem, and may require retrofit with a level spreader.
- Remove debris and accumulated sediment, based on inspection.

Education and Outreach

The target audience for this practice is developers and decision-makers involved with landscape-scale stormwater issues. Developers should be encouraged to include riparian buffers in the design for retrofit projects as well as to maintain existing buffers in undeveloped areas. Opportunities to present information about this practice include collaborative training and workshops and the green infrastructure (GI) incentive program. Decision-makers include city and county government officials who approve stormwater management plans. This group will be educated about riparian buffers through participation in the watershed team and stormwater management training. Education of officials is vital to preventing delays or difficulties in the permit approval process that may occur when GI practices are used in place of conventional practices. Property owners will be encouraged to use restored riparian buffers in model retrofit projects.

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Gully Repair

Description

Gullies are a severe form of erosion typically caused by concentrated water flow on erosive soils. Concentrated water flow may begin as minor sheet flow, produce rills, and eventually result in major gully formation. Due to the highly erosive nature of soils in the Reservoir watershed, gullies tend to form easily on any area of exposed soil. Gullies can have major impacts on an area by risking collapse of roads and taking land out of production. They are a major source of sediment. Once formed, gullies typically grow with time and will continue down-cutting until resistant material is reached. They also expand laterally as they deepen. Gullies often form at the outlet of culverts or cross-drains due to the concentrated flows and relatively fast water velocities. Gullies can form in forested areas along roads, if there are erosive soils or structures that cause concentrated water flow.

Design Considerations

The design needed to stabilize a gully depends on the size of the gully, soil types, and slopes. Small gullies can sometimes be managed and prevented from growing simply by establishing vegetation in the channel and along the side walls. Stabilizing small gullies shortly after they form is always simpler and less expensive than repairing large gullies. Stabilization of larger gullies typically requires removing or reducing the source of water flowing through the gully and refilling the gully with dikes, or small dams, built at specific intervals along the gully. Reshaping and stabilizing over-steep banks may also be needed.

Source: Mississippi Department of Environmental Quality

For large gullies, bioengineered stabilization structures are needed. These can be constructed of rock, gabions, logs, wood stakes with wire or brush, bamboo, or vegetative barriers. Bioengineering methods offer a combination of physical structure along with vegetative measures for physical protection as well as additional long-term root support and aesthetics. In large gullies, a headcut structure is sometimes needed to stabilize the upslope, or top-most portion of the gully, and prevent additional headward movement. Grade stabilization structures are typically used to prevent the formation and advancement of gullies in row crop and pasture areas.

Live gully repair is a method that alternating layers of live branch cuttings and compacted soil to repair small rills and gullies a maximum of 2 feet wide and 1 foot deep. This method involves planting live branch cuttings and compacted fill material.

Detailed design information (including a diagram) and requirements for gully repair are available in *Water Related Best Management Practices in the Landscape*. This publication is available from the Center for Sustainable Design and online at http://www.abe.msstate.edu/csd/NRCS-BMPs/pdf/streams/bank/livegully.pdf.

Implementation

- Urban areas (gullies often form near roads on areas with exposed soil and concentrated flows).
- Row-crop agriculture and pasture (gullies may form near areas with steep grades and disturbances of the soil).

Pollutant Removal Efficiency

Specific pollutant removal efficiencies of gully stabilization structures are not available. The pollutant loads reduced depend on the size of the gully and the nutrient content of the soil. A large gully in a row-crop or pasture area can contribute as much as 40 tons per acre per year of sediment.

Cost

The cost of repairing an individual gully is highly variable and project-dependent. NRCS cost-sharing programs are available for producers to repair gullies on their property.

Benefits

- Land area lost to gullies can be costly to producers and cause significant damage in urban areas.
- Reduces contributions of sediments and associated nutrients to downstream waterbodies.

Maintenance

- Inspect on a routine basis.
- Repair and re-vegetate as needed.

Education and Outreach

The target audiences for this practice are landowners who manage row-crop and pasture lands and local leaders who manage road construction and maintenance. It is up to the individual landowners to recognize the formation of gullies on their properties. Local leaders also need to be able to identify gullies and understand the methods of repairing them. Education targeted for these audiences should stress the need for prevention and early intervention, which will result in significantly lower costs than cost of repairing a major gully.

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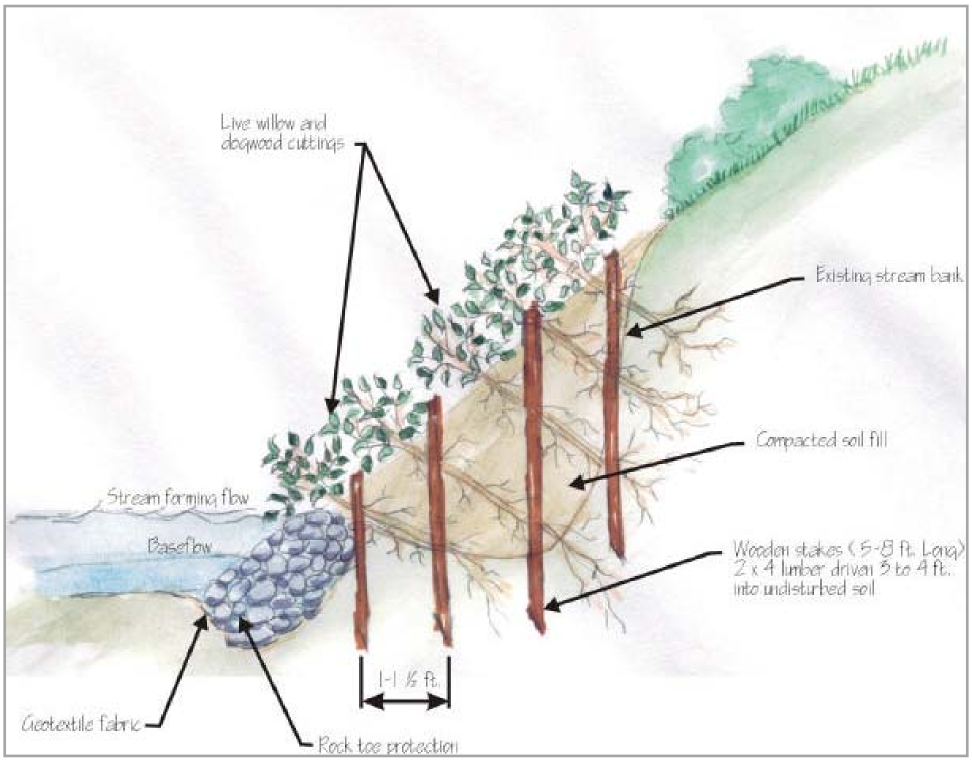
Branch Packings

Description

Branch packing is used to repair small, localized slumps and holes in streambanks. It consists of alternating layers of live branches and compacted backfill. Branches trap sediment that refills the localized slump or hole, while roots spread throughout the backfill and into the surrounding earth to form a unified mass.



Source: *Lake Wallenpaupack Homeowner Streambank and Shoreline Restoration Handbook*.

Design Criteria

Detailed design information and requirements for branch packings are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 1: Erosion and Sediment Control Manual. This publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Applications and Effectiveness

- Repairs slumps and holes in streambanks (ranging from 2 to 4 feet in height and depth and 4 feet in width) effectively and inexpensively.
- Retards runoff and reduces surface erosion and scour as plant tops begin to grow.
- Establishes a vegetated streambank rapidly.
- Enhances conditions for colonization of native vegetation.
- Provides immediate soil reinforcement.
- Serves as tensile inclusions for reinforcement once live branches are installed.

Applicability in Reservoir Watershed

- Areas where bank scouring is observed.
- Areas where minimal to no site disturbance is desirable.
- Areas where rapid establishment of riparian vegetation is desirable.
- Areas where low slope lengths are a limiting factor.

Cost

Material costs of branch packings are typically $5 per packing.

Maintenance

- Regular maintenance until vegetation is stabilized.
- Repair and maintenance as needed, typically after each significant storm event.

References

Information in the factsheet is adapted from:

Eubanks, C.E., and D. Meadows. 2002. *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization* [FS-683]. US Department of Agriculture Forest Service, Technology and Development Program. Accessed October 2011 at http://www.fs.fed.us/publications/soil-bio-guide/.

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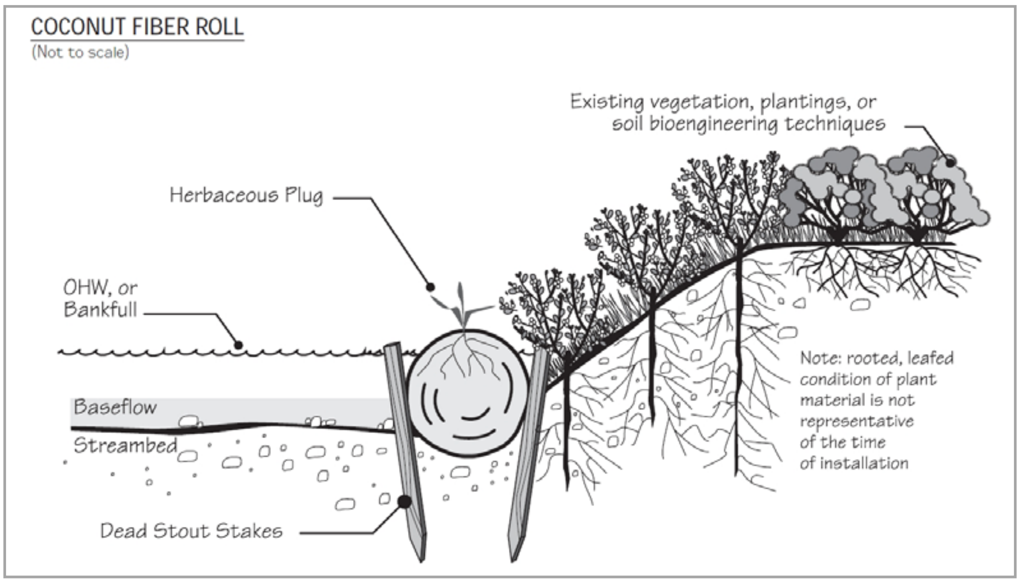
Coconut Fiber Rolls

Description

A coconut fiber roll (Coir™ log) is used to protect a bank's toe and to define its edge. It is a cylindrical structure composed of coconut husk fibers bound together with twine woven from coconut fiber. This product is most commonly manufactured with a diameter of 12 inches and a length of 20 feet. However, purchases of prefabricated rolls can be expensive. Stakes or duckbills can be used to anchor it in place at the toe of the slope, generally at the ordinary high-water mark or bankfull level.



Source: *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization*.

Source: *Lake Wallenpaupack Homeowner Streambank and Shoreline Restoration Handbook*.

Design Criteria

Detailed design information and requirements for coconut fiber rolls are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 1: Erosion and Sediment Control Manual. This publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Applications and Effectiveness

- Protects slopes from shallow slides or undermining.
- Molds to existing curvature of the streambank.
- Traps sediment in and behind the roll.
- Produces a well-reinforced toe without much site disturbance.
- Lasts an estimated 6 to 10 years (to be confirmed by manufacturer).

Applicability in Reservoir Watershed

- Areas where protection is desired above and below bankfull depth.
- Areas where grading is difficult; coconut fiber logs provide flexibility.
- Areas where minimal to no site disturbance is desirable.
- Areas where bank protection is required from shallow slides.
- Areas where low slope lengths are a limiting factor.

Cost

Coconut fiber logs cost approximately $0.30 to $0.75 per square foot.

Maintenance

- Regular maintenance until vegetation is stabilized
- Repair and maintenance as needed, typically after each significant storm event.

References

Information in the factsheet is adapted from:

Eubanks, C.E., and D. Meadows. 2002. *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization* [FS-683]. US Department of Agriculture Forest Service, Technology and Development Program. Accessed October 2011 at http://www.fs.fed.us/publications/soil-bio-guide/.

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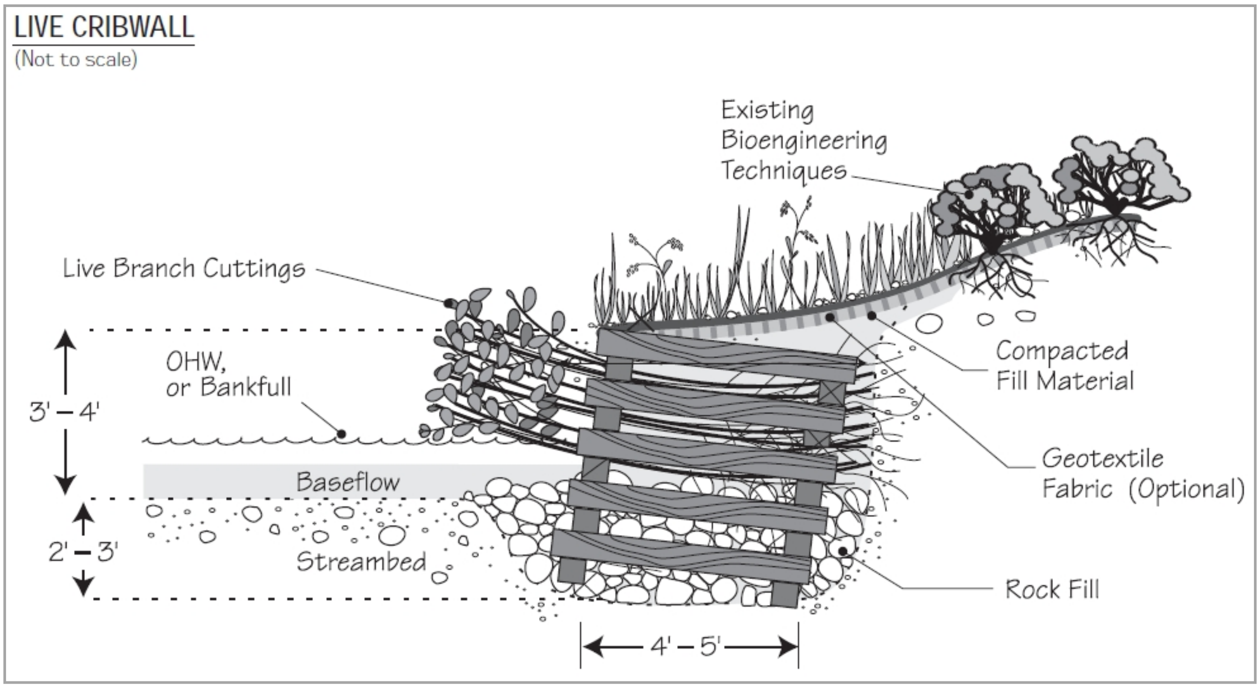
Live Crib Walls

Description

A live cribwall is used to rebuild a bank in a nearly vertical setting. It consists of a boxlike interlocking arrangement of untreated log or timber members. The structure is filled with rock at the bottom and soil beginning at the ordinary high water mark or bankfull level. Layers of live branch cuttings root inside the crib structure and extend into the slope. Once the live cuttings root and become established, vegetation gradually takes over the structural functions of the wood members.



Source: *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization.*

Design Criteria

Detailed design information and requirements for live crib walls are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 1: Erosion and Sediment Control Manual. This publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Applications and Effectiveness

- Appropriate at the base of a slope where a low wall may be required to stabilize the toe of the slope and to reduce its steepness.
- Appropriate above and below the water level where stable streambeds exist.
- Useful where space is limited and requires a more vertical structure.
- Useful in maintaining a natural streambank appearance.
- Useful for effective bank erosion control on fast flowing streams.
- Tilt back.
- Complex and expensive.
- Effective on outside bends of streams where strong currents are present.
- Effective in locations where an eroding bank may eventually form a split channel.
- Excellent habitat provider.
- Provides immediate protection from erosion and long-term stability.

Applicability in Reservoir Watershed

- Areas where immediate protective cover from the bank is required.
- Areas requiring protection of banks from shallow slides.
- Areas where space is limited, requiring rapid reestablishment of vegetation.

Cost

Live crib walls cost $13 to $33 per square foot.

Maintenance

- Regular maintenance until vegetation is stabilized.
- Repair and maintenance as needed, typically after each significant storm event.

References

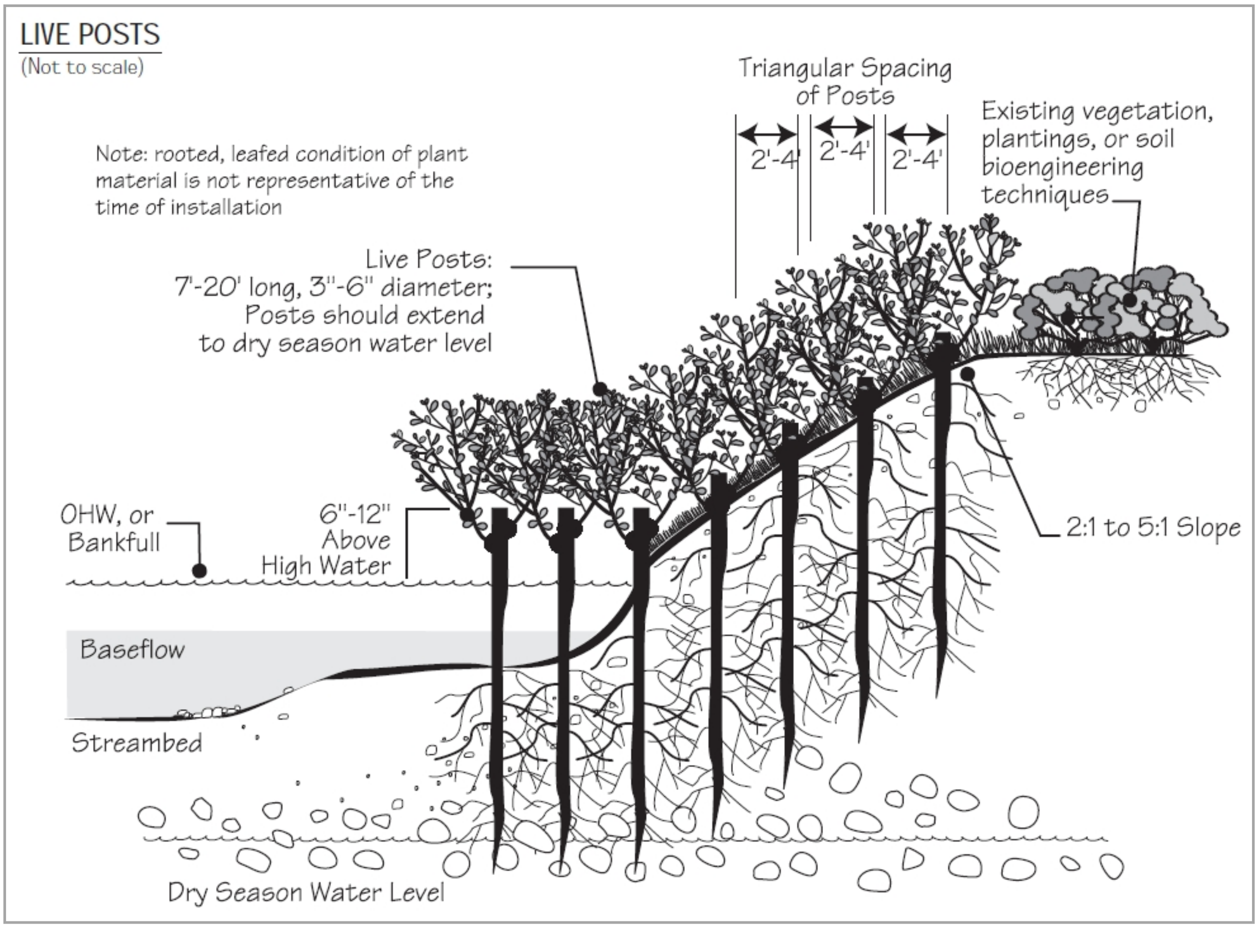
Information in the factsheet is adapted from:

Eubanks, C.E., and D. Meadows. 2002. *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization* [FS-683]. US Department of Agriculture Forest Service, Technology and Development Program. Accessed October 2011 at http://www.fs.fed.us/publications/soil-bio-guide/.

Live Posts

Description

Live posts form a permeable revetment. They reduce stream velocities and cause sediment deposition in the treated area. The roots help to stabilize a bank. Dormant posts are made of large cuttings installed in streambanks in square or triangular patterns. Unsuccessfully rooted posts at spacings of about 4 feet can also provide some benefits by deflecting higher stream flows and trapping sediment.



Source: *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization.*

Design Criteria

Detailed design information and requirements for live posts are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 1: Erosion and Sediment Control Manual. This publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Willow posts and stone toe protection. (Source: Hollis Allen, Mississippi Department of Environmental Quality.)

Applications and Effectiveness

- Well-suited to smaller non-gravel streams. If high flows and ice are a problem, they can be cut low to the ground.
- Used in combination with other soil bioengineering techniques.
- Installed by a variety of methods including water jetting or mechanized stringers (Hoag et al. 2001) to form planting holes or by driving the posts directly with machine-mounted rams.
- Quickly reestablishes riparian vegetation.
- Enhances conditions for colonization of native species.
- Repairs itself. For example, posts damaged by beavers often develop multiple stems.

Applicability in Reservoir Watershed

- Areas where treatment is required above and below bankfull depth.
- Areas where strong currents and high flows are expected.
- Areas where water level fluctuates.
- Areas where rapid reestablishment of vegetation is desired.
- Areas where reduced slope length and space are limiting factors.

Cost

Live posts cost $7 to $15 per linear foot.

Maintenance

- Regular maintenance until vegetation is stabilized.
- Repair and maintenance as needed, typically after each significant storm event.

References

Information in the factsheet is adapted from:

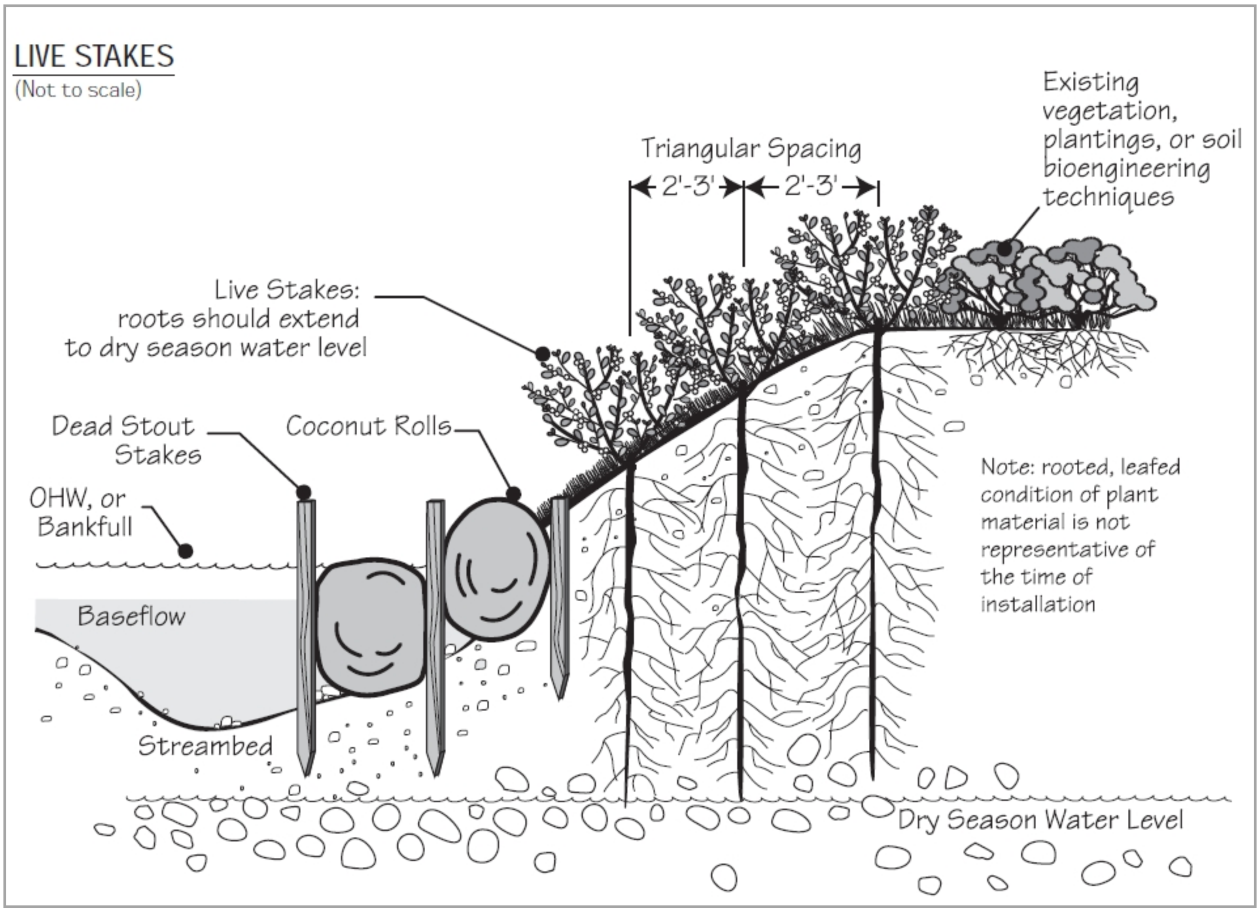
Eubanks, C.E., and D. Meadows. 2002. *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization* [FS-683]. US Department of Agriculture Forest Service, Technology and Development Program. Accessed October 2011 at http://www.fs.fed.us/publications/soil-bio-guide/.

Hoag, J.C., B. Simonson, B. Cornforth, and L. St. John. 2001. *Waterjet Stinger: a tool to plant dormant unrooted cuttings of willow, cottonwood, dogwood, and other species* [Technical Note Plant Materials No. 39]. US Department of Agriculture, Natural Resources Conservation Service. Boise, ID. 13 pp.

Live Stakes

Description

Live stakes create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Most willow species root rapidly and begin to dry out an excessively wet bank soon after installation. Live, rootable vegetative cuttings are inserted or tamped into the ground. If correctly prepared, handled, and placed the live stake will root and grow.



Source: *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization*.

Design Criteria

Detailed design information and requirements for live stakes are available in the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 1: Erosion and Sediment Control Manual. This publication is available from the Mississippi Department of Environmental Quality and online at http://www.deq.state.ms.us.

Willow trees placed as live stakes with stone toe protection. (Source: Hollis Allen, MDEQ.)

Applications and Effectiveness

- Suitable for use in the wetted zone of banks or where precipitation is likely to keep the soil moist during growing seasons.
- Provides a technique where site conditions are uncomplicated, construction time is limited, and an inexpensive method is needed.
- Repairs small earth slips and slumps that are frequently wet.
- Enhances the performance of geotextile fabric by serving as pegs to hold fabric down.
- Enhances conditions for natural colonization of vegetation from the surrounding plant community.
- Produces streamside habitat.
- Stabilizes areas among other bioengineering techniques, such as live fascines.

Applicability in Reservoir Watershed

- Areas where high wind and water velocities hit the banks.
- Areas where space is a constraint.

Cost

Live stakes cost $2 each.

Maintenance

- Regular maintenance until vegetation is stabilized.
- Repair and maintenance as needed, typically after each significant storm event.

References

Information in the factsheet is adapted from:

Eubanks, C.E., and D. Meadows. 2002. *A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization* [FS-683]. US Department of Agriculture Forest Service, Technology and Development Program. Accessed October 2011 at http://www.fs.fed.us/publications/soil-bio-guide/.

Reservoir Shoreline Restoration and the Impact of Waves on Water Quality

Description

Figure 1. Riparian buffer in Pelahatchie Bay.

Wave energy in the Reservoir is derived from two sources: wind-generated waves and boat-generated waves. Wind-generated waves are a function of wind velocity and fetch, the open distance across the Reservoir over which the wind blows unimpeded and along which waves can build energy. The depth of water that receives mixing as a result of wave action is approximately half the wave-length. Natural woody vegetation has been removed in many areas along the shoreline due to residential and recreational development.

Due to the shallow depths and long wind fetch in the Reservoir, wind-generated waves can be of significant concern because they resuspend sediments from the Reservoir bottom. The primary purpose of Reservoir shoreline restoration is to restore woody vegetation to reduce erosion from wave action and reduce wind fetch along the open water. Mature woody vegetation planted along cleared areas of the shoreline functions as a windbreak. Once established, a windbreak will slow the wind on the downwind side for a distance of approximately ten times the height of the tree canopy. This ground cover created by trees and associated debris also protects soil from rill and sheet erosion. Ground cover helps improve water quality by filtering excess nutrients and chemicals from surface runoff. Riparian buffers planted in trees also provide shade, resulting in temperature refuge for fish and other aquatic life.

Design Considerations

Landscaping or replanting locations must be selected and agreed upon by both the current lease holders and the Pearl River Valley Water Supply District (PRVWSD). The selected locations should also consider the prevailing wind direction in relation to the long axis of the Reservoir. The wind rose from the Jackson airport indicates that wind blows from the south to southeast approximately 26% of the time, and from the north to north-northwest approximately 14% of the time. A windbreak situated

Figure 2. Mill Creek at Spillway Road with no buffer.

perpendicular to the prevailing wind direction (running east to west or southwest to northeast on the Rankin County shoreline) would be the most effective.

Soil types on the Reservoir shoreline are characterized as highly erodible silt loam. Although there are currently no reported concerns of bank failures, replacing vegetation along the shoreline could improve bank stabilization and prevent future failures. Native species of shrubs and trees should be used for shoreline restoration. Native vegetation is adapted to survive in the climate and soil conditions of Mississippi and requires less maintenance (fertilizer, watering, etc.). Recommended vegetative plantings for the areas nearest to the shoreline include the following non-woody species: switchgrass (*Panicum virgatum*), cattail (*Typha* spp.), soft rush (*Juncus effusus* and *Juncus* spp.), soft stem bulrush (*Scirpus validus*), maidencane (*Panicum hemitomon*), and water willow (*Dianthera americana*). Suitable woody trees and shrubs are numerous and include willow (*Salix* spp.), cypress (*Taxodium distichum*), overcup oak (*Quercus lyrata*), pin oak (*Quercus palustris*), Nuttall oak (*Quercus texana*), red maple (*Acer rubrum*), sycamore (*Platanus occidentalis*), river birch (*Betula nigra*), water tupelo (*Nyssa aquatica*), green ash (*Fraxinus pennsylvanica*), and sweetbay magnolia (*Magnolia virginiana*). Suitable shrub species include buttonbush (*Cephalanthus occidentalis*), common alder (*Alnus serrulata*), elderberry (*Sambucus canadensis*), red chokeberry (*Aronia arbutifolia*), Virginia sweetspire (*Itea virginica*), deciduous holly (*Ilex decidua*), and nonflowering dogwood (*Cornus amomum* and *C. foemina*). Rose mallow (*Hibiscus moscheutos*) is a non-woody perennial that is shrub-like in appearance and provides large colorful flowers. Trees for areas farther away from the shoreline include all of those listed above; these tree species are especially tolerant of root flooding for long periods but will thrive further from the shoreline. The Mississippi State University Extension Service has developed the following excellent guides for selecting appropriate native vegetation: *Native Trees for Mississippi Landscapes* and *Native Shrubs for Mississippi Landscapes* (Brzuszek 2007a, 2007b).

Initially the smaller, faster-growing plants would establish the restored riparian buffer zone. These plants will be replaced by interspersed, slower-growing, taller species for an enhanced wind block. The smaller species should be thinned as necessary to accommodate the growth of taller trees.

Implementation

- Reservoir shoreline with little or no riparian buffer zone.
- Along tributaries near the Reservoir with little or no riparian buffer zone.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	60%
Total Nitrogen	30%
Total Phosphorus	35%

*Same as restored riparian buffer/vegetated buffer

Cost

The cost of riparian buffers ranges from low to almost negligible if established prior to site development. Typically, the most effective buffer is one that is left alone and in place. Therefore, there is no cost of establishment and the only monetary constraint may be that associated with an alternative site design that excludes these areas from development. However, the added aesthetic value of buffers easily translates to increased property values and often offsets such foregone costs. Furthermore, buffers reduce the size and cost of downstream control facilities. The cost of creating or restoring riparian buffer areas is highly variable and project-dependent.

Benefits

Maintaining or developing an attractive riparian zone can:

- Increase property values.
- Reduce excessive erosion.
- Protect water quality.
- Enhance wildlife habitat.
- Contribute to the natural beauty of the land.
- Dissipate noise from reservoir traffic, roads, and nearby properties.
- Reduce maintenance time and related costs.
- Provide privacy.
- Enhance scenic views.

Limitations

Buffers alone may not provide sufficient stormwater control to maintain flows at predevelopment levels. Buffers can typically handle smaller storms, but larger events can bypass the infiltration and treatment capability of the buffer and directly discharge runoff to streams. Therefore, additional stormwater and water quality control measures are often necessary within highly developed areas.

Some landowners may be resistant to establishing vegetation along the shoreline. Some concerns may include loss of views, limiting access to the water, and concerns that the vegetated area may attract unwanted wildlife.

Not all sites will support vegetation because of toxic soil conditions or insufficient soil moisture. Erosion must be controlled upgradient from the corridor before vegetation can be successfully established.

Maintenance

Only minimal maintenance is required for riparian buffers. Dead vegetation should be allowed to remain, as it provides terrestrial and eventually aquatic habitat. Soil disturbance and compaction and vegetation disturbance should be avoided. However, maintenance is required for the first 2 to 3 years so native vegetation can become established.

After they become established, native plants usually require much less physical effort to maintain than lawns. They can reduce or eliminate the need for lawn mowers, trimmers, and other gasoline-powered equipment. Native plants are also less costly to maintain because they generally don't need the fertilizers and pesticides that turf grass and other non-native species may require.

Education and Outreach

The limiting factor in the placement of restored riparian buffer zones in landowner participation, thus education activities for this management practices should be targeted towards owners of shoreline property. Landowners need to be made aware of the positive benefits of riparian buffer zones and the technical assistance needed to properly install them. Funding assistance to purchase and install the vegetation would be helpful to landowner adoption. An educational flyer, titled *Vegetated Buffers*, gives specific tips for homeowners about how to establish and maintain a shoreline buffer on their property.

References

Alcovy Watershed Protection Project. (no date.) "Riparian Buffers: A Technical Perspective." Accessed October 2011 at http://www.georgiaplanning.com/watertoolkit/Documents/WatershedPlanningTools/16_RiparianBuffersATP.pdf.

Brzuszek, R.F. 2007a. *Native Shrubs for Mississippi Landscapes* [Publication 2334]. Mississippi State University Extension Service, in cooperation with the US Department of Agriculture. Accessed October 2011 at http://msucares.com/pubs/publications/p2334.pdf.

Brzuszek, R.F. 2007b. *Native Trees for Mississippi Landscapes* [Publication 2330]. Mississippi State University Extension Service, in cooperation with the US Department of Agriculture. Accessed October 2011 at http://msucares.com/pubs/publications/p2330.pdf.

NRCS. (no date.) "Mississippi Online Soil Survey Manuscripts" [webpage]. US Department of Agriculture, Natural Resources Conservation Service. Online at http://soils.usda.gov/survey/online_surveys/mississippi/.

NRCS. 1996. "Chapter 16, Streambank and Shoreline Protection." *Part 650 - Engineering Field Handbook*. US Department of Agriculture, Natural Resources Conservation Service. Accessed October 2011 at http://policy.nrcs.usda.gov/17553.wba.

Beneficial Use of Dredge Material

Description

Dredged material is a potentially valuable resource if properly applied in a beneficial use. Significant value or benefit can be realized if proper planning and coordination exist between all parties involved. The suitability of dredged material for different uses varies; however, a wide variety of beneficial use options are available for consideration.

The Pearl River Valley Water Supply District (PRVWSD) removes significant amounts of dredged material from the Ross Barnett Reservoir each year. This material is currently disposed of in upland areas near dredge sites, marginal wetland areas, and in-reservoir disposal areas to create small islands and wildlife habitat. Identifying proper disposal sites for managers is a significant concern because dredging activities are expected to continue on a frequent basis.

Dredging operations in Pelahatchie Bay.

Design Considerations

Beneficial uses of dredged material can be classified in three broad categories: engineered uses, agricultural and product uses, and environmental enhancement. Possible beneficial uses for sediments in the Reservoir are listed below.

- Land creation and improvement.
- Berm creation.
- Shore protection.
- Topsoil for agricultural areas.
- Mine reclamation.
- Manufactured construction material.
- Wetland habitat improvement.

The selection of a beneficial use of dredge material removed from the Reservoir will depend on a number of factors:

- Grain size distribution.
- Contaminant status of materials.

- Technical feasibility (such as the distance that dredge material would need to be pumped).
- Cost/benefit and legal constraints.

Huge amounts of sediment could be pumped or conveyed to areas onshore and stockpiled until used for landscaping soil, fill, or other purposes. It is possible that it may be built into large mounds and planted with trees or grasses until needed.

Pollutant Removal Efficiency

Pollutant removal efficiency cannot be estimated. However, one would expect a reduction of total suspended solids (TSS) released to the Reservoir from marginal disposal sites.

Cost

The cost of beneficial use projects is project- and site-specific. Some federal funding programs administered by the US Environmental Protection Agency (EPA) are available for cost-share. Other options are available to develop local sources of funding. Details of these programs are described in *Identifying, Planning, and Financing Beneficial Use Projects: Beneficial Use Planning Manual* (EPA and US Army Corps of Engineers [USACE] 2007).

Benefits

- Project cost savings.
- Habitat improvement.
- Enhanced recreational opportunities.
- Agricultural improvement.

Limitations

- Sediments need to be analyzed for toxic content prior to use.
- Costs to transport the sediments would have to be weighed against the benefits.
- Requires logistical coordination between the dredging of material and placement in the beneficial use.

Education and Outreach

The initial decision to pursue beneficial uses for dredge material and initiate project partners would be made by reservoir managers. The success of a beneficial use project often depends on the public's perception of the project's purpose and its impacts on human health, property values, and the environment. Thus, interested stakeholders should be included in the decision making process. The following recommendations are included in *Identifying, Planning, and Financing Beneficial Use Projects: Beneficial Use Planning Manual* (EPA and USACE 2007).

- Involve the public from the outset. Go to the public; do not wait for the public to come to you.

- Identify and respond to issues of local concern.
- Understand the decision-making process and schedule to identify points of public access.
- Make it clear how the public's input will be used.
- Use a variety of methods to inform and involve segments of the public with different levels of interest.
- Involve representatives of the public in project decision making.

References

Information in the factsheet is adapted from:

EPA and USACE. 2007. *Identifying, Planning, and Financing Beneficial Use Projects: Beneficial Use Planning Manual* [EPA842-B-07-001]. US Environmental Protection Agency and US Army Corps of Engineers. Accessed October 2011 at http://el.erdc.usace.army.mil/dots/budm/pdf/PlanningManual.pdf.

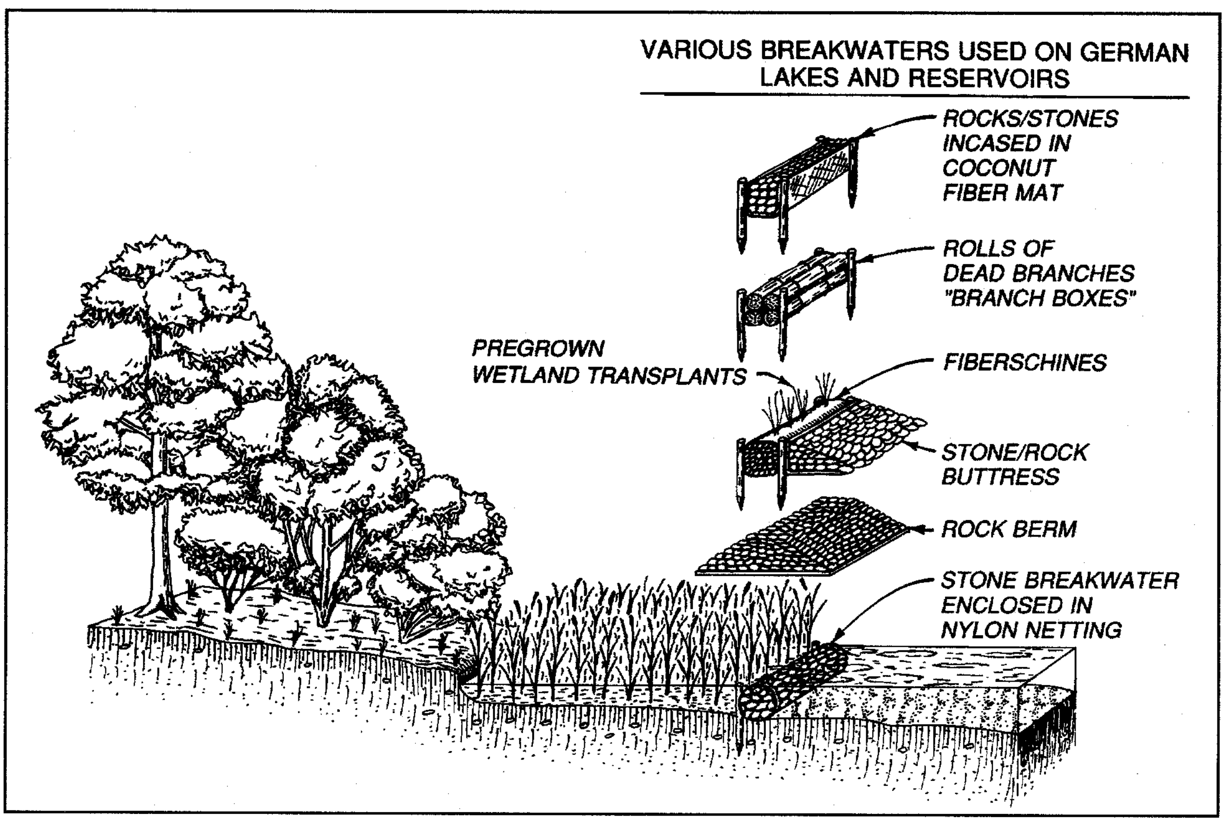
US Army Corps of Engineers. 2006. "Beneficial Uses of Dredged Material." Accessed October 2011 http://el.erdc.usace.army.mil/dots/budm/intro.cfm?Topic=Intro.

Artificial Wetlands for Shoreline Stabilization

The information in this fact sheet is summarized from *__Bioengineering Technique Used for Reservoir Shoreline Erosion Control in Germany__* *[WRP Technical Note WG-SW-3.1]. Point of contact is Mr. Hollis Allen (formerly with the US Army Corps of Engineers Waterways Experiment Station, now with the Mississippi Department of Environmental Quality).*

Description

This management practice involves the installation of a biodegradable breakwater with wetlands planted between the breakwater and the shore. Naturally occurring materials, including woody trees such as willow, cottonwood, and alder, can be used to construct the breakwater. This method is applicable to reservoirs that do not have significant water level fluctuation. Thus, it could be used in the Ross Barnett Reservoir. Development of wetlands near the shoreline would stabilize the shoreline, act as a filter for nutrients and suspended sediments in overland runoff, and provide wildlife habitat. Although shoreline failure has not been identified as a particular concern in the Reservoir, breakwater and artificial wetlands would protect the shoreline from erosion due to waves and prevent future issues.



Source: *Bioengineering Technique Used for Shoreline Reservoir Erosion Control in Germany*.

Design Considerations

The technique includes a combination of a breakwater and planted wetlands. The breakwater can be constructed from various materials, including stone or rocks, branches and poles, or fiberschines (large coconut fiber rolls). The branchbox breakwater is one of the more commonly used structures. It which consists of biodegradable materials composed of long poles and faschines (bundles of small dead branches, such as willow and poplar, collected from woodlands). The breakwater is usually constructed at a water depth of 1 meter. Construction of this type of breakwater is described in detail in the referenced WRP Technical Note WG-SW-3.1. Wetland plants can be pre-grown in a coconut fiber substrate and transferred to the site after the breakwater is constructed. Coconut fiber substrate allows for short-term shore stabilization until the vegetation becomes established. Recommended plants for the Reservoir include bulrushes (*Scirpus* spp.), water willow (*Dianthera americana*), horsetail (*Equisetum* spp.), iris (*Iris* spp.), pickerel weed (*Pontederia cordata*), rushes (*Juncus* spp.), powdery thalia (*Thalia dealbata*), and other water-loving herbaceous plants in addition to buttonbush (*Cephalanthus occidentalis*), a woody shrub species.

Implementation

- Shoreline areas with suitable depth and light conditions, in areas at risk for future bank failure.

Pollutant Removal Efficiency

No information is available to estimate pollutant removal efficiency. Expected performance would depend on site-specific conditions.

Cost

A cost estimate for the wetland system from 1991, including the branchbox breakwater, the wetland plants installed as pallets and bulbs, and the coconut-fiber filter fabric, was between $400 and $460 per linear meter for a 10- to 20-meter swath from the breakwater landward.

Benefits

- Low-cost erosion control without destroying the existing shoreline habitat.
- Wetlands trap sediment and remove nutrients.
- Aesthetic improvement.

Limitations

- Damage to the breakwater structure may result in the loss of wetlands.
- Breakwater/wetland systems will not work if water fluctuations exceed 1 meter.

Maintenance

- Inspect every few months until the wetland vegetation becomes established, then at least annually after that.
- Repair the breakwater structure as needed.

Education and Outreach

Reservoir managers would need to be aware of this practice and be able to identify potential sites for installation. If this practice is installed near areas with public access via boats or shoreline, members of the public need to be instructed not to disturb the wetland plants or damage the breakwater. Restoration sites should be marked with appropriate signs with these instructions.

References

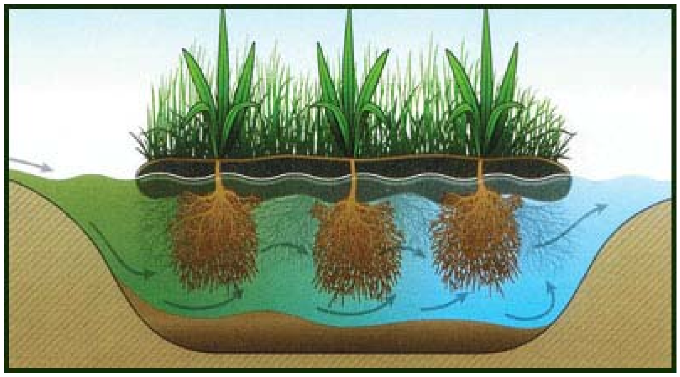
Information in the factsheet is adapted from:

Brzuszek, R.F. 2010. "Home Landscape in Mississippi" (fact sheet). Published by the Mississippi Agricultural and Forestry Experiment Station and the Mississippi State University Extension Service. Accessed October 2011 at http://msucares.com/lawn/landscape/sustainable/runoff.html.

US Army Corps of Engineers. 1992. *Bioengineering Technique Used for Reservoir Shoreline Erosion Control in Germany* [Wetlands Research Program Technical Note WG-SW-3.1]. US Army Corps of Engineers, Waterways Experiment Station. Point of contact is Mr. Hollis Allen. Accessed October 2011 at http://el.erdc.usace.army.mil/wrtc/wrp/tnotes/wgsw3-1.pdf.

Artificial Floating Islands (Schwimmkanmpen Islands)

Description



Source: Floating Island Environmental Solutions

Floating islands consist of modules that are planted with wetland plants and float within a body of water. The islands can take various shapes and consist of a planting substrate made of granular fibers, cork, or other materials. Wetland plants such as iris, sedges, rushes, or pickerelweed are planted within the substrate. The planting substrate supported by a frame made of plastic or other material that is resistant to corrosion, aging due to sunlight, and destruction by pests. Once placed in the water, the islands float on the surface. Vegetation typically becomes fully established in 2 years.

Artificial floating islands were first used in Germany where they were called "Schwimmkanmpen" islands (loosely translated as floating grassland areas). Presently, there are several commercial companies in the United States that manufacture floating islands.

Design Considerations

Floating islands are made of lightweight, corrosion-proof plastics. The islands are planted with native wetland plants, including iris, sedges, rushes, pickerelweed, and arrow arum. Under the surface, the plant's roots extend through the planting substrate and into the water. The plant roots and microbes that develop around them remove nutrients from the water. Floating islands must be moored to the bottom or shoreline. Mooring systems may include poles, buoys, anchors, ropes, chains, and weights.

Implementation

- Floating islands could be used in coves or other protected areas of the Reservoir. Placing them in open water is not recommended because they could restrict boat movement.
- Manufacturers of floating islands claim that they can be used to improve quality in small ponds and wet stormwater detention ponds. They have also been used to enhance existing wetlands.

Pollutant Removal Efficiency

A commercial manufacturer states that floating islands can remove more than 10 grams of total nitrogen per square foot per year and 0.7 gram of total phosphorus per square foot per year. These rates are based on information from one manufacturer.

Cost

Commercial manufacturers in the United States sell the islands for $35 per square foot. This cost does not include shipping, planting mix, installation, plants, or mooring.

Maintenance

- No maintenance is required once the islands are deployed unless they are vandalized.

Benefits

- Erosion and shoreline protection:
  - When placed near the shoreline, the islands can protect sensitive banks by reducing the energy of waves.
  - Can serve as a "wind break" by reducing wind fetch.
- Water quality improvement through biological uptake of nutrients.
- Improved landscape features.
- Improved wildlife habitat.

Limitations

- Boaters in the Reservoir would need to be aware of the islands and refrain from disturbing them.
- The floating islands could cause damage to boats or docks if they break free from the moorings.

Education and Outreach

The initial decision to pursue the installation of floating islands in the Reservoir would be made by Reservoir managers. Funding would be needed for design and installation of the islands. A small demonstration of the use of the islands should be considered to analyze the cost versus the benefits of this measure. If installed, the public would need to be aware of them and their use as a water quality improvement measure. This could be included in the public outreach campaign.

References

Information in this factsheet is adapted from:

Floating Island Environmental Solutions. (no date.) Floating Islands Environmental Solutions Home Page. Accessed October 2011 at http://www.floatingislandes.com.

Floating Island International. (no date.) “Biohaven Technology” [web page]. Accessed October 2011 at http://www.floatingislandinternational.com/products/biohaven-technology.

Hoeger, S. 1988. Schwimmkampen: Germany’s artificial floating islands. *Journal of Soil and Water Conservation* 43(4):304-306. July-August 1988.

Construction Stormwater and Surface Mine BMP Enforcement

Description

The Ross Barnett Reservoir Stormwater Compliance Initiative is tracking issues with large construction sites and surface mines in areas near the Reservoir with rapid commercial and residential development. Activities of the Stormwater Compliance Initiative have significantly increased the Mississippi Department of Environmental Quality's (MDEQ) presence in the watershed with the following activities.

- Additional review of stormwater management plans for new developments.
- Frequent informal surveys of the area and increased "official" compliance inspections.
- Increased enforcement actions.

Source: MDEQ.

Implementation

- Urban retrofit.
- New development.

Pollutant Removal Efficiency

MDEQ inspectors have conducted a significant number of Compliance Evaluation Inspections (CEIs) at sites in the Ross Barnett Reservoir with large construction stormwater general permits. In addition, MDEQ conducted "windshield surveys" to document the condition and effectiveness of management practices before, during, and after storm events. Pollutant loads for properly versus improperly functioning management practices were not quantified. Literature values must be used to estimate the overall effectiveness of best management practice (BMP) systems installed on a construction or surface mine site (Edwards 2003).

- Sites with <u>insufficient</u> BMPs averaged 11,000 mg/L total suspended solids (TSS) in runoff.
- Sites with <u>sufficient</u> BMPs averaged 600 mg/L TSS in runoff.

CEIs conducted in 2008 through 2010 found violations at 20 of the 38 sites inspected (53% of the sites). According to MDEQ personnel, the majority of these violations have been corrected, and developers have improved BMP installation and maintenance. It can be assumed that less than 10% of construction and mine sites will have insufficient BMPs if the program continues with the same level of effort.

Cost

Costs for MDEQ include personnel involved in the Ross Barnett Reservoir Stormwater Compliance Initiative, as well as time and equipment for inspections and follow-up enforcement actions.

Costs for developers include the design, installation, and maintenance of practices according to MDEQ requirements. This will vary based on the characteristics of each site (weather conditions, soil conditions, slopes, existing vegetation).

Benefits

- Reduced sediment, nutrients, and other pollutants in construction site and surface mine runoff.
- Improved understanding of the importance of BMPs among developers and contractors.
- Improved relationships among local stormwater enforcement officials and developers/contractors.

Limitations

- Site inspections are time-consuming.
- Inspections not conducted on construction sites smaller than 1 acre.

Maintenance

Efforts in the past few years have resulted in improved compliance among developers. MDEQ personnel feel as if many of the previously identified "hot spots" have been addressed. Continued presence of MDEQ personnel will be important when development increases with an improved economy.

References

More information pertaining to construction stormwater and surface mine BMP enforcement is available in *Mississippi's Phase II Small Municipal Separate Storm Sewer System (MS4) Guidance Manual* and the *Planning and Design Manual for the Control of Erosion, Sediment, and Storm Water*, Volume 1: Erosion and Sediment Control Manual. These publications are available from MDEQ and online at http://deq.state.ms.us/MDEQ.nsf/page/epd_epdgeneral?OpenDocument and http://www.deq.state.ms.us, respectively.

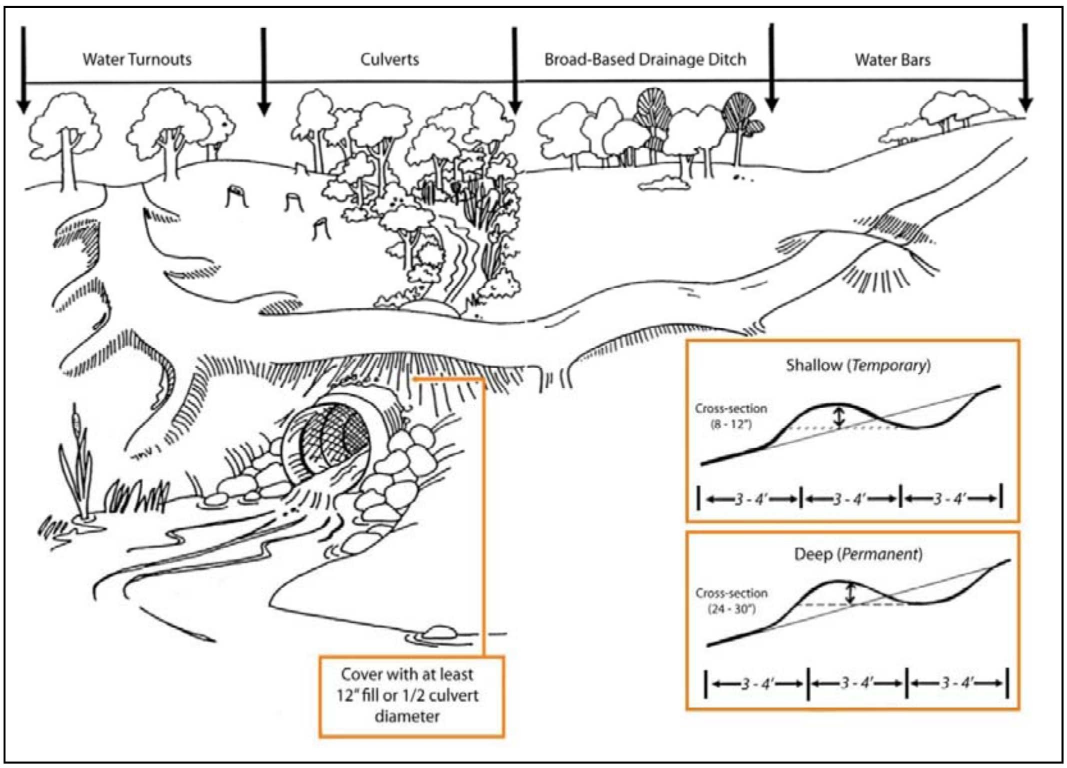
Information in this factsheet is adapted from:

Edwards, FG. 2003. *Stormwater Pollution Prevention BMP Workshop, Demonstration, and Evaluation, Project 700 FY01 CWA Section 319(h), Final Report*. University of Arkansas, Department of Civil Engineering. Prepared for the Arkansas Soil and Water Conservation Commission.

Properly Designed Skid Trails and Landings

Description

Forest management and harvest entails construction of skid trails, haul roads, stream crossings, and landings and concentration yards. All of this construction can increase erosion and sediment loading to forest land streams and downstream waterbodies. To reduce the potential for these water quality impacts, guidelines have been developed for siting, constructing, maintaining, and closing trails, roads, and landings. These guidelines also include recommendations for structural erosion control measures, including cross drains, water turnouts, slash dispersal, revegetation, silt fences and hay bales, water bars, outslopes, broad-based drainage ditches, and bank stabilization.



Source: *Mississippi's BMPs: Best Management Practices for Forestry in Mississippi* (MFC 2008).

Design Considerations

- Recommendations differ slightly for temporary and permanent trails, roads, and stream crossings.
- When forest operations occur in wetlands, best management practices (BMPs) related to trails and roads are federally mandated.

- Slope of the land and soil characteristics influence recommendations for siting, construction, maintenance, closing and BMPs for trails, roads, stream crossings, and landings.
- The grade of the trail or road influences BMP specifications.
- Siting of trails, roads, and landings should be such that they efficiently serve their intended purpose, and facilitate adequate control of runoff, erosion, and sedimentation.
- Detailed design information and requirements for skid trails and landings are available in *Mississippi's BMPs: Best Management Practices for Forestry in Mississippi*. This publication is available from the Mississippi Forestry Commission (MFC) and online at http://www.mfc.ms.gov/water-quality.php.

Implementation

- Private and commercial timberlands.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	24% to 99%, depending on practice and site characteristics
Total Nitrogen	60% to 80%
Total Phosphorus	85% (will be similar to TSS reduction)
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Applicability in Reservoir Watershed

Approximately 30% of the watershed is forest land that may be harvested.

Cost

The Mississippi Natural Resources Conservation Service (NRCS) estimates costs for forest harvest trails and landings as between $480 and $780 per acre for the 2011 Environmental Quality Incentives Program (EQIP). In the southeast, trail and landing BMPs have been estimated to add approximately $12 per acre to harvest costs (1987 dollars).

Benefits

- Slows runoff velocities.
- Reduces erosion.
- Reduces pollutants in runoff.

Limitations

- Can increase cost of harvest.
- May result in longer and/or less efficient skid trail or haul road routes.
- May result in less convenient locations for landings or concentration yards.
- Changes in harvesting costs can increase timber prices.

Maintenance

Erosion control BMPs need to be routinely inspected and repaired and cleaned of debris as needed.

References

Information in the factsheet is adapted from:

Cubbage, F.W. 2004. Costs of forestry best management practices in the south: A review. *Water, Air, and Soil Pollution: Focus* 4(1):131-142.

Edwards, P.J. and K.W.J. Willard. 2010. Efficiencies of forestry best management practices for reducing sediment and nutrient losses in the eastern United States. *Journal of Forestry* 108(5):245-249. July/August 2010.

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Mississippi Forestry Commission. 2008. *Mississippi's BMPs: Best Management Practices for Forestry in Mississippi, Fourth Edition* [MFC Publication No. 107]. Mississippi Forestry Commission. Available online at http://www.mfc.ms.gov/pdf/Mgt/WQ/Entire_bmp_2008-7-24.pdf.

Streamside Management Zones

Description

Streamside vegetation and soils act as buffer zones and have a strong influence on the health of adjacent aquatic systems. Streamside management zones (SMZs) protect water quality by providing bank stability and acting as a filter for sediment, nutrients, and other chemicals. Requirements for forestry activities within the SMZ are designed to reduce the potential for damage to stream channels due to tree removal and road crossings. The SMZ should provide sufficient canopy cover to maintain shade, protect the streambank, and filter pollutants from stormwater.

Design Considerations

- Recommended SMZ width based on whether the waterbody is a perennial or intermittent stream, or a wetland.
- Because the outflow of Ross Barnett Reservoir is a perennial stream, the recommended SMZ width for the reservoir shoreline is the same as for a perennial stream.
- Soil characteristics and slope of the land adjacent to the waterbody affect recommended SMZ width.
- SMZs are not required for drains (ephemeral streams and gullies).

Source: *Alabama's Best Management Practices for Forestry (Alabama Forestry Commission 2007).*

- Some forestry activities recommended for the SMZ vary based on whether the waterbody is a perennial or intermittent stream, or a wetland.
- Detailed design information and requirements for streamside management zones are available in *Mississippi's BMPs: Best Management Practices for Forestry in Mississippi*. This publication is available from the Mississippi Forestry Commission (MFC) and online at http://www.mfc.ms.gov/water-quality.php.

Implementation

- Private and commercial timber lands.

Pollutant Removal

Pollutant	Efficiency
Total Suspended Solids (TSS)	50% to 98%
Total Nitrogen	0% to 80%
Total Phosphorus	18% to 86%
Pathogens (coliform, *E. coli*)	Forestry practices are not generally considered to be significant sources of pathogen loads to waterbodies.

Cost

The cost of SMZs is usually estimated based on the value of unharvested timber in the SMZ. At least one estimate also included cost of added skid distance.

Benefits

- Slows water velocities.
- Low maintenance requirements.
- Supplies shade.
- Reduces pollutants in runoff.
- Provides wildlife corridor.
- Provides wildlife habitat.
- Provides species diversity.
- Stabilizes banks.
- Reduced timber harvest which can increase value of harvested timber.

Limitations

- Reduces harvest area.
- May result in longer and/or less efficient skid trail or haul road routes.
- May result in less convenient locations for landings or concentration yards.
- Increases total cost of harvest.
- Changes in harvesting costs can increase timber prices.

Maintenance

Involves keeping track of activities occurring in the SMZ, and may include posting and personnel education.

References

Information in this factsheet is adapted from:

Alabama Forestry Commission. 2007. *Alabama's Best Management Practices for Forestry*. Alabama Forestry Commission in cooperation with the Alabama Department of Environmental Management and the US Environmental Protection Agency. Accessed October 2011 at http://www.forestry.state.al.us/BMPIndex.aspx?bv=2&s=1.

Cubbage, F., and P. Lickwar. 1991. *Estimating the Costs of Water Quality Protection on Private Forest Lands in Georgia* [Georgia Forest Research Paper No. 86]. Georgia Forestry Commission, Research Division.

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Kluender, R., R. Weih, M. Corrigan, and J. Pickett. 1997. Assessing the cost of best management practices in Arkansas. *Journal of the Arkansas Academy of Science* 51:103-108.

LeDoux, C.B. 2006. Assessing the opportunity cost of implementing streamside management zone guidelines in eastern hardwood forests. *Forest Products Journal* 56(6):40-44.

Mayer, P.M.; S.K. Reynolds, Jr.; T.J. Canfield; and M.C. McCutchen. 2005. *Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations* [EPA/600/R-05/118]. US Environmental Protection Agency, Office of Research and Development, National Risk Management Laboratory. Ada, OK.

Mississippi Forestry Commission. 2008. *Mississippi's BMPs: Best Management Practices for Forestry in Mississippi, Fourth Edition* [MFC Publication No. 107]. Mississippi Forestry Commission. Available online at http://www.mfc.ms.gov/pdf/Mgt/WQ/Entire_bmp_2008-7-24.pdf.

Wenger, S. 1999. *A Review of Scientific Literature on Riparian Buffer Width, Extent, and Vegetation*. University of Georgia, Institute of Ecology, Office of Public Research and Outreach. Athens, GA. Revised Version, March 5, 1999. 59 pp.

Artificial Vegetation Regeneration

Description

The Mississippi Forestry Commission (MFC) recommends replanting of erodible, disturbed sites to stabilize soil when the natural regrowth process would be inadequate. In disturbed wetland areas, replanting is recommended to preserve wetland vegetation and prevent conversion of the wetland to a non-wetland.

Design Considerations

Source: USDA Forest Service.

- Site preparation may be necessary where soils are compacted, or undesirable plant species are present.
- Soil amendment may be necessary where soils are inadequate to support vegetation.
- Mulching improves erosion control while vegetation is becoming established.
- MFC recommends replanting with native wetland vegetation in disturbed wetland areas.
- Species recommendations vary depending on the site conditions and the time of year.
- Machine- or hand-planting can be used.
- In wetland areas, appropriate herbicides can be used to control competing plant species.
- Detailed design information and requirements for artificial vegetation regeneration are available in *Mississippi's BMPs: Best Management Practices for Forestry in Mississippi*. This publication is available from the Mississippi Forestry Commission and online at http://www.mfc.ms.gov/water-quality.php.

Implementation

- Commercial and private timber lands.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	12% - 100%
Total Nitrogen	Insufficient data
Total Phosphorus	12% - 100% sorbed to sediment
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Applicability in Reservoir Watershed

Approximately 30% of the watershed is in forest land. The percentage of that which is harvestable forest land is currently unknown.

Cost

Reported costs for planting range from $23 per acre to approximately $150 per acre for seeding (1998 dollars). Some mulching options can cost over $5,000 per acre (1998 dollars).

Benefits

- Reduced erosion.
- Reduced pollutants in runoff.

Limitations

- Effectiveness depends on maintaining the protective vegetation cover.

Maintenance

- Regeneration sites will be regularly inspected for signs of erosion, and repaired as needed.
- Wetland regeneration sites will be inspected regularly for signs of undesired vegetation.
- Undesired vegetation will be controlled.

References

Information in the factsheet is adapted from:

Bethlamy, N., and W.J. Kidd, Jr. 1966. *Controlling Soil Movement from Steep Road Fills* [USDA Forest Service Research Note INT-45]. US Department of Agriculture, Forest Service.

EPA. 2005. *National Management Measures to Control Nonpoint Source Pollution from Forestry* [EPA 841-B-05-001]. US Environmental Protection Agency, Office of Water. Washington, DC. Accessed October 2011 at http://water.epa.gov/polwaste/nps/forestry/forestrymgmt_index.cfm.

Mississippi Forestry Commission. 2008. *Mississippi's BMPs: Best Management Practices for Forestry in Mississippi, Fourth Edition* [MFC Publication No. 107]. Mississippi Forestry Commission. Available online at http://www.mfc.ms.gov/pdf/Mgt/WQ/Entire_bmp_2008-7-24.pdf.

Fencing for Grazing Control

Description

Temporary or permanent fencing is installed to exclude livestock from sensitive areas likely to be damaged by grazing, or to create paddocks that can be managed to control the harvest of pasture forage.

Design Considerations

Source: National Fish and Wildlife Foundation website.

- Type of fencing depends on the kind and habits of livestock, and whether the fence line is to be permanent or temporary.
- Soil characteristics and slope of the land can affect the ability of the pasture to withstand grazing pressure.
- Grazing in riparian areas is not recommended when streambanks are eroding, or when conditions are too wet.
- Detailed design information and requirements for fencing for grazing control are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Private and commercial pasture lands.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	Insufficient data
Total Nitrogen	Insufficient data
Total Phosphorus	Insufficient data
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Cost

The Mississippi NRCS 2011 Environmental Quality Incentives Program (EQIP) payment schedule lists costs for fencing at less than 1$ to over 3$ per linear foot, and costs for prescribed grazing at $80 to $180 per acre.

Applicability in Reservoir Watershed

Approximately 12% of the watershed is in pasture.

Benefits

- Improved pasture forage condition.
- Improved pasture soil condition.
- Increased livestock productivity.
- Improved livestock health.
- Reduced feed costs.
- Reduced bank erosion and land loss.
- Reduced sediment, nutrient, and pathogen loads to stream.
- Managed grazing can reduce use of herbicides and/or fertilizers.

Limitations

- Fencing cost may increase production cost.
- Managed grazing can be more work than continuous grazing.

Maintenance

Maintenance involves keeping the fence in good repair and keeping the fence line clear of weeds and brush.

References

Information in this factsheet is adapted from:

Agouridis, C.T., S.R. Workman, R.C. Warner, and G.D. Jennings. 2005. Livestock grazing management impacts on stream water quality: A review. *Journal of the American Water Resources Association* 41(3):591-606.

National Fish and Wildlife Foundation. (no date.) "Rotational Grazing" [web page]. Accessed October 2011 at http://www.nfwf.org/Content/NavigationMenu/ChesapeakeBayStewardshipFund/ConservationResults/AgriculturalConservation/RotationalGrazing/default.htm.

NRCS. (no date.) *Rankin County Field Office Technical Guide*. Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

NRCS. 2010. *FY 2011 EQIP HU Payment Schedule*. Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

Alternative Water Sources for Pastures

Description

Alternative water sources are provided to lure cattle away from pasture streams. Cattle in streams physically destroy stream habitat, increase sediment load by de-stabilizing stream channels and banks, and increase nutrient and pathogen loads by defecating in the stream.

Design Considerations

Source: Research Planning, Inc. website.

- Design of watering device depends on the type and habits of the livestock and their daily water requirements, weather, and the water sources available.
- Location of watering devices can be used to promote more even grazing and protect sensitive areas.
- Location of watering devices may be influenced by the location of the alternative water source.
- In hot weather, cattle are likely to use streams for cooling, so it may be necessary to provide shade as well as drinking water sources away from streams to effectively reduce the time cattle spend in streams.
- Detailed design information and requirements for fencing for grazing control are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Private and commercial pasture lands.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	30% - 90%
Total Nitrogen	15% - 54%
Total Phosphorus	22% - 81%
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Applicability in the Reservoir Watershed

Approximately 20% of the watershed is in the pasture. Thus, there are many miles of pasture streams in the watershed that may benefit from alternative water sources.

Cost

The Mississippi NRCS 2011 Environmental Quality Incentives Program (EQIP) payment schedule lists costs for watering facilities ranging from approximately $80 to over $500 each.

Benefits

- Improved herd health – wet muddy conditions increase risk of a number of livestock illnesses, as well as foot and leg injuries from slipping.
- Reduced exposure of livestock to water-borne disease organisms.
- Better quality drinking water for livestock.
- Good public relations.
- Improved habitat for fish.
- Improved and/or increased wildlife habitat along stream corridor.
- Reduced flood frequency.
- Improved groundwater recharge.
- Reduced bank erosion and land loss.
- Reduced sediment, nutrient, and pathogen loads to stream.

Limitations

- Alternative water source may be more expensive, increasing operating costs.
- Without other options, cattle will wade and wallow in streams to cool off during hot weather.

Maintenance

Maintenance involves keeping the watering devices in good repair.

References

Information in this factsheet is adapted from:

Agouridis, C.T., S.R. Workman, R.C. Warner, and G.D. Jennings. 2005. Livestock grazing management impacts on stream water quality: A review. *Journal of the American Water Resources Association* 41(3):591-606.

Dillaha, T.A., T.W. Simpson, and S.E. Weammert. 2007. *Off-Stream Watering with Fencing and Off-Stream Watering without Fencing Practices: Definitions and Nutrient and Sediment Reduction Efficiencies. For Use in Calibration and Operation of the Chesapeake Bay's Phase 5.0 Program Watershed Model.* Chesapeake Bay Program. Accessed October 2011 at http://archive.chesapeakebay.net/pubs/bmp/Year_1_Reports/Offstream%20Watering.pdf.

Line, D.E. 2003. Changes in a stream's physical and biological conditions following livestock exclusion. *Transactions of the American Society of Agricultural and Biological Engineers* 46(2):287-293.

NRCS. (no date.) *Rankin County Field Office Technical Guide.* Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

NRCS. 2010. *FY 2011 EQIP HU Payment Schedule.* Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

Research Planning, Inc. (no date.) "Environmental and Coastal Resources Management; Water Resource Analysis, Modeling and Management; Nonpoint Source Pollution Identification and Mitigation" [web page]. Accessed October 2011 at http://www.researchplanning.com/services/envir/watershed/dhec319.html.

Sheffield, R.E., S. Mostaghimi, D.H. Vaughan, E.R. Collins Jr., and V.G. Allen. 1997. Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. *Transactions of the American Society of Agricultural and Biological Engineers* 40(3):595-604.

Row-Crop Residue Management

Description

This practice involves managing the amount, orientation, and distribution of crop and other plant residues on the soil surface year-round. A variety of planting and tilling practices can be applied as part of residue management, including mulch till, no-till, strip till, and ridge till.

Design Considerations

Source: Torbert, Ingram, and Prior 2007.

- Where reduction of erosion is a goal of residue management, the tillage system will be determined based on the soil loss objective using an approved erosion prediction technology.
- Combines or similar harvest machines will be equipped with spreaders capable of redistributing residue over at least 80% of the working width of the header.
- Where cotton pickers or similar machines are used for harvest, the stalks will be mowed after harvest, except where flooding is a problem.
- Mowing is recommended for corn and sorghum residues.
- Each tilling practice has its own specific design considerations.
- Detailed design information and requirements for row-crop residue management are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- All cropland.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	64% - 90%
Total Nitrogen	50% - 55%
Total Phosphorus	38% - 45%
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Applicability in Reservoir Watershed

Just over 1% of the watershed is in cropland.

Cost

In the early 1990s, in the Chesapeake Bay watershed, the median annual cost per acre of residue management was $17.34. Residue management is not a practice eligible for NRCS Environmental Quality Incentives Program (EQIP) funding; however the 2011 EQIP payment schedule gives the cost for residue management of winter annuals and vegetables as $40.50 per acre.

Many researchers report cost savings to producers as a result of reduced machinery use, increased yield, and reduced inputs. Factors that affect the economics of residue management include:

- Changes in machinery and labor operating costs.
- Changes in herbicide application.
- Differences in crop yields and yield variability, and associated changes in harvest and hauling costs.
- Improved product quality resulting from reduced plant stress.
- Changes in land rental charges.
- Changes in management time and skills.

Benefits

- Reduced sheet and rill erosion.
- Reduced nutrients and other chemicals in runoff.
- Reduced runoff volume.
- Increased water infiltration.
- Increased soil moisture.
- Improved soil organic content, structure, and productivity.
- Reduced machinery and labor use.
- Improved crop yield.
- Reduced air pollution (from reduced machinery use and wind erosion).
- Reduced input costs.
- Reduced incidence of some insect pests.
- Increased incidence of predatory insects.
- Reduced incidence some plant diseases.
- Food and escape cover for wildlife.

Limitations

- There may be no improvement in crop yield.
- Increased nutrient leaching.

- Increased weed germination.
- Increased use of herbicide to control weeds.
- Emergence of herbicide-resistant weeds.
- Increased incidence of some plant diseases.
- May require specialized equipment.
- Requires more detailed management.
- May require learning new skills and techniques.

Maintenance

Maintenance involves use of the appropriate harvest, till, and planting practices to maintain the desired amount of crop residue on the field.

References

Information in the factsheet is adapted from:

EPA. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* [EPA-840-B-93-001C]. US Environmental Protection Agency. Washington, DC.

Evans, B.M., and K.J. Corradini. 2001. *BMP Pollution Reduction Guidance Document*. Pennsylvania Department of Environmental Protection.

NRCS. (no date.) *Rankin County Field Office Technical Guide*. Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

NRCS. 2010. *FY 2011 EQIP HU Payment Schedule*. Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

Torbert, H.A., J.T. Ingram, and S.A. Prior. 2007. Photo 4B in "Planter aid for heavy residue conservation tillage systems." *Agronomy Journal* 99:478-480. Accessed October 2011 at https://www.crops.org/publications/aj/articles/99/2/478#fig4.

Unger, P., ed. 1994. *Managing Agricultural Residues*. CRC Press. Boca Raton, FL.

Wiebe, K., and N. Gollehon, eds. 2006. *Agricultural Resources and Environmental Indicators, 2006 Edition* [Economic Information Bulletin No. EIB-16]. US Department of Agriculture, Economic Research Service. Washington, D.C.

Cover Crop

Description

Cover crops are usually close growing legumes and/or small grains grown primarily for seasonal protection of land from soil erosion, as well as increase organic matter in soil. These crops are typically planted in the fall, after the primary crop is harvested, and grown for less than one year.

Design Considerations

Source: NRCS

- Some commonly used cover crops harbor insects or disease that may affect the primary crop.
- Planting method used to plant the cover crop can increase erosion.
- Recommended cover crop species and planting rates vary depending on the purpose of the cover crop (e.g., erosion control, nitrogen fixing, green manure) and the field characteristics.
- Detailed design information and requirements for cover crops are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Private and commercial crop lands.
- Wildlife areas.
- Recreation areas.
- Orchards.
- Vineyards.
- Any cleared land.

Pollutant Removal

Cover crops reduce pollutant exports from fields under conventional tillage. They provide no significant erosion control benefit on fields under conservation tillage. Pollutant removal varies with the cover crop species used and the planting method.

Pollutant	Efficiency
Total Suspended Solids (TSS)	10% - 20%
Total Nitrogen	10% - 45%
Total Phosphorus	7% - 30%
Pathogens (coliform, *E. coli*)	Cropland in the watershed is not identified as a source of pathogen pollution

Cost

The Mississippi NRCS 2011 Environmental Quality Incentives Program (EQIP) payment schedule lists the cost for cover crops as ranging from approximately $40 per acre to $60 per acre.

Benefits

- Improvement in soil microbial activity, structure, and water storage capacity.
- Improvement in water infiltration.
- Provide food and cover for wildlife, including beneficial insects.
- Reduction of erosion.
- Uptake of nutrients resulting in reduced nutrient runoff.
- Chokes out weeds.

Limitations

- Cost of cover crop may increase production costs.
- Some cover crops can harbor insects or diseases harmful to primary crops.
- Erosion control benefits are limited in conservation till systems.
- Cover crops do not significantly increase organic matter in Mississippi soils when tillage is performed.

Maintenance

Watering as needed.

References

Information in this factsheet is adapted from:

Dillaha, T.A., T.W. Simpson, and S.E. Weammert. 2007. *Off-Stream Watering with Fencing and Off-Stream Watering without Fencing Practices: Definitions and Nutrient and Sediment Reduction Efficiencies. For Use in Calibration and Operation of the Chesapeake Bay's Phase 5.0 Program Watershed Model.* Chesapeake Bay Program. Accessed October 2011 at http://archive.chesapeakebay.net/pubs/bmp/Year_1_Reports/Offstream%20Watering.pdf.

Evans, B.M., and K.J. Corradini. 2001. *BMP Pollution Reduction Guidance Document.* Pennsylvania Department of Environmental Protection.

NRCS. (no date.) *Rankin County Field Office Technical Guide*. Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

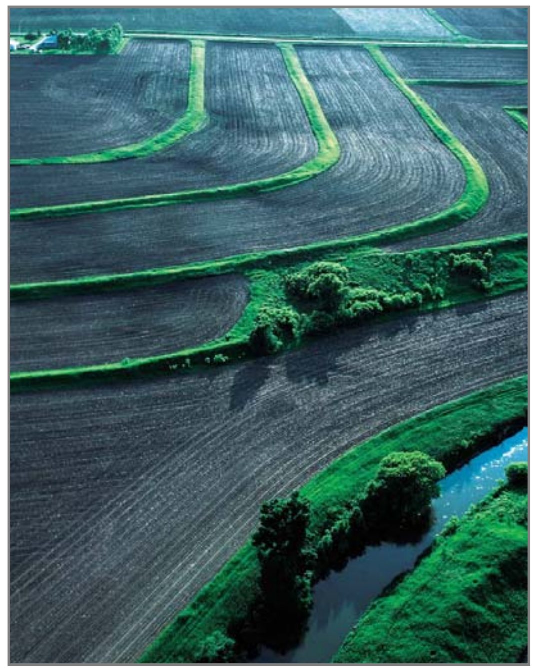
NRCS. 2010. *FY 2011 EQIP HU Payment Schedule*. Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

Terraces

Description

The Natural Resources Conservation Service (NRCS) defines terraces as earth embankments or ridge and channel systems constructed perpendicular to the field slope.

Design Considerations



Source: NRCS

- Terrace characteristics are determined by the field slope, soil conditions, hydrology, and cropping practice.
- Terraces will have the capacity to control the runoff from a 10-year frequency, 24-hour storm without overtopping.
- Terraces impact field hydrology, including water table depth, and volumes and rates of runoff, infiltration, evaporation, transpiration, deep percolation, and groundwater recharge.
- Toxic materials in soils may be exposed in terrace construction.
- Restrictive soil layers can cause salinity issues as a result of increased infiltration.
- Terraces affect the movement of dissolved substances into groundwater.
- Detailed design information and requirements for terraces are available in the National Conservation Practice Standards. This publication is available from NRCS and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Private and commercial crop lands.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	85%
Total Nitrogen	20%
Total Phosphorus	70%
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Crop lands in the watershed are not identified as a source of pathogen pollution.

Applicability in Reservoir Watershed

Just over 1% of the watershed is in cropland.

Cost

The Mississippi NRCS 2011 Environmental Quality Incentives Program (EQIP) payment schedule lists the cost for terraces as ranging from a little over $1 per linear foot to a little over $9 per linear foot.

Benefits

- Reduced erosion and gully formation.
- Reduced runoff volume.
- Reduced sediment in runoff.
- Moisture conservation.
- Improved farmability.
- Reduced flooding.

Limitations

- Cost of construction and maintenance of terraces may increase production costs.
- Damage to terraces can result in erosion and sediment in runoff.

Maintenance

Remove accumulated sediment to maintain storage capacity. Inspect and repair ridges as needed.

References

Information in this factsheet is adapted from:

EPA. 1993. "Management Measures for Agriculture Sources." Chapter 2 in *Guidance Specifying Management Measures for Sources of Non-Point Pollution in Coastal Waters.* US Environmental Protection Agency, Office of Water. Washington, DC. Accessed October 2011 at http://www.epa.gov/OWOW/NPS/MMGI/Chapter2/index.html.

Evans, B.M., and K.J. Corradini. 2001. *BMP Pollution Reduction Guidance Document.* Pennsylvania Department of Environmental Protection.

Lankin, S.J. 2008. "Terrace maintenance and contour farming." News Release. US Department of Agriculture, Natural Resources Conservation Service, Kansas Office. Lakin, KS.

NRCS. (no date.) *Rankin County Field Office Technical Guide*. Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

NRCS. 2010. *FY 2011 EQIP HU Payment Schedule*. Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

Scheuerman, C.T. 2008. "Terrace maintenance." News Release. US Department of Agriculture, Natural Resources Conservation Service, Kansas Office. Hays, KS.

Grade Stabilization Structures

Description

These are structures installed in natural or man-made channels to control the grade and head-cutting. As a result, grade stabilization structures control erosion, enhance environmental quality, and reduce pollution hazards. Grade stabilization structures include embankment or pond-sized dams; drop, chute, and box inlet drop spillways; island-type structures; and side-inlet drainage structures.

Design Considerations

Source: Washington County Soil and Water Conservation Service.

- Usually installed as part of a vegetated runoff control system.
- Differences in adjoining channel depths and widths, and spoil disposal need to be addressed.
- There may be a need for emergency flow bypass.
- Stability of channel sides influences structure design.
- Structures need to be designed to accommodate expected outlet flow volume and velocity.
- Different structures act on the landscape differently.
- Each structure type has its own criteria and construction specifications.
- Structures must be designed to have appropriate sediment storage capacity.
- Fencing may be necessary if structures are installed in areas used by livestock, or in urban areas.
- The potential of these structures to change runoff volume and rate, groundwater recharge and water table level, soil moisture, the susceptibility of downstream channels to erosion, and downstream water quality, and the impacts of these changes must be considered.
- Temporary runoff and sediment control may be required during construction.
- Detailed design information and requirements for grade stabilization structures are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

These structures can be installed anywhere the concentration and velocity of flow results in channel instability and/or gully erosion. This includes:

- Cropland,
- Pasture,
- Urban areas, and
- Forest lands.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	80% - 90%
Total Nitrogen	Insufficient data
Total Phosphorus	70% - 90%
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Applicability in Pelahatchie Creek Watershed

Implementation	Watershed Area (%)
Cropland	1%
Pasture	12%
Urban	26%
Forest	30%

Cost

Depending on the type of grade stabilization structure, installation costs can range from $80 up to over $24,000. Construction costs include site preparation, excavation, fill placement, construction materials, and revegetation of the construction site. There may also be labor costs associated with maintaining the structure, as well as repair costs.

Benefits

- Reduced runoff volumes and peak flows.
- Slower runoff velocities.
- Reduced erosion.
- Reduced sediment and associated pollutants in runoff.
- Improved downstream channel stability, aquatic habitat, and water quality.
- Increased soil moisture, groundwater recharge, and/or water table level.

Limitations

- Maintenance is required to sustain effectiveness.
- Potential for negative impacts downstream due to changes in flow, soil moisture, groundwater recharge, or water table level.
- Can be complex to design so downstream flow, channel stability, and aquatic habitat are not negatively affected.

Maintenance

Inspect the structure periodically, and after major storms, looking for:

- Piping, erosion, or settling of fill around structure.
- Damage to any protective vegetation.
- Scouring in channel at structure inlet or outlet.
- Debris or sediment in the channel or structure that interfere with its function.
- Cracking of concrete.
- Erosion in emergency by-pass areas.

Make repairs as needed.

References

Information in the factsheet is adapted from:

EPA. 1993. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters* [EPA-840-B-93-001C]. US Environmental Protection Agency, Office of Water. Washington, DC. Accessed October 2011 at http://www.epa.gov/owow/NPS/MMGI/index.html.

NRCS. (no date.) *Rankin County Field Office Technical Guide*. Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

NRCS. 2010. *FY 2011 EQIP HU Payment Schedule*. Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

Center for Sustainable Design. 1999. "Grade Stabilization Structure." In Section C, Erosion Control, of Water Runoff Management Section. In *Water Related Best Management Practices in the Landscape*. Prepared by Mississippi State University, Departments of Landscape Architecture, Agricultural and Biological Engineering, and the Colleges of Agriculture and Life Science. Prepared for the Watershed Science Institute, Natural Resources Conservation Service, US Department of Agriculture. Accessed October 2011 at http://www.abe.msstate.edu/csd/NRCS-BMPs/pdf/water/erosion/gradestabilize.pdf

Field Borders

Description

Field borders are strips of permanent vegetation established and maintained at the edge or around the perimeter of crop fields. Field borders can be used as turn rows for farm machinery, to filter runoff, and as wildlife habitat.

Design Considerations

Source: Missouri Agricultural Extension Service

- Minimum recommended border widths range from 20 to 35 feet, depending on farm machinery to be used in the field.
- At least 75% ground cover must be established in the border during the first growing season.
- Borders can be sized and planted to act as wildlife habitat.
- Water bars or berms may be required to distribute or redirect concentrated runoff flows.
- Borders can be planted or seeded with selected grasses and/or clovers, or native plants can be allowed to establish in the borders naturally.
- Trapping efficiency can be increased by including a 3- to 5-foot strip of Alamo switchgrass at the edge of the field.
- Detailed design information and requirements for field borders are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Around crop fields.
- Between fields and forest.
- Between fields and buffers.
- Between fields and recreation areas.

Pollutant Removal Efficiency

Field borders can act as filter strips.

Pollutant	Efficiency
Total Suspended Solids (TSS)	40%
Total Nitrogen	30%
Total Phosphorus	35%
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Applicability in Reservoir Watershed

Field crops are grown in approximately 1% of the watershed.

Cost

NRCS assigns a cost of around $200 per acre for establishment of filter strips under the Environmental Quality Incentives Program (EQIP). Establishing field borders is similar to establishing a filter strip. The estimated maintenance costs for filter strips are roughly $865 per hectare ($350 per acre) per year.

Benefits

- Reduced runoff volumes and peak flows.
- Reduced runoff velocities.
- Reduced erosion.
- Reduced sediment and nutrients in field runoff.
- Food and cover for wildlife.

Limitations

- Variability in pollutant removal efficiencies, depending on design.
- Filtering is most effective with gentle slopes (less than 6%).
- Improper grading can greatly diminish pollutant removal.
- Requires changes in field machine operation.
- Careful management and maintenance are required for sustained performance and longevity.

Maintenance

- Inspect field borders periodically.
- Reshape and/or reseed areas of the border damaged by storms, chemicals, tillage, and equipment.
- Remove sediment when 6 inches has accumulated at the field/border edge.
- Shut off sprayers and raise tillage equipment when in the border.
- Fertilize, mow, and control noxious weeds as needed to maintain plant vigor.

- Fill and reseed any rills or gullies that form in the border.

References

Information in the factsheet is adapted from:

Alabama Soil and Water Conservation Committee. 2009. Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas. Volume 1: Developing Plans and Designing Best Management Practices. Montgomery, AL. March 2009. Accessed September 2011 at http://swcc.alabama.gov/pages/erosion_handbook.aspx.

AMEC Earth & Environmental, the Center for Watershed Protection, Debo and Associates, Jordan Jones and Goulding, and the Atlanta Regional Commission. 2001. *Georgia Stormwater Management Manual, Volume 2: Technical Handbook (first edition)*. Atlanta Regional Commission. Accessed September 2011 at http://www.georgiastormwater.com/GSMMVol2.pdf.

Clark, C., G. Acomb, M. Dukes, M.E. Hostetler, B. Larson, T. Ruppert, O. Wells, J. Kipp, G. Boles, S. Hofstetter, B.T. Philpot, and H. Knowles. 2008. *The Florida Field Guide to Low Impact Development: Stormwater Management Practices for Application in Master Planned Community Development.* Program for Resource Efficient Communities, University of Florida. 82 pp.

Comprehensive Environmental Inc. and New Hampshire Department of Environmental Services. 2008. Post-Construction Best Management Practices: Selection & Design. Volume 2 of *New Hampshire Stormwater Manual*. Accessed September 2011 at http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-08-20b.pdf.

Massachusetts Department of Environmental Protection. 2008. Structural BMP Specifications for the Massachusetts Stormwater Handbook. Chapter 2 in Volume 2 of *Massachusetts Stormwater Handbook*. Accessed September 2011 at http://www.mass.gov/dep/water/laws/v2c2.pdf.

North Carolina Department of the Environment and Natural Resources. 2007. *Stormwater Best Management Practices Manual*. North Carolina Department of the Environment and Natural Resources, Division of Water Quality. Accessed September 2011 at http://portal.ncdenr.org/web/wq/ws/su/bmp-manual.

NRCS. (no date.) *Rankin County Field Office Technical Guide*. Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

NRCS. 2010. *FY 2011 EQIP HU Payment Schedule*. Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

US Department of Defense. 2010. "Low Impact Development" [UFC 3-210-10]. Series 3-200: Civil/Geotechnical/Landscape Architecture in *Unified Facilities Criteria*. Administered by the US Army Corps of Engineers, the Naval Facilities Engineering Command, and the Office of the Air Force Civil Engineer. 15 November 2010. Accessed September 2011 at http://www.wbdg.org/ccb/DOD/UFC/ufc_3_210_10.pdf.

Animal Mortality Facilities

Description

Animal mortality facilities are on-farm facilities for treatment and/or disposal of livestock or poultry carcasses. The facilities may utilize composting, freezers, or incinerators.

Design Considerations

Source: New York NRCS

- Facilities can be designed to address normal mortality rates, or catastrophic mortality events.
- Facilities will be located at least 900 feet from residences to minimize odor and other air quality impacts to neighboring residences.
- Facilities will be located outside of the 100-year floodplain.
- Facilities will be located at least 200 feet from surface water to minimize impacts to surface water quality.
- Facilities will be sited to minimize impacts to groundwater quality.
- Facilities will be sited at least 200 feet downgradient of springs and wells.
- Facilities will be designed to be in compliance with applicable federal, state, and local regulations.
- Facilities will be sited as close as practical to the source of mortality.
- Runoff should be diverted away from the facility.
- Facility design will be appropriate for available equipment at the site, operator's management capabilities, and the animals to be disposed.
- Detailed design information and requirements for animal mortality facilities are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Livestock operations.
- Poultry operations.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	Insufficient data
Total Nitrogen	Insufficient data
Total Phosphorus	Insufficient data
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Cost

For the Mississippi NRCS Environmental Quality Incentives Program (EQIP), the costs for animal mortality facilities range from a little over $6 per square foot for composters, up to approximately $5,800 (total) for a large incinerator.

Benefits

- Decreased nonpoint source pollution of surface water and groundwater.
- Reduced odor from animal mortality.
- Decreased likelihood of spread of disease and pathogens.

Limitations

- Site characteristics may result in a less-than-ideal location for the facility, in which case, impacts from the facility may be possible.
- Outputs from the facilities may be regulated and require special handling.

Maintenance

Facilities will need to be inspected routinely and repaired as needed. Specific operation and maintenance needs vary depending on the type of facility.

References

Information in the factsheet is adapted from:

NRCS. 2010a. Animal Mortality Facility [Conservation Practice Standard Code 316]. *National Handbook of Conservation Practices*. US Department of Agriculture, Natural Resources Conservation Service. Accessed October 2011 at ftp://ftp-fc.sc.egov.usda.gov/NHQ/practice-standards/standards/316.pdf.

NRCS. 2010b. *FY 2011 EQIP HU Payment Schedule*. Accessed October 2011 at: http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

Integrated Pest Management

Description

Source: MSU.

Integrated Pest Management (IPM) is an environmentally responsible and economically practical method of landscaping and crop protection. It includes prevention, avoidance, monitoring, and suppression of weeds, insects, diseases and other pests. IPM combines biological, cultural, and other alternatives to chemical control with the planned use of pesticides to keep pest populations below damaging levels, while minimizing harmful effects of pest control on humans and natural resources. The practice is site-specific in nature, based on approaches suited for the particular crop or landscape, pest, and location.

Design Considerations

- Mulching can be used to prevent weeds where turf is absent, fencing installed to keep rodents out, and netting used to keep birds and insects away from leaves and fruit.
- Visible insects can be removed by hand (with gloves or tweezers) and placed in soapy water or vegetable oil. Alternatively, insects can be sprayed off the plant with water or in some cases vacuumed off of larger plants.
- Store-bought traps, such as species-specific, pheromone-based traps or colored sticky cards, can be used.
- Slugs can be trapped in small cups filled with beer that are set in the ground so the slugs can get in easily.
- In cases where microscopic parasites, such as bacteria and fungi, are causing damage to plants, the affected plant material can be removed and disposed of (pruning equipment should be disinfected with bleach to prevent spreading the disease organism).
- Small mammals and birds can be excluded using fences, netting, and tree trunk guards.
- Beneficial organisms, such as bats, birds, green lacewings, ladybugs, praying mantis, ground beetles, parasitic nematodes, trichogramma wasps, seed head weevils, and spiders that prey on detrimental pest species can be promoted.
- Detailed design information and requirements for integrated pest management practices are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

IPM must be implemented on a voluntary basis by private landowners. It could be incorporated into landscape management policy at the municipal or county level.

Pollutant Removal Efficiency

Pollutant removal efficiency depends on the actual practices used by the individuals. Overuse and misuse of pesticides are common in urban areas. Use of IPM has the potential to reduce pesticides transported in urban stormwater.

Applicability in Reservoir Watershed

This practice could be used in residential areas and by owners of cropland.

Cost

Cost would vary depending on site-specific practices. The cost of alternative methods may be less than the cost of purchasing traditional chemical pesticides. Crop producers would need to consider the risk of the potential for some crop loss due to insects.

References

Information in the factsheet is adapted from:

Mississippi State University. 2007. "Financial Incentives for IPM" [web page]. Accessed October 2011 at http://www.ipm.msu.edu/farmbill.htm.

NRCS. 2006. *Conservation Practices that Save: Integrated Pest Management*. US Department of Agriculture, Natural Resources Conservation Service, "Save ENERGY, Save MONEY" Program. Accessed October 2011 at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_023629.pdf.

NRCS. 2010. Integrated Pest Management [Conservation Practice Standard Code 595]. *National Handbook of Conservation Practices*. US Department of Agriculture, Natural Resources Conservation Service. Accessed October 2011 at http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_025930.pdf.

Nutrient Management Plans

Description

These are plans for managing the source, amount, timing, form, and placement of plant nutrients and soil amendments on agricultural lands.

Design Considerations

- Plans will comply with applicable federal, state, and local laws, regulations, and ordinances.
- Plans will be compatible with applicable requirements for erosion control, pest and residue management, etc.
- Nutrient planning will be based on current soil or plant test results.
- Plans for agricultural lands will utilize nutrient application guidelines developed by the Rankin County Soil and Water Conservation District.
- Detailed design information and requirements for nutrient management plans are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Livestock operations.
- Poultry operations.
- Croplands.

Pollutant Removal Efficiency

Pollutant	Efficiency
Total Suspended Solids (TSS)	Insufficient data
Total Nitrogen	15%
Total Phosphorus	35%
Metals	Insufficient data
Pathogens (fecal coliform, *E. coli*)	Insufficient data

Applicability in Pelahatchie Creek Watershed

Approximately 12% of the watershed is pasture, and 1% is cropland.

Cost

The Natural Resources Conservation Service (NRCS) has estimated that in the Delta states (including Mississippi), the average cost for developing required comprehensive nutrient management plans for animal feeding operations is approximately $5,400 per farm (99 hours at $55 per hour). This is the cost to NRCS for providing technical assistance to producers preparing comprehensive nutrient management plans. The amount of technical assistance required for developing a nutrient management plan for croplands may be less. Average cost for implementing an animal feeding operation comprehensive nutrient management plan in the Delta states was estimated to be approximately $4,800 per year.

Benefits

- Reduced production costs as a result of increased efficiency and reduced inputs.
- Reduced nutrients in runoff.

Limitations

- Nutrient management may require additional labor, training, and/or equipment.
- Nutrient management plans are only effective if they are implemented properly.

Maintenance

Plans will need to be modified when changes are made to operations or processes.

References

Information in the factsheet is adapted from:

EPA. 1993. *Guidance Specifying Management Measures for Sources on Nonpoint Pollution in Coastal Waters* [EPA 840-B-92-002]. US Environmental Protection Agency. Washington, DC. Online at http://www.epa.gov/owow/NPS/MMGI/.

NRCS. 2003. *Costs Associated With Development and Implementation of Comprehensive Nutrient Management Plans, Part I – Nutrient Management, Land Treatment, Manure and Wastewater Handling and Storage, Recordkeeping*. USDA NRCS. Washington, DC. Online at http://www.nrcs.usda.gov/technical/NRI/pubs/cnmp1.html.

NRCS. 2007. Nutrient Management[Conservation Practice Standard Code 590]. *National Handbook of Conservation Practices*. US Department of Agriculture, Natural Resources Conservation Service. Accessed October 2011 at http://efotg.sc.egov.usda.gov/references/public/MS/Nutrient_Management_August_07.pdf.

Stream Crossings

Description

Stream crossings are constructed to prevent disturbance to the stream ecosystem from livestock, equipment, and/or vehicles crossing the stream.

Design Considerations

Source: NRCS web page.

- Crossings will be located where streambed is stable.
- Width of crossing is determined by what (e.g., cattle, machinery) and how the crossing will be used.
- Crossing side slopes will be designed to be stable for the soils present.
- The type of crossing to be constructed will depend on the hydraulic characteristics of the stream, the uses to be made of the crossing, and how often it will be used.
- Diversions will be used to direct runoff from the road away from the stream.
- Detailed design information and requirements for grade stabilization structures are available in the National Conservation Practice Standards. This publication is available from the Natural Resources Conservation Service (NRCS) and online at http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Implementation

- Private and commercial pasture lands.

Pollutant Removal

Pollutant	Efficiency
Total Suspended Solids (TSS)	no data
Total Nitrogen	no data
Total Phosphorus	no data
Pathogens (coliform, *E. coli*)	no data

Stream crossings are often associated with stream fencing, and may contribute to pollutant removal reported for that practice.

Cost

The Mississippi NRCS 2011 Environmental Quality Incentives Program (EQIP) payment schedule lists the cost for a stream crossing at almost $3 per linear foot.

Benefits

- Improved herd health– wet muddy conditions increase risk of a number of livestock illnesses, as well as foot and leg injuries from slipping.
- Reduced exposure of livestock to water-borne disease organisms.
- Good public relations.
- Improved habitat for fish.
- Improved groundwater recharge.
- Reduced bank erosion and land loss.
- Reduced sediment, nutrient, and pathogen loads to stream.

Limitations

Construction and maintenance of crossings may increase operating cost.

Maintenance

Crossings will be inspected at least annually, and any necessary repairs made in a timely manner.

References

Information in this factsheet is adapted from:

NRCS. (no date.) *Rankin County Field Office Technical Guide*. Online at http://efotg.sc.egov.usda.gov/treemenuFS.aspx.

NRCS. 2010. *FY 2011 EQIP HU Payment Schedule*. Online at http://www.ms.nrcs.usda.gov/programs/2011_Historically_Underserved_EQIP_Payment_Schedule.pdf.

APPENDIX O

GREEN INFRASTRUCTURE RESOURCES FOR LOCAL GOVERNMENTS

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1.0 CHECKLIST FOR GREEN INFRASTRUCTURE REQUIREMENTS

Local ordinances, zoning requirements, stormwater management plans, and comprehensive watershed management plans play an important role in the use of green infrastructure in developing and urban areas. Local policies can promote the use of green infrastructure by treating it as the “standard practice” rather than an alternative design. Local governments interested in promoting green infrastructure could begin by reviewing their current policies. As an initial step, governments in the Reservoir watershed can compare their policies to the Checklist of Recommended Elements to Promote Green Infrastructure (Table O.1).Table O.1 includes recommended elements for stream buffers; green spaces; construction site erosion and sediment control; and post-construction stormwater management. Based on review of this checklist, local leaders may find that existing ordinances and zoning codes incorporate many of the recommended elements. The checklist may also help local leaders identify opportunities to enhance ordinances to promote green infrastructure and improve water quality. For example, some cities near the Reservoir require preservation of a buffer zone with woody vegetation along tributaries and drainage channels in new developments.

In some cases, local leaders may want to enhance zoning requirements to promote green infrastructure. Current zoning codes for areas near the Reservoir specify requirements for open space (requirements vary from 5% to 20% depending on the zone). However, existing zoning codes do not include requirements for green space, open space with undisturbed vegetation, or open space replanted with woody vegetation. These types of “open space” are more desirable as elements of green infrastructure.

Table O.1. Checklist of recommended elements to promote green infrastructure*.

Have	Desire	Stream Buffers
		A required stream buffer zone to enhance protection of the streams with design criteria for the buffer zone, including specification of minimum buffer zone width (i.e., 50 ft).
		A system to mark the location of the buffer zone and a long-term maintenance system for the area.
		An education program to assist future residents in maintaining the area
		Requirements and guidance for replacement of damaged buffer areas.
Have	**Desire**	**Undisturbed Vegetated Areas or "Green Space"**
		Requirements for a specific amount of green space (possibly specified in zoning ordinance as a percent of the area left as open space).
		Allowable methods to reduce impervious surfaces such as cluster development, unpaved walkways, pervious pavement, narrower streets, shared driveways, and single sidewalks.
		Language to address maintenance and liability of green space.
		Requirements for a long-term management plan of green space (community property associations, land trust, or conservation easements).
		Local comprehensive plans that recognize the role of green space in sustainable stormwater management.
		Restrictions on development in floodplains.
		Provisions to protect mature tree canopy and to forbid clear cutting.
		Restrictions for development in aquifer recharge areas, steep slopes, and along drainage ditches and creeks.
Have	**Desire**	**Construction Site Erosion and Sediment Control**
		Language that emphasizes the use of techniques to limit clearing and grading and preserve natural areas.
		Requirement that any public trees removed or damaged during construction be replaced onsite or offsite with an equivalent amount of tree caliper (e.g., remove a 24-inch-diameter tree, but replace with six 4-inch-diameter trees).
		Standards for tree preservation for new development or retrofitting projects, requirement for prior approval before removal of trees larger than a specified size.
		Regulations that require restoration of degraded riparian areas on a development site
		Requirement that contractors are certified or have formal training to install, maintain and inspect erosion and sediment control practices.
		Approval process for an erosion and sediment control (ESC) plan and a specific list of the requirements for the plan.
		Stipulations to ensure that ESC requirements are correlated with the process for obtaining a building permit (for example, require that erosion and sediment controls are properly installed to obtain permits and pass inspections).

Table O.1. Checklist of recommended elements to promote green infrastructure (continued).

Have	Desire	Construction Site Erosion and Sediment Control (continued)
		Clearly stated enforcement actions for failure to maintain ESC measures at a construction site.
		The authority to issue stop-work orders for violations.
		Provisions to ensure that the community has the staff and resources necessary for enforcement of the ordinances.
Have	**Desire**	**Post-Construction Stormwater Management**
		Requirement for a post-construction stormwater management plan that specifies parties responsible for long-term maintenance and routine inspections.
		Stormwater quality and quantity performance standards for developed sites (e.g., restrictions on sediment levels, pre-/post-development flow quantity, and flow regime). Performance standards may vary according to the area receiving the discharge (e.g., stricter requirements for wetlands and sensitive waterbodies).
		Zoning and subdivision regulations that specifically allow green infrastructure practices, including but not limited to; infiltration approaches, such as bioretention and rain gardens, curb extensions, planter gardens, permeable and porous pavements, green roofs, and other designs where the intent is to capture and manage stormwater using soils and plants, water harvesting devices, such as rain barrels and cisterns, and downspout disconnection.
		Requirement that some percentage of less-frequently utilized parking lots, alleys, or roads in a development utilize pervious materials.
		Standards requiring a minimum area of parking lots to drain to green infrastructure practices, including trees, vegetated islands, swales, rain gardens, or other approaches.

*Note: This checklist is adapted from model ordinances available from the Center for Watershed Protection[1] and the EPA Smartgrowth Scorecard[2].

[1] http://cwp.org
[2] www.epa.gov/smartgrowth

2.0 RESOURCES FOR LOCAL GOVERNMENT

Development of stormwater ordinances and zoning codes that support green infrastructure is a local activity that requires the input and expertise of local government officials. There is no "one-size-fits-all" solution for stormwater management. Policies that work well must be developed from within each individual government by leaders who know the personnel, funding, and level of technical expertise available to enforce ordinances and manage the permit approval process. Each area has unique physical characteristics (topography, climate, soil types) and local culture (individual beliefs, common practices, and customs) that must be considered when developing enforceable mechanisms.

The successful development of policies to promote use of green infrastructure requires a long-term approach that involves government officials, developers, and the general public. The approach recommended for the Reservoir watershed is summarized below and described in more detail in the *Comprehensive Education and Outreach Plan for Rez*onate! (FTN 2011). The approach includes the following action items:

1. Educate local leaders and citizens about green infrastructure and show success through locally led demonstration projects.
2. Form a workgroup that includes developers, contractors, and representatives from local governments to discuss technical elements of green infrastructure and build consensus on its use.
3. Reach a broad audience with the use of a media campaign to build support of the use of green infrastructure among the general public.
4. Compare existing ordinances and zoning codes to model ordinances and technical guidance. Consider what rules need to be changed. Identify the "road blocks" that limit the use of green infrastructure and how they can be changed. Develop a set of engineering and technical requirements for incorporating green infrastructure practices into local ordinances.
5. Work with local elected officials to make the specific ordinance and zoning code changes.

Many references and publications have been developed to educate local leaders and citizens about green infrastructure. These publications are intended to assist local governments assess their level of support for green infrastructure and make needed improvements to ordinances, comprehensive plans, zoning ordinances, and standards for street and road design. Publications recommended for local governments in the Reservoir watershed are described below:

- Water Quality Scorecard[3]

  This scorecard offers policy options for protecting and improving water quality across different scales of land use and across multiple municipal departments. EPA's Water Quality Scorecard was developed to help local governments identify opportunities to remove barriers, and revise and create codes, ordinances, and incentives for better water quality protection. It addresses five key areas: 1) preserve natural resources (including trees) and open space; 2) promote efficient, compact developments, and infill; 3) design complete, smart streets, and reduce overall imperviousness; 4) encourage efficient provision of parking, and 5) adopt green infrastructure stormwater management provisions. The scorecard describes alternative policy or ordinance information that, when implemented, would support a comprehensive green infrastructure approach.

- Sustainable Design and Green Building Toolkit for Local Governments[4]

  Sustainable design includes considering not just how buildings and the surrounding site are constructed, but also where they are constructed. EPA has many resources for local governments and the real estate industry on smart growth: compact, pedestrian-friendly, mixed-use development that takes advantage of existing infrastructure and protects critical natural lands.

  This document provides guidance for local governments to help them change their existing ordinances and permitting processes to allow/promote sustainable design and smart buildings. There are often barriers in existing ordinances to prevent developers from taking full advantage of green infrastructure practices for stormwater management. This document offers suggestions to overcome those barriers with an appropriate action plan. The action plan can help communities implement necessary regulatory and permitting changes to allow for more sustainable design.

[3] http://www.epa.gov/smartgrowth/water_scorecard.htm
[4] www.epa.gov/smartgrowth

- Essential Smart Growth Fixes for Urban and Suburban Zoning Codes[5]

  This publication recognizes common road blocks to green infrastructure in zoning codes. Suggestions on how to remove road blocks and allow more sustainable development practices are included.

- The Southeast Tennessee Green Infrastructure Handbook for Local Governments[6]

  This publication was developed by the Southeastern Tennessee Development District with input from local governments. It describes various green infrastructure techniques useful at the community, street, and individual site scales. The handbook features local examples, colorful photographs, and an eye-catching layout.

- Better Site Design: A Handbook for Changing Development Rules in Your Community[7]

  The Center for Watershed Protection has developed a set of urban design principles called Better Site Design (BSD). BSD includes 21 specific recommendations for street design, open space preservation, and stormwater management. The majority of these principles are consistent with green infrastructure.

- Model ordinances for stormwater management, landscaping, and clearing and grading

  National examples are available from EPA[8] and the Center for Watershed Protection[9].

  Local ordinances adopted by the City of Hernando, Mississippi[10], and Desoto County, Mississippi[11], have been highly successful and are good examples of green infrastructure requirements that are working well within Mississippi.

[5] www.epa.gov/smartgrowth/essential_fixes.htm
[6] http://www.sedev.org/downloads/GreenInfrastructureHandbook.pdf
[7] http://www.cwp.org/
[8] http://www.epa.gov/owow/NPS/ordinance/stormwater.htm
[9] http://www.cwp.org/
[10] http://www.cityofhernando.org/
[11] http://www.desotoms.com/departments/environmental-services/stormwater

- Delaware's Inland Bays Pollution Control Strategy[12]

  The Inland Bays Pollution Control Strategy recommends three main regulatory strategies to reduce nonpoint source pollutants from urban areas: 1) buffers, 2) stormwater controls, and 3) wastewater treatment. Voluntary measures are recommended for agricultural areas.

[12] http://www.dnrec.state.de.us/water2000/sections/watershed/ws/ib_pcs.htm

3.0 STORMWATER MANAGEMENT PLANS

Urban areas in the Reservoir watershed designated as municipal separate storm sewer systems (MS4s) have developed Stormwater Management Plans (MS4 Plans). These areas are Rankin County, City of Flowood, Madison County, City of Madison, and City of Ridgeland. The following list includes suggestions to enhance existing MS4 Plans in the Reservoir watershed. These suggested actions are voluntary, but could significantly improve stormwater management in the watershed if incorporated by local stormwater managers.

1. Monitor and track properties that need improved stormwater management by developing an inventory of locations with insufficient stormwater controls (i.e., parking lots and subdivisions that were designed with insufficient stormwater management and areas where repairs or maintenance are needed). Contact landowners and encourage them to voluntarily improve stormwater management on their properties.
2. Identify specific locations where active bank failures or knickpoints are visible within stream systems. Also identify locations of actively eroding gullies in upland areas. Work with the Mississippi Department of Environmental Quality (MDEQ) and the Natural Resources Conservation Service (NRCS) to install management practices to correct the problems noted at these locations.
3. Include a listing of total maximum daily loads (TMDLs) within the regulated area. Review the pollutant reduction requirements for TMDL waters. Include provisions to take action towards meeting pollutant reduction goals. Coordinate with MDEQ Basin Managers on these actions.
4. Create a regional stormwater management consortium comprised of representatives from city and county governments within the watershed. The consortium would improve communication and collaboration among governments in the Reservoir watershed. Some requirements for public education and outreach and public participation could be satisfied through participation in the Rez*onate* Initiative. This would result in consistent programs for the watershed and potential cost savings by sharing training events and materials.
5. Institute a certification program for contractors and developers such as the Certified Professional in Erosion and Sediment Control (CPESC) program.[13]

[13] www.cpesc.org

6. Establish a buffer zone designated for limited development in selected areas around the Reservoir and along contributing streams. This would allow vegetative filtering of stormwater runoff entering these waterbodies as well as bank protection.

7. Improve development and implementation of Stormwater Pollution Prevention Plans (SWPPPs) for individual construction sites within the watershed. The Environmental Compliance and Enforcement Division at MDEQ should continue to review SWPPPs. The Pearl River Valley Water Supply District (PRVWSD) should also have the option to review and comment on SWPPPs for construction permits issued within their lease land. Consider a requirement for an onsite "pre-construction meeting" to take place after erosion and sediment controls have been implemented but before any land-disturbing activities have begun. This would allow the jurisdictional authority to ensure that the controls are in place and properly installed.

8. Encourage contractors/developers to inspect construction sites following any significant rain event (i.e., greater than 0.25 inch in a 24-hour period) and implement corrective action for any needed maintenance. Documents of routine contractor self-inspections should be available to a city/county inspector upon request.

9. Improve stormwater conveyance system maps developed by cities/counties. Maps are required for MS4 Plans; however, the features displayed are typically limited to major stormwater outfalls and publicly owned areas (i.e., city parks). Encourage development of a more comprehensive map that includes stormwater management features (swales, retention/detention ponds, open space, and infiltration/bioretention areas). Also identify on these maps, waterbodies and critical resource areas such as wetlands, aquifer recharge areas, and source water protection areas.

10. Provide incentives for developers to utilize green infrastructure, minimize impervious areas, and use infiltration and/or other design considerations to improve post-construction stormwater management. Incentives for redeveloping existing properties are needed to encourage retrofits.

11. Allow offsite, regional water retention/detention in certain cases (such as retrofits of developed areas that lie in high-density urban zones). This will avoid costly onsite retention in densely developed infill areas and provide benefit to priority retrofit sites.

4.0 MANAGEMENT MEASURES

Selected green infrastructure management measures that are recommended for use in the Reservoir watershed are described below. The text includes information on how and where these practices would be most effective. Appendix N to the *Comprehensive Protection and Restoration Plan* includes fact sheets that give design specifications for these practices.

4.1 Bioretention Areas

Bioretention areas can be installed in landscaped areas and designed to connect to existing stormwater infrastructure systems within the developed and urbanized area of the watershed. In addition to retrofitting, they can be incorporated into the design of the stormwater management system of proposed developments. They can be installed in any soil type; however, if installed in a low-permeability soil (types C and D), the bioretention basins should be designed with underdrain systems connecting to the downstream best management practices (BMPs) or outfall. In such situations, bioretention basins can still be used to treat the stormwater by removing suspended solids, nutrients, and pollutants and then discharging the stormwater, with much lower total suspended solids (TSS) and pollutant loads into other parts of the stormwater conveyance system such as bioswales or a stormwater pond. Small bioretention areas installed by property owners on individual lots are called rain gardens.

4.2 Stormwater Retention Ponds

Stormwater retention ponds (also called wet ponds or wet-extended detention ponds) are commonly used to collect stormwater in developed areas. MDEQ requires that construction sites larger than 10 acres install a sediment basin. These basins are often converted to permanent stormwater ponds after construction is complete. Stormwater retention ponds remove pollutants through settling and biological uptake. Pollutant removal performance of wet ponds is typically much greater than that of dry detention ponds. Dry detention basins fail to demonstrate an ability to meet the majority of water quality goals, are prone to clogging and resuspension of previously settled solids, and require a higher frequency of maintenance than wet ponds.

Stormwater retention ponds require a significant amount of space, which can be a limiting factor in retrofitting. Some cities have allowed sharing of stormwater retention ponds (Flowood and Madison). Shared stormwater retention ponds reduce construction costs and allow for a large enough contributing drainage area to maintain desired pool elevations in wet ponds.

4.3 Constructed Wetlands

Constructed stormwater wetlands are another option for managing stormwater. These systems are highly recommended because they are among the most effective stormwater treatment practices in terms of pollutant removal, and also offer aesthetic value and wildlife habitat. Constructed wetlands have limitations due to land requirements and costs (typically 25% higher than stormwater ponds). Constructed stormwater wetlands work best in soils that have water holding capacity (types C and D).

4.4 Streamside Buffer Zones

Streamside buffer zones (also called riparian buffers) are natural or constructed low-maintenance ecosystems adjacent to surface waterbodies, where trees, grasses, shrubs, and herbaceous plants function as a filter to remove pollutants from overland stormwater flow prior to discharge to receiving waters, and they function to stabilize banks. Maintaining a vegetated buffer or setback along creeks, streams, and rivers provides an attractive landscape and can improve water quality by removing sediment and chemicals before they reach the waterway. In addition, buffers provide flood control, help recharge groundwater, prevent soil erosion, and preserve or improve certain types of wildlife habitat.

Regulatory controls to prevent disturbance of riparian buffer zones near perennial streams are an important protection strategy for the Reservoir watershed. MDEQ’s Large Construction Storm Water General Permit (issued January 2011) recommends maintaining a 150-ft buffer zone between the land disturbance and any perennial waterbody[14]. EPA has proposed a new general National Pollutant Discharge Elimination System (NPDES) permit for discharges from construction activities. If approved, this permit would require a 50-ft buffer of undisturbed

[14] http://deq.state.ms.us/MDEQ.nsf/page/epd_epdgeneral?OpenDocument

natural vegetation between the disturbed areas of a construction site and any water of the state. In lieu of a buffer zone, the developer will be required to provide sediment and erosion controls that achieve the equivalent pollution load reduction of a 50-ft buffer[15].

4.5 Level Spreaders

Level spreaders are used to distribute concentrated runoff onto vegetated areas (restored riparian buffers and open space), so that it can be treated via infiltration and evaporation. Since it uses infiltration to treat stormwater, this practice works best in areas with type B soils.

4.6 Vegetated Filter Strips and Water Quality Swales

Vegetated filter strips provide treatment for stormwater running off parking lots and other impervious areas. In areas where slopes permit and water velocities are slow enough to prevent scouring, water quality swales or grassed swales should be used to convey stormwater in place of concrete structures. Water quality swales are more expensive to build and maintain than grassed swales, but have higher pollutant removal rates than grassed swales.

4.7 Cluster Development

County zoning ordinances in Madison and Rankin Counties allow cluster development in areas zoned as Planned Urban Development (PUD) districts. PUDs allow for reduced length of roads and utility rights-of-way through clustering of housing. PUD districts are superimposed over residential developments and must maintain the density requirements of the residential zone over which they are imposed. However, minimum lot size and width can be reduced and remaining land reserved in contiguous tracts of common open space for use by residents. The requirement in Rankin County is that 20% of the developed area be preserved as common open space.[16] However, there are no restrictions on the amount of this area that must be kept as green space.

[15] http://cfpub.epa.gov/npdes/stormwater/cgp.cfm
[16] Zoning Ordinance of Rankin County, Mississippi 2004. Revised December 2010. Prepared by Central Mississippi Planning and Development District. Available online at www.cmpdd.org.

4.8 Overlay District

Overlay districts are commonly used to retain certain landuses and architectural guidelines within a specific area. They are also commonly used to protect drainage areas of surface water supplies used for drinking water (Kitchell, no date). There is presently a citizen group interested in developing an overlay district in the developed area near the Reservoir within Rankin County. Although the main intent of this group is to develop guidelines to maintain architectural guidelines and landuse controls, additional requirements to protect source water could also be incorporated. It is recommended that Rez*onate* project managers coordinate with this citizen group regarding the overlay district.

4.9 Other Stormwater Control Measures

Other green infrastructure stormwater controls applicable to the Reservoir watershed include rain barrels, green roofs, preservation of green spaces and trees, and BMPs for fertilizer and herbicide application. Fact sheets that fully describe these measures are included in Appendix N of the *Comprehensive Protection and Restoration Plan for the Ross Barnett Reservoir Watershed, Mississippi*.

5.0 REFERENCES

Kitchell, A. 2001. Managing Lakes for Pure Drinking Water. *Watershed Protection Techniques* 3(4). Center for Watershed Protection. Online at http://www.cwp.org/documents/cat_view/74-articles-from-watershed-protection-techniques-special-issue-on-urban-lake-management.html.

APPENDIX P

SEDIMENT BUDGET FOR MILL-PELAHATCHIE HUC12 WATERSHED

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1.0 INTRODUCTION

Sediment budgets include both upland sources of sediments and sediments contributed from within stream channels. Upland sources can be attributed to land management activities that result in removal of natural vegetation and lead to erosion of exposed sediments from construction sites, surface mining, forest harvesting, and agricultural activities. Land development removes natural vegetation and increases impervious surface areas results in reduced infiltration and increased peak flows in urban streams. This leads to erosion of stream banks and resuspension of stream bed sediments.

A preliminary sediment budget has been developed for the Mill-Pelahatchie Creek watershed as delineated by US Geological Survey (USGS) 12-digit hydrologic unit code (HUC12). The sediment budget was based on watershed modeling and available monitoring data. The budget can be used to guide management practices and manage expectations related to sediment reductions expected from implementation of practices. This sediment budget should be considered preliminary because it is based on many simplifying assumptions. The budget was developed for annual average conditions. Thus, it does not reflect temporal variation in sediment loads (i.e., the large amount of sediment movement that occurs during high-flow events). Also the budget does not consider differences in sediment particle size, which can be used as an indicator of the sediment source. Sediments from the upland watershed are typically fine-grained sediments (silts and clays), while sediments from stream beds are typically larger (sands and gravels). Larger sediments often take many years to move downstream through a stream system, while fine materials move through the system quickly.

This sediment budget uses a simplified process to simulate sediment sources (Figure P.1). Sediment generated from rural areas must travel over land surfaces and within ditches and small stream channels before reaching the watershed boundary. Sediments lost during transport are referred to as hillslope storage. The percentage of sediments not deposited as hill slope storage can be estimated as the sediment delivery ratio (SDR). Urban sediment sources include gully erosion and construction and surface mining sites. Urban sediments are also subject to hillslope storage. Once reaching the stream, sediments may be subject to aggradation (settling) or degradation (resuspension) based on the flow energy and sediment content of the overlaying water. Bank failure may also contribute sediments. The total instream sediment contribution is the sum of degradation and bank failure minus aggradation.

The budget can be summarized by the following equation, where all sediment is measured in kilograms per year:

Measured sediment load = (rural uplands erosion * SDR) + (gully erosion * SDR) + (construction and mine sites erosion * SDR) + instream contribution from bed and banks

In developing the sediment budget, sediment loads from erosion in rural uplands, gully erosion in urban areas, and erosion at construction and surface mining sites were estimated using the methods described in Sections 2.0 through 5.0. The measured sediment load was calculated from available monitoring data. The instream contribution from bed and banks was estimated as the measured sediment load minus the sum of the sediment loads from rural erosion, gully erosion in urban areas, and erosion at construction and surface mining sites.

The preliminary sediment budget for the Mill-Pelahatchie Creek HUC12 is shown in Table P.1 and on Figure P.2. This budget indicates that the majority of the annual sediment load is from instream sources. The second greatest sediment source is rural uplands. Rural upland sediments originate from row-crop agriculture, pastures, forest/woodlands, and shrublands.

Table P.1. Preliminary sediment budget for the Mill-Pelahatchie Creek watershed.

Source	Sediment Load (kg/year)	Percent of Load
Rural uplands*SDR	46.40E+05	29.2%
Construction/mine sites*SDR	8.24E+05	5.2%
Gully erosion*SDR	1.78E+05	1.1%
Instream contribution from bed and banks	103.00E+05	64.5%
Measured Sediment Load	**159.00E+05**	**100.0%**

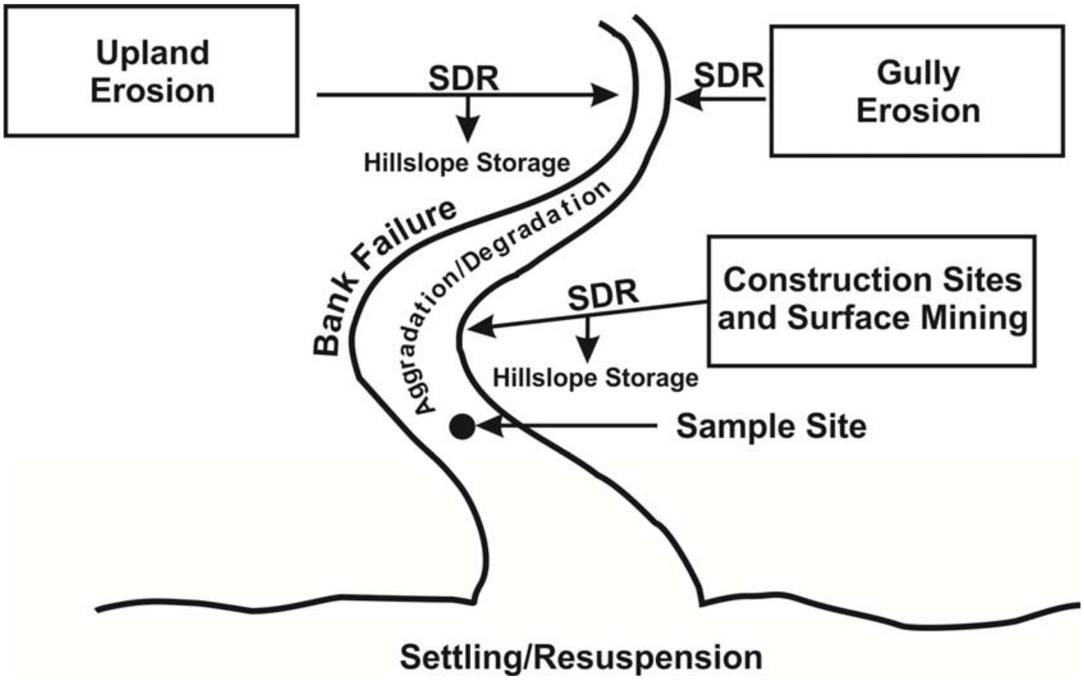

Figure P.1. Schematic of sediment sources.

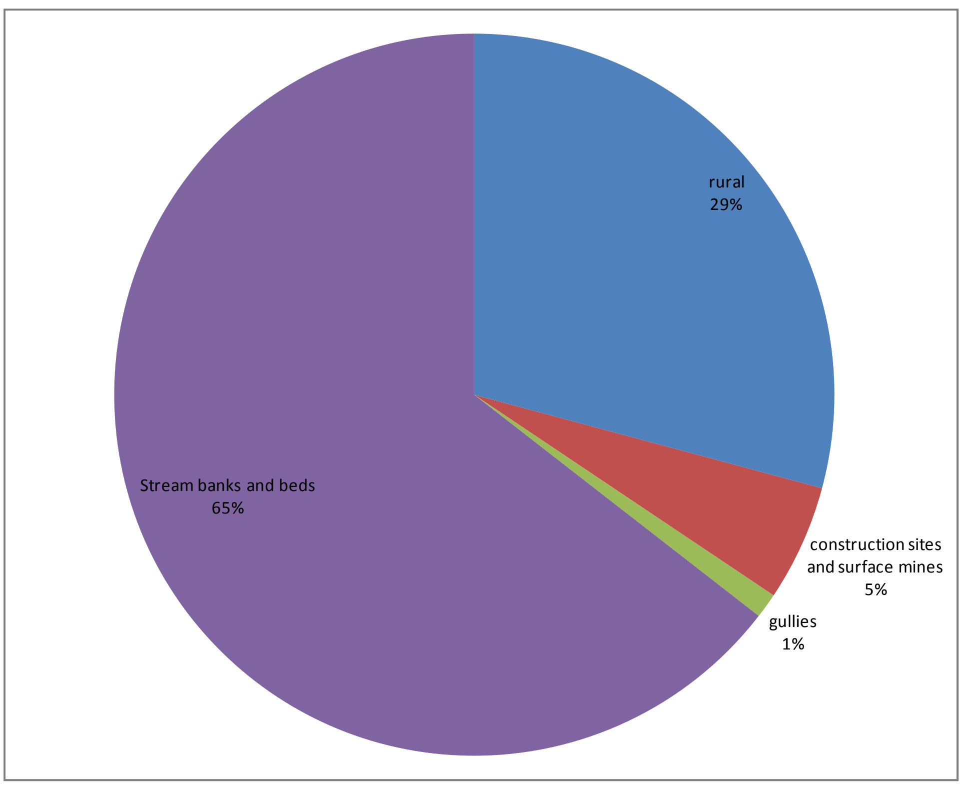

Figure P.2. Estimated sediment sources for Mill-Pelahatchie Creek watershed.

2.0 RURAL, UPLAND EROSION

Sediments generated from rural, upland areas are based on the Generalized Watershed Loading Function (GWLF) Model (Dai et al. 2000). Loads were predicted on a monthly basis for a 5-year period (2000 through 2005). The GWLF model simulates the hydrologic cycle in a watershed and predicts streamflow based on precipitation, evapotranspiration, land uses, and soil characteristics (Dai et al. 2000). The model was used to provide monthly estimates of streamflow, soil erosion, and sediment yield. The model is also capable of predicting nutrient loads based on loading functions from surface runoff, groundwater, point sources, and septic systems. Nutrients were not predicted in this application of the model. However, this capability may be useful in future applications when sufficient nutrient monitoring data are available.

2.1 GWLF Model Setup

The GWLF model uses the universal soil loss equation to (USLE) estimate soil loss from rural lands. The sediment yields predicted by the USLE include <u>sheet and rill erosion</u>. GWLF predicts sediment yields on a monthly basis using the assumption that sediment yields are proportional to the amount of runoff. The amount of runoff is computed daily using the Soil Conservation Service (SCS) curve number equation (Ogrosky & Mockus 1964). An SDR estimates the amount of soil generated that actually reaches the streams. Table P.2 gives a summary of the types of input data, sources of the data, and the value used in the GWLF model of the Mill-Pelahatchie HUC12. Tables P.3 through P.6 include additional data needed for the GWLF model. A summary of the ULSE factors is given in Table P.7.

Table P.2. Sediment input parameters for GWLF model of Mill-Pelahatchie Creek watershed.

Input Parameter	Explanation/Data Source	Input Values
Daily Precipitation and Temperature	Jackson International Airport, COOPID 224472 (downloaded from National Climatic Data Center in December 2010)	Varies daily; the model was run for a 5-year period (April 2000 through May 2005). Model output from years 2 through 5 was processed as the model output.
Curve Number	GWLF manual and SCS tables.	Varies based on land use and condition, and hydrologic soil group C (see Table P.3 for details).
SDR	GWLF calculates the SDR based on the watershed area	13% for Mill-Pelahatchie Creek HUC12.
Soil Erodibility Factor (K)	The soil erodibility factor measures the resistance of the soil to detachment and transportation by raindrop impact and surface runoff. Soil erodibility is a function of the inherent soil properties, including organic matter content, particle size, permeability, etc. Values of K were based on the State Soil Survey Geographic (SSURGO) database. The average value for the HUC12 was used in the model.	The average value for the HUC12 is 0.32.
Slope Length Factor (L) and Slope Steepness Factor (S)	The L factor accounts for the effects of slope length on the rate of erosion. The S factor accounts for the effects of slope angle on erosion rates. An average LS value for the HUC12 was calculated using the 10-meter USGS digital elevation model (DEM) using the derived flow accumulation and slope of the DEM. The flow accumulation and slope were used within the following formula to derive the LS for any given 10-meter pixel: 1.6 * Pow(([flowacc] * resolution) / 22.1, 0.6) * Pow(Sin([temporal_slope] * 0.01745) / 0.09, 1.3)[1] The 10-meter DEM data were downloaded from Maris in August 2010. The DEM was derived from the USGS 1:24000 contour lines.[2] Supporting documentation for this method is available from the University of Texas.[3]	The average LS value for the HUC12 is 1.4. This value was used for all landuse types, with the exception of agricultural crops. The LS value for agricultural crops was obtained from consultation with the Natural Resources Conservation Service (NRCS).[4] NRCS suggested that a lower LS value was more realistic for fields in the Mill-Pelahatchie Creek watershed. An average value of 0.354 was used for the GWLF model.
Cover Management Factor (C)	The C factor accounts for the influence of soil and cover management, such as tillage practices, cropping types, crop rotation, and fallow on soil erosion rates	Varies based on landuse type (see Table P.4 for details).

[1] http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?id=6335&pid=6312&topicname=Pow
[2] http://www.maris.state.ms.us/metadata/DEM/10Mdem.htm
[3] http://www.utexas.edu/depts/grg/hudson/grg360g/EGIS/labs_04/Lab9/lab9_soil_erosion_05.htm
[4] Personal communication, Murray Fulton, NRCS, Brandon, Mississippi.

Table P.2. Sediment input parameters for GWLF model (continued).

Input Parameter	Explanation/Data Source	Input Values
Erosion Control Factor (P)	The P factor accounts for the influence of support practices such as contouring, strip cropping, and terracing on soil erosion rates.	An assumed value of P=0 was used for all landuse types except for agricultural crops. P = 0 was used because no information is known about specific practices on the HUC12 scale. This is a conservative assumption. NRCS was consulted about the P value for agricultural crops and suggested that P=0.5 was realistic for the Mill-Pelahatchie watershed.
Evapotranspiration Cover Coefficient (ET)	ET varies according to land use type and period within the growing season. The value is usually between 0 (impervious surfaces) and 1 (e.g., water).	The average value for the HUC12 is 0.61 during the growing season and 0.60 during the non-growing season. (see Tables P.5 and P.6 for estimates during the growing and non-growing seasons). The growing season was assumed to be April – October. The non-growing season was assumed to be November – March.

Table P.3. Curve numbers for Mill-Pelahatchie Creek watershed.

Landuse	Curve Number	Notes
Agricultural Crops	82	Assumed row crops, SR + CR good, HSG C
Pasture/Grassland	79	Assumed pasture continuous forage for grazing, fair condition
Forest/Woodland	73	Assumed woods, fair condition
Shrubland	60	Assumed brush, fair condition
Developed	86	Open space has grass cover of < 50%

Table P.4. Cover management factors.

Landuse Type	Value
Agricultural Crops	0.2*
Pasture/Grassland	0.13*
Forest/Woodland	0.005**
Shrubland	0.008**
Developed	0.2**

*Mississippi Handbook for the Universal Soil Loss Equation, USDA, April 1984.
**GWLF Manual (Dai et al. 2000).

Table P.5. ET during the growing season.

Land Use	Area (ha)	Fraction of Total Watershed Area	ET Cover Coefficient	Weighted Coefficient
Agricultural Crops	109.5	0.01	1	0.01
Pasture/Grassland	873.1	0.12	1	0.12
Forest/Woodland	2,170.5	0.30	1	0.30
Shrubland	884.1	0.12	1	0.12
Wetlands	676.2	0.09	0	0.00
Water	742.1	0.10	0	0.00
Developed	1,878.6	0.26	0.25	0.06
			Sum of Weighted Coefficients	**0.61**

Table P.6. ET during the non-growing season.

Land Use	Area (ha)	Fraction of Total Watershed Area	ET Cover Coefficient	Weighted Coefficient
Agricultural Crops	109.5	0.01	0.3	0.00
Pasture/Grassland	873.1	0.12	1	0.12
Forest/Woodland	2,170.5	0.30	1	0.30
Shrubland	884.1	0.12	1	0.12
Wetlands	676.2	0.09	0	0.00
Water	742.1	0.10	0	0.00
Developed	1,878.6	0.26	0.25	0.06
			Sum of Weighted Coefficients	**0.60**

Table P.7. Summary of RUSLE input data for Mill-Pelahatchie Creek watershed.

Landuse Type	Soil Erodibility (K)	Length-Slope (LS)	Cover Management Factor (C)	Erosion Control Practice Factor (P)
Agricultural Crops	0.32	0.354	0.2	0.5
Pasture/Grassland	0.32	1.41	0.13	1
Forest/Woodland	0.32	1.41	0.005	1
Shrubland	0.32	1.41	0.008	1
Developed	0.32	1.41	0.2	1

2.2 GWLF Model Results

The model was run for a period of 5 years (April 2000 through May 2005). These years include both a dry year (2000) and a wet year (2003). The model output includes monthly estimates of runoff resulting from rainfall. The GWLF model gives runoff in terms of depth (cm) per contributing drainage area of the watershed. Runoff amounts for each landuse type vary depending on the curve number. The annual average runoff predicted for each landuse type is given in Table P.8.

Table P.8. Annual average runoff per landuse.

Landuse Type	Annual Runoff Depth (cm)
Agricultural Crops	31.06
Pasture/Grassland	25.89
Forest/Woodland	18.2
Shrubland	8.41
Wetlands	157.43
Water	157.43
Developed	40.08
Average for All Landuses	**50.65**

The model generates estimates of soil erosion based on the monthly runoff amounts. The product of the monthly soil erosion and the SDR is equal to the sediment yield. Monthly average sediment yields from rural landuses are shown in Table P.9. Note that the GWLF model was used to generate sediment yield estimates from rural landuses only (agricultural crops, pasture/grassland, forest/woodland, and shrubland).

Table P.9. Monthly average sediment yield from rural landuses.

Month	Sediment Yield (tons)
April	327
May	90
June	65
July	302
August	292
September	396
October	233
November	736
December	364
January	206
February	1193
March	906
Yearly Total	**5,112**

3.0 GULLY EROSION

The sediment load from gully erosion was estimated using the following equation:

Sediment Load = SDR * (total length of all gullies * gully erosion rate).

There are no data on the length of actively eroding gullies in the Mill-Pelahatchie Creek watershed. For these calculations, a value of 1,000 meters (3,280 feet) was used. This value was an estimate used to serve as a place holder until actual data to quantify the length of actively eroding gullies can be determined. The National Sedimentation Laboratory has recently developed remote sensing technology to identify sites with a high potential for ephemeral gully formation (Bingner et al. 2010). However, this method has only been applied to agricultural fields. A possible method to estimate this with a higher level of certainty would be to use low-level aerial photography[5] (available for Rankin County in 2006 and 2008) with ground-truthing to measure the length of gullies in a small area and extrapolate that value to the entire watershed. However, given that the current estimated sediment load from gully erosion accounts for such a small percentage of the total load (i.e., 1.1%), it is not expected that using a length of gullies based on measurements would significantly change the proportioning of the sediment load among the different sources. So, even with a gully length based on measurements, the estimated load would still be two orders of magnitude less than the total load.

The amount of soil eroded from the sides of gullies was estimated to be 0.46 ton per foot per year (1,368.8 kg/m/year). This erosion rate reflects an assumed annual rate of lateral advancement of 1 foot per year and a depth of eroding sides of 5 feet, with both sides eroding. These assumptions result in an average annual soil loss of 5 cubic feet along each foot of gully. The unit weight of soil was assumed to be 0.046 ton per cubic foot. These assumptions are consistent with those used to estimate tons of soil saved through gully stabilization in the Mill Creek watershed (Rankin County Board of Supervisors et al. 2009).

[5] Available for the Mill Creek watershed from 2006 and from all of Rankin County in 2008. Data were collected by the Rankin County Board of Supervisors.

The resulting equation used to calculate gully erosion is shown below:

Gully erosion = 1,368.8 kg/m/year * 1,000 meters = 1.37E6 kg/year

The yield from gullies (given in kilograms of total suspended solids [TSS] per year) was then calculated as the product of the erosion and the SDR. Results for Mill-Pelahatchie Creek watershed are given below:

Annual Sediment Yield (kg TSS/year) = 1.37E6*0.13

Annual Sediment Yield = 1.78E5 kg TSS/year

4.0 CONSTRUCTION AND SURFACE MINE SITES

The sediment load from construction and surface mining in the Mill-Pelahatchie HUC12 was estimated by multiplying the area of disturbed land in the watershed associated with these activities, by the amount of runoff per area, a sediment concentration for the runoff, and an SDR. The assumptions used in estimating sediment loads from urban land-disturbing activities (construction sites and surface mines) are described below.

4.1 Disturbed Area

The area disturbed by construction and mining activities was estimated based on MDEQ permitting programs. As of December 2010, there were 20 active Large Construction Stormwater General Permits[6] in the Mill-Pelahatchie HUC12. The area disturbed under each permit could not be easily determined from records, so an average area of 20 acres was assumed.

Records of Small Construction Stormwater General Permits are maintained by the county government in which they are located. Rankin County reported 249 sites under the small construction general permit in 2010. Because records of the site locations were not readily available, it was assumed that 20% of the sites, or 50 sites, were located in the HUC12.[7] The average disturbed area associated with small construction sites was assumed to be 5 acres.

MDEQ permit records indicate that there are three surface mining sites located in the Mill-Pelahatchie HUC12. Sizes of the mining sites were also not readily available, however the permits in this HUC12 are all “exempt” from office of geology permits. This means that the sites are smaller than 4 acres. As a conservative assumption, a size of 4 acres was assigned for the three mines.

The size of disturbed areas in the HUC12 was estimated as shown in Table P.10.

[6] Large Construction General Permits are issued for construction sites 5 acres or greater.
[7] We first considered an even distribution within Rankin County, based on size of Rankin County (795 square miles or 508,800 acres) compared to the size of the Mill-Pelahatchie Creek HUC12 (18,123 acres). 249 construction sites per 508,800 acres is equivalent to 9 sites within the HUC12. However, it is known that much of the construction activity is concentrated near the Reservoir in this HUC12, so the even distribution did not seem to be a good assumption.

Table P.10. Disturbed areas by construction and mining activity in the watershed.

Type	Disturbed Area
Large Construction Sites	20 sites* 20 acres = 400 acres
Small Construction Sites	50 sites * 5 acres = 200 acres
Surface Mines	3 sites * 4 acres = 12 acres
Total	662 acres (2.68 square kilometers)

4.2 Sediment Concentrations in Runoff

Literature values must be used to estimate the amount of sediment contained in stormwater runoff from construction and mine sites. The following literature values for runoff sediment concentrations were used[8]:

- The TSS in runoff from sites with insufficient best management practices (BMPs) = 11,000 mg/L.
- The TSS in runoff from sites with effective BMPs= 637 mg/L.

MDEQ conducted Compliance Evaluation Inspections in 2008 through 2010 and found violations at 20 of the 38 sites inspected near the Reservoir (53% of the sites). From these inspections, it was estimated that 50% of the disturbed areas had insufficient BMPs and 50% of the sites had effective BMPs. Using this estimate, the average TSS concentration in disturbed area runoff is 5,927 mg/L.

4.3 Runoff from Construction and Mining Sites

The GWLF model was used only to calculate the amount of runoff for developed areas. Sediment loads were not calculated with this model. The amount of runoff from developed areas was calculated by the GWLF model as 40.08 cm/year (1.07E6 m^3/year). Note that the model input for the developed landuse is included in Tables P.2 through P.6.

[8] Calculate erosion per acre using TSS concentrations from Edwards (2003; as cited in ADEQ 2004) assuming that half of acres have no BMPs (i.e., TSS in runoff is 11,217 mg/L) and the other half have effective BMPs (TSS in runoff is 637 mg/L).

4.4 Estimated Sediment Load from Construction and Mining Sites

The amount of erosion from disturbed areas was calculated as follows:

Erosion (kg TSS/year) = 1.07E6 m^3/year * 5,927 mg/L = 6.34E6

The yield from disturbed areas was then calculated as the product of the erosion and the SDR. Results for Mill-Pelahatchie Creek watershed are given below:

Annual Sediment Yield (kg TSS/year) = 6.34E6 * 0.13

Annual Sediment Yield = 8.24E5 kg TSS/year

5.0 MEASURED SEDIMENT LOAD

Data collected from monitoring stations located in the Mill-Pelahatchie Creek HUC12 was used to calculate the measured sediment load. USGS has monitored flow and suspended sediments at several locations in the Mill-Pelahatchie Creek HUC12. Only two stations have simultaneous records of flow and suspended sediments, so that the sediment samples can be converted into instantaneous measurements of sediment load (Table P.11).

Table P.11. Monitoring data summary.

Station	Data Availability
Mill Creek at Hwy 25, USGS 02485574	Daily flow measurements (1998 – present); 707 suspended sediment samples with instantaneous flow readings (01/2008 – 09/2009)
Mill Creek Tributary 1, USGS 02485577	1,476 suspended sediment samples with instantaneous flow readings (09/2006 – 08/2010).

Linear regressions were developed relating the log of the flow yield (flow per amount of drainage area) and the log of the suspended sediments yield (suspended sediments load per amount of drainage area) from both sites. However, only the relationship developed for Mill Creek at Highway 25 was used in the final analysis. This is because the sediment yields from Tributary 1 were elevated due to known compliance problems as a large construction site. The yields measured Highway 25 were assumed to be representative of the yields expected in the HUC12 subwatershed, and the relationship was used to estimate sediment loads expected for the HUC12. It should be noted that the majority of the samples collected at Highway 25 are associated with rain event monitoring.

The linear regression for Mill Creek at Highway 25 was used to calculate the annual average sediment load contributed from land in the Mill-Pelahatchie Creek HUC12 (Figure P.3). The relationship can be expressed with the following equation:

$$\text{Log(kg suspended sediments/km}^2\text{/day)} = 1.517 * \text{Log(m}^3\text{/sec/km}^2\text{)} + 5.493$$

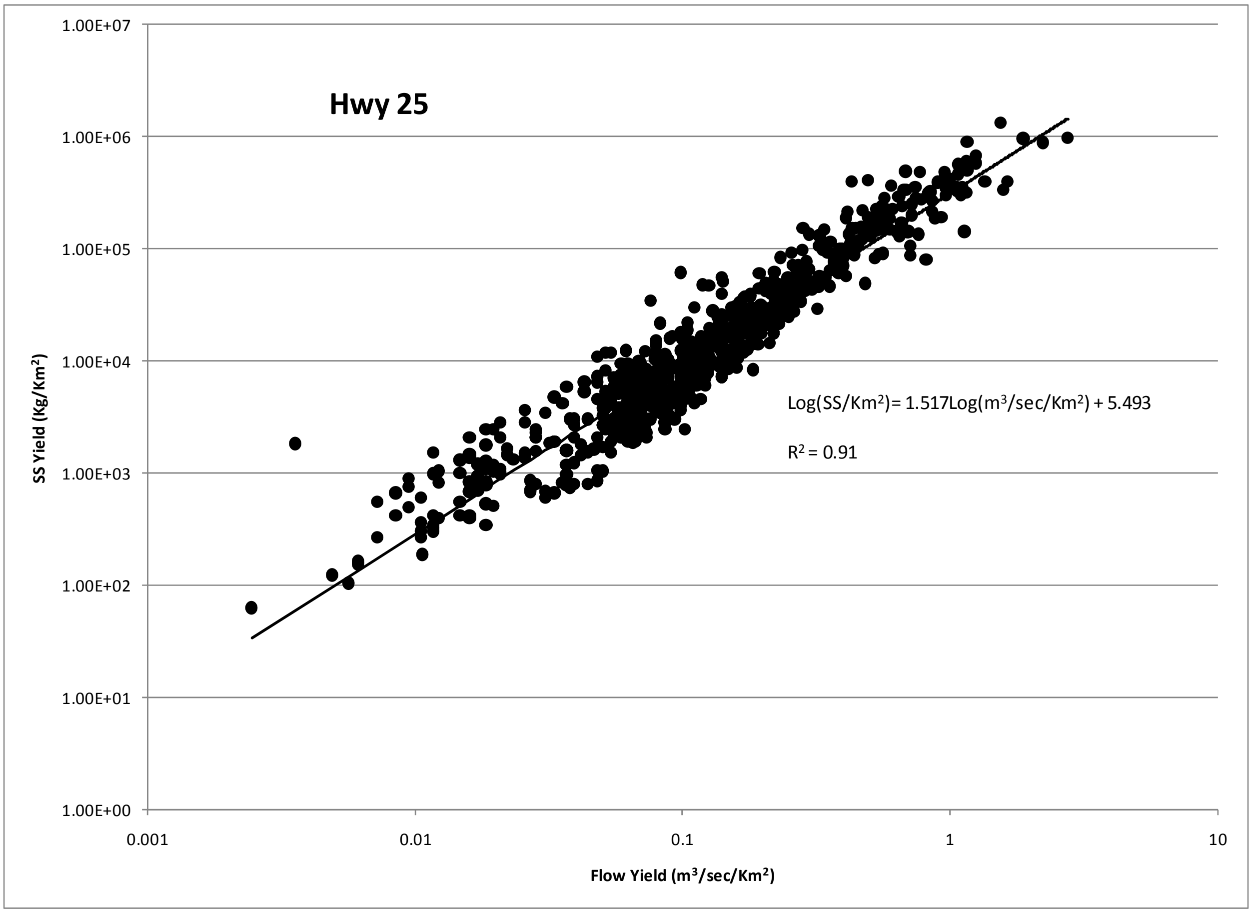

Figure P.3. Regression between flow and sediment yield for Mill Creek at Highway 25.

The annual flow yield from the Mill-Pelahatchie Creek HUC12 from the GWLF model is 50.65 cm (1.18 m^3/second for the area of 18,221 acres). Using the above equation, the estimated sediment load is 1.59E7 kg/year for the Mill-Pelahatchie Creek HUC12. Note that this is the measured sediment load indicated in Table P.1.

6.0 CONCLUSIONS

This analysis indicates that the largest sediment source in the Mill-Pelahatchie is instream sources, with smaller contributions coming from rural upland areas, disturbed urban areas, and gullies. A reasonable conclusion from this finding is that management measures to stabilize eroding stream banks and beds are needed to reduce the overall sediment loads in the system. However, instream management practices alone are not likely to reduce sediment loads enough to measurably improve water quality and reach the total maximum daily load (TMDL) goal of a "stable sediment yield at the effective discharge."

Plans for instream management practices should be developed with an understanding of the geomorphology of the system and possible geomorphic changes in stream channels. Stream stabilization measures alone that are installed at selected reaches could alter the energy-sediment balance and cause unintentional erosion problems at other locations. Watershed management decisions, especially the increase of impervious surface area in the watershed, are critical to preventing further erosion of stream channels. This is because stream channels in impervious watersheds experience increased peak flows in response to rain events. Increased peak flows are a direct cause of stream bank and bed erosion.

For these reasons, the management practices recommended for the Mill-Pelahatchie HUC12 include measures to reduce sediment and peak flows from upland areas along with instream practices. There are several reasons for this:

- The large sediment contribution from stream beds and banks also accounts for sediment stored in the stream channels from previous upland activities. Previous activities include historical row-crop agriculture and land development that occurred prior to regulation of construction sites. Sediments contributed from these activities are likely to aggregate in quiescent areas of the stream channels and floodplains. These sediments can be resuspended during high-flow events and flushed downstream. However it is likely to take tens to hundreds of years for this process to completely wash out existing sediments.
- Instream management practices can be extremely costly, with establishment of "natural" streambank stabilization methods costing as much as $200 per linear foot. Due to the high cost, it is unlikely that resources will be available to install these practices on a large scale.

- Practices that capture and infiltrate storm water flows from impervious surface areas within the watershed are highly recommended to reduce erosion-causing peak-flow events in the Mill-Pelahatchie HUC12.
- Preservation and restoration of riparian buffer zones is a highly recommended BMP. Riparian buffer zones have many positive benefits to adjacent streams including stabilization of eroding stream banks and reduction of peak-flow events. This would likely be effective for reducing sediment contributions from stream beds and banks.
- Management practices placed at headwater locations are less costly to implement, and their results often become visible to the public in a shorter amount of time. Public visibility is vital to the success of any watershed restoration project so that the public can "see" the results of their financial investments towards restoring and protecting water quality.

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APPENDIX Q

LITERATURE REVIEW:
SEDIMENT BUDGETS AND SOURCE STUDIES

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1.0 INTRODUCTION

Sediment budgets include both upland sources of sediments and sediments contributed from stream corridors (erosion of stream banks and resuspension of stream bed sediments). Upland sources can be attributed to land management activities that result in removal of natural vegetation (i.e., erosion of exposed sediments from construction sites, increased peak flows in urban areas, surface mining, forest harvesting, and agricultural activities).

Developing a sediment budget that delineates loads between upland and instream sources would be helpful to guide management practices and manage expectations related to sediment reductions expected from implementation of practices. However, attributing cumulative sediment loads to individual sources may be difficult without detailed information. Furthermore, attributing sources to one particular source over others may be controversial among the effected groups if this is done without adequate supporting information. Within urban areas, for example, quantifying sediment due to transport of sediments from construction sites due to sheet flow vs. gullies formed in areas with concentrated flows would require site-specific observation of where and when these process are occurring.

Most studies that have attempted to make accurate estimates of instream loads have included extensive field data collection activities and modeling efforts. A summary of several such studies is included in Section 2.0.

2.0 SEDIMENT YIELD STUDIES

2.1 James Creek

James Creek is a tributary of the Tennessee-Tombigbee Waterway located in Level III Ecoregion 65. Sediment yields were calculated using a combination of methods were used including empirical analysis of historic data from other sites, field reconnaissance and detailed data collection and surveying, and numerical modeling of uplands and channels. Models (AnnAGNPS and CONCEPTS) and direct comparison of channel cross sections measured over time were used to estimate yields.

"Actual" sediment yields (determined with field data and modeling) were compared with "reference" sediment yields for Ecoregion 65. Reference yields were adjusted to account for bed material particle size and given as 2.22 tons per day per square kilometer at the $Q_{1.5}$ flow (the high-flow condition that is expected statistically to occur once every one and a half years). (Note that this reference yield value is for stable streams). Modeling data predicted actual yield for recent years at the $Q_{1.5}$ to be 39 tons per day per square kilometer. Annual average yield for recent years calculated with monitoring data is 727 tons per year per square kilometer. (Please note that the annual average yield cannot be compared to reference yields at the $Q_{1.5}$ because the annual average yield is calculated in terms of tons per year, not per day.)

Based on historical record, sediment yields were 89% from the bed and banks and 11% from upland sources. High bed and bank sources were attributed to historical stream channel modification, which included clearing with a dragline. More recent years (1970-2002) show that 70% of the sediments originate from banks and 30% are from the watershed. Management practices should focus on stream-channel processes and stabilizing eroding reaches and tributaries.

2.2 Town Creek near Tupelo

The Mississippi State University (MSU) Department of Civil Engineering, in cooperation with the National Sedimentation Laboratory (NSL), has conducted extensive field work and sediment budget calculations on Town Creek near Tupelo. Results indicated that up to 70% of the sediments delivered to the outlet originated in the upper region of the watershed. The drainage area of the upper region constitutes approximately 30% of the total drainage area (Ramirez-Avila et al. 2010b). Sources in the upper watershed were gulley erosion from agricultural lands and erosion from incised channels. Downstream reaches appeared to be stabilizing, and functioned as a zone of deposition due to influence of the Tennessee-Tombigbee waterway (Ramirez-Avila et al. 2010a).

Additional conclusions were as follows:

- Upper reaches appeared to be in the degradation stage (active bank failure and channel widening), based on data analysis and visual observation. Middle and lower reaches appeared to be in aggradation; channels are wide and stable with the presence of vegetation (Ramirez-Avila et al. 2010b).
- Estimated suspended sediment yield at the $Q_{1.5}$ flow was 80 tons per day per square kilometer. This estimate was obtained using the transport curve for Nettleton, Mississippi.
- Regional relationships for sediment yield are significantly lower than estimates obtained from local data. Reference yield for Ecoregion 65 streams is 3.9 tons per day per square kilometer. This is the median value for all sites in Mississippi given in Simon et al. 2002a.
- Temporal analysis shows a reduction of sediment loads at baseflow conditions.
- Increased loads under higher flow conditions in upper reaches were attributed to active geomorphic processes.

Field data collected for this effort included the following:

- Spatially distributed grab samples at 24 locations;
- Automatic sampling during storm events at three locations, including analysis of riding limb and falling limb samples;
- Stream bank erosion monitoring by cross-section surveys and erosion pin arrays (with analysis of change over time), and
- Stream bed sediment sampling (Ramirez-Avila 2010).

Efforts to develop correlations between stream bank erosion and physical and geomorphic variables (riparian vegetation, streambank soil saturation, bank height and angle) have not been successful at this point in the research. However, researchers expect to be able to draw some conclusions relating sediment deposition rates to riparian vegetation and geomorphic variables.

2.3 Harland Creek

Researchers studied Harland Creek, a stream located near Yazoo City in the hill region of the Yazoo River Basin. This study described the economic benefits of streambank stabilization practices and reduction of phosphorous contributed via bank erosion (Hubbard et al. 2003). Sediment and associated phosphorus loads were estimated for a selected reach of the creek using lateral bank migration rates estimated from an analysis of aerial photographs from 1955, 1973, 1980, and 1991. Bank heights were estimated from cross sections measured at multiple sites along the study reach. Volumes of sediment eroded from the stream banks were estimated for the time periods between each set of aerial photographs. Phosphorus loads associated with eroded stream banks were calculated based on measurements of soil density and phosphorus content.

Several methods of bank protection were installed as part of the Demonstration Erosion Control (DEC) project on Harland Creek, including bendway weirs and willow posts. Reductions in sediment contributions from bank erosion were estimated by comparing volumes of sediment lost before and after the installation of management practices.

2.4 West Fork White River, Arkansas

The Arkansas Department of Environmental Quality (ADEQ) used Bank Erosion Hazard Index (BEHI) to estimate streambank erosion rates and an annual sediment load due to streambank erosion in the West Fork White River (WFWR). This method uses criteria including bank angle, root depth, and bank material. Data also included cross-section surveys of stream banks. Toe pins were used to measure lateral movement of banks. Researchers used a graphical model based on physical measurements to estimate lateral erosion rates and total sediment contributed from inventoried streambanks. Sediment loads from streambanks averaged 329 tons per year per square mile. Authors concluded that 80% of the of the estimated suspended sediment load for the watershed resulted from erosion of the streambanks along the main stem of the WFWR that were included in the inventory (Van Eps et al. 2004).

2.5 Chesapeake Bay

Sediment studies conducted throughout Chesapeake Bay watershed have been summarized by a large workgroup in a comprehensive report (US Geological Survey 2003). The report included a review of literature from many authors addressing sediment erosion, deposition, and resuspension processes. Implications of various management practices on the bay were also explored. The report concluded that attributing loads to individual sources is difficult and uncertain even in the most highly studied watersheds. The importance of this is summarized in a quote from the executive summary:

> "… one of the most important conclusions drawn by the SWGP was that the relative contribution of upland sediment and the sediment stored in stream corridors has not been quantified in the bay watershed. Such information is important to formulate effective sediment-reduction strategies."

However, a few specific examples were cited where this determination was made. Two studies conducted in Baltimore County, Maryland, found that approximately two thirds of the loads were the result of channel erosion and one third of the load was due to watershed sediment contribution.

Most of the sediment yield from the watershed to the bay is transported during bankfull conditions, which take place on average every 1 to 2 years, and during relatively large storm events. The report also discusses "legacy sediments" that were washed into streams during initial land clearing following colonial settlement. Unknown amounts of sediments from initial land development are now stored in hill slopes, riparian areas, stream beds, and floodplains. Eventually these sediments will be washed downstream, but this process may take decades or even hundreds of years.

3.0 COMPONENTS OF SEDIMENT BUDGET

Sediment budgets can be developed with a mass balance approach to account for sediment sources, sinks and yield (output) of sediment. Yield is discussed as a sediment delivery ratio (the ratio of sources to output). It can vary from 0 to greater than 1 (greater than 1 indicates the washing out of previously stored sediment).

Components of a sediment budget include:

- Sources – surface, gulley and mass erosion + channel erosion; and
- Sinks – hillslope storage, floodplain storage, and channel storage.

Budgets are usually calculated on an annual yield, and do not predict large amounts of sediment movement during short time periods (high-flow events). Budgets can be used to guide management practices and estimate the influence of local landscape changes on the sediment yield.

4.0 SEDIMENT REFERENCE YIELDS AND TMDL TARGETS

Effective discharge is defined as the water discharge or range of discharges that shape channels and perform the most geomorphic work (erosion and transport of sediment) over the long term. The Mississippi Department of Environmental Quality (MDEQ) uses "target yields," which represent a range of sediment yields at the $Q_{1.5}$ flow for stable and unstable streams for sediment total maximum daily loads (TMDLs). Yields differ for each Level III Ecoregion. The target yields are based on the work of NSL (Simon et al 2002a).

NSL calculated the effective discharge for ten sites in Mississippi where a sufficient record of flow and suspended sediment concentrations were available (all sites included at least 10 years of record). The average ratio of $Q_{1.5}$ to effective discharge was 1.2, showing that the $Q_{1.5}$ can be used as a surrogate for effective discharge. NSL used this assumption to calculate suspended sediment yields at the $Q_{1.5}$ flow for all sites with available data. Ranges of the $Q_{1.5}$ yields (25th and 75th percentile) became the TMDL targets for stable and unstable streams.

MDEQ has developed sediment TMDLs using ranges of expected sediment yields for stable versus unstable streams. The TMDL targets are based on expected yields at the effective discharge. This discharge can be estimated as the $Q_{1.5}$.

The effective yields were developed by NSL based on analysis of suspended sediment and flow data for streams in each ecoregion. Streams with an adequate record of monitoring data were grouped as stable and unstable based on a geomorphic assessment (Simon et al. 2002a). The majority of the Reservoir watershed is located in Ecoregion 65, the Southeastern Plains. The exception to this is a portion of the Pelahatchie Bay watershed, which is in Ecoregion 74, the Loess Plains. Soils in the Loess Plains are among the most erosive soils in the Unites States. For this reason, the TMDL targets are an order of magnitude higher for streams in the Loess Plains. MDEQ used the 25th and 75th percentile of the yields calculated for each ecoregion as the low and high targets for sediment TMDLs (Table Q.1).

Table Q.1. Sediment yields for stable and unstable streams.

Ecoregion	Stream Type	25th Percentile Yield (tons/day/sq km)	75th Percentile Yield (tons/day/sq km)
65	Stable	0.09884	0.44478
	Unstable	0.4942	13.3434
74	Stable	0.81543	3.4594
	Unstable	73.6358	458.6176

Comparing sediment measures to the TMDL targets requires a long-term record of flow (so that the $Q_{1.5}$ flow can be calculated) along with measurements of suspended sediment concentration during various flow conditions. There is no specific rule as to how much data is adequate, but 5 years is a typical rule of thumb. Using this rule, there are three stations in the Reservoir watershed with adequate data. These stations are Mill Creek at Highway 25, and unnamed tributary to Mill Creek, and Fannegusha Creek near Sand Hill. The $Q_{1.5}$ sediment yields were estimated for these stations (Table Q.2).

Table Q.2. $Q_{1.5}$ sediment yields for streams in the Reservoir watershed.

Station	USGS Station Number	$Q_{1.5}$ Flow (cfs)	$Q_{1.5}$ Yield (tons/day/sq km)	Notes
Mill Creek at Highway 25	02485574	750	302.1	Within unstable stream range for Ecoregion 74.
Mill Creek Tributary #1 at Grants Ferry Road	02485577	240	1,072.4	Greater than unstable streams range for Ecoregion 74. High yields were due to construction site runoff.
Fannegusha Creek near Sand Hill	02484760	2300	22.41	Greater than the range for unstable streams in Ecoregion 65.

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APPENDIX R

PRELIMINARY SCOPE OF WORK AND COST OF SEDIMENT BUDGET

Broad-Scale Geomorphic Assessment and Sediment Budget for the Pearl River Watershed Upstream of the Ross Barnett Reservoir

Note: This scope was developed by David S. Biedenharn, PhD, of the Biedenharn Group, LLC, and was submitted on September 20, 2011. Current contact information is phone number (601) 529-4685 and email bidenharngroup@yahoo.com.

This scope of work describes the tasks involved in the development of a broad-scale geomorphic assessment and sediment budget for the Pearl River Watershed upstream of the Ross Barnett Reservoir, and provides an estimate of costs to develop the assessment. Developing a sediment budget for a large system such as the Pearl River Watershed is complex, and there will be considerable uncertainty in the results, no matter what level of study is conducted. Because of this, it is often advisable, particularly in reconnaissance and feasibility level studies to conduct a more general assessment of representative segments of the watershed and then extrapolate these results to the remaining watershed. Development of a broad-scale sediment budget to estimate the amount of sediment delivered to the Ross Barnett Reservoir from the contributing basin includes identification of potential sediment sources and sinks, quantification of these data by grain size, and consideration of the uncertainty of the data. The sediment budget estimates the volumes and transport rates of sediments in the contributing watershed and provides a scientific framework for identifying, screening and evaluating potential alternatives for the purpose of reducing sediment yield and improving water quality. The broad-scale assessment also serves as the foundation for more detailed geomorphic analyses and sediment modeling if these efforts are deemed necessary.

1. **Aerial Reconnaissance (with Red Hen).** A helicopter reconnaissance of the Pearl River Watershed upstream of the Ross Barnett Reservoir will be conducted to provide a broad perspective of the watershed processes. A geo-referenced video will also be collected from the helicopter using the Red Hen methodology. Approximately 1,130 miles of channels will be reconnoitered as part of this aerial investigation.

   Cost Estimate: $97,410

2. **Analyze All Red Hen Videos.** The Red Hen videos will be analyzed to document the status of existing channels and structures, location of problem areas, identification of type and extent of bed and bank erosion, sediment sources and sink areas, and significant morphological features.

   Cost Estimate: $19,680

3. **Field (Ground) Investigations.** Using the results of the Red Hen analysis, a ground investigation of the watersheds will be conducted. These ground investigations will be used to supplement the information gained through the aerial reconnaissance. During these ground investigations, sediment samples will be collected from representative sediment sources (streambanks, gullies, stream beds, etc.) throughout the watersheds. All samples will be analyzed to develop gradations of the sediment sources.

   Cost Estimate: $19,220

4. **Analysis of Gage Records.** An analysis of all available stage and discharge data in the watershed will be conducted. Stage trends will be analyzed to assess degradational and aggradational trends. An analysis of the available measured suspended sediment data will also be conducted. Total annual sediment loads will be developed for the period of records available at each gage. If data are available, the annual loads will be developed by grain size. An analysis will be conducted to assess spatial and temporal trends in the data.

   C**ost Estimate: $7,380**

5. **Estimates of Sediment Supply from Sources.** The major sediment sources in the reconnoitered streams will be identified. Typical sources may include sediment supply from stream bank erosion, upland erosion from the watershed, gullies, and the channel bed. Quantitative estimates of the annual supply of sediment, by grain size, will be developed for these sediment sources. Estimates will also be made of the un-surveyed portions of the watersheds since these 1^{st} and 2^{nd} order streams may represent a significant source of sediment in these watersheds.

   Each sediment source will be analyzed with as much accuracy as possible, given limitations of available data sources and methods by which input was developed. However, it must be recognized that there will still be considerable uncertainty in the development of all these estimates. A value of variability (e.g., +/-25%, +/- 10%, etc.) will be assigned to each individual source estimate and an uncertainty analysis will be conducted to present a range of values for these inputs.

   Cost Estimate: $24,360

6. **Develop Sediment Budget.** A spreadsheet-based sediment budget will be developed by integrating the knowledge gained through the tasks above. The sediment budget will identify the major sources and sinks in the system, and how these source sediments are related to the sinks. A range of results will be developed reflecting the uncertainty analyses.

   Cost Estimate: $17,880

7. **Report.** A report summarizing the findings of the study will be prepared and submitted to the Mississippi Department of Environmental Quality.

   Cost Estimate: $7,380

Total Cost for All Tasks – $198,310

APPENDIX S

PERFORMANCE MEASURES FOR GREEN INFRASTRUCTURE

The following appendix contains recommended design criteria for specific stormwater best management practices. The design criteria were developed by the Mississippi Department of Environmental Quality (MDEQ) in order to assist developers in designing stormwater management structures that improve water quality. The recommendations are consistent with green infrastructure enhancement in the Ross Barnett Reservoir watershed. The design criteria are reprinted below and will be included in MDEQ's *Planning and Design Manual for the Control of Erosion, Sediment, and Stormwater*.

Additional Recommended Design Criteria, Specifications and Methodologies

The following criteria, specifications, and methodologies are recommended for stormwater management systems that are not specified by applicable regulatory requirements of federal, state or local jurisdictions.

Wet Detention Systems: These systems collect and temporarily store stormwater in a permanently wet impoundment in such a manner as to provide for treatment through physical, chemical, and biological processes with subsequent gradual release of the stormwater. These systems should be designed to meet the following requirements:

1. Required volume: First 0.5 inch of runoff or 1.5 inches of runoff from impervious area

2. Return time: Outfall structure must discharge one half (½) volume of stormwater within 48 to 72 hours. No more than one half (½) the volume will be discharged within 48 hours.

3. Permanent pool: Provide average residence time at least 14 days during wet season

4. Littoral zone design:

    1. Sloped (4:1 or flatter) to a depth of at least 2 feet below control elevation; approximately 30 percent of the wet detention system surface area should be littoral zone (ratio of vegetated littoral zone to surface area of the pond at the control elevation).
    2. The treatment volume should not cause pond level to rise more than 18 inches above the control elevation, unless the littoral zone vegetation can survive at greater depths.
    3. Eighty percent coverage of the littoral zone vegetation should be established within the first 24 months. Portions of the littoral zone may be established by placement of wetland topsoils (at least a four inch depth) containing a seed source of desirable native plants. To utilize this alternative, the littoral zone must be stabilized by mulching or other means.

4. A forebay should be established at the pond inflow points to capture larger sediment particles and be 4 to 6 feet deep. The forebay volume should equal about 20% of the total basin volume. Multiple inlets may require additional volume. Direct maintenance access should be a minimum of 15 feet wide, with a maximum slope of 5:1.

5. Mean depth of the permanent pool should be between 2 and 8 feet. The maximum depth should not exceed 12 feet below the invert of the outlet device, unless the deeper depths will not inhibit physical, chemical, and biological treatment processes or cause re-suspension of pollutants into the water column due to anaerobic conditions in the water column.

6. Flow path through pond should have an average length to width ratio of at least 2:1. The alignment and location of inlets and outlets should maximize flow paths in the pond. If short flow paths are unavoidable, the effective flow path should be increased by adding diversion barriers such as islands, peninsulas, or baffles to the pond. Inlet structures should be designed to dissipate the energy of water entering the pond.

7. Outlet devices incorporating dimensions smaller than three inches minimum width or less than 20 degrees for “v” notches should include a device to eliminate clogging. Examples include baffles, grates, and pipe elbows.

8. Outlet structure invert elevations should be at or above the estimated post-development normal ground water table elevation. If the proposed structure is set below this elevation, ground water inflow must be considered in the drawdown calculations, calculation of average residence time, estimated normal water level in the pond, and pollution removal efficiency of the system.

9. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system, including the pond, littoral zone, inlets, and outlet should be established.

Dry Retention Systems: These systems are designed to collect and temporarily store stormwater in a normally dry basin with subsequent gradual release of the stormwater. Dry detention is recommended as an off-line system, but if the design calls for an in-line system, additional volume may be required. Additional volume may be required for on-line systems. These systems should be incorporated as a best management practice in a treatment train approach, which includes other best management practices, including but not limited to, grassed swales, level spreaders, filter strips, buffer zones, bioretention, and skip curbs all with water flow lengths less than 300 feet. Dry retention systems are not recommended for use in areas that require piped water conveyance systems. These systems should be designed to meet the following requirements:

1. Required volume: first 1.0 inch of runoff or 2.5 inches from impervious areas, whichever is greater?

2. Return Time: Discharge one-half the appropriate treatment volume of stormwater specified above between 24-30 hours following a storm event.

3. Discharge structures should include a device to prevent the discharge of accumulated sediment, minimize exit velocities, and prevent clogging. A perforated riser enclosed in a gravel jacket and perforated pipes enclosed in sand or gravel is a good example.

4. Contain areas of standing water for no more than 3 days following a storm event.

5. Stabilized with permanent native vegetative cover.

6. Average flow path through the basin should have a length to width ratio of at least 3:1. The alignment and location of inlets and outlets should be designed to maximize flow paths in the basin. If short flow paths are unavoidable, the effective flow path should be increased by adding diversion barriers such as baffles.

7. Inlet structures should be designed to dissipate the energy of water entering the basin.

8. A maintenance schedule is recommended for removal of sediment and debris on at least a bi-monthly basis, as well as mowing and removal of grass clippings.

9. Basin floor should be level or uniformly sloped (1-2% maximum) toward the outfall structure.

10. Basin floor should be at least three feet above the seasonal high ground water table elevation. Sumps may be placed up to one foot below the control elevation.

11. Permanent maintenance easements or other acceptable legal instruments should be in place to allow for access to and maintenance of the system. The easement or other acceptable instrument should cover the entire stormwater system.

Constructed Wetland Systems: Wetland systems collect and temporarily store stormwater in a permanently wet impoundment and provides treatment through physical, chemical, and biological processes. These systems should be designed to meet the following requirements.

1. Required volume: First 1.0 inch of runoff or 2.5 inches of runoff from impervious area.

2. Inflow of water must be greater than infiltration.

3. Designed for an extended detention time of 24 hours for the 1-year storm event.

4. Protection against blockage should be installed around outlets vulnerable to blockage form plant material or other debris that will enter the basin with stormwater runoff. Reverse slope pipes are recommended.

5. Surface area of the wetland should account for a minimum 3% of the area of the watershed draining into it.

6. The length to width ratio should be at least 3 to 1.

7. Deeper area of the wetland should include the outlet structure so that the outflow from the basin is not impeded by sediment buildup.

8. A forebay should be established at the pond inflow points to capture larger sediment particles and be 4 to 6 feet deep. The forebay volume should equal about 20% of the total basin volume. Multiple inlets may require additional forebay volume. Direct maintenance access should be a minimum of 15 feet wide, with a maximum slope of 5:1.

9. In cases where water velocities exceed 0.5 ft/s, energy dissipation devices should be installed.

10. Pre- and post-grading pondscaping design should be used to create both horizontal and vertical diversity and habitat.

11. Approximately 30 to 50 percent of the shoulder (12 inches or less) area of the basin should be planted with native wetland vegetation.

12. A 25-foot buffer, for all but pocket wetlands, should be established and planted with native riparian and upland vegetation.

13. Surrounding slopes should be stabilized by planting in order to minimize sediment and pollutants from entering the wetland.

14. A written maintenance plan should be provided and adequate provision made for on going inspection and maintenance. Maintenance should be scheduled more often during the first three years after construction.

15. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system is recommended. The easement or other acceptable instrument should cover the entire stormwater system.

Swale Systems: These systems are man-made trenches which filter and treat stormwater runoff as part of a treatment train approach. Swale system criteria may vary depending on its place in the treatment train. However, at a minimum these systems should be designed to meet the following requirements:

1. Required volume should be designed for a 6-month, 24-hour design storm event.

2. No contiguous areas of standing or flowing water within 72 hours following storm event.

3. Peak discharges should be 5 to 10 cfs.

4. Water velocity should be 1.0 to 1.5 ft/s.

5. Maximum design flow depth should be 1 foot.

6. Swale slopes:
   a. Graded as close to zero as possible and still permit drainage
   b. Should not exceed 2%

7. Must have a top width to depth ratio of greater than 6:1, or cross-section side slopes of 3:1 (horizontal:vertical) or flatter.

8. Swale length should be at least 100 feet per acre of drainage area.

9. Underlying soils should have high permeability.

10. Swales must be planted with or have stabilized native vegetation suitable for soil stabilization, stormwater treatment, and nutrient uptake.

11. Soil erodibility, soil percolation, slope, slope length, and drainage area must be taken into account, in order to prevent erosion and reduce pollutant concentration of any discharge.

12. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system is recommended. The easement or other acceptable instrument must cover the entire stormwater system.

Manufactured Stormwater Treatment Systems: These systems are recommended for use in commercial and industrial developments. The manufactured systems should satisfy the following conditions:

1. Field test data from the southeastern United States should be available. The test data should be from an area with similar rainfall distribution as the project area.

2. Field test data should provide the following results:
   a. Removal of 70-80% of total suspended solids (TSS)
   b. Particle size distribution for TSS removal rates
   c. Conditions under which TSS removal is obtained (storm event, rainfall intensity, etc.)

3. Maintenance information should include how often the system should be serviced.

4. Manufactured systems should be structurally sound and designed for acceptable municipal and commercial traffic loadings.

5. Manufactured systems should not allow inflow or infiltration.

6. Weirs, openings, and pipes should be sized to pass, as a minimum, the storm drain system design storm.

7. Manholes should be provided to each chamber to provide access for cleaning.

8. Treatment train approach incorporating the use of other appropriate best management practices is recommended because efficiency will be increased and maintenance reduced.

9. Permanent maintenance easements or other acceptable legal instruments to allow for access to and maintenance of the system is recommended.

Detention Practice Criteria: These criteria are recommended when post-construction runoff volumes should be kept to pre-construction values in order to prevent downstream degradation and flooding. Detention basins and associated outflow structures should be designed to address the 2-year, 5-year, 10-year, and 25-year, and 50-year, 24-hour storm events.

> Runoff volumes and rates may be calculated using the SCS Runoff Curve Number Method (see Appendix Volume, Appendix A, A-16).
>
> Detention storage may be determined using the Short Cut Floodrouting Method for determining drainage areas and runoffs that fall with the method's limits. If drainage areas and runoffs fall outside the method's limits other detention sizing methodologies should be used.

Erosion and Sediment Control Calculations for Estimated Reductions: The effect of BMPs may be calculated using the USLE methodology (see Appendix Volume, Appendix A, A-2). During construction, the BMP plan should demonstrate the ability to keep sediment yield to 115% of the pre-disturbance sediment yield (15% increase in sediment above pre-disturbance conditions). This is knows as performance based planning. A performance based plan can demonstrate that selected practices may meet the desired results.

Effectiveness of Erosion and Sediment Control BMPs: An estimate of the effectiveness of a selection of the more common erosion and sediment control BMPs may be found on Page A-11 of the Appendix Volume). These estimates can help in performance based planning.

APPENDIX T

COST ESTIMATES FOR MANAGEMENT MEASURES

INTRODUCTION

Cost estimates for installing management measures in the watersheds targeted for restoration were developed based on the areas proposed for new development and retrofits. Costs on a per-area or per-practice basis are based on estimated costs from various sources. Table T.1 also includes the relative land consumption that was used to estimate the footprint of the management practice based on the land area treated by the practice. For example, a correctly sized bioretention basin designed to treat the first-flush of stormwater will require approximately 5% of the land area draining into it. Tables T.2 through T.4 include cost estimates for management measures recommended for targeted watersheds. Cost estimates were converted to 2010 values based on an annualized inflation rate of 2.39%.[1]

[1] Per Measuring Worth website. Online at http://www.measuringworth.com/uscompare/. Average Annualized inflation rate from 1997 to 2010 is 2.39% based on the consumer price index.

Table T.1. Urban green infrastructure cost estimates.

Measure	Unit	Estimated Cost per Unit	Relative Land Consumption of Measure (% drainage area)	References and Notes
Bioretention areas/rain gardens	sq ft	$8.07	5% [2]	Cost estimates from various sources showed a wide range of variation depending on soil types and design criteria. Costs per acre of development range from $5,000 to $10,000 for larger areas and costs per square foot of treatment area range from $3 to $15[1]. Another reference estimated the cost of bioretention basins to be $240,000 per acre (WERF 2003). This cost estimate is based on $7 per square foot (2004 cost) or $8.07 square foot (2010 cost).
Stormwater detention/ retention basins	sq ft	$0.76	2% [2]	A typical retention basin costs $45,700 per acre-foot (Brown and Schueler 1997) [3]. Other sources give the average cost of installing a stormwater retention pond at $15,500 per acre of impervious surface area (CWP 2005).This cost estimate is based on a cost of $33,057 per acre-foot (2010 cost) and an assumed depth of 2 feet.
Infiltration systems	sq ft	$7.93	3% [2]	The construction cost of subsurface infiltration structures can vary greatly depending on design variations, configuration, location, desired storage volume, and site-specific conditions, among other factors. Typical construction costs are about $5.70 per square foot, which includes excavation, aggregate (2.0 feet assumed), non-woven geotextile, pipes and plantings.[4] This cost is $7.93 per square foot when corrected for 2010.
Constructed stormwater wetlands	sq ft	$1.92	4% [2]	A typical constructed stormwater wetland cost is $60,000 per acre-foot (Brown and Schueler 1997).[5] Cost estimate is based on an assumed depth of 1 foot. The cost corrected to 2010 is $83,514 per acre or $1.92 per square foot. Another study gave a cost of $125,000 for construction of a constructed stormwater wetland treating a 50-acre development (WERF 2003). The wetland footprint was approximately 2 acres at a cost of $62,500 per acre.
Pervious pavement	sq ft	$10.73	--	Estimate for the cost of pervious pavement is based on Hathaway and Hunt 2007.
Water quality swales/bioswales	sq ft	$1.39	--	$1.00 per square foot[6] based on 1997 prices. Cost estimates assume a standard width of 10 feet.

Table T.1. Urban green infrastructure cost estimates (continued).

Measure	Unit	Estimated Cost per Unit	Relative Land Consumption of Measure (% drainage area)	References and Notes
Grassed swales	sq ft	$0.70	--	$0.50 per square foot[7] based on 1997 prices. Cost estimates assume a standard width of 10 feet.
Vegetated filter strips with level spreaders	sq ft	$0.97	--	$0.70 per square foot[8] based on 1997 prices Cost estimates assume a standard width of 20 feet.
Green roof	sq ft	$20.00	--	$20 per square foot.[9] Cost estimates assume the applicable rooftop area of a building is 1,000 square feet.
Rain barrels/cisterns	per bldg	$200.00	--	Estimated cost for rain barrels is $200 per building.
Planned Urban Development (PUD)	acre	$7,500.00	--	Costs estimates based on low impact development subdivisions from TetraTech 2009.
Preservation of vegetation/trees on urban sites	--	--	--	Planning costs are included within the cost of improved stormwater controls on individual lots. There is little additional cost for preserving existing vegetation.
Homeowner education programs	--	--	--	Costs calculated in budget of the *Comprehensive Education & Outreach Plan for Rez*onate!.
Disconnected impervious areas	--	--	--	Costs included in the management measures used to treat disconnected stormwater (i.e., grassed swales, bioretention areas, etc.).

Notes:

(1) See Fact Sheet on Bioretention Basins/Rain Gardens in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

(2) WERF 2003. Table B-3, Cost and Relative Land Consumption by BMPs.

(3) See Fact Sheet on Stormwater Retention/Detention in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

(4) See Fact Sheet on Infiltration Devices in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

(5) See Fact Sheet on Constructed Stormwater Wetlands in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

(6) See Fact Sheet on Water Quality Swales in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

(7) See Fact Sheet on Grassed Swales in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

(8) See Fact Sheet on Vegetated Swales in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

(9) See Fact Sheet on Green Roofs in Appendix N of the *Comprehensive Protection and Restoration Plan* for details.

Table T.2. Measures for stream banks and buffer zones.

Measure	Unit	Cost per Unit	Notes
Vegetative stream bank protection/stabilization using bioengineering measures	LF	$190.00	Cost estimate based on median range from TetraTech 2009.
Restored riparian buffer/vegetative buffers	LF	$2.04	Cost for planting a forest buffer based on Lynch and Tjaden 2000. Cost of $700 per acre ($886 per acre for 2010) was converted to linear feet using the assumption that riparian buffers are 100 feet in width.

Table T.3. Other measures.

Measure	Unit	Cost per Unit	Notes
Improved stormwater controls on individual lots	acre	$2,000.00	This estimate represents the cost to the developer for erosion and sediment controls (silt fences, sedimentation basins, and phasing) from Tetra Tech 2009. The costs for local and state agency permitting and inspections are not included.
Green space and buffer zone maintenance	acre	$75.00	Cost to maintain natural open space with only minimal maintenance, trash/debris cleanup. This represents a significant cost savings over turf grass areas that must be maintained with regular mowing, which costs up to $300 per acre per year.*

*Note: from North Carolina Forest Service, Green Infrastructure. Available online at http://www.dfr.state.nc.us/Urban/urban_green_infrastructure.htm

Table T.4. Measures for lands in agricultural production.

Measure	Unit	Cost per Unit	Notes
Fencing of pastures (interior to facilitate rotational grazing) Alternative water sources for pasture Livestock stream crossing	acre	$150.00	The Mississippi Natural Resources Conservation Service (NRCS) 2011 Environmental Quality Incentives Program (EQIP) payment schedule lists the following costs: • Fencing at less than $1 to over $3 per linear foot, • Prescribed grazing at $80 to $180 per acre, • Watering facilities from approximately $80 to over $500 each, and • Stream crossing at almost $3 per linear foot. An average value of $150 per acre is assumed for best management practices (BMPs) needed to fence cattle and provide appropriate alternative water sources and stream protection.
Field borders	acre	$200.00	Establishing field borders is similar to establishing a filter strip.
Filter strips	acre	$200.00	NRCS assigns a cost of around $200 per acre for establishment of filter strips under EQIP.
Preserved/restored riparian buffer zones	LF	$0.88	Cost for planting a grassed buffer based on Lynch and Tjaden 2000. Cost of $300 per acre ($380 per acre for 2010) was converted to linear feet using the assumption that riparian buffers are 100 feet in width.
Nutrient management	acre	$8.00	Mississippi NRCS estimates costs for nutrient management vary from $1.80 to $14.4 per acre depending on the practice (ranges from basic nutrient management with soil testing to enhanced precision agriculture techniques with yield monitors for EQIP in 2011.
Properly designed skid trails and landings	acre	$500.00	Mississippi NRCS estimates costs for forest harvest trails and landings as between $480 and $780 per acre for EQIP in 2011.
Streamside management zones (SMZs)	--	Not available	The cost of SMZs is usually estimated based on the value of unharvested timber in the SMZ. The values varies based on the type of timber and market variability.
Forest regeneration	acre	$133.00	Reported costs for planting range from $23 per acre to approximately $150 per acre for seeding (1998 dollars). Cost is based on $100 per acre corrected to 2010.
Conservation easements	acre	$2,500.00	Cost estimate based on median range from Tetra Tech 2009.

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APPENDIX U

NINE KEY ELEMENTS FOR WATERSHED PLANS

Table U.1. Nine key elements for watershed plans.

Elements	Location in *Comprehensive Protection and Restoration Plan*
1. An identification of the causes and sources or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item 2. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; number of acres of row crops needing improved nutrient management or sediment control; or number of linear miles of eroded stream bank needing remediation).	Section 4.0, Sections 7.5 through 7.8, Appendix H
2. An estimate of the load reductions expected for the management measures described under item 3 (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). Estimates should be provided at the same level as in item 1 (e.g., the total load reduction expected for dairy cattle feedlots; row crops; or eroded stream banks).	Sections 7.5 through 7.8, Appendix N
3. A description of the nonpoint source management measures that will need to be implemented to achieve the load reductions estimated under item 2 (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.	Section 7.0
4. An estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, states should consider the use of their Section 319 programs; State Revolving Funds; USDA's Environmental Quality Incentives Program and Conservation Reserve Program; and other relevant federal, state, local and private funds that may be available to assist in implementing this plan.	Sections 7.5 through 7.8, Section 8.0
5. An information/education component that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.	*Comprehensive Education & Outreach Plan for Re*zonate! (FTN 2011)
6. A reasonably expeditious schedule for implementing the nonpoint source management measures identified in the Plan.	Section 8.0
7. A description of interim, measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.	Section 9.0

Table U.1. Nine key elements for watershed plans (continued).

Elements	Location in *Comprehensive Protection and Restoration Plan*
8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a nonpoint source total maximum daily load (TMDL) has been established, whether the nonpoint source TMDL needs to be revised.	Section 9.0
9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item 8.	*Ross Barnett Reservoir Monitoring Plan* (FTN 2011)