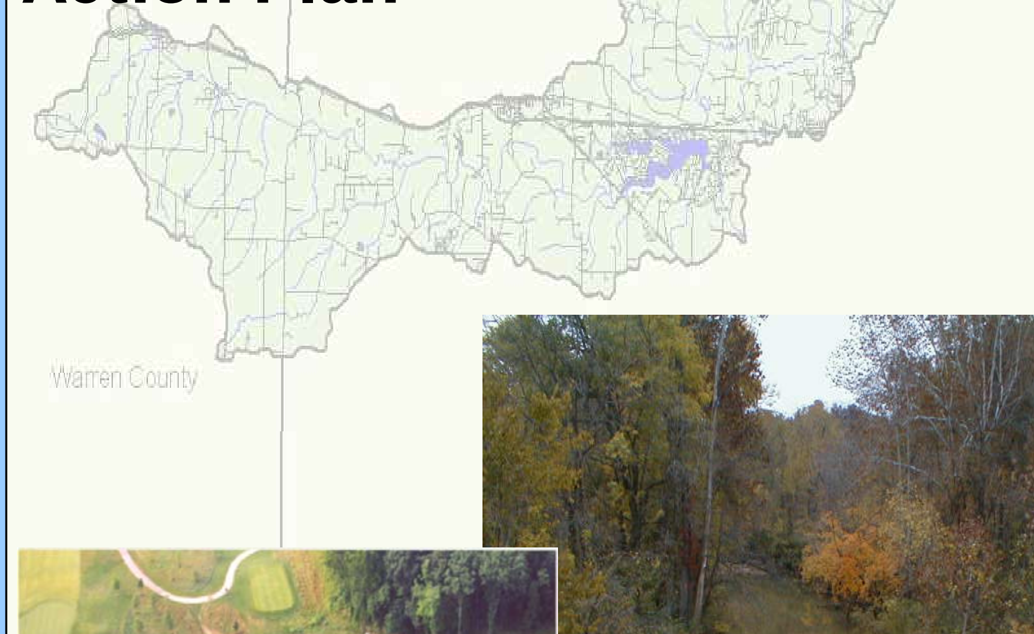
City of Lake Saint Louis

Peruque Creek Watershed Study

May 2005

Watershed Management Action Plan



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List of Abbreviations

BMP	Best Management Practices
CMA	Calcium Magnesium Acetate
CWP	Center for Water Protection
EPA	Environmental Protection Agency
E&SC	Erosion and Sediment Control
EMC	Event Mean Concentrations
GIS	Geographic Information Systems
HBA	Home Builders Association
HHWs	Household Hazardous Wastes
IBI	Index of Biological Integrity
IPM	Integrated Pest Management
LMVP	Lakes of Missouri Volunteer Program
LSLCA	Lake Saint Louis Community Association
MDC	Missouri Department of Conservation
MDNR	Missouri Department of Natural Resources
MoDOT	Missouri Department of Transportation
MSDIS	Missouri Spatial Data Information System
NRCS	Natural Resources Conservation Service
NURP	Nationwide Urban Runoff Program
NVSS	Non-Volatile Suspended Solids
PCWA	Peruque Creek Watershed Alliance
SWCD	St. Charles County Soil and Water Conservation Service
SCS	Soil Conservation Service Soil Surveys
TKN	Total Kjeldahl Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
UMC	University of Missouri-Columbia
USDA	United States Department of Agriculture
WMM	Watershed Management Model
WRDA	Watershed Resources Development Act
WWTP	Wastewater Treatment Plant

Section 1
Introduction

1.1 Project Understanding

The Peruque Creek Watershed is a small water resource region with numerous water uses and multiple objectives for improving environmental and economic conditions along Peruque Creek and its tributaries. Traditional water management strategies have focused on developmental controls, best management practices (BMPs), and site-specific compliance measures. While these types of measures are usually beneficial, they fail to account for all of the complex physical, environmental, and economic interrelationships within a watershed. What the Peruque Creek Watershed needs, is a unified and comprehensive watershed management action plan that addresses all of the stakeholders' objectives throughout the basin, and is based upon a sound, scientific assessment of the relationships related to the water and land use resources within the watershed. A grant was issued to the City of Lake Saint Louis, through the United States Environmental Protection Agency (USEPA), Region VII, to conduct a study of the Peruque Creek Watershed. The Peruque Creek Watershed Study is to outline the proposed approach to restoring and protecting the water quality in Peruque Creek, while sustaining economic development within the watershed. The primary objective of this study is to determine what measures are necessary to protect the designated uses in the Peruque Creek watershed. Other secondary watershed study objectives include the following:

Our Guiding Philosophy

"Protect the designated uses in Peruque Creek while fostering appropriate and sustainable development in the watershed. This will be done through the development of consistent and cooperative ordinances and actions taken by governmental authorities in St. Charles and Warren counties."

- Identifying and involving stakeholders in the study
- Targeting priority problems within the watershed
- Work with stakeholders to integrate goals and solutions in addressing water quality problems
- Form the basis for continual/long-term monitoring and assessment of water quality in Peruque Creek and associated tributaries (i.e. 5-year rotating schedule)
- Evaluate the progress and effectiveness of implemented measures and targeted areas
- Develop strategies for stream restoration and protection
- Promote inter-jurisdictional cooperation to restore and maintain the quality of Peruque Creek to its confluence with the Mississippi River
- Recommend changes to St. Charles and Warren County ordinances as necessary to achieve and enhance water quality goals.

The ultimate objective of the beginning of this project was to understand the basin, the source of its primary problems, the objectives of all its stakeholders, and the possibilities for restoration and abatement initiatives. This Watershed Management Action Plan is being developed so it can be used by residents and stakeholders to protect, enhance and comply with the water quality standards and designated uses of Peruque Creek and Lake Saint Louis while providing for long-term growth. This plan describes project objectives and goals, the results from the watershed inventory, water quality problems and sources, environmental indicators, a funding plan, potential remedial actions to reduce and eliminate water quality impairment, and any commitments from participating governmental agencies.

Under the current Missouri law, for those waters not meeting water quality standards, an analysis must be made of the sources of waste causing the water quality standards violation. Then a Total Maximum Daily Load (TMDL) must be developed that will define the total amount of pollutants that may be discharged into a particular stream segment within any given day based upon a particular use of that stream segment. The relationship between developing a TMDL and use of the watershed approach is very important. The TMDL process historically has been used in a very narrow fashion. The focus of this study was not the preparation of a formal TMDL that will be submitted for regulatory review and approval, but instead, a watershed management action plan which could be used in guiding water quality decisions in the watershed. The watershed management action plan can be utilized as a tool to protect the full-body contact recreation in Lake Saint Louis and to protect the warm water aquatic life and livestock watering uses in Peruque Creek.

One of the most important keys to the success of developing a watershed management action plan that achieve stakeholder objectives and are implementable, is the effective development of implementation strategies. These strategies must specify who will do what by when to achieve the pollution/stressor reduction or other responsibilities identified in the watershed management plan so as to eliminate the use impairments.

Finally, a critical aspect of developing this plan was keeping all stakeholders abreast of the success of the project and the progress that had been made. A project website was created to keep the stakeholders, public officials and the general public informed about the status of the project. The current website address is: www.peruquecreek.com

1.2 Peruque Creek Background

Peruque Creek was settled in 1797 by the Zumwalt family, who built a home and sawmill from logs hewn along the creek. Later in 1816, James Audrain moved his family to Missouri and settled on Peruque Creek, where he built a sawmill and distillery. Colonel Audrain and his wife were baptized in Peruque Creek. Jacob Zumwalt's old homestead came to be known as Fort Zumwalt. Two families occupied the homestead for nearly ninety years. Other farmers moved into the area and then small businesses emerged. For over 100 years the area was mainly agricultural. It was not until the past fifty years that the population boom occurred in St. Charles and Warren counties.

Nowadays, the Peruque Creek Watershed shown in **Figure 1-1** and **1-2** drains portions of the municipalities of Wright City, Foristell, Wentzville, Lake Saint Louis, and O'Fallon as well as unincorporated areas of St. Charles and Warren counties. The drainage basin is typical of a watershed under development and has a variety of urban and rural features.

A watershed is a geographical area defined by topography such that all tributaries and streams drain in this area. The Peruque Creek watershed is used in many ways. There is still a large portion of the watershed that is farmland and forest land. In addition, the watershed has been highly developed into subdivisions, roads and highways, shopping areas and even some industry. Each type of land use can impact the quality of the water in the creek and lake. The roads, buildings and parking lots cover the land surfaces. The vast amount of hard surfaces covering the land causes rain water to runoff into Peruque Creek at a rapid rate and in large volume (PCWA 2002).

Figure 1-1 - Peruque Creek

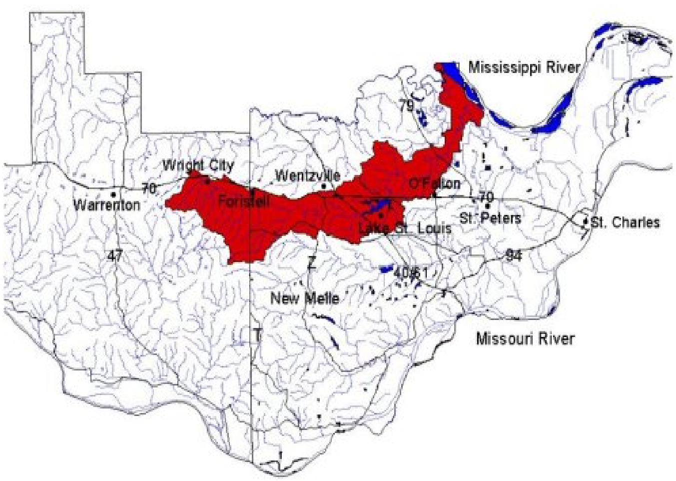


Figure 1-2 - Peruque Creek Watershed Alliance 2002

1.3 Peruque Creek Watershed Management Plan Overview

A well-crafted and implemented watershed management plan is arguably the best and most comprehensive tool to protect urban streams and riparian corridors from the cumulative impacts of new land development and existing urbanization. Storm water runoff is part of a natural hydrologic process. However, urbanization and other human activities can alter natural drainage patterns and add pollutants to runoff and streams, causing declines in habitat quality and limiting the public's ability to enjoy many of the benefits that water provides. The practice of watershed protection is about making choices about what tools and measures to apply and in what combination. This draft report is the culmination of the watershed planning process for the Peruque Creek watershed and documents the resulting findings, conclusions, and recommendations.

Watershed stakeholders will need to carefully review these recommendations, make any needed revisions, and adopt the finalized plan as a comprehensive guidebook for improving the Peruque Creek watershed.

Section 1 of this draft Watershed Management Plan summarizes the history of the Peruque Creek watershed study and the previously completed tasks and analyses that were conducted in support of this plan, the relative roles of the various institutional entities in the watershed, and outlines the process for review and finalization of this draft document. Section 2 of the draft plan documents the problems that were identified and goals that were established for the Peruque Creek watershed. The watershed planning process was supported by existing and new data and analyses. Section 3 summarizes the pertinent input from completed hydrologic/hydraulic and water quality investigations and analyses. The watershed planning process identifies and assesses non-structural best management practices and structural remediation measures and technologies to mitigate or remediate point and non-point sources within the watershed. Section 4 of the draft plan documents the alternative non-structural measures and Section 5 documents the structural alternatives that were pertinent to the Peruque Creek watershed. Section 6 documents the assessment and screening process that was conducted on each of the alternative control measures that were considered. Section 7 documents the Watershed Management Plan elements that are recommended for review, revision, adoption, and implementation by the watershed stakeholders.

Successful watershed planning in Peruque Creek will require a combination of existing and new institutional organizations to focus the resources of a diverse group of stakeholders to implement the plan. A long-term management structure is not only critical to prepare and implement the plan, but to revisit and update the plan as goals are achieved or circumstances change over time. The following institutional entities either have or will have significant roles in reviewing, revising, adopting, and implementing the watershed management plan.

Peruque Creek Watershed Alliance: The Alliance was formed to help develop recommendations to communities and counties in the watershed. It works in conjunction with the Missouri Department of Conservation (MDC), NRCS, St. Charles County Soil and Water Division (SWCD). The objectives of the Alliance are to:

- Lead and ensure success of the Watershed Management Plan,
- Reduce flooding impacts to natural levels,
- Encourage appropriate agencies to make standard enforcement of existing ordinances a priority,
- Develop a watershed district that recommends ordinances supported by all communities and ensures the health of the watershed,
- Maintain and restore ecological balance of the watershed,
- Improve water quality,

- Make recommendations and maintain best management practices (BMPs) at construction sites,
- Recommend methods to control nutrients,
- Educate the public on the importance of the watershed,
- Educate developers on the importance of maintaining BMPs, and
- Draw support from the environmental agencies and groups.

The alliance is comprised of citizen volunteers with diverse backgrounds, interests, and areas of expertise. Association members represent the interests of the Peruque Creek watershed, home and business owners in the watershed, and other stakeholders in the watershed.

Municipal Government

Five municipalities have jurisdiction over their respective portions of the Peruque Creek watershed. They are Warrenton, Wright City, Foristell, Wentzville, Lake Saint Louis, O'Fallon, St. Paul and Josephville as well as unincorporated areas of St. Charles and Warren counties. These municipalities will need to work together as a unified watershed entity and transcend existing municipal borders. The municipalities will have the authority to revise and enforce ordinances that would shape new development and restorative redevelopment, control the disposal of pet wastes and household hazardous wastes, and oversee the rehabilitation of aging sewer, storm drain and pavement systems in the watershed. Municipalities in the Peruque Creek watershed also will need to carefully review this draft management plan and make any needed revisions. **Figure 1-3** shows government officials learning more about the Peruque Creek watershed.

Figure 1-3 - Tour of Peruque Watershed with Government Officials

Sewer Districts

The Duckett Creek Sanitary District is a political sub-district of the State of Missouri. It services geographical drainage areas bounded by Interstate 70, Highway 40-64 and the Missouri River. It also services some areas south of Highway 40-64, within the Peruque Creek Watershed. The District is tasked with maintaining sanitary sewer mains only.

Agencies

The MDC, Missouri Department of Natural Resources (MDNR), NRCS and Environmental Protection Agency (EPA) are existing regulatory and voluntary agencies that have authority and jurisdiction over environmental quality within the Peruque

Creek watershed. They have been active in the watershed in the past and will have active roles in the future implementation of the Peruque Creek Watershed Management Plan. The EPA has issued a grant to the City of Lake Saint Louis to conduct a study of the Peruque Creek watershed. The study was tasked to outline a proposed approach to restoring and protecting water quality in Peruque Creek, while sustaining economic development within the watershed.

1.4 Project Tasks

A series of successive tasks has been conducted to develop and implement the watershed planning process for Peruque Creek. The watershed planning process identifies and prioritizes problems and sets goals and objectives for future work. The completed Watershed Management Plan identifies and assesses non-structural best management practices and structural remediation measures and technologies to mitigate or remediate point and non-point sources within the watershed. The following tasks have been completed and documented in the watershed planning process.

Figure 1-4 - Stakeholder Meeting

Coordination with Stakeholders and Agencies

Policy committee meetings were conducted every month (**Figure 1-4**) with the stakeholders to identify and prioritize problems and goals for the Peruque Creek watershed. Watershed management planning activities were coordinated with various municipalities and agencies working in the watershed to insure that proposed activities are consistent with watershed goals. Also, meetings were conducted with CDM and the City of Lake Saint Louis for the development of the Peruque Creek Project Work Plan. The plan was finalized and modified to allow the addition of other important tasks. After modifications were made, stakeholders reviewed and approved the plan.

Public Support

A tour of the watershed was conducted to give stakeholders (government officials and individuals from the Home Builders Association [HBA] and environmental groups) a chance to ask questions and to learn more about the watershed. In addition, CDM conducted a logo contest for area grade school students, participated in radio broadcasts about the Peruque Creek watershed and developed a public website www.peruquecreek.com with information on the Peruque Creek Watershed Project and access to an electronic room for stakeholders.

Gather Pertinent Historic and Background Information and Summarize in a Watershed Assessment Report

The foundation of the watershed management plan was prepared by obtaining pertinent historic and background information on the Peruque Creek watershed. Data from the Peruque Creek watershed was collected and reviewed to assess the defined impairments, evaluate the adequacy of the data for analysis and finally select the methodologies and models that will be used for the watershed assessment. In addition, CDM reviewed existing databases for the following information: climate data, hydrologic conditions in the watershed, water quality, available flow data, land use data, physical characteristics of the watershed, point sources and ecological data (e.g. fisheries, macroinvertebrates).

Figure 1-5 - Peruque Creek Watershed Flyover

Conduct Field Investigations and Gather New Data

Additional field investigations were conducted along Peruque Creek and Lake Saint Louis to obtain new field data in support of watershed planning and modeling. To refine the assessment and characterization of water quality, samples were obtained along Peruque Creek and at Lake Saint Louis. Also, a watershed flyover **(Figure 1-5)** was carried out to collect data on the current conditions of Peruque Creek and the watershed. This information can be compared to previous data gathered by the MDC and the Lake Saint Louis Community Association.

Create a Public Peruque Creek Watershed Sourcebook Brochure

Figure 1-6 - Volunteers Work to Clean up the Watershed

The Peruque Creek Watershed Sourcebook brochure was developed utilizing recommendations from the stakeholder advisory committee to protect and enhance water quality in the watershed. It seeks to educate the general public on the state of the watershed. This includes how problems can be corrected to protect the designated uses of Peruque Creek and Lake Saint Louis and improve water quality, enhance fish and wildlife habitat and restore watershed functions. Recommendations in the brochure have been made carefully so that they provide for long-term growth, as well as guide those programs and projects to improve watershed health. **Figure 1-6** shows volunteers working trying to improve the conditions of Peruque Creek watershed.

Develop a Watershed Management Plan for Peruque Creek

This task is the culmination of the watershed planning process. The associated report documents the resulting findings, conclusions, and recommendations from the completed watershed planning activities. The watershed planning process identified and prioritized problems and set goals and objectives for future work. Sedimentation is the main problem for water quality degradation of Peruque Creek as shown in **Figure 1-7**. The watershed planning process was supported by existing and new data and analyses. The watershed planning process identified and assessed non-structural best management practices and structural remediation measures and technologies to mitigate or remediate point and non-point sources within the watershed. The planning process included the assessment and screening process conducted on each of the alternative control measures considered. Finally, the Watershed Management Plan documents control and remediation elements recommended for implementation.

Figure 1-7 - Peruque Creek at Duello Road

Section 2
Problems and Goals for the Peruque Creek Watershed

The impacts of urbanization within the Peruque Creek watershed have altered natural drainage patterns, altered natural rainfall-runoff-storage relationships, and added pollutants to storm water runoff and watershed streams. These urban impacts have resulted in a decline in the quantity and quality of aquatic and riparian habitat and limited opportunities for the public to enjoy the many benefits that water provides to the Peruque Creek watershed. Public meetings were conducted by the SWCD with stakeholders within the Peruque Creek watershed to identify and prioritize watershed problems and goals. The outline of the proposed approach covers the restoration and protection of the water quality in Peruque Creek while sustaining economic development within the watershed.

2.1 Goals for the Peruque Creek Watershed

Figure 2-1 - Geese on Lake Saint Louis

The primary objective of the Peruque Creek Watershed Study is to determine what measures are necessary to protect the designated uses in the Peruque Creek watershed. The designated uses for the creek, as defined in the Missouri State Statutes, 10 CSR 20-7, are protection of full-body contact, livestock and wildlife watering, warm water aquatic life and human health. **Figure 2-1** shows an example of a designate use for warm water aquatic life. Along with wildlife use, recreational boating, swimming, waterskiing, and fishing are some of the primary activities occurring on Lake Saint Louis. The State of Missouri has adopted water quality standards to protect these uses.

2.2 Problems in the Peruque Creek Watershed

The following subsections detail problems in the Peruque Creek watershed identified by visual inspections by the project team during the planning process, review of historical information, and field inspections conducted by organizations represented in the stakeholder advisory committee.

2.2.1 Flow Along Peruque Creek

Urbanization within the Peruque Creek watershed has resulted in significant changes to rainfall-runoff-storage relationships and negative impacts to watershed flow during both dry and wet weather periods. During the watershed planning process, the following problems were identified with regard to flow along watershed streams.

- **Diminished Dry Weather Flow -** Base flow along Peruque Creek is minimal during extended periods of dry weather. Urbanization within the watershed has resulted in the loss of wetlands and surface depression storage that formerly acted as watershed sponges. Urbanization has also resulted in a loss of connectivity between stream channels and their adjacent floodplains.

Figure 2-2 - High Turbulent Water at Point Prairie Road

- **Increased Storm Flow:** Storm flows along Peruque Creek have increased significantly (**Figure 2-2**). Increases in impervious area associated with urbanization have resulted in increased runoff volumes and peak flows during storms. Stormwater is generally considered non-point source pollution because its pollutants are not generated from one specific point. Non-point source pollution increases as areas become more developed and rainfall washes nutrients and toxic chemicals from lawns, agricultural fields, golf courses, roads, and parking lots into waterbodies.

  During a wet-weather event, stormwater flows over streets, yards, farmlands and parking lots where it picks up soil, debris, fertilizers, pesticides, oils, other chemicals and animal wastes which are then carried into Peruque Creek. Stormwater contaminants contribute to the degradation of water quality in Lake Saint Louis.

  As land use within the Peruque Creek watershed changes, trees, shrubs and grass are being replaced with more impervious surfaces (i.e. surfaces that do not allow precipitation to soak into the ground - roads, rooftops, parking lots, and other hard surfaces). Without vegetation to store water or slow the flow of surface water, the rate and volume of water moving across the surface of the land will increase. Less rainfall is able to soak into the ground because impervious cover blocks this infiltration. This means a greater volume of rain water travels across the land surface and reaches the creek faster. Increased volumes reaching the creek, can in turn, lead to more flooding during storm events and reduced flow in Peruque Creek during normal or dry periods. The reduced amount of infiltrating water can lower groundwater levels thus lowering the baseflow found in the creek during times other than storm events. Reduced baseflow particularly during drier periods can create ecological stress within the creek.

Higher stormwater velocities in Peruque Creek creates a potential for erosion of stream banks and scouring of channels due to the increased volume. Sediment from eroded stream banks settles to the stream bottom degrading habitat and smothering the gills of aquatic insects such as macroinvertebrates which live part of their life cycle under the rocks in the creek. Stormwater in Peruque Creek may carry sediments and soil particles from the land surface which contain nutrients such as nitrogen and phosphorous or contaminants which attach to the soil particles. These additional nutrients and contaminants can reach Peruque Creek and Lake Saint Louis in increased amounts and volumes both during storm events causing an impairment to water quality.

- **Impacts to Floodplain:** The Peruque Creek floodplain is a broad and relatively flat area adjacent to either side of the mainstem of the creek as shown in **Figure 2-3**. The floodplain was formed by a series of flood flows which spilled over the river edge and flowed across the flat areas along the channel. The floodplain is narrow in the upper reaches of the creek in Warren County and widens as it flows downstream to the Mississippi River. However, much of the floodplain in the Peruque Creek watershed has been constrained by agricultural development, particularly in the lower reaches of the creek where levees and dikes have been constructed. Flood flows in the lower portions of Peruque Creek are controlled to some extent by the dam at Lake Saint Louis. Flooding can occur in the lower reaches when the Mississippi River overflows it's bank and overflows into the Peruque Creek channel.

Figure 2-3 - Peruque Creek Floodplain at Confluence with Mississippi River

The flooding of the creek and associated floodplains results in the formation of terraces, wetlands, backwaters and branches. Additionally, the floodplain provides sediment loading to the creek during high flow events and attenuates the velocity during wet-weather events. Where floodplains are reduced and narrowed, the stream velocity will increase causing further erosion of steep banks and increase sediment load to the creek. .Floodplains are a vital part of Peruque Creek's ecosystem. They are important because they act as flood buffers, water filters, nurseries and provide habitat for the biological life in the creek. Floodplains also contain most of the riparian vegetation found along the creek. These riparian areas contain many of species of trees, shrubs, forbs and grasses that are utilized by a variety of wildlife. The riparian zone acts as buffer to minimize overland flow from reaching Peruque Creek. It is important to remember that even if you are not directly adjacent to the river or creek, your actions could impact the quality of the water. Storm water drains to the waterways and carries with it any pollutants it encounters along the way. Common pollutants, which seriously impact the water quality, include fertilizer, pesticides and oils.

Floodplains provide many benefits and functions, which are valuable to the watershed. Simply put, a properly functioning floodplain helps reduce flood losses and erosion, improves water quality and wildlife habitat, and provides recreational and educational opportunities.

2.2.2 Erosion Along Peruque Creek

Urbanization within the Peruque Creek watershed has degraded the natural morphology of streams. **Figure 2-4** shows an example of erosion problems from a discharge to Peruque Creek. Field inspections conducted by MDC and visual inspections by the project team identified the following problems regarding erosion along Peruque Creek.

Figure 2-4 - Erosion from Discharge to Peruque Creek at Hepperman Road

- **Incised Stream Channels -** Increased storm runoff volumes and flow velocities have deepened stream channels, severing natural connections between channels and their respective flood plains.
- **Straightened Channel Alignments -** Increased urban runoff and associated erosion have resulted in the loss of natural channel meanders, increased channel slopes, and increased stream velocities.
- **Lateral Scouring -** Channel erosion caused by increased urban runoff has made channel banks unstable and natural width to depth ratios have been degraded.
- **Bed Loads -** Accelerated erosion along urban watershed streams has significantly increased bed-load volumes of gravel, sand, and grit. These bed loads and bars are unstable and potentially destructive to aquatic habitat.

2.2.3 Water Quality Along Peruque Creek

MDNR has placed Peruque Creek on the state's 303d list for sediment based upon historical water quality data. Urbanization within the Peruque Creek watershed has introduced water quality constituents that may affect in-stream water quality. Field investigations, sampling, and laboratory analyses conducted during the early phases of the watershed planning process identified problems during dry and wet weather which included several serious pollutants that exceed water quality standards. Also, the results of the sampling show heavy rain increase pollutants in Peruque Creek and Lake Saint Louis.

Figure 2-5 - Runoff from Pipe at Hepperman Road

- **Non-Point Discharges During Wet Weather -** During storms heavy metals, deicing salts, and other water quality constituents are washed into streams from highways (**Figure 2-5)** and nutrients are washed from lawns in the urbanized portions of the watershed. Animal wastes from unleashed pets can also contribute bacteria to streams.

- **Point Sources -** There are four notable point sources of municipal and domestic wastewater within Peruque Creek. These include the cities of O'Fallon, Wright City, Foristell and Castlegate Estates subdivision. These discharges are regulated by the MDNR through the National Pollutant Discharge Elimination System (NPDES). The NPDES programs provide permits to these facilities, which include water quality, permit limitations and monitoring requirements. Recent monitoring data for each facility show treatment efficacy typical of well-operated activated sludge treatment plants.

- **Floatable Materials from Urban Runoff -** Floatable materials such as styrofoam cups and plastic bags; trash and debris from careless dumping; and other urban solid wastes catch on rocks and tree branches and degrade the aesthetic and habitat quality of watershed streams.

- ***E. coli*** - This is bacteria found in the digestive tracts of warm-blooded animals, including humans. *E.coli* can enter a stream by direct discharge from mammals and birds, from livestock runoff, or from open or broken sewers. When water tests positive for *E.coli,* there could be harmful pathogens (disease causing organisms) present, and it would be risky to drink it or swim in it.

- **Stormwater Runoff -** Increased flow which causes a loss of habitat and an increase in sedimentation. This is also a problem in Peruque Creek.

- **Sedimentation (Soil and Sand) -** This is the main source of water quality degradation. Soil, sand and other solids flow into the creek and lake when it rains. Sediment harms fish and bottom dwelling organisms. It also reduces water clarity. Sedimentation has contributed to the degradation of Lake Saint Louis and has resulted in the Lake Saint Louis Community Association to spend hundreds of thousands of dollars every three years to dredge selected locations within the lake. The sedimentation also contributes to lower the aesthetic quality of the lake and Peruque Creek.

Figure 2-6 - Algal Bloom on Lake Saint Louis

- **Nitrogen and Phosphorous from Fertilizers -** These chemicals contribute to high levels of nutrients in the creek and lake. These nutrients entering the water result in algal blooms (**Figure 2-6**) in Lake Saint Louis. When huge amounts of algae grow, it reduces the amount of dissolved oxygen for fish and other water creatures, and creates odor problems in the waterway. The "fishy" smell around water bodies is from algae.

2.2.4 Urban Impacts on Watershed Vegetation

Urbanization within the Peruque Creek watershed has imposed negative impacts on the biodiversity of plant species. In 2001, MDC conducted habitat assessment during fish sampling within the watershed. Also, visual inspections were performed by the project team. The following problems with regard to watershed vegetation were identified.

- **Invasion of Exotic Species -** Aggressive, invasive exotic plant species (e.g. Japanese Knotweed, Tree-of-Heaven, Bush Honeysuckles, and others) have colonized disturbed areas, out competing native species while offering lower ecological value. Many of these ornamental exotics from urbanized residential and park areas have become the dominant species of the riparian zone.

- **Lack of Wetland Vegetation -** Wetland areas and vegetation purify water, mitigate storm flows, provide low flow augmentation, and provide quality habitat. Urbanization has impacted much of the natural wetland areas within the Peruque Creek watershed.

- **Lack of Streamside Vegetation -** Healthy shoreline vegetation is an integral part of watershed management because it stabilizes stream banks, provides cooling shade, and provides critical habitat and cover. Urbanization has contributed to hydrologic and hydraulic conditions that have disturbed shoreline vegetative communities.

2.2.5 Urban Impacts on Aquatic and Riparian Habitat

The impacts of urbanization within the Peruque Creek watershed can significantly stress and limit available aquatic and riparian habitat. In order to characterize habitat quantity and quality, field investigations and analyses were conducted by MDC while visual inspections were conducted by the project team. The following habitat area problems were identified.

- **Urban Impacts on Stream Quantity and Quality -** The diversity and quantity of aquatic and riparian animal species is limited due to minimal base flow along streams and adverse urban water quality constituents.

- **Impacts of Mowing Stream Channel Banks -** Much of Peruque Creek is located along urban suburban properties. Natural vegetative cover along streams has been replaced with mowed grass, significantly degrading riparian habitat quality.

2.2.6 Impacts of Watershed Recreation

Urban recreation can sometimes produce negative environmental impacts to the watershed. The watershed planning process identified the following problems:

- **Location of Existing Golf Course -** As a consequence of the existing golf course's immediate location to Peruque Creek, nutrient runoff and increased stormwater drainage from the course occur. Due to the lack of riparian vegetation and/or an active buffer strip, some areas of the golf course are eroding into Peruque Creek. The Golf Club of Wentzville is located along Peruque Creek as shown in **Figure 2-7**.

Figure 2-7 - Golf Course Along Peruque Creek

- **Competition Between Watershed Recreation and Habitat -** Active recreation and riparian habitat tend to be mutually exclusive land uses - the mowed grass associated with the golf course makes a poor riparian habitat. Active recreation such as wading, swimming and fishing have been observed within the Peruque Creek watershed. There is also a significant need to expand wetlands and riparian habitat. The watershed planning process will need to determine an optimal balance between the competing land uses.

Section 3
Watershed Assessment

3.1 Historical Data Review

3.1.1 Historical Data Overview

The following data sources, summarized in **Table 3-1**, were identified and are described throughout the remainder of this section:

- Climate data
- Hydrologic data
- Hydraulic data
- Land use
- Water quality
- Point sources
- Fish sampling
- Soils data

3.1.2 Climate Data

Two climate stations are available for the watershed—the Weldon Springs station and St. Charles County station. Daily climate data were collected by the National Climatic Data Center for Station 8805 in Weldon Springs, Missouri, from June 1, 1957 to December 31, 2000. However, several daily measurements were not performed since 1985 and measurements were not collected for the entire months of December 1986, June 1988, September to November 1988, November 1990 to March 1991, and July 1999. This dataset includes daily precipitation, daily snowfall, and low, high, and mean daily temperatures. The average annual rainfall at this gage from April 1, 1985 to March 31, 2000 was 36.1-inches. The average monthly rainfall at this gage is shown in Table 2-2. Daily climate data were collected by the Midwestern Regional Climate Center for Station 237398 in St. Charles County, Missouri from January 1, 1978 to December 31, 2001. This dataset includes daily precipitation, daily snowfall, and low, high, and mean daily temperatures. The average annual rainfall at this gage from April 1, 1985 to March 31, 2000 was 35.7-inches. The average monthly rainfall at this gage is also shown in **Table 3-2**.

3.1.3 Hydrologic Data

Long-term hydrologic data are not available for Peruque Creek due to the absence of flow gaging stations. The nearest long-term gaging station is located approximately 19 miles northwest of the Lake Saint Louis dam on the Cuivre River near Troy, Missouri (USGS Station ID 05514500). These gaging stations were established in 1923, providing 79 years of hydrologic data. Two gaging stations are also located east of the Lake Saint Louis dam on Dardenne Creek at O'Fallon and Old Town St. Peters (USGS Station ID 05514840 and 05514860, respectively). However, these stations were installed in 2000, providing limited historical data and the accuracy of the flow data is questionable, since field measurements collected at these stations are not adequate to develop accurate rating curves (the relationship between measured river stage and estimated discharge).

Table 3-1
Summary of Available Historical Data for the Peruque Creek Watershed

Type	Data Description	Source	Years Recorded
Biological	Biological Assessment Reports for Peruque Creek and North Fork Cuivre River	MDC	1962, 1995, 2001
	Biological Assessment Report for Peruque Creek	MDNR	2003
Climate	Precipitation and Temperature Data at Weldon Springs, Missouri	MRCC	1957-2000
	Precipitation and Temperature Data at St. Charles, Missouri	MRCC	1978-2001
GIS	Land Use in St. Charles and Warren Counties	MSDIS	1991-1993
	Land Use in St. Charles County	SCCG	2002
	Land Use in St. Charles and Warren Counties	MDC	2001
	Land Use in St. Charles and Warren Counties	MDNR	2001
Hydraulic	Physical and Habitat Data for Peruque Creek	MDC	2001
	Flood Plain Information Study of Peruque Creek	USACE	1973
Hydrologic	Discharge of Cuivre River at Troy, Missouri	USGS	1923-Present
	Discharge of Dardenne Creek at O'Fallon and St. Charles, Missouri	USGS	2000-Present
Pathogens	Fecal Coliform in Lake Saint Louis and Lake Sainte Louise	LSLCA	1997-2002
	DNA Fingerprinting Using E. Coli Sampled in Paris Cove	LSLCA	1998-2000
Soils	Soil Survey of Montgomery and Warren Counties	USDA	1978
	Soil Survey of St. Charles County	USDA	1982
	Soil Survey of State of Missouri	STATSGO/NRCS	1994
Water Quality	Water Quality in Peruque Creek, Dardenne Creek and North Fork Cuivre River	MDC	2002
	Peruque Creek Water Quality	BE	2001
	Peruque Creek Water Quality	MST	1994-1997
	Peruque Creek Water Quality	USGS	1983, 1984
	Lake Saint Louis and Lake Sainte Louise Water Quality	LMVP	1978-2002
	NPDES Discharges at Wright City, Foristell and Castlegate Estates Subdivision Wasteload Allocation Study	MDNR MDNR	1998-2002 2002

Sources:
MDC - Missouri Department of Conservation
MRCC - Midwest Regional Climate Center
MSDIS - Missouri Spatial Data Information Service
NRCS – Natural Resources Conservation Service
USGS - United States Geological Survey
LSLCA - Lake Saint Louis Community Association
STATSGO - State Soil Geographic
LMVP - Lakes of Missouri Volunteer Program
MDNR - Missouri Department of Natural Resources
SCCG - St. Charles County Government
BE - Brookside Environment
MST - Missouri Stream Team
USACE – United States Army Corps of Engineers
USDA - United States Department of Agriculture

Table 3-2
Average Monthly and Annual Rainfall (inches)
From April 1, 1985 to March 31, 2000

Month	Weldon Springs Station 8805	St. Charles Station 237398
April	3.4	3.5
May	4.0	3.9
June	3.9	4.1
July	4.0	3.3
August	3.0	2.8
September	2.8	2.7
October	2.9	2.7
November	3.5	3.5
December	2.0	2.2
January	1.7	1.7
February	2.2	2.5
March	2.8	2.8
Annual	**36.1**	**35.7**

The Cuivre River gaging station data should be relatively representative of historic Peruque Creek discharge after accounting for the difference in watershed area. These data should be representative since watershed characteristics (i.e., soils, slopes, morphology) of these watersheds are relatively similar. The Cuivre River gaging station watershed area is approximately 903 square miles compared to the Peruque Creek watershed area at the Lake Saint Louis dam of approximately 56 square miles.

The annual discharge at the Cuivre River gaging station averaged 11.5-inches per year (in/yr) (770 cubic feet per second) since 1982 (20 years). Expression of discharge in units of length per time are useful since these account for watershed size and may be directly used to estimate discharge at watersheds of differing areas. Median annual discharge was 9.4-in/yr, which may be more representative of typical annual flow since averages are typically skewed by extreme low and high discharge years. Annual discharge ranged from approximately 3- and 33-in/yr (1989 and 1993, respectively) (**Figure 3-1**). Discharge is typically highest during April and May, yielding over 1.5-inches per month (in/mo) (**Figure 3-2**)**.** Discharges during February, March, November, and December are also significant, typically yielding 1 to 1.3-in/mo. August and October are typically the driest months, yielding an average discharge less than 0.5-in/mo.

The Cuivre River discharge data may be utilized to estimate water budget for Lake Saint Louis. These calculations typically utilize estimated inflow, precipitation onto the reservoir surface, and evaporation to calculate reservoir discharge. Seepage was not estimated due to difficulty in accurate estimation and relative insignificance into typical water budgets. The estimated Lake Saint Louis water budget is included as **Table 3-3**.

Table 3-3
Lake Saint Louis Estimated Water Balance

Source	Loading	
	(ac-ft/yr)	(m^3/yr)
Surface Water Inflow	34,506	42,595,072
Precipitation	1,815	2,239,941
Evaporation	1,638	2,022,013
Outflow	34,682	42,813,000

3.1.4 Hydraulic Data

Two sources of hydraulic data were found for Peruque Creek. The Peruque Creek Flood Plain Information Study performed by the USACE in 1973, discusses factors affecting flooding, past floods, future floods, and contains maps of the floodplain, high water profiles and selected cross sections. Since the Flood Plain Information Study was conducted 30 years ago and more detailed information is now available from the MDC, this information will not be used. The MDC conducted habitat surveys at various locations upstream of Lake Saint Louis on Peruque Creek in June 2001. The five sites surveyed include Archer Road on June 21, 2001, Duello Road on June 28, 2001, Hepperman Road on June 25, 2001, Hwy T on June 20, 2001, Wilmer Road on June 29, 2001, and Wright City on June 18, 2001. Each site included 10 transects. Depth and substrate size were taken at left bank, left center, center, right bank, and right center at each transect. Average depths from these transect measurements are shown in **Table 3-4**. In addition, embeddedness measurements were also performed at some sites. Bank measurements at each transect included wetted width, bankful width, bankful height, incised height, bar width, left bank undercut, left bank angle, right bank angle, and backside bearing. The thalweg profile was also obtained at each transect for each site including depth, wetted width, bar width, and a channel unit code was assigned.

Table 3-4
Average Depth of Peruque Creek Cross Sections
(in meters, based on average of 10 transects)

Station	Left Bank	Left Center	Center	Right Center	Right Bank
Archer Road	0.00	0.17	0.21	0.09	0.00
Duello Road	0.02	0.36	0.50	0.31	0.00
Hepperman Road	0.00	0.27	0.27	0.33	0.00
Hwy T	0.03	0.10	0.12	0.10	0.04
Wilmer Road	0.12	0.37	0.38	0.39	0.01
Wright City	0.05	0.25	0.22	0.18	0.00

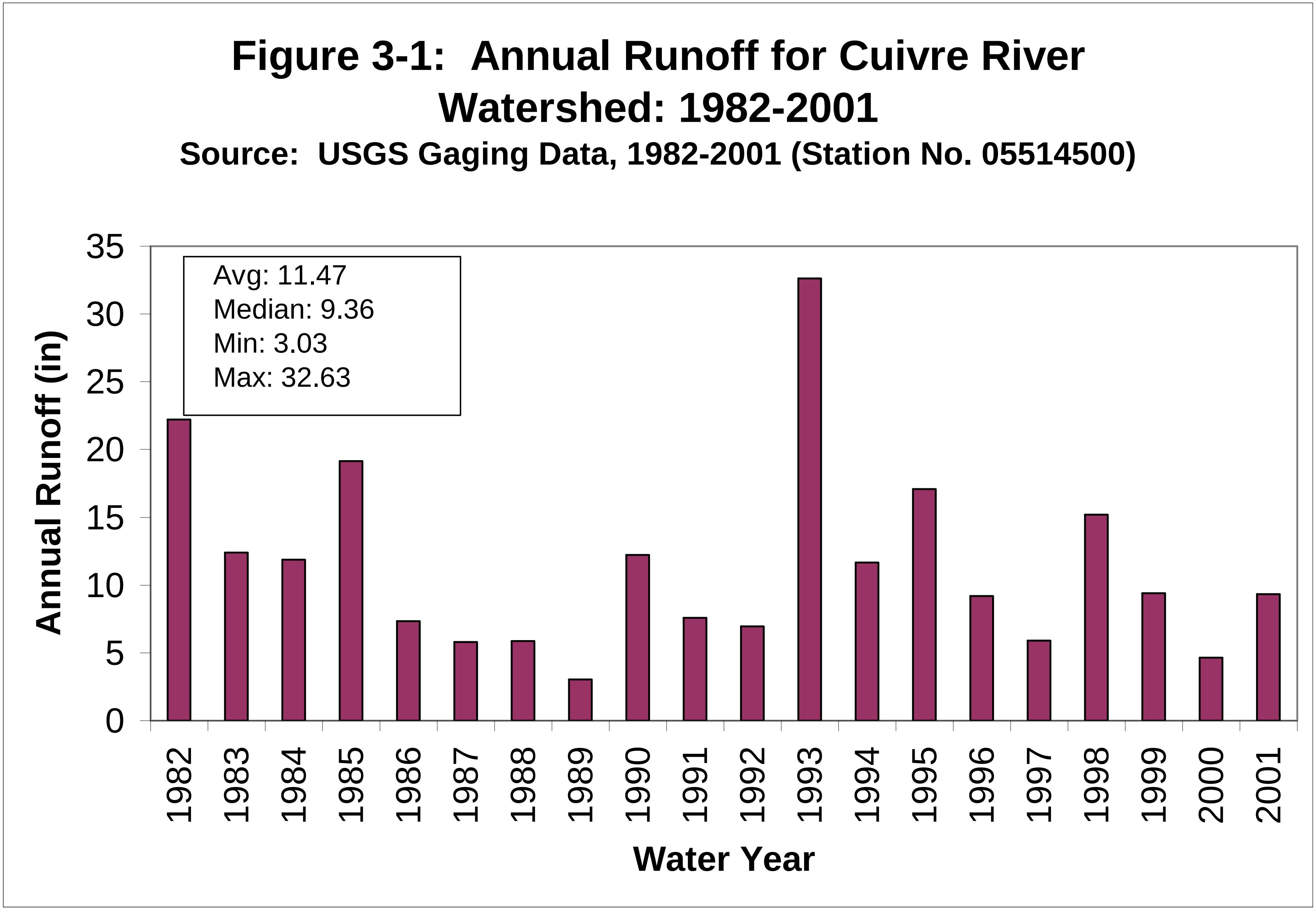
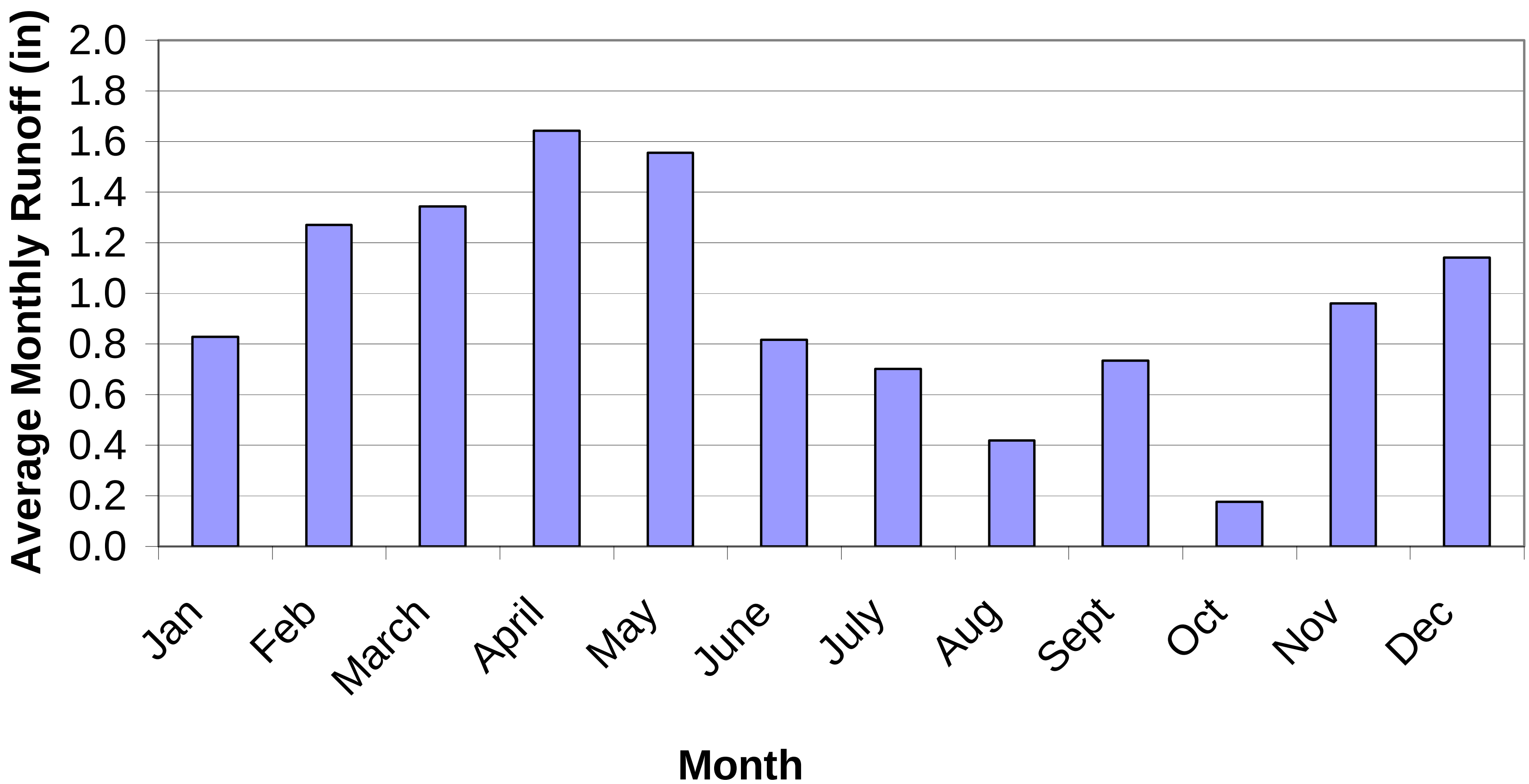


Figure 3-1: Annual Runoff for Cuivre River Watershed: 1982-2001
Source: USGS Gaging Data, 1982-2001 (Station No. 05514500)
Avg: 11.47
Median: 9.36
Min: 3.03
Max: 32.63
Annual Runoff (in)
0
5
10
15
20
25
30
35
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Water Year

Figure 3-2: Average Monthly Runoff for Cuivre River Watershed: 1982-2001

Source: USGS Gaging Data, 1982-2001 (Station No. 05514500)



3.1.5 Land Use Data

Land use data is available from the St. Charles County Government for St. Charles County, and from the Missouri Spatial Data Information System (MSDIS) for St. Charles and Warren Counties. Land use data for the entire Peruque Creek watershed is currently being processed by the MDC and SWCD. Therefore, land use from the St. Charles County Government and MSDIS will be used for modeling and is shown in **Table 3-5**. However, once MDC and SWCD data is available it would be useful to update the project database because this land use will cover the entire watershed while the land use data from the MSDIS was not taken within the last five years, and the land use data from the St. Charles County Government does not include Warren County.

Table 3-5
Peruque Creek Land Use Acreages

Land Use Type	Area Upstream Lake Saint Louis (Acres)	Area Downstream Lake Saint Louis (Acres)	Total Area for Peruque Creek Watershed (Acres)
Forested	2455	--	2455
Agriculture/Pasture	16350	11565	27915
Medium Density Residential	6661	4575	11236
High Density Residential	90	83	173
Commercial	1907	2267	4174
Industrial	146	760	906
Highway Street	1523	1124	2647
Open Water/Wetlands	903	25	927
Open Grassland - Non Urban	4183	--	4183
Urban Grassland	532	--	532
Total	**34749**	**20399**	**55148**

Notes:
Upstream Lake Saint Louis area of watershed used land use from two sources - Missouri Resources Assesment Partnership (1999, Land Use/Land Cover 1991-1993) for Warren County and St. Charles County Government (2004) for St. Charles County. Downstream Lake Saint Louis area of watershed used land use from St. Charles County Government (2004) only. The data from St. Charles County did not have land use categories for Forested, Open Grassland - Non Urban, or Urban Grassland

3.1.6 Historic Water Quality Data

Water quality data within Peruque Creek, Lake Saint Louis, and Lake Sainte Louise have been collected by various organizations and agencies over the last 20 years. The datasets provided by these sources vary with regards to sampling parameters, frequency, duration, and quality assurance practices. The following sections describe the data available for these water bodies with respect to stream and reservoir monitoring. Sampling locations are presented as **Figure 3-3**.

3.1.6.1 Stream Water Quality Data

Three organizations and agencies have collected Peruque Creek water quality data within the last five years. Stream data older than five years were not included in this assessment since those data may not be representative of existing conditions. The data collecting organizations and agencies include the Peruque Creek Stream Team, MDC and MDNR. Stream Team data are typically collected by volunteers to develop local interest and provide education with respect to water quality issues. Stream Team data have also been utilized as a screening mechanism to identify the needs for additional monitoring by water resource agencies. However, these data are typically not utilized for interpretative and assessments purposes and were, therefore not included in this data assessment.

The MDC and MDNR conducted a cooperative water quality study of Peruque and Dardenne Creeks in 2002. MDC conducted continuous water quality and river stage monitoring during 2002, as well as discrete water quality sampling. Monitoring locations included Peruque Creek at Hepperman Road, Point Prairie Road, and

Highway T. MDNR performed the majority of the water quality analyses. Automatic sampling equipment was also deployed for collection of runoff event samples; however, equipment difficulties during high flow events prevented collection of samples after late April. Eighteen to 20 discrete sampling events were performed at each site from March through September 2002. The data collected during these monitoring events are depicted for selected parameters in **Figures 3-4** and **3-9**. Continuous stage and water quality data has recently been made available by MDC.

These MDC/MDNR data provide useful characterization of water quality conditions during baseflows and limited runoff events. Average water quality data during baseflow conditions are shown in **Table 3-6**. These data are typical of stream water quality in Ozark Border streams. MDC/MDNR data also includes data at two sites on the North Fork Cuivre River, the background site, for comparison to the Peruque Creek data. The results, shown in Table 3-6, indicate that the North Fork Cuivre River has similar characteristics to Peruque Creek, except it has higher concentrations of nutrients.

Figure 3-3: Sampling Locations

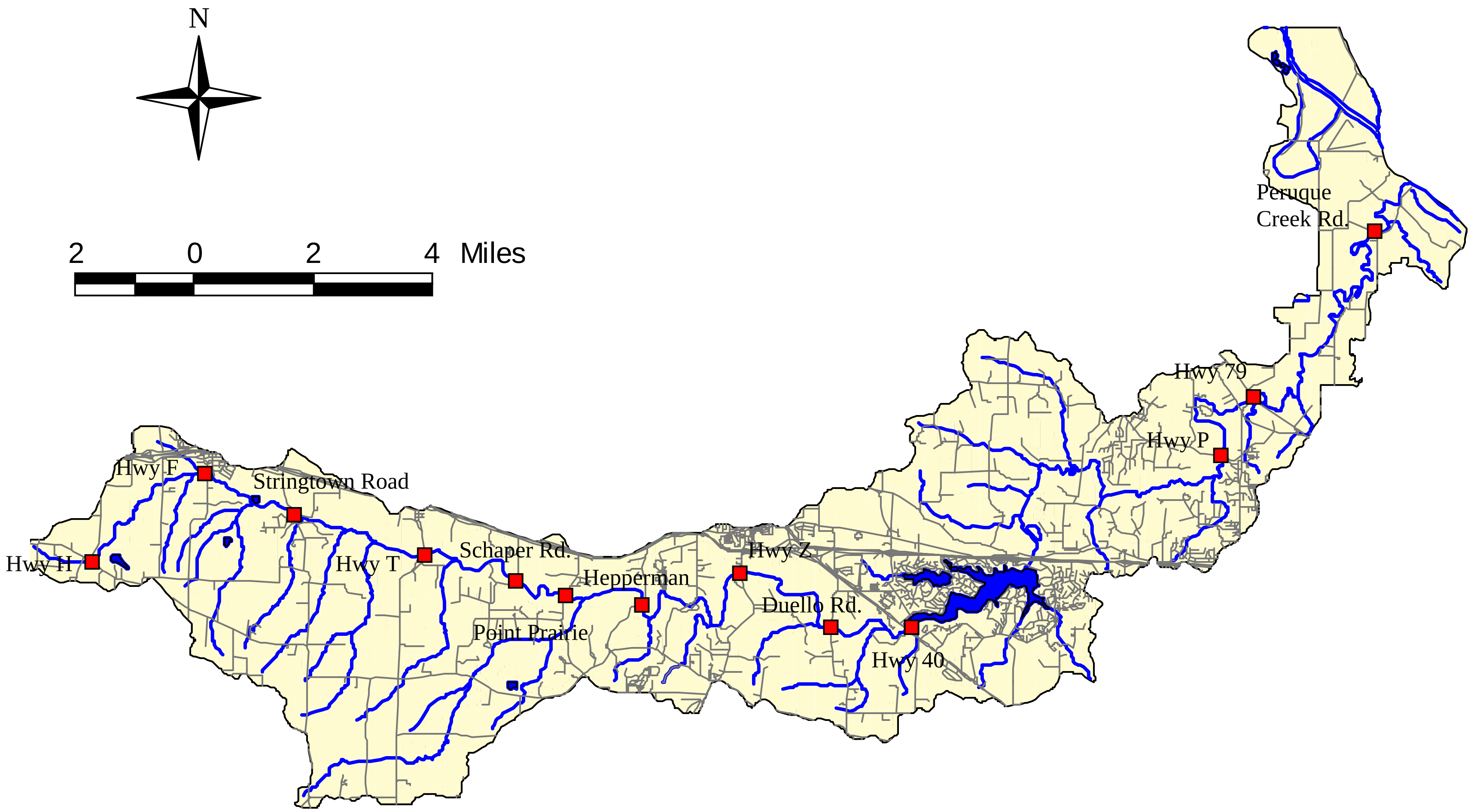


Table 3-6
Summary of MDC Peruque Creek Baseflow Water Quality Data

Site Name	Peruque Cr. @ Hwy T	Peruque Cr. @ Point Prairie Rd	Peruque Cr. @ Hepperman Rd.	North Fork Cuivre River @ Hwy 161	North Fork Cuivre River @ Rd. 325
River Mile	32.8	29.7	28.0	--	--
Temperature (°C)	19.8	21.7	22.4	22.0	22.2
Dissolved Oxygen (mg/L)	9.4	9.3	7.4	7.9	7.6
pH (Median)	8.2	8.2	7.8	8.1	8.0
Specific Conductivity (µS/cm)	428	380	403	407	388
Total Kjeldahl Nitrogen (mg/L)	0.437	0.372	0.377	0.405	0.529
Ammonia (mg/L N)	0.025	0.025	0.025	0.025	0.025
Nitrate (mg/L N)	0.227	0.235	0.171	1.360	1.121
Total Nitrogen (mg/L N)	0.693	0.621	0.549	1.790	1.675
Total Phosphorus (mg/L)	0.090	0.050	0.047	0.123	0.112
Total Suspended Solids (mg/L)	10.5	6.2	10.2	11.4	19.2
Turbidity (NTU)	13.6	7.4	10.3	8.6	10.8

Note:
Data expressed as averages, with the exception of pH.

Two runoff events were sampled on April 8 and August 19, 2002, based on the collected water quality data. These discrete data provide some insight into the characteristics of runoff water quality conditions. Wet weather data typically exhibit high variability due to many factors that contribute to runoff water quality from nonpoint sources of pollution, such as, season, discharge, and sampling time within the runoff hydrograph. Therefore, additional wet weather data collection is required to adequately characterize high flow water quality, which typically dominates annual watershed pollutant loading (Section 3.2).

The MDNR also collected baseflow water quality data during July and September 2002. The purpose for these monitoring activities was to assess stream water quality impacts from three municipal and domestic wastewater treatment plant (WWTP) effluents. The studied WWTP effluents included Wright City, Foristell, and Castlegate Estates subdivision. Flow and water quality data were collected longitudinally downstream from these discharges, with the goal of providing calibration data for a steady state water quality model.

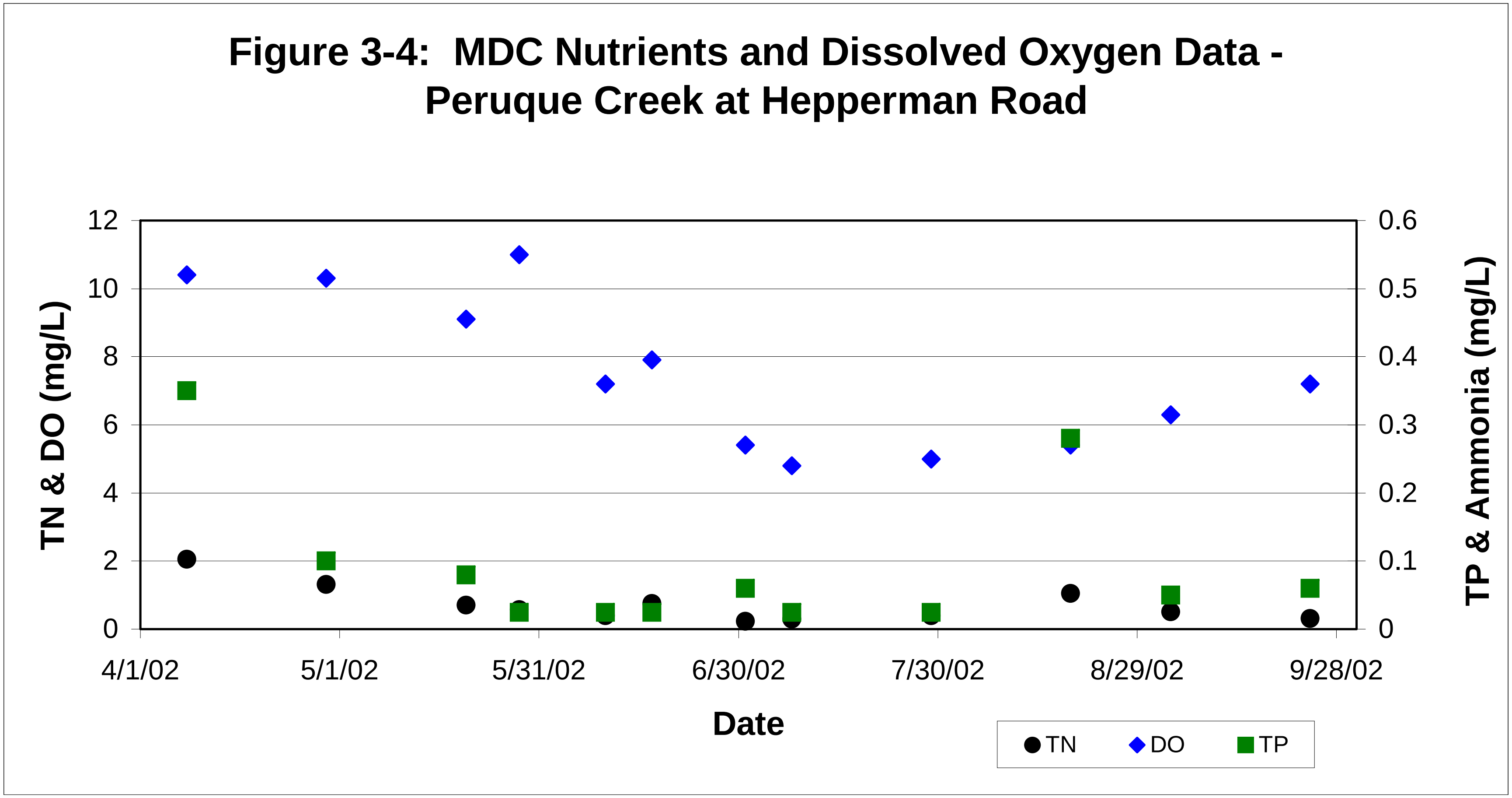


Figure 3-4: MDC Nutrients and Dissolved Oxygen Data -
Peruque Creek at Hepperman Road
TN & DO (mg/L)
TP & Ammonia (mg/L)
0
2
4
6
8
10
12
0
0.1
0.2
0.3
0.4
0.5
0.6
4/1/02
5/1/02
5/31/02
6/30/02
7/30/02
8/29/02
9/28/02
Date
TN
DO
TP

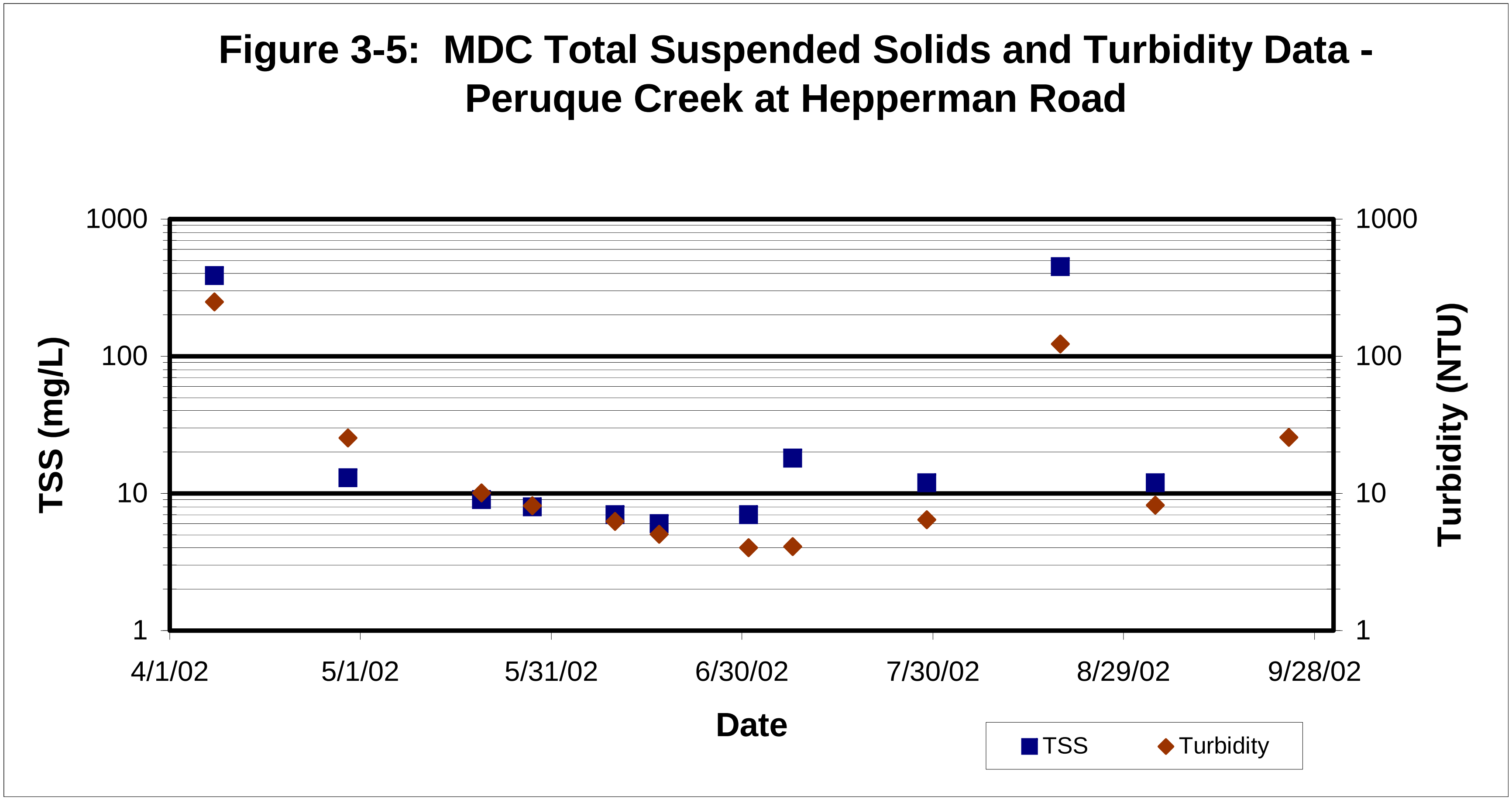


Figure 3-5: MDC Total Suspended Solids and Turbidity Data -
Peruque Creek at Hepperman Road
TSS (mg/L)
Turbidity (NTU)
1000
100
10
1
4/1/02
5/1/02
5/31/02
6/30/02
7/30/02
8/29/02
9/28/02
Date
TSS
Turbidity

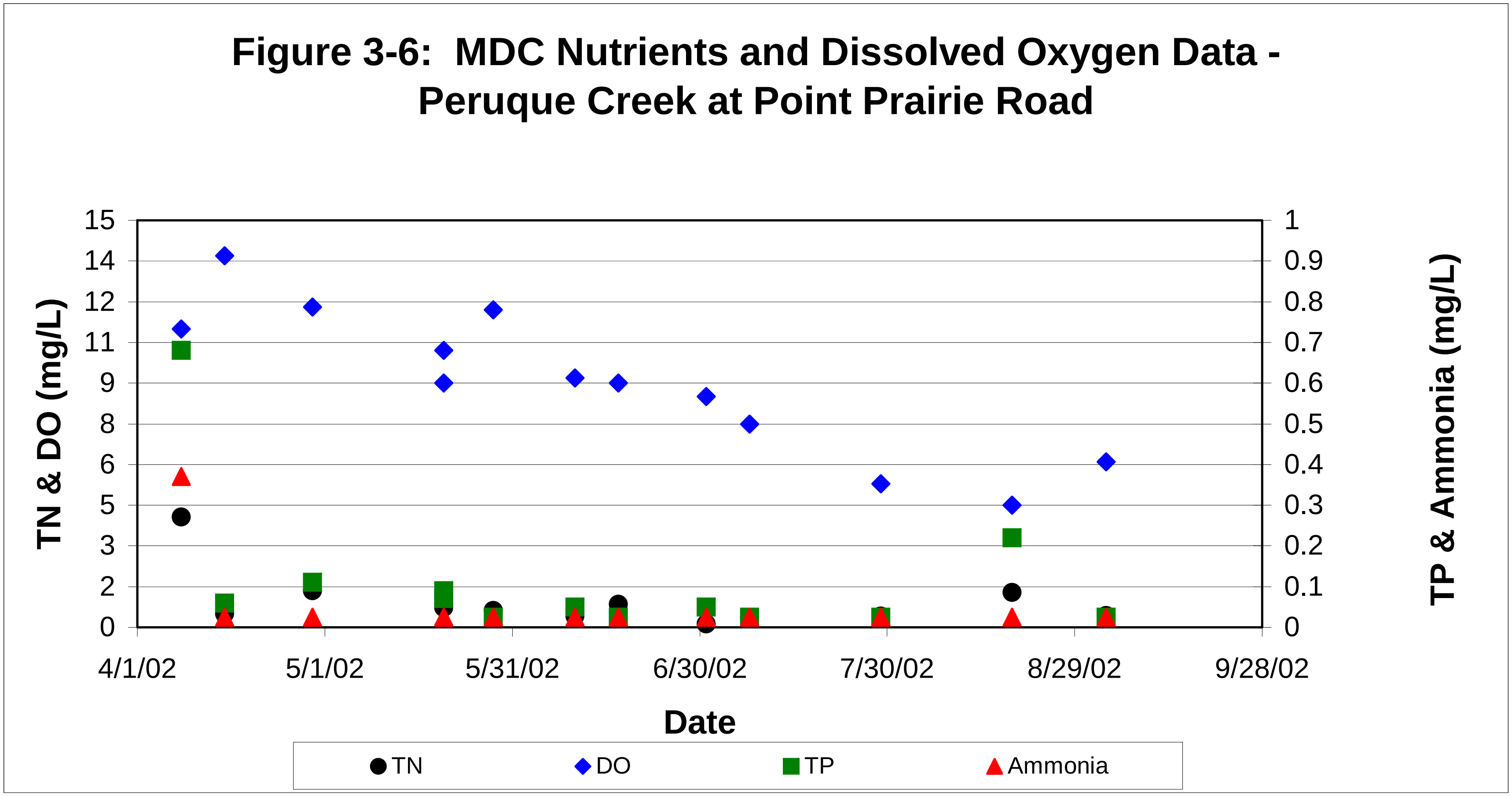


Figure 3-6: MDC Nutrients and Dissolved Oxygen Data -
Peruque Creek at Point Prairie Road
TN & DO (mg/L)
TP & Ammonia (mg/L)
15
14
12
11
9
8
6
5
3
2
0
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
4/1/02
5/1/02
5/31/02
6/30/02
7/30/02
8/29/02
9/28/02
Date
TN
DO
TP
Ammonia

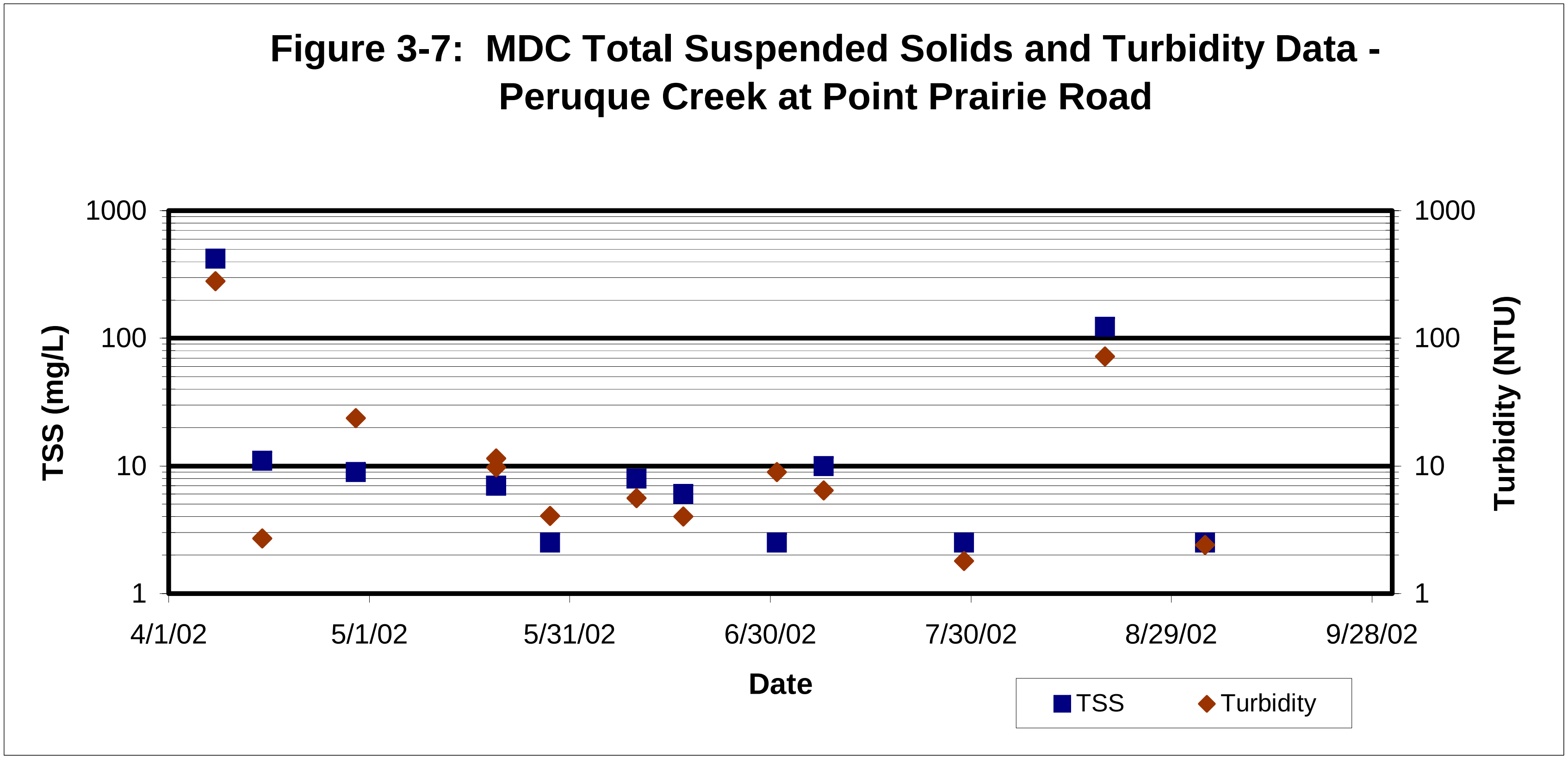


Figure 3-7: MDC Total Suspended Solids and Turbidity Data -
Peruque Creek at Point Prairie Road
1000
100
10
1
TSS (mg/L)
Turbidity (NTU)
4/1/02
5/1/02
5/31/02
6/30/02
7/30/02
8/29/02
9/28/02
Date
TSS
Turbidity

Figure 3-8: MDC Nutrients and Dissolved Oxygen Data - Peruque Creek at Highway T Bridge

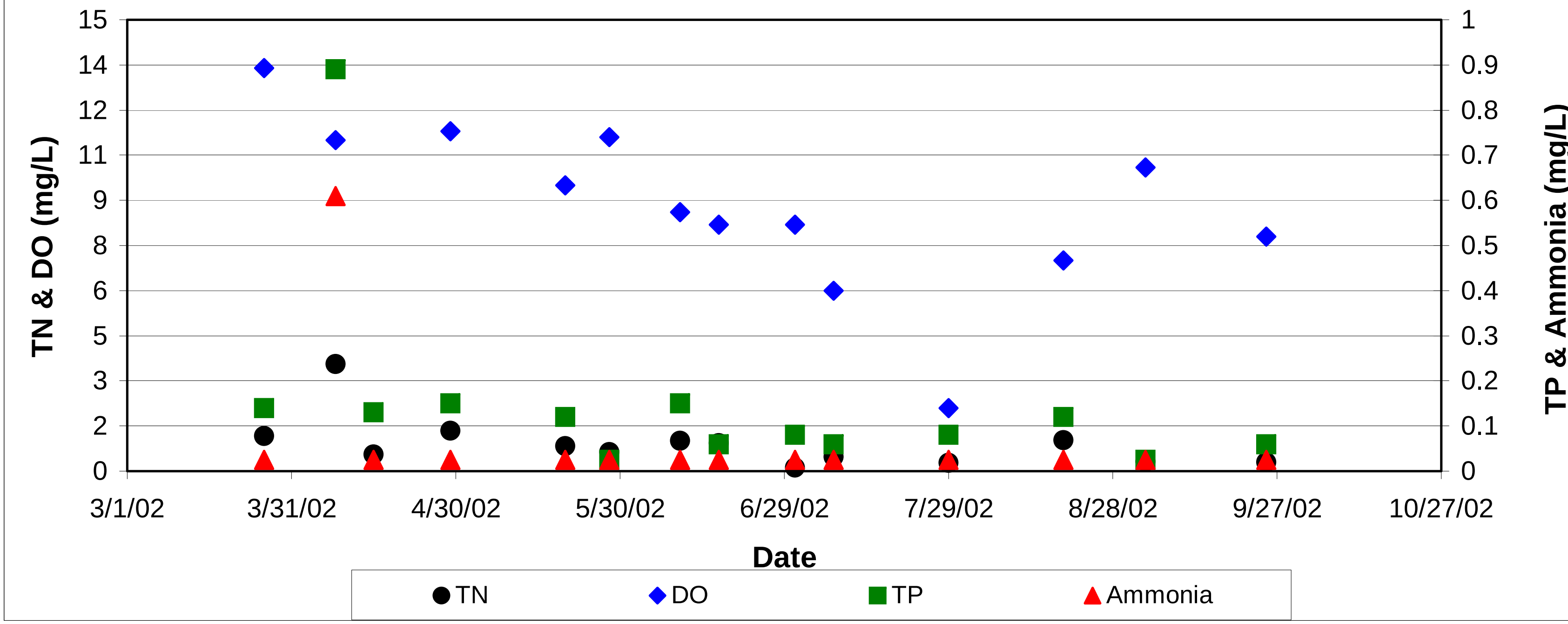
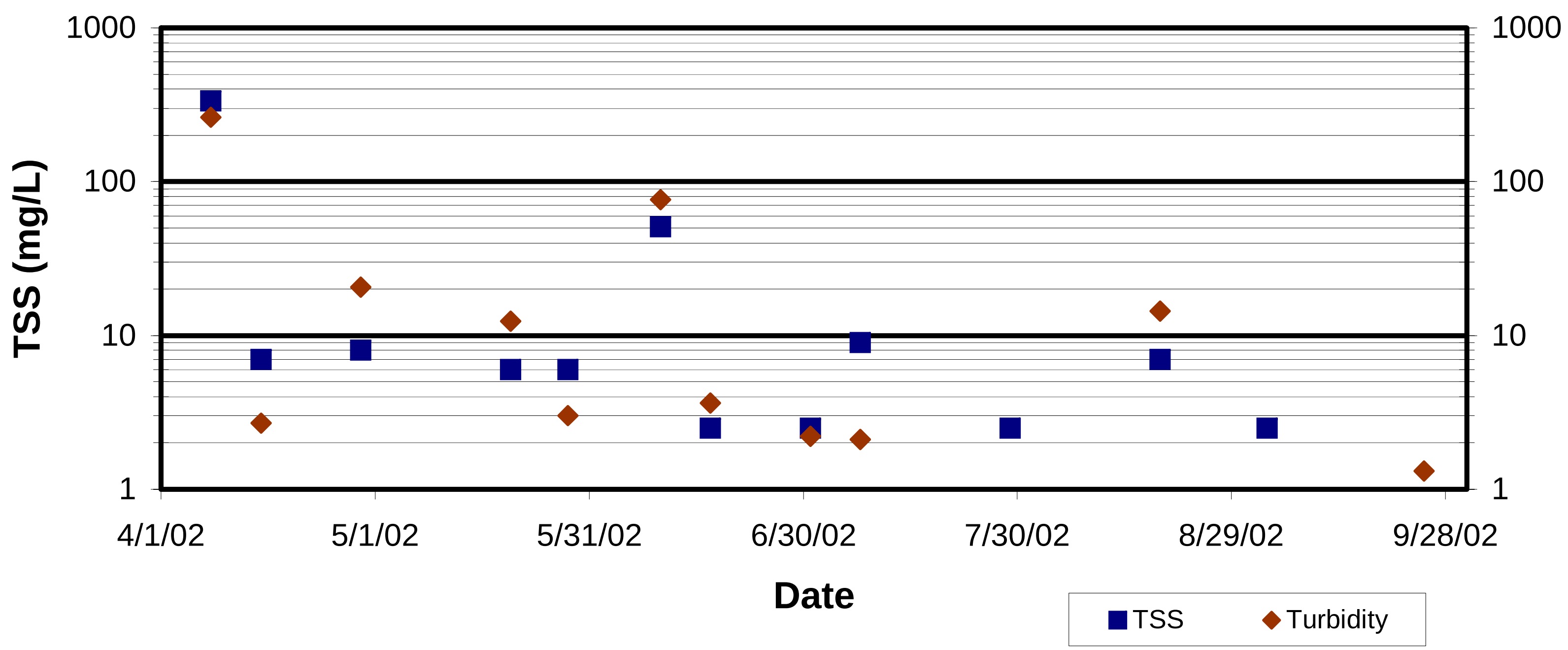


Figure 3-9: MDC Total Suspended Solids and Turbidity Data - Peruque Creek at Highway T



The MDNR water quality data demonstrate the assimilative capacity of Peruque Creek, as water quality improves significantly as the discharges from the WWTPs travel downstream (**Figure 3-10**). The data also show that dissolved oxygen and ammonia water quality criteria for protection of aquatic life were not always met during these events. However, water quality conditions above the Wright City WWTP suggest that natural background dissolved oxygen conditions may be below the criterion of 5 mg/L. Background conditions below the criterion are not atypical in Ozark Border and Northern Plains headwater streams in Missouri. Therefore, it is unclear whether WWTP effluents impair dissolved oxygen concentrations beyond natural stream conditions. The ammonia data collected within the Peruque Creek tributary downstream of the Castlegate WWTP were above the chronic ammonia criteria for limited warmwater fisheries, but below the acute ammonia criteria. The chronic ammonia criterion is 1.1 mg/L to 2.5 mg/L as nitrogen for warmwater fisheries with typical Missouri stream pH and temperature. The acute ammonia criterion is 11.8 mg/L to 26.8 mg/L as nitrogen for warmwater fisheries with typical Missouri stream pH and temperature. This result is not surprising as low flow conditions in Peruque Creek are typical less than 1 cfs. However, in-stream ammonia concentrations were below detection within Peruque Creek downstream of this tributary.

3.1.6.2 Reservoir Water Quality Data

Lake Saint Louis and Lake Sainte Louise water quality data have been collected at various periods since 1989. The primary sources of data include the University of Missouri-Columbia (UMC) Lakes of Missouri Volunteer Program (LMVP) and the Lake Saint Louis Community Association (LSLCA). In addition, the UMC Department of Fisheries and Wildlife Sciences collected Lake Saint Louis water quality data between 1979 and 1995. Although some of these data are older than five years, the entire reservoir dataset produced by these sources will be utilized for assessment purposes since the older data are useful for reservoir water quality trend analyses.

The LMVP monitoring activities were initiated in 1996 for Lake Saint Louis and Lake Sainte Louise. This program consists of surface water sample collection by a group of volunteers throughout the State within various reservoirs. These samples are transported to the UMC Limnology Laboratory for water quality analysis. UMC Department Fisheries and Wildlife Sciences personnel train these volunteers to provide consistent sampling methodologies. Although these data are collected by

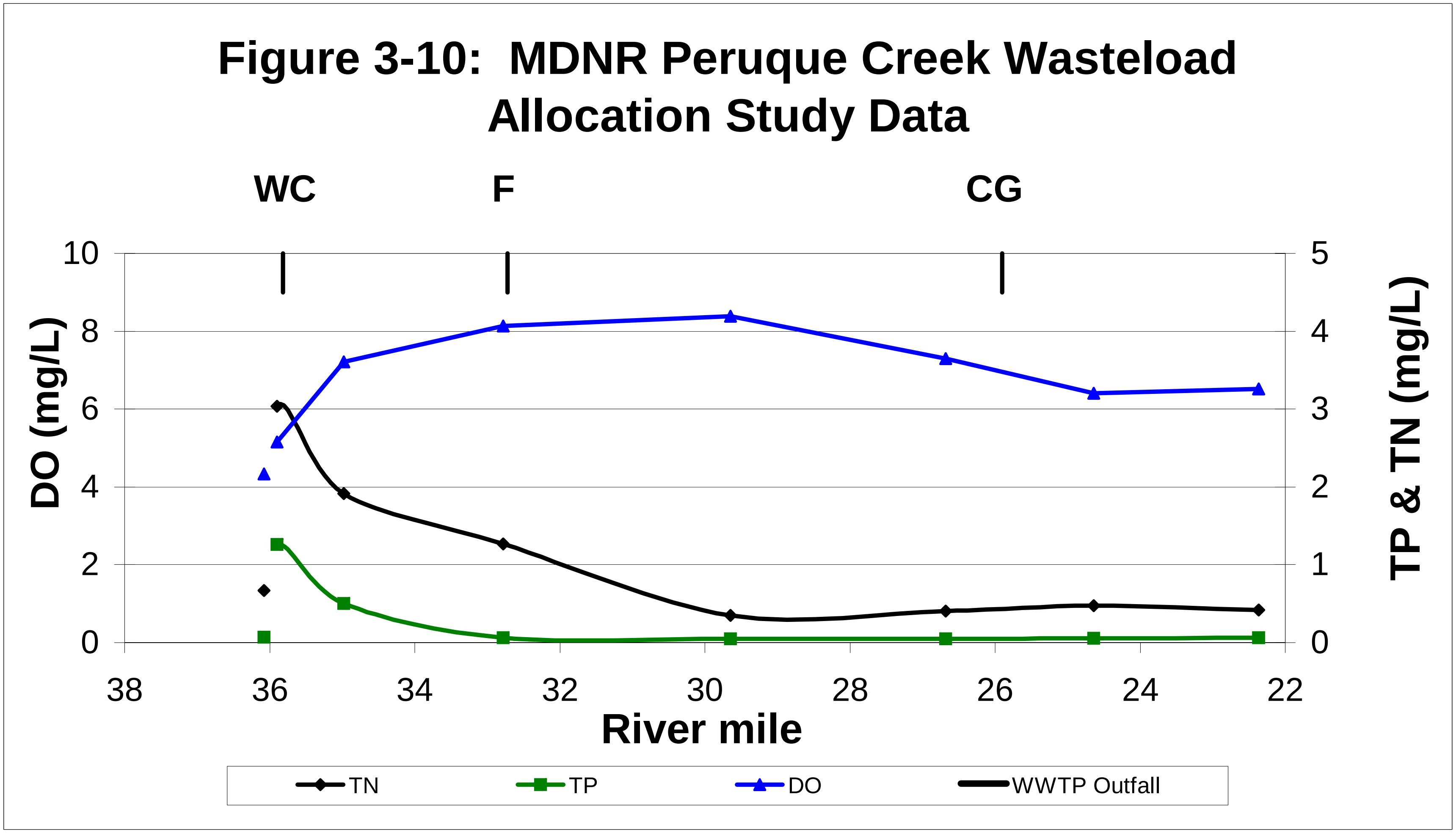


Figure 3-10: MDNR Peruque Creek Wasteload Allocation Study Data
WC
F
CG
DO (mg/L)
TP & TN (mg/L)
River mile
TN
TP
DO
WWTP Outfall

volunteers, data quality validation studies (Obrecht et al. 1998) indicate that this program produces relatively high quality data. Field and laboratory water quality analyses include water clarity (secchi depth), total nitrogen and phosphorus, chlorophyll (measure of algal biomass), total suspended solids (TSS), and nonvolatile suspended solids. LMVP sampling frequency is monthly and occurs from April through September. The UMC data collected during various years from 1979 and 1995 were assessed collectively with the LMVP data since the monitoring parameters and analytical methods were very similar.

The UMC and LMVP data provide useful characterization of surface water quality conditions during summer periods. These data demonstrate the wide variability in Lake Saint Louis surface water quality that typically occurs in Missouri reservoirs (**Figure 3-11** and **3-12**). Lake Sainte Louise water quality was relatively constant during the LMVP monitoring period (**Figures 3-13** and **3-14**). The data from these reservoirs may also be compared to nutrient criteria recommended by the U.S. Environmental Protection Agency (EPA) for the applicable ecoregions (**Figures 3-15** and **3-18**). These data demonstrate that Lake Saint Louis water quality typically does not meet these criteria, indicating potential impairment of reservoir's uses. Lake Sainte Louise water quality is significantly better than Lake Saint Louis. Lake Sainte Louise water quality typically meets or exceeds the EPA Level III Ecoregion nutrient criteria.

The UMC and LMVP data demonstrate several important relationships between water quality parameters. Water clarity, measured as secchi depth, appears to be related to nonvolatile suspended solids (sediment) (**Figure 3-19**). This trend is typically observed in central and northern Missouri reservoirs, indicating that sediment is the primary determinant of water clarity when NVSS concentrations exceed approximately 10 to 20 mg/L. Algal biomass becomes an important factor influencing water clarity when NVSS concentrations fall below this range.

Phosphorus appears to be the primary limiting nutrient in Lake Saint Louis as indicated by an average total phosphorus to total nitrogen (TN:TP) ratio of 15:1 (**Figure 3-20**). TN:TP ratios above approximately 10:1, are typically considered phosphorus limited. Therefore, reducing in-lake phosphorus concentrations should lower algal productivity within the reservoir. The relationship between total phosphorus and chlorophyll is presented in **Figure 3-21**. This graph illustrates the Lake Saint Louis data with the Jones, Bachman relationship and its 95 percent confidence interval (Jones and Knowlton 1993). The Jones, Bachman relationship was developed for numerous Missouri reservoirs and potentially allows prediction of chlorophyll with various total phosphorus concentrations. This depiction illustrates that Lake Saint Louis behaves similar to other Missouri reservoirs with respect to nutrient influences on algal population.

A lake or reservoir's trophic state is used to categorize and compare it to other water bodies, as well as to manage the lake for its intended uses. Typically, trophic classifications are based on surface water quality and can include the oxygen content

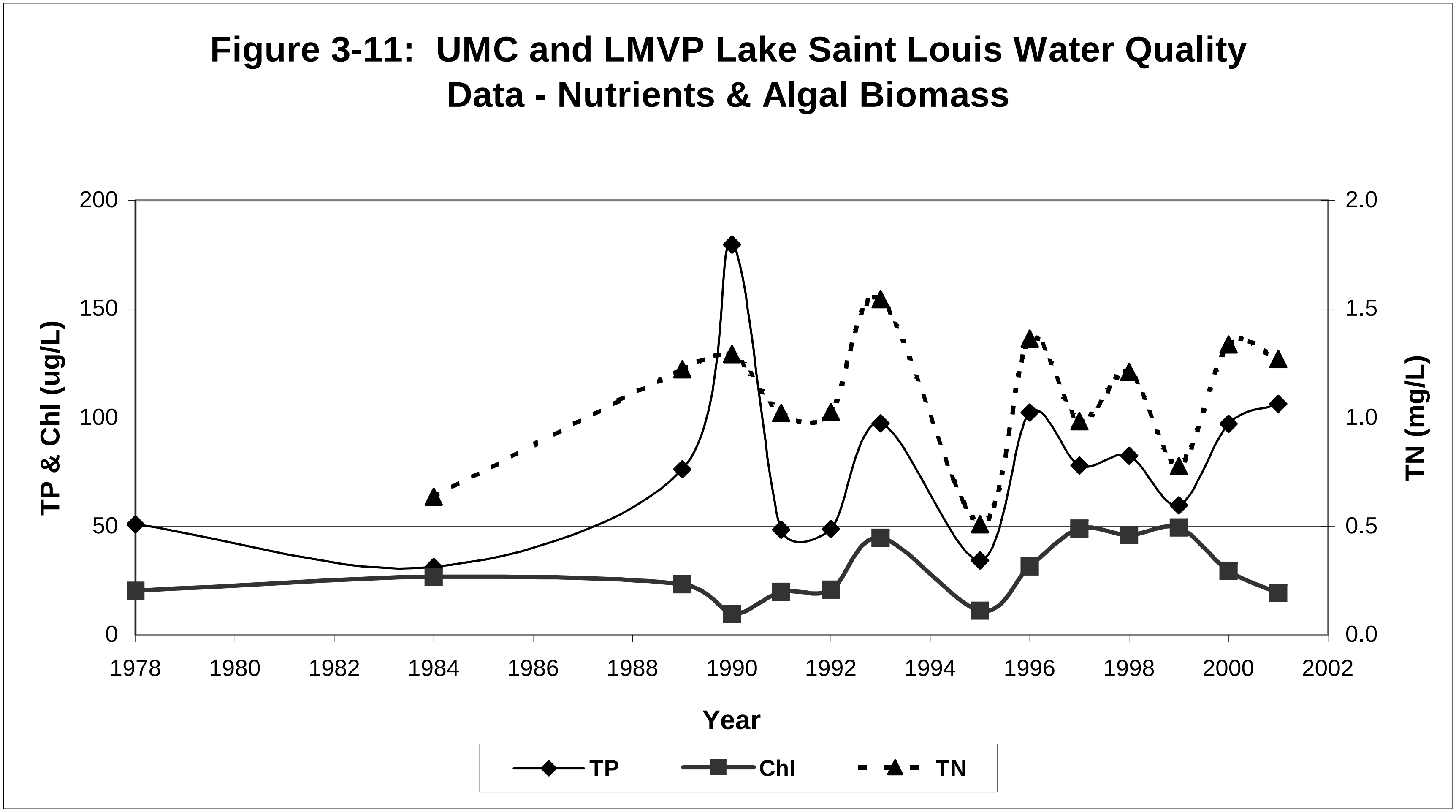


Figure 3-11: UMC and LMVP Lake Saint Louis Water Quality Data - Nutrients & Algal Biomass
TP & Chl (ug/L)
TN (mg/L)
Year
0
50
100
150
200
0.0
0.5
1.0
1.5
2.0
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
TP
Chl
TN

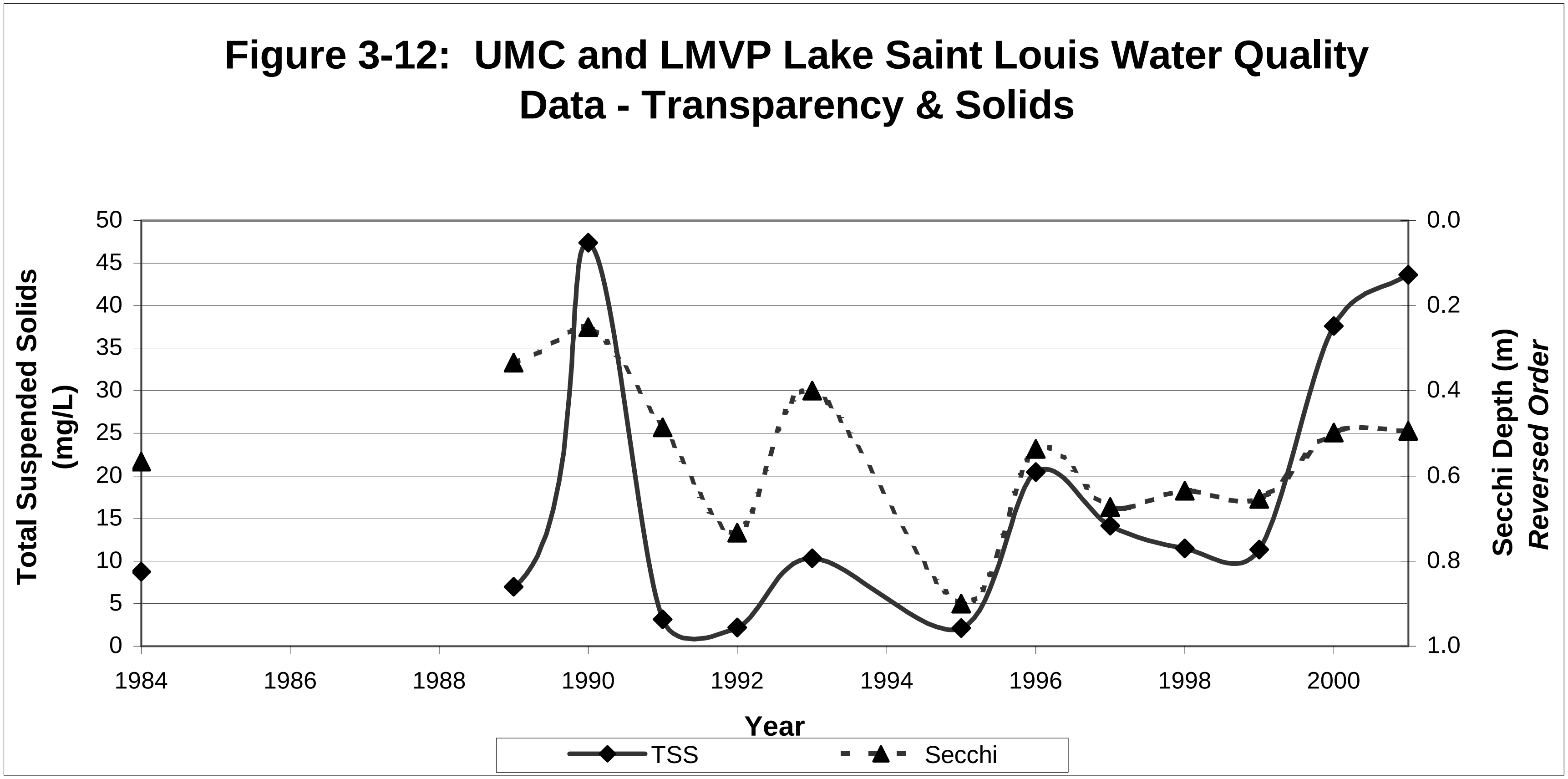


Figure 3-12: UMC and LMVP Lake Saint Louis Water Quality Data - Transparency & Solids
Total Suspended Solids (mg/L)
Secchi Depth (m)
Reversed Order
Year
TSS
Secchi
0
5
10
15
20
25
30
35
40
45
50
0.0
0.2
0.4
0.6
0.8
1.0
1984
1986
1988
1990
1992
1994
1996
1998
2000

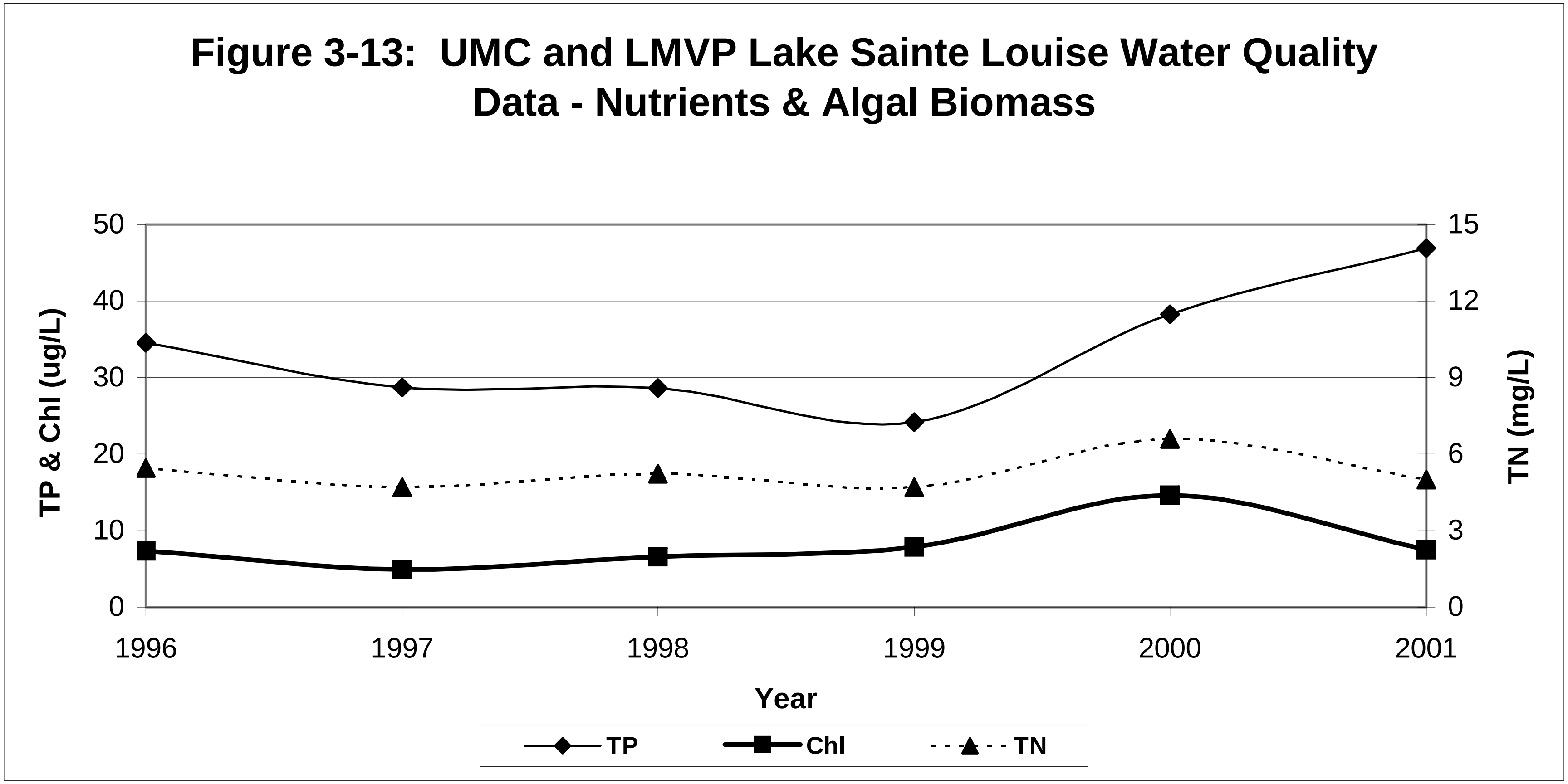


Figure 3-13: UMC and LMVP Lake Sainte Louise Water Quality Data - Nutrients & Algal Biomass
TP & Chl (ug/L)
TN (mg/L)
50
40
30
20
10
0
15
12
9
6
3
0
1996
1997
1998
1999
2000
2001
Year
TP
Chl
TN

Figure 3-14: UMC and LMVP Lake Sainte Louise Water Quality Data - Transparency & Solids

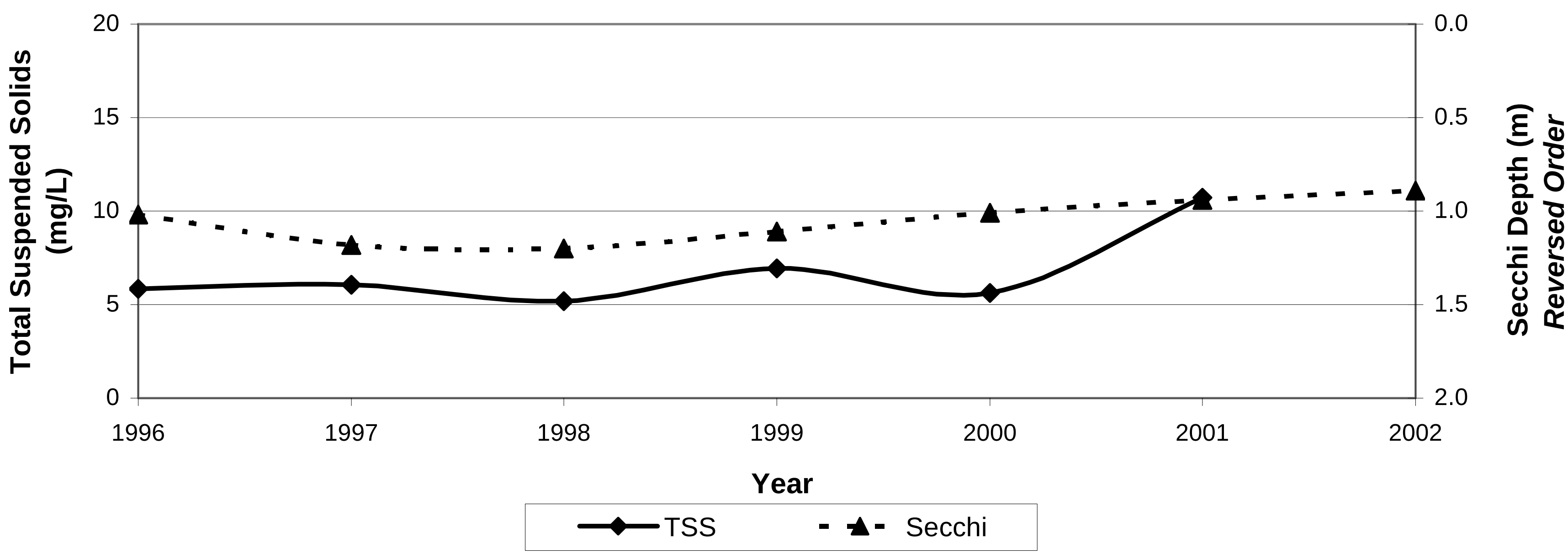
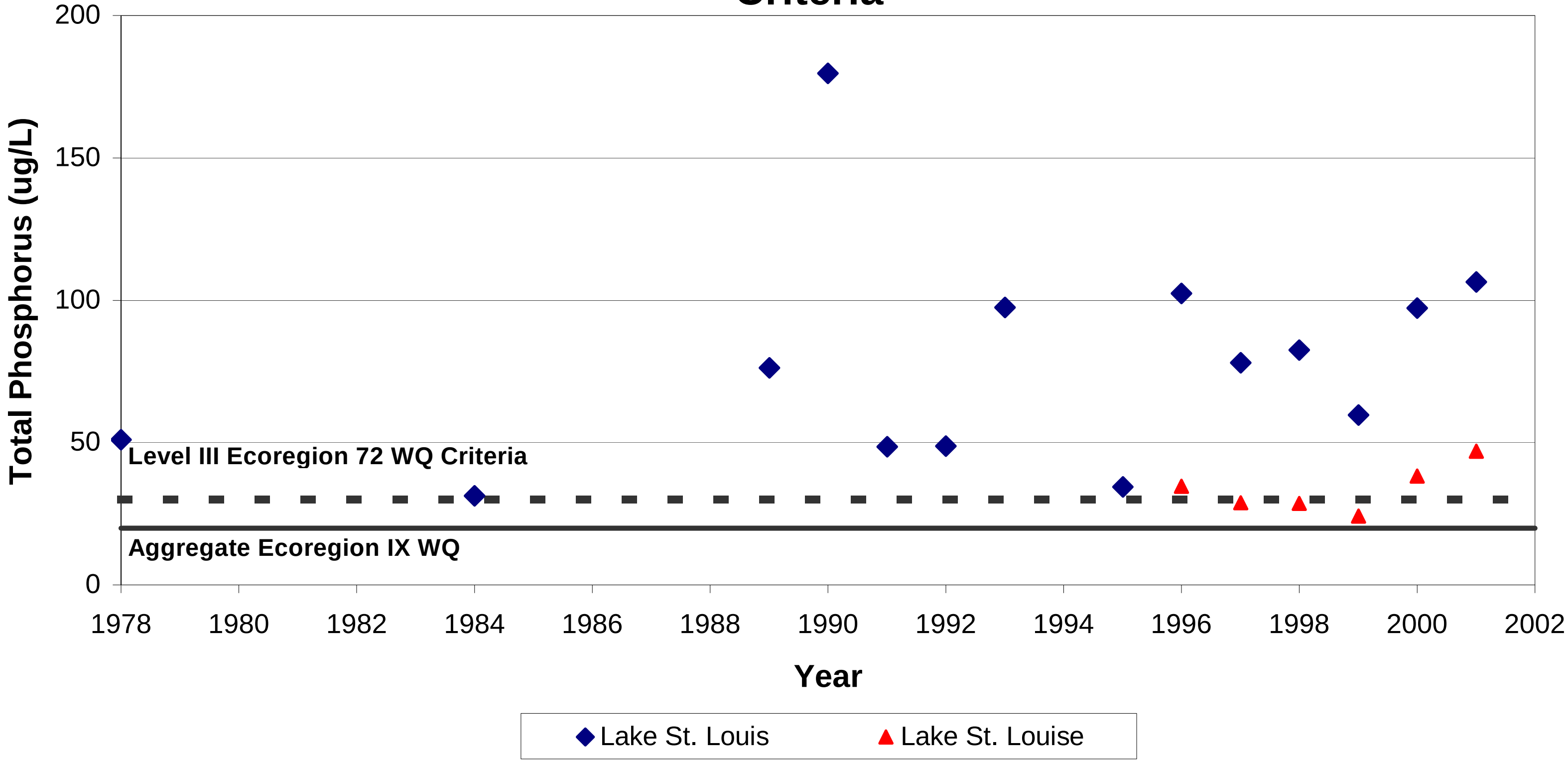


Figure 3-15: Comparison of Lake Saint Louis and Lake Sainte Louise Water Quality Data and EPA Ecoregion Water Quality Criteria



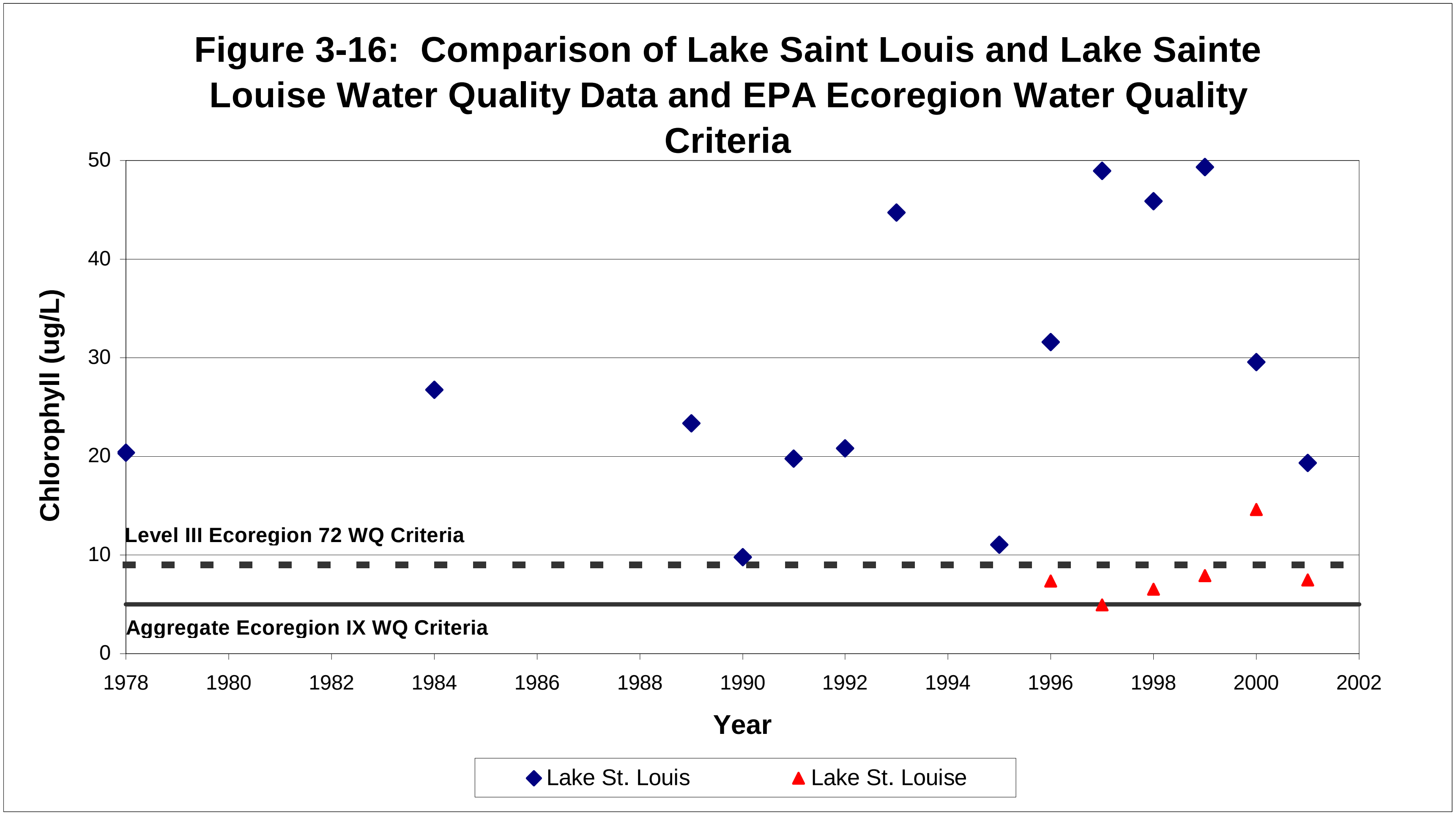


Figure 3-16: Comparison of Lake Saint Louis and Lake Sainte Louise Water Quality Data and EPA Ecoregion Water Quality Criteria
Chlorophyll (ug/L)
50
40
30
20
10
0
Level III Ecoregion 72 WQ Criteria
Aggregate Ecoregion IX WQ Criteria
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
Year
Lake St. Louis
Lake St. Louise

Figure 3-17: Comparison of Lake Saint Louis and Lake Sainte Louise Water Quality Data and EPA Ecoregion Water Quality Criteria

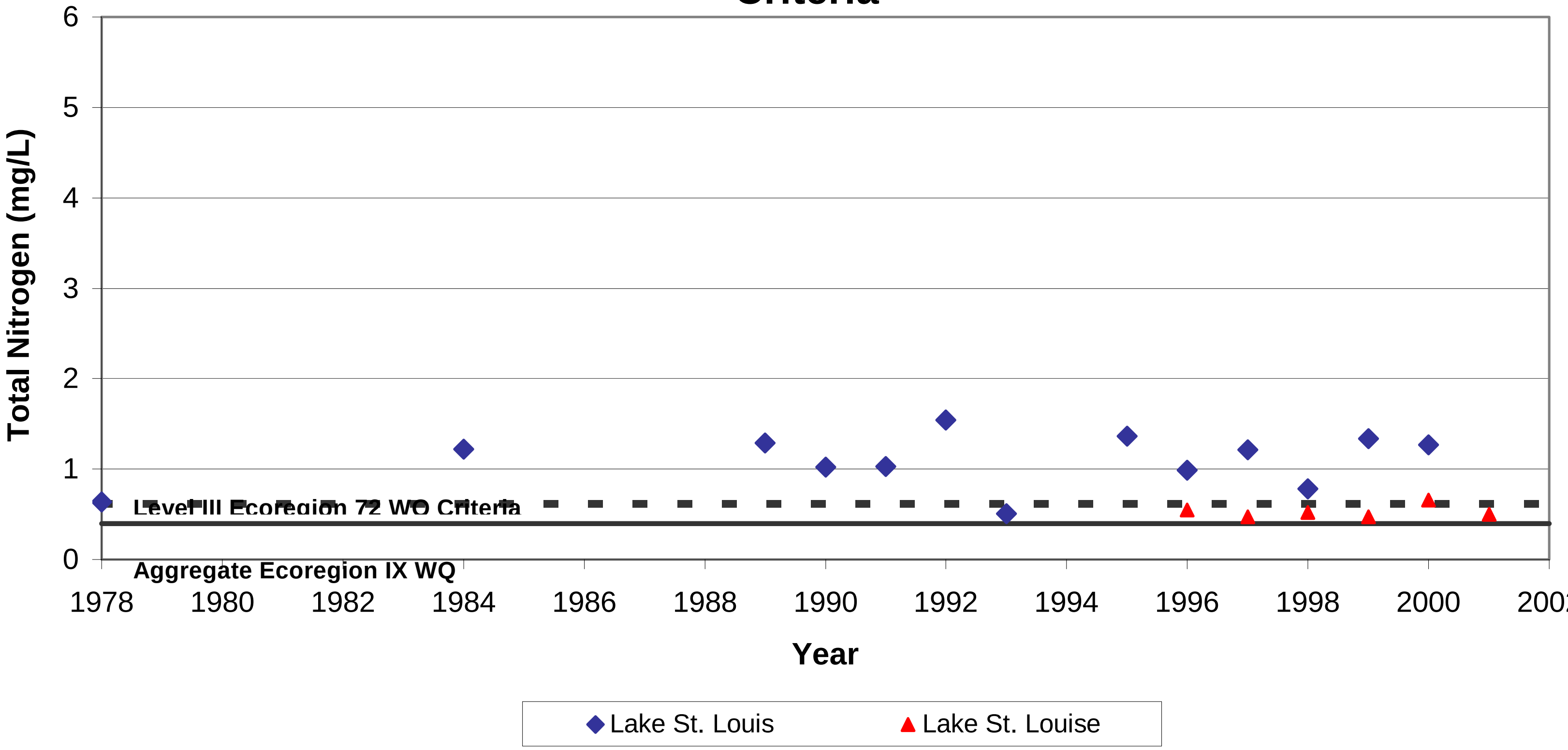
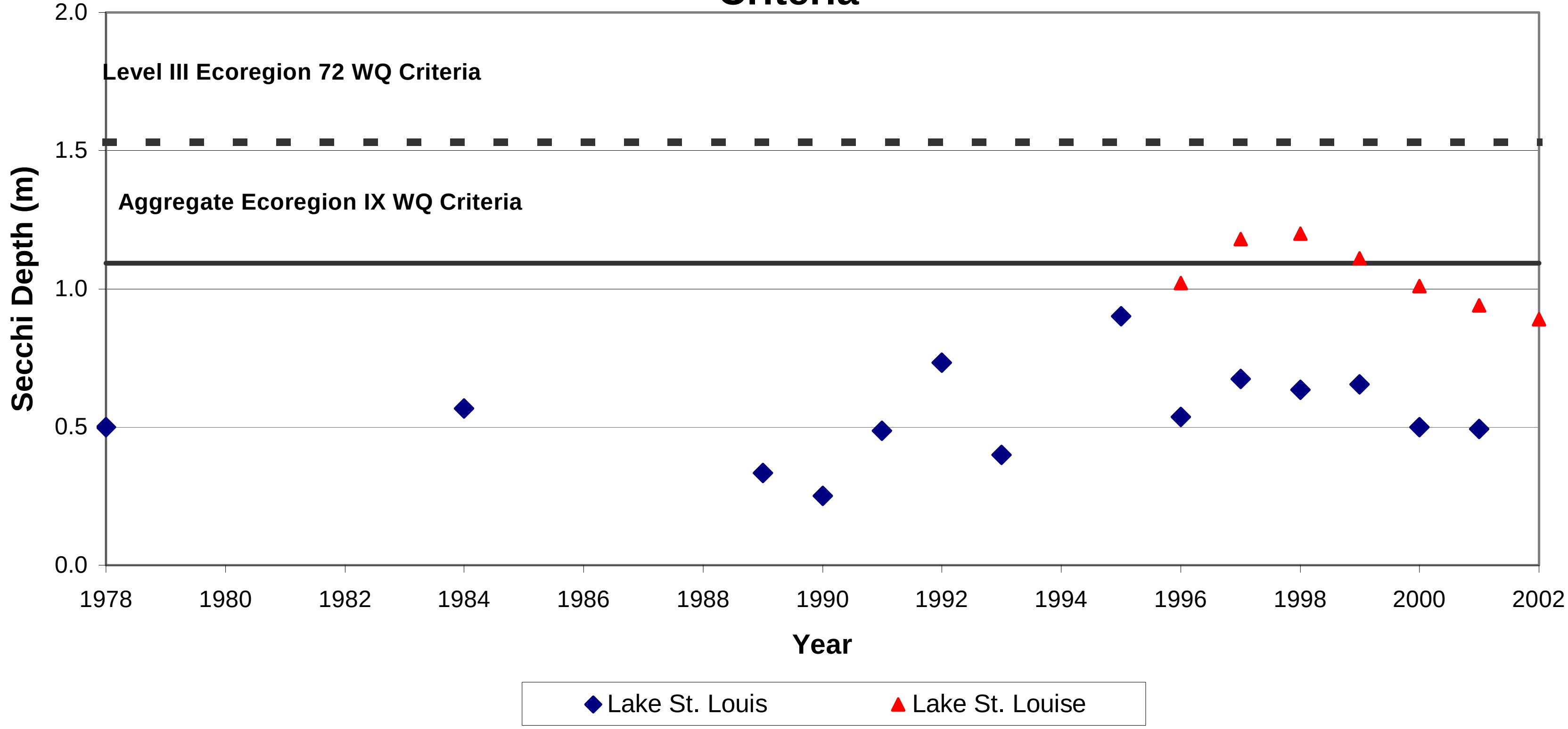


Figure 3-18: Comparison of Lake Saint Louis and Lake Sainte Louise Water Quality Data and EPA Ecoregion Water Quality Criteria



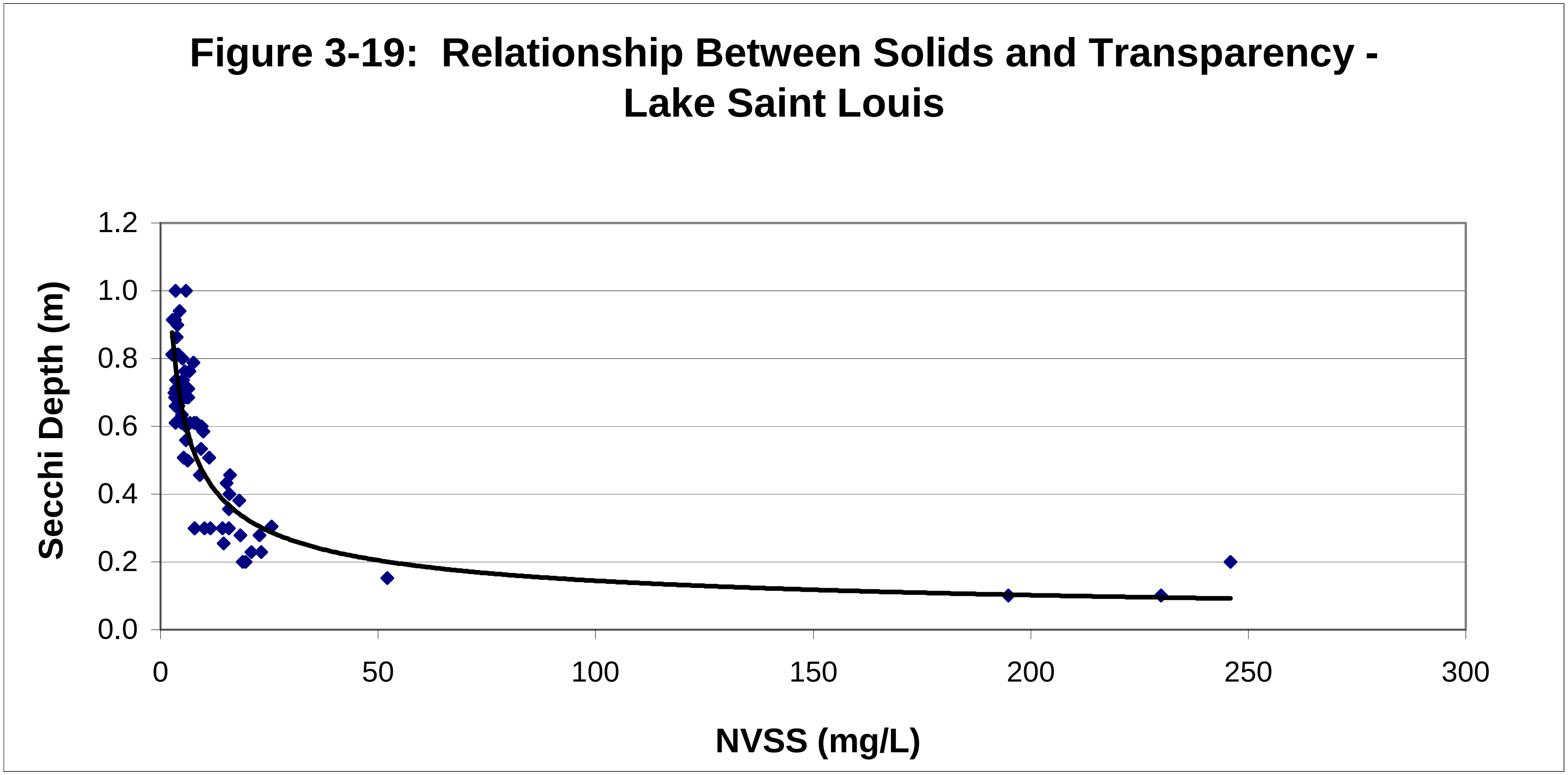


Figure 3-19: Relationship Between Solids and Transparency -
Lake Saint Louis
Secchi Depth (m)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
NVSS (mg/L)

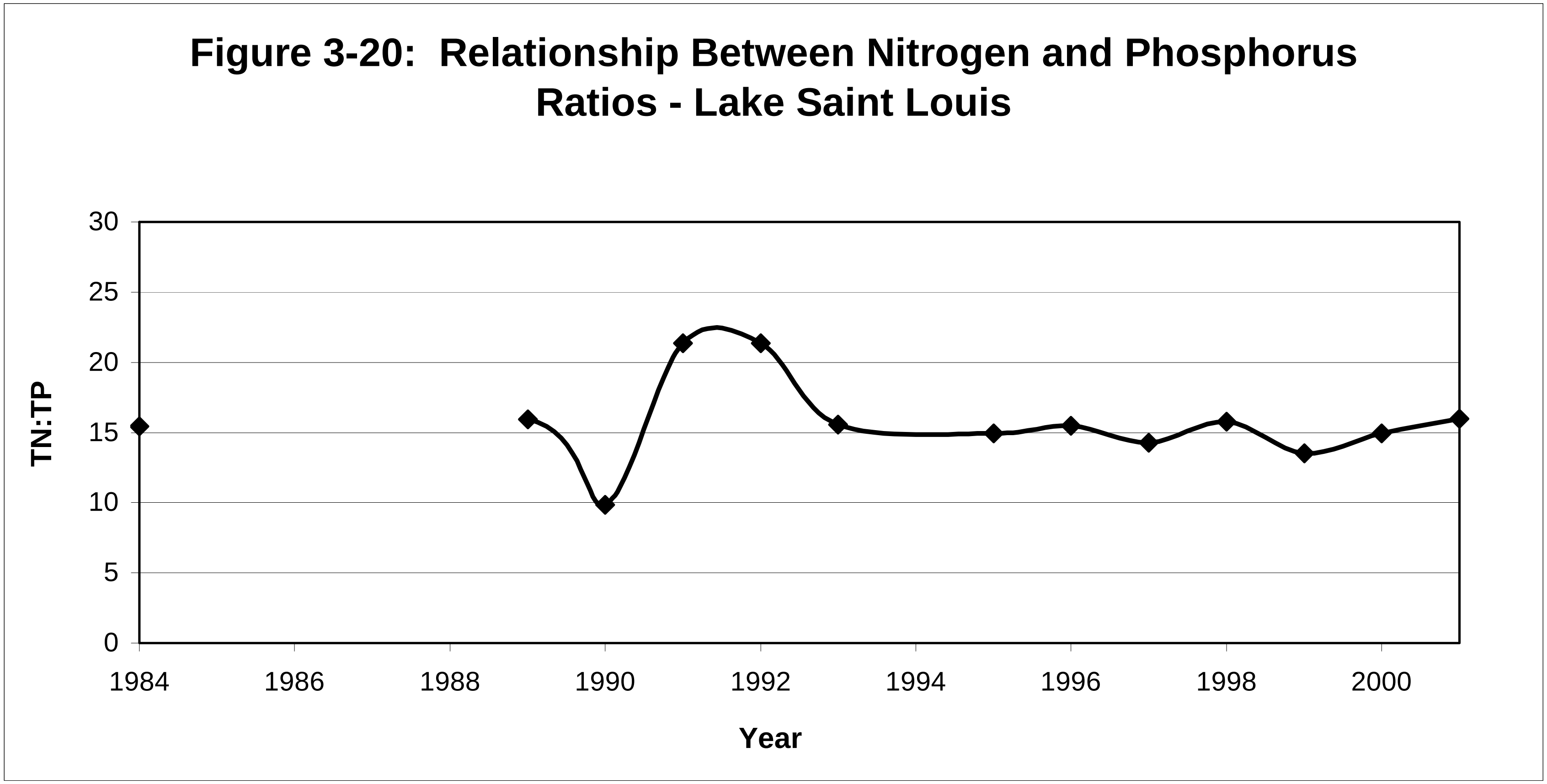
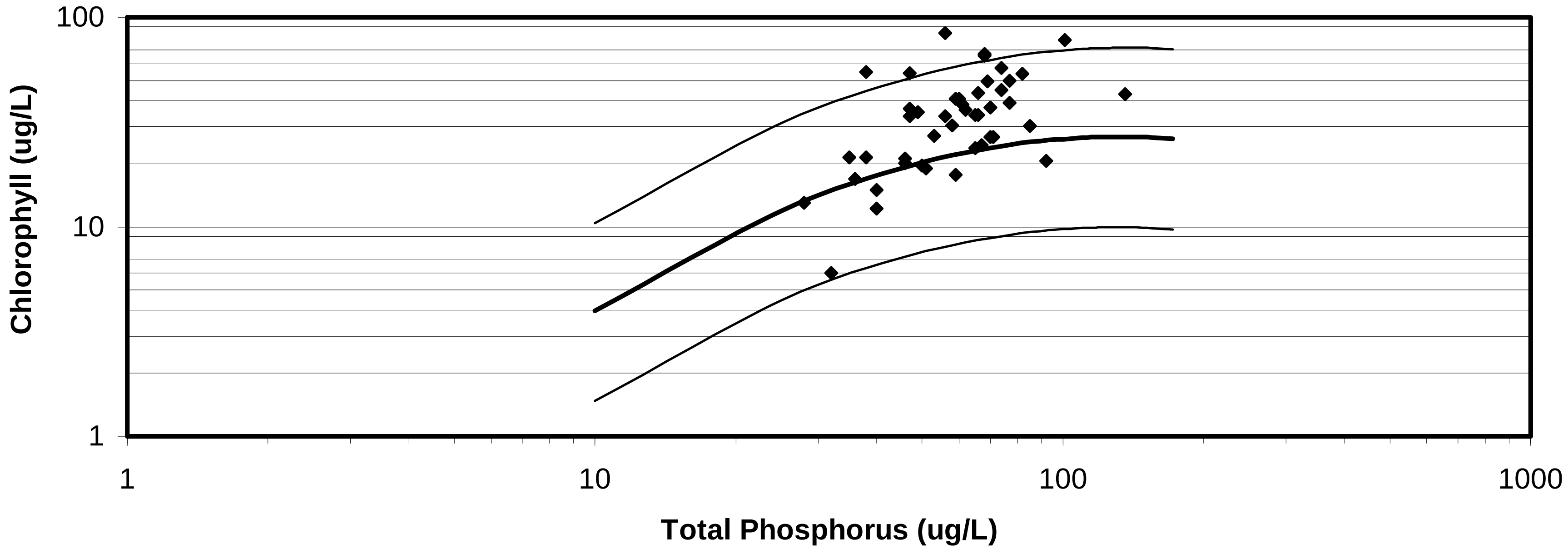


Figure 3-20: Relationship Between Nitrogen and Phosphorus Ratios - Lake Saint Louis
TN:TP
30
25
20
15
10
5
0
1984
1986
1988
1990
1992
1994
1996
1998
2000
Year

Figure 3-21: Relationship Between Phosphorus and Algal Biomass



of the hypolimnetic water. Often these classifications are used to categorize lakes into oligo-, meso-, eu- and hypereutrophic lake types and are based on the quantity of nutrients, algal chlorophyll and transparency. **Table 3-7** lists the typical characteristics for these typical classifications. Nurnberg (1996) compiled a review of the literature and established concentration thresholds that can be used to classify lake types. Using these criteria (**Tables 3-8** and **3-9**), Lake Saint Louis would be considered eutrophic to hypereutrophic and Lake Sainte Louise would be considered mesotrophic to eutrophic.

The LSLCA performed pathogen monitoring at numerous locations within Lake Saint Louis from 1997 to 2002, however data from 2002 was not available until recently and is not summarized graphically in this document. Formal quality assurance procedures were not utilized for the LSLCA monitoring activities. Therefore, the accuracy of these data is not verifiable. As a result, this assessment utilized the LSLCA data only as a screening mechanism.

The LSLCA monitoring data suggests that pathogen concentrations in Lake Saint Louis exceed the Missouri fecal coliform criterion of 200 colony forming units/ 100 milliliters (cfu/100 mL) for whole-body contact recreation during periods of the summer. The LSLCA data are depicted in logarithmic format as **Figures 3-22** through **3-25**. **Table 3-10** summarizes these data with respect to several statistical measures. For all sites with adequate data points, the geometric means of the fecal coliform data are below the 200 cfu/100 mL criterion.

In Missouri, waters with designated uses for whole-body contact recreation are considered impaired if the fecal coliform geometric mean is greater than the criterion (MDNR 2001). Based on this criterion, the LSLCA data suggest that Lake Saint Louis may not be considered impaired for whole-body contact recreation even though several measurements were greater than the criteria. The MDNR will likely change the pathogen criteria to *E. coli*, rather than or in combination with fecal coliform, as this measure provides a better indication of human health risks. Due to the limited *E. coli* data available for Lake Saint Louis and the lack of current numeric criteria, water quality based on this measure was not assessed. Future monitoring programs should consider including *E. coli* analyses to determine if whole-body contact recreation uses are being impaired.

In addition to the *E. coli* studies, the LSLCA sent water samples collected from the Paris Cove watershed of Lake Sainte Louise to be analyzed at the University of Washington in Seattle for DNA fingerprinting of the *E. coli* isolates. The results of the DNA fingerprinting study are included in **Table 3-11**.

Table 3-7
Typical Characteristics of Lake Trophic States

Trophic State	Attributes	Water Supply	Recreation	Fisheries
Oligotrophic	Clear water, oxygenated hypolimnion.			Salmonoid fisheries in deeper lakes
Mesotrophic	Water moderately clear, but increasing probability of hypolimnetic anoxia in summer.	Iron and manganese problems. Raw water has noticeable odor, THM precursors exceed 0.1 mg/L, and turbidity exceeds 1 NTU.		Loss of salmonoid species because of hypolimnetic anoxia.
Eutrophic	Decreased transparency, anoxic hypolimnia during the summer, macrophyte problems may be evident.	Iron and manganese, taste and odor, turbidity and THM problems worsen.		Warm-water fisheries only. Bass and perch may be dominant.
Hypereutrophic	Blue-green algae dominate during the summer, algal scums probable, considerable macrophyte problems.		Boating difficult because of weeds, transparency, and algal scums discourage swimming.	Winter fish kills possible in shallower lakes. Rough fish dominate, summer fish kills possible

Adapted from Cooke and Carlson 1989

Table 3-8
Trophic Classifications of Lake Saint Louis

Parameter	Limits			Lake Saint Louis Mean Value	Trophic State
	O-M	M-E	E-H		
Total Phosphorus (µg/L)	10	30	100	78	E
Total Nitrogen (µg/L)	350	650	1200	1092	E
Chlorophyll (µg/L)	4	9	25	29	H
Secchi Depth (m)	4	2	1	0.55	H

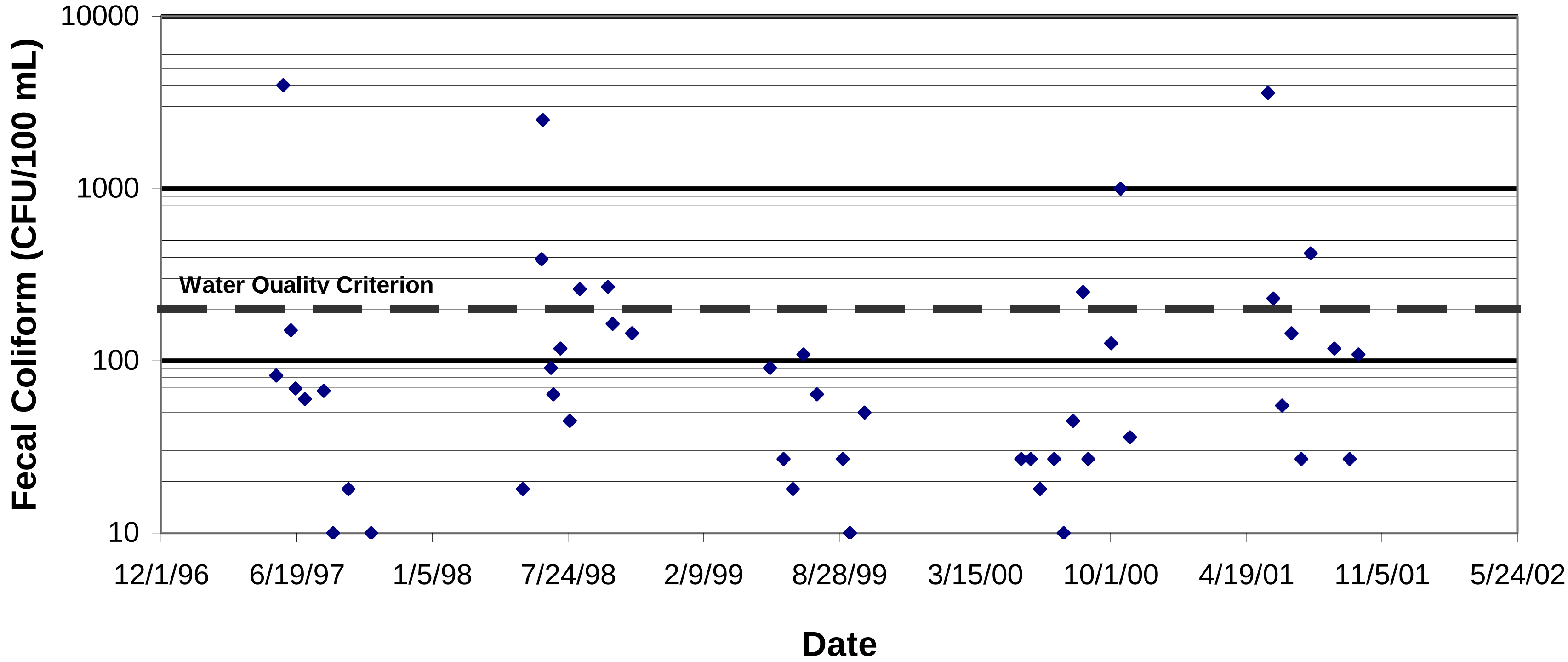
O-M Limit between Oligotrophic and Mesotrophic
M-E Limit between Mesotrophic and Eutrophic
E-H Limit between Eutrophic and Hypereutrophic

Table 3-9
Trophic Classifications of Lake Sainte Louise

Parameter	Limits			Lake Sainte Louise Mean Value	Trophic State
	O-M	M-E	E-H		
Total Phosphorus (µg/L)	10	30	100	34	E
Total Nitrogen (µg/L)	350	650	1200	529	M
Chlorophyll (µg/L)	4	9	25	8	M
Secchi Depth (m)	4	2	1	1.05	E

O-M Limit between Oligotrophic and Mesotrophic
M-E Limit between Mesotrophic and Eutrophic
E-H Limit between Eutrophic and Hypereutrophic

Figure 3-22: LSLCA Lake Saint Louis Fecal Coliform Data at Timberline Site - 1997-2001



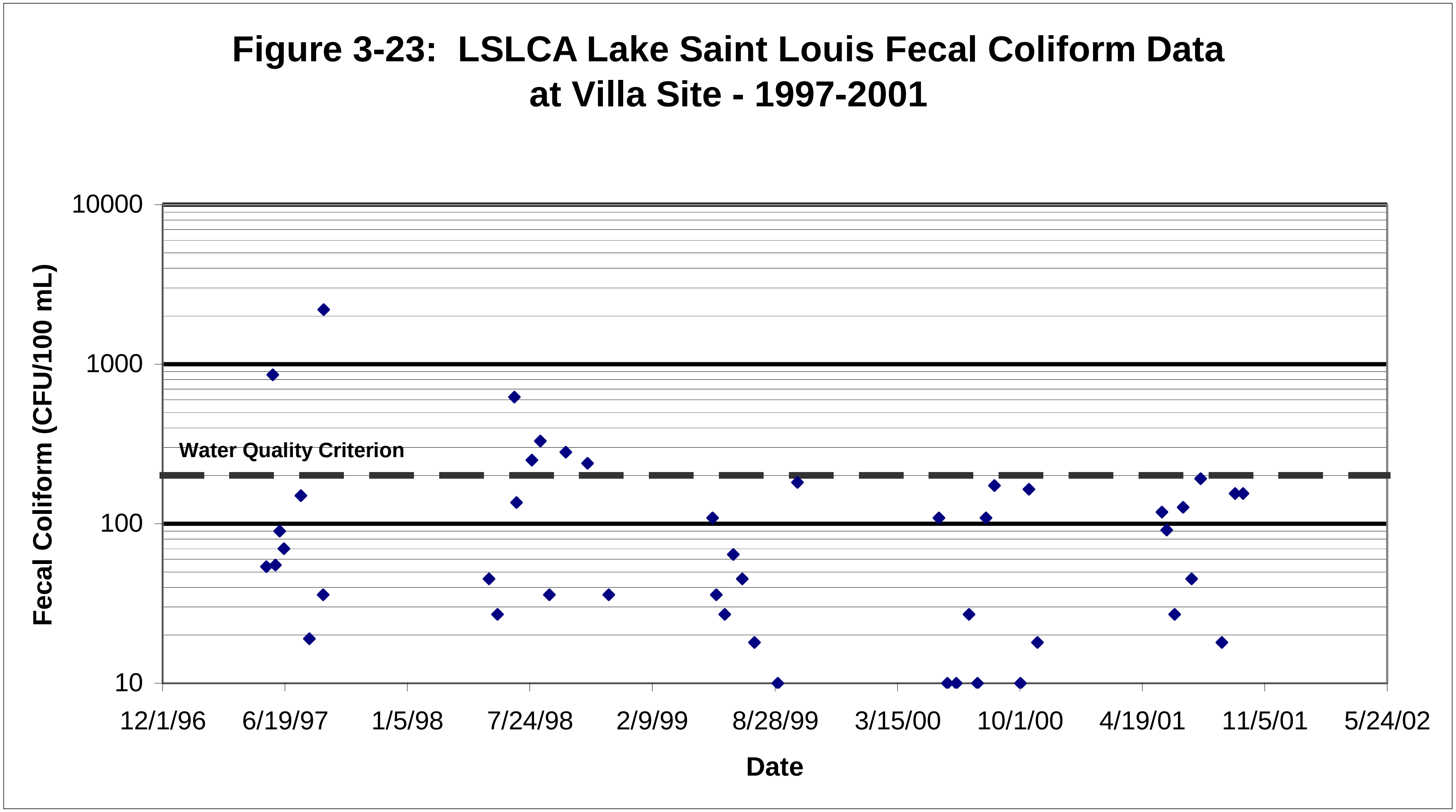


Figure 3-23: LSLCA Lake Saint Louis Fecal Coliform Data
at Villa Site - 1997-2001
10000
1000
100
10
Fecal Coliform (CFU/100 mL)
Water Quality Criterion
12/1/96
6/19/97
1/5/98
7/24/98
2/9/99
8/28/99
3/15/00
10/1/00
4/19/01
11/5/01
5/24/02
Date

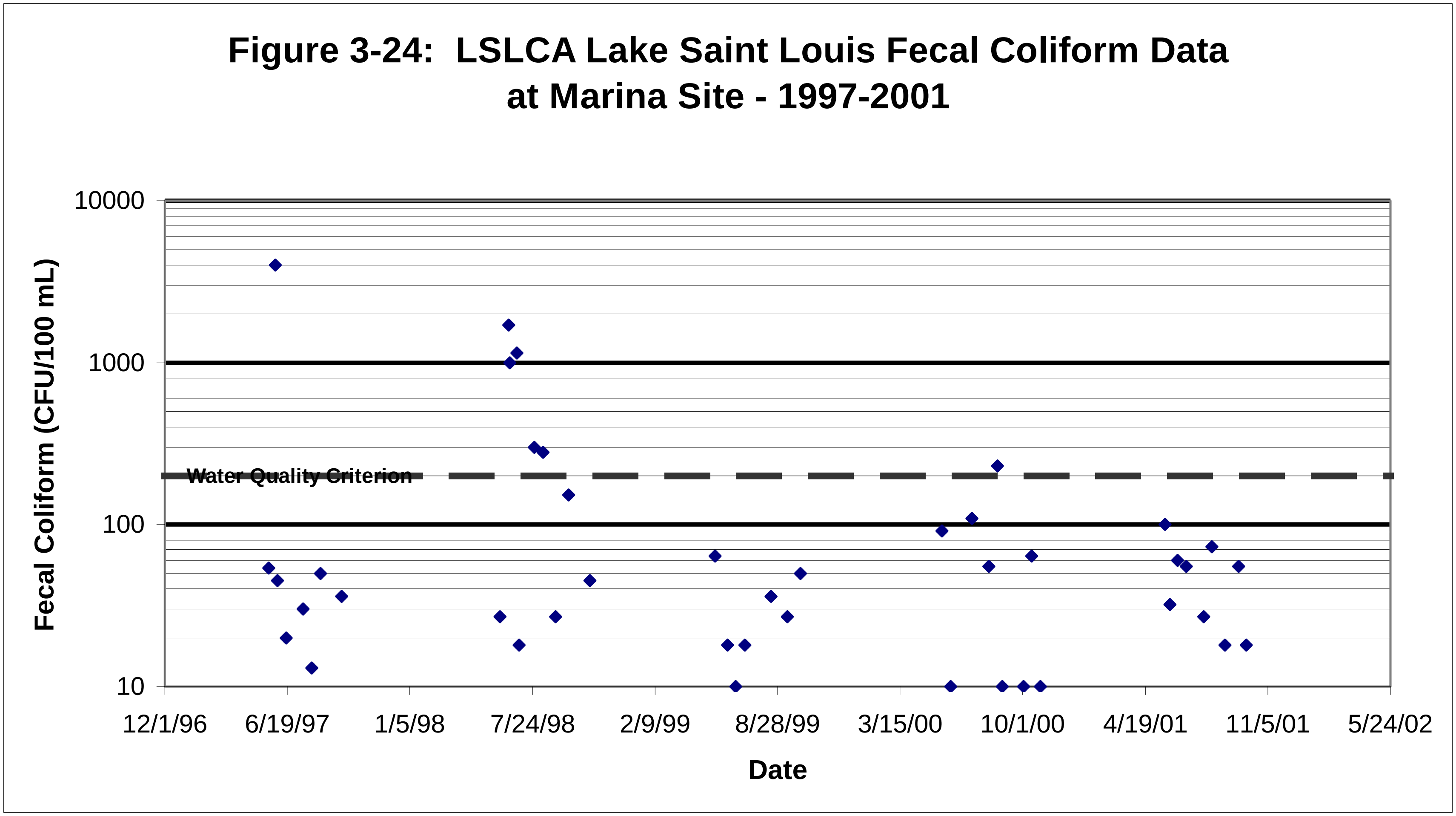


Figure 3-24: LSLCA Lake Saint Louis Fecal Coliform Data
at Marina Site - 1997-2001
10000
1000
100
10
Water Quality Criterion
Fecal Coliform (CFU/100 mL)
12/1/96
6/19/97
1/5/98
7/24/98
2/9/99
8/28/99
3/15/00
10/1/00
4/19/01
11/5/01
5/24/02
Date

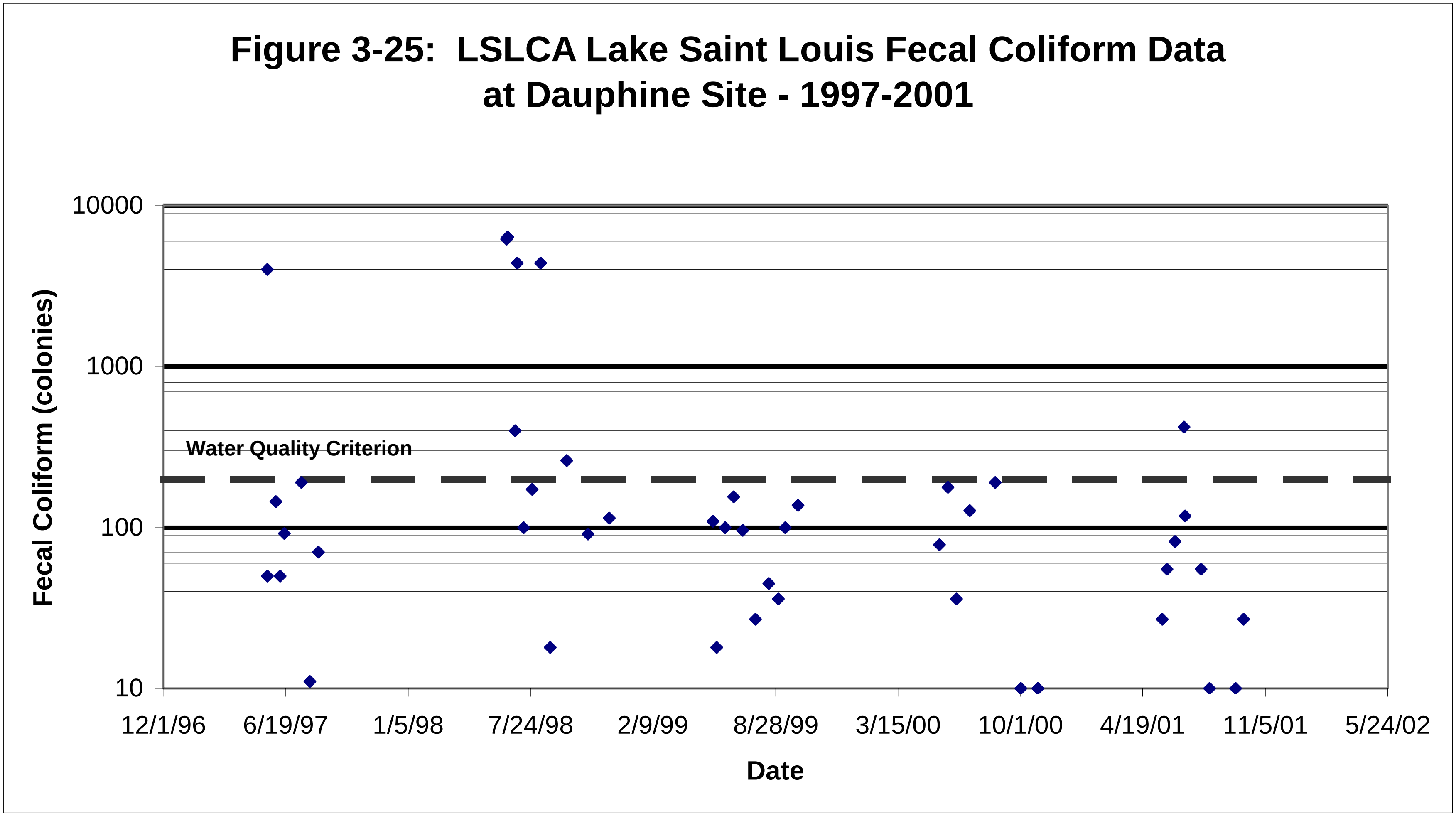


Figure 3-25: LSLCA Lake Saint Louis Fecal Coliform Data
at Dauphine Site - 1997-2001
10000
1000
100
10
Fecal Coliform (colonies)
Water Quality Criterion
12/1/96
6/19/97
1/5/98
7/24/98
2/9/99
8/28/99
3/15/00
10/1/00
4/19/01
11/5/01
5/24/02
Date

Table 3-10
Summary of LSL CA Fecal Coliform Data at Selected Sites - 1997-2001

Site Name	Fecal Coliform (cfu/100 mL) n=	Geometric Mean	Min	Max	*E. coli* (cfu/100 mL) n=	Geometric Mean	Min	Max
Lake Saint Louis-Timberline	59	47	5	4000	4	27	3	62
Lake Saint Louis- Villa	58	40	5	2200	4	30	6	85
Lake Saint Louis-Marina	57	30	5	4000	4	9	2	18
Lake Saint Louis-Dauphine	55	61	5	6400	2	14	4	49

Table 3-11
DNA Fingerprinting Results at Paris Cove

Source	# of Isolates from Source	Percent
Avian (bird, duck, geese, etc)	35	26.52%
Dog	33	25.00%
Human	11	8.33%
Rodent	7	5.30%
Cat	5	3.79%
Opossum	4	3.03%
Deer	3	2.27%
Raccoon	3	2.27%
Skunk	3	2.27%
Fox	2	1.52%
Unidentified	26	19.70%
Total	132	100.00%

3.1.7 Point Sources

The primary point sources of municipal and domestic wastewater within Peruque Creek include the cities of O'Fallon, Wright City, Foristell and Castlegate Estates subdivision. These discharges are regulated by the MDNR through the National Pollutant Discharge Elimination System (NPDES). The NPDES programs provide permits to these facilities, which include water quality, permit limitations and monitoring requirements as summarized in **Table 3-12**. A minor discharge is also present at Boone Ridge Estates subdivision near the crossing of Peruque Creek by Wilmer Road; however, the current average discharge from this facility is only 4,000-gallons per day (gpd) and was excluded from data review.

Although these treatment plants vary in size, each utilizes extended aeration activated sludge process for biological treatment. Recent monitoring data for each facility show treatment efficacy typical of well-operated activated sludge treatment plants. While infrequent excursions of permit limitations occurred, the long-term averages of the biochemical oxygen demand (BOD) and TSS data were relatively low (5 to 18 mg/L). In addition, the 90th percentile of these data was well below permit limitations. The NPDES monitoring data for these facilities are presented in time series plots (**Figures 3-26** through **3-28**) and as box plots for statistical representation (**Figures 3-29**). Infrequent excursions of permit limitations are expected due to the infrequent monitoring and variability in activated sludge effluent quality caused by occasional upsets of the biological processes. None of these plants are considered in significant noncompliance by the MDNR.

Table 3-12
Summary Information of Peruque Creek Source Dischargers

		O'Fallon WWTF	Wright City WWTF	Castlegate Estates	Foristell Interim STP
		MO-0028720	MO-0023191	MO-0057801	MO-0116114
Design Flow (gpd)		7,500,000	350,000	50,000	22,000
Actual Average Flow (gpd)		7,155,000	290,000	20,000	16,000
BOD (mg/L)	MDL		25		
	AWL			25	45
	AML			25	30
TSS (mg/L)	MDL				
	AWL	45	45	25	45
	AML	30	30	25	30
Ammonia	MDL Apr-Oct		2	3	
(mg/L as N)	MDL Nov-Mar		5	3	

BOD Biochemical Oxygen Demand
TSS Total Suspended Solids
MDL Maximum Daily Limit
AWL Average Weekly Limit
AML Average Monthly Limit

3.1.8 Biological Data Collection

3.1.8.1 Fish Sampling Locations

During the summer of 2001, several locations at Peruque Creek were sampled for fish species through the use of electro-fishing and/or seining. Sampling also occurred at select locations in the summer of 1995 and at one location in 1962. Sampling conducted in 2001, 1995 and 1962 was completed by the MDC. The fish that were obtained were identified, counted, then released. The locations are ordered by River Mile, with the largest number reflecting the most upstream location. The section of Peruque Creek covered is from Wright City Park to Duello Road, with Wright City Park at river mile 37.5 being the furthest upstream from Lake Saint Louis. Figure 3-3 shows the sampling locations. The areas, dates of sampling, and river mile location are identified in the following **Table 3-13**. **Appendix B** contains a recent MDC report describing additional biological sampling in Peruque Creek.

Table 3-13
Fish Sampling Location Summary

Area	Date	River Mile
Wright City Park	6/18/01	37.5
Archer Road	6/12/01	35.9
Hwy T	6/20/01	33.3
#5	8/11/95	30.9
Hepperman Road	6/25/01	28.2
Pflieger #4	8/25/62	27
#4	9/27/95	26.8
Wilmer Road	6/29/01	26.6
#3	8/11/95	22.7
Duello Road	6/28/01	22.6

Figure 3-26: NPDES Monitoring Data for Wright City Wastewater Treatment Facility: 1998 – 2002

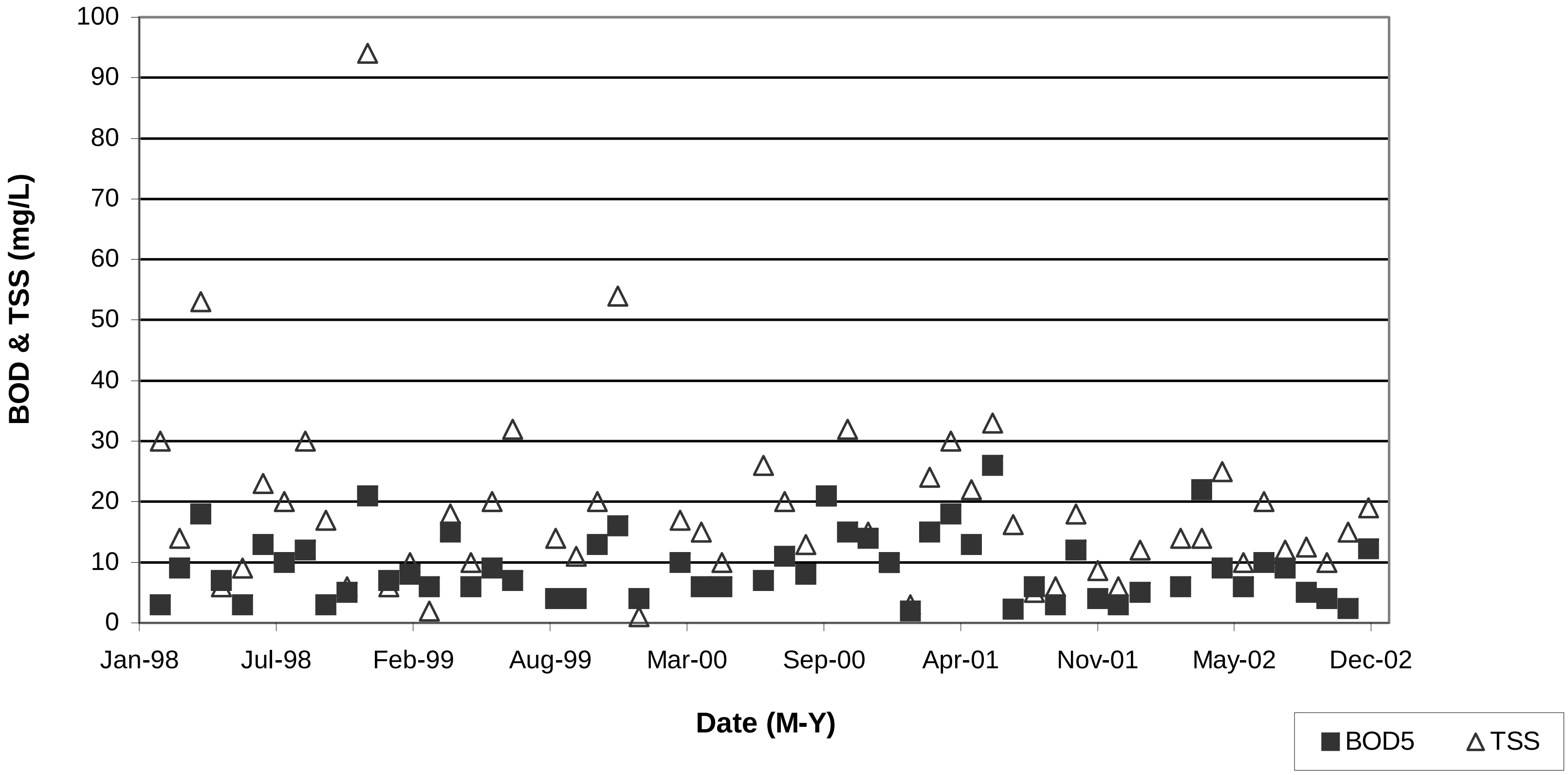


Figure 3-27: NPDES Monitoring Data for Foristell Wastewater Treatment Plant: 1998 – 2002

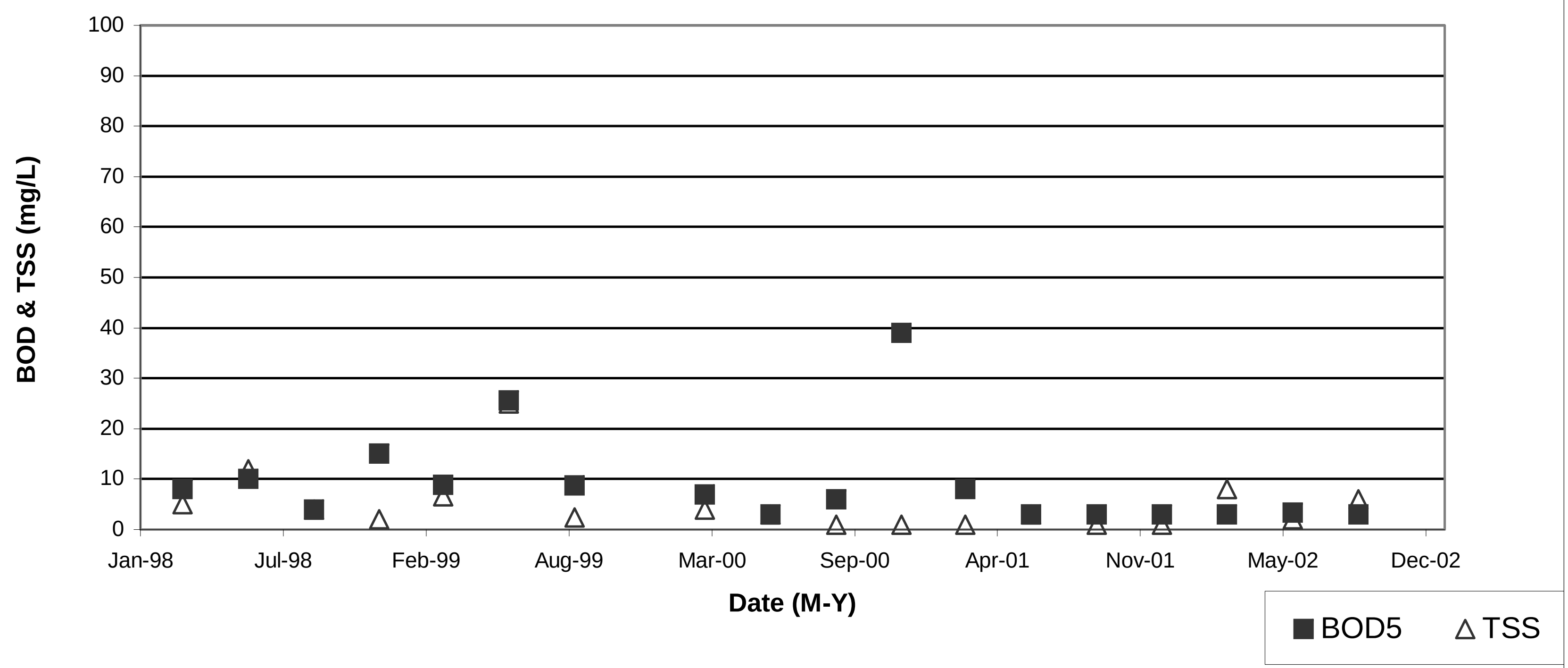


Figure 3-28: NPDES Monitoring Data for Castlegate Estates Wastewater Treatment Plant: 1998 – 2002

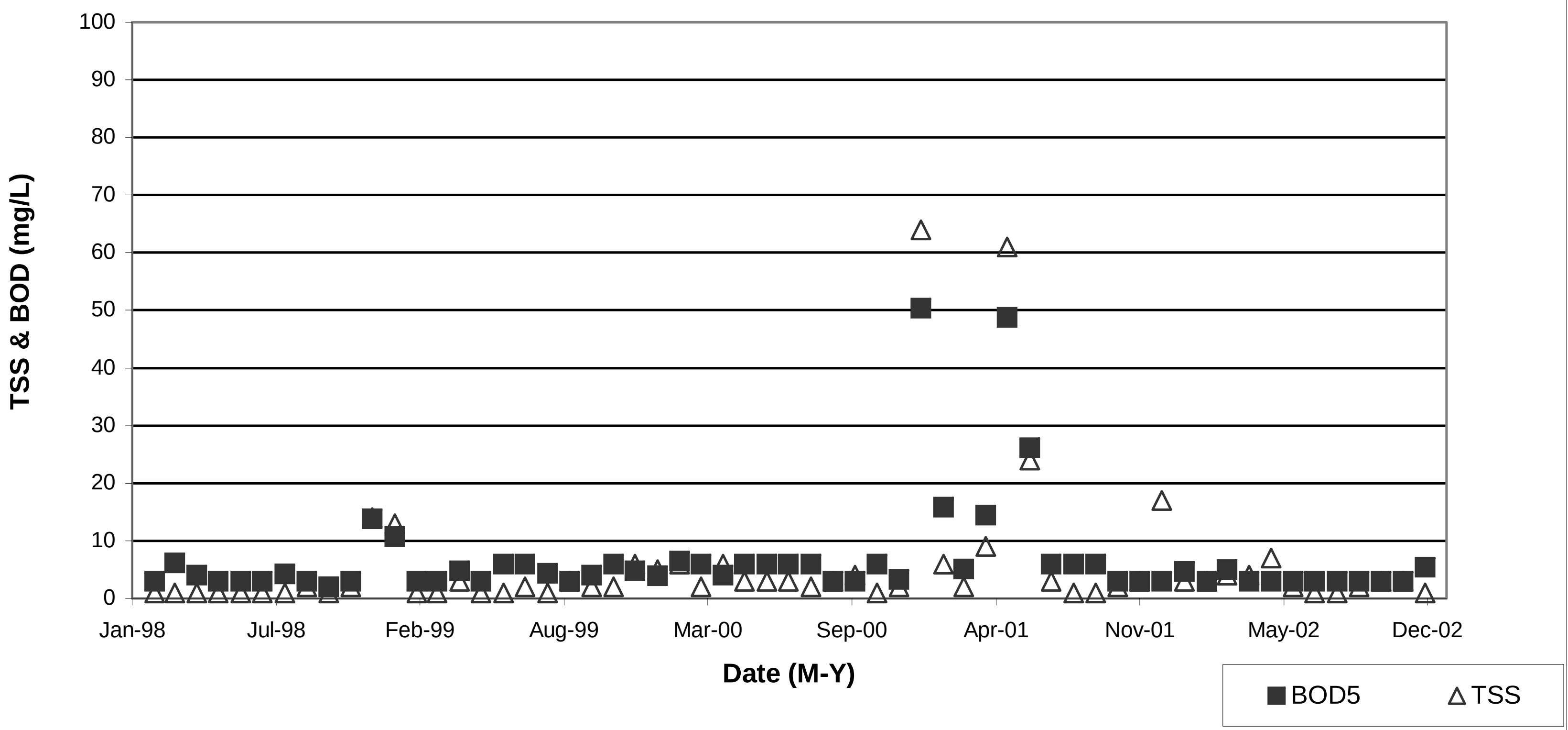
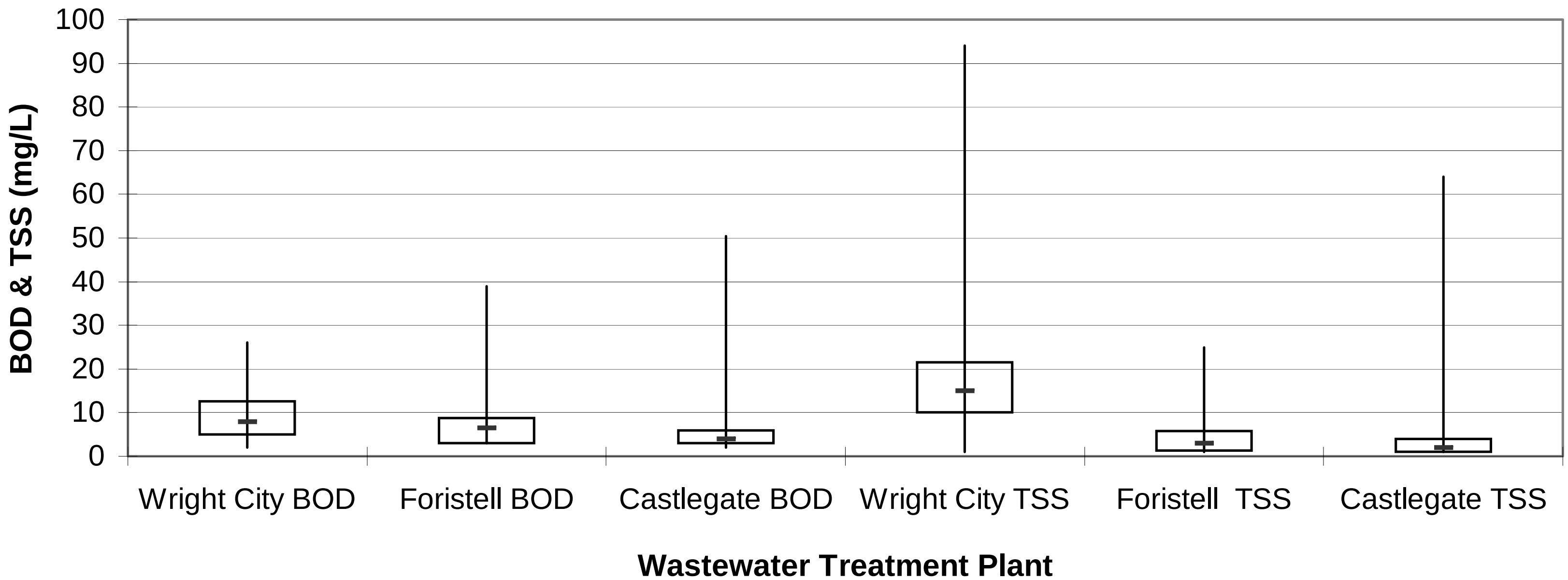


Figure 3-29: Summary of NPDES Monitoring Data for Municipal and Domestic Discharges: 1998-2002



3.1.8.2 Sampling Methods

Electro-fishing and seining were both used at each location surveyed in 2001. Only seining was used during the 1995 and 1962 surveys. Overall, a wider variety of fish species were observed in the 2001 sampling period, and this could be attributed to the use of electro-fishing during those surveys.

3.1.8.3 Species Collected

Thirty-two different fish species were collected from ten sites. Three species, the bluntnose minnow (*Pimephales notatus*), the orangethroat darter (*Etheostoma caeruleum*), and the central stoneroller (*Campostoma pullum*) were found at all ten locations. The five most commonly found species were the central stoneroller (1,074 individuals), the orangethroat darter (515 individuals), the redfin shiner (*Lythrurus umbratilis*) (261 individuals), the red shiner (*Cyprinella lutrensis*) (249 individuals), and the bluntnose minnow (218 individuals). The redfin shiner was not found at the Hwy T location, and the red shiner was not found at Archer Road, Hwy T, or location #5.

The two least found species were the black redhorse (*Moxostoma duquesnei*) with only one individual found at Hepperman Road, and the common carp (*Cyprinus carpio*), with one individual found at Wilmer Road, and one at Duello Road.

Table 3-14 shows how many unique species were identified at each location, and the total number of individuals of any kind collected from each location.

Table 3-14
Number of Species and Individuals by Site

Area	Total Species	Total Individuals
Wright City Park	17	241
Archer Road	14	114
Hwy T	13	453
#5	17	313
Hepperman Road	22	432
Pflieger #4	18	140
#4	17	106
Wilmer Road	20	546
#3	17	117
Duello Road	25	970

3.1.8.4 Temporal Distribution

Bigmouth shiner (*Notropis dorsalis*) were collected at all locations sampled in 1962 and 1995, but were not found at any location in 2001.

Fifteen species, including, bluegill (*Lepomis macrochirus*), bluntnose minnow, creek chub (*Semotilus atromaculatus*), fantail darter (*Etheostoma flabellare*), golden redhorse (*Moxostoma erythrurum*), green sunfish (*Lepomis cyanellus*), johnny darter (*Etheostoma nigrum*), largemouth bass (*Micropterus salmoides*), northern studfish (*Fundulus catenatus*), orangethroat darter, red shiner, redfin shiner, sand shiner (*Notropis* *ludibundus*), slender madtom (*Noturus exilis*), and central stoneroller were all found during each sampling period in at least one location.

Ten species which include black bullhead (*Ameiurus melas*), black crappie (*Pomoxis nigromaculatus*), black redhorse, channel catfish (*Ictalurus punctatus*), common carp, fathead minnow (*Pimephales promelas*), logperch (*Percina caprodes)*, ozark minnow (*Notropis nubilus*), rainbow darter (*Etheostoma caeruleum*), and white crappie (*Pomoxis annularis*) were only found during the 2001 sampling period in at least one location.

Two species, which include the blackstripe topminnow (*Fundulus olivaceus*) and the white sucker (*Catastomus commersoni*) were only found during the 1962 and 2001 sampling periods.

Four species, including the gizzard shad (*Dorosoma cepedianum*), longear sunfish (*Lepomis megalotis*), smallmouth bass (*Micropterus dolomieu*), and the yellow bullhead (*Ameiurus natalis*) were only found during the 1995 and 2001 sampling periods.

3.1.8.5 Spatial Distribution

Gizzard shad and smallmouth bass were only identified at Hepperman Road and sites further downstream. Golden redhorse, largemouth bass, and sand shiner were not found upstream of location #5. Rainbow darter were only found at Wright City Park and Hwy T, both upstream locations.

Other species exhibited more uniform distribution over the sampling locations.

3.1.8.6 Trend Analysis

River Mile 26.6 to 27

Pflieger #4 sampled in 1962, location #4 sampled in 1995, and Wilmer Road sampled in 2001 are located within 0.4 miles of one another. Due to the close proximity, trends can be examined for this location over time.

Eleven species (bluntnose minnow, golden redhorse, green sunfish, johnny darter, northern studfish, orangethroat darter, red shiner, redfin shiner, sand shiner, slender madtorn, and central stoneroller) were found during all three of the sampling periods at this location. Numbers of bluntnose minnow, golden redhorse, green sunfish, orangethroat darter, slender madtorn, and central stoneroller increased over time.

Two species (blackstripe topminnow and whitesucker) were only found in 1962 at this location. Three species (longear sunfish, smallmouth bass, and yellow bullhead) were not found in 1962, but were located in both 1995 and 2001.

Four species (black crappie, common carp, gizzard shad, and logperch) were only found in the 2001 sampling period, when only one individual of each species was captured.

Three species (bigmouth shiner, creek chub, and largemouth bass) were captured in both 1962 and 1995, but were not captured in 2001 at this location.

Bluegill and fantail darter were not captured in 1995, but were located in both 1962 and 2001 at this location, with two individuals of each species located during each time period they were found.

River Mile 22.6 and 22.7
Location #3, located at river mile 22.7 sampled in 1995, and Duello located at river mile 22.6 and sampled in 2001 may be examined for trends over time.

Species found during both sampling periods, but in greater numbers in 2001 include: bluegill, bluntnose minnow, gizzard shad, golden redhorse, green sunfish, largemouth bass, longear sunfish, orangethroat darter, red shiner, redfin shiner, sand shiner, central stoneroller, and slender madtorn. The type of fishing method may have played a significant roll in the number of individuals captured in the case of bluegill, golden redhorse, longear sunfish, and central stoneroller. For these species, if only those individuals captured by seining in 2001 are counted, then the 1995 and 2001 numbers of individuals captured are more nearly equal.

Three largemouth bass were captured using seining in 1995, and five were captured in 2001 using electrofishing. No largemouth bass were seined in 2001.

Two green sunfish were captured using seining in 1995, and 14 were captured in 2001 using electrofishing. No green sunfish were seined in 2001.

Species found during both sampling periods, but in greater numbers in 1995 include creek chub and fantail darter. Two fantail darters were captured using seining in 1994, and one was captured in 2001 using electrofishing. No fantail darter was seined in 2001.

Eleven species (black crappie, blackstripe topminnow, channel catfish, common carp, fathead minnow, johnny darter, logperch, northern studfish, ozark minnow, white crappie, and yellow bullhead) were found only during 2001. Of these, channel catfish, common carp, logperch, ozark minnow, and yellow bullhead were captured by electrofishing only, and not captured in 2001 using seining.

3.1.8.7 Site Conditions and Descriptions

The 2001 survey also included general descriptions of stream habitat.

Wright City Park
The streambed at this location is primarily sand, coarse and fine gravel, with some cobbles in few areas. The types of fish cover were not surveyed at this location.

Archer Road
The streambed at this location varied from sand to coarse and fine gravel and cobbles, and in some areas is smooth bedrock.

Types of fish cover that are present include primarily overhanging vegetation, boulders, and some undercut banks. Very isolated areas include macrophytes, brushy debris, and artificial structure.

Highway T
The streambed at this location is primarily cobbles with some fine and coarse gravel and sand. Types of fish cover that are present include some brushy and woody debris, and some overhanging banks. Overall fish cover was not present to a great degree.

Hepperman Road
The streambed at this location is primarily fine and coarse gravel with some sand. Also present in isolated locations is silt and clay. Types of fish cover that are present include macrophytes, overhanging vegetation, undercut banks, and some boulders.

Wilmer Road
The streambed at this location is widely varied from sand, silt, and clay to smooth and rough bedrock to fine and coarse gravel. Types of fish cover that are present include a few boulders, some bank undercutting, and a small amount of macrophytes.

Duello Road
The streambed at this location varies from sand to fine and coarse gravel to cobbles. Some silt and clay is also present. Types of fish cover that are present include some undercut banks and brushy and woody debris.

3.1.8.8 North Fork Cuivre River Fish Data Comparison

The MDC also conducted the survey in 2001 at the North Fork Cuivre River on July 10 and August 30. Species were electro-fished and seined at the Hwy 161 bridge. On July 10, 713 individuals of 23 species were collected at the site, and on August 30, 585 individuals of 27 species were collected at the site. These results in an average of 25 species and 649 individuals collected at the North Fork Cuivre River during 2001, which is much greater than the Peruque Creek sites which averaged 18 species and 343 individuals. Only the Wilmer Road and Duello Road sites had comparable or greater numbers of individual fish. Species richness typically improves with increasing stream orders, i.e. the number of fish species increases in a downstream fashion.

The survey also included the Index of Biological Integrity (IBI) scores for each of the sites sampled on Peruque Creek and on the North Fork Cuivre River. The Index of Biotic Integrity is used to compare the similarity of a stream (or sampling location) with a reference condition. The North Fork Cuivre River was used as a reference stream for Peruque Creek. The total IBI scores are detailed in **Table 3-15**.

Table 3-15
Total IBI Scores from Peruque Creek and North Fork Cuivre River Sites Sampled During 2001

Site	Total IBI Score
North Fork Cuivre River	
Hwy 161 - 7/10/01	86
Hwy 161 - 8/30/01	86
Average	**86**
Peruque Creek	
Wright City	65
Archer Road	59
Hwy T	64
Hepperman Road	64
Wilmer Road	77
Duello Road	85
Average	**69**

Highway 161 sampling location on the North Fork Cuivre River is comparable in location in watershed size to the Wilmer Road and Duello Road sampling locations on Peruque Creek. Therefore, it is reasonable to compare the IBI scores for these sites. Table 3-15 shows that the IBI scores for these sampling locations are similar, indicating that the fish community in Peruque Creek is similar to another stream that is less impacted. However the species richness at Duello Road maybe greater due to the influence from Lake Saint Louis, which can backflow to this site during high water levels.

3.1.9 Soils Data

Soil survey data is available in hard copy from the NRCS, or in GIS from the State Soil Geographic (STATSGO) Database. Due to the nature of the models, the STATSGO data will be used. The STATSGO data, created by the USDA-NRCS Soil Survey Division, are aggregated soil surveys for GIS use published for Missouri in 1994. The STATSGO shapefiles were downloaded by CDM from the EPA BASINS website. STATSGO data are presented as map units of soils in which each map has a unique code linking it to attribute tables listing percentages of soil types within a map unit, soil layer depths, hydrologic soil groups, and soil texture among other soil properties.

The soils adjacent to and within the Peruque Creek streambed are divided by their geographic locations within the vicinity of Peruque Creek. The adjacent soil locations consist of the far western portion of the watershed, west-central portion, east-central portion and easternmost portion of the watershed. For the soil types located within the streambed, Peruque Creek is divided into two locations- the western and eastern portions. The description of the soil in these locations are in the sections below. The soil data was taken from the United States Department of Agriculture (USDA) – Soil Conservation Service Soil Surveys (SCS) of St. Charles County, Missouri (USDAb, 1982) and Montgomery and Warren Counties, Missouri (USDAa, 1978).

3.1.9.1 Soils Adjacent to Peruque Creek

Far Western Portion of the Watershed, near the Headwaters in Warren County

The soils in the western portion of the watershed are nearly level (0- to 3 percent slope), gently sloping (3- to 8 percent slope) to moderately sloping (8- to 15 percent slope). This is mainly due to the location of the soil on crests of ridges and long, gentle side slopes. The internal drainage characteristics of the soils range from somewhat poorly drained, moderately well drained, and poorly drained. The permeability of the soils (ease at which liquids, gasses and plant roots penetrate or pass through a layer of soil) range from moderately slow to slow. The internal drainage, permeability, slope, and other soil characteristics are major factors in determining the flow of water across the soil surface (surface runoff). The surface runoff for the soil is classified as slow to medium to rapid. There are some areas where the soil has been severely eroded and other areas where further erosion is of critical concern.

West-Central Portion of the Watershed from Warren County to Lake St. Louis in St. Charles County

Nearly the same soil types that can be found in the far western region of the watershed are also found in the west-central region. The soils in this region are gently and moderately sloping. The internal drainage of the soil range from well-drained and somewhat poorly drained. The permeability of the soil ranges from slow to moderate. The surface runoff ranges from medium to rapid, and there are portions where the soil is severely eroded.

East-Central Portion of the Watershed from Lake St. Louis to O'Fallon

The predominant soil located along the northern rim of Lake St. Louis consists of gently to moderately sloping urban land. The internal drainage is classified as well-drained to moderately well-drained. The permeability is moderately slow for these urban areas; however, there are streets, parking lots and buildings that obscure or alter the soils so that classification is not practical. The urban land can also be found in few areas adjacent to Peruque Creek, tributaries of Peruque Creek and within O'Fallon. Soils located in the east-central portion of the watershed (not urban soils) consist of nearly level to very steep slopes (over 35 percent slope). The internal drainage ranges from well-drained to moderately well-drained. The permeability is moderate to moderately slow. The surface runoff ranges from medium to rapid, and erosion control is a major concern.

East Portion of the Watershed, at the Mouth in St. Charles County

The main soil types in this region are nearly level alluvial (materials deposited by running water) flood plains found along rivers and stream branches. These soils are located within the Mississippi River floodplain and are subject to occasional flooding. The internal drainage ranges from poorly drained to well-drained. Permeability ranges from very slow to moderate. The runoff is classified as slow.

3.1.9.2 Soils within the Peruque Creek Streambed

Western Portion of the Watershed

The soils contained within the Peruque Creek streambed in the western region have slopes that are moderately sloping to steep (25- to 35 percent slope). The internal drainage classification ranges from poorly drained to moderately well-drained. The permeability is slow to moderate. Surface runoff ranges from slow to rapid. There are some areas where the soil has been severely eroded and other areas where further erosion is of critical concern.

Eastern Portion of the Watershed

The soils located within the streambed near the Mississippi River Floodplain are nearly level. The same soils types located adjacent to Peruque Creek are also mainly found within the streambed in the eastern region. Therefore, nearly the same characteristics and classifications apply. The internal drainage of the soil is somewhat poorly drained to well-drained. Permeability ranges from very slow to moderate. The runoff is classified as slow.

3.1.10 MDNR Biological Assessment Report

The Missouri Department of Natural Resources (MDNR) prepared its Biological Assessment Report for the Peruque Creek Watershed in 2003 (MDNR, June 2003). The report compares a nearby drainage area, the North Fork Cuivre River, with Peruque Creek to determine whether environmental factors such as development and urbanization would differentiate Peruque Creek from rural streams, such as the North Fork Cuivre River. The two watersheds are of similar size and are located near each other.

Macroinvertebrate sampling was conducted in March 2002 and September 2002. MDNR standardized sample analysis procedures were used for the macroinvertebrate samples to determine the Stream Condition Index (SCI). The macroinvertebrate data was compared to reaches where BMPs were being used and reaches where poor land practices were in place; they were compared to the North Fork Cuivre River samples; and both watersheds were compared to reference streams with the same ecological drainage unit (EDU) and watershed size classification.

Water quality samples were collected at 6 stations on Peruque Creek and 2 stations on the North Fork Cuivre River. Stream velocity and habitat characteristics were also measured at each station. Fecal coliform was analyzed at three stations on Peruque Creek and two stations on the North Fork Cuivre River. The results of these analyses were discussed in Sections 3.1.4 and 3.1.6. Instream deposits of fine sediments were also estimated at each macroinvertebrate station. These results, as well as the water quality sampling results, can be referenced in more detail in **Appendix B**.

Four of the six stations surveyed for macroinvertebrates had adjacent land uses consistent with BMPs and the remaining two stations had poor land uses impacted by property development (Hepperman Road and Hwy T stations). A SCI score between

20-16 is full supporting, between 14-10 are partially supporting, and 8-4 are considered non-supporting. The results are listed in Table 3-16.

Table 3-16
SCI Scores for Peruque Creek and North Fork Cuivre River Sampling Sites
Spring 2002 and Fall 2002

Site	SCI	Support
Peruque Creek #6 Ruge Park - Spring	12	Partial
Peruque Creek #6 Ruge Park - Fall	12	Partial
Peruque Creek #5 Stringtown Road Bridge - Spring	12	Partial
Peruque Creek #5 Stringtown Road Bridge - Fall	16	Full
Peruque Creek #4 State Road T - Spring	10	Partial
Peruque Creek #4 State Road T - Fall	16	Full
Peruque Creek #3 Hepperman Road - Spring	14	Partial
Peruque Creek #3 Hepperman Road - Fall	16	Full
Peruque Creek #2 Wilmer Road - Spring	18	Full
Peruque Creek #2 Wilmer Road - Fall	18	Full
Peruque Creek #1 Duello Road - Spring	18	Full
Peruque Creek #1 Duello Road - Fall	18	Full
N. Fork Cuivre #2 Highway 161 - Spring	14	Partial
N. Fork Cuivre #2 Highway 161 - Fall	14	Partial
N. Fork Cuivre #1 County Road 235 - Spring	12	Partial
N. Fork Cuivre #1 County Road 235 - Fall	16	Full

Using the standardized sample analysis procedure, MDNR concluded that during spring 2002 the macroinvertebrate community of Peruque Creek Stations 1 and 2 was fully supporting and partially supporting at the remaining upstream four sites. All Peruque Creek sample sites, with the exception of Station 6, were fully supporting during fall 2002.

Metrics for Peruque Creek and the North Fork Cuivre River were used to compare with biological criteria for reference sites. Peruque Creek and the North Fork Cuivre River were both second to third order streams. Both are small streams, which usually correspond to lower biodiversity and available habitat when compared to larger streams. The metrics are shown in **Table 3-17**. The biological criteria are shown in **Table 3-18**.

Table 3-17
Peruque Creek and North Fork Cuivre River Metric Values for Spring 2002 and Fall 2002
Macroinvertebrate Samples

Stream	TT	EPTT	BI	SDI
Peruque Creek Spring – All Sites	67 - 96	8 - 18	6.81 – 8.19	2.60 – 3.37
Peruque Creek Fall – All Sites	53 - 93	4 - 19	6.54 – 7.77	3.07 – 3.58
North Fork Cuivre River Spring – All Sites	73 - 84	12 - 13	6.69 – 7.17	2.83 – 2.87
North Fork Cuivre River Fall – All Sites	72 - 79	12 - 13	7.33 – 7.35	3.11 – 3.23

TT = Total Taxa, EPTT = Ephemeroptera, Plecoptera, and Trichoptera, BI = Biotic Index, and SDI = Shannon Diversity Index

Table 3-18
Biological Criteria for Warm Water Reference Streams in the Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Spring and Fall Seasons

	Spring			Fall		
Criteria	**Score=5**	**Score=3**	**Score=1**	**Score=5**	**Score=3**	**Score=1**
TT	>78	78-39	38-0	>76	76-38	37-0
EPTT	>17	17-8	7-0	>18	18-9	8-0
BI	<6.20	6.20-8.10	8.11-10	<6.34	6.34-8.17	8.18-10
SDI	>3.19	3.19-1.60	1.50-0	>3.00	3.00-1.50	1.40-0

TT = Total Taxa, EPTT = Ephemeroptera, Plecoptera, and Trichoptera, BI = Biotic Index, and SDI = Shannon Diversity Index

The metrics calculated for both sampling seasons for Peruque Creek and North Fork Cuivre River were comparable to the criteria reference metrics with few seasonal differences. During the Spring and Fall sampling seasons, total taxa was comparable for Peruque Creek and the North Fork Cuivre River. EPT taxa was also comparable for Peruque Creek and the North Fork Cuivre River during the Fall sampling season, however, only the upper reaches of Peruque Creek were similar to the North Fork Cuivre River samples in the spring, where the proportions of mayflies were much higher. Therefore, MDNR concluded that total taxa and EPT Taxa tended to increase in downstream Peruque Creek stations and that fall sample season trends among sites for these two metrics mirrored those from spring (MDNR, 2003). In addition, MDNR concluded that lack of available habitat and flow appeared to be dominant factors affecting benthic macroinvertebrates at both Peruque Creek and North Fork Cuivre River (MDNR, 2003).

3.2 2003 Water Quality Sampling

A sampling program was implemented for Peruque Creek and Lake Saint Louis from May to October 2003. The purposes of the sampling were to: (1) assess current water quality conditions, (2) compare these data to historic data and proposed USEPA lake nutrient criteria, (3) evaluate the influence of runoff events and baseflows on lake water quality and physical lake processes (i.e. stratification), and (4) provide data for calibration of the water quality model. The program and results are detailed below.

3.2.1 Peruque Creek Sampling

Sampling Program

Automatic sampling stations were installed at Point Prairie Road and Duello Road along Peruque Creek to collect water quality samples and flow data. The purposes of these sampling stations were to evaluate watershed loadings and potential relative contribution. Pressure transducers were utilized for stage data collection.

The automatic sampling stations for watershed loading estimates were operated from May 2003 to October 2003. Single, flow-weighted composite samples were collected from eight runoff events. Water quality analyses included total suspended solids (TSS), non-volatile suspended solids (NVSS), total phosphorus, total nitrogen, ammonia and nitrate+nitrite. Field blanks and duplicate samples were collected and analyzed to assess sampling quality assurance. Flow measurements were performed for development of the stage and discharge relationship (rating curve) for each site.

Monthly baseflow samples were collected at the aforementioned automatic sampling stations five times from May 29, 2003 to August 21, 2003. Water quality analyses included TSS, NVSS, total phosphorus, total nitrogen, ammonia and nitrate+nitrite. Field blanks and duplicate samples were collected and analyzed to assess sampling quality assurance. Flow measurements were performed during these discrete sampling events.

3.2.1.1 Data Review

Flow statistics measured at the sampling sites during runoff events are shown in **Table 3-19**. Average and maximum water quality conditions for baseflow and runoff samples are shown in **Table 3-20** and **Figures 3-30** to **3-31** for each site. Missouri Water Quality Standards were compared to the average conditions. No Missouri Water Quality Standard was exceeded during sampling. The difference between water quality in baseflow and runoff samples is apparent. For most parameters the runoff concentration is one to two orders of magnitude greater than baseflow concentration.

Table 3-19
Measured Flow at Sampling Sites During Runoff Events

Measured Flow During Runoff Events	Point Prairie Rd.	Duello Rd.
Average Flow (cfs)	118	91
Maximum Flow (cfs)	3,362	2,880
Minimum Flow (cfs)	0.03	0.02

3.2.2 Lake Saint Louis Sampling

3.2.2.1 Sampling Program

In-situ reservoir monitoring equipment (thermistors and pressure transducers) were installed within the reservoir to monitor water temperature at discrete depths and water level, respectively. These data provide valuable information related to lake stratification mechanisms as well as potential runoff volumes.

Water quality sampling was performed six times from May 8, 2003 to August 21, 2003. Water quality sampling occurred in three locations spatially and at three depths during stratified conditions and two depths during mixed conditions. Dissolved oxygen, temperature, and specific conductivity profiles and transparency measurements were performed at each sampling location. Water quality analyses included pH, TSS, NVSS, total phosphorus, total nitrogen, nitrate+nitrite, ammonia, soluble reactive phosphorus, and chlorophyll. Field blanks and duplicate samples were collected and analyzed to assess sampling quality assurance. Water temperature and level loggers were serviced and downloaded during each sampling event.

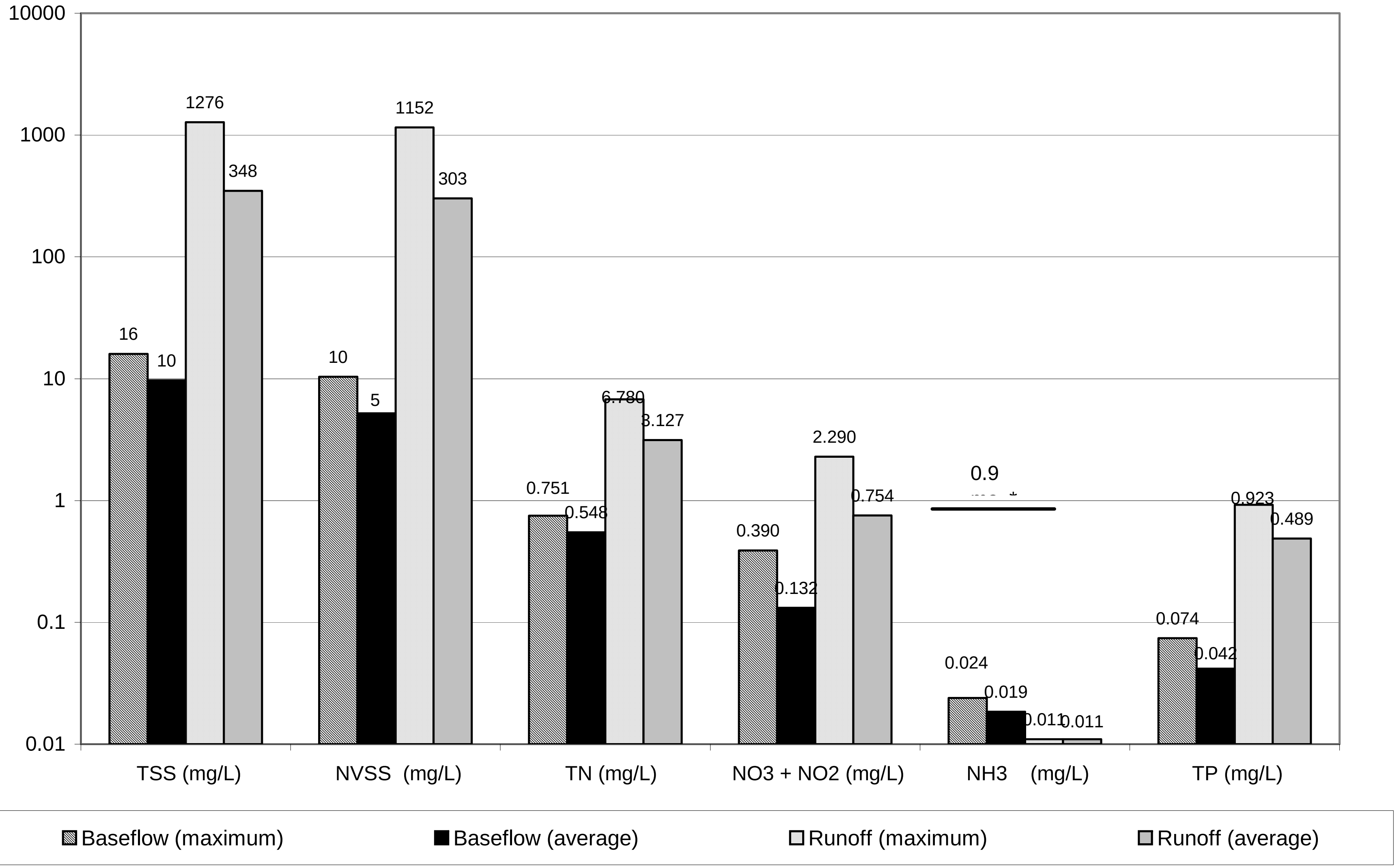
Table 3-20
2003 Stream Sampling Summary

Site	Type	No. of Samples	Sample Dates	Temp (°C)*	DO (mg/L)*	pH*	Cond (uS/cm)*	Average TSS (mg/L)	Average NVSS (mg/L)	Average TN (mg/L)	Average NO3 + NO2 (mg/L)	Average NH3 (mg/L)**	Average TP (mg/L)
Duello Road	Baseflow	5	5/30/03 - 8/21/03	25.38	4	7.95	487	10	5	0.548	0.132	0.019	0.042
Duello Road	Runoff	7	5/11/03 - 10/18/03	--	--	--	--	348	303	3.127	0.754	0.011	0.489
Point Prairie Road	Baseflow	5	5/29/03 - 8/21/03	26.37	3.02	8.03	430	4	ND	0.326	0.056	0.020	0.036
Point Prairie Road	Runoff	8	6/11/03 - 10/18/03	--	--	--	--	221	188	3.230	2.777	0.074	0.517
Missouri Water Quality Standards				32.2 (max)	5 (min)	6.5 - 9.0						0.900 (max)	

Notes:

*	Only the 8/21/03 baseflow samples included Temperature, DO, pH and Conductivity measurements.
**	The Missouri Water Quality Standard for ammonia can only be applied to the 8/21/03 baseflow samples because temperature and pH measurements were only taken on these samples and the standard is temperature and pH dependant.
Temp	Temperature
DO	Dissolved Oxygen
Cond	Electrical Conductivity
TSS	Total Suspended Solids
NVSS	Non-volatile Suspended Solids
TN	Total Nitrogen
NO3 + NO2	Nitrate and Nitrite
NH3	Ammonia
TP	Total Phosphorus

Figure 3-30 Duello Road Water Quality
2003 Baseflow and Runoff Sample Results

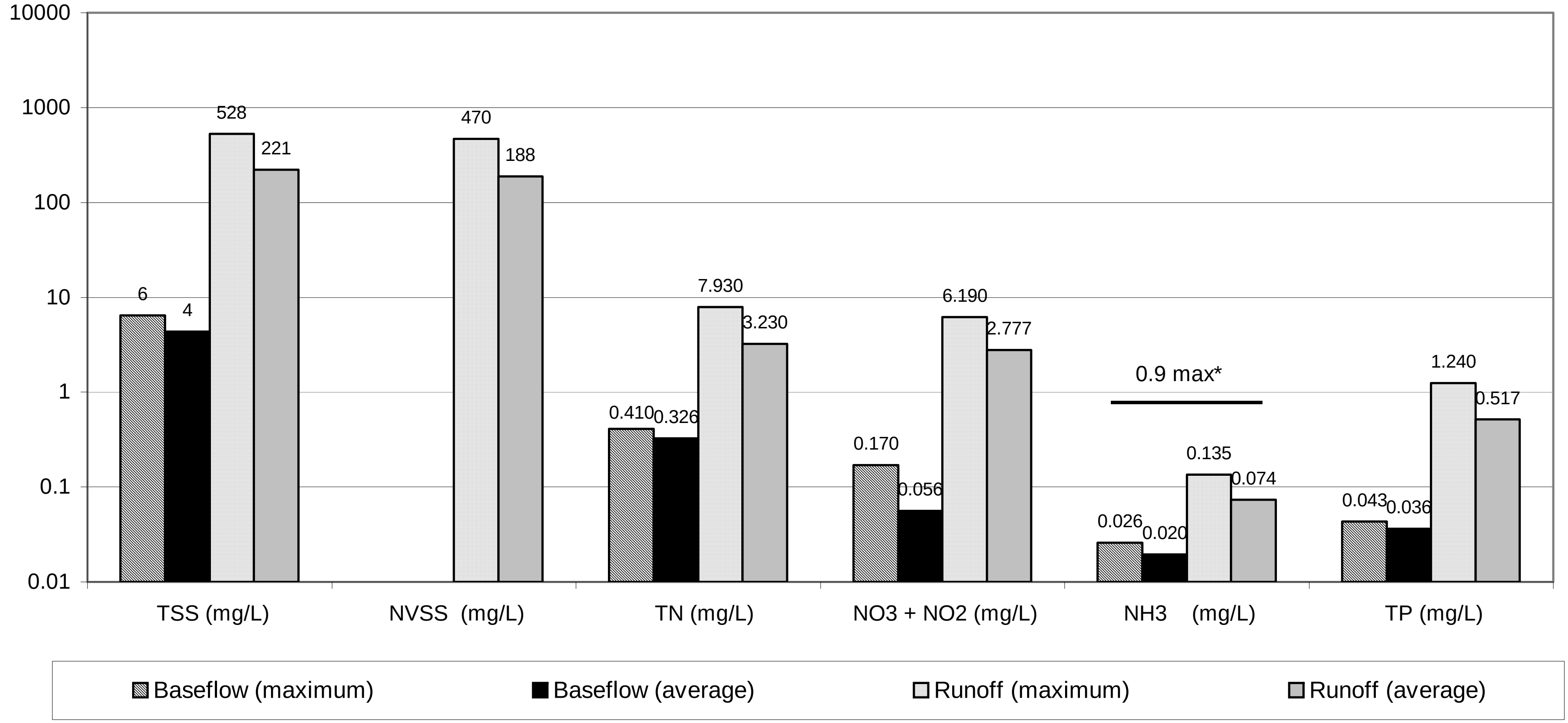


Notes:

* The Missouri Water Quality Standard for ammonia can only be applied to the 8/21/03 baseflow samples because temperature and pH measurements were only taken on these samples and the standard is temperature and pH dependant.

Temp - Temperature, DO - Dissolved Oxygen, Cond - Electrical Conductivity, TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TN - Total Nitrogen, NO3 + NO2 - Nitrate and Nitrite, NH3 - Ammonia, TP - Total Phosphorus

Figure 3-31 Point Prairie Road Water Quality
2003 Baseflow and Runoff Sample Results



Notes:
* The Missouri Water Quality Standard for ammonia can only be applied to the 8/21/03 baseflow samples because temperature and pH measurements were only taken on these samples and the standard is temperature and pH dependant.
Temp - Temperature, DO - Dissolved Oxygen, Cond - Electrical Conductivity, TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TN - Total Nitrogen, NO3 + NO2 - Nitrate and Nitrite, NH3 - Ammonia, TP - Total Phosphorus

3.2.2.2 Data Review

Water quality at each reservoir site is summarized on **Figures 3-32** to **3-34**. Average and maximum conditions are shown in comparison to Missouri Water Quality Standards. No Missouri Water Quality Standard was exceeded during the sampling period. The data is comparable with the historical data discussed in Section 3.1. The TN:TP ratio averaged 23:1, which indicates that the reservoir is phosphorus limited. The trophic state of the reservoir was also comparable to historic data. This data demonstrates that Lake Saint Louis is eutrophic to hypereutrophic (using the trophic state guidelines outlined in Tables 3-7 and 3-8) with an average total nitrogen of 1324 µg/L, average total phosphorus sampled at 57 µg/L and average chlorophyll-a sampled at 31 µg/L. Reservoir temperature and dissolved oxygen profiles at each site are shown in **Figures 3-35** to **3-37**. Because the data shows that Lake Saint Louis is polymictic (well mixed) and not thermally stratified, modeling of the reservoir is not possible.

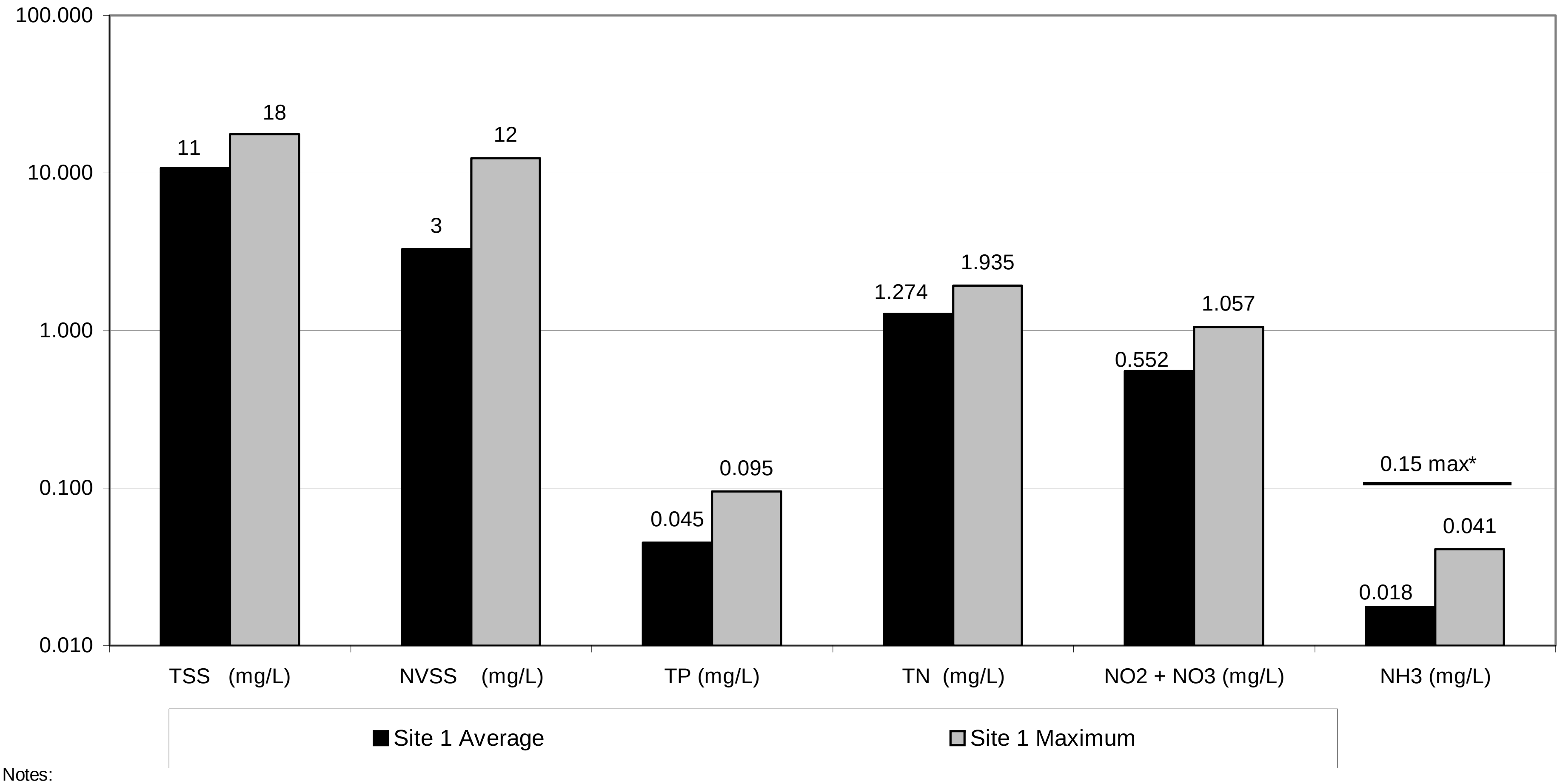
3.3 WMM Model

There is a potential for high non-volatile suspended solids and phosphorus loading from the Peruque Creek Watershed, especially during wet weather events. Due to the limited amount of historical data available, including limited flow data which would be necessary to calibrate more detailed models, a simple watershed model, the Watershed Management Model (WMM), was used to estimate phosphorus and nitrogen loadings from the Peruque Creek watershed. The WMM model is a simple watershed loading model that does not require extensive calibration to estimate loadings from the land surface due to runoff. To supplement the WMM model, sedimentation was assessed using literature values to qualify the source of sediment loading.

The model uses annual or seasonal total mean precipitation values (I) and subbasin physical characteristics (area [A] and mean runoff coefficient [C]) to calculate mean total runoff flow from a subbasin. Runoff coefficients are estimated within the model based on assumed pervious and impervious percentages for each landuse type and weighted according the percentage of each landuse type within the subbasin.

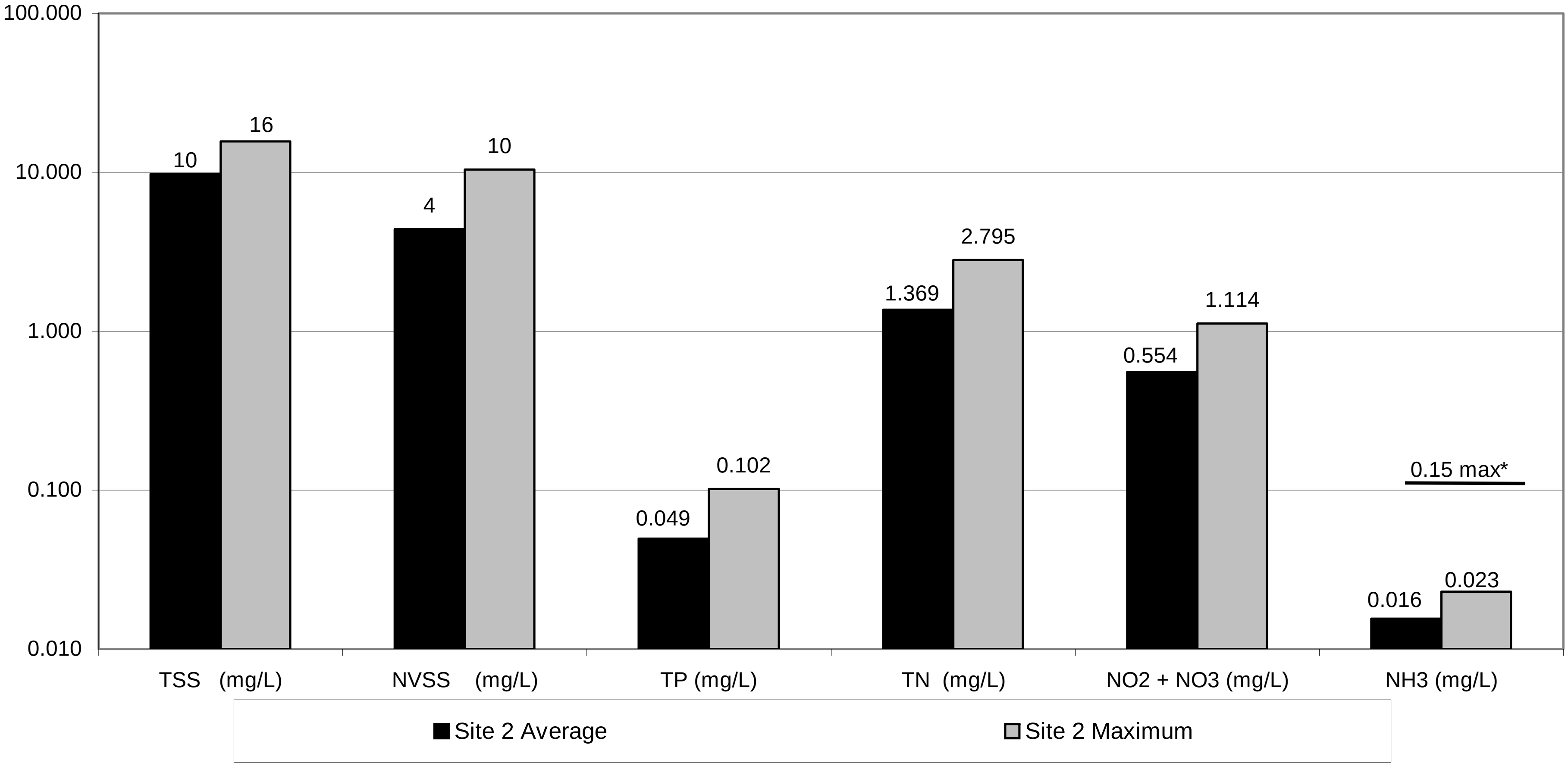
Concentrations of the target constituents associated with the runoff events are user-input as event mean concentrations (EMCs). The EMC is defined as the average of individual measurements of stormwater pollution loads divided by the storm runoff volume. These concentrations are commonly set according to site specific measurements or published values.

Figure 3-32 Lake Saint Louis Water Quality: Average and Maximum of Parameters at All Depths for All 2003 Site 1 (Near Dam) Samples (5/8/03 - 8/21/03)



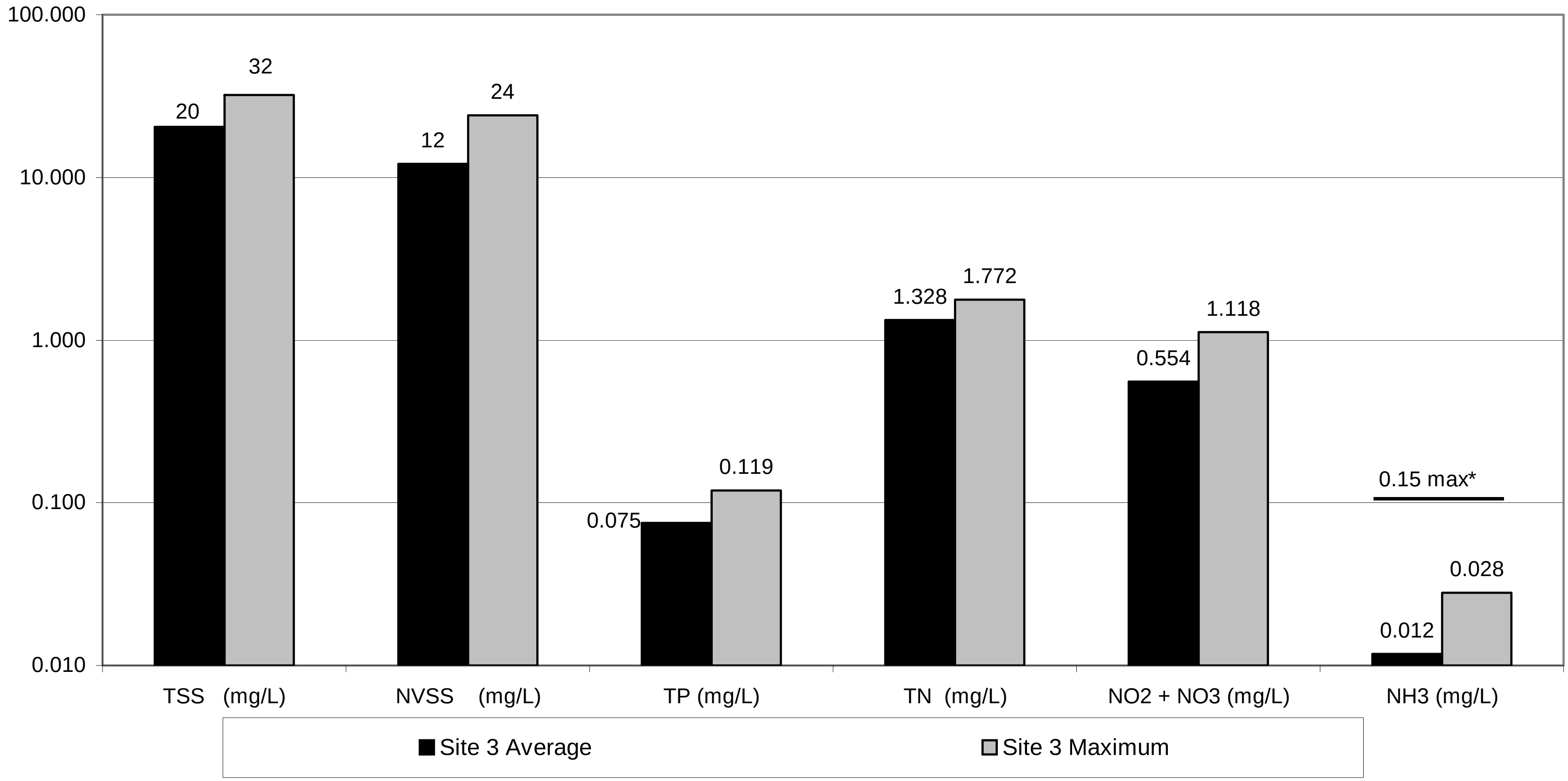
Notes:
TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus, TN - Total Nitrogen, NO3 + NO2 - Nitrate and Nitrite, NH3 - Ammonia
* The chronic ammonia (NH3) water quality standard is pH and temperature dependant for each sample. 0.15 mg/L represents the minimum standard for the pH and temperature range sampled

Figure 3-33 Lake Saint Louis Water Quality Average and Maximum of Parameters at All Depths for All 2003 Site 2 (Center) Samples (5/8/03 - 8/21/03)



Notes:
TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus, TN - Total Nitrogen, NO3 + NO2 - Nitrate and Nitrite, NH3 - Ammonia
* The chronic ammonia (NH3) water quality standard is pH and temperature dependant for each sample. 0.15 mg/L represents the minimum standard for the pH and temperature range sampled

Figure 3-34 Lake Saint Louis Water Quality - Average and Maximum Parameters of All Depths for All 2003 Site 3 (Near Hwy 40) Samples (5/8/03 - 8/21/03)



Notes:
TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus, TN - Total Nitrogen, NO3 + NO2 - Nitrate and Nitrite, NH3 - Ammonia, CHL a - Chlorophyll a
* The chronic ammonia (NH3) water quality standard is pH and temperature dependant for each sample. 0.15 mg/L represents the minimum standard for the pH and temperature range sampled

Figure 3-35 Lake Saint Louis Dissolved Oxygen and Temperature Profiles
Site 1 (Near Dam)

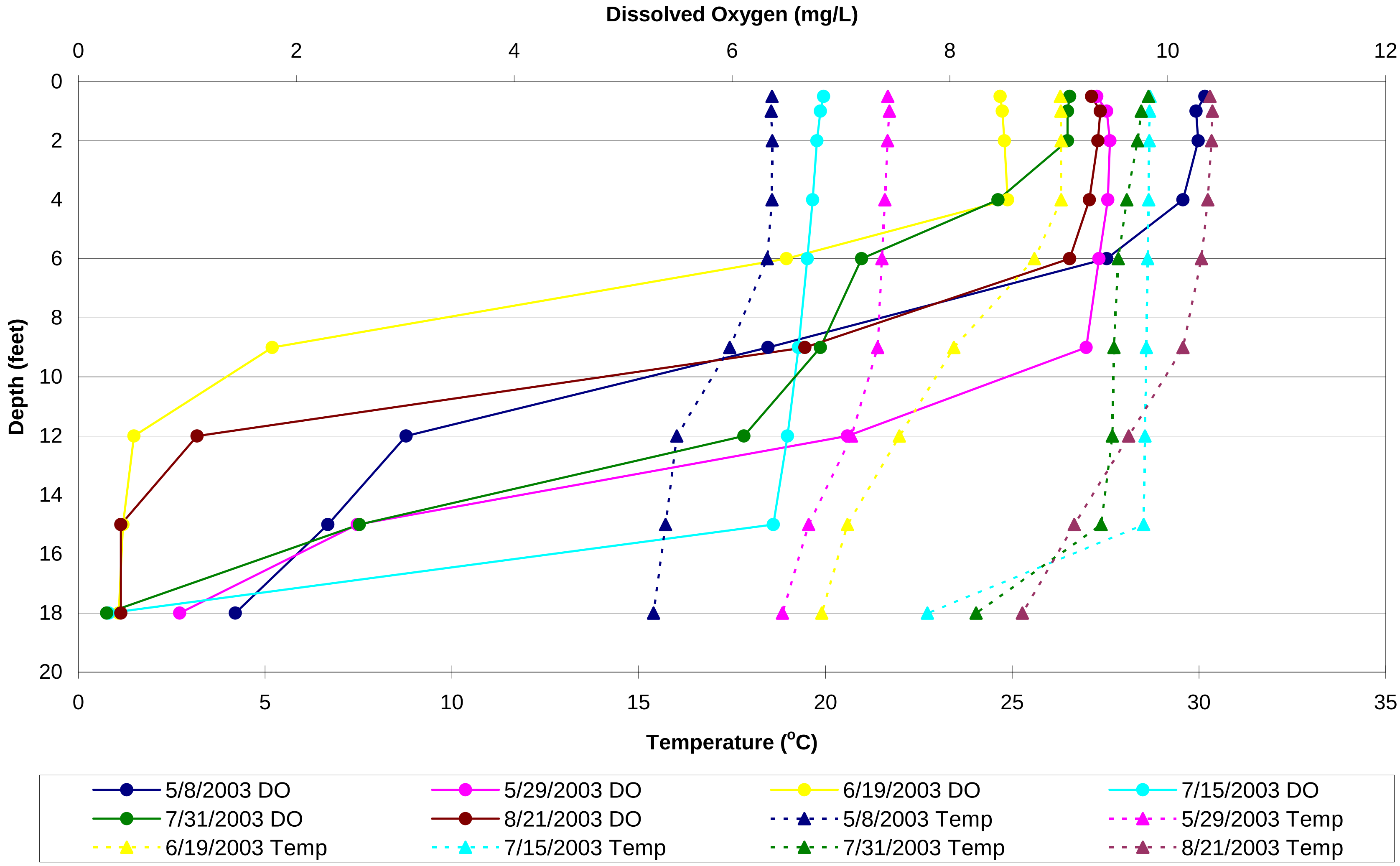


Figure 3-36 Lake Saint Louis Dissolved Oxygen and Temperature Profiles
Site 2 (Center)

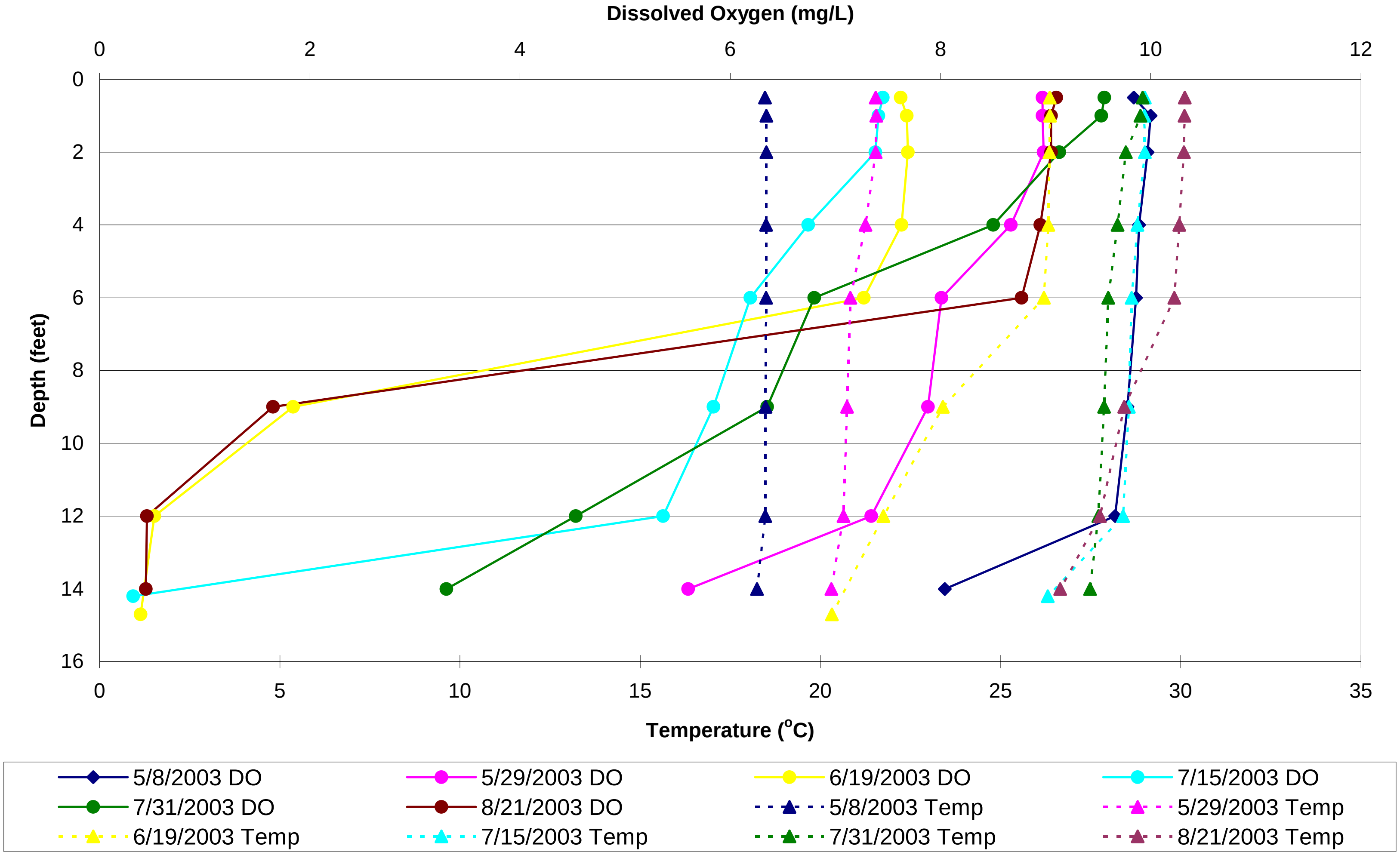
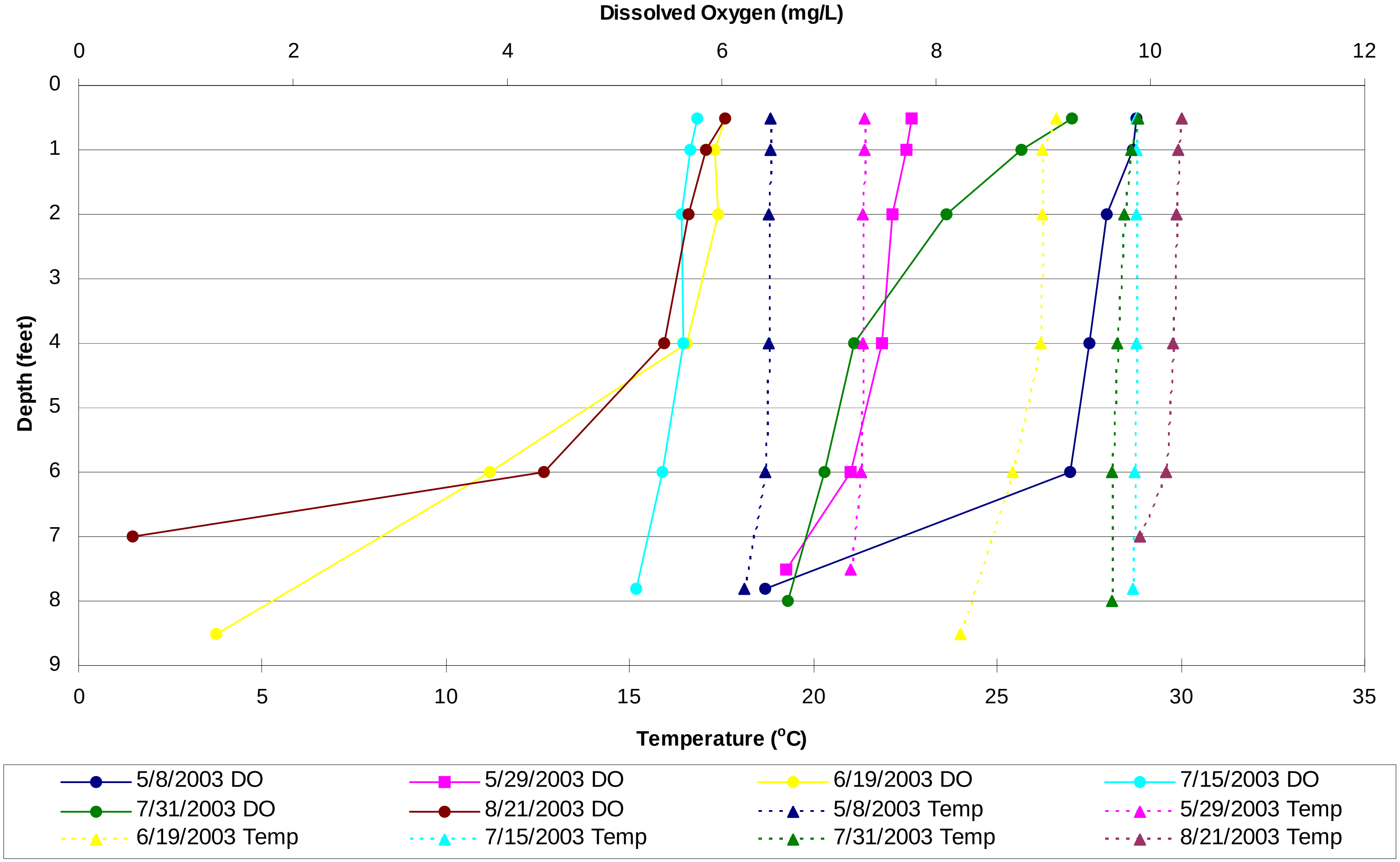


Figure 3-37 Lake Saint Louis Dissolved Oxygen and Temperature Profiles
Site 3 (Near Hwy 40/61)



WMM can simulate up to 4 nutrient (nitrogen and phosphorus) forms, up to 5 metals, plus TSS, TDS, COD, and BOD. The model also allows for point source loadings, individual sewage disposal system (ISDS) overflows, and in-channel attenuation of certain species. Data from 2003 sampling along Peruque Creek at Point Prairie Road and Duello Road was used to calibrate the model for the watershed upstream of Lake Saint Louis. The nutrients assessed were Nitrates (NO2 + NO3), Total Kjeldahl Nitrogen (TKN) and Total Phosphorus (TP).

3.3.1 Sub Basin Delineation

Sub basins were delineated based on topography, similar land use patterns and proximity to the 2003 sampling points. A map of the sub basins is included in **Figure 3-38**.

3.3.2 Model Inputs

3.3.2.1 Land Use and Impervious Area

Land use is shown in **Figure 3-38**. Land use acreages by sub basin are detailed in **Table 3-21**. Impervious area was input for each land use type based on reference values found in the *WMM User's Manual* (Wayne County, Michigan, September 1998). The values used are listed in **Table 3-22**.

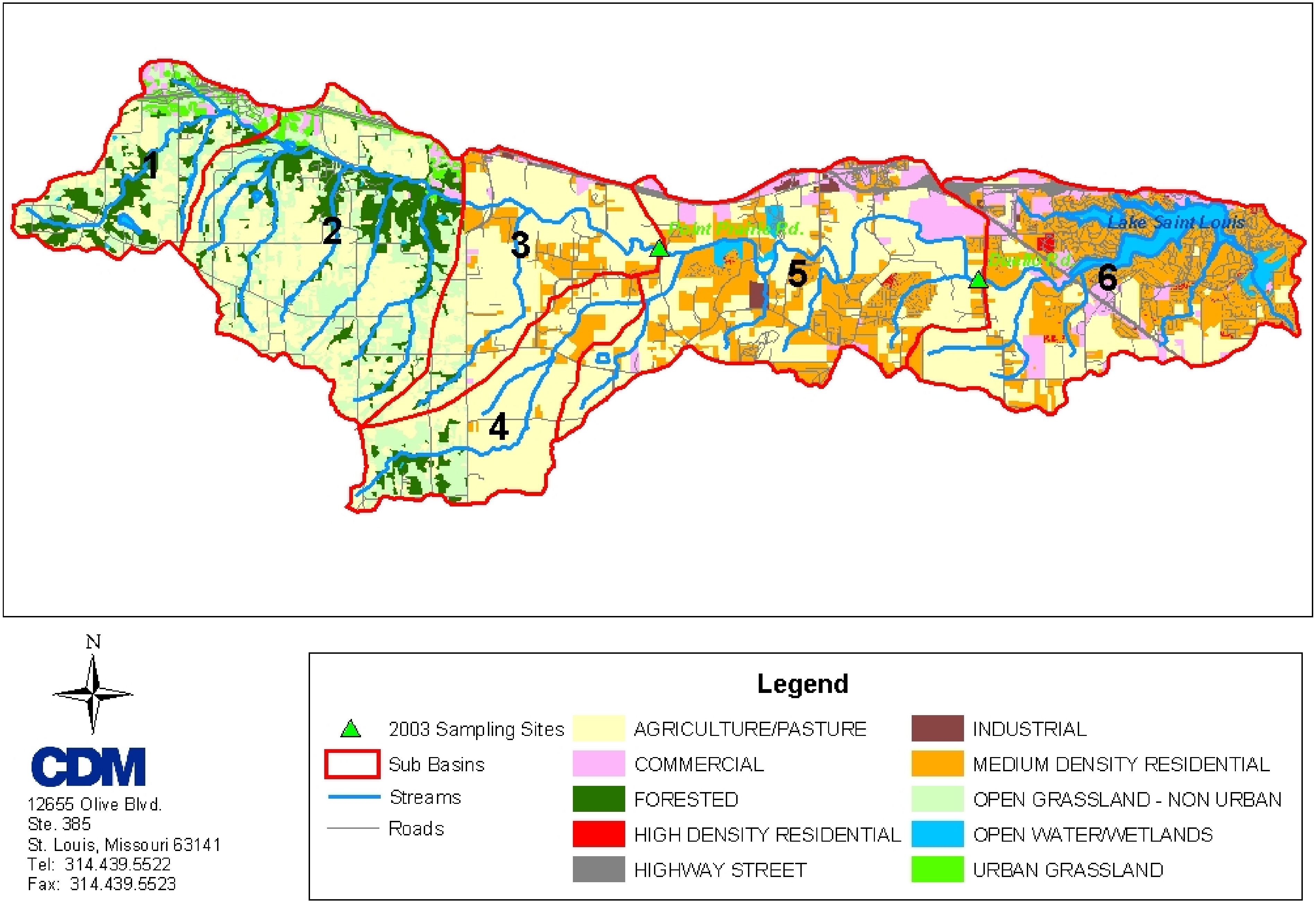
Table 3-21
Land Use Acreages for Sub Basins Upstream of Lake Saint Louis

Land Use Type	Sub Basin 1	Sub Basin 2	Sub Basin 3	Sub Basin 4	Sub Basin 5	Sub Basin 6	Upstream Lake Saint Louis
Forested	671	1,498	62	224	0	0	2,455
Agriculture/Pasture	1,067	3,568	3,105	2,475	4,041	2,094	16,350
Medium Density Residential	0	0	634	302	2,606	3,118	6,661
High Density Residential	0	0	0	0	15	76	90
Commercial	148	170	77	0	740	772	1,907
Industrial	0	0	14	0	118	13	146
Highway Street	0	0	146	23	514	839	1,523
Open Water/Wetlands	36	43	0	3	123	698	903
Open Grassland - Non Urban	992	2,405	237	549	0	0	4,183
Urban Grassland	269	260	3	0	0	0	532
Total	**3,183**	**7,943**	**4,280**	**3,577**	**8,157**	**7,610**	**34,749**

Note:
Land use was from two sources - Missouri Resources Assesment Partnership (1999, Land Use/Land Cover 1991-1993) for Warren County and St. Charles County Government (2004) for St. Charles County. The data from St. Charles County did not have land use categories for Forested, Open Grassland - Non Urban, or Urban Grassland

Figure 3-38

Peruque Creek Watershed Upstream of Lake Saint Louis



CDM
12655 Olive Blvd.
Ste. 385
St. Louis, Missouri 63141
Tel: 314.439.5522
Fax: 314.439.5523

Table 3-22
Event Mean Concentrations

Land Use Type	TP	TKN	NO2+NO3
Agriculture/Pasture	0.2	1.92	4.06
Commercial	0.27	1.46	1.02
Forested	0.11	0.78	1.02
High Density Residential	0.22	1.45	1.39
Highway Street	0.43	1.82	0.83
Industrial	0.32	1.91	1.28
Low Density Residential	0.25	2.53	1.25
Med Density Residential	0.52	2.53	1.1
Open Grass land - non urban	0.15	0.8	0.89
Urban Grassland	0.11	0.94	0.8
Urban Open	0.11	0.94	0.8
Open Water/Wetlands	0.05	0.91	0.59

Note:
Event mean concentrations were obtained from the WMM User's Manual (Wayne County, Michigan, September 1998) and PLOAD User's Manual (EPA, January 2001).

3.3.2.2 Precipitation

Precipitation was taken from the St. Louis Lambert International rain gauge from May 2003 to October 2003. The measured precipitation for this time period was 28.3 in/yr.

3.3.2.3 Event Mean Concentrations

EEMCs were obtained from the WMM User's Manual (Wayne County, Michigan, September 1998) and PLOAD User's Manual (EPA January 2001). These manuals contain literature values from the EPA's NURP database. The EMCs used in the WMM model are shown in **Table 3-23**.

Table 3-23
Percent Impervious by Land Use Type

Land Use Type	% Impervious
Forested	0.50%
Agriculture/Pasture	0.50%
Medium Density Residential	30%
High Density Residential	50%
Commercial	90%
Industrial	80%
Highway Street	90%
Open Water/Wetlands	100%
Open Grassland - Non Urban	0.50%
Urban Grassland	0.50%

Note:
Percent impervious values were obtained from the WMM User's Manual (Wayne County, Michigan, September 1998).

3.3.2.4 Uncertainty

Uncertainty was quantified for model runoff load calculations using a WMM feature that estimates 90th and 10th percentile, "high" and "low", EMC values based on user-input data standard deviations and an assumption of a normal distribution. These high and low EMCs are then used to generate a range of nutrient loadings that better characterize potential loads. Standard deviations for the model EMCs listed in Table 3-20 were again taken from EPA's NURP study database and vary by both constituent and landuse category.

Point source uncertainty quantification was described above with high and low point source concentrations combined with high and low EMCs to generate final ranges of total loadings.

3.3.3 Model Calibration

The model was calibrated in two steps. The first step was to perform a runoff quantity calibration to ensure the flow was adequately represented. Once the runoff quantity was calibrated, the second step was to calibrate the nutrient loads. The model was calibrated to data obtained from the 2003 sampling efforts at the Duello Road site. This site represents the downstream most sampling location above Lake St. Louis. Sampling was also performed during the same period at Point Prairie Road, but these data were not used in the calibration process.

3.3.3.1 Runoff Calibration

Flow data from the 2003 sampling effort were used as the benchmark to calibrate runoff quantity. Ten-minute flow data for the Duello Road sampling site from May 2003 to October 2003 was summed to obtain a total observed runoff of 11,200 acre feet. The impervious and pervious runoff coefficients were varied until an acceptable modeled runoff quantity was obtained (within 10 percent of observed flows). Final calibrated runoff coefficients are 1.0 for impervious land areas and 0.05 for pervious land areas. These values result in a modeled total runoff for the given time period of 10,200 acre feet (within 9 percent of the measured value). Modeled runoff quantities by sub basin for the calibration simulation are shown in **Table 3-24**.

Table 3-24
Modeled Runoff - Calibration Simulation
(May - October 2003)

Sub Basin	Runoff (acre-feet per year)
1	789
2	1,464
3	1,445
4	715
5	5,797
Total	10,210

3.3.3.2 Load Calibration

Concentration and flow data from the 2003 sampling effort were used as the benchmark to calibrate nutrient loads. Estimated average nutrient concentrations in runoff were multiplied by the measured seasonal runoff total (11,200 acre feet) at Duello Road to calculate the observed total runoff load for each nutrient for the given time period. These estimated observed loads are as follows:

- 17,500 lbs, NO2 + NO3;
- 55,800 lbs, TKN; and
- 12,800 lbs, TP.

As described above, WMM simulations incorporated data uncertainty by predicting a range of nutrient loads based on assumed high and low EMC values and point source concentrations. The model was therefore calibrated by varying the pollutant delivery ratio until all measured nutrient loads were within these modeled ranges. The calibrated delivery ratios are: 30 percent, 60 percent, 60 percent, 30 percent and 60 percent for sub basins 1 to 5, respectively. The resulting modeled ranges of pollutant loads are presented in **Table 3-25**.

Table 3-25
Modeled Nutrient Loads (lbs)
Calibration Simulation (May - October 2003)

Sub Basin	NO2 + NO3		TKN		TP	
	Low	High	Low	High	Low	High
1	1,100	2,931	1,228	2,957	147	544
2	3,325	8,856	2,590	6,494	339	1,255
3	2,987	8,695	3,694	10,658	568	2,104
4	1,564	4,453	1,487	4,530	195	722
5	7,913	24,153	14,485	41,028	2,245	8,316
Total	16,889	49,088	23,484	65,667	3,494	12,941

3.4 Sediment Loading

Using the land use upstream of Lake Saint Louis (Table 3-21), sediment loading by land use type was calculated using literature values.

3.4.1 Sedimentation Rates

Sedimentation rates for urban and construction land uses were found in the *Non-Point Source Management Guide* (MDNR 2000) for TSS. These rates are detailed in **Table 3-26**. A sedimentation rate for construction is included at 30 tons/acre year (MDNR 2000). Area of construction was estimated as percent of residential parcels receiving new building permits. The U.S. Census Bureau reported that there were 105, 414 residential parcels in St. Charles County in 2000. St. Charles County reported that 4,121 new building permits were issued in 2003. Therefore, 3.9 percent of the residential parcels were under construction in 2003. Applying 3.9 percent to the residential land use areas in Table 3-21 (medium and high density residential land uses) gives an estimate of 264 acres under construction in St. Charles County in 2003. Sedimentation rates for the agricultural/pasture land uses were estimated to be 3 tons/acre-year for this area by the St. Charles County Soil and Water Conservation District (SWCD, 2005).

Table 3-26
Sedimentation Estimates by Land Use Type Upstream of Lake Saint Louis

Land Use Type	Acres	Typical TSS Loadings (tons/acre-year)	Peruque Creek Sediment Loading (tons/year)	Percentage of Watershed Sediment Loading
Forested*	2,455	0.0015	4	0.005%
Agriculture/Pasture**	16,350	3	49,051	68.3%
Medium Density Residential*	6,401	0.095	608	0.8%
High Density Residential*	87	0.21	18	0.025%
Construction*	264	30	7,918	11.0%
Commercial*	1,907	0.5	954	1.3%
Industrial*	146	0.43	63	0.1%
Highway Street*	1,523	0.44	670	0.9%
Open Water/Wetlands*	903	0.0015	1	0.002%
Open Grassland - Non Urban**	4,183	3	12,548	17.5%
Urban Grassland*	532	0.0015	1	0.001%
Total	**34,749**		**112,901**	**100.0%**

Notes:
* Table 11, Page 306 of MDNR Non-Point Source Management Guide (2000)
** Average Annual Soil Erosion By Water, as directed from St. Charles County Soil and Water Conservation District (Cook, 2005)

3.4.2 Results

As shown in Table 3-26, it is estimated that the major portion of sedimentation is from non-urban land uses, such as agriculture/pasture (68.3 percent) and open grassland – non urban (17.5 percent). Approximately 59 percent of the watershed is agriculture/pasture and open grassland – non urban, so it is expected that most of the sedimentation would be attributed to these areas. However, because these land use categories are not separated, it is possible that this is a conservative estimate since pasture is vegetated and therefore likely to be less erosive than agricultural land. It is estimated that construction results in 11 percent of the sediment in the watershed. This is a conservative estimate because no data was available for construction in Warren County.

3.5 Predictive Modeling

The WMM nutrient model and sedimentation rate estimates were utilized to predict how nutrient and sediment loads would change upstream of Lake Saint Louis if the current trend of converting agricultural land to residential and commercial developments continue. Loads were predicted for 10, 15, 25, 50 and 75 percent conversion from agriculture/pasture land use to residential commercial land uses.

3.5.1 Runoff and Nutrient Model Predictions

Because the WMM model was calibrated for the 2003 sampling season, it was necessary to modify the model to generate the baseline average annual conditions in order to predict future runoff and nutrient loads. Therefore, the annual average rainfall of 36.1-inches/year from the Weldon Springs gauge was input into the calibrated WMM model to establish the baseline annual runoff and nutrient loads. Once baseline conditions were established, 10, 15, 25, 50, and 75 percent of the agriculture/pasture land use acreages upstream of Lake Saint Louis (Table 3-21) were allocated according to their current distribution percentage to medium density residential, high density residential and commercial land uses. The resulting runoff compared to the baseline runoff is shown in **Table 3-27**.

Table 3-27
Predicted Runoff when 10, 15, 25, 50, and 75 Percent of Existing Agriculture/Pasture Land Use Upstream of Lake Saint Louis is Converted to Residential/Commercial Land Uses

Scenario	Annual Runoff (acre-feet/yr)	Percent Change from Baseline
Base	13,010	--
10 Percent	15,222	17%
15 Percent	16,319	25%
25 Percent	18,530	42%
50 Percent	24,052	85%
75 Percent	29,568	127%

The model predicts that the decrease in agriculture/pasture land use, and subsequent increase in residential/commercial land uses will increase annual runoff from 13,010 acre feet/year at baseline conditions up to 29,568 acre feet/year at 75 percent conversion. This is due to the increase in impervious area which is higher in residential/commercial land uses.

The resulting nutrient loads compared to baseline nutrient loads are shown in **Table 3-28**. All nutrient loads increased with increasing land use conversion. Nitrates were predicted to increase up to a range of 53 percent to 62 percent from base line at 75 percent land use conversion. TKN was predicted to increase up to a range of 132 percent to 133 percent from base line at 75 percent land use conversion. TP was predicted to increase up to 142 percent from base line at 75 percent land use conversion. The increasing nutrient loads are a combination of increased runoff and increased TKN and TP concentrations for residential land uses.

Table 3-28
Predicated Nutrient Loads when 10, 15, 25, 50, and 75 Percent of Existing Agriculture/Pasture Land Upstream of Lake Saint Louis is Converted to Residential/Commercial

Scenario	Low Nutrient Load (lb/yr)	Percent Change from Baseline	High Nutrient Load (lb/yr)	Percent Change from Baseline
NO2 + NO3				
Baseline	21521	--	62551	--
10 Percent	23038	7%	67771	8%
15 Percent	23787	11%	70357	12%
25 Percent	25302	18%	75575	21%
50 Percent	29085	35%	88610	42%
75 Percent	32862	53%	101623	62%
TKN				
Baseline	29925	--	83677	--
10 Percent	35209	18%	98496	18%
15 Percent	37833	26%	105863	27%
25 Percent	43116	44%	120682	44%
50 Percent	56313	88%	157704	88%
75 Percent	69498	132%	194696	133%
TP				
Baseline	4451	--	16490	--
10 Percent	5298	19%	19627	19%
15 Percent	5718	28%	21185	28%
25 Percent	6565	47%	24322	47%
50 Percent	8679	95%	32157	95%
75 Percent	10792	142%	39986	142%

3.5.2 Sediment Loading Predictions

To predict future sediment loads, 10, 15, 25, 50, and 75 percent of the agriculture/ pasture land use acreages upstream of Lake Saint Louis (Table 3-26) were allocated according to their current distribution percentage to medium density residential, high density residential, construction and commercial land uses. In addition, since the percentage of residential construction was based on percentage of annual residential new building permits in St. Charles County, and realizing that sites could be under construction for several years and that some sites may be unaccounted for in Warren County, it was assumed that residential development could be higher than what was estimated, so sediment loading was predicted at construction of 3.9 percent, 5 percent, 10 percent and 15 percent of residential land uses. The resulting sediment loads compared to baseline conditions are shown in **Tables 3-29 to 3-32**.

Table 3-29
Predicted Sediment Loads when 10, 15, 25, 50 and 75 Percent of Existing Agriculture/Pasture Land Use Upstream of Lake Saint Louis is Converted to Residential/Commercial Land Use and Construction is 3.9% of Residential Parcels (264 Acres)

Land Use Type	Baseline		10 Percent		15 Percent		25 Percent		50 Percent		75 Percent	
	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load
Forested	4	0.005%	4	0.005%	4	0.006%	4	0.006%	4	0.007%	4	0.008%
Agriculture/Pasture	49,051	68.280%	44,145	64.448%	41,693	62.379%	36,788	57.917%	24,525	44.414%	12,263	26.134%
Medium Density Residential	608	0.846%	700	1.021%	745	1.115%	837	1.317%	1,066	1.930%	1,294	2.759%
High Density Residential	18	0.025%	20	0.029%	20	0.030%	21	0.034%	24	0.044%	27	0.058%
Construction	7,920	11.025%	9,078	13.253%	9,668	14.465%	10,847	17.078%	13,796	24.984%	16,745	35.688%
Commercial	954	1.327%	1,267	1.850%	1,424	2.130%	1,737	2.735%	2,521	4.565%	3,304	7.042%
Industrial	63	0.087%	63	0.092%	63	0.094%	63	0.099%	63	0.114%	63	0.134%
Highway Street	670	0.933%	670	0.978%	670	1.003%	670	1.055%	670	1.214%	670	1.428%
Open Water/Wetlands	1	0.002%	1	0.002%	1	0.002%	1	0.002%	1	0.002%	1	0.003%
Open Grassland - Non Urban	12,548	17.467%	12,549	18.321%	12,549	18.775%	12,549	19.757%	12,549	22.726%	12,549	26.745%
Urban Grassland	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.002%
Total	71,837	100%	68,497	100%	66,837	100%	63,518	100%	55,219	100%	46,921	100%

Table 3-30
Predicted Sediment Loads when 10, 15, 25, 50 and 75 Percent of Existing Agriculture/Pasture Land Use Upstream of Lake Saint Louis is Converted to Residential/Commercial Land Use and Construction is 5% of Residential Parcels (338 Acres)

Land Use Type	Baseline		10 Percent		15 Percent		25 Percent		50 Percent		75 Percent	
	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load
Forested	4	0.005%	4	0.005%	4	0.005%	4	0.006%	4	0.006%	4	0.007%
Agriculture/Pasture	49,050	66.251%	44,145	62.133%	41,693	59.941%	36,788	55.263%	24,525	41.499%	12,263	23.751%
Medium Density Residential	601	0.812%	692	0.973%	737	1.059%	827	1.243%	1,053	1.782%	1,280	2.478%
High Density Residential	18	0.024%	19	0.027%	20	0.029%	21	0.032%	24	0.041%	27	0.052%
Construction	10,127	13.678%	11,639	16.381%	12,395	17.820%	13,907	20.892%	17,688	29.929%	21,468	41.582%
Commercial	954	1.288%	1,267	1.783%	1,424	2.047%	1,737	2.609%	2,521	4.265%	3,304	6.400%
Industrial	63	0.085%	63	0.088%	63	0.090%	63	0.094%	63	0.106%	63	0.122%
Highway Street	670	0.905%	670	0.943%	670	0.963%	670	1.007%	670	1.134%	670	1.298%
Open Water/Wetlands	1	0.002%	1	0.002%	1	0.002%	1	0.002%	1	0.002%	1	0.003%
Open Grassland - Non Urban	12,549	16.950%	12,549	17.662%	12,549	18.042%	12,549	18.852%	12,549	21.234%	12,549	24.306%
Urban Grassland	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.002%
Total	74,037	100%	71,049	100%	69,555	100%	66,568	100%	59,098	100%	51,629	100%

Table 3-31
Predicted Sediment Loads when 10, 15, 25, 50 and 75 Percent of Existing Agriculture/Pasture Land Use Upstream of Lake Saint Louis is Converted to Residential/Commercial Land Use and Construction is 10% of Residential Parcels (675 Acres)

Land Use Type	Baseline		10 Percent		15 Percent		25 Percent		50 Percent		75 Percent	
	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load
Forested	4	0.004%	4	0.004%	4	0.004%	4	0.005%	4	0.005%	4	0.005%
Agriculture/Pasture	49,050	58.302%	44,145	53.412%	41,693	50.900%	36,788	45.739%	24,525	31.963%	12,263	16.791%
Medium Density Residential	570	0.677%	655	0.793%	698	0.852%	784	0.974%	998	1.301%	1,212	1.660%
High Density Residential	17	0.020%	18	0.022%	19	0.023%	20	0.025%	23	0.030%	25	0.035%
Construction	20,253	24.073%	23,277	28.164%	24,790	30.264%	27,814	34.582%	35,375	46.104%	42,936	58.794%
Commercial	954	1.133%	1,267	1.533%	1,424	1.738%	1,737	2.160%	2,521	3.285%	3,304	4.525%
Industrial	63	0.075%	63	0.076%	63	0.077%	63	0.078%	63	0.082%	63	0.086%
Highway Street	670	0.797%	670	0.811%	670	0.818%	670	0.833%	670	0.873%	670	0.918%
Open Water/Wetlands	1	0.002%	1	0.002%	1	0.002%	1	0.002%	1	0.002%	1	0.002%
Open Grassland - Non Urban	12,549	14.916%	12,549	15.183%	12,549	15.320%	12,549	15.602%	12,549	16.355%	12,549	17.184%
Urban Grassland	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%
Total	84,131	100%	82,651	100%	81,910	100%	80,430	100%	76,729	100%	73,028	100%

Table 3-32
Predicted Sediment Loads when 10, 15, 25, 50 and 75 Percent of Existing Agriculture/Pasture Land Use Upstream of Lake Saint Louis is Converted to Residential/Commercial Land Use and Construction is 15% of Residential Parcels (1,013 Acres)

Land Use Type	Baseline		10 Percent		15 Percent		25 Percent		50 Percent		75 Percent	
	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load	Sediment Load (tons/yr)	Contribution to Total Sediment Load
Forested	4	0.004%	4	0.004%	4	0.004%	4	0.004%	4	0.004%	4	0.004%
Agriculture/Pasture	49,050	52.056%	44,145	46.837%	41,693	44.229%	36,788	39.014%	24,525	25.991%	12,263	12.986%
Medium Density Residential	538	0.571%	619	0.656%	659	0.699%	740	0.785%	942	0.999%	1,145	1.212%
High Density Residential	16	0.017%	17	0.018%	18	0.019%	19	0.020%	21	0.023%	24	0.025%
Construction	30,380	32.242%	34,916	37.046%	37,184	39.447%	41,721	44.247%	53,063	56.234%	64,404	68.205%
Commercial	954	1.012%	1,267	1.344%	1,424	1.510%	1,737	1.842%	2,521	2.671%	3,304	3.499%
Industrial	63	0.067%	63	0.067%	63	0.067%	63	0.067%	63	0.067%	63	0.066%
Highway Street	670	0.711%	670	0.711%	670	0.711%	670	0.711%	670	0.710%	670	0.710%
Open Water/Wetlands	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%
Open Grassland - Non Urban	12,549	13.318%	12,549	13.314%	12,549	13.312%	12,549	13.309%	12,549	13.299%	12,549	13.290%
Urban Grassland	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%	1	0.001%
Total	94,225	100%	94,252	100%	94,265	100%	94,292	100%	94,360	100%	94,428	100%

Because agricultural land has a higher sedimentation rate than residential/ commercial land, and since there is a large area of agricultural land in the watershed, overall the sediment load is predicted to decrease with increasing conversion from agricultural land to residential/commercial development. However, because the agriculture and pasture land uses were combined, it is possible that the sediment load predicted from this land use type is conservative because it is based on erosion rates from agriculture land which is typically higher than erosion from pasture. The model does not take into consideration the increase in erosion rates from increased velocity as the amount of impervious areas increase in the watershed. Therefore, instream erosion will contribute more to the sediment load as the watershed is developed. Currently, instream erosion from high velocities, along with erosion from construction sites and agricultural land are contributing to heavy sediment loading to Lake Saint Louis and the creek during wet-weather events.

3.5.3 Point Sources

Point sources were not included in the nutrient and runoff model because point sources are part of the baseflow. However, because point sources contribute to the nutrient load in the stream, they are worth noting and are detailed in **Table 3-33**. Nutrient concentration data, contained in Table 3-12, for each significant point source upstream of Lake Saint Louis (Wright City, Foristell and Castlegate Estates) were obtained from 2002 MDNR sampling. A range of concentrations, representing the mean ± 1 standard deviation, were assumed for each constituent in the loading calculations performed here. The point source flow used was the average daily flow listed on the respective NPDES permits. Table 3-33 contains the flow and range of loads calculated for each point source.

Table 3-33
Point Source Characteristics Upstream Of Lake Saint Louis

Point Sources Flow (acre-ft/yr)		370
Nutrient	**Low Range Load (lb/yr)**	**High Range Load (lb/yr)**
NO2 + NO3	342	946
TKN	3,983	4,801
TP	1,240	2,146

Comparing the characteristics of the point sources detailed in Table 3-33 to that of total runoff in Tables 3-24 and 3-25 demonstrates that the point sources are insignificant when compared to total runoff.

3.6 Summary

3.6.1 Water Quality

Water quality samples were taken in Peruque Creek by MDC/MDNR in 2002, and by the Peruque Creek Watershed Study Project Team in 2003. Samples were taken at

Highway T, Hepperman Road and Point Prairie Road in 2002, and at Point Prairie Road and Duello Road in 2003. Results at Point Prairie Road were comparable for both data sets .

Of the MDC/MDNR sampling sites, ammonia concentration was constant at all three sites. Similar ammonia levels were measured at Point Prairie and Duello Road in 2003 during baseflow conditions. Even during runoff conditions, ammonia standards were not exceeded at either 2003 sampling site.

Nutrient criteria does not exist for this stream, however it is known that nutrient levels contribute to algal blooms in Lake Saint Louis. Therefore, TKN, nitrate, TN and TP were measured in 2002 and nitrate + nitrite, TN and TP were measured in 2003. All nutrients – TKN, nitrate, TN, TP, decreased from Hwy T downstream to Hepperman Road in 2002 In 2003, nitrate + nitrite increased, while TN and TP both decreased from Point Prairie Road downstream to Duello Road. The reduction in nutrient concentration further downstream may be due to adjacent land uses. High nutrient concentrations are generally associated with agricultural land use which decreases downstream where the watershed urbanizes. Concentrations of nutrients increased significantly during storm events, but even during these events, the trend of decreasing nutrient concentrations further downstream continued. All nutrient concentrations were lower at Duello Road than at Point Prairie Road.

TSS was sampled in 2002 and 2003. Baseflow TSS was low at all sites during both sampling periods. However, during storm events sampled in 2003, TSS increased by an average factor of 45 at both sites. TSS concentration nearly doubled from Point Prairie Road to Duello Road. The increase in sediment concentration further downstream may be due to adjacent land uses. The area between Point Prairie and Duello Road is experiencing rapid development. Higher sediment loads are generally associated with construction areas.

Increased flow during storm events is also significant. Average flow was measured at 118 cfs at Point Prairie Road and 91 cfs at Duello Road. The maximum flow measured at each site was 3362 cfs and 2880 cfs at Point Prairie Road and Duello Road, respectively. With higher concentrations of nutrients and sediment during storm events, the increased flows can have a significant impact on water quality in Lake Saint Louis and further downstream.

Both LMVP sampling data and 2003 Peruque Creek Watershed Study Project Team sampling data have indicated that Lake Saint Louis is phosphorus limited. Therefore, reducing phosphorus concentrations should lower algal concentration within the reservoir. During dry conditions, the clarity of the reservoir is dependent on algal biomass. If the current trend of converting agriculture/pasture land to residential/commercial land uses continue in the watershed, predictive modeling has shown that nutrient contributions may increase by 7% to 142%, respectively, if 10% to 75% of this land is converted. Runoff contributions may also increase by 17% to 127%, respectively, if 10% to 75% of this land is converted. Increased runoff is due to increased impervious area. In contrast, predictive modeling has shown that sediment loading may decrease because of less agriculture/pasture land. However, the modeling did not take into account in-stream erosion and sediment transport, which would most likely increase due to increased flow.

NPDES monitoring and watershed modeling have shown that point sources do not have a significant impact on the stream. Currently, all NPDES dischargers are in compliance with their permits and have had infrequent excursion from their permitted limits. Sampling has shown low dissolved oxygen near an upstream NPDES discharger, however further monitoring has indicated that this is most likely a naturally occurring condition in the upper reach of Peruque Creek.

High fecal coliform counts have been measured at all sites sampled on Lake Saint Louis by the LSLCA. However, because the geometric mean is below the criterion of 200 cfu/100 mL, the lake is in compliance with current standards.

3.6.2 Habitat and Biodiversity

MDC conducted a habitat survey during sampling of Peruque Creek in 2002. Habitat was generally good along most sites sampled. However, it was noted that fish cover was not present to a great degree at the Hwy T site.

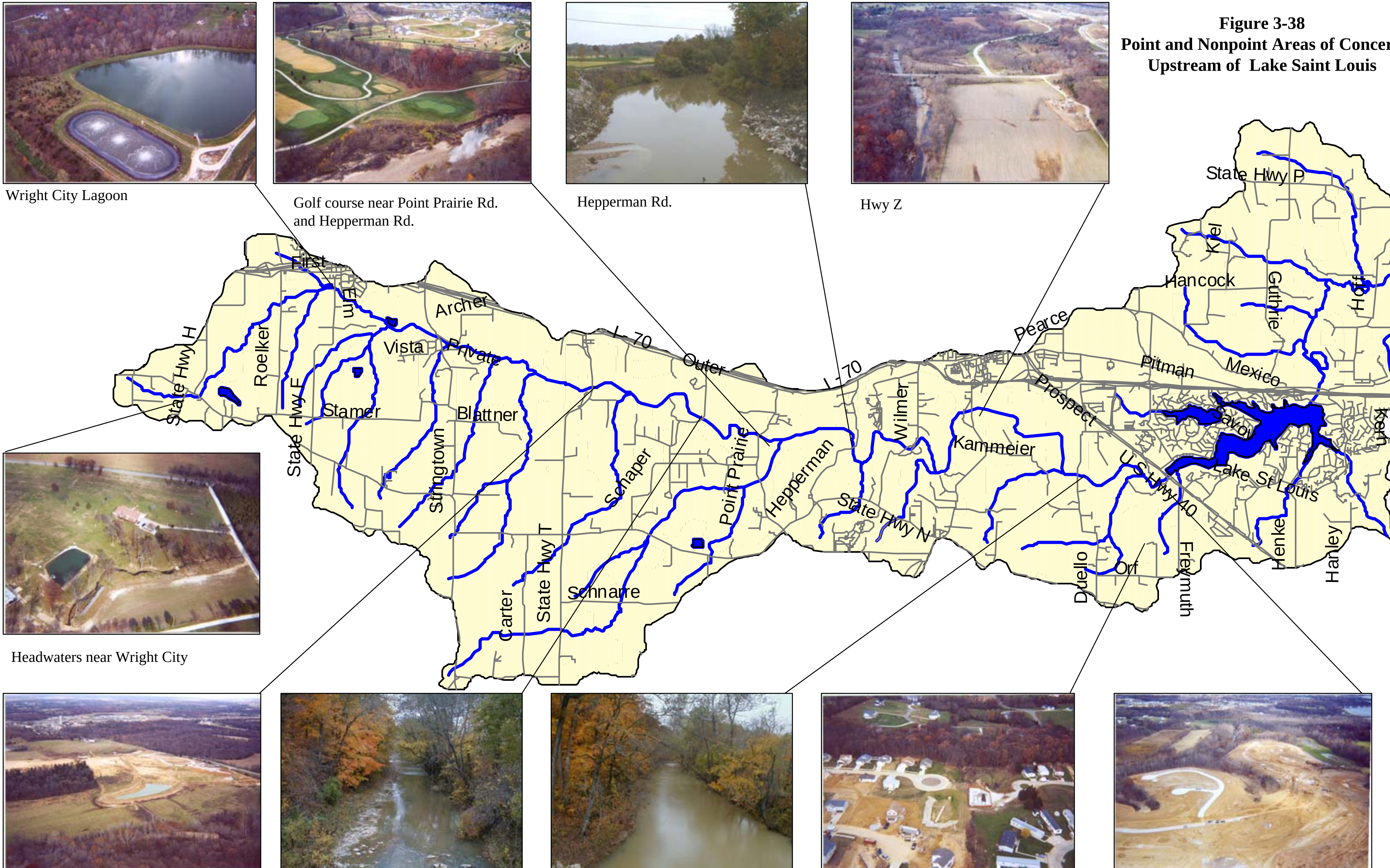
Compared to the reference site, the North Fork Cuivre River, Peruque Creek had fewer species of fish and total individuals. Total sampling along Peruque Creek included 18 species and 343 individuals, while 25 species and 649 individuals were collected along the North Fork Cuivre River. The sites immediately upstream of Lake Saint Louis had a wider variety of species than the sites further upstream. Greater diversity at these sites may be influenced by backwater from Lake Saint Louis.

During the macroinvertrebrate study of 2002, MDC noted that Hepperman Road and Hwy T had poor adjacent land uses impacted by property development. Ruge Park at Wright City had SCI scores indicating only partially supporting in spring and fall, while Hwy T and Hepperman Road were partially supporting in the spring but fully supporting in the fall. All other sites were fully supporting during spring and fall.

3.6.3 Areas of Concern

Several aerial assessments of the watershed have been performed in recent years. Flyovers were conducted in 1993 by the City of Lake Saint Louis, in 2000 by MDC, and in 2002 by the Peruque Creek Watershed Study Project Team. In addition, numerous field inspections were performed by the project team during the study period. A pictorial map of the watershed is included in Figure 3-39. Based upon these inspections, as well as the aforementioned water quality and habitat assessments, several areas warrant further monitoring. The following “areas of concern” are listed from upstream to downstream:

Figure 3-38
Point and Nonpoint Areas of Concern
Upstream of Lake Saint Louis



Wright City Lagoon

Golf course near Point Prairie Rd. and Hepperman Rd.

Hepperman Rd.

Hwy Z

Headwaters near Wright City

Hwy T

Schaper Rd.

Duello Rd.

Package Treatment Plant at Stone Meadows

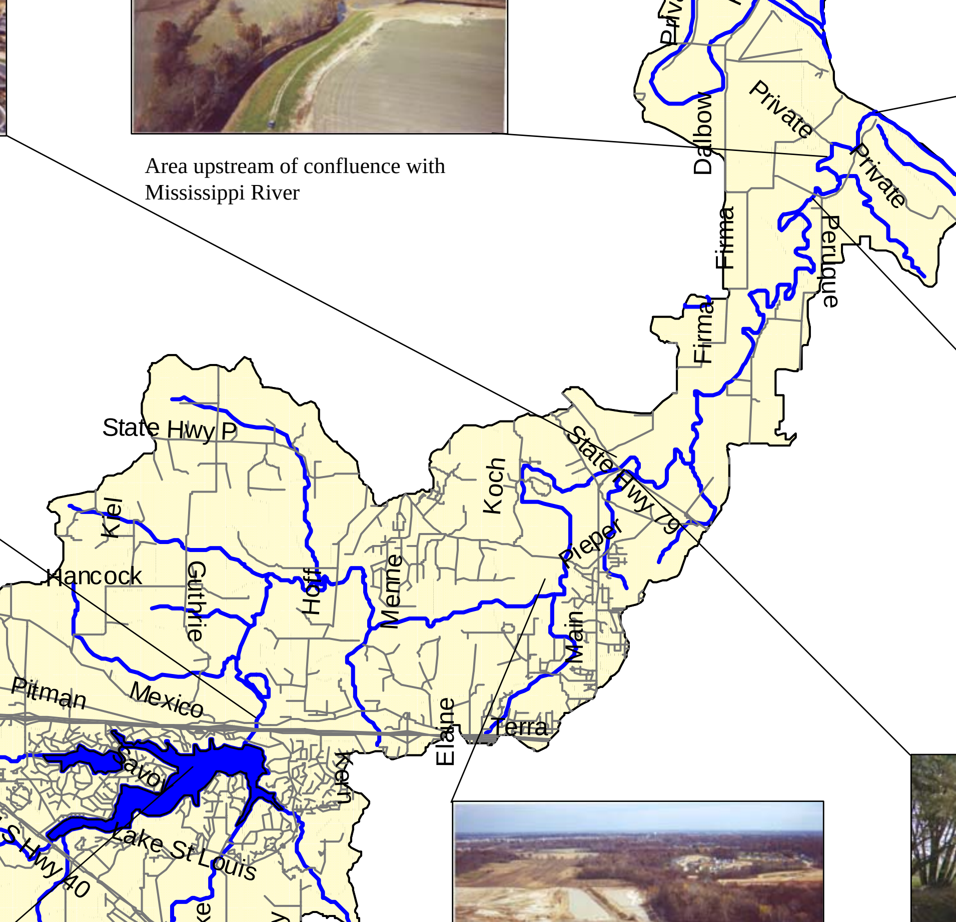
Near Lake Saint Louis

Figure 3-38 (Cont.)
Point and Nonpoint Source Areas of Concern
Downstream of Lake Saint Louis


O'Fallon WWTP


Area upstream of confluence with Mississippi River


Sewage Disposal Ponds north of I-70 and Lake Saint Louis Dam




Confluence with Mississippi River


Peruque Creek Rd.


Lake Saint Louis


Construction near Hwy P


Hwy 79

- Headwaters
  Concerns: Adjacent land uses, low dissolved oxygen concentration, erosion

Figure 3-40
Property adjacent to headwaters in October 2002

Figure 3-41
Headwaters in Summer 2002

- Stringtown Road
  Concern: Erosion

Figure 3-42
Erosion at Stringtown Road in October 2002

- Hwy T
  Concerns: Poor fish cover, adjacent land uses

Figure 3-43
Property development near Hwy T
October 2002

Figure 3-44
Peruque Creek at Hwy T
October 2002

- Point Prairie Road to Hepperman Road
  Concerns: Adjacent land use, property development, increased runoff to stream, erosion

Figure 3-45
Adjacent golf course between Point Prairie Road and Hepperman Road
October 2002

Figure 3-46
Storm pipe draining into Peruque Creek at Hepperman Road
October 2002

- Area near Hwy Z Road Crossing
  Concerns: Adjacent land uses, unmarked dam, site of old sewage disposal ponds, sedimentation

Figure 3-47
Old sewage disposal ponds at Hwy Z
October 2002

Figure 3-48
Sod farm and unmarked dam near Hwy Z
October 2002

- Duello Road
  Concerns: High flows, increased runoff to stream, sediment load, property development

Figure 3-49
Peruque Creek at Duello Road during storm event
June 2003

Figure 3-50
Peruque Creek at Duello Road during baseflow conditions
June 2004

- Lake Saint Louis
  Concerns: Low clarity, high sediment load, fecal coliform exceedances

Figure 3-51
Lake Saint Louis
October 2002

Figure 3-52
Lake Saint Louis Dam
October 2002

- North of I-70 Crossing
  Concern: Adjacent land uses

Figure 3-53
Sewage disposal ponds adjacent to Peruque Creek just north of I-70 crossing
October 2002

Section 4
Identification of Alternative Nonstructural Control Measures

4.1 Land Use Controls

Impervious cover directly influences urban streams by dramatically increasing surface runoff during storm events. The conversion of farmland, forests, and meadows to rooftops, roads, parking lots, and driveways creates a layer of impervious surface in the urban landscape.

Since impervious cover has such a strong influence on watershed quality, a watershed management plan should critically analyze the degree and location of future development and redevelopment that is expected to occur within a watershed. The basic goal is to apply land use planning techniques to redirect development, preserve sensitive areas, and maintain or reduce the impervious cover within a given subwatershed. This goal can be addressed by applying the following land use controls:

- Direct Regulatory Approaches for New Development
- Indirect Regulatory Approaches for New Development
- Regulatory Approaches for Restorative Redevelopment
- Land Acquisition to Maintain Open Areas and Buffer Zones
- Runoff Control Programs for Industrial and Commercial Sites
- Improvements to Current Site Plan Review Process

This section of the watershed management plan lists and explains potential land use control measures that *could* be considered for the Peruque Creek watershed. It is important to note that not all of the alternative management measures documented in this section have equal applicability to the specific conditions within the Peruque Creek watershed. The alternative measures have differing implementation costs and differing effectiveness in improving water and habitat quality. The alternative measures that are listed in this section are evaluated and screened in Section 6.1.

4.1.1 Direct Regulatory Approaches for New Development

Planning for new development is best conducted at the subwatershed scale, where it is recognized that stream quality is related to land use and consequently impervious cover. One of the goals of watershed planning is to shift development toward subwatersheds that can support a particular type of land use and/or density.

Most of the Peruque Creek watershed consists of agriculture, residential and commercial areas. At present, approximately 64 percent of the Peruque Creek watershed area is undeveloped space. The majority of this space is in the western portion of the watershed. A land use map of the Peruque Creek watershed is shown in **Figure 4-1**.

New development in Peruque Creek is significant. Regulatory approaches are needed to control pollutant discharges in storm water runoff from new development projects using zoning, erosion and sedimentation control, and grading and filling ordinances. These approaches are briefly described below.

Zoning
A wide variety of techniques can be used to manage land use and impervious cover in subwatersheds. These techniques have been employed in a wide variety of watershed applications by many local governments across the country. Some of these techniques include the following:

- Watershed Based Zoning
- Overlay Zoning
- Urban Growth Boundaries
- Large Lot Zoning

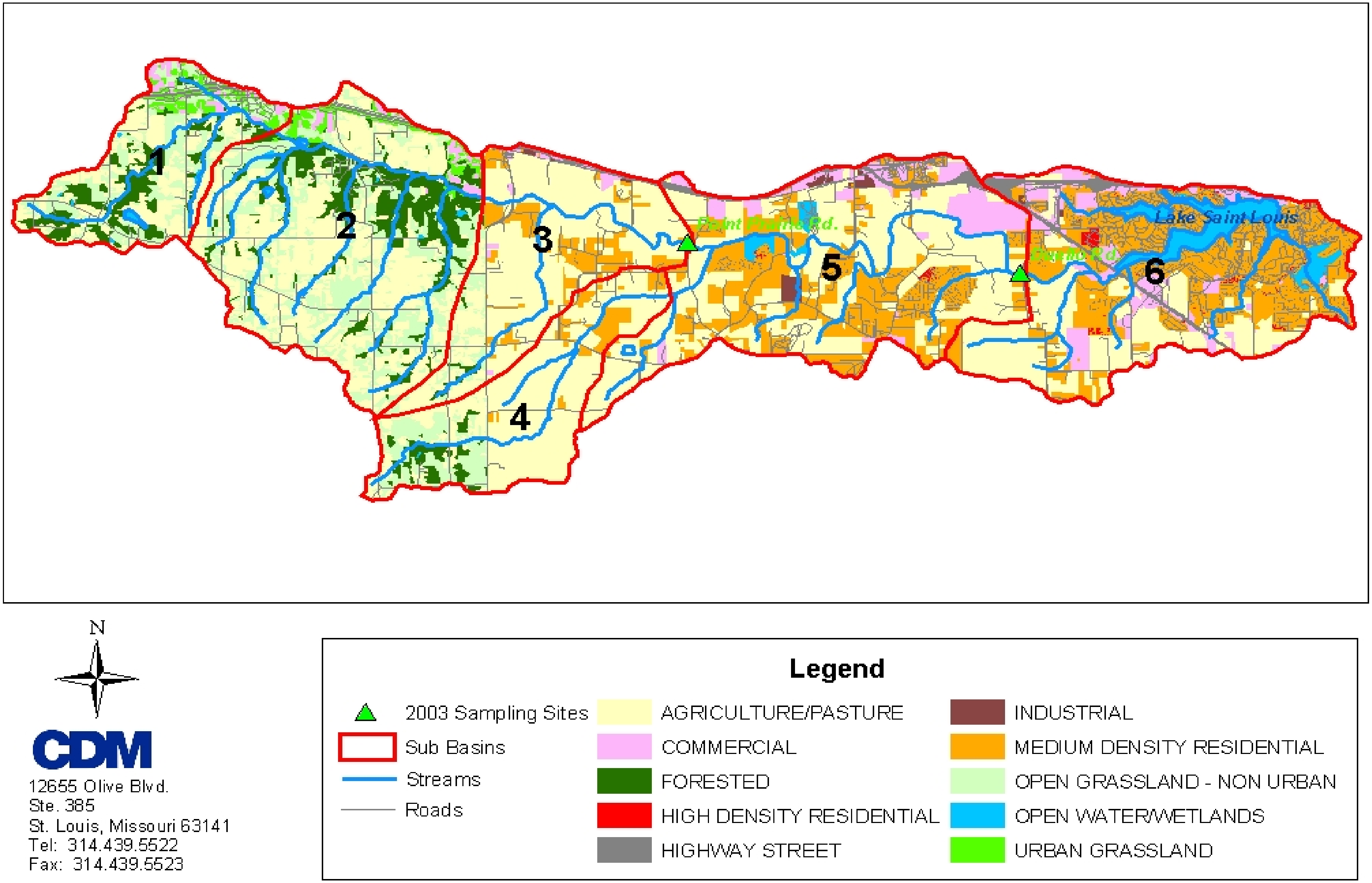
Watershed-Based Zoning

This specialized technique is the foundation of a land use planning process using subwatershed boundaries as the basis for future land use decisions. Watershed based zoning involves defining existing watershed conditions, measuring current and potential future impervious cover, classifying subwatersheds based on the amount of future imperviousness, and most importantly modifying master plans and zoning to shift the location and density of future development to the appropriate subwatershed management categories. Watershed based zoning can employ a mixture of land use and zoning options to achieve desired results.

Overlay Zoning

This land use management technique consists of superimposing additional regulatory standards, specifying permitted uses that are otherwise restricted, or applying specific development criteria onto existing zoning provisions. Overlay zones are mapped districts that place special restrictions or specific development criteria without changing the base zoning. The advantage is that specific criteria can be applied to isolated areas without a threat of being considered spot zoning. An overlay zone may take up only a part of an underlying zone or may even encompass several underlying zones. Often the utilization of an overlay zone is optional. A developer can choose to develop a property according to the underlying zone provisions. However, in order to develop certain uses or densities, the overlay provisions kick-in. Overlay zones can

Figure 4-1
Peruque Creek Watershed Upstream of Lake Saint Louis



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also be created to protect particular resources such as wetlands, forests, or historic sites. Here the provisions of the overlay zone incorporate mandatory requirements that restrict development in some way to reach the desired end.

Urban Growth Boundaries

This planning technique establishes a dividing line between areas appropriate for urban and suburban development, and areas appropriate for agriculture, rural and resource protection. Boundaries are typically set up for a 10- or 20-year period and should be maintained during the life of the planning period. Boundaries may be examined at planning period renewal intervals to assess whether conditions have changed since they were established. Boundaries should rarely be changed between planning cycles to ensure a consistent playing field for both the marketplace and citizens.

Large Lot Zoning

This land use planning technique is perhaps the most widely used to try to mitigate the impacts of development on receiving water quality. This technique involves zoning land at very low densities to disperse impervious cover over large areas. From the standpoint of watershed protection, large lot zoning is most effective when lots are extremely large (5 to 20 acres). While large lot zoning does tend to reduce the impervious cover and therefore the amount of storm water runoff at a particular location, it also spreads development over large areas. The road networks required to connect these large lots can actually increase the amount of imperviousness created for each dwelling unit. In addition, large lot zoning contributes to regional sprawl. Sprawl-like development increases the expense of providing community services such as fire protection, water and sewer systems, and school transportation.

The use of zoning as a watershed management tool would have a significant impact on the Peruque Creek watershed.

Erosion and Sedimentation Controls

Lake Saint Louis has an effective Erosion and Sediment Control (E&SC) program to reduce the potentially severe impacts generated by the construction process. For those communities that don't have E&SC program, this watershed management plan helps define which specific E&SC practices need (**Figure 4-2**) to be applied within the watershed to best protect sensitive aquatic communities, reduce sediment loads, and maintain the boundaries of conservation areas and buffers.

Perhaps the most critical stage at a construction site is when soils are exposed both during and after construction. Erosion of these exposed soils can be sharply reduced by stabilizing the soil surface and erosion controls. For many contractors, erosion control is just shorthand for hydroseeding. However, a wide range of erosion control options are available that include mulching, blankets, silt fencing, and sodding among others.

Erosion controls have benefits beyond controlling erosion. First, they can improve the performance of sediment controls. Controlling erosion reduces the volume of sediment going to a sediment control device. Consequently, less treatment volume is reduced by sedimentation and "clean out" frequencies are lower. In addition, many erosion controls can lower surface runoff velocities and volumes, preventing damage of perimeter controls.

Erosion controls can actually preserve topsoil, and reduce the need for re-grading at the site because of rill and gully formation. Furthermore, erosion control reduces landscaping costs by limiting the need to import topsoil.

Figure 4-2 - Erosion Control at St. Joseph Hospital in Lake Saint Louis

There is a significant opportunity for impacts of erosion and sedimentation from construction activities within the Peruque Creek watershed. Many new residential developments are being built or planned along Peruque Creek and tributaries. Some homebuilders have implemented erosion control procedures, however, many of these controls have not been maintained

Figure 4-3 - Eroding Stream Banks in Peruque Creek

Erosion and sedimentation is a significant issue regarding the Peruque Creek stream. Sporadic high velocity storm flows have been responsible for significant stream bank erosion and subsequent deposition of sediments (**Figure 4-3**). These sporadic high velocity flows and erosion have lead to the destruction of the native wildlife and plant habitat and the resuspension of sediments in the watershed.

Clearing and Grading Ordinances

Perhaps the single most destructive stage in the development process involves the clearing of vegetative cover and the subsequent grading of the site to achieve a more buildable landscape. The potential impacts to a stream and its watershed in this stage are numerous and profound. Trees and topsoil are removed, and soils are exposed to erosion. Heavy equipment compacts underlying soils, reducing permeability of the soil. Steep slopes are cut, and the natural topography and drainage of the site is altered. The existence of buffers and environmentally sensitive areas are at risk from clearing or erosion. This is particularly true of the residential developments being constructed in the Peruque Creek watershed

Clearing and grading should only be performed within the context of the overall stream protection strategy. Some portions of the residential development site should never be cleared and graded, or clearing in these areas should at least be sharply restricted. These areas include the following:

- Stream Buffers
- Forest Conservation Areas
- Wetlands, Springs, and Slopes
- Highly Erodible Soils
- Steep Slopes
- Environmental Features
- Storm water Infiltration Areas

A site designer should go even further and analyze the entire site to find other open spaces where clearing and/or grading can be avoided. Ideally, only those areas actually needed to build structures and provide access should be cleared. This technique, known as fingerprinting, can sharply reduce earthwork and E&SC control costs, and is critical for forest conservation. All "protected" areas should be delineated on construction drawings and shown as "limits of disturbance" or LOD. The LOD must be clearly visible in the field, and posted by signage, staking, flagging, or most preferably, fences (i.e. silt fence or temporary safety/snow fence). The limits and the purpose of the LOD should be clearly conveyed to site personnel and the construction foreman at pre-construction meetings. In addition, paving and other subcontractors that will be working on the site during the later stage of construction should also be routinely notified about the LOD as they arrive.

4.1.2 Indirect Regulatory Approaches for New Development

There are additional indirect regulatory approaches to control and reduce runoff from new development projects such as controlling the use of steep slopes, impervious surfaces, wetland and floodplain disturbance, and tree and vegetation removal during new development.

Steep Slopes

One indirect regulatory approach toward new development avoids placing houses and roads on steep slopes. Generally, the steeper the slope, the greater the erosion hazard. This is because the effect of gravity and reduced friction between soil particles on steep slopes means it takes less energy for water to dislodge and transport soil particles. In addition, steep slopes lead to greater areas of soil disturbance in order to accommodate facilities compared to flatter slopes. This is because most development projects generally require extensive grading to create flat areas for such things as roads and buildings.

Impervious Surfaces

Reducing the amount of impervious cover created by subdivision and parking lots for new developments can lead to savings for municipalities and developers. Impervious cover can be minimized by modifying local subdivision codes to allow narrower or shorter roads, smaller parking lots, shorter driveways, and smaller turnarounds. Infrastructure normally constitutes over half of the total cost of subdivision development. Much of the infrastructure creates impervious surfaces. Thus, builders can realize significant cost savings by minimizing impervious areas. These structural tools make both economic and environmental sense and will be discussed in Section 5 as structural control methods. In addition to these direct cost savings, developers will realize indirect savings. For example, costs for storm water treatment and conveyance are a direct function of the amount of impervious cover. Thus, for each unit of impervious cover that is reduced, a developer can expect a proportionately smaller cost for storm water management and control.

Wetland Disturbance and Flood Plain Development

Wetlands and floodplains can be used to control storm water runoff. Wetlands maintain wildlife habitat while decreasing the stream gradient and allowing slow flow areas to store and regulate flow. Ponded water and wetland areas mitigate the effects of storm water flow and its destructive effect on stream habitat. They mitigate the effects of storm water flows by slowing down the water and allowing more time for pollutants associated with storm water to be settled, filtered out, or assimilated by plants. The greater percentage of existing wetlands and floodplains that are preserved and maintained during new development projects, the quicker the system will recover from storm water runoff and reduce its effects on stream habitat and water quality.

Tree and Vegetation Removal

Another indirect regulatory approach toward new development includes preserving existing areas of dense vegetation. Good vegetative cover is an extremely important factor in preventing erosion. Disturbance of areas with a well-established, dense vegetative cover exposes valuable topsoil, making it highly susceptible to erosion. Destruction of such vegetation adds significant expense to the construction budget for clearing and destroys an inherently valuable attribute to the site (mature trees have recognized value in real estate appraisals and market absorption rates for home sales forecasts).

4.1.3 Regulatory Approaches for Restorative Redevelopment

Few of the properties and systems of sewage, drainage, transportation, and pavements in Peruque Creek have deteriorated, however some properties in the eastern portion of the watershed may need to be restored, revitalized, or reconstructed. As redevelopment progresses, buildings will be renovated and reconstructed, driveways will be repaved, patios and sidewalks will be replaced, and storm water and wastewater utilities will be rehabilitated or replaced. The technical key for restoring and revitalizing urban watersheds is to remove storm water from sewers and reintroduce it to the soil and vegetation, and reduce the area of impervious surfaces within the watershed. Regulatory land use approaches can be used to encourage home and business owners to apply the principals of restorative redevelopment whenever existing facilities wear out and need to be replaced or revitalized.

Every rainfall over the Peruque Creek watershed brings with it the diverse pollutants associated with urban watersheds; oils, trash, salts, pesticides, fertilizers all end up in the stream. Culverts convey abrupt pulses of peak storm flow, eroding the stream channels. Flows from rooftops and street runoff get into the sanitary sewers, producing overflows that negatively impact environmental quality. When the rain is not falling, the base flow of watershed streams is almost nonexistent, drying up at times because the water has never entered the soils of the watershed.

The soils in Peruque Creek are relatively porous and permeable. These soils allow water to move through soil particles and filter out pollutants. Microorganisms decompose pollutants and turn them into nutrients. Storage in the soil and the deeper groundwater turns intermittent pulses of rainfall into a perennial moisture supply discharging slowly, almost steadily, months after the rain falls, to the streams and wetlands where aquatic organisms can survive over dry summers. Even after a soil has been churned and compacted by construction, nature tends to restore these kinds of processes wherever it is allowed to work freely.

Taking advantage of natural processes to store and treat storm water brings additional benefits as well. Recharging the groundwater supports riparian vegetation, providing wildlife habitat and opportunities for human interaction with the natural world. Reductions in impervious surfaces and tree planting help moderate urban temperatures, increasing human comfort. Porous pavements can be designed to improve pedestrian access to desirable places. Re-vegetation of landscapes beautifies neighborhoods.

A variety of techniques are available for removing storm water from sewers, reducing the quantity of impervious surfaces, and restoring beneficial natural processes. Land use regulations are watershed management measures that can encourage the use of these techniques. These strategies include:

- **Capturing Roof Runoff** in tanks or cisterns for irrigation or indoor graywater use
- **Disconnecting Pavement and Roof Drainage** from sewer lines and directing it to adjacent vegetated soil or to infiltration basins
- **On-lot Infiltration Basins** – install "water gardens", dry wells, and subsurface recharge beds - to collect runoff and percolate it into the soil
- **Planting Trees** to intercept a portion of rainwater
- **Rehabilitating Soils** to increase infiltration rates and pollutant - neutralizing microbial activity
- **Reconfiguring Driveways, and Parking Areas** to turn more of a site to pervious, vegetated soil
- **Using Porous Pavements for Driveways and Parking Areas** – special varieties of asphalt, concrete, masonry, and other materials with open pores that allow water to pass through
- **Routing Runoff Through Vegetated Surface Channels** – "swales" – to slow its velocity, remove pollutants, and infiltrate it into the soil

Urban retrofit and redevelopment projects can disconnect storm water drainage from sanitary sewers, and reconnect it with the vegetation and soil. A range of measures can use natural processes to reuse, infiltrate, treat, and detain rainwater with individual sites and neighborhoods.

The informed, creative retrofit and redevelopment of urban places can solve watershed problems at the source, while revitalizing older communities. It can reduce impervious cover, disconnect storm drains from sewers, build storage and treatment features into the fabric of urban places, educate the residents about where they live, and allow natural processes to operate again.

Existing land use controls can be revised so that future retrofit and redevelopment projects are encouraged to implement restorative redevelopment management measures. The following patterns of site-specific restorative redevelopment should be encouraged to restore watershed processes while revitalizing specific urban sites:

- Make components multi-functional

- Use every square inch
- Use freely available natural processes
- Find out what is possible
- Engage the community

Make Components Multi-Functional

Everything that is done in a retrofit or redevelopment project should produce multiple, mutually reinforcing benefits. When a component is multi-functional, it attracts advocates promoting each of its several functions, and attracts a broad community and political support. Land use controls are a regulatory watershed management tool that can encourage this principal.

For instance, storm water has traditionally been moved off city roofs and streets through a single-purpose system of underground pipes. Instead, if it was kept on the surface, recreating a creek that was lost or recharging the groundwater and nourishing vegetation could be accomplished. In either case, it provides ecosystem benefits in terms of habitat for wildlife, human benefits in experiencing the beauty and wonder of natural systems, and financial benefits in reduced municipal costs of maintaining a hidden infrastructure.

Whenever an important storm water management component of a project has a cost that may be deemed undesirable by a developer or homeowner, it is important to point out the additional desirable benefits resulting from that storm water management component. The project budget is thereby enlarged as the cost for the storm water management becomes absorbed into the provision of other functions deemed more “necessary” by the developer or homeowner. Multiple functions as various as water quality improvement, employment, housing, separation of storm drainage from sanitary sewers, parking improvements, noise reduction, pedestrian safety, temperature moderation, and social equity can and should be found in the design of every building, street, sidewalk, park, water course, drainage system, residential yard, and institutional landscape.

One of the functions every restorative development should have is the education of people about natural processes and on-site connections to the watershed. Storm water systems should be visible and a tangible part of the urban framework of the watershed. Creating and implementing public education programs for watershed protection is discussed later in Section 4.2 of the plan.

Use Every Square Inch

Urbanized areas can be crowded places. Successful restoration and revitalization depends on utilizing every square inch of a retrofit or redevelopment project for positive, multiple functions. Every component is in the midst of community life, and must have a positive community benefit in addition to technical function.

As older cities and urban communities were built, the cumulative impacts of transforming the landscape mounted, and municipalities had to replace natural systems with cost-intensive infrastructure. Now, when much of the older infrastructure fails to perform to today's standards, an opportunity is made available to reconsider the form and function of the urban landscape – and ultimately integrate each site into a seamlessly operating whole.

The redevelopment of every site can contribute incrementally to the restoration of watershed process. For example, retrofitting of a single house with separation of roof drainage from storm sewers contributes only a small amount to the reduction of stormwater overflows – but the impact is both immediate and maintainable when a large number of homes disconnect their downspouts and allow the stormwater to flow over open land. The solution to a watershed-wide problem requires the contribution of many similar projects throughout the watershed. The cumulative public benefits are enormous. There must be a constant search for restoration and revitalization opportunities on additional sites. Once started, the endeavor must be maintained with purpose over many human generations. Existing land use controls can be revised to encourage the implementation of this management principal.

Use Freely Available Natural Processes

Freely available natural processes are capable of working for the greater benefit of watershed restoration. Vegetated soils absorb rainwater and the chemical and microbial processes of the soil capture and degrade most pollutants that may be present. The infiltrated water recharges groundwater tables and restores flows to streams. These processes reduce peak flows and erosion, reduces sewer overflows, prevent and mitigate pollution, and sustain watershed ecosystems.

The regenerative capacity of soils and ecosystems is strong within the Peruque Creek watershed. Taking advantage of this regenerative capacity enacts a new concept of storm water infrastructure to include the capacities of soil and vegetation to absorb water and filter pollutants. This is a "smarter", "cheaper" approach to infrastructure because it puts nature to work, and reduces the work humans must do, in contrast to the more active systems of pipes and facilities for conveyance and mechanically-dependant treatment.

Find Out What is Possible

Diverse, flexible, economical techniques for treating and storing storm water within urban retrofit and redevelopment projects have been proven in applications throughout Missouri and the Midwest. Developers, public officials, and citizens need to be aware of the alternatives that are available. This will allow for examination and selection of numerous techniques, old and new, that can be applied in the Peruque Creek watershed in ways that are economical, effective, and supportive of economic vitality and quality of life. These techniques also can contribute to progress on local agendas, including ecosystem restoration and community social and economic development.

Engage the Community

Most leaders and professionals recognize that decisions having profound impacts on people and places – infrastructure choices, facility siting, provision of public amenities, policy development, and more – should be made with the full participation of those who will bear the effects of those decisions. Moreover, each city and its respective communities have a unique social and political history, style of governance, method of public discourse, and capacity for action. Local application of potential solutions needs to be carefully defined in order to build cohesive cultural forces for long-term success.

Collaborative, community-based efforts are key to developing sustainable approaches to issues as broad as sewer overflows, ecosystem restoration, and community development. If functions and benefits in these areas are to be coordinated and maximized, the community must be involved in the search for the solutions. The PCWA, MDC, and NRCS have all done an excellent job in keeping the public abreast of watershed issues in St. Charles County and Warren County through leadership and education. Creating and implementing public education programs for watershed protection is discussed later in Section 4.2 of this storm water management plan.

4.1.4 Land Acquisition for Preservation of Open Space and Buffer Zones

A stream buffer is the region immediately beyond the banks of a stream that serves to limit the entrance of sediment, pollutants, and nutrients into the stream. It acts as a "right-of-way" for a stream and functions as an integral part of the stream ecosystem. When forested, a stream buffer promotes bank stability and serves as a major control of water temperature. As a result, stream and wetland buffers are an increasingly popular watershed protection technique due to simplicity, low cost, ease of implementation, and capability to protect resource areas. As an alternative watershed management measure, local governments may choose to purchase land to maintain existing open areas and buffer zones to protect valuable resources from the effects of development.

The Municipal Code of St. Charles County (September 2004- Section 405.5025) states the minimum standards for vegetated buffers in St. Charles County are:

A. *A vegetated buffer for a natural watercourse which is left in its natural state shall consist of a vegetated strip of land extending along both sides of a natural watercourse.*
B. *The vegetated buffer shall begin at the edge of the bank of the natural watercourse.*
C. *For those sites where vegetation does not exist, developers or owners shall allow the vegetated buffer to succeed naturally.*
D. *The minimum width of the vegetated buffer shall be:*
    1. *Fifty (50) feet along the main branch of the Dardenne Creek, the Peruque Creek, the Femme Osage Creek, the Big Creek, and the McCoy Creek;*
    2. *Twenty-five (25) feet along all other natural watercourses left in their natural*

state.

E. *The following land uses and/or activities are designated as potential water pollution hazards and must be set back from any natural watercourse left in its natural state by the distance indicated below:*
   1. *Drain fields from on-site sewage disposal and treatment systems (i.e., septic systems)--one hundred (100) feet;*
   2. *Raised septic systems--two hundred fifty (250) feet. (Ord. No. 02-004 §1, 1-30-02; Ord. No. 02-088 §5, 6-26-02)*

The 50-foot setback (**Figure 4-4**) along the edge of streams preventing developers from developing extremely close to them. However, this may not be enough of a setback to protect the stream, particularly in the lower portions of Peruque Creek. Smaller setbacks maybe more acceptable in headwater streams or small tributaries to Peruque Creek, but larger setbacks of up to 100-feet may be more appropriate to protect water quality. The width of a buffer strip can vary, however, the greater the width, the more effective it is in filtering out stormwater flow, nutrients and contaminants. **Table 4-1** provides an overview of some percent removal rates for nutrients and suspended solids.

Table 4-1. Percent Pollution Removal Rates in Buffer Zones

Reference	Buffer Vegetation Type	Buffer Width (feet)	Pollutant		
			Total Suspend Solids	Total Phosphorus	Total Nitrogen
Dillaha *et al*.1989	Grass	15	63	57	50
		30	78	74	67
Magette *et al*. 1987	Grass	15	72	41	17
		30	86	53	51
Schwer and Clausen 1989	Grass	85	89	78	76
Lowrance *et al.* 1983	Native hardwood forest	65 - 130	-	23	-
Doyle *et al*. 1977	Grass	5	-	8	57
Barker and Young 1984	Grass	260	-	-	99

Stream buffers add to the quality of the stream and the community in many diverse ways as shown in **Table 4-2**.

Table 4-2
Twenty Benefits of Urban Stream Buffers

1.	**Reduces watershed imperviousness.** An average buffer width of 100-feet can protect a significant portion of the watershed area from future development.
2.	**Distances areas of imperviousness cover from the stream.** More room is made available for placement of storm water practices. *(f)*
3.	**Reduces small drainage problems and complaints.** When properties are located too close to a stream, residents are likely to experience and complain about backyard flooding, standing water, and bank erosion. A buffer reduces complaints.
4.	**Stream "right-of-way" allows for lateral movement.** Most stream channels shift or widen over time; a buffer protects both stream and nearby properties.
5.	**Effective flood control.** Other, expensive flood controls not necessary if buffer includes 100-yr floodplain.
6.	**Protection from streambank erosion.** Tree roots consolidate the soils of floodplain and stream banks, reducing the potential of severe bank erosion. *(f)*
7.	**Increase property values.** Homebuyers perceive buffers as attractive amenities to the community. 90% of buffer administrators feel buffers have a neutral or positive impact on the property values. *(f)*
8.	**Increased pollutant removal.** Buffers can provide effective pollutant removal for development located within 150 feet of the buffer boundary, when designed properly.
9.	**Foundation for present or future greenways.** Linear nature of the buffer provides for connected open space, allowing pedestrians and bikes to move more efficiently through a community. *(f)*
10.	**Provides food and habitat for wildlife.** Leaf litter is the base food source for many stream ecosystems; forests also provide woody debris that creates cover and habitat structure for aquatic insects and fish. *(f)*
11.	**Mitigates stream warming.** Shading by the forest canopy prevents further upstream warming in urban watersheds. *(f)*
12.	**Protection of associated watersheds.** A wide stream buffer can include riverine and palustrine wetlands that are frequently found along the stream corridor.
13.	**Prevent disturbance to steep slopes.** Removing construction activity from these areas is the best way to prevent soil erosion. *(f)*
14.	**Preserves important terrestrial habitat.** Riparian corridors are important transition zones, rich in species. A mile of stream buffer can provide 25-40 acres of habitat area. *(f)*
15.	**Corridors for conservation.** Unbroken stream buffers provide "highways" for migration of plant and animal populations. *(f)*
16.	**Essential habitat for amphibians.** Amphibians require both aquatic and terrestrial habitats and are dependant on riparian environments to complete their life cycle. *(f)*
17.	**Fewer barriers for fish migration.** Chances for migrating fish are improved when stream crossings are prevented or carefully planned.
18.	**Discourages excessive storm drain enclosures/channel hardening.** Can protect headwater streams from extensive modification.
19.	**Provides space for storm water ponds.** When properly placed, structural storm water practices within the buffer can be an ideal location for storm water practices that remove pollutants and control flows from urban areas.
20.	**Allowance for future restoration.** Even a modest buffer provides space and access for future stream restoration, bank stabilization, or reforestation.

(f) = Benefit by or requires forest cover

4.1.5 Runoff Control for Industrial and Commercial Sites

Industrial and commercial facilities can be considered potential "hot spots" as sources of pollutants. While only a small portion of the total watershed area is designated as industrial/ commercial land use, routine or accidental discharges from these few industrial or commercial facilities can discharge pollutants such as petroleum hydrocarbons, heavy metals, and toxic organic materials in quantities far beyond the proportion of industrial/ commercial land use. For this reason, runoff controls for industrial and commercial sites are an important nonstructural watershed management tool.

Figure 4-4 - Riparian Buffer Strip along Peruque Creek

Industrial and commercial activities, even small businesses and relatively small facilities, have the potential to be a significant pollutant contributor if the facility operator does not pay attention to routine operations that may discharge pollutants. The "operational practices", or BMP, approach to pollution prevention can be especially attractive to smaller facilities and businesses, which may not generate pollutants in large quantities that make hydraulic treatment methods feasible but nevertheless can be occasional sources of significant amounts of pollutants. Further, small businesses may not have the wherewithal to implement extensive structural controls or to develop in-house expertise on specialized environmental issues. The intent of this pollution prevention approach is to achieve a level of on-site pollution control at the point of origin so that storm water need not be treated in an off-site regional hydraulic detention facility or pollutant removal device. The approach is highly practical from a business standpoint because it focuses on industrial/ commercial operations and low-cost pollution control practices rather than expensive constructed solutions like new industrial structures or new storm water detention or treatment facilities.

Pollution prevention practices can be divided into three groups (**Table 4-3**). The first two concentrate heavily on operational practices and nonstructural pollution prevention methods and the third could entail some structural control measures.

The first recommends to all facilities: employee training, customer awareness, spill prevention, and eliminating non-storm water discharges. The second includes

Table 4-3
Industrial/Commercial Storm Water Practices

A. Storm water pollution prevention practices recommended for all facilities ▪ Training and education for employees and customers ▪ Eliminating improper discharges to storm drains ▪ Spill prevention, control, and cleanup
B. Categories for industrial/commercial activity for which pollution prevention practices may be adequate for storm water control ▪ Outdoor process equipment operations and maintenance ▪ Outdoor materials handling and storage ▪ Waste handling and disposal ▪ Vehicle and equipment washing and stream cleaning ▪ Trucking and shipping/receiving ▪ Fleet vehicle maintenance ▪ Fueling fleet vehicles and equipment ▪ Building and grounds maintenance ▪ Building repair, remodeling, and construction
C. More extensive practices that may be needed for some industrial/commercial activities ▪ Loading dock design features ▪ Equipment yard design features ▪ Fleet or equipment fueling area design features ▪ Controls and design features for access roads and rail corridors

pollution prevention practices that may be conducted at a typical facility (e.g. methods of handling wastes, pollution prevention for outdoor equipment, and proper methods of building and grounds maintenance, vehicle maintenance, shipping and receiving, and equipment washing). The third group may entail some structural modifications to facilities to enhance pollution prevention: design features of loading dock areas, vehicle fueling and maintenance areas, and access roads and rail facilities on the site.

While only a small portion of the total Peruque Creek watershed area is designated as industrial/commercial land use, discharges from industrial or commercial facilities located within the Peruque Creek watershed can contribute to storm water pollution. Even small businesses and relatively small facilities have the potential to be significant pollutant contributors. Industries implementing the nonstructural management and control practices described above can reduce storm water pollution and avoid the need for expensive constructed solutions (i.e. detention/treatment facilities).

4.1.6 Better Site Design

Individual development and redevelopment projects can be designed to reduce the amount of impervious cover they create, and increase the natural areas they conserve. Many innovative site-planning techniques have been shown to sharply reduce the impact of development. Designers, however, are often not allowed to use these techniques in many communities because of outdated local zoning and/or subdivision codes.

The better site design watershed protection tool is a nonstructural management measure that seeks to foster better site designs that can afford greater protection to a watershed. Four better design strategies that have special merit for watershed protection include:

- Open space residential subdivisions
- Green parking lots
- Headwater streets
- Rooftop runoff management

Open Space or Cluster Residential Subdivisions

Cluster development designs minimize lot sizes within a compact developed portion of a property while leaving the remaining portion open. Housing can still be detached single-family homes as well as multi-family housing or a mix of both. Clustered development creates protected open space that provides many environmental as well as market benefits. Cluster or open space development design typically keeps 30 to 80 percent of the total site area in permanent community open space with much of the open space managed as natural area.

The key benefit of open space or cluster development is that it can reduce the amount of impervious cover created by a residential subdivision by 10 to 50 percent (CWP 1998a; DEREC 1997; Dreher and Price 1994; Maurer 1996; SCCCL 1995). Clustering can also provide many community and environmental benefits. It can eliminate the need to clear and grade 35 to 60 percent of total site area and can reserve up to 15 percent of the site for active or passive recreation. When carefully designed, the recreation space can promote better pedestrian movement, a stronger sense of community space, and a park-like setting. Open space designs provide developers some "compensation" for lots that would otherwise have been lost due to wetland, floodplain, or other requirements. This, in turn, reduces the pressure on buffers and other natural areas. In addition, the ample open spaces within a cluster development provide a greater range of locations for more cost-effective storm water runoff practices. These same development concepts can be applied to new homes and businesses constructed on individual lots as well as entire subdivisions. Better site design can significantly reduce the quantity of new impervious area constructed on the lot, direct storm water runoff to vegetated areas, and maximize green space.

Green Parking Lots

When viewed from the air, parking lots are usually the largest feature of a commercial area, at least in terms of surface area. Over time, local parking codes have evolved to ensure that all workers, customers, and residents have convenient and plentiful parking. In this respect, local parking codes have been a great success. One by-product, however, has been the creation of large expanses of often-needless impervious cover.

A key strategy to reduce impervious cover involves the construction of green parking lots. Green parking refers to an approach that downsizes parking areas while still providing convenient access for the motorist. Green parking can be achieved through careful design and a comprehensive revision of local parking codes. The common theme in green parking lots is minimization of impervious area at every stage of parking lot planning and design. The concept of green parking lots can also be applied to existing parking lots when they are refurbished.

Headwater Streets

Since streets are one of the biggest components of impervious cover created by car transport needs, headwater streets are built or restored on a revised classification system where street widths decline with decreasing average daily trips (much like headwater streams which decrease in size with decreasing drainage area). This is essential, since streets are a key source area for storm water pollutants and do not allow the natural infiltration of water into the ground. By revisiting and changing some local subdivision codes, many of the traditionally accepted standards can be addressed to change this issue.

Rooftop Runoff Management

Re-directing rooftop runoff over pervious surfaces before it reaches paved surfaces can decrease the annual volume runoff from a site by as much as 50 percent for medium to low density residential land uses (Pitt 1987). This can significantly reduce the annual pollutant load and runoff volume being delivered to receiving waters and therefore can have a substantial benefit in reducing downstream impacts.

New development in Peruque Creek is significant. The Peruque Creek watershed comprises an area of approximately 55,000 acres of which 36 percent is developed, with a large portion of the undeveloped areas consisting of agricultural land. The key toward revitalizing the Peruque Creek watershed will lie with direct and indirect regulatory controls for development.

4.2 Public Education and Volunteer Programs

A portion of Peruque Creek is an urban headwater stream. It is important to note that even if the rapid development problems were to be controlled and aquatic habitat improved, the stream would continue to be subjected to the wide variety of problems typically related to urban runoff. These include water quality degradation due to runoff contaminated with pet wastes, lawn care chemicals, petroleum products from automobiles, and volumes of trash among others. All of these pollutants can be linked to individual behavior and watershed ethic.

The public does not always practice good watershed ethic, and continues to engage in many behaviors that are linked to water quality problems. Watershed education is the primary tool for changing these behaviors and is an important watershed management element. Some communities have attempted to craft education programs in recent years to influence watershed behaviors. These initial efforts have gone by an assortment of names such as public outreach, source control, watershed awareness, pollution prevention, citizen involvement, and stewardship, but they all have a common theme: educating residents on how to live within their watershed.

Figure 4-5 - Informing the public on watershed issues in St. Charles County

It is imperative that the public is properly educated as to the potential impairment to public safety and water quality resulting from poor watershed ethics. For the Peruque Creek watershed, the following potentially polluting behaviors can be linked to the observed water quality problems and will be discussed as alternative public education program elements:

- Littering
- Illegal Dumping
- Landscaping and Lawn Care
- Automobile Maintenance
- Car Washing
- Animal Waste Collection
- Vegetation Controls and Tree Planting

This section of the watershed management plan lists and explains potential public education programs that *could* be considered for the Peruque Creek watershed. It is important to note that not all of the alternative management measures documented in this section have equal applicability to the specific conditions within the Peruque Creek watershed. The alternative measures have differing implementation costs and differing effectiveness in educating residents on how to live within their watershed. The alternative measures that are listed in this section are evaluated and screened in Section 6.2.

The first step in crafting better watershed educational programs is to compile some baseline information on local awareness, behaviors, and media preferences (**Figure 4-5)**. The following are some of the key questions that should be considered for the Peruque Creek watershed management plan:

- Is the typical individual aware of water quality issues in the Peruque Creek watershed?

- Is the individual or household behavior directly linked to water quality problems?
- Is the behavior widely prevalent in the Peruque Creek watershed population?
- Do specific alternative(s) to the behavior exist that might reduce pollution?
- What is the most clear and direct message about these alternatives?
- What outreach methods are most effective in getting the message out?
- How much individual behavior change can be expected from these outreach techniques?

The best way to elicit this information is to conduct a market survey within the watershed. If funding for a market survey is not available, a watershed manager can consult other residential surveys from similar areas.

The next step in developing alternative measures for a watershed education program is to consider the alternative outreach techniques. Media campaigns and intensive training outreach techniques have shown promise in actually changing behavior.

Figure 4-6 - Stream Team Training Workshop

The Missouri Stream Team program is a program that brings together citizens to address water quality issues in their watershed. Collectively, Stream Team members learn to monitor water quality on a local scale and add to the State's water quality data base. Stream Team volunteers also help re-vegetate riparian areas, stabilize stream banks, and improve fish and wildlife habitats. Through this study, a Stream Team was formed to bring together public and private resources to educate the public about the Peruque Creek watershed (**Figure 4-6**). The Stream Team collects water quality and biological data from Peruque Creek and on an annual basis conducts a Stream Team cleanup in the watershed.

Media campaigns typically use a mix of radio, television, direct mail, and signs to broadcast a general watershed message to a large audience. Intensive training uses workshops, consultation, and guidebooks to send a much more complex message about watershed behavior to a smaller and more interested audience. Intensive training requires a substantial time commitment from residents of a few hours or more.

The remainder of this section will present alternative elements of a comprehensive public education program for the Peruque Creek watershed. All the alternative education elements will include watershed ethic and how it can improve the quality of an urban watershed. Watershed behaviors, especially the most potentially polluting behaviors associated with Peruque Creek, will be discussed in detail. Descriptions of the impacts these behaviors have on a watershed and suggestions on how to educate the public on these behaviors will be discussed as well.

4.2.1 Littering

Littering is a pervasive problem in the United States, as well as in the Peruque Creek watershed. Refuse may be blown out of overflowing trash bins or inexcusably tossed by consumers onto streets and into yards. The litter can eventually make its way into receiving streams thus making it a risk to public safety and water quality.

Education is the key to changing behavior and attitudes with regards to littering. The key is to successfully educate the public on the problem and its implications. Effective litter prevention programs use practices that educate and involve the community in an effort to eliminate littering. Many communities in Missouri utilize an effective way to promote stream litter awareness by hosting a stream cleanup. A stream cleanup allows concerned citizens to become directly involved in litter prevention **(Figure 4-7**). Participants volunteer to walk (or paddle) the length of the stream or river, collecting trash and recording information about the quantity and types of garbage that has been removed. These stream cleanups benefit both the waterbody and the community. These efforts help citizens feel more involved in their community and foster a sense of responsibility for the waterways in their community. In addition, the cleanup efforts improve aesthetics, habitat, and water quality. During the course of the Peruque Creek investigation, several stream cleanups were hosted by local municipalities and private industry. Many municipalities conduct these stream clean ups on a regular basis, and in addition to helping remove trash and debris from the waterways, the associated media coverage of the cleanup event has increased public awareness in protecting their streams.

Figure 4-7 - Peruque Creek Stream Team

Some of the alternative prevention strategies that need to be considered and addressed when creating a public litter awareness program include:

- Creating a maintenance plan to keep an area clean
- Addressing problem disposal items

- Conducting comprehensive education campaigns

A number of groups have ongoing efforts to educate the public about litter reduction. These groups concentrate their efforts on changing the behavior of those who are littering our lands and waterways.

The media can be another useful tool to increase public awareness on litter reduction and can send the message that littering will not be tolerated. To maximize their educational role, the media should be involved before, during, and after cleanup projects.

Local litter control and cleanup programs focus on community involvement. The team approach not only provides most, if not all, the resources needed to conduct the cleanups, but, most importantly, it provides the involvement and commitment needed to keep the sites clean. Volunteers provide people power to remove litter that does not require heavy equipment. Often trash is scattered, and removal by equipment would cause undue damage to the environment. Sources of volunteers can include local residents, people with special interests in the area, and local service groups or businesses. Volunteers who live nearby or have a special interest are essential team players in keeping the area clean. Businesses can also provide many resources. **Table 4-4** below shows a list of businesses and the types of resources they could provide.

Table 4-4
Litter-Prevention Resources from Businesses

Business	Resource(s)
Waste Industry	Disposal or recycling
Utilities	Equipment, cleanup supplies, deterrents, and re-beautification supplies
Food Vendors	Food and beverages for volunteers
Contractors	Equipment

Government, particularly local government, can assist in trash cleanups as well. They may provide hauling, labor, heavy equipment, and physical deterrents such as guide rails or fill to prevent access to a cleaned site. In addition, enforcement agencies can be essential players and should be encouraged to meet with volunteers and discuss ways they can work together to increase successful prosecution of littering offenders.

Another deterrent to littering is natural beauty. If a land is naturally beautiful and well cared for, it is less likely to be trashed by uncaring people.

The cost of litter control programs can vary due to economic and social factors, but with creative thinking and community involvement potential costs may be reduced. Funding sources, such as foundations, corporations, and government agencies may provide funds to acquire essential resources not attainable from your community.

4.2.2 Illegal Dumping

Illegal dumping can occur in both urban and rural settings in all geographic regions, including Peruque Creek. For the Peruque Creek watershed management plan, illegal dumping control is important in preventing contaminated runoff from entering wells and surface water, as well as averting flooding due to blockages of drainage channels for runoff. Additionally, all this material can end up in Lake Saint Louis which can create a safety issue for recreational activities, such as water skiing and boating. Illegal dumping control as a management practice involves using public education to familiarize residents and businesses with how improperly disposed materials can affect storm water. Locating and correcting these practices through educational measures can prevent the many risks of public safety and water quality associated with these actions.

Several types of illegal dumping can occur. The first is the illegal dumping (also known as “open dumping,” fly dumping,” or “midnight dumping”) of litter that occurs at abandoned industrial, commercial, or residential buildings; vacant lots; and poorly lit areas such as rural roads and railway lines. This dumping primarily happens to avoid disposal fees or the time and effort required for proper disposal at landfills or recycling facilities. These items include auto batteries, refrigerators and other scrap appliances, and even Christmas trees.

A second type is the illegal dumping of water that has been exposed to industrial activities and then released to the storm drainage system, including pollutants into storm water runoff. A third type is the illegal pouring of pollutants such as used motor oil, engine antifreeze, paint thinner, pesticides, or other Household Hazardous Wastes (HHWs) into storm drains.

Illegal dumping control programs focus on community involvement and targeted enforcement to eliminate or reduce these acts. The key to successfully using this practice is increasing public awareness of the problem and its implications. Effective illegal dumping control programs use practices that educate and involve the community, local industries, and elected officials in an effort to eliminate the illegal discarding of wastes. Some of the alternative issues that need to be examined and considered when creating a public awareness program include:

- The locations of persistent illegal dumping activity
- The types of waste that are dumped and the profile of dumpers
- Previous education and cleanup efforts that have been used
- Existing sources of funding and additional resources that may be required

Cleanup projects will require coordinated planning efforts to ensure that adequate resources and funding are available. Once a site has been cleaned, signs, lighting, or barriers may be required to discourage future dumping. Landscaping and beautification efforts may also discourage illegal dumping, as well as provide open space and increased property value. Stenciling storm drains may make residents more aware that the pollutants that they illegal pour down storm drains will eventually end up in watershed streams.

The organization of special cleanup events where communities are provided with the resources to properly dispose of illegally dumped materials increase the understanding among residents of illegal dumping impacts and supplies opportunities to correctly dispose of materials. There are existing volunteer groups within the watershed that could provide labor resources needed to implement cleanup programs. Integration of illegal dumping prevention into community policy programs may also be an effective way to increase enforcement opportunities without the additional cost of hiring new staff. Producing simple messages relating the cost of illegal dumping on local taxes and proper disposal sites will aid in eliminating the problem. Having a hotline where citizens can report illegal activities and educating the public on the connection between the storm drain and water quality will decrease disposal of waste into storm drain inlets.

Implementing a tracking and evaluation tool of the prevention efforts will determine if goals are being met. Using mapping techniques and computer databases allows officials to identify areas where dumping most often occurs, record patterns in occurrence, and calculate the number of citations issued and the responsible parties. This allows for better allocation of resources and more specific targeting of outreach and education efforts for offenders.

The cost of illegal dumping control programs can vary due to economic and social factors, but with creative thinking potential costs may be reduced. Possible sources of labor for dumping site cleanups can include volunteer community and youth groups.

4.2.3 Landscaping and Lawn Care

Lawn care and landscaping are important topics to consider when developing alternative elements for a comprehensive public education program for the Peruque Creek watershed. The community of Lake Saint Louis that surrounds the lake contains the highest density of residential homes and lawns within the watershed. Many of these homes have extensive landscaping and large lawns that are immediately adjacent to Lake Saint Louis (**Figure 4-8**).

Figure 4-8 - Residential Homes Surrounding Lake Saint Louis

Landscaping and lawn care are a big business and it has been estimated that there are 25 to 30 million acres of turf and lawn in the United States. To put this statistic in perspective, consider that if lawns were classified as a crop, they would rank as the fifth largest one in the country on the basis of area (USDA 1992). In terms of fertilizer inputs, nutrients are applied to lawns at about the same application rates as those used for row crops (Barth 1995). The urban lawn is estimated to receive an annual input of five to seven pounds of pesticides per acre (Schueler 1995).

Not many residents understand that lawn fertilizer can cause water quality problems – overall less than one-fourth of residents rated it as a water quality concern (Syferd 1995, Roberts 1989 and Lawn and Landscape Institute 1999). Unlike farmers, suburban and rural landowners are often ignorant of the actual nutrient needs of their lawns. According to surveys, only 10 to 20 percent of lawn owners take the trouble to take soil tests to determine whether fertilization is even needed (CWP 1999a). The majority of landowners are not aware of the phosphorus or nitrogen content of the fertilizer they apply or that mulching grass clippings into lawns can reduce or eliminate the need to fertilize. Informing residents and lawn care professionals on methods to reduce fertilizer and pesticide application, limit water use, and avoid land disturbance can help alleviate the potential impacts of a major contributor of nonpoint source pollution in residential communities.

Because landscaping and lawn care are such common practices, education programs for both residents and lawn care professionals on reducing storm water impacts of these practices are an excellent way to improve local water quality. Education programs that seek to change the impacts of fertilizer, pesticide, and herbicide use on receiving water quality should first consider creating training programs for those involved in the lawn care industry. Nationally, lawn care companies are used by 7 to 50 percent of consumers, depending on household income and lot size. Lawn care companies can exercise considerable authority over which practices are applied to the lawns they tend, as long as they still produce a sharp looking lawn. For example, 94 percent of lawn care companies reported that they had authority to change practices, and about 60 percent of their customers were "somewhat receptive to the new idea" according to a Florida study (Israel et al. 1995). It is important to make residents aware of the environmental options within lawn care services so they can insist that lawn care professionals use them.

Training for employees of lawn and garden centers is another important tool in spreading the message regarding lawn care and pollution control. Study after study indicated that product labels and store attendants are the primary and almost exclusive source of lawn care information for the average consumer who takes care of his or her own lawn. Often the key strategy to implementing a program like this is to substitute watershed friendly products for those that are not, and to offer training for the store attendants to pass on to consumers at the point of sale on how to use, and perhaps more importantly, how not to abuse or overuse such products.

The overriding public desire for green lawns is probably the biggest impediment to limiting pollution from this source. For example, when residents were asked their opinions on over thirty statements about lawns in a Michigan survey, the most favorable overall response was to the statement "a green attractive lawn is an important asset in a neighborhood" (De Young 1997). Nationally, homeowners spend about 27 billion dollars each year to maintain their own yard or pay someone else to do it (PLCAA 1999). Convincing residents that a nice green lawn can be achieved without using large amounts of chemicals and fertilizers is difficult when conventional lawn care techniques are often seen as more effective, less-time consuming, and more convenient.

A recent CWP survey of 50 nutrient education programs provides a number of tips to program managers on making outreach programs more effective. **Table 4-5** provides some of these tips that appear to work best at relaying pollution prevention messages and could be applied to the Peruque Creek watershed.

Table 4-5
Tips for Creating More Effective Lawn Care Outreach Programs

Tip 1: Develop a stronger connection between the yard, the street, the storm, and the stream Outreach techniques should continually stress the link between lawn care and undesirable water quality it helps to create (e.g. algae blooms, sedimentation)
Tip 2: Form regional media campaigns Since most communities operate on small budgets, they should consider pooling together to develop regional media campaigns that can use the outreach techniques that are proven to reach and influence residents. In particular, watershed-based campaigns allow communities to hire the professionals needed to create and deliver a strong message through the media, such as radio, television, and print, to reach a wider segment of the population. It is important to keep in mind that since no single outreach technique will be recalled by more than 30% of the population at large, several different outreach techniques will be needed in an effective media campaign.
Tip 3: Use television wisely Television is the most influential medium for influencing the public, but careful choices need to be made on the form of television that is used. The CWP survey found that community cable access channels are much less effective than commercial or public television channels. Program managers should consider using cable network channels targeted for specific audiences, and develop thematic shows that capture the interest of the home, garden, and lawn crowd (e.g., shows along the lines of "Gardening by the Yard"). Well-produced public service announcements on commercial television are also a sensible investment.
Tip 4: Keep messages simple and funny Watershed education should not be preachy, complex, or depressing. Indeed, the most effective outreach techniques combine a simple and direct message with a dash of humor.
Tip 5: Make information packets small, slick, and durable Educators continually struggle about how to impart the detailed information to residents on how to practice good lawn care behavior, without losing their interest. The trick is to avoid a ponderous and boring handbook that looks great to a bureaucrat but ends up lining a birdcage. One solution is to create small, colorful, and durable packets that contain the key essentials about lawn care behaviors, and direct contact information to get better advice. These packets can be stuck on the refrigerator, the kitchen drawer or the workbench for handy reference when the impulse for better lawn care behavior strikes.
Tip 6: Understand the demographics of your watershed Knowing the unique demographics of a watershed allows a program manager to determine what outreach techniques are likely to work for that particular area. Watershed managers should consider more direct channels to send watershed messages to reach particular groups such as through church leaders or ethnic specific newspapers and television channels.

The effectiveness of pollution prevention programs designed to educate residents on lawn care and landscaping practices have not been well documented to date. However, the need for such programs is evident. Source area monitoring in Marquette, Michigan found that nitrogen and phosphorus concentrations in residential lawn runoff were 5 to 10 times higher than any other source area (CWP 1999a). This confirms that earlier Wisconsin research findings that residential lawns yielded the highest phosphorus concentrations of twelve urban pollutant sources examined (Bannerman et al. 1993).

The cost of creating and maintaining a program that addresses lawn care and landscaping practices and water quality varies depending on the intensity of the effort and what outreach techniques are selected. Media campaigns often require a greater amount of money to create, but are also more likely to reach the largest portion of the community. Intensive training campaigns may not require as large a creation cost, but often require more staff time. Production costs for materials such as flyers and brochures is often inexpensive ($0.10 to $0.50 per brochure), and soil kits and testing may be done through a local university to reduce expense. Many cooperative extension offices have already produced materials on lawn care and landscaping techniques to protect water quality and program managers may save money by utilizing these available resources.

4.2.4 Automobile Maintenance

The automotive repair industry is the leader in number of generators and the amount of total waste produced for small quantity generators of hazardous waste in the United States (USEPA 1985). Therefore, it is important to consider the topic of automotive maintenance in a comprehensive public education program for the Peruque Creek watershed. Common activities at maintenance shops (**Figure 4-9**) that generate this waste include the cleaning of parts, changing of vehicle fluids, and replacement and repair of equipment. These activities are also performed by residents at home in their driveway in the course of normal vehicle care. Since the use of automobiles is not limited by geographic or climatic conditions, maintenance facilities are present nationwide, including the Peruque Creek watershed.

Figure 4-9 - Automotive Repair Shop

Dumping automotive fluids down storm drains can be a major water quality problem, since only a few quarts of oil or a few gallons of antifreeze can have a major impact on streams and wetlands during low flow conditions. Historically, the major culprit has been the backyard mechanic who changes his or her own automotive fluids. The number of backyard mechanics who change the oil and antifreeze in their cars, however, has been dropping steadily in recent decades. With the advent of the $20 oil change special, it is reported that only about 30 percent of car owners change their own oil or antifreeze anymore (CWP 1999a).

Automotive maintenance facilities are considered to be storm water “hotspots” where significant loads of hydrocarbons, trace metals, and other pollutants can be produced that can affect the quality of storm water runoff. Some of the types of waste generated at automobile maintenance facilities and by residents performing their own car maintenance at home include:

- Solvents (paints and paint thinners)
- Brake fluid and brake lining
- Batteries
- Motor oils
- Fuels (gasoline, diesel, kerosene)
- Lubricating grease

The most effective way to minimize the impacts of automotive maintenance generated waste is by avoiding its production in the first place. Pollution prevention programs seeking to reduce liquid discharges to sewer and storm drains from automotive maintenance should stress techniques that allow facilities to run a dry shop. Among the suggestions for creating a dry operation:

- Do not use water for clean up whenever possible and clean up spills immediately
- Seal floor drains that are connected to the sanitary sewer
- Hire a solvent service to supply parts cleaning materials, and to collect the spent solvent

Other methods are available to help prevent or reduce the discharge of pollutants from vehicle maintenance. **Table 4-6** lists some of the common suggestions that can help reduce vehicle maintenance and repair impacts. Many of these practices apply both to business owners and to residents who maintain their own vehicles.

Table 4-6
Recommendations for Reducing the Storm Water Impacts of Automotive Maintenance

Method	Suggested Activities
Water Reduction	▪ The number of solvents used should be kept to a minimum to make recycling easier and to reduce hazardous waste cost ▪ Do all liquid cleaning at a centralized station to ensure solvents and residues stay in one area ▪ Locate drip pans and draining boards to direct solvents back into solvent sinks or holding tanks for reuse
Using Safer Alternatives	▪ Use non-hazardous cleaners when possible ▪ Replace chlorinated organic solvents with non-chlorinated ones like kerosene or mineral spirits ▪ Recycled products such as engine oil, transmission fluid, antifreeze, and hydraulic fluid can be purchased if available to support the market of recycled products
Spill Clean Up	▪ Use as little water as possible to clean spills, leaks, and drips ▪ Rags should be used to clean small spills, dry absorbent material for larger spills, and mop for general cleanup
Good Housekeeping	▪ Employee training and public outreach are necessary to reinforce proper disposal practices ▪ Conduct maintenance work such as fluid changes indoors ▪ Update facility schematics to accurately reflect all plumbing connections ▪ Parked vehicles should be monitored closely for leaks and pans placed under any leaks to collect the fluids for proper disposal ▪ Promptly transfer used fluids to recycling drums or hazardous waste containers ▪ Do not pour liquid waste down floor drains, sinks, or outdoor storm drain inlets ▪ Obtain and use drain mats to cover drains in the event of a spill ▪ Store cracked batteries in leakproof secondary containers
Parts Cleaning	▪ Use detergent based or water based cleaning systems instead of organic solvent degreasers ▪ Steam cleaning and pressure washing may be used instead of solvent parts cleaning ▪ Wastewater generated from steam cleaning should be discharged to a pretreatment structure

4.2.5 Car Washing

Car washing is a common routine for residents and a popular way for organizations such as scout troops, schools, and sports teams to raise funds. This activity is not limited by geographic region, but its impact on water quality is greatest in urban areas of Peruque Creek. Few pollution prevention programs incorporate proper car washing practices as part of the overall message to residents on ways to reduce nonpoint source pollution. Therefore, it is important to consider car washing in a comprehensive public education program for the Peruque Creek watershed. This pollution management measure involves educating the general public on the water quality impacts of the outdoor washing of automobiles and how to avoid allowing polluted runoff to enter the storm drain system. Outdoor car washing has potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions, as the detergent-rich water used to wash automobiles flows down the street and into storm drains. Storm drain stenciling programs emphasize the connection between the storm drain and runoff and help reinforce that car washing activities can have an effect on local water quality. The development of a prevention program to reduce the impact of car wash runoff includes outreach on management practices to reduce discharges to storm drains. Some of these management practices include:

- Using a commercial carwash
- Washing your car on gravel, grass or other permeable surfaces
- Blocking off storm drains during charity car wash events or using an insert to catch wash water
- Pumping soapy water from car washes into sanitary sewer drains
- If pumping into a drain is not feasible, pumping car wash water onto grass or landscaping to provide filtration
- Using hoses with nozzles that automatically turn off when left unattended
- Using only biodegradable soaps

In the Pacific Northwest, outreach programs provide materials to charity car wash organizers to prevent car wash water from entering storm drains. These "water friendly" car wash kits are provided free of charge to charity organizers along with draining and educational videos on planning an environmentally friendly car wash. Two types of equipment are available for charity organizations to borrow: a catch-basin insert with a sump pump or a vacuum/boom device known as a Bubble Buster (Kitsap County 1999). Both devices capture wash water runoff, allowing it to be pumped to either a sanitary sewer or a vegetative area for treatment.

For businesses, good housekeeping practices can minimize the risk of contamination from wash water discharges. **Table 4-7** gives some general best management practices that those businesses that have their own vehicle washing facilities can incorporate to control the water quality impacts of wash water discharges.

The biggest limitation to implementing residential car wash best management practices may be the lack of knowledge regarding the impacts of polluted runoff. Many people do not associate the effects of their vehicle washing activities with local water quality, and may be unaware that discharges that enter storm drains are not treated at plants before being discharged into local waters.

The effectiveness of car washing best management practices at reducing nonpoint source pollutant loads has yet to be measured accurately. It is often difficult to

Table 4-7
Storm Water Management Practices for Car Washing Facilities

▪ Have all vehicle washing done in areas designed to collect and hold the wash and rinse water or effluent generated. Recycle, collect, or treat wash water effluent prior to discharge to the sanitary sewer system.
▪ Pressure cleaning and steam cleaning should be done off-site to avoid generating runoff with high pollutant concentrations. If done on-site, no pressure cleaning and sream cleaning should be done in areas designated as wellhead protection areas for public water safety.
▪ Map on-site storm drain locations to avoid discharges to the storm drain system.
▪ Immediately contain and treat spills

determine the exact impact of a particular pollution prevention measure at reducing pollutant loading. While not much is known about the water quality of car wash water, it is very clear that car washing is a common watershed behavior. Three surveys have asked residents where and how frequently they wash their vehicles (**Table 4-8**).

Table 4-8
Summary of Car Washing Surveys

Study	Car Washing Behavior
Smith 1996 Maryland	60% washed car more than once a month
Pellegrin 1998 California	73% washed their own cars 73% report that wash water drains to pavement
Hardwick 1997 Washington	56% washed their own cars 44% used commercial car wash 91% report that wash water drains to pavement 56% washed car more than once a month 50% would shift if given discounts or free commercial car washes

Residents are typically unaware of the water quality consequences of car washing, and do not understand the chemical content of the soaps and detergents they use. Car washing is a difficult watershed behavior to change since it is often hard to define a better alternative. However, as with all pollution prevention measures, the reduction of pollutant loads from outdoor car washing activities are bound to have a positive effect on storm water quality

Most car washing best management practices are inexpensive, and rely on more good housekeeping practices (where vehicles are washed, planning for collection of wash water) than on expensive technology. However, the construction of a specialized area for vehicle washing can be expensive for businesses. Also, for facilities that cannot recycle their wash water, the cost of pretreating wash water through either structural practices or planning for collection and hauling of contaminated water to sewage treatment plants can represent a cost limitation.

4.2.6 Animal Waste Collection

Figure 4-10 - Pet Waste

Animal waste collection as a pollution control source involves using a combination of educational outreach and enforcement to encourage residents to clean up after their pets. Municipal enforcement for pet waste cleanup will be discussed in Section 4.3. The presence of pet waste in storm water runoff has a number of implications for urban stream water quality with perhaps the greatest impact from fecal bacteria. According to recent research, non-human waste represents a significant source of bacterial contamination in urban watersheds. The bacteria can pose health risks to humans and other animals, and result in the spread of disease. Public education on animal waste collection as a pollution control source is necessary in the Peruque Creek watershed. Residents need to be educated on the implications of their pet's waste on the stream water quality (**Figure 4-10**).

Residents seem to be of two minds when it comes to dog waste. While a large majority agrees that dog waste can be a water quality problem, they generally rank it as the least important local water quality problem. This finding strongly suggests the need to dramatically improve watershed education efforts to increase public recognition about the water quality and health consequences of dog waste.

Public education programs are a way to encourage pet waste removal. Often pet waste messages are incorporated into a larger non-point source message relaying the effects of pollution on local water quality. Brochures and public service announcements describe proper pet waste disposal techniques and try to create a storm drain water quality link between pet waste and runoff. Signs in public parks and the provision of receptacles for pet waste also encourage cleanup.

The reluctance of many residents to handle dog waste is the biggest limitation to controlling pet waste. According to a Chesapeake Bay survey, 44 percent of dog walkers who do not pick up indicated they would still refuse to pick up even if confronted by complaints from neighbors, threatened with fines, or provided more sanitary and convenient options for retrieving and disposing of dog waste. **Table 4-9** provides factors that compel residents to pick up after their dog, along with some rationalizations for not doing so.

The cost of animal waste collection programs will vary depending on the intensity of the effort and the paths chosen to control pet waste. The most popular way is through an ordinance, but managers must consider the cost of the enforcement, including staff and equipment requirements. The type of materials produced and the method of distribution selected determine public education program costs. Signs in

Table 4-9
Dog Owners' Rationale for Picking Up or Not Picking Up After Their Dog
(HGIC 1996)

Reasons for not picking it up:	**Reasons for picking up:**
• Because it eventually goes away • Just because • Too much work • On edge of my property • It's in my yard • It's in the woods • Not prepared • No reason • Small dogs, small waste • Use as fertilizer • Sanitary reasons • Own a cat or other kind of pet	• It's the law • Environmental reasons • Hygiene/health reasons • Neighborhood courtesy • It should be done • Keep the yard clean

parks may initially have a higher cost than printed materials, but can last for many years. Signs may also be more effective, since they act as on-site reminders to dog owners to clean up in parks.

4.2.7 Restorative Redevelopment

The concept of restorative redevelopment as an alternative land use control measure was discussed in detail in Section 4.1.3 of the watershed management plan. Here the management practice will be summarized briefly as an important element of a comprehensive public education program. Some of the older residential, commercial, and industrial properties in the Peruque Creek watershed have deteriorated and may need to be restored, revitalized, or reconstructed. As redevelopment progresses, buildings will be renovated and reconstructed, driveways and parking areas will be repaved, and patios and sidewalks will be replaced. The technical key for restoring and revitalizing urban watersheds is to remove storm water from sewers and reintroduce it to the soil and vegetation, and reduce the area of impervious surfaces within the watershed. Public education programs can be used to encourage home and business owners to apply the principals of restorative redevelopment whenever existing facilities wear out and need to be replaced or revitalized. These principals and alternative applications for the Peruque Creek watershed were previously described in detail in Section 4.1.3.

4.2.8 Vegetation Controls and Tree Planting

Vegetation control typically involves a combination of chemical (herbicide) application and mechanical methods. Mechanical methods are discussed herein, vegetation control by herbicides were addressed previously (Landscaping and Lawn Care). Public education of mechanical vegetation control includes properly collecting and disposing of clippings, cutting techniques, leaving existing vegetation, and planting new trees and vegetation.

Clippings and cuttings are the primary waste produced by mowing and trimming. Clippings and cuttings are almost exclusively leaf and woody materials. However, in some cases, litter may be intermingled with the clippings. Clippings/cuttings carried into the storm water system and receiving streams can degrade water quality in several ways. Suspended solids will increase causing turbidity problems. Since most of the constituents are organic, the biological oxygen demand will increase causing a lowering of the available oxygen to plant and aquatic animal life. In areas like Peruque Creek where litter and other solid waste pollution exist, toxic materials may be released into receiving streams with a resulting degradation of water quality. For the most part, the solution to this problem involves behavior modification through education. Awareness of the problem is the first step toward the solution.

Once vegetative waste is generated, the main concern is to avoid transport of clippings/cuttings to receiving water bodies. Often, people will discover that clippings/cuttings can easily be disposed of by dumping them down a nearby ravine or on the slope of a creek or drainage channel. This practice introduces a large quantity of decaying organic matter into the storm water collection system that is subsequently carried to receiving streams during the next rainfall event. Disposing of cuttings/clippings in and around catch basins should also be avoided by using either bagging equipment or manually picking up the material.

Mowing should only be performed at optimal times. Mowing should not be performed if significant rain events are predicted. Also, the use of mulching mowers may be recommended for certain areas. Mulching mowers should be encouraged for homeowners in flat areas. Mulching mowers have the added benefit of reducing fertilizer demand through reuse of organic material.

Other techniques are available to supplement existing biodiversity and density as well. One approach is through maintaining existing vegetation and planting new vegetation. This can be accomplished from the education of homeowners and the formation of citizen volunteer groups.

Firstly, the easiest and least expensive measure is to leave existing vegetation in place. Native vegetation typically requires much less maintenance than introduced vegetation. However, introducing new vegetation is a watershed priority as trees, shrubs, and grasses transpire rainfall through their leaves, consume carbon dioxide, release oxygen, and moderate urban temperatures. Many ground covers can thrive where grass does not. These ground covers provide aesthetically pleasing, innovative landscapes that are adaptable to the environment. Alternative ground covers which require little maintenance and are drought tolerant include native woodland species, perennial or self-sowing wildflowers, and deciduous or evergreen shrubs.

Converting managed turf to native vegetation should be a goal in both the public and private sectors of the watershed. For residential yards, a homeowner can encourage a portion of his/her property to seed in with native species, particularly if there is an adjacent wooded or meadow area with desirable vegetation. Over years, many different plants will colonize such an area, becoming even more attractive with time. The natural zone can be supplemented, or even created, with carefully selected plantings including trees, wildflowers, and different warm-season grasses. In addition, the notion that manicured lawns are more attractive than natural landscapes can be altered with education and examples. For example, allowing nature to landscape a portion of a residential yard that is visible from a heavily traveled road is an effective method of demonstrating the attractiveness of a native landscape.

Alternate landscaping and the introduction of new vegetation can be applied to any land use of any size area. Community awareness through programs, seminars, and field trips can be arranged to emphasize the advantages of natural public areas. Citizens will realize the beauty of a natural setting if exposed to one on a regular basis. Encouraging volunteer community groups to plant native vegetation in public areas, such as parklands, can be a workable goal. These natural areas should be adjacent to watercourses in order to act as a storm water filter and the final product is a landscape within floodplain areas with varying color and texture that do not require intensive labor or pesticide input. In addition, new and existing vegetation should be maintained regularly. Undesirable plants such as Japanese knotweed, ragweed, poison ivy, and multiflora rose should be removed to the greatest extent practical.

4.3 Municipal Measures

The quality of the waters in a developing watershed is influenced by storm water runoff, deicing salts, and other impacts of watershed urbanization. As was discussed previously in Section 4.2, public education on the risks of public safety and water quality resulting from poor watershed ethic is a vital element for successful watershed protection. Municipal coordination and enforcement are other alternative ingredients for successful watershed management and protection.

Municipalities have many tools at their disposal to address environmental degradation in urban areas. In Peruque Creek, the stream will continue to be subject to the wide variety of problems typically related to urban runoff if action is not taken on the municipal level. In order to manage and control these problems related to urban runoff, municipal management programs should be considered in the following areas:

- Storm Inlet Maintenance
- Street Sweeping
- Pet Waste Ordinances and Leash Laws
- Household Hazardous Waste Collection
- Pest Control (control of fertilizers, pesticides, and herbicides used on public land)
- Bridge and Roadway Maintenance

- Vegetation Controls

4.3.1 Storm Inlet Maintenance

Implementing a comprehensive inspection and maintenance program for storm inlets can be an effective nonstructural management measure. Catch basins and storm inlets are the points of input to the municipal storm drain system. They typically include a grate or curb inlet where storm water enters and they may include a sump to capture sediment, debris and associated pollutants. The performance of these devices at removing sediment and other pollutants depends on routine maintenance to retain the storage available in the sump to capture sediment.

Storm inlets have three major limitations in their potential to improve water quality in the Peruque Creek watershed, including:

- Even carefully operated and maintained storm inlets cannot remove pollutants as well as other alternative storm water treatment practices such as wet ponds, sand filters, and storm water wetlands.

- Unless frequently maintained, storm inlets can become a source of pollutants through re-suspension.

- Storm inlets cannot effectively remove soluble pollutants or fine particles.

Inspection and maintenance of storm inlets includes checking the quantities of trapped gravel and sediment and removal of sediment using a vacuum truck. Operators need to be properly trained in storm inlet maintenance. Maintenance should include keeping a log of the amount of sediment and/or trash collected (**Figure 4-11**), and the date of removal. Some cities have incorporated the use of Geographic Information Systems (GIS) to track sediment collection, and to optimize future cleaning efforts.

Figure 4-11 - Typical Storm Inlet in New Residential Development in Peruque Creek Watershed

At a minimum, storm inlets should be cleaned once or twice per year (Aronson et al. 1983). Two studies suggest that increasing the frequency of maintenance can improve the performance of storm inlets, particularly in industrial or commercial areas. However, the cost of increased operation and maintenance needs to be weighed against the improved pollutant removal and the minimal industrial land use areas in the Peruque Creek watershed.

4.3.2 Street Sweeping

Implementing a street sweeping program can be an effective municipal management measure to improve water quality in the Peruque Creek watershed. Street sweeping often is practiced in most urban areas as an aesthetic practice to remove sediment buildup, debris, and litter from curb gutters. In colder climates, street sweeping is used during the spring snowmelt to reduce pollutant loads from road salt and to reduce sand export to receiving waters. Seventy percent of cold climate storm water experts recommend street sweeping during the spring snowmelt as a pollution prevention measure (Caraco and Claytor 1997). The frequency and intensity of rainfall for a region are key variables in determining how streets need to be swept to obtain a desired removal efficiency. Other factors that affect a street sweeper's ability to reduce nonpoint pollution include the condition of the street, its geographical location, the operator's skill, the presence of parked cars, and the amount of impervious area devoted to roadways.

Street cleaning practices are designed to remove sediment, debris, litter, and other pollutants from road and parking lot surfaces that are a potential source of pollution impacting urban waterways (Bannerman 1999). Although older performance monitoring studies for the Nationwide Urban Runoff Program (NURP) indicted that street sweeping was not very effective in reducing pollutant loads (USEPA 1983), recent improvements in street sweeper technology have enhanced the ability of present day machines to pick up the fine grained sediment particles that carry a substantial portion of the storm water pollutant load. Many of today's sweepers can now significantly reduce the amount of street dirt entering streams and rivers, some by significant amounts (Runoff Report 1998).

Figure 4-12 - Traditional Mechanical Street Sweeper

Arguably the most essential factor in using street sweeping as a pollutant removal practice is to be sure to use the most sophisticated sweepers available. Today, communities have a choice in three basic sweeping technologies to clean their urban streets:

- Traditional mechanical sweepers that utilize a broom and mechanical belt (**Figure 4-12**)
- Vacuum-assisted sweepers
- Regenerative-air sweepers

Innovations in sweeper technology have improved the performance of these machines. The vacuum-assisted dry sweeper has the ability to pick up a very high percentage of even the finest sediment particles under dry pavement conditions and, unlike other sweepers, may work effectively in wet or frozen conditions. Regenerative air sweepers blast air onto the pavement surface to loosen particles and quickly vacuum them into a hopper. By using the most sophisticated sweepers in areas with the highest pollutant loads, greater reductions in sediment and accompanied pollutants can be realized.

A benefit of high-efficiency street sweeping is that by capturing pollutants *before* they are made soluble by rainwater, the need for storm water treatment practices may be reduced. Storm water treatment practices, such as filtering systems, can be very costly when compared to collecting pollutants before they become soluble. Street sweepers that can show a significant level of sediment removal efficiency may prove to be more cost-effective than certain storm water treatment practices, especially in more urbanized areas with higher areas of paving.

The frequency of and location of street sweeping is another consideration for any program. How often and what roads to sweep are determined by the program budget and the level of pollutant removal the program wishes to achieve. Computer modeling in the Pacific Northwest suggest that from the standpoint of pollutant removal, the optimum sweeping frequency appears to be once every week or two (Claytor 1999). More frequent sweeping operations yielded only a small increment in additional removal. The model also suggests that somewhat higher removal could be obtained on residential streets as opposed to more heavily traveled arterial roads.

Another important aspect of street sweeping programs is the ability to regulate parking. The ability to impose parking regulations in densely populated areas and on heavily traveled roads is essential.

Sweeping of parking lots may also be employed at commercial and industrial sites. This sweeping involves using brooms to remove small quantities of dry chemicals and solids from areas that are exposed to rainfall or storm water runoff. While the effectiveness of this practice at pollutant removal is unknown, the sweeping and proper disposal of materials is a reasonably inexpensive method of pollution prevention that requires no special training or equipment.

The largest expenditures for street sweeping programs are in staffing and equipment. The capital cost for a conventional street sweeper is between $60,000 and $120,000. The cost for newer technologies is higher than that, with prices approaching $180,000. The average useful life of a conventional sweeper is about four years, and programs must budget for equipment replacement. Sweeping frequencies will determine equipment life, so programs that sweep more often should expect to have a higher cost of replacement. The potential inability to restrict parking in urban areas may present another limitation. Additional possible limitations include the need for training for sweeper operators; the inability of current sweeper technology to remove oil and grease; and the lack of solid evidence regarding the level of pollutant removal that can be expected. Proper disposal of swept materials may also be a limitation in some instances.

4.3.3 Pet Waste Ordinances

Animal waste collection ordinances can be an effective pollutant source control management tool. The alternative involves using a combination of educational outreach and enforcement to encourage residents to clean up after their pets (public education on animal waste collection was discussed in Section 4.2.6). The presence of pet waste in storm water runoff has a number of implications for urban stream water quality with perhaps the greatest impact from fecal bacteria. The bacteria can pose health risks to humans and other animals, and result in the spread of disease. Pet waste ordinances need to be implemented, posted, and enforced to reduce (if not eliminate) pet waste from affecting the stream water quality.

The reluctance of dog owners to handing dog wastes is the biggest limitation to controlling pet waste. This strong resistance to handling dog wastes suggests that an alternative message may be necessary.

Animal waste collection programs use awareness and education, signs, and pet waste control ordinances to alert residences to the proper disposal techniques for pet droppings. Implementing programs to control pet waste typically use "pooper-scooper" ordinances to regulate pet waste cleanup. These ordinances require the removal and proper disposal of pet waste from public areas and other people's property before the dog owner leaves the immediate area. Often a fine is associated with failure to perform this act as a way to encourage compliance. Some ordinances also include a requirement that pet owners remove pet waste from their own property within a prescribed time frame.

In some parts of the country, the concept of parks or portions of parks established specifically for urban dog owners has gained in popularity. With provisions for proper disposal techniques for dog feces, these parks may represent another option for protecting local water quality. Another option might be to enforce the practice of rudimentary manure management by training dogs to use areas that are not hydraulically connected to the stream. Enforcing leash laws can help in preventing dogs from using areas that are not hydraulically connected to the stream.

The pollutant removal of abilities of pet waste collection programs has never been quantified although there is ample evidence that programs such as these are necessary. For example, in the Four Mile Run watershed in Northern Virginia, a dog population of 11,400 is estimated to contribute about 5,000 pounds of solid waste every day and has been identified as a major contributor of bacteria to the stream. Approximately 500 fecal coliform samples have been taken from Four Mile Run and its tributaries since 1990, and about 50 percent of these samples have been over Virginia water quality standards for fecal coliform bacteria (NVPDC 1998).

The cost of animal waste collection programs will vary depending on the intensity of the effort and the paths chosen to control pet waste. The most popular is through an ordinance, but managers must consider the cost of enforcement, including staff and equipment requirements.

4.3.4 Household Hazardous Waste Collection

A HHW collection program was considered as an alternative municipal management measure for the Peruque Creek watershed. HHWs are those wastes produced in households (**Figure 4-13)** that are hazardous in nature, but are not regulated as hazardous waste, under federal and state laws. For example, studies in Pennsylvania have shown that each person produces an average of four pounds of HHW each year. Such consumer waste products, if carelessly managed can, and frequently do, create environmental and public health hazards. Improper disposal of HHW in Peruque Creek can affect stream water quality as wastes may be improperly discarded into municipal storm inlets or dumped down sewer drains during storm events.

Figure 4-13 - Household Hazardous Waste

The best method of managing HHW is to prevent its generation in the first place. This involves encouraging residents to select the least toxic item "to do the job" and to buy only the minimum amounts necessary. Buying in large quantities is not a bargain if half of it has to be discarded. If the material is still useable (i.e. has not been damaged/shelf life expired, etc.) residents should be encouraged to check with friends and neighbors to see if they might be able to use it. Also, community groups such as Little League, Habitat for Humanity, etc. should be checked with to see if they are able to use the product.

If the material is not useable and/or if such "outlets" are not available, it should be taken to a community HHW Collection Program. Such programs ensure that the HHW is recycled or, otherwise, managed, in an environmentally preferable way, under the hazardous waste provisions of the law. In addition, used motor oils can be taken to a used oil collection site. Also, spent lead acid (automotive) batteries can be returned to sellers.

The University of Missouri Outreach and Extension, Office of Waste Management encourages local governments and private organizations to sponsor collection events for HHW. Financial and technical assistance are available for programs that register. These programs provide sites for residents to drop off their HHW. The materials at these sites are then reused, recycled, and, when necessary, disposed of at a permitted hazardous waste facilities.

There are thousands of consumer chemical products that may qualify for inclusion in a collection event. However, in order to reduce operational costs and maximize the effectiveness of collection events, a waste targeting protocol is recommended. It is also recommended that all participants be pre-registered, at which time the nature of their waste can be discussed and a decision made on which items should not be brought to the collection event. The following HHW categories should be targeted for collection.

Corrosive Materials (drain cleaners, rust removers, muriatic acid, and oven cleaners)

Highly Flammable Materials (gasoline, gasoline/oil mixtures, kerosene, fuel oil, lighter fluids, oil-based paints, and paint thinners)

Highly Toxic Materials (carbon tetrachloride, benzene, cyanide compounds, lead arsenate, thallium sulfate, strychnine, parathion, and mirex/kepone)

Strong Oxidizers (chlorinated pool chemicals, sodium hypochlorite, and various peroxides)

Air/Water Quality Hazards (rechargeable nickel cadmium household batteries, mercury-containing batteries, thermostats, thermometers, and lead acid batteries)

Wildlife Hazards (old chlorinated pesticides such as DDT, chlordane, dieldrin, heptachlor, etc. and compound containing heavy metals)

Unknowns (unidentified materials such as those with no ingredient information or signal words on the label that could present a potential threat to human health and the environment)

The following are tips to help make the facilitation of a community collection event an efficient and successful one:

- Educate the public as to the scope of a collection event. Many chemicals that show up at a collection event are the result of the incomplete use of the chemicals.

- Contact other programs. There is no substitute for first hand experience. The experience of similar programs in nearby areas may help in making more accurate estimates regarding the amount of waste to be expected.

- Anticipate high costs with these programs. The major costs will be for contracted services involving the classification, packing, transportation, and management of the collected hazardous waste materials. Generally costs average 30 to 80 cents per pound of hazardous waste but may run as high as $1.00 per pound.

- Take advantage of the available funding. Contractors will be reluctant to prepare bid responses for sponsoring agencies that do not appear to be on sound financial footing.

- Provide special packaging and transportation instructions to all participants to ensure the safe transportation of all materials to the collection site.

- Expect to receive more participants and waste than may be initially anticipated.

- Take steps to reduce the amount of collected HHW requiring disposal. Waste motor oil, if collected, should always be recycled. Organizations such as little leagues, boy/girl scouts, and other community groups often collect old paint. Restrict the materials that truly need to be disposed of as a hazardous waste. Materials that do not qualify as hazardous may not need to be collected in the first place and, if collected, may possibly be disposed of as municipal waste.

4.3.5 Pest Control - Control of Pesticides and Herbicides Used on Public Land

Another alternative watershed management measure would be to implement a municipal program to control the use and misuse of pesticides and herbicides. The major sources of pesticides in urban streams are applications of products designed to kill insects and weeds in the lawn and garden. It has been estimated that an average acre of a well-maintained urban lawn receives an annual input of five to seven pounds of pesticides (Schueler 1995). Pesticide prevention programs try to limit the adverse impacts of insecticides and herbicides by providing information on alternative pest control techniques other than chemicals or explaining how to determine the correct dosages needed to manage pests. The use of products designed to kill insects and weeds in the lawn and garden cannot be enforced on private property. However, control over the use of these products can be regulated in public areas under municipal maintenance (e.g. parks) and schools.

There are two parallel elements to a municipal pest control program. The first element involves educating residents and businesses on alternatives to pesticide use and this topic was previously discussed in Section 4.2 of the watershed management plan. The second element involves implementing proper application and storage techniques for municipal parklands and public schools. The presence of pesticides in storm water runoff has a direct impact on the health of aquatic organisms and can present a threat to humans through contamination of drinking water supplies. The pesticides of greatest concern are insecticides, such as diazinon and chloropyrifos, (CWP 1999b and Schueler 1995) that can be harmful to aquatic life even at very low levels.

The USEPA estimates that nearly 70 million pounds of active pesticide ingredients are applied to urban lawns each year. **Table 4-10** compares surveys on residential pesticide use in eleven different areas of the country, broken down by insecticide and herbicide use. At first glance, it appears that pesticide application rates vary greatly,

Table 4-10
A comparison of Eleven Surveys of Residential Insecticide and Weed Killer Use

Study	Number of Respondents	Percent Using Insecticides	Percent Using Herbicides
Chesapeake Bay Swann 1999	656	21%	- -
Maryland Kroll and Murphy 1994	403	42%	32%
Virginia Aveni 1998	100	66%	- -
Maryland Smith *et al.* 1994	100	23%	n/a
Minnesota Morris and Traxler 1996	981	- -	75%
Michigan De Young 1997	432	40%	59%
Minnesota Dindorf 1992	136	- -	76%
Wisconsin Kroupa 1995	204	17%	24% **
Florida Knox *et al*. 1995	659	83%	- -
Texas NSR 1998	350	87%	- -
California Scanlin and Cooper 1997	600	50%	- -

** Note difference in self reported herbicide use and those that use a weed and feed product (herbicide combined with fertilizer)

ranging from a low of 17 percent to a high of 87 percent. Some patterns do emerge, however. For example, insecticides tend to be applied more widely in warm weather climates where insect control is a year round problem (such as Texas, California, and Florida). Anywhere from 50 to 90 percent of residents reported that they had applied insecticides in the last year in warm-weather areas. This can be compared to 20 to 50 percent levels of insecticide use reported in colder regions where hard winters can help keep insects in check. In contrast, herbicide application rates tend to be higher in cold weather climates to kill the weeds that arrive with the onset of spring (60 to 75 percent in the Michigan, Wisconsin and Minnesota surveys).

An Integrated Pest Management (IPM) program is a municipal watershed management element that encourages the use of alternatives to chemical pesticides on public land. IPM reflects a holistic approach to pest control that examines the interrelationship between soil, water, air, nutrients, insects, diseases, landscape design, weeds, animals, weather, and cultural practices to select an appropriate pest management plan. The goal of an IPM program is not to eliminate pests but to manage them to an acceptable level while avoiding disruptions to the environment. An IPM program incorporates preventative practices in combination with non-chemical and chemical pest controls to minimize the use of pesticides and promote natural control of pest species. Three different non-chemical pest control practices - biological (good bugs that eat pests), cultural (handpicking of pests, removal of diseased plants, etc) and mechanical (zappers, paper collars, etc) are used to limit the need for chemicals. In those instances when pesticides are required, programs encourage the use of less toxic products such as insecticidal soaps. The development of higher tolerance levels for certain weed species is a central concept of IPM programs for reducing herbicide use.

The public perception that no effective alternative to pesticide use exists is probably the greatest limitation to this alternative management measure. Surveys tell us that the public has a reasonably good understanding about the potential environmental dangers of pesticides. Several surveys indicate that residents do understand environmental concerns about pesticides, and consistently rank them as the leading cause of pollution in the neighborhood (Elgin DDB 1996). Even so, pesticide use still remains high in many urban areas. The time required for homeowners to learn more about alternative pest control techniques may also limit program effectiveness. Many residents prefer the ease of just spraying a chemical on their lawns to other pest control techniques they perceive as more time intensive and less reliable.

The IPM practices can be enforced for municipal parklands and schools to limit pollutants washed off the ground during storm events. The parks in Peruque Creek tend to be located near surrounding streams causing the potential for pest control pollutants to enter the stream to be great. An example of successful use of IPM is the Grounds Maintenance Program for the City of Eugene, Oregon. This program was started in the early 1980s and includes all the city public parks and recreation areas. The city uses a variety of IPM methods, including water blasting to remove aphids, insecticidal soaps and limited use of pesticides. The city has also adopted higher tolerance levels for certain weed and pest species that reduces the need to apply pesticides and herbicides.

Since the programs inception, pesticide usage by the City of Eugene has dropped by more than 75 percent (Lehner *et al*. 1999). No exact cost savings have been calculated from the use of the IPM program, but the city turf and grounds supervisor is convinced that it saves money and has little citizen opposition. A similar program could be implemented for pest control in the public park and recreation areas of the Peruque Creek watershed.

The cost of educating residents and parkland grounds supervisors on proper pesticide use varies greatly depending on the intensity of the effort. Like lawn care and landscaping programs, some cities have begun partnerships that include training of retail employees and parkland supervisors on IPM techniques. In addition, promotional materials and displays on safer pesticide alternatives are set up. The cost of staff time for training and production of materials must be included in any cost estimate. Since there are currently a number of good fact sheets on IPM and pesticide use available through cooperative extension programs, the Peruque Creek watershed management plan should consider using these existing resources instead of trying to create new ones. Another way to save cost would be to utilize master gardener volunteers to help with training for residents, parkland supervisors, and store employees.

4.3.6 Bridge and Roadway Maintenance

Municipal management of level of pollutants from road and bridge runoff involves incorporating pollution prevention techniques to reduce or eliminate pollutant loads from existing road surfaces as part of routine operation and maintenance. Substantial amounts of sediment and pollutants are generated during daily roadway and bridge use and scheduled repair operations, and these pollutants can impact local water quality by contributing heavy metals, hydrocarbons, sediment and debris to storm water runoff.

Table 4-11 below provides a list of the potential pollutants that are often encountered on roadways and bridges, along with their primary sources. These highway pollutants can significantly influence the quality of storm water runoff and watershed streams. The proper performance of general maintenance activities such as street sweeping, vegetation maintenance, and cleaning runoff control structures can help alleviate the impacts of these pollutants. Modifications in roadway resurfacing practices can also help reduce pollutant loads to storm water runoff and protect the quality of receiving waters.

Road and bridge maintenance programs have a number of options for reducing the level of pollutants generated during the maintenance of existing road surfaces. Changes in the methods used for maintaining road surfaces, removing debris and sediment from roadways, and cleaning of runoff control structures can help improve the overall quality of storm water discharges from roads and bridges.

There are four categories of alternative management measures for bridge and roadway maintenance that are being considered for the Peruque Creek watershed.

- Alterations to road and bridge resurfacing practices
- Alterations to the ways deicing materials are used and applied
- Alterations to the ways roadside vegetation is controlled
- Alterations to existing bridge scupper drains

Table 4-11
Highway Runoff Constituents and their Primary Sources (US EPA, 1993)

Constituent	Primary Sources
Particulates	Pavement wear, vehicles, atmosphere
Nitrogen, Phosphorus	Atmosphere, roadside fertilizer application
Lead	Tire wear, automobile exhaust
Zinc	Tire wear, motor oil, grease
Iron	Auto body rust, steel highway structures, moving engine parts
Copper	Metal plating, brake lining wear, moving engine parts, bearing and bushing wear, fungicides and insecticides
Cadmium	Tire wear, roadside insecticide application
Chromium	Metal plating, moving engine parts, brake lining wear
Nickel	Diesel fuel and gasoline, lubricating oil, metal plating, brake lining wear, asphalt paving
Manganese	Moving engine parts
Cyanide	Anticake compound used to keep deicing salt granular
Sodium, Calcium, Chloride	Deicing salts
Sulphate	Roadway beds, fuel, deicing salts
Petroleum	Spills, leaks, or blow-by of motor lubricants, antifreeze and hydraulic fluids, asphalt surface leachate

Resurfacing Activities

Proper planning for road and bridge resurfacing operations is a simple but effective method to control pollution. There are a number of suggestions that can be implemented to control the impacts of this maintenance operation. First, paving operations using concrete, asphalt, or other sealers should be performed only in dry weather situations to prevent contamination of runoff. Second, use proper staging techniques to reduce the spillage of paving materials during the repair of potholes and worn pavement. This can include covering storm drain inlets and manholes during paving operations, using erosion and sediment control measures to decrease runoff from repair sites, and utilizing pollution prevention materials such as drip pans and absorbent material for all paving machines to limit leaks and spills of paving materials and fluids. Finally, resurfacing operations could consider employing porous asphalt for pothole repair and for shoulder areas to reduce the level of storm water runoff from road systems.

Deicing Materials

Proper application of road salt or other deicers is essential for reducing storm water pollution. By routinely calibrating spreaders, a program manager can prevent over-application of deicing materials. In addition to reducing the effects of these materials on the aquatic environment, a cost savings may be realized due to reductions in the purchase of deicing materials. Training for transportation employees in proper deicer application techniques, the timing of deicer application, and what type of deicer to apply will also alleviate impacts to water quality and aquatic habitat.

An understanding of snowpack and snowmelt dynamics is useful to develop effective techniques for treating snowmelt runoff. Different techniques should be employed at each stage of the meltwater sequence, so as to effectively address the constantly changing flows and pollutant concentrations that occur as the melt progresses. A list of some effective techniques is provided in **Table 4-12**.

Table 4-12
Watershed Protection Techniques for Snow and Snowmelt Conditions

• Use of Deicing Compounds Use alternative de-icing compounds such as $CaCl_2$ and calcium magnesium acetate (CMA) Designate "salt-free" areas on roads adjacent to key streams, wetlands, and resource areas Reduce use of de-icing compounds through better driver training, equipment calibration, and careful application Sweep accumulated salt and grit from roads as soon as practical after surface clears
• Storage of Deicing Compounds Store compounds on sheltered, impervious pads Locate at least 100-feet away from streams and floodplains Direct internal flow to collection system and route external flow around shelters
• Dump Snow in Pervious Areas Where It Can Infiltrate Stockpile snow in flat areas at least 100 feet from stream or floodplain Plant stockpile areas with salt-tolerant ground cover species Remove sediments and debris from dump areas each spring Choose areas with some soil-filtering capacity
• Blow Snow from Curbside to Pervious Areas
• Operate Stormwater Ponds on a Seasonal Mode
• Use Level Spreaders and Berms to Spread Meltwater Over Vegetated Areas
• Intensive Street Cleaning in Early Spring can Help Remove Particulates on Road Surface

Most states have traditionally employed road salt as a primary chemical deicer and sand as an abrasive (for better traction). Although sodium chloride is an inexpensive and effective choice, concerns are frequently raised about its potential negative impacts on aquatic habitat, highway infrastructure, and vehicles. The potential impacts of road salt are listed in **Table 4-13**.

Table 4-13
Impacts of Road Salt (MDOT, 1993)

- Contamination of drinking water supplies
- Corrosion of automobiles
- Corrosion of bridges and other structures
- Damage to vegetation within 50 ft. of roadside
- Temporary reduction in soil microbes, followed by summer recovery
- Sensitivity of various deciduous trees
- Attraction of deer to salts on roadways, increasing the risk of accidents
- Stratification of small lakes, hindering seasonal turnover
- Secondary components (3-5% of road salt composition) include N, P, and metals in concentrations exceeding those in natural waters

A number of potential alternatives to sodium chloride exist. **Table 4-14** lists various deicing materials and their primary components. Calcium chloride applied in pellet or liquid form could be the most attractive deicer for areas where fast melting is a priority. It also causes less corrosion and is only about 10 to 15 percent more expensive per road mile than road salt. Verglimit contains calcium chloride, but has relatively low deicing ability – a result of its significantly lower concentration of salt and tendency to absorb water, rendering it largely ineffective at lower temperatures. In regions where the environmental and corrosive effects of deicers are important management issues, CMA may be the preferred choice. However, CMA only works above 23°F, has less deicing ability, and is the most expensive option.

Table 4-14
Primary Components and Costs of Selected Deicing Materials (MDOT 1993)

Deicing Material	Primary Components	Chloride as Fraction of the Total Mass	Material Cost Per Ton
Calcium magnesium acetate (CMA)	Ca, Mg, $C_2H_3O_2$	0%	$650-675
Calcium chloride	Ca, Cl	>57%	$200
Calcium chloride (Verglimit)	Ca, Cl	2.2 to 4.8%	$109-145
Sodium chloride (road salt)	Na, Cl	~58%	$20-40
Corrosion inhibitor (CG-90 Surface Saver)	Na, Cl	46%	$185
	Mg, Cl	17%	
Potassium chloride (CMS-B/Motech)	K, Cl	Unknown	$0.40-0.50/gal
Sand	Si, O	0%	$5

Ca=calcium
Mg=magnesium
$C_2H_3O_2$=acetate
Cl=chloride
Na=sodium
K=potassium
Si=silicon

Road salt will probably continue to be an attractive deicing agent because of its high deicing ability, utility at low temperatures, and low cost. The corrosive effects of road salt can and have been reduced through design and material modifications to both road structures and vehicles over the past years. Such developments may make road salt even more attractive as a deicing agent. Consequently, management measures should be taken to minimize runoff (**Figure 4-14**) containing road salt and other deicing agents into sensitive environmental areas.

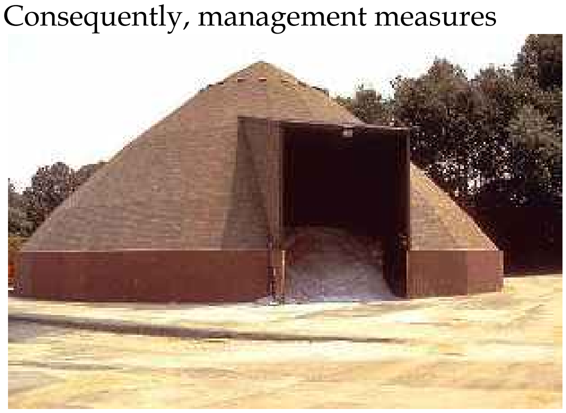


Figure 4-14 - Proper Storage of Road Salt

Roadside Vegetation

Maintenance practices for roadside vegetation also determine the storm water quality of road runoff. Restrictions on the use of herbicides and pesticides on roadside vegetation and training to ensure that employees understand the proper handling and application of pesticides and other chemicals can help prevent contamination of runoff. Selection of roadside vegetation with higher salt tolerances will also help to maintain vegetated swales that filter out runoff.

Bridge Runoff

Additional maintenance practices may be needed to eliminate adverse storm water runoff impacts from bridge runoff. In addition to some of the roadway practices listed above, there are practices in bridge siting and design that can help reduce water quality impacts. One alternative is to avoid using bridge scupper drains for any new bridges and to routinely clean existing ones to avoid sediment and debris buildup. Scupper drains can cause direct discharges to surface waters and have been found to carry relatively high concentrations of pollutants (CDM 1993). An alternative management measure could consider endorsing retrofits of scupper drains with catch basins or redirecting water from these drains to vegetated areas to provide treatment. Other techniques such as using suspended tarps, booms and vacuums to capture pollutants (e.g. paint, solvents, rust and paint scrapings) generated during bridge maintenance will also help reduce impacts to receiving waters. In addition, using deicers such as glycol, urea or calcium magnesium acetate (CMA) reduces the corrosion of metal bridge supports that can occur when salt is used.

Effectiveness

There is limited data available on the actual effectiveness of road and bridge maintenance practices at removing pollutants from storm water runoff. **Table 4-15** examines the effectiveness and cost of some of the operation and maintenance practices recommended for storm water pollution control.

While data may be limited on cost and effectiveness, preventative maintenance and strategic planning are time-proven and cost effective methods to limit contamination of storm water runoff. It can be assumed that the management practices recommended will have a positive effect on storm water quality by working to reduce pollutant loads and the quantity of runoff. Protecting and restoring roadside vegetation, removal of debris and sediment from roads and bridges, and directing runoff to vegetated areas are all effective ways to treat storm water runoff. Other practices such as minimizing deicer application, litter control, and proper handling of fertilizers, pesticides, and other toxic materials work to control some of the sources of storm water pollution. Employing good road and bridge maintenance practices is an efficient and low cost means of eliminating some of the impacts of pollutants associated with road systems on local streams and waterways.

Table 4-15
Road and Bridge Maintenance Management Practices: Cost and Effectiveness (USEPA 1993)

<table>
<tr><th>Practice</th><th colspan="2">Effectiveness (% Removal)</th><th>Cost</th></tr>
<tr><td>Maintaining Roadside Vegetation</td><td colspan="2">Sediment - 90% average
Phosphorus and Nitrogen - 40% average
COD, Pb, and Zn - 50% average
TSS - 60% average</td><td>Natural succession allowed to occur
Average: $100/acre/year
Reported Range:
$50 -$200/acre/year</td></tr>
<tr><td>Street Sweeping</td><td>Smooth Street Frequent Cleaning:
TSS - 20%
COD - 5%
Pb - 25%</td><td>Smooth Street Infrequent Cleaning:
TSS - Not applicable
COD - Not applicable
Pb - 5%</td><td>Average: $20/curb mile
Reported Range: $10 -$30/curb mile</td></tr>
<tr><td>Litter Control</td><td colspan="2">Not applicable</td><td rowspan="3">All are accepted as economical practices to control or prevent storm water impacts</td></tr>
<tr><td>General Maintenance</td><td colspan="2">Not applicable</td></tr>
<tr><td>Minimizing Deicer Application</td><td colspan="2">Not applicable</td></tr>
</table>

TSS - Total Suspended Solids
COD - Chemical Oxygen Demand
Pb - Lead

Generally speaking, limitations to instituting pollution prevention practices for road and bridge maintenance involve the cost for additional equipment and training. Since maintenance of roadways and bridges is already required in all communities, staffing is usually in place and alteration of current practices should not require additional staffing or administrative labor. The maintenance of local roads and bridges is already a consideration of most community public works and transportation departments. Therefore, the cost of pollutant reducing management practices will involve the training and equipment required to implement these new practices.

4.3.7 Vegetation Controls

Mechanical vegetation controls include elements such as properly collecting and disposing of clippings, cutting techniques, leaving existing vegetation, etc., and can be implemented as both municipal management measures and public education measures. The public education element of vegetation control previously was discussed in Section 4.2.8. This section will address the municipal side of vegetation management, which would include the practices by which public works and park maintenance crews actively manage and control vegetation on public lands.

Clippings and cuttings are the primary waste produced by mowing and trimming. Clippings and cuttings are almost exclusively leaf and woody materials. However, in some cases, litter may be intermingled with the clippings. Clippings/cuttings carried into the storm water system and receiving streams can degrade water quality in several ways. Suspended solids will increase causing turbidity problems. Since most of the constituents are organic, the biological oxygen demand will increase causing a lowering of the available oxygen to plant and animal life.

A related problem exists with the illegal dumping of clippings/cuttings in or near drainage facilities. Often, park maintenance crews will discover that clippings/ cuttings can easily be disposed of by dumping them down a nearby ravine or on the slope of a creek or drainage channel. This practice introduces a large quantity of decaying organic matter into the storm water collection system that is subsequently carried to receiving streams during the next rainfall event.

Once vegetative waste is generated, the main concern is to avoid transport of clippings/cuttings to receiving water bodies. It is necessary to pick up and properly dispose of clippings/cuttings on the slopes and the bottom drainage facilities, including storm water detention/retention facilities. In addition, the presence of clippings/cuttings in and around catch basins should be avoided by either using bagging equipment or manually picking up the material. Materials disposed on flat surfaces are generally not supported by storm water runoff unless the event is particularly intense. Therefore, it is not necessary to pick up or bag clippings/cuttings on flat or nearby flat surfaces. Municipal operators should be trained to use good judgement in determining whether clippings/cuttings should be collected or left in place. Also, mowing should only be performed at optimal times. Mowing should not be performed if significant rain events are predicted.

Municipal anti-dumping ordinances should be enacted or reinforced (if necessary) so that private dumping of vegetative debris is not allowed. It is important that these ordinances be clear and enforceable.

Composting is one of the better alternatives if locally available. Most municipalities either have or are planning yard waste composting facilities as a means of reducing the amount of waste going to landfills. Lawn clippings from municipal maintenance programs as well as private sources would probably be compatible with most composting facilities.

Measures to improve the disposition of clippings/cuttings are relatively simple and inexpensive. Cost considerations include possible upgrading of certain mowing equipment for bagging. Another potential cost is for additional laborers involved in hand cutting and picking up clippings where mechanical cutting and collection is not practical. A third possible cost includes the training of municipal employees on proper vegetation control.

Section 5
Identification of Alternative Structural Control Measures

The impacts of development within the Peruque Creek watershed have altered natural drainage patterns, altered natural rainfall-runoff-storage relationships, and added pollutants to storm water runoff and watershed streams. These urban impacts have resulted in a decline in the quantity and quality of aquatic and riparian habitat and limited opportunities for the public to enjoy the many benefits that water provides to the Peruque Creek watershed. Impervious surfaces in the watershed have most likely contributed to higher than natural storm water flow rates with decreased times of concentration and reduced runoff periods. The natural morphology of the stream has been altered significantly by increased flow in the creek and siltation is occurring in the downstream reach of the stream and Lake Saint Louis.

Alternatives directed toward restoring the Peruque Creek watershed can include the enhancement and expansion of existing wetlands, the creation of additional water storage capacity, and the restoration of more natural flow conditions and habitat. Watershed restoration can include the modification and stabilization of the stream channel, the creation of acceptable water quality, and reintroducing hydrologic variability. Restoration of Peruque Creek will provide benefits to the ecosystem and the surrounding communities in an aesthetically and ecologically improved natural area.

Section 4 discussed alternative non-structural source control measures that can be implemented within the Peruque Creek watershed to address the wide variety of problems typically related to urban runoff. Applying land use controls, public education programs, and non-structural municipal measures can have a significant impact on improving water quality and overall watershed protection. However, many structural tools are also available to address environmental degradation in urban watershed areas like Peruque Creek. In contrast to non-structural measures, structural alternatives typically require complex engineering analyses and construction to implement. This section, divided into the following topics, will discuss these alternative structural measures.

- Source Control Measures
- New Regional Facilities
- Stream Erosion and Velocity Controls

5.1 Source Control Measures

A comprehensive storm water management program often requires certain structural source control measures be implemented on existing development. A wide-range of structural source control measures are available to address problems related to urban runoff. This section will examine alternative structural control measures in the following areas:

- Reconfigure paved surfaces to decrease the percentage of impervious area
- Use porous pavements to promote infiltration
- Construct roof-top gardens over public and private buildings
- Capture roof runoff in constructed tanks or cisterns for irrigation

5.1.1 Reconfiguring Paved Surfaces to Reduce Impervious Area

An alternative structural management measure to consider for the Peruque Creek watershed would be to reconfigure existing and proposed paved surfaces to reduce the overall impervious area within the watershed. Impervious surfaces represent the imprint of land development on the landscape. They are comprised of two primary components: 1) the rooftops under which residents live, work, and shop, along with their ancillary patios, decks and walkways, and 2) the transportation system, including roads, driveways, and parking lots that residents use to get from one roof to another. Previously in Section 4.2.7, a public education program was described as an alternative nonstructural management measure to encourage residents and business owners to reduce the quantity of impervious surfaces within their properties. This section will address a structural management measure to reduce the total impervious area within the Peruque Creek watershed by reducing the quantity of pavement.

The opportunity for new development in the Peruque Creek watershed is significant. As a result, there are many opportunities to reduce the share of imperviousness from the transportation component in new development projects. However, opportunities also exist to decrease impervious area by reconfiguring existing paved surfaces through restorative redevelopment efforts. Some simple but effective strategies for communities to reduce the share of imperviousness from the transportation component include the following:

- Reduce the quantity of pavement within public parking areas
- Reduce the quantity of pavement area within residential lots
- Reduce the quantity of pavement area within street and alley right-of-ways
- Further reduce impervious area within public right-of-ways by narrowing sidewalks or removing redundant or unnecessary sidewalks

Reduce the Quantity of Pavement Within Public Parking Areas

There are many opportunities for new commercial development projects within the Peruque Creek watershed. There are also several existing smaller commercial lots where restorative redevelopment techniques could be applied. Eventually existing parking areas will deteriorate and need to be replaced. Restorative redevelopment techniques can be applied when lots are resurfaced. Alternative measures to be considered and discussed include the following:

- Reduce the number of parking spaces, if possible
- Reduce the size of parking stall dimensions, where possible
- Eliminate unnecessary pavement areas and replace them with vegetated landscape islands
- Create new vegetative infiltration swales and infiltration ditches
- Use semi-pervious building materials, such as brick pavers, instead of asphalt

Most communities routinely build more public parking spaces than are needed to meet actual parking demands. This is a result of using outdated or overly generous local parking codes to determine minimum parking ratios. However, the parking areas that would be resurfaced or reconstructed under the principals of restorative redevelopment have already existed for a long time and actual parking demands are already known. Whenever an existing parking area is scheduled to be repaved, business owners should carefully evaluate their parking needs and reduce the number of unnecessary parking spaces. Even small reductions in parking can reduce the construction and storm water management costs that are accrued during these resurfacing projects.

Reducing the size of parking stall dimensions represents another opportunity to reduce impervious cover. During repaving projects, the length and sometimes the width of existing parking stalls can be reduced by a foot or more. Existing parking stalls can also be amended to provide a percentage of smaller stalls for compact cars. Parking areas for small businesses are often unlined. Without clearly defined and marked parking stalls, business patrons park anywhere in the lot and the paved areas are inefficiently used. Existing unmarked parking areas should be lined to clearly define parking stalls, and unnecessary pavement areas should be removed.

Many existing commercial establishments within the Peruque Creek watershed have the entire area around their building paved. Often, a significant portion of this paved area is rarely trafficked, if at all. During repaving construction, these unused paved surfaces can be removed and replaced with vegetated landscape islands and/or infiltration ditches.

Business owners should be encouraged to replace unnecessary pavement area with landscape islands, vegetative swales, and infiltration ditches. Vegetative swales are grassed channels designed to convey storm water, where pollutants are removed by filtration through settling and infiltration through the soil. Typically vegetative swales cost less to construct than paved areas and curbs. Infiltration ditches temporarily store runoff in a stone filled reservoir and exfiltrate the runoff through surrounding soil media. A vegetated buffer strip can complement the ditch to prevent the entrance of sediments.

When existing parking areas deteriorate to the point of needing reconstruction, business owners can be encouraged to replace the existing asphalt pavement with semi-pervious building materials such as brick pavers with sand-filled joints. While the initial cost of permeable surfacing materials can be more expensive to install, the ambiance and charm of brick pavers can add long-term value to the commercial site and often have a longer design life than asphalt. Special varieties of porous pavements that can be used will be discussed in Section 5.1.2.

Reduce the Quantity of Pavement Area Within Residential Lots

Significant opportunities are available to reduce overall imperviousness in residential areas by applying the principals of restorative redevelopment when existing driveways are repaved or reconstructed. Many of the existing homes and driveways within the Peruque Creek watershed eventually will be in need or repair or replacement. Encouraging residents to use permeable paving materials, narrow the driveway width, and eliminate unnecessary paved areas during restoration can have a significant impact on reducing total impervious area in the Peruque Creek watershed.

Pavement area can also be reduced in new development. Typical residential driveways are 12-feet wide for one car driveways and 20-feet wide for two. By specifying narrower driveways, promoting permeable paving materials, and allowing two-track driveways or gravel and grass surfaces, communities can sharply reduce the typical 400 to 800 square feet of impervious cover created by each driveway.

Many current subdivision codes have very strict requirements that govern lot geometry, including setbacks and lot shape. These criteria constrain site planners from designing open space or cluster developments that can reduce impervious cover. Smaller front and side setbacks, often essential for open space designs, are typically not allowed or require a zoning variance that may be difficult to obtain. Relaxing setback requirements allows developers to create attractive, compact lots that are marketable and livable. For example, side yard setbacks can be as close as 5-feet from detached housing without specific fire protection measures. Often, fears about fire safety, noise, parking capacity and site distance impairment are cited as impediments to shorter setbacks, but the reality is that these concerns can be overcome with careful design.

Creating narrower driveways, using permeable paving materials, and promoting more gravel and grass surfaces in developments can reduce the amount of impervious area generated from new development such as the development in **Figure 5-1**.

Figure 5-1 - New Subdivision Development in Wentzville

Reduce the Quantity of Pavement Area Within Street and Alley Right-of-Ways

Wide streets are the greatest source of impervious cover in existing neighborhoods and new subdivisions. Wide residential streets are created by blanket applications of high volume and high speed design criteria, the perception that on-street parking is needed on both sides of the street, and the perception that wide streets provide unobstructed access for emergency vehicles.

Communities with new expansion development have significant opportunities to reduce impervious cover by revising their street standards to widths of smaller residential access streets. Residential street widths should be designed to handle expected traffic volumes, provide adequate parking, and ensure access for service, maintenance, and emergency vehicles. Two strategies can help to narrow streets: using queuing streets and critically evaluating the need for on street parking on both sides of the street. Several national engineering organizations have recommended residential streets as narrow as 22-feet in width.

Many communities require the end of cul-de-sacs to be 50- to 60-feet in radius, creating large circles of needless impervious cover. There are several different planning options to reduce the impervious cover created by traditional cul-de-sacs. One option is to reduce the radius of the turnaround bulb. Several communities have implemented this successfully and the smaller radii can range from 33- to 45-feet. Since vehicles only use the outside of the cul-de-sac when turning, a second option is to create a pervious island in the middle of the cul-de-sac, creating a donut-like effect. A third planning option is to replace cul-de-sacs with loop roads and hammerheads.

Many of the above-mentioned alternatives to reduce street coverage apply to new development. However, opportunities to reduce street cover exist during street rehabilitation efforts as many of the existing roads within the watershed are older and will need to be repaved or reconstructed.

One application that can be considered while restoring existing streets is the use of porous pavements. Either the entire width of existing streets could be replaced with porous pavement, or just the on-street parking areas that line the traffic cartway.

Local soils, frost depths, freeze-thaw cycles, and traffic loads all need to be carefully assessed so that selected porous pavement materials are suitable for local conditions. Alternative materials include masonry pavers with open joints, a bituminous mix with open-graded aggregate or compacted gravel. The use of porous pavements to promote infiltration will be discussed in more detail in Section 5.1.2.

In addition, street widths can be evaluated with current traffic volumes when existing streets are scheduled to be reconstructed. Evaluating the need for on street parking on both sides of the street in many of the residential areas within the watershed can be evaluated as well. Reducing current street widths and on street parking provides opportunities for the communities within the Peruque Creek watershed to reduce impervious cover.

Further Reduce Impervious Area Within Public Right-of-Ways by Narrowing Sidewalks

Additional opportunities exist within the Peruque Creek watershed to reduce impervious area by modifying existing sidewalks. In most watershed neighborhoods, sidewalks exist on both sides of residential streets, are constructed of impervious concrete or asphalt, and are 4- to 6-feet wide. While these construction practices were intended to promote pedestrian safety, they often result in unnecessary sidewalk areas that could be eliminated. For example, a sidewalk on one side of the street often is sufficient. In fact, in a study of pedestrian accidents associated with sidewalks, there was a negligible difference in accident rates when sidewalks were reported on just one side of the street versus sidewalks on both sides of the street (NHI 1996).

In older neighborhoods, many of the older concrete sidewalks will need to be replaced. During this process, the existing concrete sidewalks can be replaced with semi-permeable pavement systems that will promote infiltration. When sidewalks are being replaced, the watershed communities should also consider reducing sidewalk widths to 4-feet and placing them further from the street. Sidewalk design should emphasize the connections between neighborhoods, schools, and shops, instead of merely following the road layout. In addition, replacement sidewalks could be regraded to drain toward pervious front yard vegetation rather than the street. These alternatives could reduce impervious cover and provide safe, practical, and attractive travel paths.

5.1.2 Using Porous Pavements to Promote Infiltration

The use of permeable pavement systems in lieu of traditional asphalt and concrete pavement is an alternative structural control measure to improve water quality within the Peruque Creek watershed. Permeable pavements systems can be used to reduce the imperviousness of trafficked surfaces such as patios, walkways, driveways, fire lanes, and parking areas for the purpose of reducing surface runoff and increasing infiltration. The permeable paving systems also are used as inlets and covers for infiltration trenches. Permeable pavements can be effective in helping to reduce peak surface runoff rates or in improving the groundwater recharge characteristics of developed sites.

Permeable pavement requires moderately permeable soil and the depth to the seasonal high water table or bedrock being greater than 3-feet below grade. Because of the large area over which infiltration occurs, permeable pavement minimizes the potential for groundwater mounding or concentrated discharges to groundwater. Because permeable pavements recharge surface runoff directly to groundwater, they should not be used where there is significant concern for contamination of surface runoff with dissolved pollutants. In particular, to prevent contamination of drinking water supplies, they should not be installed in highly permeable sand or gravel seams that are directly connected to aquifers. The Peruque Creek watershed is characterized by clay soils that tend to percolate more slowly.

Permeable pavements are typically installed in proximity to runoff-generating surfaces. The best performance is achieved when the upgradient drainage area is minimized. One strategy is to alternate areas with impervious and permeable pavement. In these instances, conventional impervious pavement would be reserved for the most heavily trafficked corridors. A wide variety of alternative concrete and brick paving systems are available and can be combined with conventional pavements to achieve functional and aesthetically pleasing designs.

Permeable paving systems are prone to clogging by suspended solids. To reduce the likelihood of clogging, permeable pavement should not be used in areas that receive significant amounts of sediment, including mud tracked onto the surfaces during wet weather and sand or cinders used in snowy conditions. To preserve the long-term performance of permeable pavement, it is important to control sources of suspended solids in storm water before the water is discharged onto the paved surfaces.

Two factors must be considered when designing permeable pavement: runoff collection and percolation.

Runoff collection is controlled by the infiltration of the surface layer (e.g. brick, gravel, or concrete) and by the storage capacity of the pavement base. For most permeable paving systems, the surface infiltration rate is large enough that this factor can be ignored as a design consideration. However, the surface infiltration rates of compacted graded aggregate or topsoil may be limiting. The infiltration potential of paving systems that use these materials should be established by field-testing. **Table 5-1** presents typical ranges for long-term surface infiltration rates for a variety of alternative paving materials.

Table 5-1
Infiltration Rates for Various Paving Materials

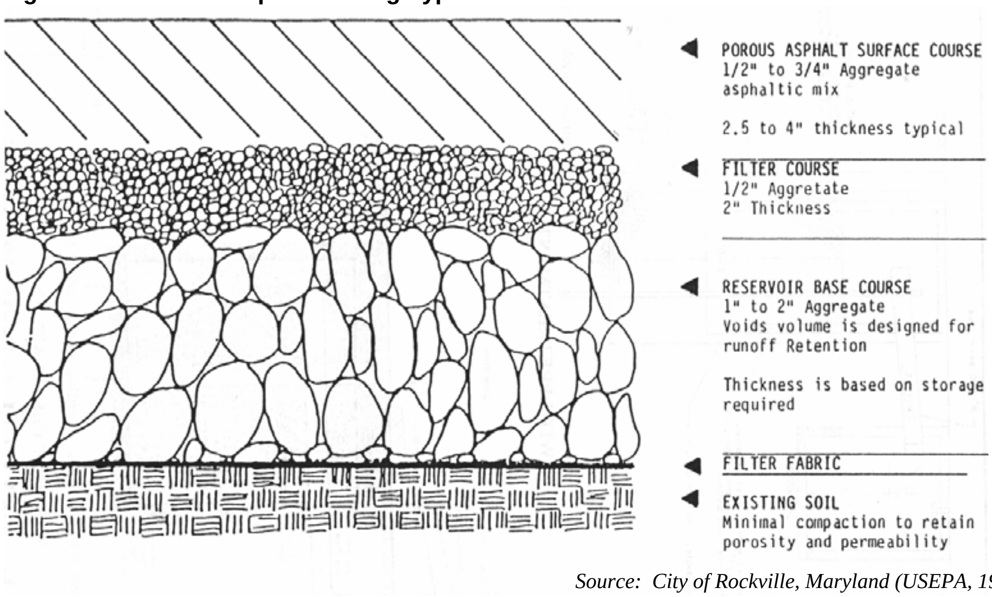
Pavement Type	Surface Infiltration Rate (inches/hour)
Permeable interlocking concrete paving blocks bedded in coarse aggregate, no vegetation (15 percent open cell area)	4.5 to 6.3 *
Compacted uniform gravel or crushed stone (uniformity coefficient < 2)	2.0 to 6.3 *
Concrete grid pavers bedded in sand, surface treatment with topsoil and vegetation (25 percent open cell area)	0.63 to 2.0
Compacted dense graded aggregate (uniformity coefficient > 10)	0.2 to 0.63

* Initial infiltration rates may exceed 150-inches/hour

Permeable paving systems require a porous base that provides a sufficient percolation rate to the groundwater table. Because of the structural stability and large porosity, uniform (open graded) crushed stone is preferred as a base material. Water will continue to infiltrate freely through the permeable pavement until the voids in the base fill with water. After the base fills with water, the residual surface infiltration rate will be dependant on the permeability of the underlying soil subgrade, which is usually less than the surface infiltration rate. Therefore, it is good practice to design the base layer to store 100 percent of the volume of water that will infiltrate. The depth of the base layer, therefore, will depend on the infiltration requirement for the paved surface. To compute the storage capacity of the base, the porosity of the compacted base material must be known. To preserve the storage potential of the base, a geotextile should be installed between the base and subgrade. The geotextile will minimize the tendency for soil to migrate upward into the base.

A typical section of porous asphalt paving is shown in **Figure 5-2** and a brief description of the characteristics and maintenance requirements of various paving materials follows.

Figure 5-2 - Porous Asphalt Paving Typical Section



Source: City of Rockville, Maryland (USEPA, 1991)

Perforated Brick Pavers and Concrete Grid Pavers

This type of pavement is best suited to areas that carry pedestrian or light vehicular traffic. Areas surfaced with pavers can be damaged by snowplows or loader buckets that are set too low to the ground. Therefore, care must be used when removing snow from these surfaces, especially in areas where differential settlement may have caused "lipping" of the pavers. If mud or sediment is tracked onto the surface, it should be swept away as soon as possible.

For best performance and longevity of the pavement, the pavers should be imbedded in concrete sand. Vegetation that colonizes the open cells or perforations should be removed. Semi-annual maintenance to remove vegetation should be adequate. Herbicides that persist in the environment should not be used to control vegetation.

For practical or aesthetic reasons, the designer may choose to fill the open cells of the pavers with topsoil and vegetation. In these cases, the vegetative layer must be maintained as any other grassed open area. Deep-rooted woody plants, which can disrupt the pavement and reduce permeability, should be prevented from colonizing the surface.

Permeable Interlocking Concrete Paving Blocks

These pavements are designed to accommodate more constant traffic and higher tire loads than concrete grid pavers or perforated brick pavers. These are comparatively easy to maintain and have long service lives. Permeable interlocking concrete paving systems should be bedded in coarse aggregate. The open cells can be filled with pea gravel to further enhance the appearance of the finished surface.

Colonization of the open cells by vegetation should be discouraged. Semiannual maintenance to remove vegetation should be adequate. Herbicides that persist in the environment should not be used to control vegetation. If mud or sediment is tracked onto the surface, it should be swept away as soon as possible.

Compacted Gravel

Gravel surfaced areas are suited to areas with very light vehicular traffic, such as overflow parking areas and service roads. Gravel surfaces are generally not recommended for pedestrian paths, because they can be difficult for older pedestrians or handicapped individuals to negotiate. The effectiveness of gravel surfaced areas in infiltrating rainfall is variable and depends primarily on the contribution of fine particles to the mix. Only open graded mixtures that contain very few fines will be associated with high surface infiltration rates. Dense graded road aggregate, which is commonly used to surface roads, is not appreciably more permeable than conventional pavement. As appropriate, the surface gravel course may consist of decorative materials such as pea gravel or slag.

Unlike areas surfaced with pavers or porous bituminous concrete, sweeping or washing of graveled areas is impractical. Therefore, gravel surfaced areas are prone to clogging by sediment. In particular, fine sediment tends to become incorporated in the loose gravel or stone in the uppermost layer of the pavement. Penetration of sediment into the base can be prevented by separating the surface course and base layers with a geotextile. The upper surface of the pavement may need to be scraped off and replaced with fresh material to restore the functioning of graveled surfaces if the surface infiltration rate decreases significantly. The longevity of gravel surfaces is generally shorter than for other types of permeable pavement in the same setting.

5.1.3 Rooftop Gardens Over Public and Private Buildings

Rooftops are perhaps an urban watershed's greatest untapped resource. Sloped or flat, large or small, industrial or residential, the possibilities for urban greening, air cleaning, community building, and food production can be numerous. Constructing rooftop gardens over public and private buildings can be an effective structural management measure to reduce urban runoff and its associated pollutants to the watershed.

Theoretically, any roof surface can be greened; even sloped or curved roofs can support a layer of sod or wildflowers. Switzerland has just passed a bylaw which states that new buildings must be designed to relocate the green space covered by the building's footprint to their roofs, even existing buildings - including historical buildings, must now green 20 percent of their rooftops. This has created an increased demand for research and material/product design, which has transpired to North American markets.

In reality, the technology and the know-how required to grow plants and trees on elevated structures has existed in the United States for a long time; an example being all the underground parking garages that support landscaped courtyards. The difference here is that these gardens are at ground level, mimicking a natural situation so a difference is not perceived. These gardens were given structural consideration during the initial design phase, not after the fact, whereas most of the roof gardens that people are interested in installing now will be retrofits to existing buildings.

Covering a rooftop with plants will allow several goals to be achieved:

- Environmentally, by increasing the biomass of the urban neighborhood, oxygen levels in the air are increased- and the amount of CO_2 produced by cars and other fuel burning technologies is decreased. In addition, dust and airborne particulates are reduced since plants act as natural filters. Also, the local climate is altered because plants absorb rather than reflect heat and because roots hold and absorb water. Every time it rains, the roof is retaining storm water runoff, thereby decreasing the load on storm drain and combined sewer systems.

- Home and building owners will benefit financially. Layers of soil and foliage have excellent insulating qualities, keeping buildings warmer in the winter and cooler in the summer thereby reducing energy bills. Because of significant temperature swings, and therefore the expansion and contraction experienced by the roof, the life span of the roofing membrane will increase due to these insulating qualities. Since the roofing will be covered, the membrane will be protected from harmful UV rays, and everyday wear and tear.

- A safe, private, outdoor space in the heart of the watershed can be created without having to buy extra land. Residents get a more aesthetically pleasing view, property value is increased, and the public is educated on the environment.

There are several issues that should be considered when creating a rooftop garden:

Loading

Soil, decking, people, planters and where they are placed on the roof deck, all have an impact on the existing structural carrying capacity of the roof, as well as that of the rest of the building. It is important to have a structural engineer confirm the additional weight that the existing roof can accommodate. One cubic foot of wet "earth" can weigh over 100 pounds, creating additional stresses on the rooftop. However, remember that earth is not soil and adding compost, mulch, and other fillers will decrease the weight. Heavy planters can be placed strategically over bearing walls or columns; grasses do not need more than 3-inches of growing medium; some plants will grow in gravel, a lot of options available.

Safety

The second consideration is safety. How is the roof accessed? How do materials and water get up to the roof? Who will be using the roof? Is there a railing? Requirements, solutions, and costs will vary depending on whether the garden is on a private residence, an apartment tower, or a public library. Building codes have specific regulations regarding structural, health, and safety issues as they relate to new and existing buildings that need to be followed.

Roofing

Roofing is also an issue. What kind is it and what condition is it in? Can it be walked on or should it be protected? Will plant roots penetrate the membrane or should planters be elevated? How and where does it drain? If it needs to be replaced or repaired within five years, can it be done without disrupting the established garden? Again, there are as many solutions as there are restrictions and regulations governing these issues.

Microclimate

Then there is the specific microclimate of the roof itself. Gardening up on a roof is quite different from gardening at grade. It is very sunny, sometimes windy, and the temperatures are often extreme. This will have a direct effect on what will grow well, how often watering needs to be done, and whether the plants can survive through the winter. The effects of heat, cold, and dryness can be tempered by using containers that retain moisture (i.e. plastic vs. terra-cotta; by insulating planters; by using mulch; by mixing moisture retaining additives into the soil; by layering or interplanting the plants; or by sticking to plants that thrive in these conditions). It is likely to be an ongoing experiment.

Another question is how to keep the soil from washing away while the plant roots grow enough to hold the soil. Plants can grow in a medium of gravel. Rainwater is sufficient to keep the plants alive. It depends on how the garden is to be used, what is intended to grow, and how often the roof needs accessed. Certainly, a flat roof, with level ground conditions, would seem to be the easiest to work with and on.

The following specific issues need to be addressed in the design and construction of a rooftop garden.

- Occupancy and the size of the garden as they relate to and impact adjacent or superimposed occupancies and occupant load (i.e. the number of people allowed to occupy the garden)

- Occupant load as it relates to and impacts structural loading and exiting requirements

- Exiting requirements such as types of exits allowed and number of exits required, the distance between exits and travel distance to exits, the sizes of exits and areas defined as "access to exits", fire separations between exits and the rest of the floor area, and possible requirements for fire alarms, exit lights, emergency lighting

- Handicapped accessibility and Barrier Free Design, either as a Code requirement or as a Client/User requirement

- Requirements for enclosures (i.e. guards, railings, parapets, walls around rooftops, terraces, and balconies) such as required heights, the placement of elements such as planters adjacent to enclosures which may reduce their effective height, climability of enclosures, and the loading and structural stability of guards and railings

- Specific requirements for structures/buildings on roofs relating to the effect on overall building height, the fire rating of structural members, and exiting

- Other applicable issues might include possible modification of window washing anchors on the roof, possible upgrading of washroom and service requirements, and possible upgrading of drainage and water-proofing requirements

In summary, there are two central elements that need to be considered when developing a rooftop garden: 1) the new loading exerted by the garden (the size and distribution of which can be altered by altering the layout of the garden) and 2) the load carrying capacity of the structure (which can be enhanced by increasing the strength of existing load bearing members or by adding new ones). When designing a roof garden, a licensed engineer should be consulted regarding the load carrying capacity of the building and to ensure that the garden design and the structural capacity are compatible.

Many of the existing homes and buildings within the Peruque Creek watershed have steeply sloped rooftops and are not eligible for the construction of a rooftop garden. However, for homes and buildings with flat rooftops that have adequate structural capacity, rooftop gardens provide a viable option for retaining storm water runoff.

5.1.4 Capturing Roof Runoff in Tanks or Cisterns for Irrigation

In many urban watersheds, storm water from rooftops is often piped into a storm drain that leads to either a combined sewer system or a municipal storm drain system. One of the best ways to mitigate the impacts of urban runoff is to manage rooftop runoff on site instead of moving storm water through a conveyance system. Redirecting rooftop runoff can be an effective management measure for reducing downstream impacts and can significantly decrease annual runoff volumes.

Rainwater harvesting, capturing and storing rainwater for later use, is a key element in storm water management. Diverting rooftop runoff into storage tanks, and ground runoff into mulched planting areas, utilizes rain to its fullest potential. Water harvesting can range from the simple to the complex, depending on need and budget. Water harvesting can be incorporated into plans for building a new home, designing a major subdivision, or restorative redevelopment efforts. Nonstructural management measures, such as installing rain barrels to existing downspouts and re-directing downspout flow to open yards are excellent ways to help control sediment and nutrient loading into Lake Saint Louis. There are significant numbers of storm water drains in the City of Lake Saint Louis and reducing the amount of flow to these drains will reduce input into Lake Saint Louis.

Rainfall can be a valuable resource as rainwater harvesting not only helps reduce the quantity of urban runoff, but also decreases the community's dependence on public water supplies for non-domestic uses. Unlike groundwater or tap water, rainwater is remarkably pure with virtually no dissolved salts or minerals. Because of this, rainwater is suited for rainwater irrigation and many other applications. Using rainwater to irrigate plants, for instance, flushes salt buildup from the soil and produces vigorous, healthy plants. By utilizing rainwater and reducing storm water runoff, a valuable water resource can be put to work.

The following lists additional advantages of harvesting rainwater:

- Provides more self-sufficiency with a water supply
- Offsets the need for pumping groundwater
- Reduces energy needed for deep well pumping and water softening
- Provides very high quality water (in most areas), soft and low in minerals

- Reduces mineral deposits on fixtures, pipes and water heaters
- Plants respond many times better to rainwater than tap water
- Reduces erosion and flooding typically created by runoff
- Reduces silting and contamination of waterways from runoff
- Encourages appreciation for and conservative use of water

A rainwater harvesting system has four main components:

- Rainwater collection
- Storage
- Distribution
- System Maintenance

Rainwater Collection

Rainwater can be captured from rooftop areas or any other impermeable surface. The amount of water that can be harvested depends on the size of the catchment area. It is important that the collected water is kept at least 3-feet away from the foundation of a home.

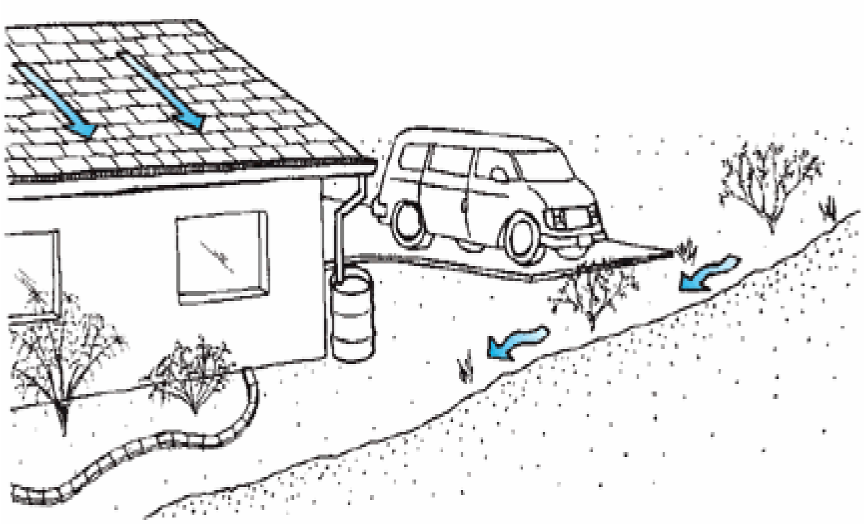


Figure 5-3 - Rainwater Storage Barrel

Storage

Storage systems can vary in complexity depending on need and catchment area. An effective system can involve nonstructural measures such as a drum or rain barrel fed by rooftop gutters and downspouts. A more involved system might include structural controls such as buried cisterns, plumbing, and a timed watering system. Types of pre-fabricated storage tanks and cisterns include galvanized steel, fiberglass, polyethylene, polypropylene, and PVC bladders. Partially pre-fabricated storage devices include a series of drums, cans, or barrels. Types of site-built storage tanks and cisterns include Ferro cement, stone, poured concrete, mortared block, and rammed earth.

Debris and leaves should be filtered before storing the water by placing screens over gutters or downspouts. Water kept in tanks or cisterns should also be covered to minimize algae growth and eliminate the potential for mosquito breeding. Placing floating lids on storage tanks is an effective solution.

Downspout Disconnection

Downspouts carry storm water from your roof away from your house. Directing storm water from downspouts away from paved areas and to vegetated areas gives water the chance to enter the ground, instead of running into sanitary sewers or storm sewers. By keeping storm water out of the sanitary or storm sewers communities can:

- Reduce stormwater overflows into Peruque Creek and Lake Saint Louis
- Reduce flooding of Peruque Creek
- Reduce water use for landscaping, thereby saving the homeowner money

Rain water that lands on your roof is collected in gutters and is discharged to the ground by downspouts. This rain water should be directed across vegetated areas where it can soak in.

Incorrect Roof Drainage
Incorrect roof drainage may involve any of four problems (**Figure 5-4**).

1. Lack of gutters at bottom edge of roof
2. Downspouts that drain directly into the sanitary sewer line

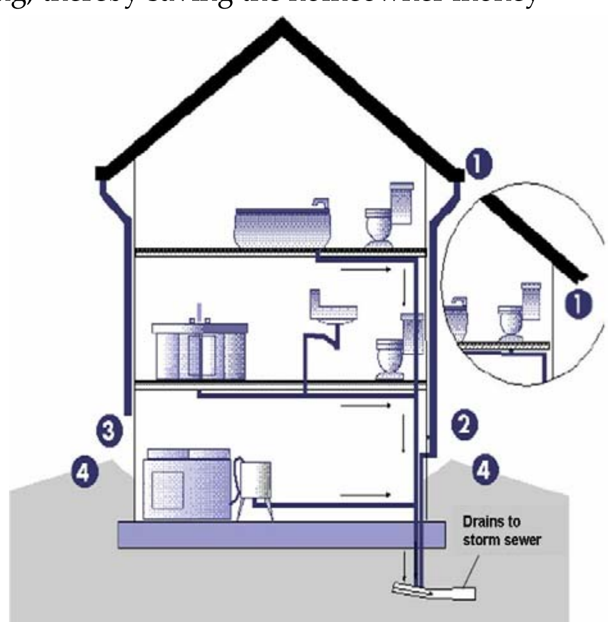


Figure 5-4 - Incorrect Roof Drainage

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3. Downspouts that drain straight down and do not direct water away from the house
4. Grading in the yard that directs water toward the house

Correct Roof Drainage

You may need to correct one or all of the roof drainage problems listed above. A correct roof drainage system should include (**Figure 5-5**)

1. Gutters on the bottom edges of your roof
2. A plug in the sanitary sewer line where the down spout had been connected
3. Downspout extensions that drain roof water away from your house
4. Grading that provides gradual slope away from the house

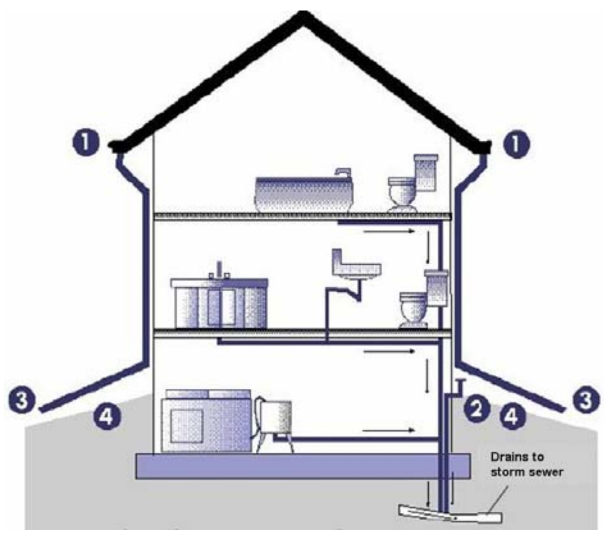


Figure 5-5 - Correct Roof Drainage

Distribution

Gutters and downspouts can be designed to catch rainwater and distribute it directly to landscape plants or into tree wells. Rainwater can also be directed to rock-lined trenches or perforated pipes and allowed to infiltrate into the soil (**Figure 5-6**). Another option is to store the harvested rainwater and then later distribute it through a regular drip irrigation system.

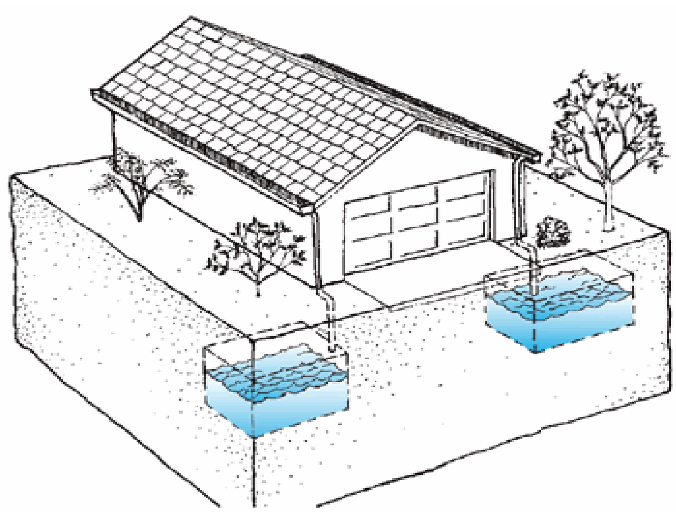


Figure 5-6 - Rain Water Collection Trenches

System Maintenance

Rainwater harvesting systems require occasional maintenance. Debris screens over gutters should be cleaned periodically and storage tanks should be drained and cleaned on a fairly routine basis.

5.2 Modification of Storm Inlets

Modifying existing storm inlets to increase the capture of sediments and floatable materials can be an effective structural management measure. Structural controls are often implemented coincidentally with nonstructural management measures, like those described previously in Section 4.3.1, for optimal watershed benefits. Wherever possible, structural measures should be taken to modify municipal storm inlets to trap floatable materials and sediment and prevent their discharge into waterways.

Many inlets have a combination of a horizontal slotted grate and a vertical curb inlet. A storm inlet configuration in a new residential development was shown in Figure 4-11. Typically, a slotted grate generally traps most trash and floatables; however, the curb inlet allows the debris to pass right through into the inlet, through the municipal storm drain system and into the receiving stream. Several commercially available devices can be added to existing curb inlets to allow storm runoff to pass through while capturing trash and floatables.

For example, a variety of filtering devices are available to capture oil, grease, trash, and sediment from storm water runoff before it enters the storm sewer system. A typical filtering device is shown in **Figure 5-7**. Filtered water passes through the unit and the basket configuration enables capture of waterborne sediment, trash, and debris that passes through into the inlet. Devices such as these are relatively easy to install and maintain. The basket configuration allows for easy, periodic cleanouts using a vactor truck.

Storm drains receiving sediment-laden runoff, trash and floatables should be protected. Devices of various designs are available which either detain sediment-laden runoff and floatables within the structure or prevent them from entering into a storm inlet. Exploring these structural alternatives for the storm drains within the Peruque Creek watershed, along with non-structural measures such as routine maintenance and cleaning, is vital for preventing dirt, debris, floatables, and associated pollutants from being discharged into receiving streams.

Figure 5-7 - Typical Storm Inlet Filter

5.3 New Regional Facilities

A number of systems are available whereby storm water runoff is collected, temporarily stored, and percolated through the soil. These systems include wet or dry ponds, detention basins, dry wells, infiltration basins, and constructed wetlands. These facilities are typically designed to fit aesthetically into the open space landscaping of new development sites. Often, these facilities are fragmented in that individual basins are sited within individual development plans, but regional basins can be constructed to provide storm water management for an entire sub-watershed area. In the Peruque Creek watershed, the opportunity for new development is significant and these structural alternatives can be considered on a regional level. Selection of these structural alternatives is dependent upon the desired level of particulate and dissolved pollutant removal, groundwater recharge, and storm water runoff flow control.

Whenever possible, priority should be given to source control alternatives. Source control measures are generally (but not always) less expensive than the regional facilities that will be described in this section. Also, these new regional facilities would not remove all pollutants in storm water from urbanized areas, and their removal efficiencies would be difficult to predict due to the limited understanding of the relationship between facility design criteria and performance. However, while source control measures should be given a higher priority, the construction of new regional facilities needs to be considered in new development projects and, in the case of the Peruque Creek watershed, retrofitted into existing development. This section will discuss:

- Factors to consider when selecting structural facilities to increase storm water storage and/or infiltration and control stream flow
- Constructing wet or dry ponds, detention basins, dry wells, and infiltration ditches to collect runoff, temporarily store it, percolate it through the soil, and increase the base flow to watershed streams
- Constructing ponds and wetlands to collect storm water runoff, detain it, and remove pollutants through settling, filtration, absorption, microbial decomposition, and vegetative uptake

5.3.1 Factors to Consider

There are general factors that are taken into consideration when selecting structural measures that increase storm water storage and/or infiltration. In every case, all structural measures must be compatible with existing flood control and storm water management objectives.

- **Slope -** Certain facilities cannot be placed on or near steep slopes as the ponding of water or velocity of flow may cause instability or excessive erosion.

- **Area Required** - Most regional facilities require considerable area, although some can be placed underground
- **Soil -** Infiltration systems must be located on suitable soils; vegetation requires good soils; wet pond bottoms require impermeable soils
- **Water Availability -** Facilities using vegetation for pollutant removal may require water during dry seasons
- **Aesthetics and Safety -** Where accessible or visible to the public, aesthetics and/or safety may be a concern with some of these measures
- **Hydraulic Head -** A few facilities may require a drop in hydraulic gradient or water elevation, which site topography may not provide
- **Environmental Side Effects- -**Considerations are needed to control mosquito breeding and groundwater contamination, as well as opportunities to enhance aquatic wildlife and passive recreation

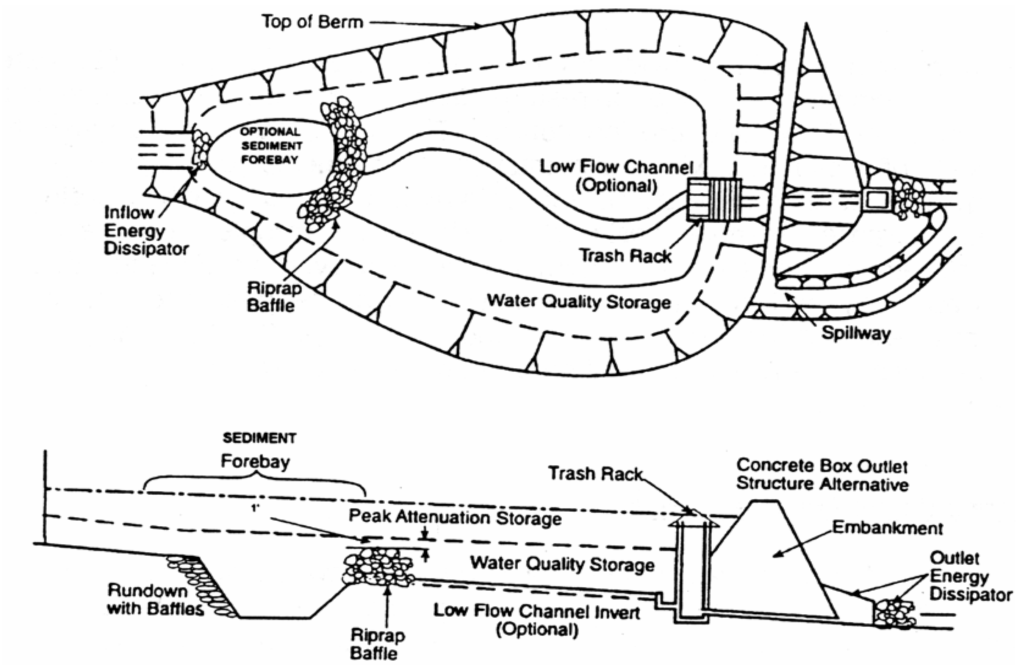
5.3.2 Extended Dry Detention Ponds, Wet Ponds, Dry Wells, and Infiltration Basins

Extended Dry Detention Ponds

Extended dry detention ponds provide flow equalization to mitigate impervious area. They can be site-specific or regional. These devices are able to store storm water runoff until it can be discharged, either by overflow, a pipe system, groundwater infiltration, or by evaporation and transpiration. Extended dry detention ponds temporarily store storm water runoff and promote the settling of solids and pollutants attached to the solids. Discharge is designed to be slow to provide time for sediment to settle. These ponds are typically designed to completely discharge the detained runoff over a 24 to 48-hour period. To enhance sediment removal, the ponds are often designed with a sediment forebay, which captures debris and larger sized sediment entering the facility. The finer particles settle out in the bottom stage of the pond.

Critical site considerations for extended dry detention ponds include drainage area, land slope, and available treatment area. Drainage areas of 20 acres or less are recommended for storm drainage applications; drainage areas in excess of 20 acres may result in permanently wet conditions in part of the pond, which may be aesthetically undesirable. However, extended dry detention ponds (**Figure 5-8**) are subject to other constraints such as minimum orifice diameter in the control structure and required length of detention time, etc. Similarly, a moderate slope is required for the pond sides and bottom, in order to maintain dry conditions in the pond between storm events. The required treatment area for the pond is typically between 0.5 and 2 percent of the tributary drainage area. Other factors such as soil permeability and depth to water table must be considered. High groundwater may contribute to the undesirable conditions of a permanently "wet" pond.

Figure 5-8 - Typical Extended Dry Detention Pond



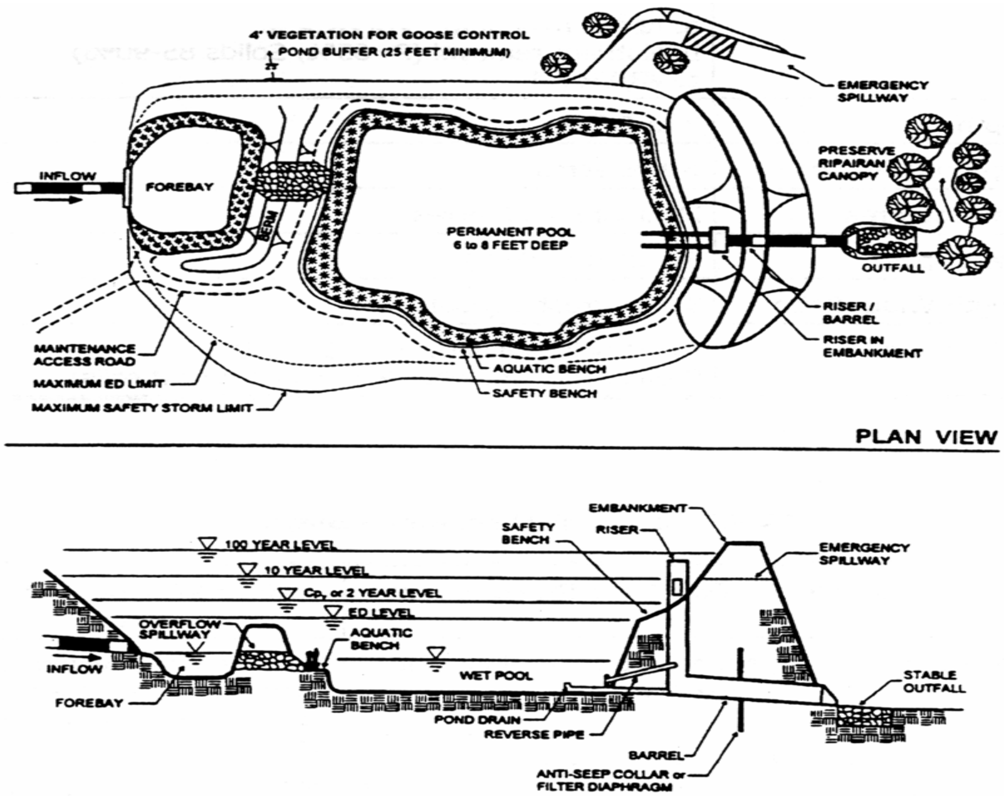
(Adapted from *Dam Design and Construction Standards*, Fairfax County, Virginia, 1991)

Proper maintenance of extended dry detention ponds includes periodic removal of sediment, seasonal mowing, removal of invasive vegetation/trees, and routine inspection for sediment removal, trash and debris removal, and structural repair and replacement. Sediment should be removed from the bottom stage of the pond every five to fifteen years. Sediment and debris should be removed from the forebay more frequently. Regularly scheduled mowing is encouraged to control weeds and pests.

Wet Ponds

A wet pond (or retention pond) is similar to a dry pond except that a permanent pool of water is incorporated into the design. Like dry ponds, these ponds can be site-specific or regional. Wet ponds are typically located in the path of storm water runoff and maintain a permanent volume of water (**Figure 5-9**). Within the permanent pool, enhanced settling and biological processes promote removal of both particulate (e.g. sediment) and dissolved (e.g. nitrate, phosphate) pollutants. Wet ponds can also provide recreational/aesthetic benefits. If there is adequate space available, rooted wetland vegetation is typically found along the wet pond perimeter and within the extended littoral zone.

Figure 5-9 Typical Wet Pond



Source: Maryland Dept. of Environment, 1986

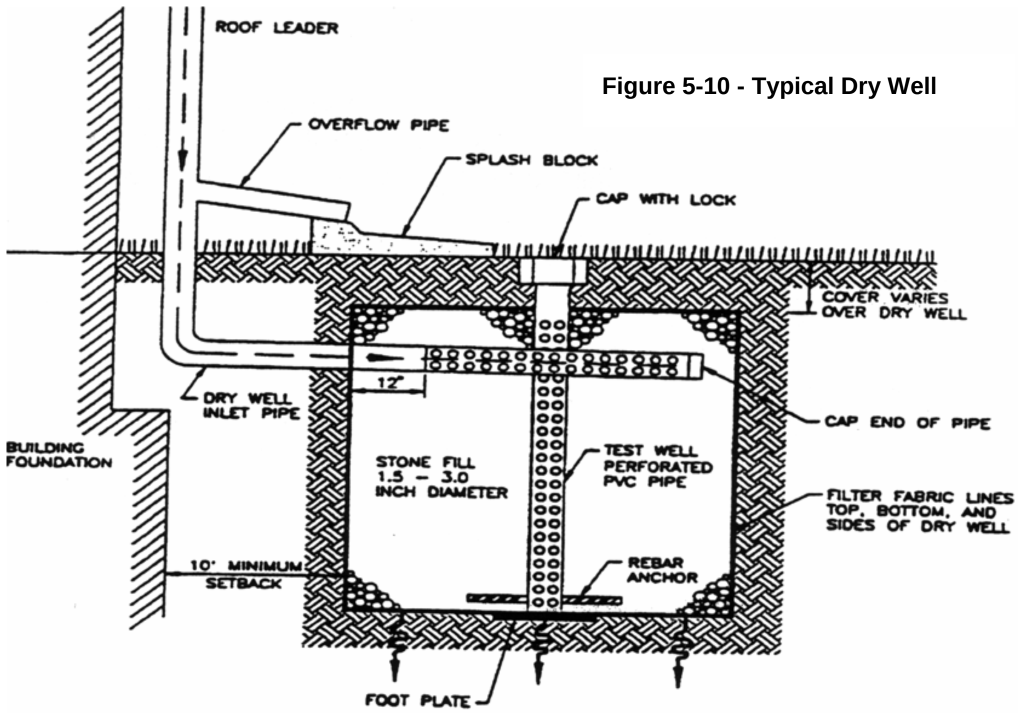
Critical site considerations for wet detention ponds include drainage area, soil permeability, land slope, and available treatment area. A wet pond should have a minimum tributary drainage area of 10 acres, and preferably 20 acres, to ensure that the permanent pool will have a sustained source of water during dry weather. Soil permeability must be limited to prevent the permanent pool from infiltrating into the subsoil. In areas with NRCS soil classifications of A or B, compaction of the pond bottom or construction of a bottom liner is recommended. Wet ponds cannot be located on steep, unstable slopes. The required treatment area for the pond is typically between 1 to 3 percent of the drainage area. Depth to water table must be considered.

Proper maintenance is required to maintain wet pond performance and prevent the ponds from breeding mosquitoes and becoming a public nuisance. Like dry ponds, maintenance activities should include regular sediment and debris removal, mowing, and inspections. Again, sediment and debris removal should be more frequent for the forebay (2 to 5 years) than for the permanent pool (5 to 15 years).

Dry Wells

A dry well is an excavated pit ranging from 3- to 12-feet that is filled with aggregate and receives storm water from roof drainage and direct surface runoff (**Figure 5-10**). Unlike dry and wet ponds, dry wells are usually only placed on individual properties. A dry well is used to capture and store runoff from rooftops or areas with low sediment loading. The use of dry wells for storm water control is applicable where soil is sufficiently permeable to allow for a reasonable rate of infiltration. Soil permeability must be sufficient to drain the entire volume of the water quality design storm within 72 hours. The soil infiltration rate should be 0.5-inches per hour or greater. Suitable soil types include sand, sandy loam, loamy sand, and gravel.

Figure 5-10 - Typical Dry Well



Source: Smith, Demer, and Normann

Surface soils within the Peruque Creek watershed are generally deposits of sand, gravel, and clay over sedimentary rock layers of shale, sandstone, limestone, claystone, and coal.

These devices are not applicable in large drainage areas or areas where high pollutant or sediment loading without pretreatment is anticipated. If the runoff will contain toxic pollutants, infiltration facilities alone are not suitable because of the potential for groundwater contamination. The minimum design storm should be the one-year 24-hour water quality design storm. An overflow system is required unless the well can be demonstrated to handle the entire volume of the flood design storm. The minimum depth to the seasonal groundwater table or bedrock shall be three feet from the bottom of the structure.

A dry well should be inspected monthly to ensure it is functioning properly. The water level in the test well should be the primary means for measuring infiltration. Corrective measures shall be taken if the structure fails to infiltrate the design storm event.

Infiltration Basins

An infiltration basin (**Figure 5-11**) is a dry pond that captures first flush storm water and treats it by allowing it to percolate into the ground through the permeable pond bottom and/or side embankments. Like dry wells, infiltration basins are usually site-specific and not regional. As the storm water percolates into the ground, physical, chemical, and biological processes occur which remove both sediments and soluble pollutants. Pollutants are trapped in the upper layers of the soil, and the water is allowed to gradually exfiltrate into the subsoil. An underdrain piping system may also be used to collect the filtered storm water.

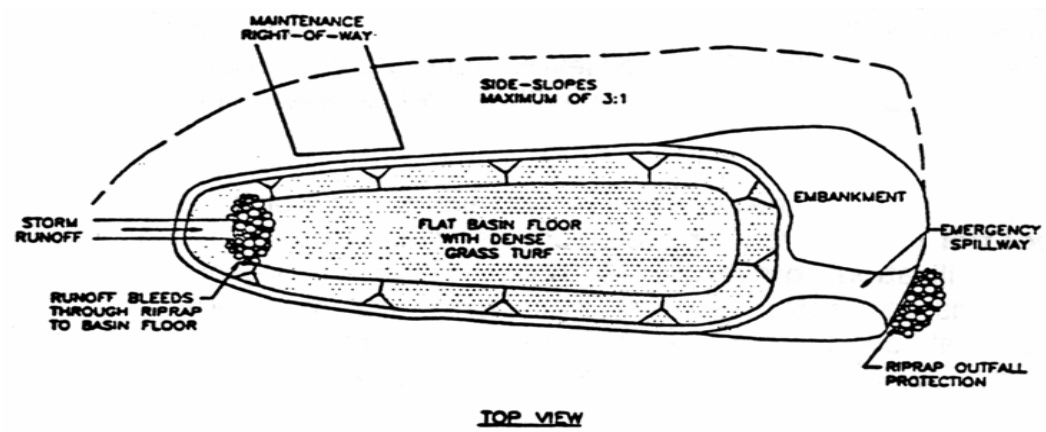
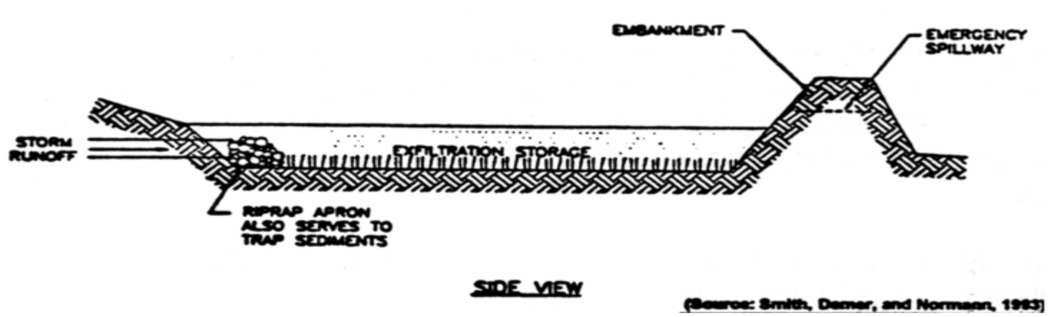


Figure 5-11 - Typical Infiltration Basin



Critical site considerations include the drainage area, depth to water table, and soil permeability. Infiltration basins are generally recommended for drainage areas between 2 and 10 acres, with a maximum of 20 acres. For drainage areas greater than 10 acres, maintenance of the infiltration basin becomes difficult, and an extended dry detention pond or wet pond would be more appropriate. To guarantee the feasibility of infiltration, the bottom of the basin should be 3- to 4-feet above the seasonally high water table. The Peruque Creek watershed is classified as having clay soil. The required treatment area for the basin is typically 0.5 to 2.0 percent of the drainage area. The use of sediment forebay may extend the functional capabilities of the basin by removing larger debris prior to entering the infiltration area.

Maintenance of infiltration basins should include sediment and debris removal, regular mowing, and regular inspection. In addition, special considerations are required to maintain the exfiltration capability of the basin. Additionally, when sediment is removed from the basin, light equipment should be used to minimize compaction. In addition, tilling or mechanical aeration of the basin bottom may be required.

The facilities described above are typically designed to fit aesthetically into the open space landscaping of new developments. They are usually placed within individual development projects or lots.

There are limitations to implementing these alternatives on a regional level. The regional facilities described above take up considerable land area because the side slopes of many of them are flat to allow for maintenance and to ensure public safety. In these cases where land availability is minimal, there are limited opportunities for regional facilities.

There are also constraints in implementing on-site alternatives into existing development due to the characteristics of the Peruque Creek watershed. For example, a dry well can be used to capture and store runoff from existing residential and commercial rooftops. However, the use of dry wells to manage storm water is only applicable where soil is sufficiently permeable to allow for a reasonable rate of infiltration. The clay soils of the watershed prevent adequate infiltration rates.

5.3.3 Wetlands

There are several scenarios for the Peruque Creek watershed where wetland creation or expansion could be used to manage storm water and provide some pollutant removal. Constructed wetlands can increase wildlife habitat while decreasing the stream gradient and creating slow flow areas to regulate flow. Using wetlands to control the storm water flows with extra storage capacity and slower flow-through rates also will reduce bank erosion and increase the variability of stream morphology and hydrologic flow characteristics.

Constructed storm water wetlands are wetland systems designed to maximize the removal of pollutants from storm water runoff through wetland vegetation uptake, retention, and settling. Constructed storm water wetlands temporarily store runoff in shallow pools that support conditions suitable for the growth of wetland plants. Like detention basins and wet ponds, constructed storm water wetlands may be used in connection with other components, such as sediment forebays and micropools.

Constructed storm water wetlands should not be located within natural wetland areas. These engineered wetlands differ from wetlands constructed for compensatory storage purposes and wetlands created for restoration. Typically, constructed storm water wetlands will not have the full range of ecological functions of natural wetlands; constructed storm water wetlands are typically designed specifically for flood control and water quality purposes. For the Peruque Creek watershed, they could be designed for water quality enhancement.

Similar to wet ponds, constructed storm water wetlands require relatively large contributing drainage areas and/or dry weather base flow. Minimum contributing drainage areas should be at least ten acres, although pocket type wetlands may be appropriate for smaller sites if sufficient groundwater flow is available.

There are four basic constructed storm water wetland design types:

- Shallow marsh systems
- Extended detention wetlands
- Pond/wetland systems
- Pocket wetlands
- Shallow Marsh Systems

Most shallow marsh systems (**Figure 5-12**) consist of pools ranging from 6- to 18-inches during normal conditions. Shallow marshes may be configured with different low marsh and high marsh areas, which are referred to as cells. Shallow marshes are designed with sinuous pathways to increase retention time and contact area. Shallow marshes may require larger contributing drainage areas than other systems, as runoff volumes are stored primarily within the marshes, not in deeper pools where flow may be regulated and controlled over longer periods of time.

Extended Detention Wetland
Extended detention wetlands (**Figure 5-13**) provide a greater degree of downstream channel protection. These systems require less space than the shallow marsh systems, since temporary vertical storage is substituted for shallow marsh storage. The additional vertical storage area also provides extra runoff detention above the normal elevations. Water levels in the extended detention wetlands may increase by as much as three feet after a storm event and return gradually to normal within 24-hours of the rain event. The growing area in the extended detention wetlands expands from the normal pool elevation to the maximum surface water elevation. Wetland plants that tolerate intermittent flooding and dry periods should be selected for the extended detention area above the shallow marsh elevations.

Figure 5-12- Typical Shallow Marsh System

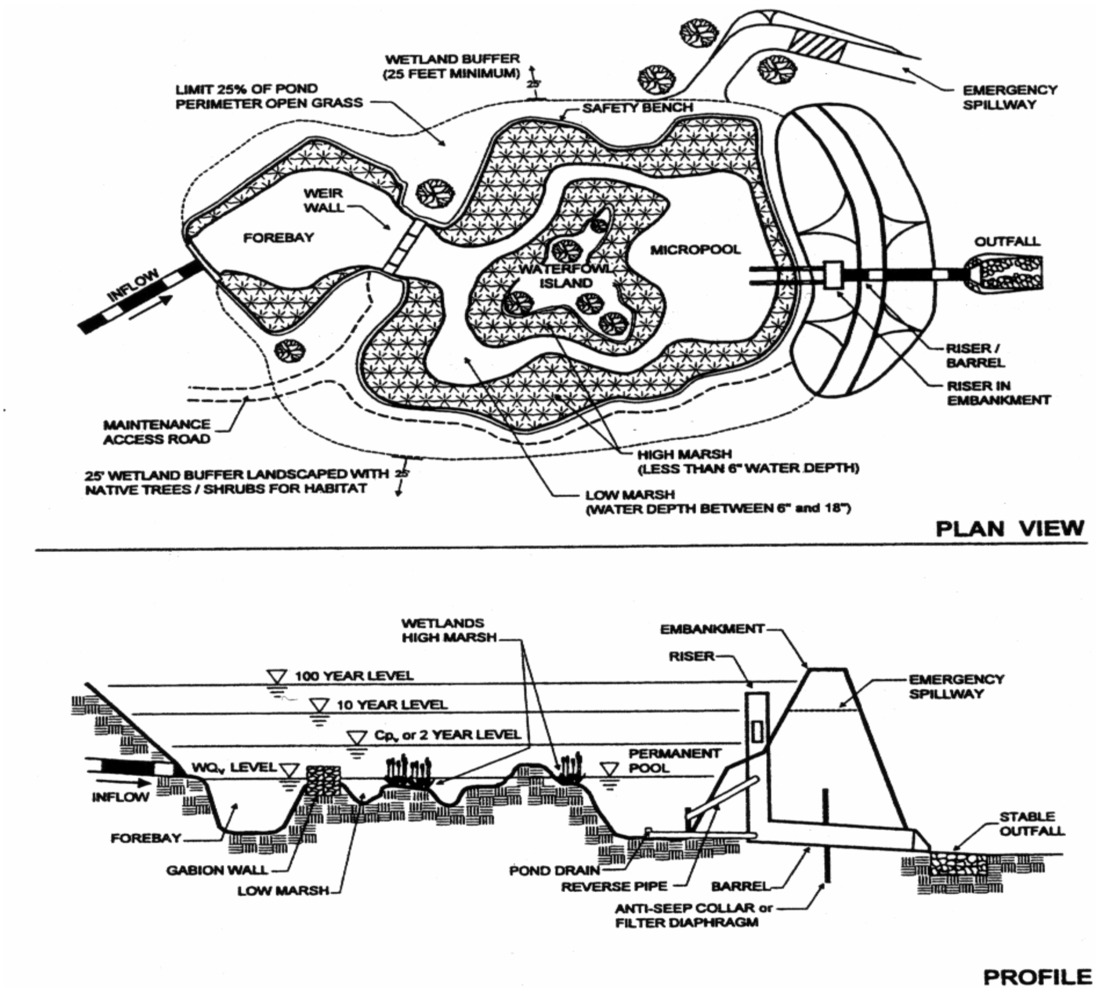
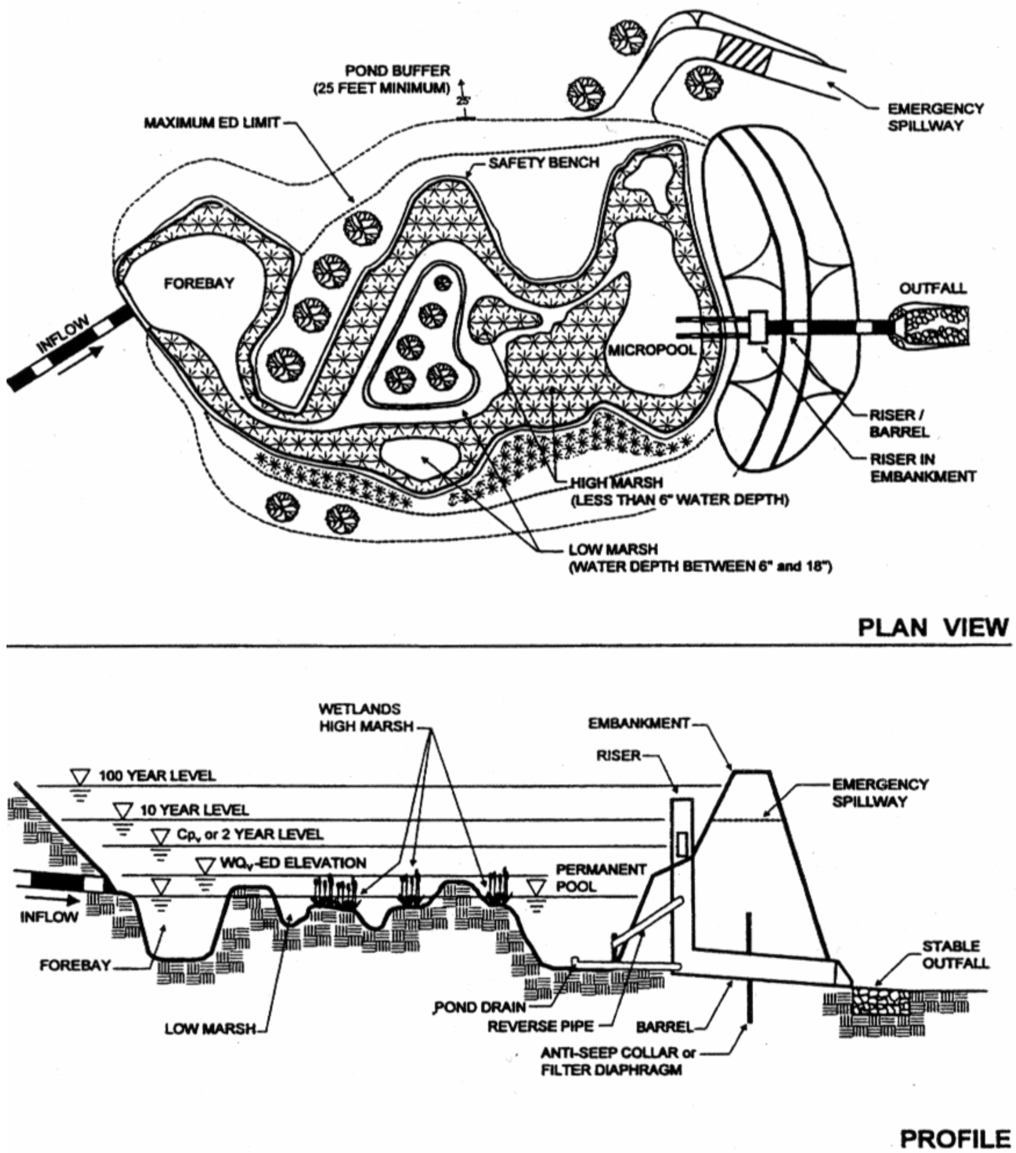


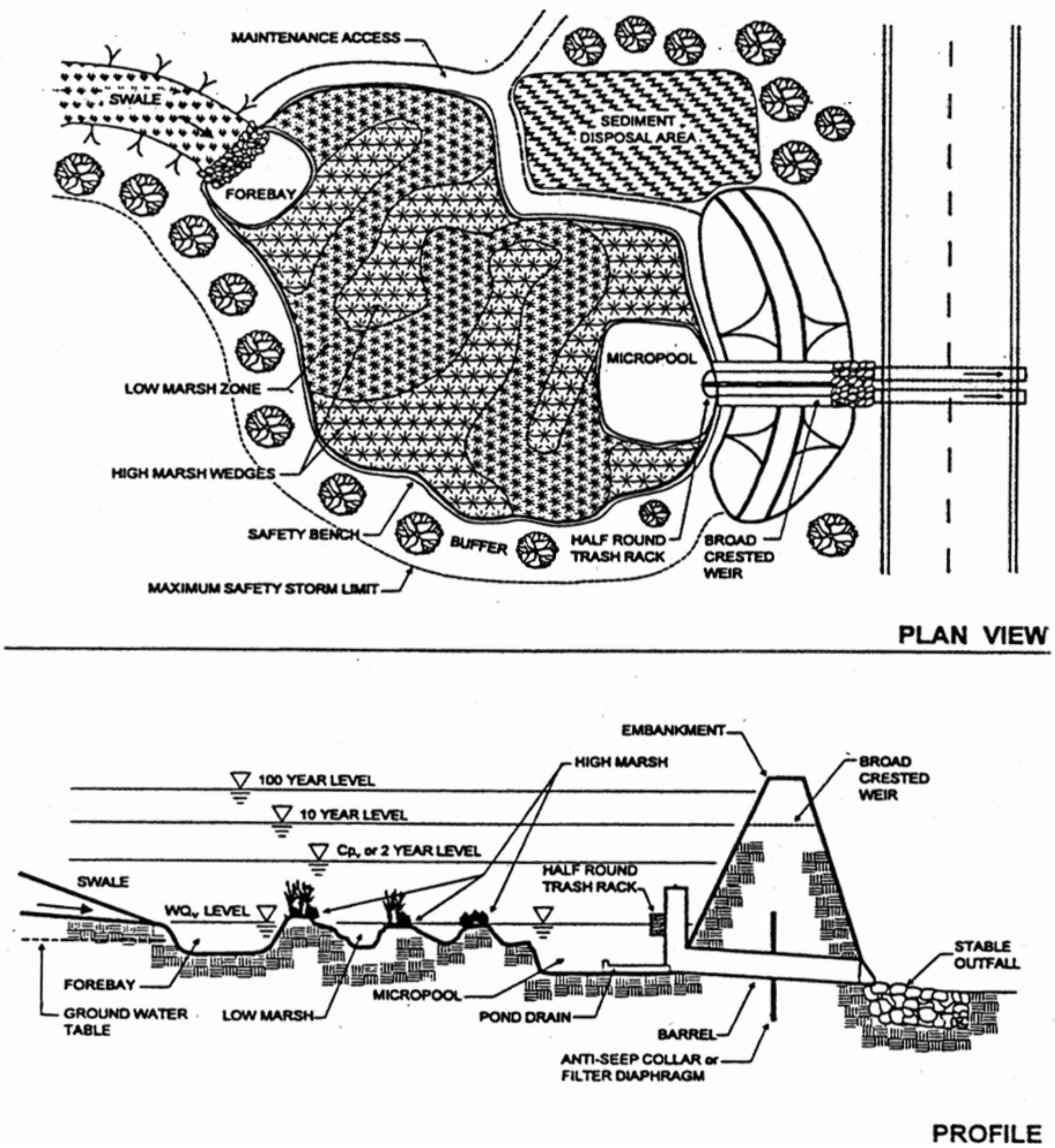
Figure 5-13 - Typical Extended Detention Wetland



Pond/Wetland System

Multiple cell systems, such as pond/wetland systems (**Figure 5-14**), utilize at least one pond component in conjunction with a shallow marsh component. The first cell is typically the wet pond that provides for particulate pollutant removal. The wet pond is also used to reduce the velocity of the runoff entering the system. The shallow marsh provides additional treatment of the runoff, particularly for soluble pollutants. These systems require less space than the shallow marsh systems and generally achieve a higher pollutant removal rate than other constructed storm water wetland systems.

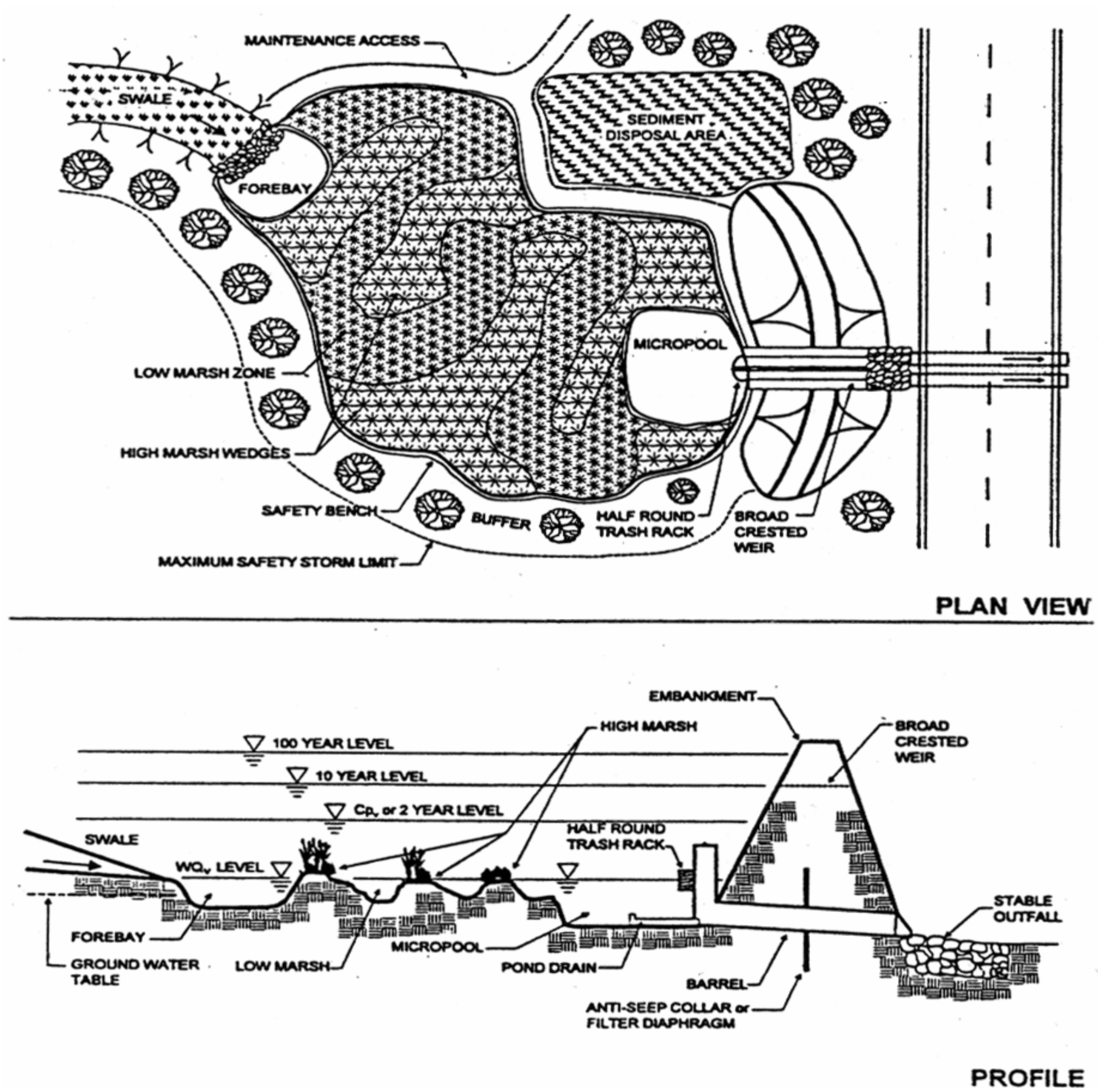
Figure 5-14 - Typical Pond Wetland System



Pocket Wetlands

These systems may be utilized for smaller sites of one to ten acres. To maintain adequate water levels, pocket wetlands are generally excavated down to the groundwater table. Pocket wetlands (**Figure 5-15**) that are supported exclusively by storm water runoff generally will have difficulty maintaining marsh vegetation due to extended periods of drought. In urban settings, natural wetlands can be altered by increases in runoff volume. The existing functions and structure of the natural wetland can be altered severely when runoff becomes a major component of the natural wetland hydrologic regime (or water balance). Ultimately, natural wetlands that have been altered by runoff function more like constructed storm water wetland systems than natural systems.

Figure 5-15 - Example of a Pocket Wetland



Sites must be carefully evaluated when planning constructed storm water wetlands. Soils, depth to bedrock, and depth to water table must be investigated before designing and siting constructed storm water wetlands.

A "pondscaping plan" should be developed for the creation of a storm water wetland. This plan should include hydrological calculations, a wetland design and configuration, elevation and grades, a site/soil analysis, and estimated depth zones. The plan should also contain the location, quantity, and propagation methods for the storm water wetland plants. Site preparation requirements, maintenance requirements, and a maintenance schedule are also necessary components of the plan.

Establishment and maintenance of the wetland vegetation is an important consideration when planning a storm water wetland. The following is a list of recommendations for creating wetlands:

- In selecting plants, consider the prospects for success more than the specific pollutant capabilities. Plant uptake is an important removal mechanism for nutrients, but not for other pollutants.
- Selection of native species should avoid those that invade vigorously. Since diversification will occur naturally, use a minimum of species adaptable to the various elevation zones within the storm water wetland.
- Give priority to perennial species that establish rapidly.
- Select species adaptable to the broadest ranges of depth, frequency, and duration of inundation (hydroperiod).
- Match site conditions to the environmental requirements of plant selections.
- Take into account hydroperiod and light conditions
- Give priority to species that have already been used successfully in constructed storm water wetlands that are commercially available.
- Avoid using only species that are foraged by the wildlife expected at the site.
- Establishment of woody species should follow herbaceous species.
- Add vegetation that will achieve other objectives, in addition to pollution control.

Constructed storm water wetlands require considerable routine maintenance, but do not require large, infrequent sediment removal, unlike conventional pond systems that require relatively minor routine maintenance and expensive sediment removal at infrequent intervals.

Careful observation of the system over time is required. In the first few years after construction, twice a year inspections are needed during both the growing season and non-growing season. Data gathered during these inspections should be recorded, mapped, and assessed. The following observations should be made during the inspections:

- Types and distribution of dominant wetland species in the marsh
- The presence and distribution of planted wetland species; the presence and distribution of volunteer wetland species; signs that volunteer species are replacing the planted wetland species
- Percentage of unvegetated standing water (excluding the deep water cells which are not suitable for emergent plant growth
- The maximum elevation and the vegetative condition in this zone; if the design elevation of the normal pool is being maintained for wetlands with extended zones.
- Stability of the original depth zones and the microtopographic features
- Accumulation of sediment in the forebay and micropool; and survival rate of plants in the wetland buffer

Regulating the sediment input to the wetland is the priority maintenance activity. The majority of sediments should be trapped and removed before they reach the wetlands either in the forebay or in a pond component. Gradual sediment accumulation in the wetlands results in reduced water depths and changes in the growing condition within the wetland that can destroy the wetland plant community.

In addition to the creation of wetlands, the restoration of the aquatic habitat of Peruque Creek will involve enhancement and expansion of existing wetlands. By providing improved and expanded wetland habitat, the stability of the Peruque Creek watershed ecosystem is increased as the impacts of the storm water flows are minimized and low flows are enhanced.

5.4 Stream Erosion and Velocity Controls

The use of structural stream restoration measures is an alternative control measure to remediate the negative impacts of watershed urbanization along watershed streams. There are several locations along the Peruque Creek stream channel where the stream channel and/or channel bank is unstable and eroding away. In stream restoration projects, alternative materials such as logs, root wads, and rock are used to control erosion, stabilize slopes, control stream gradients, create flow diversity, and provide aquatic habitat. They are used in areas for treating invert, toe, top of bank, and full bank erosion situations. Alternative remediation techniques include the use of: root wads, log vanes, rock vanes, and J-hook vanes, cross vanes, step-pools, boulder bank stabilization, and rock grade control structures.

Root Wads

Root wads are a remediation measure that can be used for limited bank stabilization and aquatic habitat enhancement. Root wads are intact stumps taken from fresh, green, healthy parent trees. Hardwood trees are preferable, with the size depending on the stream size. Root wads are placed in the lower one third of the bank, oriented perpendicularly to the direction of flow. Footer logs are placed below and perpendicular to the root wads, at or below the stream invert. Bracing boulders are placed on each side of the root wad to help to hold it in place. There are several locations along the Peruque Creek channel where this remediation measure could be used to stabilize the channel. **Figure 5-16** shows an example of how root wads can be used for channel stabilization.

Figure 5-16 - Root Wad Channel Stabilization

Log Vanes

Log vanes are an alternative remediation measure that can be used for bank stabilization and the creation of flow diversity. Log vanes are single-arm structures whose tips are partially embedded in the streambed so that they are submerged even during low flows, and whose bank-ends are at bank-full elevation. Single logs or smaller logs banded together can be used. Support pilings are used to anchor the log structure to the streambed. Rods can be used for banded logs, and boulders can be used to stabilize the log vanes. **Figure 5-17** shows a typical example of a log vane structure.

Figure 5-17 - Typical Example of a Log Vane

Rock Vanes

Rock vanes can be used along with or instead of log vanes for bank stabilization and the creation of flow diversity. Rock vanes are single-arm structures that are partially embedded in the streambed such that they are submerged even during low flows. Vane rocks are placed in a line starting in the affected bank so that each rock is touching each adjacent rock to form a tight-fitted structure. Vane rocks are placed on top of footer rocks.

Figure 5-18 - Typical J-Hook Vane

J-hook Vanes

J-hook vanes can be used for bank stability and creation of flow diversity. J-hook vanes are single-arm structures whose tips are placed in a "J" configuration and partially embedded in the streambed such that they are submerged even during low flows. Vane rocks are placed in a J-formation so that each rock is touching each adjacent rock to form a tight fit, with one to two rocks firmly anchored into the bank. Vane rocks are placed on top of footer rocks. **Figure 5-18** shows a typical example of a J-hook vane that could be used in the Peruque Creek stream channel.

Figure 5-19 - Typical Rock Cross Vane

Rock Cross Vanes

Cross vanes are an alternative measure that can be used for aquatic habitat and channel grade control. When constructed and spaced properly, cross vanes can simulate the natural pattern of pools and riffles occurring in undisturbed streams while forming gravel deposits which fish can use as spawning grounds. Cross vanes are designed in a "U" shape from bank to bank such that the apex of the structure points upstream. All rocks should touch adjacent rocks to form a tight fit, and vanes should be placed on top of footer rocks. A typical example of a rock cross vane is shown in **Figure 5-19.**

Step Pools

Step pools can be used for aquatic habitat and grade control. Step-pool channels have a succession of channel-spanning steps formed by large grouped boulders called clasts that separate pools containing finer bed sediments. Engineered steps can be made from boulders, logs, and large woody debris. Step rocks should be placed on footer rocks so that the step rock is offset in the upstream direction, and the footer rocks extend below the scour whole elevation. **Figure 5-20** shows how a series of boulder step pools could be used along the Peruque Creek stream channel.

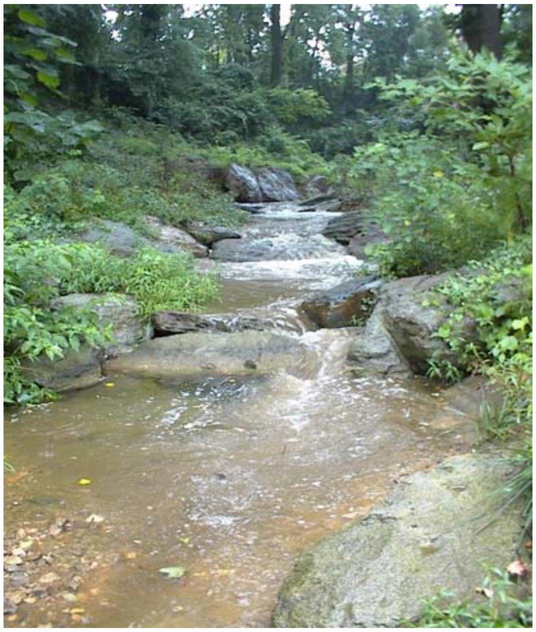


Figure 5-20 - Typical Step Pool Series in a Stream Channel

Boulder Bank Stabilization

Boulder bank stabilization can be used where channel banks are unstable due to steep slopes or stream erosion. There are several locations along the Peruque Creek channel where the existing channel banks are eroding away and need to be stabilized. Boulders are placed along the stream banks so that each is partially embedded in the stream bank and each rock touches each adjacent rock to form a tight fit. A typical example of the use of boulder bank stabilization is shown in **Figure 5-21.**

Figure 5-21 - Typical Example of Boulder Bank Stabilization

Rock Grade Control Structures

Rock grade control structures are a remediation measure that can be used for grade control and erosion reduction. They reduce the longitudinal slope of the natural channel, limit the extent of channel-bed degradation, and improve downstream aquatic habitat.

Section 6
Assessment and Screening of Management Alternatives

The practice of watershed management and protection is about making choices regarding which tools and measures to apply, and in what combination. Alternative structural and non-structural management and control measures that potentially could be considered for the Peruque Creek watershed were identified and described in Sections 4 and 5. In this section of the watershed management plan, the alternatives are evaluated and screened to determine an optimal mix of recommended management measures to apply to existing watershed problems and meet the watershed goals and objectives.

Evaluation criteria were established to facilitate the screening process and select which management alternatives are applicable and best suited to the Peruque Creek watershed. The following screening and selection criteria were formulated and used for the Peruque Creek watershed management plan.

- Applicability of the Alternative - is it technically feasible and reliable for the specific conditions within the Peruque Creek watershed
- Cost to Implement the Alternative - is the alternative cost-effective
- Effectiveness of the alternative to improve water and habitat quality and meet watershed goals and objectives
- Ability of the alternative to be implemented in the Peruque Creek watershed

This section of the plan will document how these screening criteria were applied to the alternative structural and non-structural control measures that were discussed in the previous sections. Section 7 will provide the recommended watershed management plan elements based upon the screening of management alternatives documented in this section.

6.1 Screening of Alternative Land Use Controls

A basic goal of the watershed management plan is to apply land use planning techniques to direct development, preserve sensitive areas, and maintain or reduce the impervious cover within the Peruque Creek watershed. When screening alternative land use controls, one must consider that most of the watershed is agricultural land and available land area for development.

6.1.1 Direct and Indirect Regulatory Approaches for New Residential Development

A wide variety of techniques can be used to directly and/or indirectly manage land use and impervious cover in watersheds. Watershed planners and local officials face hard choices when deciding which land use planning techniques are the most appropriate to modify current zoning. Individual development projects can be designed to reduce the amount of impervious cover they create. Some key questions to consider in the alternative screening process include:

- What economic and other incentives can be used to encourage developers, homeowners, and business owners to utilize better site designs?
- What are the most important development and rules that need to be changed to promote better site design, and can a local consensus be achieved to actually change them?
- Are existing ordinances and controls being adequately implemented and enforced, and if not, what needs to be changed?

Alternatives

- Allow zoning to control land use practices so as to prevent incompatibility of neighboring uses and restrict uses that are harmful to health and the well-being of the community

Zoning is the dividing of a municipality into districts and the establishment of regulations governing the use, placement, spacing, and size of land and buildings. Zoning ordinances can be developed which place limitations on development and encourage the most appropriate land uses.

- Utilize better site designs toward new development in the Peruque Creek watershed with the goal of the conservation of natural areas

Clustering, impervious surface reduction, setbacks, and protection areas are just some of the possible provisions toward utilizing better site designs in new development projects

- Evaluate the effectiveness of current state and local requirements for E&SC associated with new development

An effective E&SC program is an important tool to reduce the potentially severe impacts generated by the construction process. Effective E&SC practices are needed to protect sensitive aquatic communities, reduce sediment loads, and maintain the boundaries of conservation areas and boundaries.

- Evaluate the effectiveness of current state and local clearing and grading ordinances.

Effective clearing and grading ordinances can reduce the potentially severe impacts to a stream and its watershed resulting from new development. Effective clearing and grading ordinances protect environmentally sensitive areas by controlling the clearing of vegetative cover and subsequent grading of a new development site.

- Examine techniques to indirectly manage land use and impervious cover from new development projects within the Peruque Creek watershed.

There are indirect regulatory approaches toward controlling and reducing runoff from new development projects such as controlling the use of steep slopes, impervious surfaces, wetland and floodplain disturbance, and tree and vegetation removal. These indirect regulatory approaches can be used to control the potentially detrimental impacts new development can have on a watershed.

For more complete descriptions of these alternative direct and indirect municipal control measures, please refer to Sections 4.1.1 and 4.1.2 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Implementing direct and indirect regulatory approaches toward new development has extensive applicability to the Peruque Creek watershed. The Peruque Creek watershed is rapidly developing. Therefore, an examination of existing municipal zoning and subdivision ordinances would have a significant potential impact on the Peruque Creek watershed.

Most of the developable land areas with in the Peruque Creek watershed haven't been built out or set aside for open space. Because of this, the effectiveness of only select direct and indirect regulatory approaches toward new development will be discussed and evaluated below.

Effectiveness

The effectiveness of direct and indirect regulatory approaches toward new development is largely dependant on controlling the amount and location of new impervious cover within the watershed. Better site design approaches are typically applied to new development with the goal of reducing impervious cover and directing proposed development to the least sensitive areas within a watershed. This would be effective within the Peruque Creek watershed because open land is abundant.

The effects of better site design in new development projects are largely positive. For example, one approach toward better site design is through "open space" or cluster development, which minimizes lot sizes within a compact developed portion of property while leaving the remaining portion predominantly open. Cluster development creates open space that provides many market and non-market benefits. For example, some communities have found that cluster development can reserve up to 15 percent of the site for active or passive recreation. When carefully designed, the recreation space can promote better pedestrian movement, a stronger sense of community space, and a park-like setting. In addition, it has been found that cluster development can reduce site impervious cover from 10 to 50 percent (depending on the original lot size and layout). This can thereby reduce the cost for both storm water conveyance and treatment. A third benefit is that, since most of the open space is managed as natural area, the future value of the property is often increased.

Effective E&SC controls can provide direct and indirect benefits to both developers and adjacent property owners. On a typical site, the cost to install and maintain erosion and sediment can average $800 to $1,500 per cleared acre per year, depending on the duration of construction and the site conditions (SMBIA 1990; Patterson et al. 1993). By keeping soil on the site, a contractor needs to spend less time and labor re-grading a site to meet final plan elevations, and less effort stabilizing eroded slopes. Most municipalities within the Peruque Creek watershed already have erosion and sediment control ordinances in place. The effectiveness of these existing ordinances in protecting the watershed will depend on the degree that they are enforced when any new construction were to occur.

Implementing indirect regulatory approaches toward new development have shown numerous benefits as well. For example, communities have repeatedly found that conserving trees and forests on residential and commercial sites can enhance property values by an average of 6 to 15 percent and increase the rates at which units are sold (Morales 1980; Weyerhauser 1989). Conserving trees also saves money on energy bills and treatment of runoff. Studies by the American Forest Association have shown that homes and businesses that retain trees save 20 to 25 percent in energy bills for heating and cooling, when compared to homes where trees were cleared. A modeling study by Hanson and Rowntree (1988) reported that storm water runoff decreased by 17 percent due to forest cover in a Utah development during a typical 1-inch rainstorm.

Cost

Implementing land use controls toward new development within a watershed is not without costs. Effective planning requires a careful local investment in technical studies, monitoring, coordination, and outreach. As Brown (1996) notes, a community can expend several hundred thousand dollars on a watershed study to obtain the scientific data needed to justify land use decisions. Furthermore, the long-term cost to fully implement them can be significant for local governments. Watershed planners and local officials face financial decisions when determining which land use planning techniques are the most appropriate to modify current zoning. For the Peruque Creek watershed, the costs associated with the technical watershed studies may be provided by grants from federal or state agencies (e.g. NRCS, MDNR). The cost to modify existing land development ordinances would be minimal. The significant municipal cost would be to enforce the revised ordinances and ensure that any new development within the watershed would comply.

Ability to be Implemented

Managing new growth in a watershed context and reducing the impacts it has on receiving streams will be a high watershed priority. These basic management tools need to be considered for any future development that takes place within the watershed. These watershed protection goals can be a guide to where and how new development occurs. The principles of direct and indirect regulation of new development should be implemented as a management approach to the watershed.

6.1.2 Regulatory Approaches for Restorative Redevelopment

Some of the older properties within the watershed may have deteriorated and will need to be restored. Over time, buildings will be renovated, driveways and parking areas will be reconstructed, and patios and sidewalks will be replaced. Individual redevelopment projects can be designed to remove existing impervious surfaces and replace them with new semi-pervious materials and gradually reduce the amount of impervious cover in the watershed. Some key questions to consider in the alternative screening process include:

- What watershed neighborhoods and areas have the greatest potential for removing existing impervious surfaces as part of the restorative redevelopment process?
- What economic and other incentives can be used to encourage home and business owners to utilize more permeable building materials, especially when replacing deteriorated concrete or asphalt pavement on existing sites?
- Is there sufficient opportunity for redevelopment within the watershed to make a measurable impact on total impervious cover?

Alternatives

- During future restorative redevelopment projects within the Peruque Creek watershed, encourage home and business owners to replace deteriorated concrete and pavement with semi-pervious pavement materials, such as brick or concrete pavers, and to redirect storm water runoff to soil and vegetation.

In the Peruque Creek watershed, where 34 percent of the land has been urbanized, the concept of redevelopment or site restoration is important. Deteriorated driveways and parking areas will need to be replaced, buildings will need to be renovated and reconstructed, and deteriorated sidewalks and patios will need to be replaced. These changes will provide opportunities to restore the communities and ecosystems of the urban watershed to health and vitality.

For a more complete description of the concept of restorative redevelopment and its potential uses in the Peruque Creek watershed as an alternative land use control measure, please refer to Section 4.1.3 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Restorative redevelopment efforts within the Peruque Creek watershed are applicable, but may not be the key ingredient toward revitalizing this developing watershed. Many of the properties and systems of sewage, drainage, and pavements in Peruque Creek are new and may not need to be restored, revitalized, or reconstructed. The regenerative capacity of soils and ecosystems is strong in the Peruque Creek watershed. Natural processes are waiting to help mitigate the pollutant loads associated with urban runoff. Taking advantage of them enacts a new concept of storm water infrastructure to include the capacities of soil and vegetation to absorb water and filter pollutants. This is a superior approach to infrastructure management because it puts nature to work, and reduces the work humans must do.

Effectiveness

The short-term effectiveness of restorative redevelopment for the entire watershed would be low. However, the long-term effectiveness could be very high if a majority of property owners would apply these principals when existing facilities wear out and need to be replaced. The benefits of restorative redevelopment efforts will not be seen in one year, or perhaps even five years. The redevelopment of individual sites will contribute incrementally to the restoration of watershed process and the overall benefits will be seen on a long-term scale. The solution to a watershed-wide problem would require the contribution of many similar projects throughout the watershed.

Promoting the use of porous pavements at commercial, school, and church parking lots, as well residential driveways and patios, will aid in the infiltration of groundwater and reduction in storm water runoff. Also, increasing the urban forest by planting trees and shrubs can reduce storm water runoff, moderate urban climate, improve air quality, and reduce noise. Obviously, planting one tree or re-paving a single residential driveway with the intent of promoting infiltration will not showcase these benefits, but creating dense vegetative covers and reducing impervious cover throughout the watershed would be highly effective over a number of years.

Many of the subsequent sections will examine in more detail some of the measures that are available for restoring watersheds within individual sites and neighborhoods.

Cost

The costs associated with restorative redevelopment efforts will vary based upon the techniques, measures, and building materials that are implemented. There can sometimes be a cost savings for implementing restorative redevelopment principles. For example if an existing deteriorated 10-foot wide concrete driveway were to be replaced with pavers, the replacement cost could increase by 15 to 20 percent. However, if at the same time the driveway width were to be reduced to 8-feet and the old driveway borders replaced with landscaping to intercept runoff, the driveway area would decrease by 20 percent which would offset the higher material costs for the pavers.

A recent example of the potential costs savings can be seen in a shopping center in Frederick, Maryland that was renovated and redesigned. Here, the existing parking demand was reduced by about 15 percent to reflect the actual parking demand more accurately. Grid pavers were used rather than normal paving materials. The redesigned parking lot, by virtue of its lower impervious cover and improved storm water practices, produced about 20 percent less runoff than the original lot. The cost to develop the redesigned parking lot was actually marginally lower than for the conventional parking lot – about 5 percent (CWP 1998b).

The costs associated with restorative redevelopment can be lower than other management approaches. For example, planting new trees and landscaping islands to intercept rainwater and reduce storm water runoff will certainly be less expensive than constructing regional detention facilities. Many restoration projects, with the intent of watershed revitalization in mind, will yield similar costs as if the watershed was not a priority.

Ability to be Implemented

The principals of restorative redevelopment can be voluntarily implemented if home and business owners are adequately educated regarding the potential benefits to their property, their community, and the watershed as a whole. The more that watershed residents are educated about natural storm runoff processes and on-site connections to the watershed the more likely people would be to replace deteriorated on-site facilities with watershed-friendly alternatives. Storm water systems should be visible and a tangible part of the urban framework of the watershed. Public education could be even taken one step further and implemented into a school's educational curriculum. A greenhouse, utilizing water collected from the school's roof, could be a teaching tool for explaining the water cycle and the role of the school and neighborhood in the watershed. This educational process could encourage parents to implement similar management measures at their own homes. Regulatory land use approaches, when teamed up with public education, can be used to encourage home and business owners to apply the principals of restorative redevelopment whenever existing facilities wear out and need to be replaced or revitalized.

Financial incentives could also improve the rate at which the principals of restorative redevelopment are implemented. Any proposed development within the watershed can be directed to these areas first. This can be done through incentives subsided by the state or local government including loans, tax breaks, and liability control. The re-use of abandoned parking areas, for example, may then be restored to native vegetation.

Everything that is done in a retrofit or redevelopment project should produce multiple, mutually reinforcing benefits. When a component is multi-functional, it attracts advocates promoting each of its several functions, and attracts a broad community and political support.

6.1.3 Land Acquisition for Preservation of Open Space and Buffer Zones

The riparian corridor, where land and water meet, deserves special protection in the form of buffers. A buffer can be placed along the stream to physically protect it from future disturbance or encroachment. Some key questions to consider when screening alternative land acquisition measures include:

- Are existing riparian buffers sufficient to sustain the integrity of the aquatic and terrestrial ecosystems?
- Is restoration or better stewardship possible along an existing aquatic corridor?
- How much pollutant removal can realistically be expected from the buffer network?
- Who will own and maintain the buffer and how will maintenance be paid for?

Alternatives

- Purchase land to maintain existing open areas and buffer zones

Local governments can purchase land within the riparian zone to maintain existing open areas and buffer zones to protect valuable resources from the effects of development.

- Restore existing buffers to sustain the integrity of the aquatic and terrestrial ecosystems

Existing riparian buffers can be restored and enhanced to maintain the integrity of the aquatic and terrestrial ecosystems. Restoring existing buffers can add to the quality of the stream and the community in many diverse ways.

- Implement a strong educational plan to encourage greater buffer awareness and stewardship among watershed residents toward riparian buffer zones.

Future integrity of existing buffer systems require a strong educational program. The two primary goals of the program are to make the riparian buffer more "visible" to the community, and to encourage greater buffer awareness and stewardship among residents.

For more complete descriptions of buffer zones and their potential usefulness in the Peruque Creek watershed as an alternative land use control measure, please refer to Section 4.1.4 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Within the Peruque Creek watershed, private land needs to be acquired, or setback ordinances need to be established (in Warren County) and increased, to maintain existing open spaces and stream buffers along the existing riparian corridor. Stream bank vegetation along the Peruque Creek riparian corridor has been degraded as a result of historical agricultural practices. Developers who purchase this land for redevelopment should consider restoring the natural buffer strip along Peruque Creek. Re-vegetation of these areas would be beneficial, particularly in areas where the natural vegetation has been replaced with mowed grass or the bare slopes that currently have little or no vegetation. Substantial restoration benefits could be attained by re-vegetating these mowed and cleared bottomlands with native species.

Previously completed water quality studies along Peruque Creek have shown that animal wastes from unleashed dog running and improper disposal contributes to the high bacteria concentrations that were observed. Discouraging these harmful practices within existing riparian buffer zones will improve water quality in streams.

Effectiveness

Figure 6-1 - Buffer Strip Along Tributary to Peruque Creek

While the benefits of urban stream buffers are impressive, there capability to remove pollutants should not be overstated. In urban watersheds, rainfall is rapidly converted to concentrated flow. Storm water flows quickly concentrate within a short distance in urban areas and often "short-circuit" a buffer. Consequently, as much as 90 percent of the surface runoff generated in an urban watershed concentrates before it reaches the buffer, and ultimately crosses it in an open channel or storm drain pipe. So from a storm water treatment system standpoint, a buffer system will only be able to treat runoff from less than 10 percent of the contributing urban watershed to the stream.

A well-maintained and naturalistic stream buffer along the banks of a stream (**Figure 6-1**) is effective in limiting the entrance of sediment, pollutants, and nutrients to the stream itself. When forested, a stream buffer is effective in promoting bank stability and serves as a major control of water temperature (Leopold 1997). Previously completed water quality studies have shown that summertime urban runoff from heated pavement surfaces can sometimes cause stream water temperatures to exceed optimal values for healthy aquatic life. A forested buffer zone along the stream could help mitigate these urban impacts. A public education program could greatly improve the potential effectiveness of a restored buffer area by improving the public perception of the riparian greenway.

Cost

Costs could be significant if private land is to be acquired. If setback ordinances are put in a place, the costs would be minimal for administration. Another cost will lie with re-vegetating the existing buffer areas and maintaining them once they are restored. Costs will include the purchasing and planting of native plant and tree species, maintaining the buffer areas, and efforts toward educating residents on the purpose, limits, and allowable uses of these areas.

Ability to be Implemented

The creation, enhancement, and restoration of stream and wetland buffers have become an increasingly popular watershed protection technique due to simplicity, low cost, ease of implementation, and capability to protect resource areas. In some places within the Peruque Creek watershed, the buffer zone area along the stream corridor already is sufficient; however, land acquisition or setback ordinances would be required to preserve the remaining open spaces and buffer zones.

The primary focus of this management measure will lie with restoring existing buffer areas with improved vegetative cover and preventing the revitalized buffer zones from being degraded in the future. Efforts to reforest existing buffer zones can be successful, even in areas like the Peruque Creek watershed. Foresting buffer areas is relatively simplistic and can provide valuable aquatic and riparian habitat areas for a diverse range of species, reduce water temperatures in the stream, and can make the area more aesthetically pleasing to watershed residents.

Management of the forested buffer areas after they have been established should be relatively easy to implement as well. The objective should be to render them visible to residents and ensure they are protected from harmful human activities. Parks maintenance crews can add to their routine maintenance schedule periodic "buffer walks" to inspect the condition of the buffer network. Invasive and undesirable plant species that may gain a foothold in the buffer zone would need to be removed periodically to encourage native plants to flourish and promote greater species diversity.

Educating residents on the purpose, limits, and allowable uses of these areas becomes equally important. With regards to buffer awareness and stewardship among watershed residents, the underlying theme of buffer education is that most encroachment problems reflect misconceptions rather than contempt for the buffer system. Awareness and educational measures can increase the recognition of the buffer within the community. Not all residents, however, may respond to this effort, and some form of enforcement may be necessary.

6.1.4 Runoff Control for Commercial and Industrial Sites

Pollutants most frequently associated with storm water include sediment, nutrients, bacteria, oxygen demanding substances, oil and grease, and other toxic chemicals. Industrial and commercial activities, even small businesses and relatively small facilities, have the potential to be significant pollutant contributors of these pollutants. Storm water pollution prevention and runoff control at these facilities includes selecting and carrying out cost-effective actions, or BMPs that prevent the pollution of storm water discharges.

Alternatives

- Implement a BMP approach toward pollution prevention for industrial/commercial facilities located within the Peruque Creek watershed.

The intent of this pollution prevention approach is to achieve a level of on-site pollution control at the point of origin so that storm water will not need to be treated in an off-site regional hydraulic detention facility or pollutant removal device. Owner and employee training is the vital component in implementing the BMP "operational practices" approach toward storm water pollution prevention. Trained inspectors can visit a participating facility, recommend management practices based on his/her observations, and educate employees on the problems and solutions. Common pollution prevention methods that should be stressed include non-storm water discharges to drains, vehicle and equipment fueling, storage of liquids, grounds maintenance, and waste handling, among others.

For a more complete description of BMPs and their potential uses in the Peruque Creek watershed as an alternative control measures for commercial and industrial sites, please refer to Section 4.1.5 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Only a small portion of the total Peruque Creek watershed area is designated for industrial/commercial land use. However, in some cases, discharges from these industrial or commercial facilities have the potential to be significant contributors to storm water pollution. Routine or accidental releases from these few facilities can discharge pollutants in quantities far beyond the proportion of industrial/commercial land use area. As a result, implementing Best Management Practices within the Peruque Creek commercial/industrial establishments is both applicable and recommended.

Effectiveness

Pollutant loads from various commercial and industrial activities are highly variable, often episodic, and in practical terms, can defy quantification. The effectiveness of implementing the BMP approach will vary with each facility, even for the same type of industry.

It is known that certain BMP operational practices are 100 percent effective if implemented properly. However, it is difficult to determine within a reasonable degree of certainty what will be the reduction in loading, given in most cases that the original loading from the activity cannot be determined. If a facility has only one activity, then analyzing the effectiveness may be more straightforward. For a site with many activities, any prediction of loading reduction carries with it great uncertainty.

Cost

Costs associated with implementing the BMP approach toward controlling runoff from industrial and commercial sites primary involves the training and education of employees and customers. The cost of training employees can vary, depending on factors such as staff time, training components, and the extent of the training. Once an effective program is established, the cost for continuing educational materials and training will decrease significantly.

As for costs to industrial/commercial facilities for implementation, many of the "operational practices" carry minimal cost with them. For example, moving an outdoor operation indoors, discontinuing dumping pollutants into a storm drain, labeling containers or exposed piping, using drip pans, covering items stored outdoors, sweeping pavement sediments, and performing other good housekeeping practices have minimal costs associated with them.

However, if low cost "operational practices" are insufficient to meet numeric effluent pollutant limits, some structural modifications to facilities to enhance pollution prevention (design features of loading dock areas, vehicle fueling and maintenance areas, etc.) or on-site treatment control facilities (like oil/water separators) may be needed.

Ability to be Implemented

The BMPs approach to pollution prevention should be relatively easy to implement as it can be integrated into existing training programs that already may be required by other regulations. For smaller businesses not regulated by federal, state, or local regulations, developing a program is recommended. This can be especially attractive to smaller facilities and businesses that may not generate pollutants in large enough quantities to make on-site treatment or government regulation mandatory, but can be occasional sources of significant amounts of pollutants.

Further, small businesses may not have the wherewithal to implement extensive structural controls or to develop in-house expertise on specialized environmental issues and the described "operational practices" provide an attractive option. The approach is highly practical from a business standpoint because it focus on industrial/commercial operations and low-cost pollution control practices rather than expensive constructed solutions like new industrial structures or new storm water detention or treatment facilities.

In order to encourage best management practices among the participating industrial/commercial facilities, promotional tools like listings in newspaper ads, prize drawings, and discount coupon giveaways can be made available to help generate business for these participating facilities. Participating business owners can be given watershed stewardship stickers to display on-site. Watershed residents can encourage business by patronizing and supporting participating businesses who display the stickers.

6.1.5 Better Site Design

Individual development and redevelopment projects can be designed to reduce the amount of impervious cover they create, and increase the natural areas they conserve. Many innovative site planning techniques have been shown to sharply reduce the impact of development. Designers, however, are often not allowed to use these techniques in many communities because of outdated local zoning and/or subdivision codes. The better site design watershed protection tool is a nonstructural management measure that seeks to foster better site designs that can afford greater protection to the Peruque Creek watershed.

For a more complete description of better design concepts and their potential use in the Peruque Creek watershed as an alternative control measure to reduce urban runoff, please refer to Section 4.1.6 of this watershed management plan.

Alternatives

- Open Space or Cluster Residential Subdivisions

Cluster development designs minimize lot sizes within a compact developed portion of a property while leaving the remaining portion open, thus reducing the amount of impervious cover created by residential subdivision by 10 to 50 percent. The same development concept can be applied to new homes and businesses on individual lots.

- Green Parking Lots

Green parking refers to an approach that downsizes parking areas while still providing convenient access for the motorist. The common theme in green parking lots is minimization of impervious area at every stage of parking lot planning and design. The concept of green parking lots can also be applied to existing parking lots when they are refurbished.

- Roof Runoff Management

Re-directing rooftop runoff over pervious vegetated surfaces before it reaches paved surfaces can significantly decrease the annual volume runoff from a site. This can reduce the annual pollutant load and runoff volume being delivered to receiving waters and can have a substantial benefit in reducing downstream impacts.

Applicability to the Peruque Creek Watershed

There are many opportunities for implementing better site designs for new development. Significant areas of developable open space are under construction. Many of these design principals could be integrated into the design of the subdivision to maximize green space and maintain vegetated buffer zones around the perimeter of the plan.

Effectiveness

The use of better site design in new development projects can be highly effective in reducing the quantity of storm water runoff from the site and reducing the associated pollutants that are transported in urban runoff. Some communities have found that innovative site design concepts can reduce site impervious cover from 10 to 50 percent depending on the lot size and layout. This can thereby reduce the cost for both storm water conveyance and treatment.

Cost

The costs associated with implementing better site designs tend to be minimal. Reducing driveway widths and patio areas can offset the higher material cost for semi-pervious paving materials. Directing roof and driveway runoff to vegetated areas instead of the street curb usually is a no-cost or low-cost measure that can save money over time due to the reduced need for watering.

Ability to be Implemented

The principals of better site design can be voluntarily implemented if home and business owners are adequately educated regarding the potential benefits to their property, their community, and the watershed as a whole. The more that watershed residents are educated about natural storm runoff processes and on-site connections to the watershed the more likely people would be to modify their site plans to reduce the amount of impervious surface and redirect runoff from roofs and driveways onto vegetated surfaces. The principals of better site deign, when teamed up with a rigorous public education program, can be used to encourage home and business owners to develop their existing vacant properties in a way that reduces urban runoff and its associated pollutant loads to the watershed.

6.2 Screening of Public Education Programs

The goal of watershed stewardship is to increase public understanding and awareness about watersheds, promote better stewardship of private and public properties, and develop funding to sustain watershed management efforts. Promoting watershed advocacy is important because it can lay the foundation for public support and greater watershed stewardship.

An important element in crafting a watershed education program and screening alternative measures is to select the right combination of outreach techniques. Several communities have recently undertaken before and after surveys to measure how well the public responds to their watershed protection programs. From this research, two outreach techniques showed promise in actually changing behavior: media campaigns and intensive training. Media campaigns typically use a mix of radio, television, direct mail, and signs to broadcast a general watershed message to a large audience. Intensive training uses workshops, consultation, and guidebooks to send a much more complex message about watershed behavior to a smaller and more interested audience. Intensive training requires a time commitment from residents of a few hours or more.

Based on studies conducted, both media campaigns and intensive training showed 10 to 20 percent improvement in selected watershed behaviors among their respected target populations (CWP 1999a). Both outreach techniques are probably needed in the watershed, as each complements the other. For example, media campaigns cost just a few cents per watershed resident reached; while intensive training can cost a few dollars for each resident that is actually influenced. Media campaigns are generally better at increasing watershed awareness and sending messages about negative watershed behaviors. Intensive training, on the other hand, tends to be superior at changing individual practices.

6.2.1 Littering and Illegal Dumping

Littering is a problem in the Peruque Creek watershed. Education is a key to changing behavior and attitudes with regards to littering and dumping. Some key questions to consider in the alternative screening process include:

- Where are the existing dumping sites located, who owns the properties, and what can be done to encourage property owners and neighbors to clean up the site?

- What are the most cost effective ways to reach watershed residents and business owners?

- Who are the existing watershed advocates and how can the support base of volunteers be increased?

Alternatives

- Implement an educational program to familiarize residents and businesses with how littering and improperly disposed materials can affect storm water.

By locating and correcting littering and illegal dumping practices through educational measures, the many risks of public safety and water quality associated with these actions can be prevented. Littering and illegal dumping control programs focus on community involvement and focus on increasing public awareness of the problem and its implications. Alternative means to deliver the message of watershed education include public service announcements and local news features on television, newspaper ads and articles, community newsletters, brochures, internet websites, and training workshops.

- Coordinate special cleanup events where community volunteer groups conduct dumping site cleanups.

Cleanup projects require coordinated planning efforts and community involvement through volunteers to remove litter and illegally dumped materials. Residents who live nearby a dumping site or have special interests in the area are the key players. Once a site is cleaned, efforts are needed to discourage future littering and illegal dumping. Strong deterrents to littering and dumping are natural beauty and community pride. If an area is naturally beautiful and well cared for and if residents are proud of their communities, watershed properties are less likely to be trashed by uncaring people. Signs, lighting, barriers, and beautification efforts are all deterrents to discourage these acts.

For more complete descriptions of these alternative management measures and how they can be used to improve the quality of the Peruque Creek watershed, please refer to Sections 4.2.1 and 4.2.2 of this watershed management plan.

Applicability to the Peruque Creek Watershed

The need for littering and illegal dumping prevention programs in the Peruque Creek watershed to address the risks to public safety and water quality associated with these acts is both applicable and recommended. Littering and illegal dumping can occur everywhere.

Effective anti-littering and illegal dumping control programs make efforts to cleanup dumping sites and eliminate the future illegal discarding of wastes. There are existing volunteer groups within the watershed that could provide the labor resources needed to implement cleanup programs. Outreach programs such as a storm drain program which labels drains with a bright blue fish and the message "drains to stream" can be used to highlight the connection between storm drains and streams and discourage illegal dumping of pollutants down them.

Effectiveness

While the effectiveness of illegal dumping and litter control measures at reducing pollutant loads to local waters are hard to quantify, there are a number of benefits these effective programs can have on public safety and water quality.

Litter can eventually make its way into receiving streams thus making it a risk to water quality and public safety. Illegal dumping of household and commercial waste can have a variety of impacts on water quality. Hazardous chemicals generated from household, commercial, and industrial sources can contaminate ground and surface water supplies, affect drinking water and public health as well as aquatic habitat. Reduced drainage of runoff due to blockage of streams, culverts, and drainage basins can result in flooding and channel modification. Property values can decrease as a result of littering and illegal dumping and the local tax base can be affected. Controlling illegal dumping and street litter can be an effective way to improve aesthetic and water quality in the Peruque Creek watershed.

Cost

The cost of illegal dumping and litter control programs can vary due to economic and social factors. Possible sources of labor for dumping site cleanups can include community and youth groups or corporations. Equipment for cleanup may be available through either public works or transportation agencies or through donations from private companies.

Production costs for educational materials such as flyers and brochures can range from $0.10 to $0.50 per brochure.

Ability to be implemented

A number of groups already have ongoing efforts to educate the public on litter and illegal dumping reduction. For example, a stream clean up event has been sponsored annually by the Missouri Stream Team to remove litter and debris along the Peruque Creek stream. However, after time, the stream side vegetation again was littered. This indicates that the key to local litter and illegal dumping control is through public education – to discourage residents and businesses from littering and illegally disposing of materials.

Illegal dumping and littering is often spurred by cost and convenience considerations, and a number of factors will encourage these practices. The fees for dumping at a proper waste disposal facility are often more than the fine associated with the illegal dumping offense, thereby discouraging residents to comply with the law. The absence of routine or affordable pickup service for trash and recyclables in some communities also encourages these acts.

Community education and involvement, in addition to targeted enforcement, is the key to regulate waste management and eliminate littering and illegal dumping. Integration of illegal dumping prevention into community policy programs can be an effective way to increase enforcement opportunities without the additional cost of hiring new staff. Producing simple messages relating the costs of littering and illegal dumping on local taxes can aid in eliminating the problem. Having a hotline where citizens can report illegal activities and educating the public on the connection between the storm drain and water quality can decrease the disposal of wastes into storm drains.

6.2.2 Landscaping and Lawn Care

Not many watershed residents understand that lawn fertilizer can cause water quality problems. According to surveys, less than one-fourth of watershed residents rated it as a water quality concern and only 10 to 20 percent of lawn owners conduct soil tests to determine whether fertilizer is even needed. Informing residents, employees of lawn and garden centers, and lawn care professionals on methods to reduce fertilizer and pesticide application and to limit water use can help alleviate potential impacts of a major contributor of non-point source pollution in residential communities.

Alternatives

- Implement an educational program to instruct those involved in the lawn care industry on the water quality impacts associated with lawn care products.

Lawn care companies can exercise considerable authority over which practices are applied to lawns they attend, as long as they still produce a sharp looking lawn. Lawn care industry educational programs should address alternate methods to reduce fertilizer and pesticide application, limit water use, and avoid land disturbance. Local governments that want to influence lawn care industries need an active program that supports those companies that employ techniques that limit fertilizer and pesticide application by providing promotional opportunities.

- Provide training for employees of lawn and garden centers regarding lawn care and pollution control.

The key goals for implementing a program like this are to substitute watershed friendly products for those that are not, and to offer training for the store attendants to pass on to consumers at the point of sale on how to use, and perhaps more importantly, how not to abuse or overuse such products. Study after study indicates that product labels and store attendants are the primary and almost exclusive source of lawn care information for the average consumer who takes care of their own lawn.

- Implement a pollution prevention program to educate residents within the Peruque Creek watershed regarding lawn care and pollution control.

Materials such as flyers and brochures can be distributed to educate the residents within the Peruque Creek watershed, particularly the homeowners surrounding Lake Saint Louis, on the water quality impacts associated with lawn care and landscaping. MDC has been coordinating with the PCWA to develop education materials for public distribution. These outreach materials will inform residents who perform their own lawn maintenance that nutrient runoff from lawns can contribute pollutants that contaminate storm water runoff into watershed streams and are toxic to both humans and aquatic organisms. Educational materials should encourage management practices such as ways to reduce fertilizer and pesticide application, substitution of watershed friendly products for those that are not, etc.

For more complete descriptions of these alternative management measures, please refer to Section 4.2.3 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Implementing a pollution prevention program to address lawn care practices that can control pollutants and reduce storm water impacts in the Peruque Creek watershed is highly applicable to the Peruque Creek watershed.

Lawn care is practiced within the Peruque Creek watershed and controlling fertilizer application to these lawns is vital. Chemicals associated with fertilizers (nitrogen, phosphorus, potassium) can find their ways to streams and reducing the application of these chemicals can reduce the water quality problems associated with them. Education programs targeted toward employees of lawn and garden centers and residents who perform their own lawn care would be most applicable to the Peruque Creek watershed.

Effectiveness

The effectiveness of pollution prevention programs designed to educate residents on lawn care and landscaping practices have not been well documented to date. However, from the results of a number of market surveys, both media campaigns (TV, direct mail, signs) and training can each produce up to 10 to 20 percent improvement in watershed behaviors among their respected targeted populations.

Cost

The cost of creating and maintaining a program that addresses lawn care and landscaping practices and water quality varies depending on the intensity of the effort and the outreach techniques that are selected. Production costs for materials such as flyers and brochures are often inexpensive ($0.10 to $0.50 per brochure), and soil testing, and soil kits and testing to determine if fertilization is even needed may be done through a local university to reduce expense.

Ability to be Implemented

Residents are typically not aware of the water quality consequences of lawn care – overall less than one fourth of surveyed residents rated it as a water quality concern (Syferd 1995 and Assing 1994). As a result, providing residents with educational materials can inform residents on the impacts of fertilizer runoff. These materials should attempt to convince residents that a nice green lawn can be achieved without using large amounts of chemicals and fertilizers.

However, the main focus of a lawn care outreach program should be on hardware and garden stores since store attendants are the primary source of lawn care information for residents who take care of their lawns. Store attendants can pass on to consumers how to properly use lawn care products may yield the largest improvement in watershed behavioral changes toward lawn care.

6.2.3 Automobile Maintenance

Dumping automotive fluids down storm drains can be a major water quality problem, since only a few quarts of oil or a few gallons of antifreeze can have a major impact on streams and wetlands during low flow conditions. Automotive maintenance facilities are considered to be storm water "hotspots" where significant loads of hydrocarbons, trace metals, and other pollutants can be produced that can affect the quality of storm water runoff. Common activities at maintenance shops that generate this waste include the cleaning of parts, changing of vehicle fluids, and replacement and repair of equipment. These activities are also performed by residents at home in their driveway in the course of normal vehicle care.

Alternatives

- Implement an outreach and training program for businesses involved in automobile maintenance.

Automotive maintenance pollution prevention programs include targeted outreach and training to automobile maintenance businesses regarding practices that control pollutants and reduce storm water impacts. Trained inspectors can visit a participating facility and recommend management practices based on his/her observations. Common pollution prevention methods at maintenance shops that should be stressed include waste reduction, the use of safer alternatives, spill clean up, good housekeeping, and parts cleaning. In order to encourage behavioral changes among participating maintenance facilities, promotional tools like listings in newspaper ads, decals for shop windows, prize drawings, and discount coupon giveaways can be made available to help generate business for these participating facilities.

- Provide automobile maintenance educational materials to the residents within the Peruque Creek watershed.

Materials such as flyers and brochures can be distributed to educate the general public on the water quality impacts of automobile maintenance. These outreach materials should inform residents who perform their own vehicle maintenance that automobile maintenance has the potential to result in significant loads of hydrocarbons, trace metals, and other pollutants. Educational materials should encourage management practices such as the proper cleaning of parts, changing of vehicle fluids, replacement and repair of equipment, proper waste disposal, etc.

For more complete descriptions of these alternative management measures and how they can be used to improve water quality in the Peruque Creek watershed, please refer to Section 4.2.4 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Implementing a pollution prevention program to address automobile maintenance practices that control pollutants and reduce storm water impacts in the Peruque Creek watershed is applicable. As with any other urban watershed, there are a significant number of automobile maintenance facilities and backyard mechanics that perform their own vehicle maintenance. With the advent of the $20 oil change special, the number of back yard mechanics who change the oil and antifreeze in their cars has been dropping steadily. However, estimates indicate that approximately 30 percent of car owners still change their own oil and antifreeze (CWP 1999a). Fluid spills and improper disposal of materials result in pollutants, heavy metals, and toxic materials entering ground and surface water supplies, creating public health and environmental risks. Many automobile maintenance facilities and backyard mechanics are unaware of these water quality impacts resulting from automobile maintenance.

Cost

The cost of a vehicle maintenance pollution prevention program to train businesses involved in automobile maintenance depends on the intensity of the effort, what outreach techniques are selected, and the number of vehicle maintenance facilities within the watershed area. A program that had great success in controlling contaminated flows from vehicle maintenance facilities is the Clean Bay Business Program in Palo Alto, California. The initial per facility cost for the program was approximately $300, with a cost of $150 for subsequent years. The initial per facility cost includes inspector visits and follow-up work, outreach materials, mailing list, and database management.

Production costs for materials such as flyers and brochures are relatively inexpensive as well and can range from $0.10 to $0.50 per brochure.

Effectiveness

The effectiveness of automobile maintenance pollution prevention programs at removing pollutants is difficult to quantify. However, there are programs that have demonstrated the effect pollution prevention practices can have in reducing impacts from automotive fluids. The previously mentioned Clean Bay Business program in Palo Alto, California had great success in controlling contaminated flows from vehicle maintenance facilities. The effectiveness of the program at creating behavioral changes was evident in the increase in the number of businesses using all of the recommended practices. In 1992 when the program began, only four percent of the businesses used all of the recommended practices. By 1998, 94 percent of businesses had instituted the practices suggested (NRDC 1999). The effectiveness of the program at altering behaviors detrimental to storm water was impressive. After participation in the program, the changes facilities made had the following impacts:

- 78 direct discharges to storm drains were eliminated by ceasing or modifying the practices used for activities such as parking lot cleaning, vehicle washing, and wet sanding

- Violations of storm drain protection requirements fell by 90 percent from 1992 through 1995
- The number of shops conducting outdoor removal of vehicle fluids without secondary containment fell from 43 to 4

Ability to be Implemented

Numerous programs in other watersheds have had success in removing pollutants from vehicle maintenance activities by changing behavioral patterns at vehicle maintenance facilities. The minimal per facility costs associated with addressing the handful of vehicle maintenance facilities within the Peruque Creek watershed pales in comparison to the potential water quality benefits associated with these automotive maintenance pollution prevention measures.

On the other hand, distributing materials to educate Peruque Creek watershed residents on the water quality impacts of automobile maintenance may not be as beneficial. The number of backyard mechanics who perform their own vehicle maintenance has dropped steadily in recent decades. With the advent of the $20 oil change special, only about 30 percent of car owners change their own oil or antifreeze anymore. Not only would educational materials apply to only about 30 percent of the Peruque Creek residents, but studies have indicated that over 80 percent of backyard mechanics claim to dispose or recycle these fluids properly (Assing 1994).

6.2.4 Car Washing

Outdoor car washing has potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions, as the detergent-rich water used to wash automobiles flows down the street and into storm drains. Car washing is a common routine for residents and a popular way for organizations such as scout troops, schools, and sports teams to raise funds. This pollution management measure involves educating the general public on the water quality impacts of the outdoor washing of automobiles and how to avoid allowing polluted runoff to enter the storm drain system.

Alternatives

- Implement a car wash outreach program devoted to car wash education

Outreach programs provide materials to charity car wash organizers to prevent car wash water from entering storm drains. These car wash kits are provided free of charge to charity organizers along with training videos on planning an environmentally friendly car wash. A vacuum/boom device known as a Bubble Buster would need to be purchased to loan to the charity program (Kitsap County 1999).

- Provide car washing educational materials to the residents within the Peruque Creek watershed

Materials such as flyers and brochures can be distributed to educate the general public on the water quality impacts of the outdoor washing of automobiles. These outreach materials should inform car washers that car washing has the potential to result in high loads of nutrients, metals, and hydrocarbons to storm drains and streams in dry weather conditions. These materials encourage management practices such as using commercial car washes, washing cars on gravel, grass or other permeable surfaces, rinsing pavement to adjacent grassy areas, using biodegradable soaps, etc.

For more complete descriptions of these alternative management measures, please refer to Section 4.2.5 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Implementing a pollution prevention program to reduce the impact of car wash runoff in the Peruque Creek watershed is applicable. In the urban areas of Peruque Creek, there are higher concentrations of automobiles that translate to a larger potential impact on water quality from car washing. According to surveys, roughly 55 to 70 percent of households wash their own cars and approximately 60 percent could be classified as "chronic car-washers," i.e. they wash their own car at least two times a month (Smith 1996 and Hardwick 1997). Similar statistics with regards to car washing can be expected within the Peruque Creek watershed.

Effectiveness

Little is known about the water quality of car wash water except that it has the potential to result in high loads of nutrients, metals, and hydrocarbons. The effectiveness of car washing management practices at reducing pollutant source loads has yet to be accurately measured. It is difficult to determine the exact impact of a particular pollution prevention measure at reducing pollutant loading.

Cost

Car wash outreach programs are relatively inexpensive to staff and require only a limited outlay for materials (training videos, etc.). In Kitsap County, Washington, the Sound Car Wash Program requires roughly 10 to 15 hours a week of staff time over a 25 week period from April to September. The purchase of wash water containment equipment for charity car washes is often a one time expense and can be used for a number of years. The approximate cost for the Bubble Buster ranges from $2,000 to $2,500.

Production costs for materials such as flyers and brochures are relatively inexpensive as well and can range from $0.10 to $0.50 per brochure.

Ability to be Implemented

Residents are typically not aware of the water quality consequences of car washing, and do not understand the chemical content of soaps and detergents. As a result, providing residents with educational materials on the impacts of car wash runoff and providing "water friendly" car wash kits to charity organizers can minimize the risk of contamination from wash water discharges at a relatively low cost. However, car washing is a difficult watershed behavior to change, since it is hard to define a better alternative without asking people to pay to use a commercial car wash that treats its wash water. Some potential alternative messages that might work are to wash cars less frequently, wash them on grassy areas, and to buy phosphorus-free detergents and non-toxic cleaners.

6.2.5 Animal Waste Collection

The presence of pet waste in storm water runoff has a number of implications for urban stream water quality with perhaps the greatest impact from fecal bacteria. According to recent research, non-human waste represents a significant source of bacterial contamination in urban watersheds. Animal waste collection as a pollution control source involves using a combination of educational outreach and enforcement to encourage residents to clean up after their pets. Residents need to be educated on the implications of their pet's waste on the stream water quality.

Alternatives

- Implement an animal waste collection program to educate residents on how and why dog waste can be a water quality problem

An animal waste collection program should use awareness, education, and signs to alert residents as to the proper disposal techniques for pet droppings. The goal of the program should be to educate dog owners on how the presence of pet waste in storm water runoff has a number of implications on urban stream water quality and perhaps the greatest impact from fecal bacteria.

For a more complete description of this alternative management measure, please refer to Section 4.2.6 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Implementing a pollution prevention program to reduce the impact of animal waste in storm water runoff within the Peruque Creek watershed is applicable to the Peruque Creek watershed. Continuing public education efforts is important due to the number of implications pet waste in storm water runoff can have on urban stream water quality.

Effectiveness

Genetic studies by Alderiso et al. (1996) and Trial et al. (1993) both concluded that 95 percent of fecal coliform found in urban storm water is of non-human origin. Bacterial source tracking studies conducted in Seattle, Washington also found that nearly 20 percent of the bacteria isolates were matched with dogs. This indicates that animal waste represents a significant source of bacterial contamination in urban watersheds. The higher density of domestic livestock and horses in the upper parts of the Peruque Creek watershed can contribute to bacterial contamination, particularly from the small tributaries (e.g. Sam's Creek) that drain through these properties.

Residents seem to be of two minds when it comes to dog waste. A strong majority agree that dog waste can be a water quality problem (Hardwick 1997; Swann 1999). However, the reluctance of many residents to handle dog waste is the biggest limitation. According to a Chesapeake Bay survey, 40 percent of dog owners admitted to not picking up after their dog and 44 percent of the dog owners who do not pick up indicated they would still refuse to pick up even if confronted by neighbors, threatened with fines, or provided with more convenient options for disposing of dog waste.

Cost

The cost of animal waste collection programs will vary depending on the intensity of the effort and the paths chosen to control pet waste. The most popular way is through ordinances (discussed in Section 6.3), but managers must consider public education as a reinforcement alternative. Public education program costs are determined by the type of materials produced and the method of distribution selected. Production costs for sending materials such as flyers and brochures to individual households within the Peruque Creek watershed are relatively inexpensive and can range from $0.10 to $0.50 per brochure. Signs in parks may have a higher initial cost than printed materials, but can last for many years. Signs may also be more effective, since the act as on-site reminders in dog walking areas.

Ability to be Implemented

The reluctance of many residents to handle dog waste is the biggest limitation to implementing a pet waste management program. Nevertheless, distributing informative brochures to residents within the Peruque Creek watershed is a recommended approach to educating dog owners on proper pet waste management techniques. These brochures should describe the environmental and hygiene/health concerns associated with pet waste as well as communicating the message that proper pet waste cleanup is the law and is courteous to neighbors. Identifying residents within the watershed who own dogs (if possible) can significantly reduce the cost of producing and distributing these informative materials. In addition, placing signs in dog walking areas where they currently do not exist can further spread the message of proper pet waste management. Although the educational measures discussed in this section are viable alternatives, ordinances (discussed in Section 6.3) to regulate pet waste cleanup are likely to provide greater results – especially in public areas.

6.2.6 Vegetation Controls and Tree Planting

Public education of mechanical vegetation control includes properly collecting and disposing of clippings, cutting techniques, leaving existing vegetation, and planting new trees and vegetation. Clippings and cuttings are the primary waste produced by mowing and trimming and are almost exclusively leaf and woody materials. Once vegetative waste is generated, the main concern is to avoid transport of clippings and cuttings to the storm water system and receiving water bodies since the waste can degrade water quality.

Alternatives

- Implement a vegetation control program to educate the residents of the Peruque Creek watershed that clippings carried into the storm water system and receiving streams can degrade water quality

- Continue with the educational and land management activities through the NRCS as they interact with agricultural landowners in the watershed

A vegetation control program should educate residents on the importance of properly collecting and disposing of clippings, cutting techniques, leaving existing vegetation, and introducing new vegetation. Residents should be encouraged to set their mowing heights as high as possible, leave their clippings on the lawn to provide nutrients and moisture, preserve existing vegetation, and introduce as much new vegetation as possible. Distributing informative brochures to the residents of the Peruque Creek watershed is the most common approach to educating the public on vegetation controls.

- Implement a public education program that encourages residents to convert managed turf and landscape areas to native vegetation that requires less water and maintenance.

Watershed residents could be educated and encouraged to convert managed turf areas to native vegetation. The notion that manicured lawns are more attractive than natural landscapes can be altered with education and examples. Existing lawn areas can be converted to landscape areas planted with carefully selected plant materials including trees wildflowers, ground covers and warm-season decorative grasses which require little maintenance and are draught tolerant. Many ground covers can thrive where grass does not. Trees and shrubs transpire rainfall through their leaves, consume carbon dioxide, release oxygen, and help moderate urban temperatures. Community awareness through programs, seminars, and field trips can be arranged to emphasize the advantages of natural landscaping in public areas and private property.

For a more complete description of these alternative public education elements, please refer to Section 4.2.8 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Implementing a pollution prevention program to address vegetation control practices that can control pollutants and reduce storm water impacts in the Peruque Creek watershed is applicable. Many of the residential lawns within the Peruque Creek watershed are located on small lots (e.g. homes surrounding Lake Saint Louis), but the cumulative impact is significant. As a result, there are numerous opportunities to alter vegetation control behaviors and reduce the storm water impacts that poor vegetation controls can have on the watershed. There are also opportunities to encourage home owners to convert existing lawn areas to native vegetation that requires less water and maintenance.

Effectiveness

The pollutant removal abilities of a vegetation control programs are difficult to quantify and have yet to be measured accurately. However, it is clear that lawn care is a common watershed behavior and educating residents on proper vegetation controls can have numerous benefits.

Traditional lawn care practices call for raking and removing clippings, which were thought to promote thatch and disease. In fact, leaving clippings on the lawn is beneficial as they provide nutrients and moisture. Researchers at the University of Connecticut Agricultural Station used radioactive nitrogen to track the fate of applied nutrients when clippings are recycled. They found that within a week, most of the nitrogen from the clippings was incorporated into new grass growth. After three years, nearly 80 percent of the applied nitrogen had been returned to the lawn (Schultz 1989).

One-acre of lawn area generates almost six tons of grass clippings a year, or nearly a 1,000 bags worth (Jenkins 1994). Although grass clippings decompose rapidly on the lawn, they often persist for a long time in landfills. In 1981, the city of Plano, Texas, instituted a program that encouraged residents to leave clippings on home lawns to provide nutrients and moisture. Knoop and Whitney (1989) reported the results: the city saved $60,000 in disposal costs in the first year, even though the number of households served increased 12 percent over the same period. Residents participating in the program saved $22,000 in plastic bag purchases.

Traditional lawn care practices also look to the close-cropped putting green as the ideal lawn turf. Unfortunately, close mowing can weaken the grass and expose the grass crowns to sunburn. Keeping grass taller will actually shade out weeds, reducing them by more than 50 percent (Alliance for the Chesapeake Bay 1994).

Trees, shrubs, and other vegetation are a watershed priority as they transpire rainfall through their leaves; consume carbon dioxide, release oxygen, and moderate urban temperatures. As a result, existing vegetation should be left in place and new vegetation should be introduced. Most residential lawns have areas that are not suited for grass growth. These include frost pockets, exposed areas, dense shades, steep slopes, and wet, boggy areas. Converting these areas to less intensive plantings is an effective strategy for reducing lawn inputs. Existing flowerbeds or groupings of trees and shrubs can simple be expanded, or groundcovers can be used to replace grass. Other options include mimicking native plant communities such as forests, meadows, and wetlands and converting lawn areas into mulched beds.

Cost

The cost of creating and maintaining an education program that addresses vegetation control varies depending on the intensity of the effort and the outreach technique selected. Measures to improve vegetation controls, for the most part, should be simple and inexpensive. Production costs for materials such as flyers and brochures are relatively inexpensive as well and can range from $0.10 to $0.50 per brochure. Information regarding this subject could also be incorporated into other local government education programs such as household hazardous waste education programs and pesticide education efforts, thus reducing the cost.

Ability to be Implemented

The reluctance of many residents to change their conventional vegetation control techniques is the biggest limitation to implementing a vegetation control program. Nevertheless, distributing informative brochures to residents within the Peruque Creek watershed is a recommended approach to educating residents on properly collecting and disposing of clippings, proper cutting techniques, and lawn conversion. These brochures should emphasize that clippings carried into the storm water system and receiving streams can degrade water quality. As stated previously, the MDC and the PCWA have prepared a variety of educational material outlining responsible care approaches to protecting Peruque Creek water quality.

Alternative landscaping and the introduction of new vegetation can be a workable goal by encouraging volunteer community groups to plant native vegetation in public areas such as parklands.

6.3 Screening of Non-Structural Municipal Measures

The municipalities within the Peruque Creek watershed have many tools at their disposal to address environmental issues that contribute to watershed degradation. The Peruque Creek watershed will continue to be subjected to the wide variety of problems related to urban runoff if coordinated action is not taken on the municipal level. Municipal management programs impact watershed quality by the way existing municipal infrastructure is maintained and the way municipal ordinances are enforced. Storm water runoff, deicing salts, roadway runoff, household hazardous wastes, among others, all contribute pollutants loads to the Peruque Creek watershed, and all can be managed to some degree by the municipalities within the watershed.

6.3.1 Street Sweeping

Street sweeping is practiced in most urban areas to remove sediment buildup, debris, and litter from roads and parking lot surfaces. Historically, performance monitoring studies indicated that street sweeping was not very effective in reducing pollutant loads. However, recent improvements in street sweeper technology have enhanced the ability of present day machines to pick up the fine grained sediments that carry a substantial portion of the storm water pollutant load. Integrating new street sweeping technology and techniques into existing municipal street sweeping programs can impact the amount of sediment, debris, and litter that can be removed from streets and parking areas.

Alternatives

- Use the most technically improved sweeper technologies that are now available to improve performance in removing particulate matter from roadways

Many of today's sweepers can now significantly reduce the amount of street dirt entering streams and rivers. Innovations in sweeper technology have improved the performance of these machines at removing finer sediment particles, especially for machines that use vacuum assisted dry sweeping to remove particulate matter. By using the most sophisticated sweepers in areas with the highest pollutant loads, greater reductions in sediment and accompanied pollutants can be realized.

- Implement street sweeping within each community.

Each community's street sweeping programs could be examined as to how often and what roads are being swept. Each program's budget and level of desired pollutant removal should be evaluated. Studies suggest that sweeping frequency should be conducted once every week or two and higher sediment removal can be obtained on residential streets as opposed to more heavily traveled roads.

For a more complete description of street sweeping as an alternative management measure, please refer to Section 4.3.2 of the watershed management plan.

Applicability to the Peruque Creek Watershed

Improving sweeper technologies and street sweeping techniques has limited applicability within the Peruque Creek watershed. Street sweeping is practiced in only limited areas within the Peruque Creek watershed. At this time, it is unrealistic to expect that municipalities would make the large capital investment that would be required to purchase the new street sweeping equipment.

Effectiveness

Studies show that conventional mechanical broom and vacuum-assisted wet sweepers reduce non-point pollution by 5 to 30 percent; and nutrient content by 0 to 15 percent, but that newer dry vacuum sweepers can reduce non-point source pollution from 35 to 80 percent; and nutrients by 15 to 40 percent for those areas that can be swept (Runoff Report 1998). While actual reductions in storm water pollutants have not yet been established, information on the reductions in finer sediment particles that carry a significant portion of the storm water pollutant runoff is available. Recent estimates are that the new vacuum assisted dry sweepers might achieve a 50 to 88 percent overall reductions in the annual sediment loading for a residential street, depending on sweeping frequency (Bannerman 1999).

A benefit of high-efficiency street sweeping is that by capturing pollutants before they are made soluble by rainwater, the need for storm water treatment practices may be reduced – which can be very costly when compared to collecting pollutants before they become soluble. Street sweepers that can show a significant level of sediment removal efficiency may prove to be more cost-effective, especially in more urbanized areas with higher areas of paving.

Computer modeling in the Pacific Northwest suggest that from the standpoint of pollutant removal, the optimum sweeping frequency appears to be once every week or two (Claytor 1999). More frequent sweeping operations yielded only a small increment in additional removal.

Cost

The largest expenditures for street sweeping programs are in staffing and equipment. The capital cost for a conventional sweeper is between $60,000 and $120,000. Newer technologies are even higher than that, with prices approaching $180,000. The average useful life of a conventional sweeper is about four years, and programs must budget for equipment replacement. If investing in newer technologies, training for operators need to be included in operation and maintenance budgets.

Cost data for two cities in Michigan provide some guidance on the overall cost of a street sweeping program. **Table 6.1** contains a review of the labor, equipment, and materials cost for street sweeping for the year 1995 (Ferguson et al. 1997). The average cost for street sweeping was $68 per curb mile per year.

Table 6-1
Cost Data for Various Street Sweeping Programs

City	Labor	Equipment	Materials and Services	Total
Livonia	$23,840	$85,630	$5,210	$114,680
Plymouth Township	$18,050	$14,550	$280	$32,880

Ability to be Implemented

The high cost of current sweeper technologies is a large limitation to using this management practice within the Peruque Creek watershed as well as its benefit to only the urban areas. With costs approaching $200,000 for some of the newer sweeper technologies, limited municipal budgets make purchasing this equipment difficult. Additional possible limitations include the need for training for sweeper operators, the inability of current sweeper technology to remove oil and grease, and the lack of solid evidence regarding the level of pollutant removal that can be expected. The presence of parked cars along the sides of streets within the watershed presents an additional limitation to reducing non-point pollution.

6.3.2 Storm Inlet Maintenance

Storm inlets can act as accumulation points for many of the most critical non-point source pollutants within a watershed. A fast flash of runoff from a storm event detaches, mobilizes, and transports these substances directly to surface waters. The performance of these devices at removing sediment and other pollutants is dependant on routine maintenance to retain the storage available in the sump to capture sediment.

Alternatives

- Improve upon the existing maintenance of storm inlets within the Peruque Creek watershed communities

Municipal maintenance of storm inlets should include trash removal if a screen or other debris capturing device is used, and removal of the sediment using a vacuum truck. The performance of storm drains at removing sediment and other pollutants depends on this routine maintenance so that the storage available to capture the sediment is retained. Maintenance should include keeping a log of the amount of sediment collected and the data of removal.

For a more complete description of alternative management strategies for storm inlets within the Peruque Creek watershed, please refer to Section 4.3.1 of this plan.

Applicability to the Peruque Creek Watershed

Clogged storm drains are not only ineffective at collecting storm water runoff, but may even act as a source of sediments and pollutants to streams. Improving maintenance for drainage structures is applicable to the Peruque Creek watershed, however, the benefit would only be to the urban areas. Many of the new developments that are being built in the watershed have been applying this technology to control sediment loading to Peruque Creek. Once applied, on-going monitoring and maintenance needs to be implemented to ensure the technology is effective.

Effectiveness

What is known about the effectiveness of more frequent cleaning of storm drains is limited to a few studies. These studies found that trapped sediments found in storm drains were highly enriched with trace metals and petroleum hydrocarbons. Residential storm drains were found to have the lowest sediment metal concentrations, but exhibited the highest concentrations of petroleum hydrocarbons. Commercial sites (mall and vehicle maintenance operations) were comparable to industrial sites, with the exception of zinc, which was higher in commercial areas.

The same studies found that the maximum annual sediment volume could be removed by monthly cleanouts (3 to 5 cubic feet), while quarterly, semi-annual, and annual cleanouts removed about the same amount of material (1.5 to 2.5 cubic feet). For industrial inlets, monthly cleanouts removed nearly six times more sediment than annual cleanouts. A qualitative analysis of the data indicated no seasonal differences between volume of material removed.

Cost

The true pollutant removal cost associated with storm drains is the long-term maintenance cost. An aggressive storm drain cleaning program requires a significant

O&M budget. A careful study of cleaning effectiveness should be undertaken before increased cleaning is conducted.

Ability to be implemented

Few municipalities within the watershed have existing crews and equipment dedicated to cleaning storm inlets. Therefore, it is not reasonable to assume that improvements to storm drain maintenance could be implemented within the Peruque Creek watershed. However, at new construction sites, the on-site manager can monitor the storm inlets on a regular basis to ensure the inlets are preventing sediment load from entering into the creek.

The major limitations to improving storm drain maintenance are the staff time and equipment costs associated with increased cleaning and the possible difficulty in finding environmentally acceptable disposal methods for removed sediment and debris. The key to successfully implementing a successful storm drain maintenance program is to quantify the additional solids removed from storm drains and compare the removal benefits of more frequent cleanouts with the corresponding increase in municipal costs and staffing.

6.3.3 Pet Waste Ordinances

Waste from pets can be a significant non-point pollution source. Pet waste provides three primary pollutants: nutrients, organic matter, and pathogens. Bacteria levels in storm water have been found to be higher in residential areas than industrial or commercial zones. The same can be said about the nutrients nitrogen and phosphorus. A possible cause for this may be the high occurrence of pets within residential areas. In addition, pets are frequently walked on trails and parklands that are in floodplain recreation areas, thus increasing the risk of pet waste reaching stream water. As discussed in Sections 4.2.6 and 6.2.5 of this plan, public education an important tool in addressing this issue. However, to reduce pet waste problems, ordinances may need to be passed and enforced, requiring that pet owners pick up after their animals and properly dispose of the material.

Alternatives

- Pass pet waste ordinances to require pet waste cleanup within the Peruque Creek watershed

Controlling pet waste typically involves the use of "pooper-scooper" ordinances to regulate pet waste cleanup. These ordinances require the removal and proper disposal of pet waste from public areas and other people's property before the dog owner leaves the immediate area. A fine is often associated with failure to perform this act as a way to encourage compliance.

Section 4.3.3 of this watershed management plan provides a more complete and detailed description of how past waste ordinances would be used to improve water quality in the Peruque Creek watershed.

Applicability to the Peruque Creek Watershed

Passing pet waste ordinances to reduce the impact of animal waste in storm water runoff within the Peruque Creek watershed is clearly applicable to the Peruque Creek watershed. Communities within the Peruque Creek watershed have already begun taking measures toward educating residents on the importance of pet waste removal with signs in public parks and along residential streets. However, enforcement of proper pet waste management through ordinances may be a more effective measure to minimize the adverse impacts from pet waste on stream water quality.

Effectiveness

The effectiveness of pet waste ordinances on improving water quality in streams is difficult to quantify. In addition, a dog owner is not always a dog walker. It has been estimated that just about one half of dog owners actually walk their dogs. In reality, only dog owners who actually walk their dogs on residential streets and parklands can be targeted to enforce clean up after their dogs. According to the Chesapeake Bay survey, 40 percent of dog owners admitted to not picking up after their dog and 44 percent of the dog owners who do not pick up indicated they would still refuse to pick up even if confronted by neighbors, threatened with fines, or provided with more convenient options for disposing of dog waste.

Cost

The cost of animal waste collection enforcement will vary depending on the intensity of the effort and the paths chosen to control pet waste. Passing an ordinance to regulate pet waste cleanup carries with it virtually no cost. It is enforcement that adds cost. Municipal managers must consider the cost of enforcement, including equipment and staff requirements. To effectively enforce proper pet waste cleanup, proper disposal of pet waste from public areas and other people's property would need to be patrolled. A designated municipal employee would need to routinely patrol dog walking areas, enforcing proper pet waste management and perhaps issuing fines to individuals who fail to comply. An estimated cost associated with patrolling dog walking areas could be costly when considering the employees salary and benefits, vehicle costs, and administrative costs to process fines. Collected fines partially would offset the cost.

Ability to be Implemented

The majority of dog owners agree that dog waste can be a water quality problem (Hardwick 1997; Swann 1999). However, the reluctance of many residents to handle dog waste is the biggest limitation. Nevertheless, passing ordinances to regulate pet waste cleanup is likely to provide improved results in public areas.

Many of the municipalities within the Peruque Creek watershed have already posted signs along residential streets and parklands encouraging proper pet waste cleanup. A recommended approach may be to post signs in areas that are not already marked and include on these signs the threat of a fine if dog owners do not comply. Signs in public parks enforcing that dogs remain on a leash and the provision of receptacles for pet waste may also encourage cleanup.

6.3.4 Household Hazardous Waste Collection

Improperly disposed HHW can and does affect both surface water and groundwater quality. Leaking of, spillage from, and improperly disposed hazardous materials can enter sewers and degrade water quality of receiving streams. As such, HHW collection can be expected to reduce the presence of toxic materials and heavy metals in storm water runoff.

Alternatives

- Implement a municipal HHW collection program to collect and properly dispose of HHW products

HHW programs can ensure that HHW is recycled or, otherwise managed in an environmentally preferable way. These programs provide sites for residents to drop of their HHW. The materials can then be reused, recycled, and, when necessary, disposed of at a permitted hazardous waste facility.

For a more complete description of alternate HHW control programs and how they could be applied to the Peruque Creek watershed, please refer to Section 4.3.4 of this watershed management plan.

Applicability to the Peruque Creek Watershed

HHW are those wastes produced in households that are hazardous in nature. In a Pennsylvania study, each person was estimated to produce an average of four pounds of HHW each year. Such wastes, if carelessly managed can, and frequently do, create environmental and public health hazards. Therefore, implementing municipal HHW collection programs is clearly applicable to the Peruque Creek watershed.

Effectiveness

While it is generally recognized that the potential exists for hazardous household materials to come in contact with storm water runoff, it is unclear at present how significant this source of contamination is. As such, it is difficult to quantify the benefits to water quality from a HHW collection program. However, HHW collection is a preventative, rather than a curative measure, and may reduce the need for more elaborate treatment controls.

Various studies have been undertaken to categorize the quantity and quality of HHW in the municipal solid waste stream. These studies indicate that 0.5 to 2.0 percent of the total municipal solid waste stream is HHW, the number typically used is 1 percent of the total municipal solid waste stream. Although the percentage of these materials is small, the large volume of solid waste generated daily indicates that a substantial amount of HHW is generated. The benefits to storm water quality from HHW collection is unknown at present, but best engineering judgment indicates a potential of up to 15 percent.

Numerous examples of effective HHW programs exist throughout the United States. For example, one of the oldest (1998) and most convenient permanent collection centers is located in San Francisco, CA. In a single year, more than 8,800 residents brought over 123,000 containers containing more than 56,000-gallons of hazardous waste to the facility. Over 60 percent of the waste was recycled, about 25 percent burned as fuel, 10 percent incinerated, 2 percent neutralized, and less than 2 percent sent to a landfill.

Cost

HHW collection programs can be expensive. The major costs associated with these programs will be for contracted services involving the classification, packing, transportation, and management of the collected hazardous waste materials. Generally costs average 30 to 80 cents per pound of hazardous waste but may run as high as $1.00 per pound. In addition, staffing requirements will include at least one specifically trained hazardous waste professional, a full-time administrator, and trained personnel for sorting and packaging.

In-kind services, donations of material, equipment and labor from businesses, and government and community groups can all reduce program costs. In addition, discount rates on supplies and disposal fees can be provided by waste haulers and disposal companies to community collection programs. Recycling waste oil by giving it to a service station or selling it directly to a commercial recycler can reduce disposal costs and potentially generate some revenue.

Ability to be Implemented

HHW programs are similar to recycling programs in that there are a number of alternatives available for material collection. In fact, HHW programs typically employ a variety of collection methods. Permanent or periodic collection centers are the most common but mobile collection centers and even curbside collection are used. Naturally, there are advantages and disadvantages with implementing each program.

Figure 6-2 - St. Charles County Recycling Facility

Within the Peruque Creek watershed St. Charles County operates a Recycling Center at 2110 E. Pitman Ave., Wentzville, and a new Recycle Works facility located at 60 Triad South Drive in the City of St. Charles (**Figure 6-2**). The Solid Waste Management Section of the St. Charles County government, accepts on a periodic basis HHW at selected locations within the county. They publish and post the date of the HHW dropoff in the daily newspapers and on the County's website (http://www.scchealth.org/docs/es/esdocs/hhwaste.html).

In Warren County, there is more of a reliance on working with the Soil, Water and Conservation District, Farm Bureau, NRCS, MDC and related agencies as a partner to manage the disposal of hazardous farm and household waste.

6.3.5 Pest Control - Control Pesticides and Herbicides Used on Public Land

The presence of pesticides and herbicides in storm water runoff has a direct impact on the health of aquatic organisms and can present a potential threat to humans through contamination of surface water and drinking water supplies. The pesticides of greatest concern are insecticides, such as diazinon and chloropyrifos, (CWP 1999b and Schueler 1995) that can be harmful to aquatic life even at very low levels. The major sources of pesticides in urban streams are applications of products designed to kill insects and weeds in the lawn and garden.

For a more complete description of pest control management measures, please refer to Section 4.3.5 of this watershed management plan.

Alternatives

- Implement the use of integrated pest management (IPM) as a way to introduce alternatives to chemical pesticides and herbicides used on public lands

IPM reflects a holistic approach to pest control with the goal not to eliminate pests but to manage them to an acceptable level while avoiding disruptions to the environment. An effective IPM program incorporates practices in combination with non-chemical and chemical pest controls to minimize the use of pesticides and promote natural control of pest species.

Applicability to the Peruque Creek Watershed

Implementing IPM practices as a municipal management measure would only be applicable to public lands such as parks, municipal buildings, and schools. There would be no applicability to private residences and businesses. The parks and public areas in Peruque Creek tend to be located near surrounding streams causing the potential for pest control pollutants to enter the stream to be great. The IPM practices can be enforced for municipal parklands and schools to limit pollutants washed off the ground during storm events.

Effectiveness

The Grounds Maintenance Program for the City of Eugene, Oregon provides a good example of successful use of IPM as a management measure. This program was started in the early 1980s and includes all the city public parks and recreation areas. The city uses a variety of IPM methods, including water blasting to remove aphids, insecticidal soaps and limited use of pesticides. The city has also adopted higher tolerance levels for certain weed and pest species that reduces the need to apply pesticides and herbicides. Since the programs inception, pesticide usage by the City of Eugene has dropped by more than 75 percent (Lehner *et al*. 1999). No exact cost savings have been calculated from the use of the IPM program, but the city turf and grounds supervisor is convinced that it saves money and has little citizen opposition.

Cost

The cost of educating parkland grounds supervisors on proper pesticide use varies greatly depending on the intensity of the effort. Like lawn care and landscaping programs, some cities have begun partnerships that include training of retail employees and parkland supervisors on IPM techniques. In addition, promotional materials and displays on safer pesticide alternatives are set up. The cost of staff time for training and production of materials must be included in any cost estimate.

Since there are currently a number of good fact sheets on IPM and pesticide use available through cooperative extension programs, the Peruque Creek watershed management plan should consider using these existing resources instead of trying to create new ones. Another way to save cost would be to utilize master gardener volunteers to help with training, for residents, parkland supervisors, and store employees.

Ability to be Implemented

Any municipal ordinance regulating the use of products designed to kill insects and weeds in the lawn and garden cannot be enforced on private property. However, control over the use of these products can be regulated in public areas under municipal maintenance (e.g. parks and schools). It is reasonable to assume that IPM technologies can be implemented for public properties.

6.3.6 Bridge and Roadway Maintenance

There are a number of pathways for pollutant deposition on roadways and bridges that can influence the water quality of storm water runoff. Substantial amounts of sediments and pollutants are generated during daily roadway and bridge use and scheduled repair operations, and these pollutants can impact local water quality by contributing heavy metals, hydrocarbons, sediment and debris to storm water runoff.

The use of road salt is a public safety as well as a water quality issue. Aside from contaminating surface and groundwater, high levels of sodium chloride from road salt can kill roadside vegetation, impair aquatic ecosystems, and corrode infrastructure such as bridges, roads, and storm water management devices.

Alternatives

- Incorporate pollution protection techniques to reduce or eliminate pollutant loads from existing road surfaces within the Peruque Creek watershed as part of routine operations and maintenance.

A number of pollution prevention techniques are available to reduce the level of pollutants generated from road surfaces. Routine performance of general maintenance activities such as sweeping, vegetation maintenance, and cleaning of runoff control structures can help alleviate the impacts of pollutant loads. Modifications in roadway resurfacing practices can also help reduce pollutant loads to storm water runoff and protect the quality of receiving waters.

- Train municipal employees in proper deicing application techniques, the timing of deicer application, and the type of deicer to apply.

Municipal employees can be trained on the proper storage, the handling, and application practices of de-icing materials. In addition, municipal officials and employees can explore the use of alternative de-icing materials to road salt such as calcium magnesium acetate (CMA) and urea.

For detailed information on alternate management practices and deicing materials, please refer to Section 4.3.6 of this watershed management plan.

Applicability to the Peruque Creek Watershed

The Missouri Department of Transportation (MoDOT) and the municipal public works departments within the Peruque Creek watershed routinely participate in general road and bridge maintenance activities. Vegetation controls, and roadway resurfacing among others are commonly practiced. As a result, numerous opportunities exist to reduce pollutants generated from road surfaces during these practices making this alternative applicable for implementation within the watershed.

During certain days of the year, the waters of the Peruque Creek stream may contain significant concentrations of sodium chloride from de-icing salts. As a result, changes in proper deicing application techniques, the timing of deicer application, and the types of deicers to apply is highly applicable to the Peruque Creek watershed. Proper application of road salt or other deicers is essential for reducing storm water pollution.

Effectiveness

There is limited data available on the actual effectiveness of road and bridge maintenance practices at removing pollutants from storm water runoff. Table 4-14 in Section 4 examined the effectiveness and cost of some of the operation and maintenance practices recommended for storm water pollution control. It can be assumed that the recommended roadway management practices will have a positive impact on storm water quality by working to reduce pollutant loads and the quantity of runoff. Protecting and restoring roadside vegetation, removal of debris and sediment from roads and bridges, and directing runoff to vegetated areas are all effective ways to manage storm water runoff.

It is also difficult to determine the effectiveness resulting in changes in the application of road salt or other deicers. Improvements in reducing pollutants loads can be seen by reducing the use of de-icing compounds, better equipment calibration, and more careful application. However, quantifying the effectiveness of these practices is difficult.

The use of alternative de-icing materials may reduce the environmental and corrosive effects of deicers but may have less de-icing ability and cost more. The cost, de-icing ability, and environmental effects associated with the various alternative de-icing materials each need to be considered to determine the overall effectiveness of each of the de-icing agents available.

Cost

The maintenance of local roads and bridges is already a consideration of most community public works or transportation departments. Therefore, the cost of pollutant reducing management practices will involve the training and equipment required to implement these new practices. Costs associated with select maintenance management practices were shown in Table 4-14.

One area where costs can vary greatly is in the type of deicer selected for application. Table 4-13 in Section 4 included a comparison in the costs of various alternative de-icing materials and the cost for application. The material cost per ton can range anywhere from $5 per ton for sand to $650-$675 per ton for Calcium Magnesium Acetate (CMA).

Ability to be Implemented

Roadway and bridge maintenance may be one of the easier pollution control measures to implement. Limitations to instituting pollution prevention practices for road and bridge maintenance involve the cost for additional equipment and training. Since the maintenance of roadways and bridges is already required in communities, staffing is usually already in place and alteration of current practices should not require additional staffing or administrative labor.

Encouraging reduction in the use of de-icing compounds may be more challenging to implement within the Peruque Creek watershed. Many of the roadways within the watershed are hilly and any significant reduction in the application of deicing materials may potentially compromise public safety. In addition, the use of alternative de-icing materials may not be an effective option to implement within the Peruque Creek watershed. Road salt has traditionally been the most attractive de-icing agent because of its high de-icing ability, utility at low temperatures, and low cost. Although many alternative de-icing materials exist, road salt should probably remain the de-icing material of choice because of the recent improved design and material modifications of road salt, the familiarity that municipal employees have with applying road salt, and the higher de-icing ability that road salt has over many of the alternatives.

However, realistic opportunities do exist to educate municipal employees on better equipment calibration and more careful application of the deicing materials. Training municipal employees on proper de-icing application, the timing of deicer application, and the routine calibration of spreaders present viable, cost-effective options to alleviate impacts to water quality and aquatic habitat.

6.3.7 Vegetation Controls

Clippings and cuttings are the primary waste produced by mowing and trimming. Clippings and cuttings carried into the storm water system and receiving streams can degrade water quality in a variety ways. A related problem exists with the illegal dumping of clippings and cuttings in or near drainage facilities. Once vegetative waste is generated, the main concern is to avoid transport of clippings and cuttings to receiving water bodies.

Alternatives

- Incorporate mechanical vegetation controls to actively manage and control vegetation within the Peruque Creek watershed as part of routine operations and maintenance for public works crews.

Municipal operators can be trained to use good judgment in determining whether clippings and cuttings should be collected or left in place. Also, operators can be trained to perform mowing at optimal times. Also, the use of mulching mowers can be recommended for certain areas.

Applicability to the Peruque Creek Watershed

Implementing vegetation controls for public works (park maintenance) crews is applicable to the Peruque Creek watershed. The cutting of municipal parklands and roadside vegetation is a common practice among the municipalities within the watershed. As a result, numerous opportunities exist to implement proper vegetation controls in these areas.

Effectiveness

The effectiveness of vegetation controls as a practice at removing pollutants is difficult to quantify. The effectiveness is dependant upon the amount of vegetative waste generated and, more importantly, the amount of vegetative waste that does not enter receiving water bodies as a result of proper vegetation controls. Discouraging the dumping of clippings and cuttings down a nearby ravine or on the slope of a creek will reduce the amount of organic matter that can potentially enter a storm water collection system. In addition, using bagging equipment or manually picking up material can reduce the presence of clippings and cuttings in and around catch basins. Clippings and cuttings are almost exclusively leaf and woody material but litter may be intermingled with clippings. Any reduction of clippings and cuttings carried into the storm water system or receiving streams can reduce the degradation of water quality.

Cost

Vegetation control measures are relatively simple and inexpensive. A small cost will be associated with the training of municipal employees on proper vegetation control. Another potential cost may include the upgrading of certain mowing equipment for bagging. Another third potential cost is for additional laborers involved in hand cutting, raking, and picking up clippings where mechanical cutting and collecting is not practical. The magnitude of each of these costs is dependant upon the current vegetation controls used by municipal employees, the mowing equipment that is currently available, and the level of effort desired to upgrade existing vegetation controls.

Ability to be Implemented

Vegetation controls may be one of the easiest pollution control measures to implement. Limitations to instituting pollution prevention practices for vegetation controls really only involve the cost for additional training, and possibly equipment upgrades. Since municipal parkland and roadside vegetation is routinely cared for anyway, staffing is usually already in place and alteration of current practices should not require additional staffing or administrative labor. Implementing proper vegetation controls could even be taken one step further and encouraged at schools and cemeteries by educating the grounds crews at these facilities.

6.4 Screening of Alternative Structural Controls

Alternative structural control measures, often referred to as treatment controls, are physical structures designed or modified to remove pollutants from storm water runoff, reduce downstream erosion, provide flood control, and promote groundwater recharge. In contrast with non-structural control measures, structural measures typically involve complex engineering design and construction to implement.

Structural control measures evaluated in this section include:

- Source Control Measures
- New Regional Facilities
- Stream Erosion and Velocity Controls

6.4.1 Source Control Measures

Source control measures are intended to eliminate urban pollutant sources before they find their way into storm water runoff. These techniques attempt to reduce the exposure of materials to storm water, thus limiting the amount of pollutants picked up by the water. Many of these practices are non-structural alternatives such as maintenance procedures and educational programs and were evaluated earlier in this section. However, the design or redesign of structures to reduce the amounts of pollutants entering storm water and accumulating on impervious areas may be necessary. These structural alternatives often involve reducing the amount of impervious surface on a site, thus reducing the peak flow and volume of storm water runoff.

Alternatives

- Reduce the quantity of pavement within public parking areas, within residential properties, and within street right-of-ways.

Whenever an existing parking area is scheduled to be repaved, business owners should look for opportunities to reduce the number of parking spaces, eliminate unnecessary pavement in non-traffic areas, and convert these areas to vegetated landscape islands. Homeowners should look for opportunities to narrow driveway widths and eliminate unnecessary paved areas.

- Encourage the use of alternative porous pavement methods in lieu of traditional asphalt and concrete within public parking areas and within residential lots.

Permeable pavements can be used to reduce the imperviousness created by patios, walkways, driveways, sidewalks, and parking areas. These alternative paving systems can reduce surface runoff, increase infiltration, and improve groundwater recharge characteristics.

- Encourage the construction of rooftop gardens over existing public and private buildings.

Constructing rooftop gardens over private and public buildings can be an effective structural management measure to reduce urban runoff and its associated pollutants to the watershed.

- Encourage the construction of tanks or cisterns for existing residential, commercial, and public buildings to capture and store runoff and irrigate vegetated areas.

An effective way to mitigate the impacts of urban runoff is to manage rooftop runoff on site instead of moving it through a conveyance system. Capturing rooftop runoff in tanks of cisterns for irrigation can be an effective alternative for reducing storm water runoff volumes.

For a more complete description of each of these structural management measures and how they can be used to reduce runoff and pollutant loads to Peruque Creek streams, please refer to Section 5.1 of this watershed management plan.

Applicability to the Peruque Creek Watershed

There are existing pavement areas that are deteriorated and will need to be replaced in the near future. With each of these pavement restoration projects, opportunities exist to eliminate unnecessary pavement areas and replace them with vegetated landscape areas.

Encouraging the use of alternative porous pavement methods in lieu of traditional asphalt and concrete for new development projects within the Peruque Creek watershed is not readily applicable since a large portion of the watershed has already been developed. However, the existing paved surfaces within the watershed (patios, driveways, parking areas, etc.) already have or will deteriorate and will need to be replaced. Therefore, opportunities exist to encourage the use of porous pavements during future resurfacing projects conducted within the watershed.

Theoretically, constructing rooftop gardens over existing public and private buildings in the Peruque Creek watershed appears to be an effective alternative to mitigate the impacts of urban runoff by managing rooftop runoff on-site instead of moving it through a conveyance system. However, there are a number of constraints that limit the implementation of this alternative. For example, many of the existing homes within the watershed have steeply sloped rooftops and are not eligible for the construction of a rooftop garden.

Rainwater harvesting – capturing and storing rainwater for later use – is an alternative control measure that is applicable to the Peruque Creek watershed. The harvested rainwater can be used for irrigation purposes or many other applications. The limiting factor toward implementing structural management measures, such as tanks and cisterns, may be the cost. Non-structural alternatives, such as installing rain barrels to existing downspouts, may be a more realistic alternative and applicable for the Peruque Creek watershed.

Effectiveness

Eliminating unnecessary pavement areas and replacing them with vegetated landscape islands can be effective at reducing the quantity of urban runoff generated within the Peruque Creek watershed. Directing pavement runoff to flat vegetated areas where rain water can percolate into the soil and pollutants can be filtered, can further increase the effectiveness of this structural management measure.

Porous pavement itself functions less as a treatment and more as a conveyance practice to the other necessary component of the design, the underlying aggregate chamber, which functions as an infiltration device. As with other infiltration devices, treatment is provided by adsorption, filtration, and microbial decomposition in the sub-soil surrounding the aggregate chamber, as well as by particulate filtration within the chamber. Operating systems have been shown to have high removal rates for sediment, nutrients, organic matter, and trace metals (Schueler *et al*., 1992).

The effectiveness of rooftop gardens has been seen throughout the world. Dust and air-borne particles have shown to be reduced since plants act as natural filters. Oxygen levels in the air have shown to increase. In addition, rooftops gardens have revealed decreased loads on storm drains and combined sewer systems since the roof is retaining storm water runoff. However, this management alternative would be ineffective within the Peruque Creek watershed because most of the existing roofs are structurally incompatible with rooftop gardening.

Rainfall harvesting technology has proven to be very effective throughout the United States and would be effective within the Peruque Creek watershed as well. Tanks and cisterns are an effective means of capturing and storing the runoff from roofs and driveways during storm events. Tanks and cisterns are capable of providing a sufficient water supply for most domestic landscaping irrigation applications. In addition, the use of rainwater has proven to be effective in lessening the demand on the public water supply system.

Cost

Costs associated with removing unnecessary pavement are generally low. Pavement restoration and/or reconstruction is priced by the area of deteriorated pavement. The additional cost of removing unnecessary pavement areas and converting them to landscaping islands is often offset by the reduced pavement area.

Costs associated with alternative porous pavements, can be highly variable from site to site. Because of this variability, cost estimates for these devices have been widely different as shown in **Table 6-2**.

Table 6-2
Cost Estimates for Porous Pavements

Cost Estimate	Source
$50,000 per acre of porous pavement	SWRPC, 1991
$80,000 per acre of porous pavement	Schueler, 1987

These estimates can be used in the Peruque Creek watershed to provide cost estimates for the re-paving of surfaces using porous pavements. For example, assuming a typical alleyway driveway is 9-feet by 5-feet, the cost to replace the deteriorated driveway with a porous pavement system would range from $50 to $85. Similarly, assuming a typical front yard driveway is 9-feet by 30-feet, the cost would range from $300 to $500. Some alternative paving materials can be more costly than conventional paving materials but most are quite comparable.

It is important to note that the most cost effective approach toward porous pavements is not for the immediate replacement of all paved surfaces within the watershed with permeable pavements. This would not be feasible or cost effective. The idea is to encourage the use of porous pavements when existing pavements have deteriorated and need to be replaced. In many cases, costs will be reduced if the paved surface area also can be reduced. Opportunities to reduce the amount of impervious cover should always be evaluated for any re-paving project to reduce costs.

There is a wide range of costs associated with constructing rooftop gardens and these vary from site to site. There are a number of issues that need to be considered when estimating the cost for the design and construction of rooftop gardens. The size of the rooftop, the existing structural carrying capacity of the rooftop, and the quantity and type of vegetation to be included in the garden as well as many other issues need to be addressed. Cost would be prohibitive in the Peruque Creek watershed because most of the roofs are structurally incompatible with roof top gardening.

Storage tanks for irrigation are constructed of a variety of materials, including steel drums, large polyethylene plastic tanks, and underground concrete cisterns. The cost of this management measure varies considerably depending on location, type of materials used, and degree of implementation. Construction costs for underground cisterns can vary significantly, based on the size, the amount of excavation required, and the type of soil. The cost of an 8,000-gallon cistern is typically around $900 to $1,000, depending on the material used.

Ability to be implemented

Existing paved surfaces within the Peruque Creek watershed already have or will deteriorate and will need to be replaced. Roads, sidewalks, driveways, parking areas, and patios all provide opportunities to implement porous pavements during future resurfacing projects. The key element in successfully implementing this alternative management measure is encouraging watershed communities and residents to consider the use of these alternative paving systems when rehabilitating existing paved surfaces. As previously mentioned, this alternative is suggested when existing pavements have deteriorated and need to be replaced. Residents and communities need to be aware of the paving alternatives that are available and the benefits that result from reducing impervious cover.

As previously mentioned, many of the existing homes within the watershed have steeply sloped rooftops and are not eligible for the construction of a rooftop garden. In addition, the majority of the existing homes and buildings in the watershed are older and may not have the structural capacity for the additional structural loading of a rooftop garden. These constraints make the construction of rooftop gardens a difficult alternative to implement.

The construction of a rooftop rainwater catchment system can be relatively simple. Watershed residents can be trained to build one, minimizing its cost. The technology is flexible. This allows lower income households to start with a single small tank or barrel and add more when they can afford to. The key toward implementing this alternative involves educating residents on how and why capturing and storing rainwater is an important storm water management tool.

6.4.2 Remedial Measures for Existing Municipal Infrastructure

Every existing municipal sewage collection and conveyance system is unique, yet all face similar problems. Ageing and deteriorating infrastructure is a typical problem most municipalities must deal with.

Alternatives

- Modify existing storm inlets so that street litter and floatable debris is trapped and prevented from discharging into watershed streams

Floatables that enter watershed streams can have a negative impact on water quality and lead to the degradation of the stream. Existing storm inlets within the watershed can be modified to trap these floatables and prevent them from discharging into receiving streams.

For more complete and thorough descriptions of these structural measures and how they could be used in the Peruque Creek watershed, please refer to Section 5.2 of this plan.

Applicability to the Peruque Creek Watershed

Most existing storm inlets allow street litter and other floatable debris to pass through and be conveyed to streams. Implementing structural modifications to do a better job of trapping floatables and prevent their discharge into streams is clearly applicable to the Peruque Creek watershed.

Effectiveness

Floatables and debris that make their way to watershed streams can have an adverse impact on stream water and aesthetic quality. The principal advantage of storm inlet modifications as described is that they prevent these larger visible materials from entering receiving streams. The principal disadvantages with these devices is that they place a greater demand on existing municipal personnel and budget resources for regular and timely maintenance to clean these devices and dispose of the retained materials. However, these structural modifications can be considered effective.

Costs

A program should be implemented to identify existing storm inlets. These devices should then be modified so that street litter and floatable debris is trapped and prevented from discharging into watershed streams. Costs associated with implementing such a program primarily consist of materials and labor. The magnitude of these costs will be dependant upon the number and type of storm drain modifications that are made. In addition, additional costs will be accrued with regular maintenance to remove the trapped debris and floatables from these devices.

Ability to be Implemented

Structural modifications to existing storm inlets can be implemented gradually over time. A schedule should be prepared so that the modifications can be implemented within a 10 to 15 year time frame.

6.4.3 New Regional Facilities

A number of systems are available whereby storm water runoff is collected, temporarily stored, and percolated through the soil and released slowly over time. These systems include wet or dry ponds, detention basins (**Figure 6-3**), dry wells, infiltration basins, and constructed wetlands. Often, these facilities are fragmented in that individual basins are sited within individual development plans, but regional basins can be constructed to provide storm water management for an entire sub-watershed area. In the Peruque Creek watershed, these structural alternatives can be considered on a regional level and are dependant upon the desired level of particulate and dissolved pollutant removal, groundwater recharge, and storm water runoff flow control.

Figure 6-3 - Detention Basin in Newly Constructed Residential Development in Warren County

Alternatives

- Construct new wetland areas to filter urban pollutants and act as "watershed sponges" to store storm water and augment dry weather stream flow.

Storm water wetlands are designed to maximize pollutant removal through wetland uptake, retention, and settling. Constructed wetlands are ideal for large, regional tributary areas and provide multiple benefits of passive recreation and wildlife.

- Construct extended dry detention ponds and wet ponds, either on an on-site or regional basis, to temporarily store storm water runoff and discharge it slowly over time.

Extended detention ponds are dry between storm events. During a storm, the basin fills and a bottom outlet releases the storm water slowly to provide time for sediments to settle. Wet ponds are similar to extended dry detention ponds except that they have a permanent water pool to treat incoming storm water.

For more detailed descriptions of these alternative regional control facilities, please refer to Section 5.3 of this watershed management plan.

Applicability to the Peruque Creek Watershed

The alternatives listed above are typically designed to fit aesthetically into the open space landscaping of new developments. They are usually placed within individual development projects or lots.

There are limitations to implementing extended dry detention ponds and wet ponds on a regional level. These regional facilities take up considerable land area because the side slopes of many of them are flat to allow for maintenance and to ensure public safety. In these cases where land availability is minimal these regional facilities are not readily applicable.

Effectiveness

There has been a great deal of storm water monitoring data collected across the country by a number of organizations. Most of these data have focused on characterization of pollutants in runoff, and not on the effectiveness of various control measures. However, several nation-wide monitoring programs have been conducted to characterize pollutants in urban storm water runoff and to evaluate the performance of the storm water control measure. Structural control measures can be measured in terms of reductions in pollutants discharged from the system and by the degree of attenuation of storm water flow rates and volumes discharged to the environment. Various physical, chemical, and biological evaluation methods exist for determining the pollutant removal efficiency of these facilities.

Structural facility performance can vary considerably based on differences in design criteria and performance standards for which the facility is designed. Comparing pollutant removal efficiency for similar facility types with very different performance goals may result in widely disparate efficiency estimations. In addition to performance goals, variations in watershed parameters (size of the drainage area, level of watershed imperviousness, land use, etc.) can cause significant differences in performance among the alternatives. Also, differences in design parameters such as ratio of the facility volume to the contributing drainage area, the retention time in the facility, the physical dimensions and the construction of the facility further complicate direct comparisons between monitoring data.

Despite these shortcomings, some general ranges of expected efficiencies have been compiled from literature. Documents that summarize structural control measure efficiency information include the CWP's National Pollutant Removal Performance Database (Brown and Schueler, 1997), the Terrene Institute's report *The Use of Wetlands for Controlling Storm water Pollution* (Strecker et al, 1992), as well as a variety of other articles and documents contained in professional and scientific literature. **Table 6-3** below summarizes the actual performance data contained in literature on pollutant removal efficiencies for the structural alternatives described in this section.

Table 6-3
Pollutant Removal Efficiencies of Structural Alternatives

Type	Typical Pollutant Removal (percent)				
	Suspended Solids	Nitrogen	Phosphorus	Pathogens	Metals
Dry Detention Ponds	30 - 65	15 – 45	15 - 45	< 30	15 – 45
Wet Ponds	50 - 80	30 - 65	30 - 65	< 30	50 – 80
Dry Wells	50 - 80	50 - 80	15 - 45	65 - 100	50 – 80
Infiltration Basins	50 - 80	50 - 80	50 - 80	65 - 100	50 – 80
Constructed Wetlands	50 – 80	< 30	15 - 45	< 30	50 - 80

Source: Adapted from US EPA, 1993

Costs

Storm water runoff can contribute loadings of nutrients, metals, oil and grease, and litter that result in impairment of local water bodies. The extent in which these impairments are reduced or eliminated by a structural control measure depends on a number of factors, including the number, intensity, and duration of wet weather events; facility construction and maintenance activities; and the site-specific water quality and physical conditions. Because these factors will vary substantially from site to site, developing dollar estimates for individual facilities becomes difficult. Some structural control measures can represent a significant cost to communities, but these costs should be weighed against the various benefits they provide.

Table 6-4 gives some typical base capital costs for various structural alternatives. The base capital costs refer primarily to the cost of constructing the facility. This may include the erosion and sediment control during construction but the costs of design, geotechnical testing, legal fees, land costs, and other unexpected or additional costs are not included in these estimates. It should be noted that the cost of constructing any of these facilities is variable and depends largely on site conditions and drainage area.

Table 6-4
Base Capital Costs of Various Structural Facilities

Type	Typical Cost ($/ft^3)	Notes	Source
Dry Detention Ponds / Wet Ponds	0.50 – 1.00	Cost range reflects economies of scale in designing this facility. The highest unit cost represents approx. 15,000 ft^3 of storage while the lowest is approx. 150,000 ft^3. Typically, dry detention ponds are the least expensive design options among retention and detention practices.	Adapted from Brown and Schueler (1997)
Dry Wells	4.00	Represents typical costs for a 100-foot long trench.	Adapted from SWRPC (1991)
Infiltration Basins	1.30	Represents typical costs for a 0.25-acre infiltration basin	Adapted from SWRPC (1991)
Wetlands	0.60 – 1.25	Although little data are available to assess the cost of wetlands, it is assumed that they are approx. 25% more expensive (because of plant selection and sediment forebay requirements) than retention basins.	Adapted from Brown and Schueler (1997)

For extended dry detention ponds, wet ponds, and constructed wetlands, the total volume is generally a strong predictor of cost. There are some economies of scale associated with constructing these systems, as evidenced by the slope of the volume equations derived and shown in **Table 6-5**. This is largely because the costs of the inlet and outlet design - the mobilization of heavy equipment are relatively similar regardless of basin size.

Table 6-5
Cost Equations for Various Detention/Retention Facilities

Type	Cost Equation or Estimate	Costs Included		Source
		Construction	E&S Control	
Retention Basins and Wetlands	$7.75V^{0.75}$	√	√	Wiegand et al. 1986
	$18.5V^{0.70}$	√		Brown and Schueler 1997
Detention Ponds	$7.47V^{0.78}$	√	√	Brown and Schueler 1997
Wet Ponds	1.06V: 0.25 acre wet pond (23,300 cubic feet)	√		SWRPC 1991
	0.43V: 1.0 acre wet pond (148,000 cubic feet)			
	0.33V: 3.0 acre wet pond (547,000 cubic feet)			
	0.31V: 5.0 acre wet pond (952,000 cubic feet)			

Note:
V refers to the total basin volume in cubic feet

Ability to be Implemented

As was previously mentioned, there are limitations to implementing extended dry detention ponds and wet ponds on a regional level due to land availability. Also, there are constraints in implementing on-site alternatives, such as infiltration basins and dry wells soils of the watershed may preventing adequate infiltration.

However, there are several scenarios for the Peruque Creek watershed where wetland creation or expansion could be used to manage storm water and provide pollutant removal. These constructed wetlands can include design elements such as a forebay, complex microtopography, and pondscaping with multiple species of trees, shrubs, and plants for even more effective pollutant removal.

Because of their shallow depths, storm water wetlands can consume two to three times the site area compared to other storm water quality options. The land requirements of these wetlands can be sharply reduced by deepening parts of the wetland, thus reducing detention times. Limited due to space constraints; however pollutant removal can be obtained by modifying existing degraded wetlands with the watershed for storm water control. Key factors influencing the longevity of constructed wetlands that should be examined include: the selection of an experienced wetland contractor for design, the ability to regulate water depths, replacement plantings, and the control of undesirable plants.

6.4.4 Stream Erosion and Velocity Controls

Stream erosion and deposition are controlled by a stream's velocity and the discharge through the stream during storms. Velocity is controlled by the stream gradient, channel shape, and channel roughness. Storm flow is controlled by the size and slope of the contributing watershed and the degree of urbanization. Streams are very effective in sculpting the land by cutting their own valleys, deepening and widening them over long periods of time. Urbanization in the watershed accelerates this process. Implementing structural stream restoration measures provide alternative control measures to control bank erosion, stabilize slopes, control stream gradients, and provide aquatic habitat.

Alternatives

- Stabilize existing stream channels, channel banks, and over-banks using natural "green engineering" techniques to restore existing eroded areas and prevent future erosion and scour

Stream bank erosion is dictated by the stability of the banks and the energy of the flowing water. Stream banks can be protected or restored either by increasing resistance of the bank to erosion or by decreasing the energy of the water at the point of contact with the bank. Armoring the bank with stone, flattening channel slopes, re-vegetation, or a combination can stabilize the bank.

- Reconfigure existing stream channels and reconnect them to their adjacent floodplains, using sound fluvial geomorphologic principals, to restore natural channel proportions and natural frequency of over-bank flooding

Stream channels in urbanized watersheds can become incised, keeping storm flow in the channel instead of spreading out over adjacent flood plains. Rehabilitation and reconfiguring the shape and alignment of the stream can reconnect the stream channel to its over-banks and restore natural storm conditions within the flood plain.

Fluvial geomorphology is the science that assesses the shape and form of a watercourse and the contributing physical processes. This includes the conveyance of water as well as the supply and movement of sediment. Typical applications of fluvial geomorphology include inventory and assessments primarily for watershed planning, erosion assessment, and analyses for crossing structures, channel realignments and storm water management. In addition, this science applies natural channel design for restoring or rehabilitating channel reaches and provides integration with aquatic biology to enhance habitat and provide a more comprehensive understanding of channel dynamics.

For more detailed descriptions of these storm stabilization and restoration measures, and the alternative techniques that can be used to implement them, please refer to Section 5.4 of this watershed management plan.

Applicability to the Peruque Creek Watershed

Portions of the Peruque Creek stream channel have been significantly impacted and degraded by urbanization for most of its length within the watershed. The lower portions of Peruque Creek, downstream of Lake Saint Louis, has experienced the most change in channel morphology, with the creek being highly channelized.

During dry weather periods, stream flow can almost disappear completely within the channel. However, when it rains, most of the rainwater quickly runs off impervious surfaces and into storm drains. Stream flows increase rapidly in response to these storm events. Sporadic wet weather flow events have been responsible for significant stream bank erosion and subsequent deposition of sediments within the open channel segments of the stream. The use of structural stream restoration measures provides an alternative control measure to remediate the negative impacts of watershed urbanization along watershed streams, and is clearly applicable to the Peruque Creek watershed.

Effectiveness

Stream stabilization measures can be highly effective in reducing erosion and scour and improving water quality. Reconfiguring and stabilizing existing stream channels can indirectly manage storm water by managing the effects of storm water draining into the stream. Pollutant reduction can be achieved through sediment avoidance by stabilizing stream-banks that are subjected to erosion during storm events. Vegetative barriers and buffers can also filter overland runoff. Additionally, methods that reduce velocity may remove sediment from the stream through deposition. Below is a list of addition positive impacts.

- Erosion control is effective in reducing downstream siltation, increasing downstream water quality
- Green engineering techniques used alone or in concert with mechanical stabilization methods are effective to enhance riparian habitat for wildlife (food and cover sources and temperature control for aquatic and terrestrial animals)
- Vegetated and restored stream-banks may also enhance purification of overland runoff and provide aesthetic appeal

Cost

The cost to implement stream stabilization measures depends on the size of the stream and the tributary watershed, the peak storm flow and velocity, and the accessibility to get materials and equipment to the stream. Stabilizing eroded channel areas along Peruque Creek has been estimated to cost from $100 to $200 per lineal foot of stream channel.

Ability to be Implemented

The costs of restoration could be significant. However, there are funding sources available such as the Watershed Resources Development Act (WRDA) and Section 319 Grants.

6.5 Institutional Mechanisms

Successful watershed planning in Peruque Creek will require a combination of existing and new institutional organizations to focus the resources of a diverse group of stakeholders to implement the plan. A long-term management structure is not only critical to prepare and implement the plan, but to revisit and update the plan as goals are achieved or circumstances within the watershed change over time.

Alternatives

Several different options are available to structure a watershed management organization. There are three broad models to choose from to organize the stakeholders for a management plan:

- Government-Directed Model
- Citizen-Directed Model
- Hybrid Model

The primary difference between the three management options concerns the organization ultimately responsible for directing the watershed plan. In the government-directed model, local or governmental agencies assume responsibility for making decisions about how the watershed is managed. Conversely, the citizen-directed model is driven by citizen activists or grass roots organizations. A hybrid organization combines the best of both models and is recommended for the Peruque Creek watershed. The basic elements of these models are presented below in **Table 6-6**.

The hybrid management model generally includes members from the local professional community, government agencies, citizens, and non-profit organizations. The organization itself does not have regulatory authority, but makes recommendations to local government agencies like municipal government, MDNR, NRCS and MDC to insure that management strategies are implemented. The goal of the hybrid model is to incorporate and involve as many stakeholders as possible in the process of implementing the watershed management plan, either in an advisory or technical role. A technical committee is often set up to provide expertise on scientific or engineering issues, while a citizen advisory committee affords the public the opportunity to voice their opinions in the management process. A central principal behind the hybrid model structure is that greater watershed improvements can be achieved when there is proactive involvement of many watershed parties.

Table 6-6
Typical Components of Watershed Management Structures

	Government-Directed Model	**Citizen-Directed Model**	**Hybrid Model**
Formation	Created by Legislative Authority	Created at "grass-roots" level from citizens or other interested parties	Created with some governmental authority, with some support from citizens
Membership	Organization membership is appointed by governmental authority	Stakeholder participation is voluntary	Some members are required to participate, but many are volunteers
Authority	Structure has regulatory authority over land use and other permits	Advisory capacity with no regulatory authority over land use or permits	Some members have regulatory authority, and others act in a volunteer or advisory capacity
Funding	Funding is through taxes or levied fees	Funding is either by grant, donations, or by local government contributions	Funding comes from a combination of grants and local government agreement
Implementation	Government agencies at the local and state levels implement the plan.	Local governments implement the plan	Local governments implement the plan, with some assistance from state agencies.

New and existing institutional entities will all play important roles in implementing the recommended management and restoration measures within the Peruque Creek watershed. The following entities either have or will have significant roles in implementing the Peruque Creek watershed management plan.

Peruque Creek Watershed Alliance (PCWA)

A watershed alliance was established prior to the Peruque Creek Watershed Study and will oversee and implement the Peruque Creek Watershed Management Plan. The association is comprised of citizen volunteers with diverse backgrounds, interests, and areas of expertise. Alliance members represent the interests of the Peruque Creek watershed, and home and business owners in the watershed. The Alliance has no regulatory authority, but can make recommendations to all municipalities, MDNR, NRCS and MDC to implement recommended management strategies, restoration measures, and structural rehabilitation. The PCWA has no funding mechanisms at this time and are working with the SWCD.

Municipal Government

There are eight municipalities, each with jurisdiction over their respective portions of the Peruque Creek watershed. They are the City of Warrenton, City of Wright City, City of Foristell, City of Wentzville, City of Lake Saint Louis, City of O'Fallon, Village of Josephville and City of St. Paul. In addition there are unincorporated areas of St. Charles and Warren Counties within the watershed. These municipalities would need to transcend existing borders and work together as a unified watershed entity. The municipalities would have the authority to revise and enforce ordinances that would shape new development and restorative redevelopment, control the disposal of pet wastes and household hazardous wastes, and oversee the storm drain and pavement systems. Funding for municipal government activities would come from a combination of property and wage taxes, bond issues, loans, and possible demonstration grants.

Duckett Creek Sanitary District

The DCSD has no control over stormwater and no regulatory authority on development in the watershed, this agency is responsible for operating and maintaining the sanitary sewer mains only. However, since this agency's boundary lines do not coincide with any county or city boundary lines, and service many communities in the Peruque Creek watershed, they could be a potential partner in a watershed management authority.

Governmental Agencies

MDNR, NRCS and MDC are existing government agencies that provide oversight and regulatory guidance over environmental quality within the Peruque Creek watershed. These organizations have conducted field investigations and laboratory analyses and have determined that sediment, expressed as non-volatile suspended solids, in Peruque Creek exceed established water quality standards, resulting in portions of Peruque Creek being listed on the 2002 Missouri 303d List. The St. Charles County Soil and Water Conservation District (SCWD) is a locally organized and operated unit of government functioning under Missouri law. They provide financial incentives and technical assistance to agricultural landowners as well as educate their communities through field days, tours, and programs in schools. SWCD's provide the local leadership to ensure conservation practices are completed in their districts.

Applicability to the Peruque Creek Watershed

To successfully implement the Peruque Creek watershed management plan, a combination of new and existing institutional organizations will be needed to focus resources, engage stakeholders, and evaluate costs and benefits of the recommended management measures as they are enacted. The various institutional entities are clearly applicable to the Peruque Creek watershed.

Effectiveness

The combination of institutional entities that are or will be active in the watershed should be highly effective in implementing the goals and objectives for the Peruque Creek watershed. The institutions should be effective in implementing management and restoration measures that ultimately will improve water quality, reduce pollutant loads, improve aesthetic quality, and improve and expand aquatic and terrestrial habitat.

Costs and Funding

Funding to support the various institutional entities that will be active in the Peruque Creek watershed will come from a number of sources as described below.

- **The Peruque Creek Watershed Alliance -** The members of the association are a collection of citizen volunteers jointly working with the SWCD and they seek funding through a combination of grants.

- **Municipal Government -** The cost for activities conducted by municipalities would be provided by a combination of property and wage taxes, bond issues, loans, and possible demonstration grants.

- **Regulatory Agencies -** Activities conducted by environmental regulatory agencies would be provided by state and county budgets that are funded through state and county taxes. Federal funding through USEPA and the Department of Agriculture may be available.

Ability to be implemented

Most of the institutional entities that would implement the Peruque Creek watershed restoration plan already exist and are already actively involved in the watershed.

Section 7
Recommended Watershed Management Plan Elements

Watershed management and protection is about making choices regarding which measures and controls are best to apply, and in what combination. A well-crafted and implemented watershed management plan is arguably the best and most comprehensive tool to protect urban streams and riparian corridors from the cumulative impacts of new land development and existing urbanization. Existing watershed problems were identified and a series of goals, objectives, and priorities for the Peruque Creek watershed were established and documented in Section 2 of this watershed management plan. Alternative non-structural and structural management and control measures that were considered for the Peruque Creek watershed were identified and described in Sections 4 and 5, respectively. In Section 6, the alternatives were evaluated and screened to determine an optimal mix of recommended management, restoration, rehabilitation and control measures to apply to existing watershed problems and to meet the watershed goals and objectives.

This section will describe the recommended management tools, measures, and controls to utilize within the Peruque Creek watershed and the institutional mechanisms to implement them. It must be understood that this document is a watershed management action plan. Watershed stakeholders, like the PCWA and the municipalities located within the watershed, will need to carefully review this document and associated recommendations, make any needed revisions, and adopt the finalized plan as a comprehensive guidebook for improving the Peruque Creek watershed.

7.1 Recommended Institutional Mechanisms

Successful watershed planning in Peruque Creek will require a combination of existing and new institutional organizations to focus the resources of a diverse group of stakeholders to implement the plan. A long-term management structure is not only critical to prepare and implement the plan, but to revisit and update the plan as goals are achieved or circumstances change over time. Several different options are available to structure a watershed management organization. The hybrid management model is recommended for the Peruque Creek watershed to oversee the implementation of the watershed management plan. This management and other management models that were considered but not selected were described and evaluated previously in Section 6.5.

The recommended hybrid management model should include members from the local professional community, government agencies, citizens, and non-profit organizations. The management organization itself would not have regulatory authority, but would make recommendations to local agencies like municipal governments to insure that management strategies are implemented. The goal of the hybrid model is to incorporate and actively involve as many stakeholders as possible in the process of implementing the watershed management plan, either in an advisory or technical role. A technical committee should be set up to provide expertise on scientific or engineering issues, while a citizen advisory committee affords the public the opportunity to voice their opinions in the management process. A central principal behind the hybrid model structure is that greater watershed improvements can be achieved when there is proactive involvement of many watershed parties.

Recommended components and attributes of the hybrid management model are summarized as follows:

Formation

Created with some governmental authority and with some support from watershed citizens.

Membership

Some members are required to participate, but many are volunteers.

Authority

Some members have regulatory authority, and others act in a volunteer or advisory capacity.

Funding

Funding comes from a combination of grants and local government cost-sharing agreements.

Implementation

Local governments implement the watershed management plan, with some assistance from state and county agencies.

Existing institutional entities and the PCWA will all play important roles in implementing the recommended management and restoration measures within the Peruque Creek watershed. The following entities either have or will have significant roles in implementing the Peruque Creek watershed management plan.

PCWA

A watershed alliance has been established to oversee and implement the Peruque Creek Watershed Management Action Plan. The association is comprised of citizen volunteers with diverse backgrounds, interests, and areas of expertise. Alliance members represent the interests of the Peruque Creek watershed, home and business owners in the watershed, and other stakeholders in the watershed. The PCWA will have the primary responsibility for reviewing this management action plan, making any needed revisions, adopting the plan, and coordinating with the other institutional entities so that the plan is implemented, evaluated, and updated on a regular basis. The PCWA will have no regulatory authority, but will make recommendations to local municipalities, the MDNR, NRCS, and MDC to implement recommended management strategies, restoration measures, and structural rehabilitation.

Municipal Government

The cost for activities conducted by municipalities would be provided by a combination of property and wage taxes, bond issues, loans and possible demonstration grants. There are eight municipalities, each with jurisdiction over their respective portions of the Peruque Creek watershed. They are the City of Warrenton, City of Wright City, City of Foristell, City of Wentzville, City of Lake Saint Louis, City of O'Fallon, Village of Josephville and City of St. Paul. In addition there are unincorporated areas of St. Charles and Warren Counties within the watershed. These municipalities will need to work together as a unified watershed entity and transcend existing municipal boarders. The municipalities will have the authority to revise and enforce ordinances that would shape new development and restorative redevelopment, reduce stormwater runoff, control erosion from construction sites, adopt similar setback controls watershed wide, control the disposal of pet wastes and household hazardous wastes, and oversee the storm drain and pavement systems in the watershed. Municipalities in the Peruque Creek watershed also will need to carefully review this management plan and make any needed revisions.

Regulatory Agencies

MDNR, NRCS and MDC are existing regulatory agencies that have authority and jurisdiction over environmental quality within the Peruque Creek watershed. They have been active in the watershed in the past and will have active roles in the future implementation of the Peruque Creek Watershed Management Plan. These organizations have conducted field investigations and laboratory analyses and determined that sediment concentrations along the Peruque Creek stream channel exceed established water quality standards. Therefore, portions of Peruque Creek were listed in the 2000 Missouri 303d List.

Required funding to support the various institutional entities that will be active in the Peruque Creek watershed will be secured through a number of sources as described below.

PCWA

The members of the Alliance are a collection of citizen volunteers. These volunteers give over hundreds of hours in labor to educate watershed citizens. Administrative and program support is funded through seeking grant funds with assistance from the SWCD and technical assistance from NRCS, MDC and MDNR.

Municipal Government

The cost for activities conducted by municipalities would be provided by a combination of property and usage taxes, bond issues.

Regulatory Agencies

Activities conducted by environmental regulatory agencies would be provided by state and county budgets that are funded through state and county taxes.

7.2 Land Use Controls

Urbanization and impervious cover directly influence urban streams by increasing surface runoff during storm events. A variety of alternative land use control techniques can be used to directly and indirectly manage land use and impervious cover in the Peruque Creek watershed. For the Peruque Creek watershed, where much of the watershed is developing, the tools of direct and indirect regulatory approaches are especially effective land use controls. It must be understood that the land use controls documented in this watershed management plan are recommendations. Watershed stakeholders, like the PCWA and the municipalities located within the watershed, will need to carefully review this document and associated recommendations, make any needed revisions, and adopt the finalized plan as a comprehensive guidebook for improving the Peruque Creek watershed.

7.2.1 Recommended Alternatives

- **During future restorative redevelopment projects within the Peruque Creek watershed, encourage home and business owners to replace deteriorated driveways, walks and patios with semi-pervious pavement materials, and to direct storm water runoff to flat vegetated areas rather than street curbs.**

  The Peruque Creek watershed is comprised of mostly newer communities; however some of the older communities have deteriorated driveways, walkways, patios, parking areas currently or will need to be replaced. These paving projects will provide opportunities to restore the natural watershed ecosystem and the communities to health and vitality. Home and business owners will be encouraged to eliminate unnecessary pavement areas, to replace existing concrete and asphalt with more pervious alternatives and to direct roof and pavement runoff to flat vegetated areas where it can percolate into the soil. This land use control measure should be teamed with a proactive public education program to maximize opportunities to implement these management practices.

  More detailed descriptions of the concepts of restorative redevelopment and how they can be applied to the Peruque Creek watershed are provided in Section 4.1.3. The evaluation and screening process resulting in pavement reduction being a recommended land use control for the Peruque Creek watershed is documented in Section 6.1.2.

- **Restore and enhance existing buffer areas within the Peruque Creek riparian zones to sustain the integrity of aquatic and terrestrial habitat.**

  A stream buffer is the region immediately beyond the banks of a stream that serves to limit the entrance of sediment, nutrients, and pollutants into the stream. It acts as a right-of-way for a stream and functions as an integral part of the stream ecosystem. Existing riparian buffers should be restored and enhanced to promote bank stability, control stream temperature, control pollutant loads, enhance habitat, and provide an aesthetically pleasing greenway for public recreation and enjoyment.

  Within the Peruque Creek watershed, private land needs to be acquired, or setback ordinances need to be established in Warren County to maintain existing open spaces and stream buffers. Currently St. Charles County has a 50-foot minimum vegetated buffer requirement for the mainstem of Peruque Creek, and a 25-foot vegetated buffer requirement in associated tributaries. Stream bank vegetation along the Peruque Creek riparian corridor has been degraded and will continue to degrade until appropriate action is taken to minimize the destruction of the riparian zone. Revegetation of these areas would be beneficial, particularly where the natural vegetation has been replaced with mowed grass or where there is minimal existing vegetation. Some areas of concern include agricultural fields along Peruque Creek, the Golf Course at Wentzville and the lower reaches of Peruque Creek just before it empties into the Mississippi River.

  The enhancement and restoration of existing buffer zones along the riparian corridor were described in Section 4.1.4. The screening and evaluation process resulting in buffer zone restoration being recommended as a control measure was discussed in Section 6.1.3.

- **BMP approach directed toward pollution prevention for industrial and commercial facilities located within the Peruque Creek watershed.**

  This pollution prevention approach is intended to achieve a level of on-site pollution control at the point of origin so that pollutants do not leave the site during storms. The approach is highly practical from a business standpoint because it focuses on operational practices, good housekeeping measures, and other low-cost pollution control practices rather than expensive constructed control facilities. Owner and employee training is the vital component in implementing BMP measures.

  Even small industrial and commercial business and facilities have the potential to be a significant pollutant contributor and can be considered potential hot spots within the watershed. While only a small portion of the watershed is used for commercial and industrial purposes, routine or accidental discharges from these few facilities can discharge pollutants such as petroleum hydrocarbons, heavy metal, and toxic organic materials in quantities for beyond the proportion of the facility size.

Implementing best management practices as a land use control for commercial and industrial facilities in the watershed was discussed in Section 4.1.5. The evaluation and screening process resulting in these BMP measures being a recommended control measure was documented in Section 6.1.4.

- **Improve resources available for the administration and enforcement of (E&SC) requirements by municipal zoning officers and building inspectors whenever new development or redevelopment occurs in the watershed.**

  An effective E&SC Program is an important management tool to reduce the potentially severe impact generated by the construction process when soils are disturbed and exposed. Most of the municipalities within the Peruque Creek watershed have existing ordinances that require E&SC to be implemented at construction sites. Limited municipal staffing and other perceived priorities for municipal personnel may limit the frequency at which construction sites are inspected in the Peruque Creek watershed. Improved staffing and funding resources could encourage proactive implementation and enforcement measures and could increase the effectiveness of existing ordinances.

  Erosion and Sedimentation control measures and their increased enforcement were described in Section 4.1.1. The evaluation and screening process resulting in this measure being an alternative to consider was discussed in Section 6.1.1.

7.2.2 Other Alternatives to Consider

- **Use "green" site designs when empty "fill in lots" in existing urban neighborhoods are developed in order to limit impervious cover and direct runoff to flat vegetated areas.**

  Property owners who construct development and redevelopment projects on individual vacant lots should be encouraged to design their homes, driveways, walkways, and patios in ways that reduce the quantity of impervious cover on the lot, and increase the percentage of vegetated landscaping areas to reduce the impact of development. When better site designs are implemented, driveway widths and sidewalk widths are narrowed; patios, driveways and walkways are constructed of semi-pervious building materials, and runoff is directed to flat vegetated areas where it can be percolate into the ground.

7.3 Public Education & Volunteer Programs

The public does not always practice good watershed ethic, and continue to engage in many behaviors that are linked to water quality problems. Watershed education is an important watershed management element because it encourages residents to live responsibly in their watershed and is the primary tool for changing these adverse behaviors. This section will address recommended public education and citizen volunteer programs to implement within the Peruque Creek watershed. Watershed stakeholders, like the PCWA and watershed residents and business owners, will need to carefully review this document and associated recommendations, make any needed revisions, and adopt the finalized plan as a comprehensive guidebook for improving the Peruque Creek watershed.

7.3.1 Recommended Alternatives

- **Implement an education program to familiarize watershed residents and business owners on how littering and improperly disposed materials can degrade storm water and watershed quality**

  Education is the key to changing behavior and attitudes with regards to littering, dumping pollutants down storm drains, and improperly disposed materials at vacant lots or other local dump sites. The goal is to successfully educate the public on the problem and its implications. Effective litter and illegal dumping prevention programs use practices such as educational materials, the media, and volunteer cleanup programs to educate and involve the community in an effort to eliminate these problems.

  Littering and illegal dumping are problems in the upper and lower reaches of Peruque Creek watershed. Items such as auto batteries, refrigerators and other scrap appliances may be illegally dumped to avoid disposal fees or the time and effort required for proper disposal at landfills or recycling facilities. Litter and improperly disposed materials can eventually make their way into receiving streams thus making them a risk to public safety and water quality. Illegally dumped hazardous chemicals generated from household, commercial, and industrial sources can contaminate ground and surface water supplies, affect drinking water and public health as well as aquatic habitat.

  A more detailed description pertaining to the effects littering can have on the watershed and the recommended approaches toward implementing a public education program regarding litter control can be found in Section 4.2.1. The causes and effects of illegal dumping and educational programs addressing this issue were discussed separately in Section 4.2.2. The screening process used to evaluate how public education toward littering and illegal dumping could be used as a recommended control measure was discussed in Section 6.2.1.

- **Coordinate special cleanup events where community volunteer groups clean up existing dumping sites, enhance the aesthetic quality of the watershed, and encourage community and watershed pride.**

  Special cleanup events should be organized where community volunteer groups are provided with the resources to properly dispose of illegally dumped materials. These clean up activities should increase the understanding among residents of illegal dumping impacts and supplies opportunities to correctly dispose of these materials. Cleanup projects will require coordinated planning efforts to ensure that adequate resources and funding are available. Once a site has been cleaned, signs, lighting, or barriers should discourage future dumping. Landscaping and beautification efforts should also discourage illegal dumping, as well as provide open space and increased property value. The strongest deterrent to illegal dumping is natural beauty. If property is naturally beautiful and well cared for, it is less likely to be trashed by uncaring people.

Illegally dumped materials can reduce runoff drainage due to blocked streams, culverts, and drainage basins and result in local flooding and channel erosion. Property values can decrease as a result of littering and illegal dumping and the local tax base can be affected. Coordinated cleanup events will provide opportunities to properly dispose of litter and illegally dumped materials and avoid contaminated runoff from entering surface water.

Littering and illegal dumping control and the coordination of special cleanup events was discussed in Sections 4.2.1 and 4.2.2. The evaluation and screening process resulting in coordinated special cleanup events being a recommended alternative control measure was discussed in Section 6.2.1.

- **Implement a pollution prevention program to educate watershed residents on lawn care and the water quality impacts associated with lawn care products.**

Not many people understand that lawn fertilizer, weed controls, and insecticides can cause water quality problems. Some of these constituents maybe entering Lake Saint Louis through the numerous residential properties adjacent to the lake. Stormwater runoff from these properties enters storm sewers which drain to the lake or through overland flow directly into the lake.

Materials such as flyers and brochures should be distributed to educate residents and business owners within the watershed on the water quality impacts associated with lawn care and landscaping. These outreach materials will inform residents who perform their own lawn maintenance that runoff from lawns can contribute pollutants that contaminate storm water runoff into watershed streams and can be toxic to both humans and aquatic organisms. Educational materials will encourage management practices such as ways to reduce fertilizer and pesticide application and substitution of watershed friendly products for those that are not. The Lake Saint Louis Community Association (LSLCA) should notify it's constituents about the hazards of applying lawn fertilizers and pesticides improperly.

Chemicals associated with fertilizers (nitrogen, phosphorus, potassium), weed control, and insect control can find their ways to streams and reducing the application of these chemicals can reduce the water quality problems associated with them. As a result, education programs targeted toward watershed residents who perform their own lawn care should be considered. However, studies indicate that product labels and store attendants are the primary and almost exclusive source of lawn care information for the average consumer who takes care of his/her own lawn. This tends to indicate that training employees of lawn and garden centers on lawn care pollution control may be a more effective control measure to implement.

Landscaping and lawn care pollution control and educating residents on lawn care pollution control were discussed in Section 4.2.3. The evaluation and screening process resulting in this measure being a recommended alternative was discussed in Section 6.2.2.

- **Implement an outreach and training program for businesses involved in automobile maintenance.**

  Automotive maintenance pollution prevention programs include outreach and training to automobile maintenance businesses and target practices that control pollutants and reduce storm water impacts. Trained inspectors would visit a participating facility and recommend management practices based on his/her observations. Common pollution prevention methods at maintenance shops that should be stressed include waste reduction, the use of safer alternative materials, spill clean up, good housekeeping, and parts cleaning. In order to encourage behavioral changes among participating maintenance facilities, promotional tools like listings in newspaper ads, decals for shop windows, prize drawings, and discount coupon giveaways should be made available to help generate business for these participating facilities. The number of these business in the Peruque Creek watershed are limited, but still could contribute to unnecessary loadings of petroleum and heavy metals to the creek.

  Automotive maintenance facilities can be significant contributors of hydrocarbons, trace metals, and other pollutants that can affect the quality of storm water runoff. Common activities at maintenance shops that generate this waste include the cleaning of parts, changing of vehicle fluids, and replacement and repair of equipment. Since the number of car owners who perform their own automobile maintenance has dropped steadily in recent decades, automobile maintenance facilities have become the main target for outreach and training of maintenance practices that control pollutants and reduce storm water impacts.

  Automobile maintenance and the training of automobile maintenance facility employees were discussed in Section 4.2.4. The evaluation screening process resulting in the training of businesses involved in automobile maintenance being a recommended control measure was discussed in Section 6.2.3.

- **Implement a car wash outreach program devoted to providing materials to charity car wash organizers**

  Car wash outreach programs would provide materials to charity car wash organizers to prevent car wash water from entering storm drains. These “water friendly" car wash kits would be provided free of charge to charity organizers along with training and educational videos on planning an environmentally friendly car wash. A vacuum/boom device known as a Bubble Buster would be available for charity groups to borrow. This device captures wash water runoff, allowing it to be pumped to either a sanitary sewer for treatment or a vegetative area for filtering absorption into the ground. The purchase of wash water containment equipment for charity car washes is often a one-time expense and can be used for a number of years.

Car washing is a common routine for residents and a popular way for organizations such as scout troops, schools, and sports teams to raise funds. Outdoor car washing has potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions, as the detergent-rich water used to wash automobiles flows down the street and into storm drains. Providing materials to charity car wash organizers should be an effective practice to reduce this non-point source pollution.

Car washing and car wash outreach programs were discussed in Section 4.2.5. The screening process resulting in a car wash outreach program being a recommended control measure was discussed in Section 6.2.4.

- **Implement an animal waste collection program to educate residents on how and why dog waste can be a water quality problem.**

An animal waste collection program uses awareness, education, and signs to alert residents as to proper disposal techniques for pet droppings. Brochures and public service announcements will describe proper pet waste disposal techniques and try to create a storm drain water quality link between pet waste and runoff. Often pet waste messages are incorporated into a larger non-point source message relaying the effects of pollution on local water quality. Signs in public parks and along residential streets, and the provision of receptacles for pet waste, would also encourage cleanup.

Animal waste represents a significant source of bacterial contamination in the Peruque Creek watershed. The presence of pet waste in storm water runoff has a number of implications on stream water quality with perhaps the greatest impact from fecal bacteria. The bacteria can pose health risks to humans and other animals, and result in the spread of disease. Public education programs are an effective way to encourage pet waste removal.

Animal waste collection programs were discussed in Section 4.2.6. The screening process resulting in an animal waste collection program being a recommended alternative control measure was discussed in Section 6.2.5.

7.3.2 Other Alternatives to Consider

- **Provide training for employees of lawn and garden centers regarding lawn care and pollution control.**

  Convincing watershed residents that a nice green lawn can be achieved without using large amounts of chemicals and fertilizers can be challenging when conventional lawn care techniques are often seen as more effective, less-time consuming, and more convenient. Since product labels and store attendants are the primary and almost exclusive source of lawn care information for the average consumer, the strategy toward implementing a lawn care pollution control program is to encourage the substitution of watershed friendly products for those that are not, and to offer training for the store attendants to pass on to consumers at the point of sale on how to use, and perhaps more importantly, how not to abuse or overuse such products.

  Chemicals associated with fertilizers, weed controls, and insecticides can find their ways to streams and the application of these chemicals can affect the water quality of receiving streams. Educating residents on methods to reduce fertilizer and pesticide application and limit water use can help alleviate the potential impacts of this contributor of non-point source pollution in the watershed communities.

  Landscaping and lawn care pollution control and the training of lawn care and garden center employees was discussed in Section 4.2.3. The screening process resulting in the training of lawn care and garden center employees being an alternative measure to consider was discussed in Section 6.2.2.

- **Implement an education program to instruct those involved in the lawn care industry on the water quality impacts associated with lawn care products.**

  Lawn care industry educational programs would address alternate methods to reduce fertilizer, weed control, and pesticide application and limit water use. Local governments and watershed consumers that want to influence lawn care industries would be encouraged to create an active program that supports those companies that employ "environmentally friendly" techniques that limit fertilizer and pesticide application by providing promotional opportunities.

  Nutrient and chemical runoff from managed lawns can contribute pollutants that contaminate storm water runoff into watershed streams and are toxic to both humans and aquatic organisms. Those who have lawn care services have shown to have the greatest tendency to over-fertilize their lawns. As a result, implementing an educational program to instruct those involved in the lawn care industry on the water quality impacts associated with lawn care products is an alternative to consider.

Landscaping and lawn care pollution control and educating those involved in the lawn care industry were discussed in Section 4.2.3. The screening process resulting in this measure being an alternative to consider was discussed in Section 6.2.2.

- **Provide automobile maintenance educational materials to watershed residents who perform their own vehicle maintenance.**

  Materials such as flyers and brochures would be distributed to educate the general public on the potential water quality impacts of automobile maintenance. These outreach materials would inform residents who perform their own vehicle maintenance that automobile maintenance has the potential to result in significant loads of hydrocarbons, trace metals, and other pollutants. Educational materials would encourage management practices such as the proper cleaning of parts, changing of vehicle fluids, replacement and repair of equipment, proper waste disposal, etc.

  A "backyard mechanic" who simply dumps spent automotive fluids down a storm drain can cause major water quality problem, since only a few quarts of oil or a few gallons of antifreeze can have a major impact on streams and wetlands during low flow conditions. As a result, education programs targeted toward watershed residents who perform their own automobile maintenance should be an alternative to consider. However, since the advent of the $20 oil change special, the number of car owners who change their own oil or antifreeze anymore may be minimal thus limiting the potential effectiveness of this control measure.

  Automobile maintenance and educating residents on automobile maintenance pollution control was discussed in Section 4.2.4. The screening process resulting in this measure being an alternative to consider was discussed in Section 6.2.3.

- **Provide car washing educational materials to watershed residents.**

  This pollution management measure involves educating the general public on the water quality impacts from outdoor washing of automobiles and how to avoid allowing polluted wash water to enter the storm drain system. Materials such as flyers and brochures would be distributed to educate the general public on the water quality impacts associated with this behavior.

  Outdoor car washing has potential to result in high loads of nutrients, metals, and hydrocarbons during dry weather conditions, as the detergent-rich water used to wash automobiles flows down the street and into storm drains. As a result, implementing a program to educate watershed residents on the impacts of the outdoor washing of automobiles should be an alternative to consider. However, car washing can be a difficult watershed behavior to change since it is often hard to define better alternatives and the pollutant loading associated with this activity may not be as significant as other non-point sources.

Car washing and educating watershed residents on car washing pollution control was discussed in Section 4.2.5. The screening process resulting in this measure being an alternative to consider was discussed in Section 6.2.4.

- **Implement a vegetation control program to educate residents that clippings carried into the storm water system and receiving streams can degrade water quality**

  Public education on vegetation controls would include properly collecting and disposing of clippings, cutting techniques, and leaving existing vegetation. Residents would be encouraged to set their mowing heights as high as possible, leave their clippings on the lawn to provide nutrients and moisture, and preserve existing vegetation. Distributing informative brochures to the residents of the Peruque Creek watershed is the most common approach to educating the public on these vegetation controls.

  Traditional lawn care practices call for raking and removing clippings, which were thought to promote thatch and disease. In fact, leaving clippings on the lawn has proven to be beneficial as they provide nutrients and moisture. As a result, implementing a program to educate watershed residents on vegetation controls should be an alternative to consider. However, the reluctance of many residents to change their conventional vegetation control techniques presents a limitation toward implementing this alternative.

  Vegetation controls were discussed in Section 4.2.8. The screening process resulting in this measure being an alternative to consider was discussed in Section 6.2.6.

- **Implement a public education program that encourages residents to convert managed turf and landscaped areas to native vegetation.**

  Community awareness through brochures, programs, seminars, and field trips would be arranged to emphasize the importance of natural areas. Citizens would learn to realize the beauty of a natural setting if exposed to one on a regular basis. Alternative landscaping and the introduction of new vegetation can be a workable goal by also encouraging volunteer community groups to plant native vegetation in public areas such as parklands.

  Trees, shrubs, and other vegetation are a watershed priority as they transpire rainfall through their leaves; consume carbon dioxide, release oxygen, and moderate urban temperatures. As a result, existing vegetation should be left in place and new vegetation should be introduced. Most residential lawns have areas that are not suited for grass growth and require a disproportionate amount of water, fertilizers, and care. Converting these areas to less intensive plantings can be an effective strategy for reducing lawn inputs. Existing flowerbeds or groupings of trees and shrubs can be expanded, or groundcovers can be used to replace grass. Other options include mimicking native plant communities such as forests, meadows, and wetlands and converting lawn areas into mulched landscaping beds.

Converting managed turf and landscaped areas to native vegetation was discussed in Section 4.2.8. The screening process that resulted in this measure being an alternative measure to consider was discussed in Section 6.2.6.

7.4 Non-Structural Municipal Measures

Municipal management programs typically relate to maintaining the existing municipal infrastructure. Storm water runoff, deicing salts, and the impacts of watershed urbanization among others all can be managed by the municipalities within a watershed. This section will address the recommended non-structural municipal measures to implement within the Peruque Creek watershed. It must be understood that the measures documented in this watershed management plan are recommendations. Watershed stakeholders, like the PCWA and the municipalities located within the watershed, will need to carefully review this document and associated recommendations, make any needed revisions, and adopt the finalized plan as a comprehensive guidebook for improving the Peruque Creek watershed.

7.4.1 Recommended Alternatives

- I**mprove upon the existing maintenance of storm inlets within the watershed communities.**

  Proactive inspection and maintenance of storm inlets in separate systems includes checking the quantities of trapped gravel and sediment and removal of sediment using a vacuum truck.

  The proper inspection and maintenance of storm inlets are important municipal management measures that can improve water quality within the watershed. Storm inlets can act as accumulation points for many of the most critical non-point source pollutants within a watershed. A fast flash of runoff from a storm event can detach, mobilize, and transport these substances directly to surface waters. As a result, it is important for municipalities to regularly engage in cleaning storm drain structures.

  The proper inspection and maintenance of storm inlets was discussed in Section 4.3.1. The screening process resulting in this alternative being a recommended control measure was discussed in Section 6.3.2.

- **Implement a household hazardous waste (HHW) collection program to collect and properly dispose of HHW products.**

  HHWs are wastes produced in households that are hazardous in nature, but are not regulated as hazardous waste, under federal and state laws. HHW collection programs would help to ensure that these wastes are recycled, disposed, or otherwise managed in an environmentally preferable way. Such municipal programs would provide sites for residents to drop of their hazardous materials. The materials would then be reused, recycled, and, when necessary, disposed of at a permitted hazardous waste facility.

Hazardous waste products, if carelessly managed can, and frequently do, create environmental and public health hazards. Improper disposal of HHW in Peruque Creek can affect stream water quality as wastes may be improperly discarded into municipal storm inlets and catch basins or dumped down sewer drains during storm events. HHW collection can be expected to reduce the presence of toxic materials and heavy metals in storm water runoff.

A more detailed description of HHW collection programs can be found in Section 4.3.4. The evaluation and screening process resulting in HHW collection programs being a recommended alternative control measure was discussed in Section 6.3.4.

- **Implement an integrated pest management (IPM) program as a way to introduce alternatives to chemical pesticides and herbicides on public lands.**

  An IPM program is a municipal watershed management tool that encourages the use of alternatives to chemical pesticides on public land. IPM reflects a holistic approach to pest control with the goal not to eliminate pests but to manage them to an acceptable level while avoiding disruptions to the environment. An effective IPM program incorporates practices in combination with non-chemical and chemical pest controls to minimize the use of pesticides and promote natural control of pest species. The IPM practices should be encouraged for municipal parklands and schools to limit pollutants washed off the ground during storm events.

  The presence of pesticides and herbicides in storm water runoff has a direct impact on the health of aquatic organisms and can present a threat to humans through contamination of drinking water supplies. The pesticides of greatest concern are insecticides, such as diazinon and chloropyrifos, and can be harmful to aquatic life even at very low levels. The major sources of pesticides in urban streams are applications of products designed to kill insects and weeds.

  Implementing the IPM approach toward pest control on public lands was discussed in Section 4.3.5. The evaluation and screening process resulting in this alternative being a recommended control measure was discussed in Section 6.3.5.

- **Train municipal employees in improved deicing application techniques, the timing of deicer application, and on the types of deicers to apply to public roads.**

Municipal employees would be trained on improved storage, handling, and application practices of deicing materials. For example, by routinely calibrating spreaders, a program manager can prevent over-application of deicing materials. Also, different techniques can be employed at each stage of the snowmelt sequence, so as to effectively address the constantly changing flows and pollutant concentrations that occur as snowmelt progresses. In addition, municipal officials and employees would be encouraged to explore the use of alternative de-icing materials to road salt such as calcium magnesium acetate (CMA).

The use of road salt is a public safety as well as a water quality issue. Aside from contaminating surface and groundwater, high levels of sodium chloride from road salt can kill roadside vegetation, impair aquatic ecosystems, and corrode infrastructure such as bridges, roads, and storm water management devices.

A more detailed description of improved deicing techniques and alternatives can be found in Section 4.3.6. The evaluation and screening process resulting in this being a recommended alternative control measure was discussed in Section 6.3.6.

7.4.2 Other Alternatives to Consider

- **Pass and enforce pet waste ordinances to regulate pet waste cleanup within the watershed.**

These "pooper-scooper" ordinances would require the removal and proper disposal of pet waste from public areas and other people's property before the dog owner leaves the immediate area. A fine would be associated with failure to perform this act as a way to encourage compliance. Pet waste produces three primary pollutants: nutrients, organic matter, and pathogens. The presence of pet waste in storm water runoff has a number of implications for urban stream water quality with perhaps the greatest impact from fecal bacteria. The bacteria pose potential health risks to humans and other animals, and can result in the spread of disease. As a result, passing and enforcing pet waste ordinances should be an alternative to consider.

Passing an ordinance to regulate pet waste cleanup would be relatively easy and carries with it virtually no cost. Enforcing proper pet waste management can be challenging and would more than likely require a full-time municipal employee to patrol dog walking areas. As a result, this alternative should be considered but may not be the most effective approach toward proper pet waste management considering the cost associated with the enforcement of the ordinance.

Passing and enforcing pet waste ordinances was discussed in Section 4.3.3. The screening process resulting in this alternative being a control measure to consider was discussed in Section 6.3.3.

- **Incorporate mechanical vegetation controls to actively manage and control vegetation as part of routine operations and maintenance for public works crews.**

  Mechanical vegetation controls include elements such as properly collecting and disposing of clippings, cutting techniques, leaving existing vegetation, etc. Implementing these controls involves the training of municipal employees on proper vegetation control and the possible upgrading of certain mowing equipment for bagging. Since municipal parklands are currently cared for anyway, staffing is usually already in place and alteration of current practices should be relatively easy to implement. Implementing these controls could even be taken one step further and encouraged at schools and cemeteries by educating the grounds crews at these facilities.

  Grass clippings carried into the storm water system and receiving streams can degrade water quality in several ways. Suspended solids can increase causing turbidity problems. Since most of the constituents are organic, the biological oxygen demand can increase causing a lowering of the available oxygen to plant and animal life. Also, clippings and cuttings are almost exclusively leaf and woody material but litter may be intermingled with clippings. Any reduction of clippings carried into the storm water system or receiving streams can reduce the degradation of water quality. As a result, incorporating mechanical vegetation controls should be an alternative to consider. However, the effective of implementing this control may be small when compared to other alternative measures considering the relatively small number of parklands, schools, and cemeteries within the watershed.

  Vegetation controls were discussed in Section 4.3.7. The evaluation and screening process resulting in this alternative being a control measure to consider was discussed in Section 6.3.7.

7.5 Structural Control Measures

A comprehensive watershed management plan often requires certain structural control measures to be implemented, along with non-structural controls. A wide range of structural source control measures are available to address problems related to urban runoff. Other structural management measures focus on minimizing the impacts of extraneous flow in sewer collection systems. Structural stream restoration measures focus on correcting the negative impacts of watershed urbanization along watershed streams. This section will address the recommended structural measures to implement within the Peruque Creek watershed. Watershed stakeholders, like the PCWA and the municipalities located within the watershed, will need to carefully review this document and associated recommendations, make any needed revisions, and adopt the finalized plan as a comprehensive guidebook for improving the Peruque Creek watershed.

7.5.1 Recommended Alternatives

- **Reduce the quantity of impervious pavement within public parking areas, residential lots, and street rights-of-way, whenever pavement is deteriorated and scheduled to be resurfaced or reconstructed.**

  Whenever an existing parking area is scheduled to be repaved, business owners should look for opportunities to reduce the number of parking spaces, eliminate unnecessary pavement in non-traffic areas, and covered areas into landscape islands. Homeowners should look for similar opportunities to narrow driveway widths, eliminate unnecessary paved areas, and convert them to landscaping. Municipalities would have similar opportunities to narrow street and sidewalk widths. Municipalities should evaluate current traffic volumes, the need for on-street parking on both sides of the street, and corresponding street widths whenever existing streets are scheduled to be reconstructed.

  Roads, driveways and parking areas represent a significant portion of the total impervious area within the Peruque Creek watershed. This demonstrates that significant opportunities exist to reduce the quantity of impervious cover urban storm water runoff, and associated pollutant loads. Unnecessary impervious pavement areas can be converted to landscaping areas that allow storm water to percolate into the soil.

  Reconfiguring existing paved surfaces to reduce impervious area in the Peruque Creek watershed was discussed in Section 5.1.1. The evaluation and screening process resulting in pavement reconfiguration being a recommended structural control measure was discussed in Section 6.4.1.

- **Modify existing storm inlets so that street litter and floatable debris is trapped and prevented from being discharged into watershed streams.**

  Street litter and floatable debris that enter watershed streams can have a negative impact on water and aesthetic quality, and lead to degradation of the stream. Existing storm inlets within the watershed should be modified to trap these floatable materials. The trapped material would then be removed by municipal cleaning crews rather than being discharged into streams. Devices of various designs are available which detain sediment laden runoff and floatable materials within the structure or prevent them from entering a storm inlet.

  Modifying existing storm inlets to increase the capture of sediments and floatable materials is an effective structural management measure. The City of Lake Saint Louis, particularly in the areas surrounding Lake Saint Louis should implement a program to capture floatables from street runoff prior to discharge of stormwater into the lake.

  Alternative structural modifications to existing storm inlets were described in Section 5.2. The evaluation and screening process resulting in these structural modifications being a recommended control measure were discussed in Section 6.4.2.

- **Construct new wetland areas within the riparian corridors of Peruque Creek to filter urban pollutants and act as "watershed sponges" to store storm water and augment dry weather stream flow.**

  Storm water wetlands should be constructed within the watershed as regional facilities. Constructed wetlands are effective pollution control measures because they remove pollutants from urban runoff through vegetation uptake, retention and settling. Constructed wetlands increase wildlife habitat while decreasing the stream gradient and creating slow flow areas to regulate storm flow. The extra wetland flood plain storage capacity and slower flow-through rates will also reduce bank erosion and increase the variability of stream morphology.

  There are several areas within the upper portions of the watershed that could be managed as wetland areas. The channel just upstream of the Highway 40 bridge crossing, up to Dunello Road would be a prime candidate site for wetland expansion and modification to address stormwater flow into Lake Saint Louis. The site could also serve, if configured properly, as a place to reduce the number of large floatable items (e.g. trees, branches, logs) from entering into Lake Saint Louis.

  The use of constructed wetlands as a structural watershed management measure was discussed in Section 5.3.3. The evaluation and screening process resulting in wetland construction being a recommended structural management measure is discussed in Section 6.4.3.

- **Stabilize existing stream channels, channel banks and over-banks using naturalistic "green engineering" techniques to restore existing eroded areas and prevent future erosion and scour.**

  Structural stream restoration measures should be used to remediate the negative impacts of watershed urbanization along the Peruque Creek channel. In-stream stabilization measures such as log vales, root wads, root vanes, boulder backs and step pools will be constructed at selected locations along Peruque Creek. These measures will control erosion, stabilize slopes, control stream gradients, create flow diversity and provide aquatic habitat.

  There are several locations along Peruque Creek where the existing stream channel, channel banks and over-banks are unstable and are being eroded away during periods of peak storm flow. This includes the drainage along Hepperman Road, where the drain pipe flow is eroding the channel before it reaches Peruque Creek. Although restoration of this channel can be accomplished, it still will not stop the heavy stormwater flows that come down the road and enter the pipe. Streambank restoration in conjunction with stormwater management would be more applicable in those areas where restoration efforts along will not protect habitat or water quality.

Detailed descriptions and color images of alternative structural measures used to stabilize stream channels are provided in Section 5.4. The evaluation and screening process resulting in stream stabilization being selected as a recommended structural control tool is described in Section 6.4.4.

- **Reconfigure existing stream channels and reconnect them to their adjacent flood plains using sound fluvial geomorphological principles.**

Portions of the Peruque Creek stream channel have become incised, confining storm flow to the channel instead of allowing it to spread out over adjacent flood plains. Reconfiguring the size, shape, and configuration of the stream will reconnect the channel to its over-banks and restore natural connectivity to adjacent flood plains. Fluvial geomorphology is the science that assesses the shape and form of a watercourse and the contributing physical processes.

Portions of the stream channel of Peruque Creek has been significantly impacted and degraded by urbanization within the watershed. The stream channel has been gouged deeper, wider, due to the intense and flashy nature of urban runoff. Increasing the size of the channel and floodplain could help address the increase flows that result from extreme wet-weather events. However, land owner issues may prevent the acquisition and restoration of the stream channel. Preventive measures that eliminate or reduce the cause of channel incision (e.g. increased flows from stormwater runoff) should be evaluated first.

The reconfiguration of the existing stream channel to restore the connection to adjacent flood plain areas was described in Section 5.3 and 6.4.4. The evaluation and screening process resulting in this structural control measure being recommended for the watershed management plan is described in Section 6.4.4.

7.5.2 Other Alternatives to Consider

- **Encourage the use of porous pavement materials in lieu of traditional asphalt and concrete within public parking areas and residential properties.**

Permeable pavements can be used to reduce the imperviousness created by patios, walkways, driveways, sidewalks, and parking areas. These alternative paving systems can reduce surface runoff, increase infiltration, and improve groundwater recharge characteristics.

Existing concrete or asphalt paving surfaces in the watershed already have or will in the future deteriorate and will need to be replaced. Opportunities exist to encourage the use of porous pavement and this structural alternative is a potentially effective tool to consider. However, permeable paving systems are prone to clogging by suspended solids, construction costs tend to be higher than traditional pavement systems, and property owners may be hesitant to use the new technology.

The use of porous pavement for redevelopment projects was discussed in Section 5.1.2. The screening process resulting in this measure being an alternative to consider was discussed in Section 6.4.1.

- **Encourage the construction of tanks or cisterns for existing residential, commercial, and public buildings to capture and store runoff and irrigate vegetated areas.**

  Rainwater harvesting - capturing and storing rainwater for later use - is a key element in storm water management. Diverting rooftop runoff into storage tanks utilizes rain to its fullest potential. Water harvesting can range from the simple to the complex, depending on need and budget. Water harvesting can be incorporated into plans for building a new home, designing a major subdivision, or restorative redevelopment efforts. Rainwater harvesting not only helps reduce the quantity of urban runoff, but also decreases the community's dependence on public water supplies to irrigate plants.

  The use of tanks or cisterns to capture runoff for redevelopment projects was discussed in Section 5.1.4. The screening process resulting in this measure being an alternative to consider was discussed in Section 6.4.1.

Section 8
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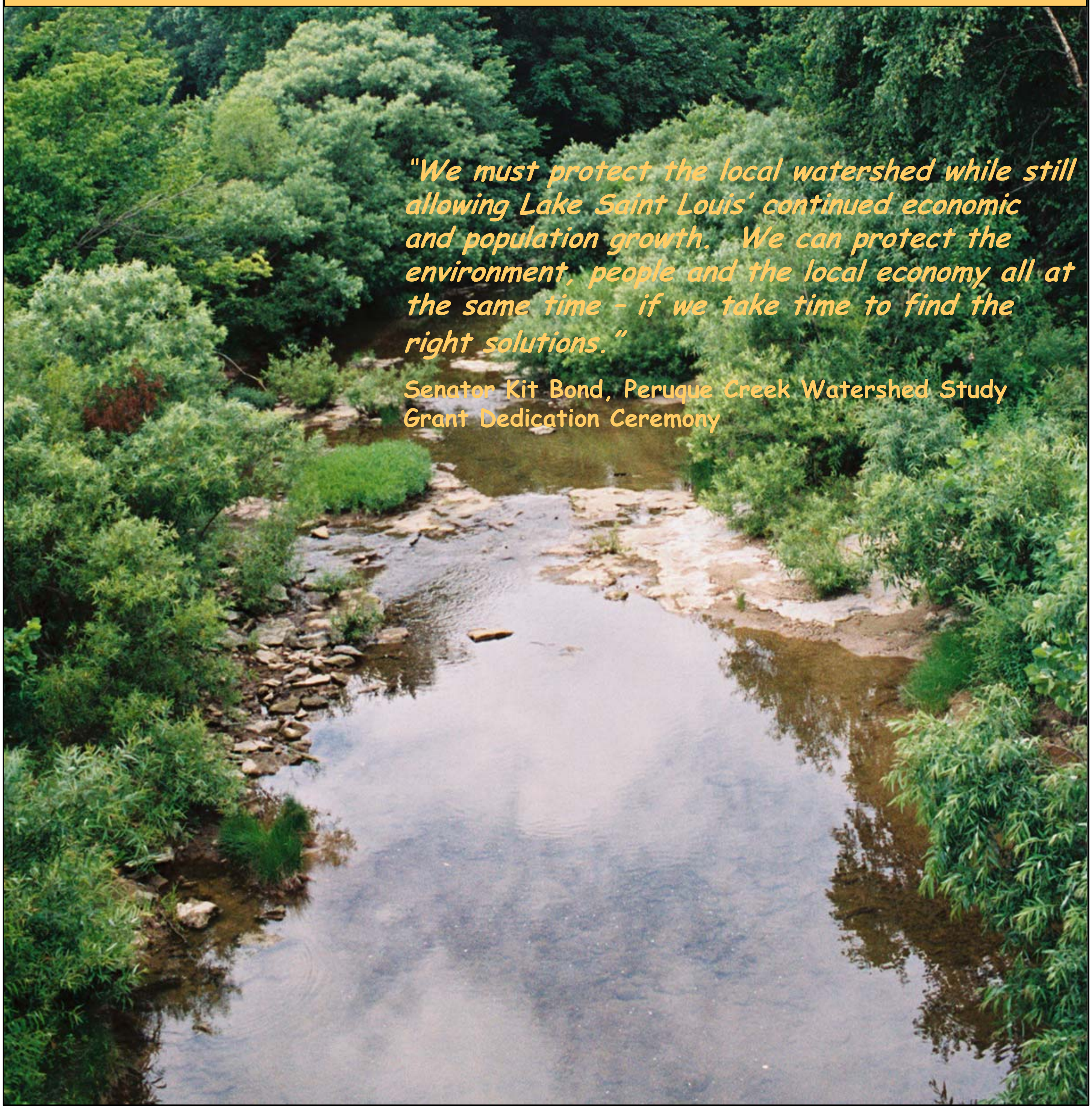
PERUQUE CREEK WATERSHED SOURCEBOOK

St. Charles County and Warren County, Missouri

December 2004



In Memoriam

Ken Maki, Project Director for the Lake Saint Louis Peruque Creek Watershed Study recently passed away in 2003. He will be deeply missed by his family, friends and all of us who have worked with him on this project. Let's remember Ken and his outstanding contribution to his community and Peruque Creek.

Prepared by:
The City of Lake Saint Louis, Missouri, for the citizens of Peruque Creek Watershed.

Project funding by:
US Environmental Protection Agency
Region VII
901 North Fifth Street
Kansas City, KS 66101
Grant number XP-9872201-0

Table of Contents

History of Peruque Creek[1]

Peruque Creek was settled in 1797 by the Zumwalt family, who built a home and sawmill from logs hewn along the creek. Later in 1816, James Audrain moved his family to Missouri and settled on Peruque Creek, where he built a sawmill and distillery. Colonel Audrain and his wife were baptized in Peruque Creek.

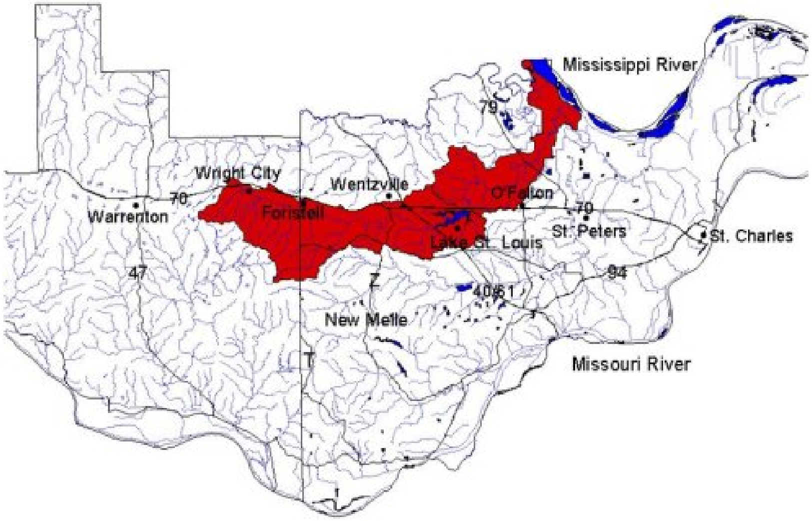
Jacob Zumwalt's old homestead came to be known as Fort Zumwalt. Two families occupied the homestead for nearly ninety years.

Other farmers moved into the area, then small businesses emerged. For over 100 years the area was mainly agricultural. It was not until the past fifty years that the population boom occurred in St. Charles and Warren counties.

Nowadays, the Peruque Creek Watershed drains portions of the municipalities of Wright City, Foristell, Wentzville, Lake Saint Louis, and O'Fallon as well as unincorporated areas of St. Charles and Warren counties. The drainage basin is typical of a watershed under development and has a variety of urban and rural features.

A watershed is a geographical area defined by topography such that all tributaries and streams drain in this area. The Peruque Creek watershed is used in many ways. There is still much farmland and forest land in the watershed. In addition, the watershed has been highly developed into subdivisions, roads and highways, shopping areas and even some industry. Each type of land use can impact the quality of the water in the creek and lake. The roads, buildings and parking lots cover the land surfaces. The vast amount of hard surfaces covering the land cause rain water to runoff into Peruque Creek at a rapid rate and in large volume.

Map of the Peruque Creek Watershed



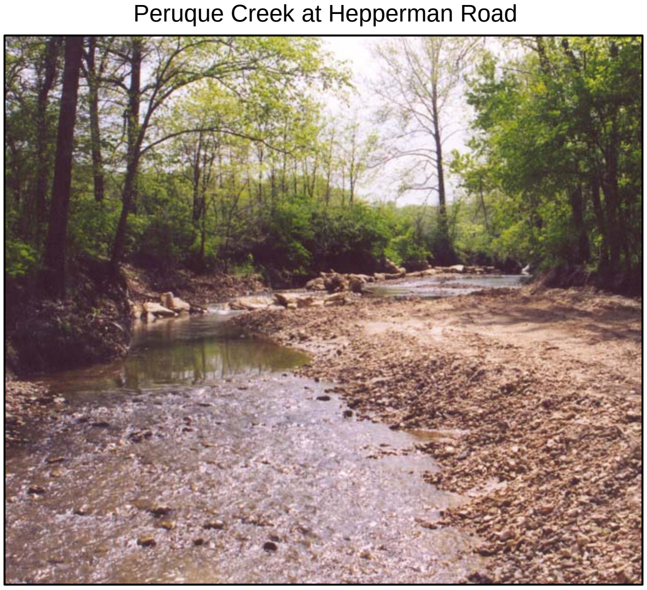
1. This section is adapted from the Draft Peruque Creek Watershed Plan (Peruque Creek Watershed Alliance, 2002)

Peruque Creek Watershed Study Project

The EPA issued a grant to the City of Lake Saint Louis to conduct a study of the Peruque Creek Watershed. The study was tasked to outline a proposed approach to restoring and protecting water quality in Peruque Creek, while sustaining economic development within the watershed.

Kids Playing at Peruque Creek near Duello Road Bridge

Peruque Creek at Hepperman Road



Sam's Creek (a tributary to Peruque Creek)

The Peruque Creek Watershed is a small water resource region with numerous water uses. There are many objectives for improving environmental and economic conditions along the creek and its tributaries.

The watershed management action plan is the result of the study. It is a comprehensive action plan that addresses all of the many objectives throughout the basin. The plan is based upon a sound, scientific assessment of the relationships among numerous water and land use resources within the watershed. The plan identifies appropriate measures that can be implemented in the Peruque Creek watershed to restore and maintain water quality to protect the stream's designated uses. This handout provides a summary of the problems occurring in the Peruque Creek watershed and what you can do to help improve the watershed.

Problems in the Peruque Creek Watershed

Some sampling of Peruque Creek and Lake Saint Louis water has already been completed. The results of the sampling show several serious pollutants exceed water quality standards. Heavy rains increase pollutants in the creek and in the lake. Based upon historical water quality data, the Missouri Department of Natural Resources (MDNR) has placed Peruque Creek on the state's 303d list for sediment.

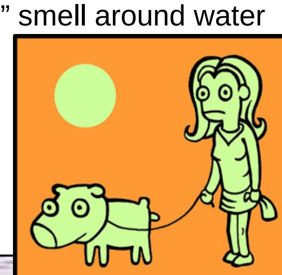
Peruque Creek at Duello Road

Lake Saint Louis

Sedimentation (soil and sand) is the main source of water quality degradation. Soil, sand and other solids flow into the creek and lake when it rains. Sediment harms fish and bottom dwelling organisms. It also reduces water clarity.

Nitrogen and Phosphorous from fertilizers contribute to high levels of nutrients in the creek and lake. These nutrients entering the water result in algal blooms in Lake Saint Louis. When huge amounts of algae grow, it reduces the amount of dissolved oxygen for fish and other water creatures, and creates odor problems in the waterway. The "fishy" smell around water bodies is from algae.

E.coli is a bacteria that is found in the digestive tracts of warm-blooded animals, including humans. *E.coli* can enter a stream by direct discharge from mammals and birds, from livestock runoff, or from open or broken sewers. When water tests positive for *E.coli* there could be harmful pathogens (disease causing organisms) present, and it would be risky to drink it or swim in it.



Stormwater Runoff from farmlands, construction sites, roadways, parking lots, residential and commercial developments contributes to increased flows in Peruque Creek, which contribute to greater erosion of the stream banks and sedimentation to the creek and Lake Saint Louis.

Geese on Lake Saint Louis

Where are the Water Quality Problems Coming From?

- Storm runoff, which increases flows and results in flooding and erosion
- Sediment loading to creek and lake from construction sites during rain storms
- Nutrient loading from wastewater treatment facilities
- Nutrient loading from storm runoff from agricultural lands and residential, and commercial properties
- Runoff from small privately owned animal holding areas
- Harmful bacteria from improperly treated wastewater, leaking septic systems, and wildlife

Clockwise From the Upper Right: Sod Farm, Development, Agriculture, Construction Site, Development, Riparian Corridor, Erosion, Golf Course, and Lake Saint Louis Dam (center picture)

The Peruque Creek Watershed Alliance

Peruque Creek at Point Praire Road

The Peruque Creek Watershed Alliance was formed to help develop recommendations to communities and counties in the watershed. The Alliance works in conjunction with the MDC, NRCS and the SWCD.

Objectives of the Alliance are:

- Lead and ensure success of the Watershed Management Plan
- Reduce flooding impacts to natural levels
- Encourage appropriate agencies to make standard enforcement of existing ordinances a priority
- Develop a watershed district that recommends ordinances supported by all communities, and ensures the health of the watershed
- Maintain and restore ecological balance of the watershed
- Improve water quality
- Make recommendations and maintain best management practices (BMPs) at construction sites
- Recommend methods to control nutrients
- Educate the public on the importance of the watershed
- Educate developers on the importance of maintaining BMPs
- Draw support from environmental agencies and groups

Clockwise from Upper Right: Peruque Creek at Headwaters near Warrenton, Construction Site near Lake Saint Louis, Peruque Creek between Hepperman Road, and Construction at Stone Meadows

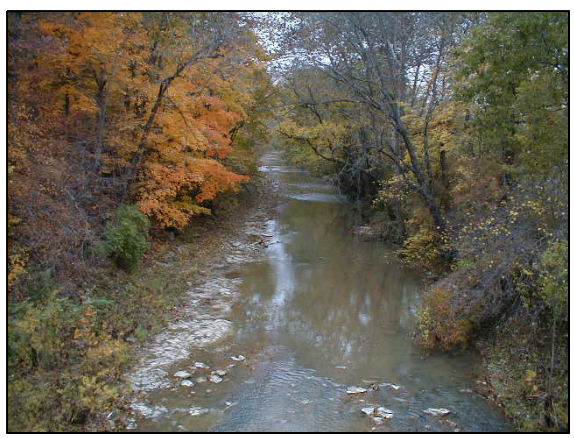
Water Quality Problems Will Be Addressed Through A Watershed Management Action Plan (WMAP) What Is It?

The Watershed Management Action Plan is a roadmap to improving water quality in the Peruque Creek Watershed.

The Watershed Management Action Plan was developed by area residents and stakeholders to protect and enhance water quality in the watershed. The plan makes recommendations for how problems can be corrected to protect the designated uses of Peruque Creek and Lake Saint Louis. The recommendations have been made carefully so that they also provide for long-term growth in the watershed. The Peruque Creek Watershed Management Action Plan will guide those programs and projects to improve watershed health. The plan will recommend corrective actions designed to improve water quality, enhance fish and wildlife habitat, and restore watershed functions. A detailed WMAP report has been prepared and is available on the Peruque Creek website www.peruquecreek.com, the City of Lake Saint Louis and the Saint Charles County Soil and Water Conservation District office. The plan is a detailed analysis of the water quality problems in the watershed.

Specifically, the Watershed Management Action Plan describes in detail the Peruque Creek Watershed Study's assessment of the watershed, and presents solutions to problems. The plan describes:

- Project objectives and goals
- Water quality problems and sources
- Solutions to water quality problems
- Environmental indicators
- Funding options



Peruque Creek at Schaper Road

The assessment described in this plan can be used as a tool to protect full-body contact recreation (swimming) in Lake Saint Louis. It can also be used to protect the warm water aquatic life and livestock watering uses in Peruque Creek.

Recommendations to Achieve Our Goals

1: Improve water quality – nutrient, bacteria and sediment control

2: Reduce flooding impacts in the watershed

3: Reduce excessive flows to the Creek

4: Reduce in-stream erosion in the watershed

5: Maintain erosion controls at construction sites and agricultural lands

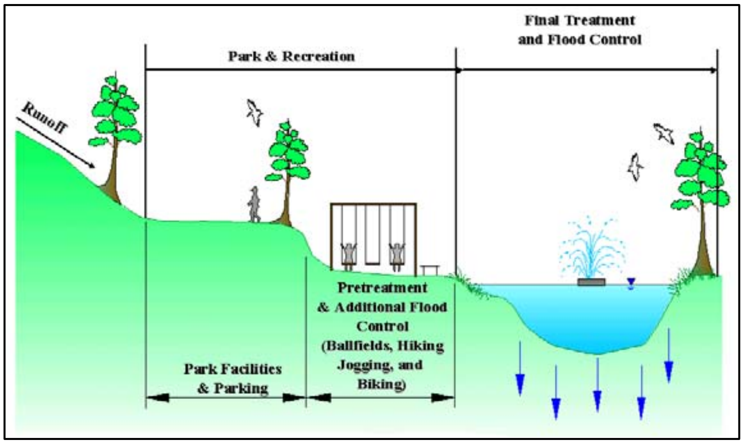
6: Maintain and restore the ecological balance of the watershed

7: Secure funding to promote watershed protection activities and pilot demonstration BMP projects

8: Educate the public and developers on the importance of protecting their watershed

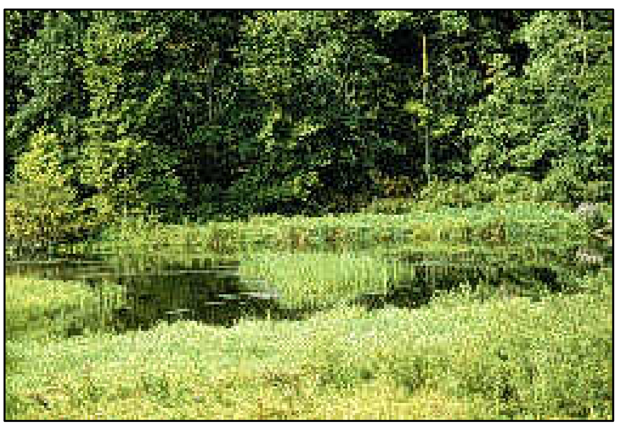
Peruque Creek between Hepperman Road and Point Praire Road

1: Improve Water Quality – Nutrient, Bacteria and Sediment Control



Excess ***Nutrients*** such as nitrogen and phosphorus from golf course and animal waste fertilizers, cause increased algae growth. Too much algae reduces the amount of oxygen in the water. Wetlands can filter as much as 91% of the phosphorus and 86% of the nitrogen. The University of Missouri Extension and the Natural Resource Conservation Service (NRCS) are working closely with local farmers to ensure they are aware on the proper application of fertilizers. Also, residential property and golf course owners in the watershed should be aware that fertilizers and pesticides applied on their lawns can find their way into the lake and creek.

Best Management Practices (BMPs) could reduce the amount of nutrients getting into the waterways. These include engineering solutions such as detention ponds and wetlands, and nonengineering solutions such as educational programs.



Wetland with emergent plants

Sediments (soil and sand) that are suspended in running water can also be removed by wetlands. As the running water enters a wetland, the water slows, and the sediments settle out. Some wetlands can retain as much as 94% of the sediment.

Larger sediments are important because they contain air pockets that aquatic life depend upon to exist. These spaces provide habitat for aquatic organisms to lay their eggs and contribute oxygen that is essential for their survival. Too much fine sediment clogs up the spaces and kills aquatic organisms.

The enforcement of existing BMPs that control erosion and sediment runoff should take high priority of local governmental agencies. A source of funding should be identified to help governmental agencies hire trained staff to deal with the enforcement of sediment and control regulations.

Urban runoff, leaking septic systems, improperly treated wastewater and wildlife can contribute to higher harmful ***Bacteria*** concentrations, such as E. Coli, if not controlled. These high levels of bacteria can restrict people from swimming and recreating in the lake and creek.

The WMAP identifies ways that you can help reduce bacterial loading, such as picking up after your pet, maintaining your septic system and ensuring regulatory agencies enforce water quality discharge permits.

2: Reduce Flooding Impacts in the Watershed

Watershed management includes balancing the community needs for flood protection with the need to protect streams and natural resources. Several land treatment measures cost little to farmers, and some, such as terracing, no till or minimum tillage, may actually benefit farm productivity by improving soil for better crops.

Floods are natural events that are good for some plants or aquatic animals. Floods do much temporary damage when the high water washes away spawning areas and eggs, uproots aquatic plants, and temporarily makes water muddy. But left in the wake of floods may be freshly washed, clean gravels that are good for fish spawning, or new pools and riffles. Most of the plants and animals in floodplain systems have adapted to the stream's flood pulse.

Various factors need to be considered when selecting appropriate methods to reduce flooding. These factors are listed below:

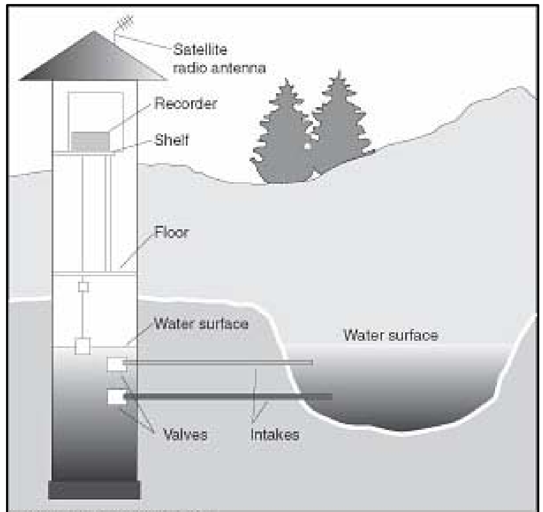
- Reasons that cause flooding in the watershed
- Compounding factors, like high rainfall combined with backwater flow from nearby rivers.
- Maintenance of wide buffer zones along stream to decrease runoff
- Amount of cover crops on farms that reduce overland flow of water to the stream
- Density of trees, shrubbery, and vegetative cover
- Use of terracing, slope stabilization, grass waterways, and contour plowing of farmlands
- Building in the floodplain

Conservation tillage

The primary areas where flooding occurs are in the lower reaches of Peruque Creek, near the Mississippi River. Backwater, which occurs when the Mississippi River level is high, causes flooding. However, the most severe flooding occurs when Peruque Creek levels are high caused by flash flooding. While it is necessary to address the causes of flooding over the long-term, it is also important to correct short term problems. Emergency removal of log jams, stream bank stabilization, and other flow mitigation measures should be implemented.

3: Reduce Excessive Flows to the Creek

The most difficult challenge in the Peruque Creek watershed is controlling runoff during and after a heavy rain. Runoff causes damage to property and aquatic habitat. Communities and natural resource agencies should assess the most cost-effective approaches to reduce runoff in the watershed. Baseline flow data from the creek should be collected by the United States Geological Survey (USGS) gaging stations. To get the best data and for the data to be meaningful, two gaging stations are needed. It is recommended that one would be established near Point Prairie Road, and another at a downstream location below the Lake Saint Louis dam.



(From Wahl and others, 1995)

The USGS may provide some cost sharing support for communities to monitor stream flows in the watershed. The USGS will maintain flow data from these locations, so that groups like the Missouri Stream Team and the Peruque Creek Watershed Alliance can analyze storm water flow data. The groups can then determine whether or not actions taken in the watershed have reduced the trend of increasing frequency, volume and velocity of flood flows.

The forested areas in the upper parts of the Peruque Creek watershed provide critical storage capacity that reduces the effect of rapid runoff on downstream areas. Protecting these natural areas from inappropriate use is essential.

Another way to control excess flow is by constructing water detention ponds in the developed portions of the watershed. Some residential developers have already created water retention ponds in their subdivisions. Buffer zones, areas of vegetation between the creek and disturbed land, can also control excessive flows by slowing the flow of runoff and allowing time for runoff to infiltrate the soil, thus reducing the amount of runoff.

Buffer zone

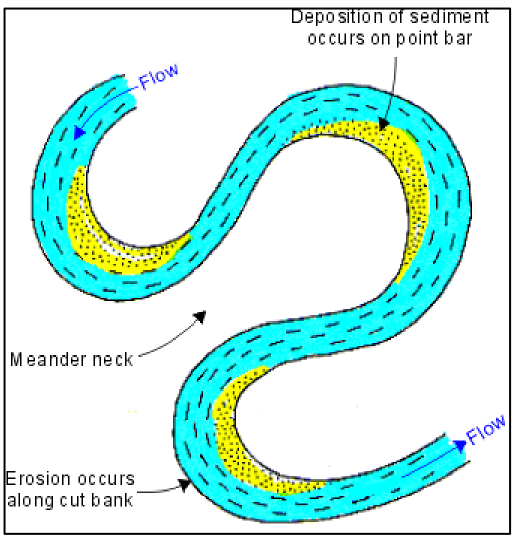
Residential Detention Pond

4: Reduce In-stream Erosion in the Watershed

Stream bank erosion is a natural process that occurs as the stream flows through its channel. Streams naturally erode their banks along the outside of a bend while depositing sediment along the inner bend. The increase in sediments also cause erosion and channelization.

As more hard surfaces, like parking lots, are created in watersheds, the flow changes, routing more runoff to streams and less into the ground. The result is an increase in stream velocity and energy and causing stream bank erosion. Activities that cause stream bank erosion include:

- Developing too close to the creek
- Cattle access to streams, which dislodges soils, destroys vegetation, and weakens soil structure
- Channelization, which increase stream velocity and energy
- Large parking lots and wider streets that drain to the creek, and
- Runoff from rooftops of home and commercial buildings.

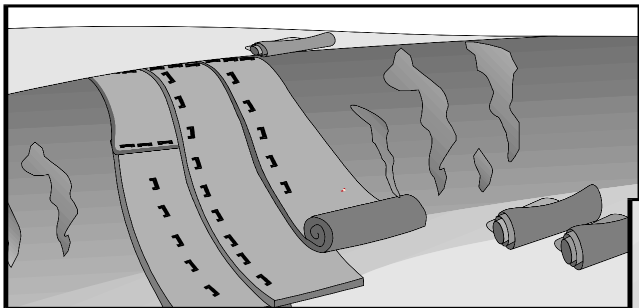


Stabilizing the stream bank to reduce the erosion is the first step in restoring a riparian buffer zone

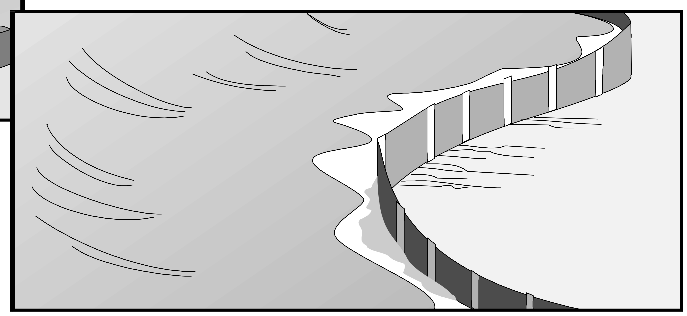
Communities should have sediment and erosion control regulations that protect waterways from land being developed. It is recommended that a standard ordinance with uniform methods of protection, such as silt fencing and hay baling, be incorporated. The cities of Lake Saint Louis and O'Fallon already have Erosion and Sedimentation Control regulations to minimize erosion and sedimentation during land development, building, landscaping, or any other type of land disturbance. Saint Charles County has an ordinance which requires a 50 ft setback along Peruque Creek and a 25 ft setback along any tributaries draining into Peruque Creek. Wentzville has an ordinance such as maintaining a 25 feet setback from the top of an existing bank ---i.e. development, such as parking areas, industrial or commercial improvements, or driveways can only be built 25 ft away from the top of an existing water body . While some sediment and erosion control ordinances are in place, they are only effective if enforced. An additional measure to control erosion is to provide educational materials to watershed residents and developers on the importance of maintaining watercourse buffers and vegetation.

5: Maintain Erosion Controls at Construction Sites and Agricultural Lands

Recommendations for erosion control at construction sites are shown in the illustrations. The controls reduce runoff during heavy rains.

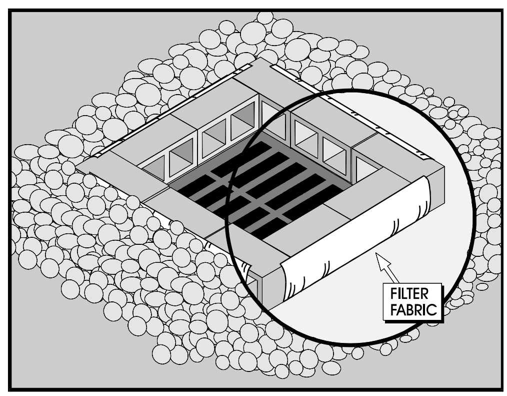


Erosion Control Using Geotextiles stabilize soil with rolled and bound fiber material

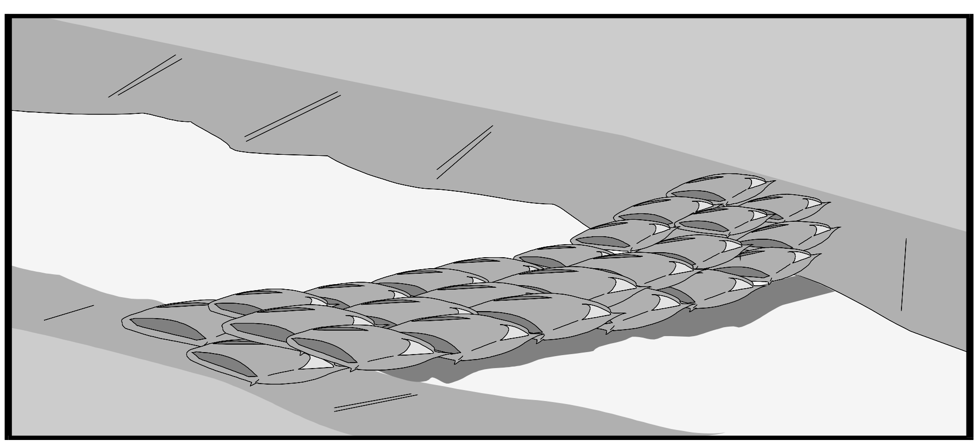


Silt Fence of filter fabric is entrenched, attached to supporting poles and backed by a wire fence to stop the flow of silt.

Temporary Storm Drain Inlets allow the sediment in runoff to settle before being discharged into a storm water inlet.



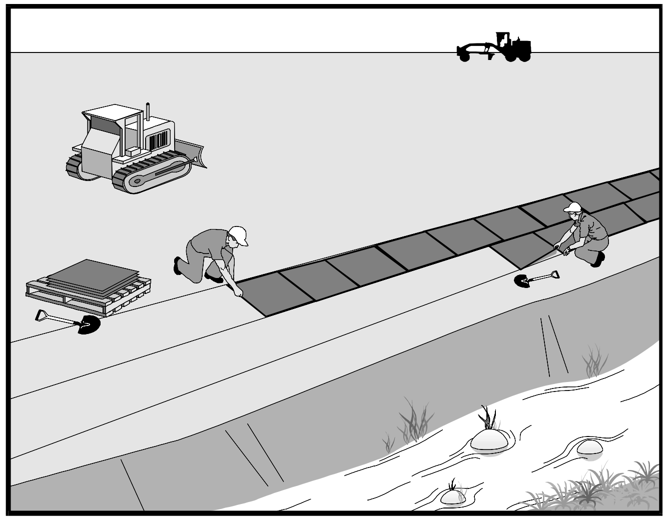
Sand Bag Barriers allow the sediment in runoff to settle before being discharged into a storm water inlet.



For more information refer to Protecting Water Quality: *A Field Guide to Erosion, Sediment and Stormwater Best Management Practices for Development Sites in Missouri and Kansas* (1995), and Illinois Urban Manual (Web Address: http://www.il.nrcs.usda.gov/technical/engineer/urban/index.html)

6: Maintain and Restore the Ecological Balance of the Watershed

When a wetland is constructed, a large percentage of the area is covered by wetland vegetation. This management practice will reduce sediment, nutrients, heavy metals, toxic materials, floatable materials, oxygen demanding substances, oil and grease. The vegetation also partially reduces bacteria and viruses. The water storage provided by wetlands aids in flood control. The creation of wetlands along tributaries (side channels) and Peruque Creek may help control sediment and nutrient loading.



Streambank Stabilization

Willow Stake

Severe erosional areas in the creek should be identified, and appropriate engineering solutions, including streambank stabilization can be integrated to prevent further habitat degradation and sediment loading.

Buffer zones along streams prevent or reduce the discharge of pollutants to the storm drain system or to the creek by using vegetation to protect soils from erosion. Buffers slow the velocity of runoff and remove sediment and other pollutants by filtering and settling. This management practice will create a significant reduction in sediment as well as partial reductions in the impacts from nutrients, heavy metals, toxic materials, floatable materials, oxygen demanding substances, and oil and grease, as well as providing habitat for local plant and animal species.

An example of a buffer zone is a riparian corridor, which is important due to its provision of habitat for wildlife and its ability to limit runoff from entering a water body. Damaged riparian zones can be restored by re-vegetating stream banks with willow plantings or other plants that are typically found along the stream corridor. These plantings should be monitored and maintained on an annual basis.

7: Secure Funding to Promote Watershed Protection Activities and Pilot Demonstration BMP Projects

The Peruque Creek Watershed Alliance, along with the St. Charles County Soil and Water Conservation District, NRCS and Missouri Department of Conservation, are the lead organizations that will work with citizens to help them address watershed problems, obtain funding and initiate pilot demonstration BMP projects.

Much of the funding for watersheds can be obtained through the EPA grants, federal resource agencies, state natural resource agencies and through private funding.

Major Federal and State Grants include:

- **Water Quality Cooperative Agreements-** These EPA grants are provided to help states, Indian tribes, interstate agencies, and other public or nonprofit organizations develop, implement, and demonstrate innovative approaches relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution.

- **Wetland Program Protection Grants-** These EPA grants provide eligible applicants an opportunity to do research projects, investigations, experiments, training, surveys, demonstrations, and studies relating to the causes, effects, extent, prevention, reduction, and elimination of water pollution.

- **Clean Water State Revolving Fund (CWSRF)-**The program also funds a variety of publicly- or privately-owned nonpoint source and estuary management projects. This is a low-interest loan with interest rates at about 2.25%

- **Section 319 Non-point Source Implementation Grants-** Clean Water Act Section 319(h) funds are provided only to state agencies, units of government, or 501c3 organizations, such as MDNR and MDC, to implement their approved on-point source management programs.

- **Environmental Justice Hazardous Substance Small Grants Program-** The purpose of this grant program is to provide financial assistance to affected local community-based organizations to support projects to examine issues related to a community's exposure to multiple environmental harms and risks. Projects must be of a research nature only, i.e., survey, research, collecting and analyzing data which will be used to expand scientific knowledge or understanding of the subject studied.

- **Section 106 Water Pollution Control Program Grants-** Section 106 of the Clean Water Act authorizes the EPA to provide federal assistance to state agencies to establish and implement ongoing water pollution control programs.

- **Missouri Watershed Information Network (MoWIN)-** MoWIN was developed to assist citizens in locating and accessing information relative to Missouri watersheds with the following goals:

1) Increase knowledge about watershed conditions and best management practices

2) Help landowners and interested citizens become aware of their watersheds

3) Impact actions or non-actions on shared natural resources, and

4) Help citizens find information to make informed decisions on natural resource stewardship

The MoWIN website can be reached at the following address: www.outreach.missouri.edu/Mowin

Additional opportunities for grant funding can be obtained through other federal agencies such as: The U.S. Army Corps of Engineers: Continuing Authorities Program (Website--http://www.mvk.usace.army.mil/Offices/pp/Projects/Small_Projects_Program/basics.htm), USEPA (Website: http://cfpub.epa.gov/fedfund/) U.S.D.A Forest Service (Website: USDA Forest Service Website: http://www.fs.fed.us/r6/coop/programs/rca/economic.htm), and private institutions. Grant funding is usually conducted through a government agency or non-government agency (NGO) such as the Peruque Creek Watershed Alliance.

8: Educate the Public and Developers on the Importance of Protecting Their Watershed

The goal of the public education program is to teach the public and developers how they can protect their watershed. The public education program will be administered by the St. Charles County Soil and Water Conservation District, Peruque Creek Watershed Alliance, Greenway Network, MDC and MDNR. The St. Charles County Soil and Water Conservation District, Peruque Creek Watershed Alliance, and MDC have created Fact Sheets that cover the following areas:

- Land disturbance
- In-stream erosion
- Fecal and nutrient pollution
- Flooding
- Stream corridor protection, and
- General watershed planning concepts

These Fact Sheets were created as an educational tool for the public and others to help them with decision-making about land use activities in the watershed.

Public awareness can also include:

- Encouraging people to report water quality and ordinance violations to authorities
- Conducting Stream Cleanup Days to encourage citizens to take ownership of their watershed
- Educating people about the availability, location and requirements of facilities for the disposal or drop-off of household hazardous waste, travel trailer sanitary wastes, chemicals, grass clippings, leaf litter, animal wastes, and motor vehicle fluids
- Educating landowners about acceptable application and disposal of pesticides and fertilizers
- Educating citizens about preferred cleaning materials and procedures for residential car washing
- Educating citizens and developers about the ultimate discharge point and potential impacts from the separate storm water drainage systems from homes
- Educating people about their responsibility and stewardship in their watershed
- Educating the public and developers about management of buffer zones to protect water quality.

These fact sheets are available from the Alliance through the Peruque Creek website www.peruquecreek.com and in hard copy from the Saint Charles County Soil and Water Conservation District.

Volunteer Programs Help Peruque Creek and Lake Saint Louis

Many volunteers are needed to put the recommendations into action. Fixing the problems in Peruque Creek and protecting it in the future is the unique responsibility of citizens who live in the watershed. It is the local people who are directly affected by the health of Peruque Creek. There are many ways people can contribute, and a list of suggestions is on the back page of this report.

One of the suggestions is to join or start a Stream Team.The Missouri Stream Team Program was created to help local citizens protect their rivers and streams.This program offers ideas, training and support in stream (creeks, rivers and lakes) restoration and protection. Another goal of Stream Teams is to stop degredation of creeks. Teams provide an opportunity for all people to get involved.

Some things that a stream team can do are:

- Litter pick-up/control
- Streamside tree planting
- Storm drain stenciling
- Water quality monitoring
- Streambank stabilization
- Stream advocacy (speaking up for a stream when it is threatened by harmful activities)

The Peruque Creek watershed has several Stream Teams. Among other activities, these teams gather water quality data, organize litter pick-ups and work with businesses along the creek.

Upper Picture: Operation Clean Stream on Peruque Creek, 2003; Lower Picture: Peruque Creek Stream Team Workshop

In March 2003, Stream Team Coordinators conducted a workshop to train volunteers to collect water samples from Peruque Creek and Lake Saint Louis. After the training, Peruque Creek Day was held with everybody collecting water samples up and down the creek for a snapshot of the whole creek.

For information on how to join the Peruque Creek Stream Team, or how to start one of your own call the Greenway Network office at 636-498-0772.
or Missouri Stream Team Program:
Phone: 1-800-781-1989
E-mail: streamteam@mdc.mo.gov
Web site: www.mostreamteam.org

Another great volunteer opportunity is Lakes of Missouri Volunteer Program. To start a lake Volunteer team, contact the Lakes of Missouri Volunteer Program at 1-800-895-2260, or check their website for information: http://www.lmvp.org/

Measuring The Success of the Watershed Management Action Plan

To determine if Watershed Management Action Plan recommendations are being implemented and are working, there needs to be a method to note the effectiveness of each project.

The following measures are proposed to evaluate how effective the actions have been in achieving the goals in the watershed. Where possible the measures focus on quantifiable improvements documented by direct sampling in Peruque Creek and Lake Saint Louis.

Water Quality in the Basin – Conduct water quality sampling on a yearly basis (over the next five years) at selected locations in the watershed. Sampling will determine if actions have had positive results, such as reducing sediment load in the creek and lake.

Erosion of Upland Soils – Note if ordinances are being enforced, and whether there have been educational programs for the public and developers on responsible property management. Conduct pilot projects to control soil erosion of upland soil and monitor the effectiveness of each activity. Determine if agricultural landowners are in compliance with federal regulations.

Habitat – A baseline habitat evaluation should be conducted to determine the existing habitat condition in the watershed. Conduct follow-up evaluations every three years to note changes. In addition, MDC will conduct evaluations every 3 to 5 years.

In-Stream Flows – Note if there has been improvement in control of overland flow runoff, highway runoff and runoff from residential construction sites. Establish USGS gaging stations in the watershed to determine whether in-stream flows have been reduced during wet-weather events.

Flooding – A baseline inventory of sites that frequently flood should be set up. Corrective actions for those sites should be monitored to determine their effectiveness.

Biological Community – Determine whether the community structure of biological communities in Peruque Creek have changed as a result of selected management strategies. Biological sampling of fish and aquatic insect communities should be conducted every five years. In addition, MDC will conduct evaluations every 3 to 5 years.

Public Education and Outreach – The St. Charles County Soil and Water Conservation District, Peruque Creek Watershed Alliance, Greenway Network, MDC and MDNR are the agencies responsible for developing educational materials to inform the public and developers on sound watershed practices. Scheduled workshops should be held and attendance recorded to determine the interest level of the community.

Appendices of Scientific Data

Upper Right: Erosion from Discharge to Peruque Creek at Hepperman Road

Lower: Peruque Creek at Hepperman Road After a Storm Event

Peruque Creek in Warren County

Land Use Patterns in the Watershed

Land uses in the Peruque Creek watershed have changed dramatically over the last ten years. Population growth in St. Charles and Warren counties and along the Interstate 70 corridor have fueled residential and commercial development in the watershed. This development has consumed large areas of farmland in the watershed.

There are no significant areas of state or federal land within the watershed. St. Charles County owns Quail Ridge Park, which totals 250 acres. Present land use in the watershed is detailed in the Table 1.

Land use changes have an impact on water quality in the watershed. Streams, lakes, and other bodies of water collect runoff from the surrounding land area. If land use is changed, then drainage patterns change.

If the watershed is covered by natural forest or grassland, most of the rainfall will seep into the ground and recharge the underlying aquifer. There is little runoff to streams. Only during very heavy rain is there enough water to saturate the ground and cause runoff to the stream. Flooding can be reduced during heavy rains because water is soaking into the aquifer.

The recharge of the aquifer allows water to slowly seep back into the stream during dry periods. Thus, the stream is always flowing, so it is able to support a diverse aquatic ecosystem, and also supports the plant and wildlife community bordering the waterway.

When land surfaces are covered with roads, parking lots and buildings, rainwater cannot soak into the ground. Consequently, there is a greater amount of runoff flowing into the stream.

Detention Basin for a Development Along Peruque Creek

Table 1. Land Use in Peruque Creek Watershed

Land Use Type	Area Upstream Lake Saint Louis (Acres)	Area Downstream Lake Saint Louis (Acres)
Forested	2455	--
Agriculture/ Pasture	16350	11565
Medium Density Residential	6661	4575
High Density Residential	90	83
Commercial	1907	2267
Industrial	146	760
Highway Street	1523	1124
Open Water/Wetlands	903	25
Open Grassland - Non Urban	4183	--
Urban Grassland	532	--
Total	**34749**	**20399**

Notes:

Upstream Lake Saint Louis area of watershed used land use from two sources - Missouri Resources Assessment Partnership (1999, Land Use/Land Cover 1991-1993) for Warren County and St. Charles County Government (2004) for St. Charles County. Downstream Lake Saint Louis area of watershed used land use from St. Charles County Government (2004) only. The data from St. Charles County did not have land use categories for Forested, Open Grassland - Non Urban, or Urban Grassland.

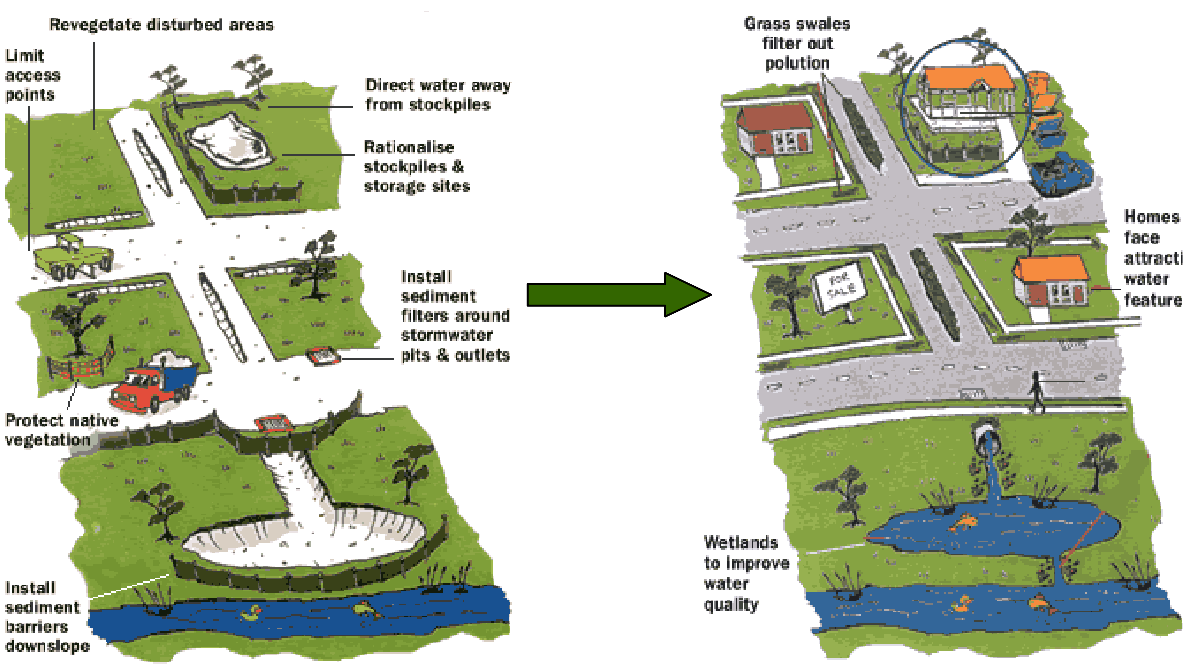
Land Use Planning

Responsible development practices benefit all of us by improving the health and appearance of our land and water. Such practices improve our lives.

Urban development and improper land use can degrade water quality in a watershed. Residential and commercial development greatly increases runoff by creating hard surfaces such as roads, parking lots, and rooftops. Agricultural practices contribute to overland surface flow into the creek from farmland. Runoff increases the velocity in the stream, which causes more sediment erosion as the high flows erode the stream banks. Since water no longer enters the aquifer, the stream may go dry during long periods without rain. Runoff from these sites carries sediment, nutrients and pesticides, all of which can have a harmful effect on aquatic life.

Keys to preventing unnecessary runoff to Peruque Creek are to properly manage residential and commercial development through the existing county and local ordinances, working with the developers to show them the importance of controlling runoff from a site, and plans for runoff control after development. Some home builders in the Peruque Creek watershed are already using proper construction site management and their practices should be acknowledged by local governmental agencies.

The following figure shows responsible development of residential and commercial areas that help improve water quality.



The way you use your land affects all of us!

The Ecology of Peruque Creek Watershed

There are abundant natural resources in the Peruque Creek Watershed that provide high quality wildlife and aquatic habitat.

Orangethroat darter *(Etheostoma spectabile) Photo: Courtesy of Ohio DNR*

The Peruque Creek watershed is host to a wide variety of small and large mammals, reptiles, amphibians, birds and insects. These animals are dependent upon the habitat along the creek. Based upon data collected by the Missouri Department of Conservation (MDC) and other investigators, thirty-two fish species have been collected in Peruque Creek upstream of Lake Saint Louis. The most common species found in the water shed include central stoneroller, orangethroat darter, redfin shiner, red shiner and the bluntnose minnow. The Lake Saint Louis fish community is dominated by game species like smallmouth and largemouth bass, bluegill, black crappie, gizzard shad and channel catfish. The lower sections of the creek were not sampled, but most likely include a mixture of species common to Lake Saint Louis and some Ozark species and fish migrating up from the Mississippi River.

In 1995 and 2001 the MDC collected fish from Peruque Creek to evaluate the overall biological health of the stream. The types and numbers of fish and aquatic insects in a stream are excellent indicators of a streams condition. If there are large numbers of fish species that are intolerant to pollution (e.g. orangethroat darter) it may indicate that the stream is doing well and hasn't been impacted by pollution or stormwater runoff.

However, if there are high numbers of tolerant species, such as carp and bluntnose minnow, it may indicate that the fish community is being stressed.

To determine the health of a stream, aquatic biologist collect fish from the waterbody, and identify and count the number and types they catch. Then they evaluate that information using a variety of biological indices to determine if impacts are occurring to the fish community. The most common index used is the Index of Biological Integrity (IBI). It measures the existing fish community in a stream and compares it with a stream that has not been impacted by pollution. The MDC used the North Fork of the Cuivre River in Lincoln County as a comparison or reference stream for upper Peruque Creek.

Based upon the fish data collected by MDC, the upper reaches of Peruque Creek are showing signs of being stressed when compared to fish communities present in the North Fork of the Cuivre River. IBI scores for the North of the Cuivre range averaged 86, whereas the IBI scores for the upper sections of Peruque Creek averaged 69. However, IBI scores greater than 55 in Missouri are usually indicative of streams in excellent health. Should water quality and habitat conditions continued to be threatened then the biological health of the stream may show a continued decline. Efforts should be made to maintain and restore the biological integrity in Peruque Creek.

The riparian corridor for Peruque Creek provides excellent habitat for deer, small mammals, birds, amphibians and reptiles. Not only does the vegetative community in riparian corridors provide water quality treatment and flow reduction, but also provide shelter for many species for animals.

Physical Condition of the Watershed

Climate

The average annual rainfall from April 1, 1985 to March 31, 2000 for Weldon Springs* is 36.1 inches and is 35.7 inches for St. Charles**.
*National Climatic Data Center Station 8805 **Midwestern Regional Climate Center Station 237398

Soils

The soils adjacent to and within the Peruque Creek streambed are divided by their geographic locations within the vicinity of Peruque Creek. The adjacent soil locations consist of the far western portion of the watershed, west-central portion, east-central portion and easternmost portion of the watershed. For the soil types located within the streambed, Peruque Creek is divided into two locations- the western and eastern portions. The description of the soil in these locations are in the sections below. The soil data was taken from the United States Department of Agriculture (USDA) – Soil Conservation Service Soil Surveys (SCS) of St. Charles County, Missouri (1982) and Montgomery and Warren Counties, Missouri (1978).

Soils Adjacent to Peruque Creek:
Far Western Portion of the Watershed, near the Headwaters in Warren County

The soils in the western portion of the watershed are nearly level (0-3% slope), gently sloping (3-8% slope) to moderately sloping (8-15% slope). This is mainly due to the location of the soil on crests of ridges and long, gentle side slopes. The internal drainage characteristics of the soils range from somewhat poorly drained, moderately well drained, and poorly drained. The permeability of the soils (ease at which liquids, gasses and plant roots penetrate or pass through a layer of soil) range from moderately slow to slow. The internal drainage, permeability, slope, and other soil characteristics are major factors in determining the flow of water across the soil surface (surface runoff). The surface runoff for the soil is classified as slow to medium to rapid. There are some areas where the soil has been severely eroded and other areas where further erosion is of critical concern.

West-Central Portion of the Watershed from Warren County to Lake St. Louis in St. Charles County
Nearly the same soil types that can be found in the far western region of the watershed are also found in the west-central region. The soils in this region are gently and moderately sloping. The internal drainage of the soil range from well-drained and somewhat poorly drained. The permeability of the soil ranges from slow to moderate. The surface runoff ranges from medium to rapid, and there are portions where the soil is severely eroded.

East-Central Portion of the Watershed from Lake St. Louis to O'Fallon
The predominant soil located along the northern rim of Lake St. Louis consists of gently to moderately sloping urban land. The internal drainage is classified as well-drained to moderately well-drained. The permeability is moderately slow for these urban areas; however, there are streets, parking lots and buildings that obscure or alter the soils so that classification is not practical. The urban land can also be found in few areas adjacent to Peruque Creek, tributaries of Peruque Creek and within O'Fallon. Soils located in the east-central portion of the watershed (not urban soils) consist of nearly level to very steep slopes (over 35% slope). The internal drainage ranges from well-drained to moderately well-drained. The permeability is moderate to moderately slow. The surface runoff ranges from medium to rapid, and erosion control is a major concern.

East Portion of the Watershed, at the Mouth in St. Charles County
The main soil types in this region are nearly level alluvial (materials deposited by running water) flood plains found along rivers and stream branches. These soils are located within the Mississippi River floodplain and are subject to occasional flooding. The internal drainage ranges from poorly drained to well-drained. Permeability ranges from very slow to moderate. The runoff is classified as slow.

Soils within the Peruque Creek Streambed:
Western Portion of the Watershed
The soils contained within the Peruque Creek streambed in the western region have slopes that are moderately sloping to steep (25-35% slope). The internal drainage classification ranges from poorly drained to moderately well-drained. The permeability is slow to moderate. Surface runoff ranges from slow to rapid. There are some areas where the soil has been severely eroded and other areas where further erosion is of critical concern.

Eastern Portion of the Watershed
The soils located within the streambed near the Mississippi River Floodplain are nearly level. The same soils types located adjacent to Peruque Creek are also mainly found within the streambed in the eastern region. Therefore, nearly the same characteristics and classifications apply. The internal drainage of the soil is somewhat poorly drained to well-drained. Permeability ranges from very slow to moderate. The runoff is classified as slow.

Present Flow Data

Current Flow Data Statistics for Data		
	Duello Road	Point Prairie
Average Rain (in)	0.000101	0.000101
Average Level (ft)	2.933489	2.520103
Average Velocity (fps)	0.234485	0.262032
Average Flow (cfs)	91.24529	117.685
Maximum Rain (in)	0.31	0.31
Maximum Level (ft)	10.635	8.094
Maximum Velocity (fps)	4.7	5.76
Maximum Flow (cfs)	2880.34	3362.137
Minimum Rain (in)	0	0
Minimum Level (ft)	2.639	2.361
Minimum Velocity (fps)	0.12	0.2
Minimum Flow (cfs)	0.021481	0.034471

Note: The average depth at Duello Road (near Lake St. Louis inlet and a sampling station) is 1.65 ft.

Watershed Use Designations and Water Quality Standards

Applicable Missouri Water Quality Standards (from 10 CSR 20-7)

The table below show the water quality standards that have been determined for the protection of aquatic life and for the water consumed by livestock and wildlife.

Protection of Aquatic Life	
Dissolved Oxygen	
Type of Fishery	*Amount of Oxygen*
Warm-Water and Cool-Water Fisheries	5 mg/L
Cold Water Fisheries	6 mg/L
Oil and Grease	10 mg/L
Temperature	
Type of Water	*Temperature (Maximum)*
Warm-Water	90° F
Cool-Water	84° F
Cold Water	68° F
Ammonia	Temperature Dependent

Livestock and Wildlife Watering	
Fecal Coliform	200 cfu/100 ml

General Criteria (10 CSR 20-7.031(3))

Sediment:

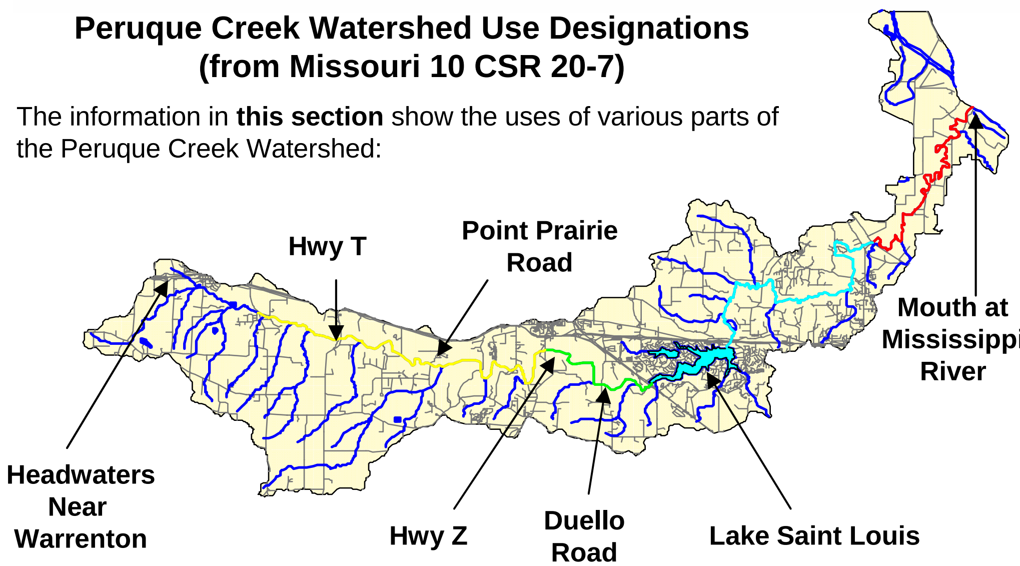
A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial use

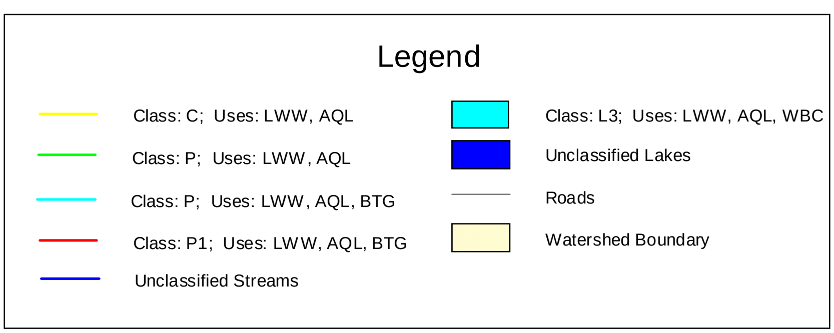
C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses

G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community

Peruque Creek Watershed Use Designations (from Missouri 10 CSR 20-7)

The information in **this section** show the uses of various parts of the Peruque Creek Watershed:





Notes

Stream Classifications

P - Streams that maintain permanent flow during drought conditions
P1 - Standing water reaches of class P streams
C - Stream that may cease to flow in dry periods but maintain permanent pools which support aquatic life

Lake Classifications

L1 - Lakes or Reservoirs used primarily for public drinking
L2 - Major Reservoirs
L3 - Other lakes which are waters of the state. These include both public and private lakes. For effluent regulation purposes, publicly owned L3 lakes are those for which a substantial portion of the surrounding lands are publicly owned or managed.

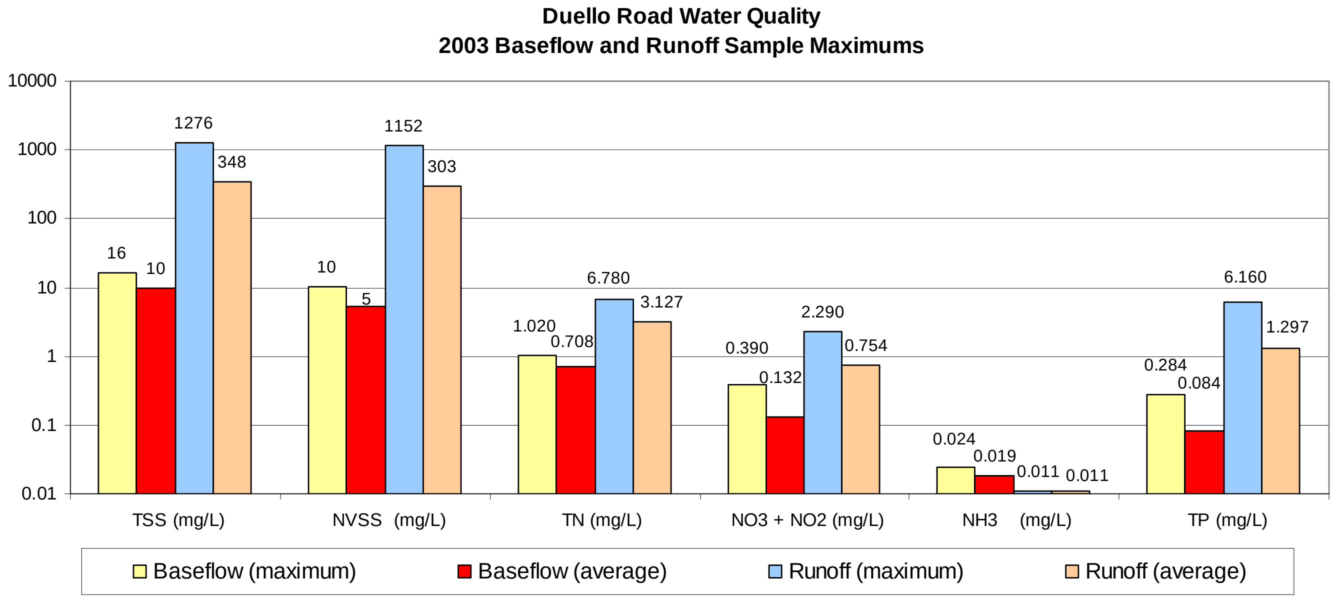
Use Designations

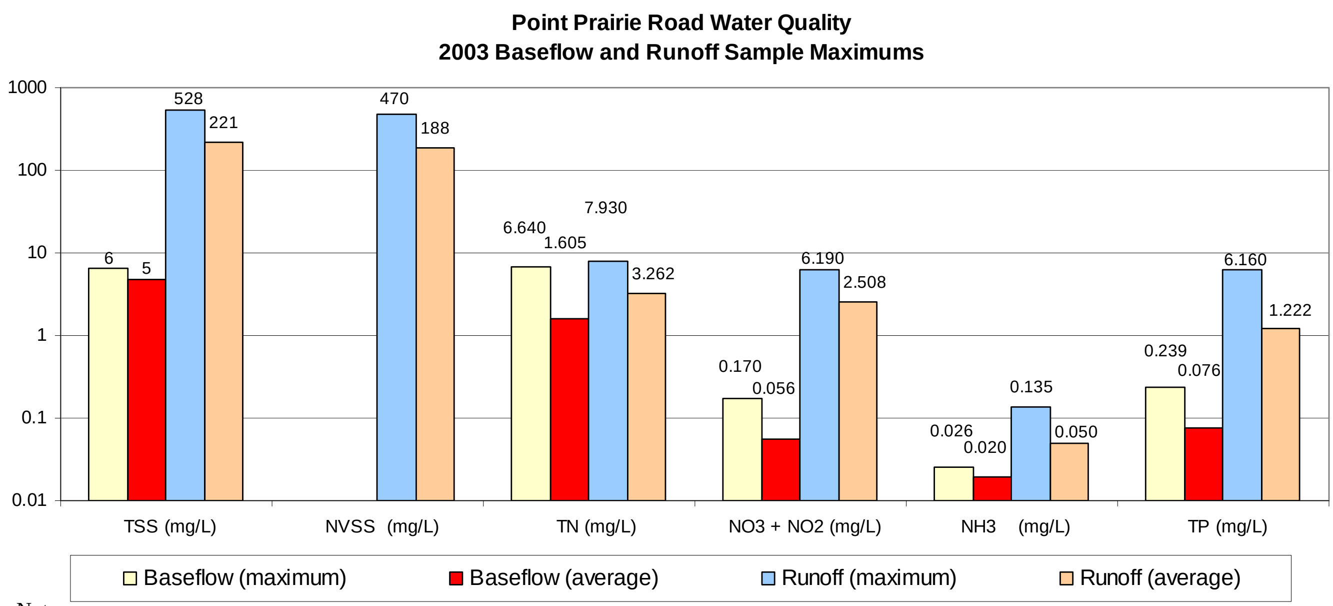
LWW - Livestock & Wildlife Watering
AQL - Protection of Warm Water Aquatic Life and Human Health/Fish Consumption
BTG - Boating and Canoeing
WBC - Whole Body Contact Recreation

Chemical Condition of Peruque Creek

It is clear that storm events and the resulting runoff contribute to degrading water in Peruque Creek and Lake Saint Louis.

Water quality samples taken from May 2003 to October 2003 at the Duello Road and Point Prairie Road crossings reveal the effect of runoff to the quality of the watershed. One indication is the increased sediment loading during the storm event (runoff). Sediment loading is detected by higher total suspended solids (TSS) and non-volatile suspended solids (NVSS) concentrations. Samples were taken at normal flow conditions (baseflow) and during storm events. Sample results are pictured on the following charts. The blue and orange columns show the maximum and average concentration of pollutants during storm events while the yellow and red columns show the maximum and average concentration of the same pollutants during normal flow conditions.





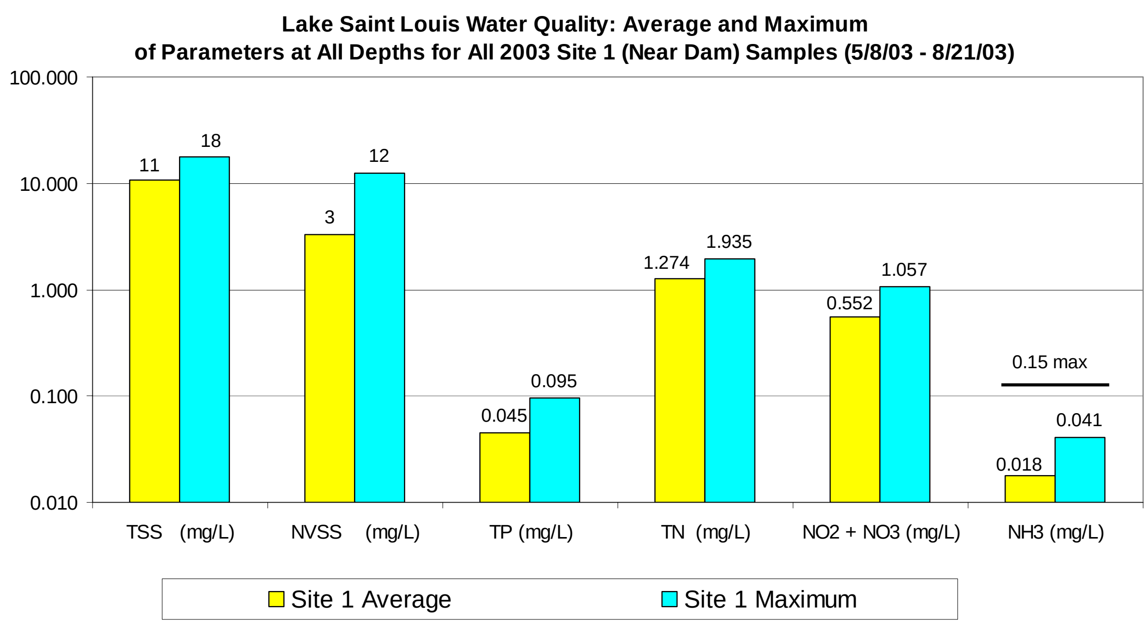
Notes:
Temp - Temperature, DO - Dissolved Oxygen, Cond - Electrical Conductivity, TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TN - Total Nitrogen, NO3 + NO2 - Nitrate and Nitrite, NH3 - Ammonia, TP - Total Phosphorus

Chemical Condition of Lake Saint Louis

Lake Saint Louis has water quality typical of Missouri reservoirs, however, during rain events sediment loading to Lake Saint Louis dramatically increases.

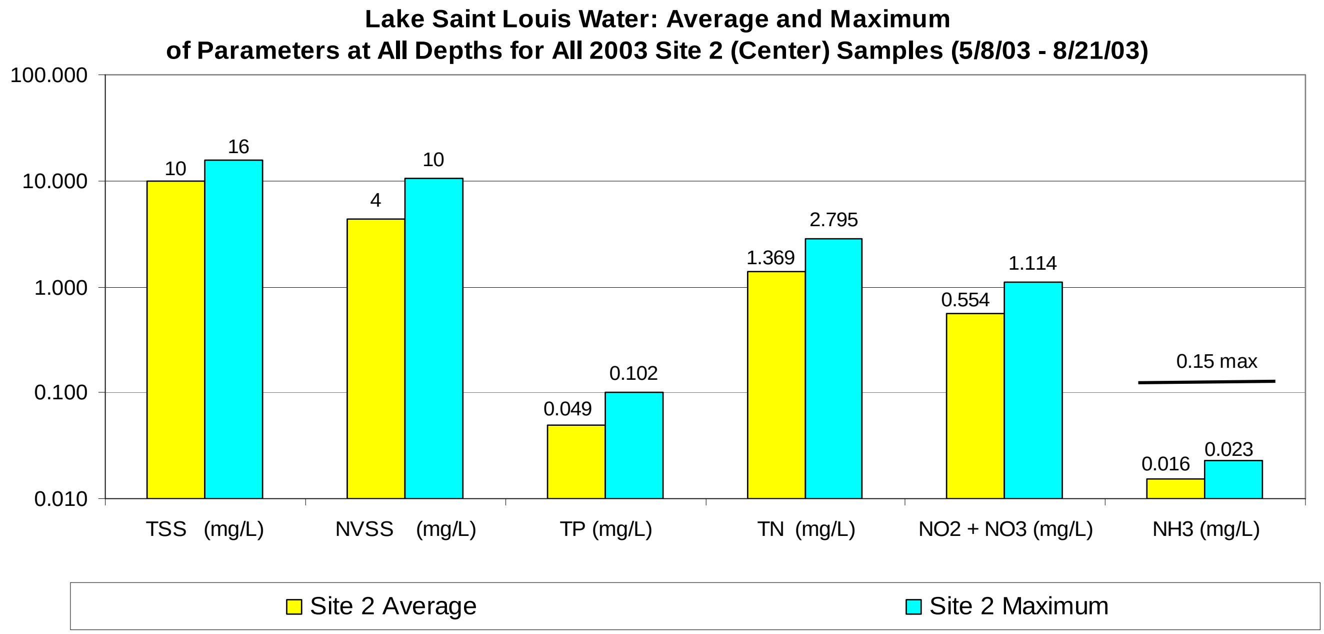
Water quality samples taken at three locations in Lake Saint Louis at various depths are shown in the figures. These water quality samples indicate that during normal flow conditions Lake Saint Louis has water quality typical of Missouri reservoirs. Bacterial data indicate the lake is significantly impacted at this time, however, there are few elevations above the acceptable limit for whole-body contact recreation.

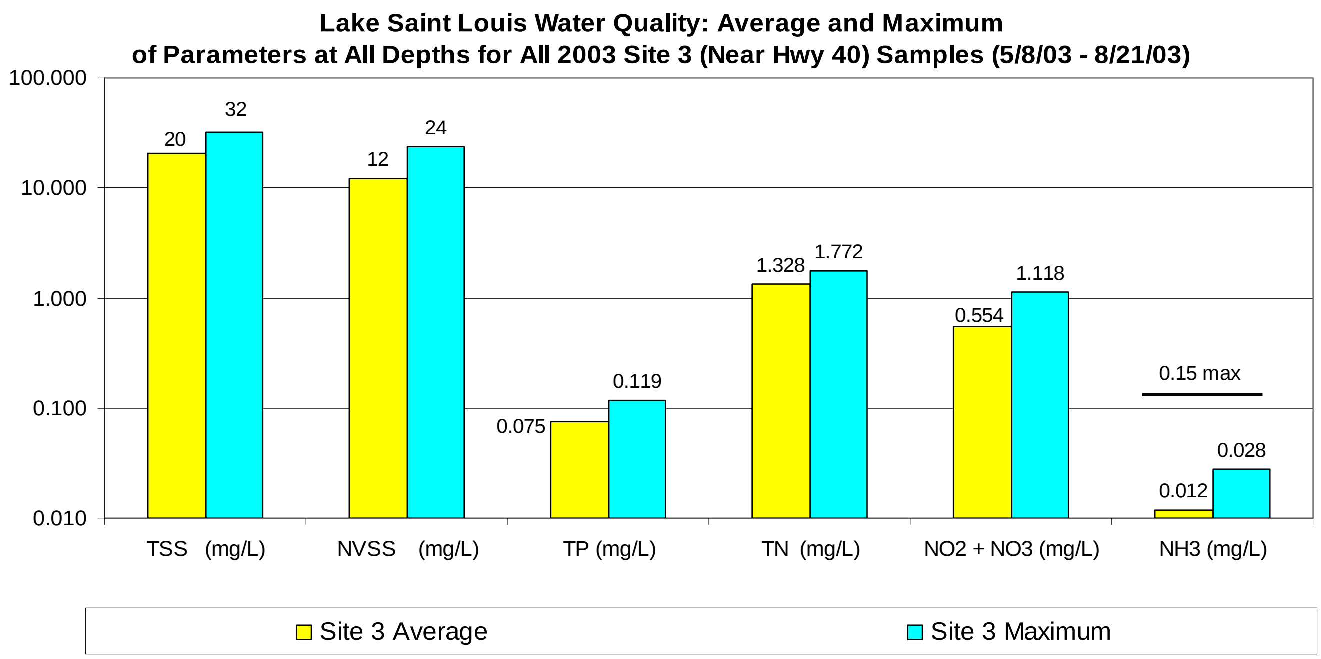
The columns in the figures indicate the average or maximum for the water quality parameter sampled over the entire sampling period from May 8, 2003 to August 21, 2003, at all depths for each site. The applicable Missouri water quality standards are also represented on the figures. Standards apply for ammonia (NH_3) and pH. No violations of these standards were measured.



Notes:
TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus, TN - Total Nitrogen, $NO_3 + NO_2$ - Nitrate and Nitrite, NH_3 - Ammonia
* The chronic ammonia (NH_3) water quality standard is pH and temperature dependant for each sample. 0.15 mg/L represents the minimum standard for the pH and temperature range sampled.

Chemical Condition of Lake Saint Louis





Notes:
TSS - Total Suspended Solids, - NVSS - Non-volatile Suspended Solids, TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus, TN - Total Nitrogen, NO3 + NO2 - Nitrate and Nitrite, NH3 - Ammonia
* The chronic ammonia (NH3) water quality standard is pH and temperature dependant for each sample. 0.15 mg/L represents the minimum standard for the pH and temperature range sampled.

Who Should You Contact?

Peruque Creek Watershed Alliance
c/o USDA Soil Conservation Service
USDA Service Center
160 Centre Blvd.
St. Peters, MO 63376-1695
636-922-2833

Missouri Stream Team
STREAM TEAM Unit
c/o Missouri Dept. of Conservation
PO Box 180
Jefferson City, MO 65102-0180
1-800-781-1989 (voice mailbox)

Missouri Department of Natural Resources
Water Protection Program
P.O. Box 176
Jefferson City, MO 65102-0176
Water Quality Violations 573-751-7428
Illegal Dumping into Waterways
573-634-2436 (24-hour hotline)

Missouri Department of Conservation
2360 Highway D
St. Charles, MO 63304
636-441-4554

US Environmental Protection Agency
Region 7
901 North 5th Street
Kansas City, KS 66101
1-800-223-0425
Nation Spill Response Center
1-800-424-8802

Greenway Network, Inc.
St. Charles Community College
4601 Mid Rivers Mall Drive
St. Peters, MO 63376
636-498-0772

County Governments:

Warren County, Warrenton
636-456-1801—County Court House

St. Charles County, St. Charles
636-949-7520—County Court House

Local Governments:

City of Warrenton
636-456-3535 – City Hall

City of Wright City
636-745-3101 – City Hall

City of Foristell
Phone: 636-463-2123 x222 - Clerk

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Phone: 636-327-5101 – City Hall

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Phone: 636-625-1200 – City Hall

City of O'Fallon
Phone: 636-240-2000 – City Hall

City of St. Paul
Phone: 314-644-0250 wk - Mayor
Phone: 636-379-0221 – Clerk

Village of Josephville
Phone: 636-327-8516 - Chairman

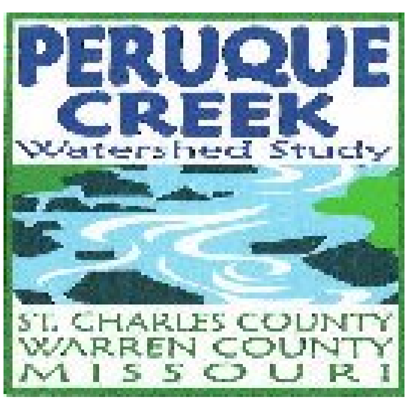
Check our Web sites:

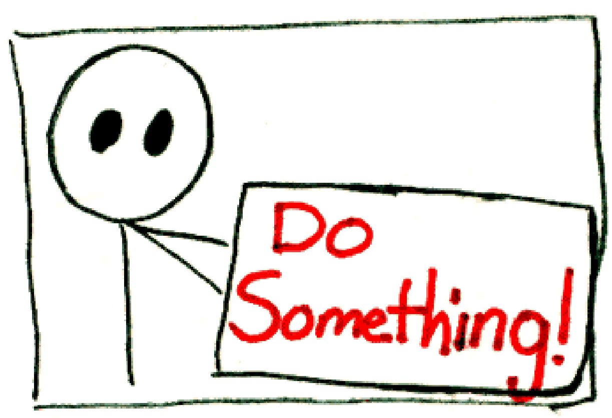
http://www.peruquecreek.com
http://www.conservation.state.mo.us/chrisd/areas/stlouis/fish_new/stream/health/peruque.htm
http://www.dnr.state.mo.us/wpscd/wpcp/tmdl/info/peruque-ck-info.pdf

How can you help?

- **Be active! Get involved! Your ideas do matter!**
- **Write to the state representative if you are unhappy with the conditions in the stream**
- **Join the “Alliance” and attend meetings.**
- **Learn how land use actions affect the stream.**
- **Learn how to have a healthy life-style for your family and the future.**
- **Promote a sustainable landscape.**
- **Prevent loss of natural habitat in the watershed.**
- **Encourage responsible growth in the watershed.**
- **Preserve open spaces, parks and greenways.**
- **Report water quality and ordinance violations to authorities.**
- **Encourage your elected officials to work together to solve watershed issues.**
- **Start a Stream Team!**

Check our Web sites:
http://www.peruquecreek.com
http://www.conservation.state.mo.us/chrisd/areas/stlouis/fish_new/stream/health/peruque.htm
http://www.dnr.state.mo.us/wpscd/wpcp/tmdl/info/peruque-ck-info.pdf





Biological Assessment Report

Peruque Creek
St. Charles & Warren Counties

June 12, 2003

Prepared for:

Missouri Department of Natural Resources
Water Protection and Soil Conservation Division
Water Pollution Control Program

Prepared by:

Missouri Department of Natural Resources
Air and Land Protection Division
Environmental Services Program
Water Quality Monitoring Section

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1.0 Introduction

At the request of the Water Pollution Control Program (**WPCP**), the Environmental Services Program's (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted a biological assessment of Peruque Creek, which flows through rural and suburban portions of Warren and St. Charles counties, Missouri. It was added to the Missouri proposed 303(d) list of impaired waters in 2002 for nonvolatile suspended solids from urban and rural nonpoint source pollution.

North Fork Cuivre River, a nearby drainage that flows through a mostly rural watershed, was used as a control site to compare with Peruque Creek. This comparison was to determine whether biological impairment could be differentiated between a rural stream setting and one under increasing pressure from development. Additionally, South River, a biological criteria reference stream, was re-sampled for comparison to both Peruque Creek and North Fork Cuivre River. Sampling was conducted on March 19-27, 2002 and on September 24-25, 2002 to provide data to the WPCP for use in evaluating and comparing the biological integrity of the two streams. Dave Michaelson and Cecilia Campbell of the Environmental Services Program, Air and Land Protection Division conducted the sampling.

On January 16, 2002 a study plan was submitted to the WPCP (Appendix A). A total of 10 null hypotheses were stated in this plan:

1) Macroinvertebrate assemblages will not differ between reaches of Peruque Creek where best management practices (**BMPs**) are in use in the watershed and reaches where poor management practices are used in the watershed;

2) Water chemistry will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used;

3) Fecal coliform concentrations will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used;

4) Benthic sediment percentage estimates will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used;

5) Measures of habitat quality will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used;

6) Macroinvertebrate assemblages will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers Ecological Drainage Unit (**EDU**);

7) Water chemistry will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU;

8) Fecal coliform concentrations will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU;

9) Benthic sediment percentage estimates will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU;

10) Measures of habitat quality will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU.

2.0 Study Area

Peruque Creek originates in eastern Warren County, west of Wright City, flows east through St. Charles County and into Lake St. Louis. At the outfall of the reservoir, the creek resumes a northeasterly course and enters the Mississippi River near the town of Firma, Missouri. Although the Peruque Creek watershed is largely rural (dominated by pasture, forest, and cropland), a sizable urbanized portion also exists (see Table 1). The lowermost sample station of the stream reach assessed is in a reach classified "P" with beneficial use designations of "livestock and wildlife watering" and "warm water aquatic life protection, human health/fish consumption." Sample stations #2 through #5 fall in a reach of the stream designated class "C" with the same beneficial use designations listed above. The uppermost sample station is unclassified.

North Fork Cuivre River originates in west central Pike County, southwest of Bowling Green, and flows southeast through a watershed that is dominated by cropland (see Table 1). The North Fork Cuivre River sample stations are in a reach classified "C" with beneficial use designations of "livestock and wildlife watering" and "warm water aquatic life protection, human health/fish consumption." This stream was chosen as a control in the study due to several factors: its close proximity to the study stream within the same EDU; a watershed of comparable size; and a relative lack of urbanization in the watershed.

Peruque Creek and North Fork Cuivre River are located within the Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers (**PMSD)** EDU. An EDU is a region in which biological communities and habitat conditions can be expected to be similar. Please see Appendix B for maps of the EDU and the 14-digit Hydrologic Units (**HU**), #07110009010001 and #07110008010003, that contain the sampling reaches for Peruque Creek and North Fork Cuivre River, respectively. See Table 1 for a comparison of land use for the 14-digit HUs. In addition to Peruque and North Fork Cuivre River, land use for comparable biological criteria reference streams within the PMSD EDU have been included in Table 1 for comparison. Land cover data were derived from the Thematic Mapper satellite data from 1991-1993, and interpreted by the Missouri Resource Assessment Partnership (**MoRAP**).

Table 1
Percent Land Cover

	Urban	Crops	Grassland	Forest	Swamp
PMSD* EDU	1.1	43.5	35.9	17.1	0.2
Peruque Creek	11.8	25.5	33.1	26.2	0.0
North Fork Cuivre River	0.2	56.5	29.2	13.4	0.0
North River	0.0	30.0	45.8	10.2	0.4
South River	0.2	53.2	34.7	10.2	0.4
South Fabius River	0.2	37.9	45.2	15.6	0.1

*Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers

3.0 Site Descriptions

With the exception of Station 6 and Station 5, which were in Warren County, all Peruque Creek macroinvertebrate sample stations were located in St. Charles County. North Fork Cuivre River sample sites were in Pike County. The average width and discharge measurements during both survey periods are given for each sampling station in Table 2 in the Data Results section.

Peruque Creek Station 1 (SW ¼ sec. 32, T. 47 N., R. 2 E.) was located downstream of the Duello Road bridge. Geographic coordinates at the upstream terminus of this station were Lat. 38.787287˚, Long. –90.827498˚.

Peruque Creek Station 2 (NE ¼ NE ¼ sec. 35, T. 47 N., R. 1 E.) was located upstream of the Wilmer Road bridge. Geographic coordinates at the downstream terminus of this station were Lat. 38.792738˚, Long. –90.872231˚.

Peruque Creek Station 3 (Sur. 149, T. 47 N., R. 1 E.) was located upstream from the Hepperman Road bridge. Geographic coordinates at the downstream terminus of this station were Lat. 38.792247˚, Long. –90.885220˚.

Peruque Creek Station 4 (W ½ sec. 30, T. 47 N., R 1 E.) was located upstream from the State Road T bridge. Geographic coordinates at the downstream terminus of this station were Lat. 38.804294˚, Long. –90.955551˚.

Peruque Creek Station 5 (SW ¼ SW ¼ sec. 23, T. 47 N., R. 1 W.) was located upstream from the South Stringtown Road bridge. Geographic coordinates at the midpoint of this station were Lat. 38.815637˚, Long. –90.997554˚.

Peruque Creek Station 6 (NW ¼ sec. 22, T. 47 N., R. 1 W.) was located at Ruge Memorial Park in Wright City, Missouri. Geographic coordinates at the midpoint of this station were Lat. 38.821845˚, Long. –91.202815˚.

North Fork Cuivre River 1 (W ½ sec. 13, T. 51 N., R. 3 W.) was located downstream of Pike County Road 325. Geographic coordinates at the upstream terminus of this station were Lat. 39.193592˚, Long. –91.202815˚.

North Fork Cuivre River 2 (E ½ sec. 33, T. 52 N., R. 3 W.) was located upstream of Highway 161. Geographic coordinates at the downstream terminus of this station were Lat. 39.234612˚, Long. –91.2466625˚.

Water quality samples were collected at three sites on Peruque Creek and two sites on North Fork Cuivre River for fecal coliform analysis. Fecal coliform counts are presented in Table 7 in the Data Results section.

Peruque Creek Fecal Coliform Site 1 (W ½ sec. 30, T. 47 N., R 1 E.) was located at the State Road T bridge, just upstream from the Foristell Wastewater Treatment Facility tributary. Geographic coordinates at the point of collection were Lat. 38.804400˚, Long. –90.959100˚.

Peruque Creek Fecal Coliform Site 2 (NE ¼ NE ¼ sec. 33, T. 47 N., R. 1 E.) was located at the Pointe Prairie Road bridge. Geographic coordinates at the point of collection were Lat. 38.794800˚, Long. –90.911000˚.

Peruque Creek Fecal Coliform Site 3 (Sur. 149, T. 47 N., R. 1 E.) was located at the Hepperman Road bridge. Geographic coordinates at the point of collection were Lat. 38.792250˚, Long. –90.885222˚.

North Fork Cuivre River Fecal Coliform Site 1 (W ½ sec. 13, T. 51 N., R. 3 W.) was located at the Highway 161 bridge. Geographic coordinates at the point of collection were Lat. 39.234611˚, Long. –91.246666˚.

North Fork Cuivre River Fecal Coliform Site 2 (W ½ sec. 13, T. 51 N., R. 3 W.) was located at the Pike County Road 325 bridge. Geographic coordinates at the point of collection were Lat. 38.193500˚, Long. –91.203000˚.

4.0 Methods

4.1 Macroinvertebrate Collection and Analyses

A standardized sample collection procedure was followed as described in the Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**) (MDNR 2001a). Three standard habitats-flowing water over coarse substrate, depositional substrate in non-flowing water, and rootmat at the stream edge-were sampled at all locations. During the fall sample season, however, there was insufficient flowing water to provide a coarse substrate sample at Peruque Creek Station 6.

A standardized sample analysis procedure was followed as described in the SMSBPP. The following four metrics were used: 1) total taxa (TT); 2) total number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera (EPTT); 3) biotic index (BI); and 4) Shannon diversity index (SDI). These metrics are combined to form the Stream Condition Index (**SCI**). Stream Condition Indices between 20-16 qualify as fully supporting, between 14-10 are partially supporting, and 8-4 are considered nonsupporting of aquatic life. The multi-habitat macroinvertebrate data are presented in Appendix C as laboratory bench sheets.

Additionally, macroinvertebrate data were analyzed in three specific ways. First, comparisons were made between Peruque Creek reaches where BMPs were being used and reaches where poor land practices were in place. Patterns were illustrated using XY line graphs with stream location (station number) on the X-axis and biological characteristics on the Y-axis. Secondly, Peruque Creek stations were compared to North Fork Cuivre River stations. Finally, data from Peruque Creek and North Fork Cuivre River were compared to biological criteria from reference streams within the same EDU and the same watershed size classification. Biocriteria data collected from fall 2002 and previous survey years constituted the basis of the comparison.

4.2 Physiochemical Data Collection and Analysis

During each survey period, *in situ* water quality measurements were collected at all stations. Field measurements included temperature (˚C), dissolved oxygen (mg/L), conductivity (µS/cm), and pH. Additionally, water samples were collected and analyzed by ESP's Chemical Analysis Section for turbidity (NTU), chloride, total phosphorus, ammonia-N, nitrate/nitrite-N, and total Kjeldahl nitrogen (**TKN**).

Stream velocity was measured at each station during each survey period using a Marsh-McBirney Flo-Mate Model 2000. Discharge was calculated per the methods in the Standard Operating Procedure MDNR-FSS-113, Flow Measurement in Open Channels (MDNR 2003).

Stream habitat characteristics for each sampling station were measured during the spring 2002 survey period using a standardized assessment analysis procedure as described for riffle/pool habitat in the Stream Habitat Assessment Project Procedure (MDNR 2000).

Physiochemical data were summarized and presented in tabular and graphic form for comparison among stations on Peruque Creek, and between Peruque Creek stations and those of North Fork Cuivre River and reference streams.

4.3 Benthic Sediment Percentage Estimation

Instream deposits of fine sediment [i.e., particle size less than approximately 2 mm (coarse sand)] were visually estimated for percent coverage per area at each macroinvertebrate sample station. To ensure sampling method uniformity, percent sediment coverage was estimated at the upper margins of pools and lower margins of riffle/run (coarse substrate) habitat. Depths of the sample areas did not exceed two (2.0) feet and water velocity was less than 0.5 feet per second (fps). A Marsh McBirney flow meter was used to ensure that water velocity of the sample area was within this range.

Three sediment estimation areas (grids) were placed within each macroinvertebrate sampling station (see Figure 1). Within each grid, six contiguous transects traversed the stream (see Figure 2). A tape measure was stretched from bank to bank at each grid. A 0.25 m^2 sample quadrat was placed directly on the substrate within each of the six transects. Placement of the quadrat within each transect was determined by using a random number that equated to one foot increments on the tape measure. The downstream edge of the quadrat was placed on the random foot increment. Two investigators estimated the percentage of the stream bottom covered by fine sediment within each quadrat. Estimates were accepted if the two observations were within a ten percent margin of error. If estimates diverged by more than ten percent, the investigators repeated the process until estimates were within an acceptable margin of error. An average of these two estimates was recorded and used for analysis.

Sediment deposition among sites was compared using Kruskal-Wallis one way analysis of variance on ranks. The mean percent sediment deposition at Peruque Creek stations was statistically compared to each other and to North Fork Cuivre River Station 1, which served as a control. All statistical interpretations were conducted using SigmaStat® (version 2.03, Jandel Scientific, San Rafael, California) software. An *a priori* p-value of <0.05 was selected to determine statistically significant differences among data sets.

4.4 Fecal Coliform Analysis

WQMS personnel collected water samples for fecal coliform analysis at three Peruque Creek locations and two North Fork Cuivre River locations. Samples were collected four times, at least two weeks apart, during the period from July 1 through September 4. Sample collection and analysis were conducted according to established MDNR

Figure 1: Sediment Estimation Grids within a Macroinvertebrate Sample Station

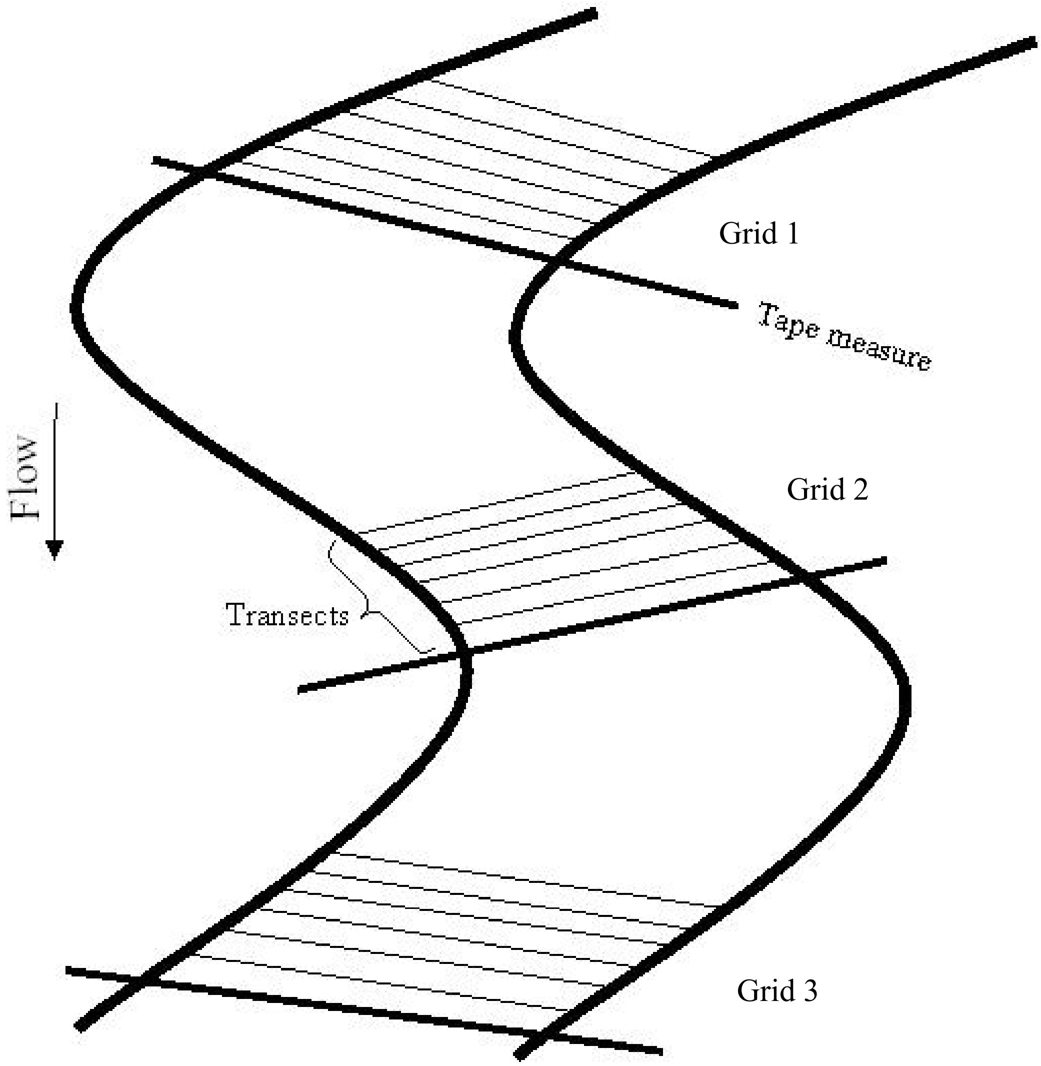
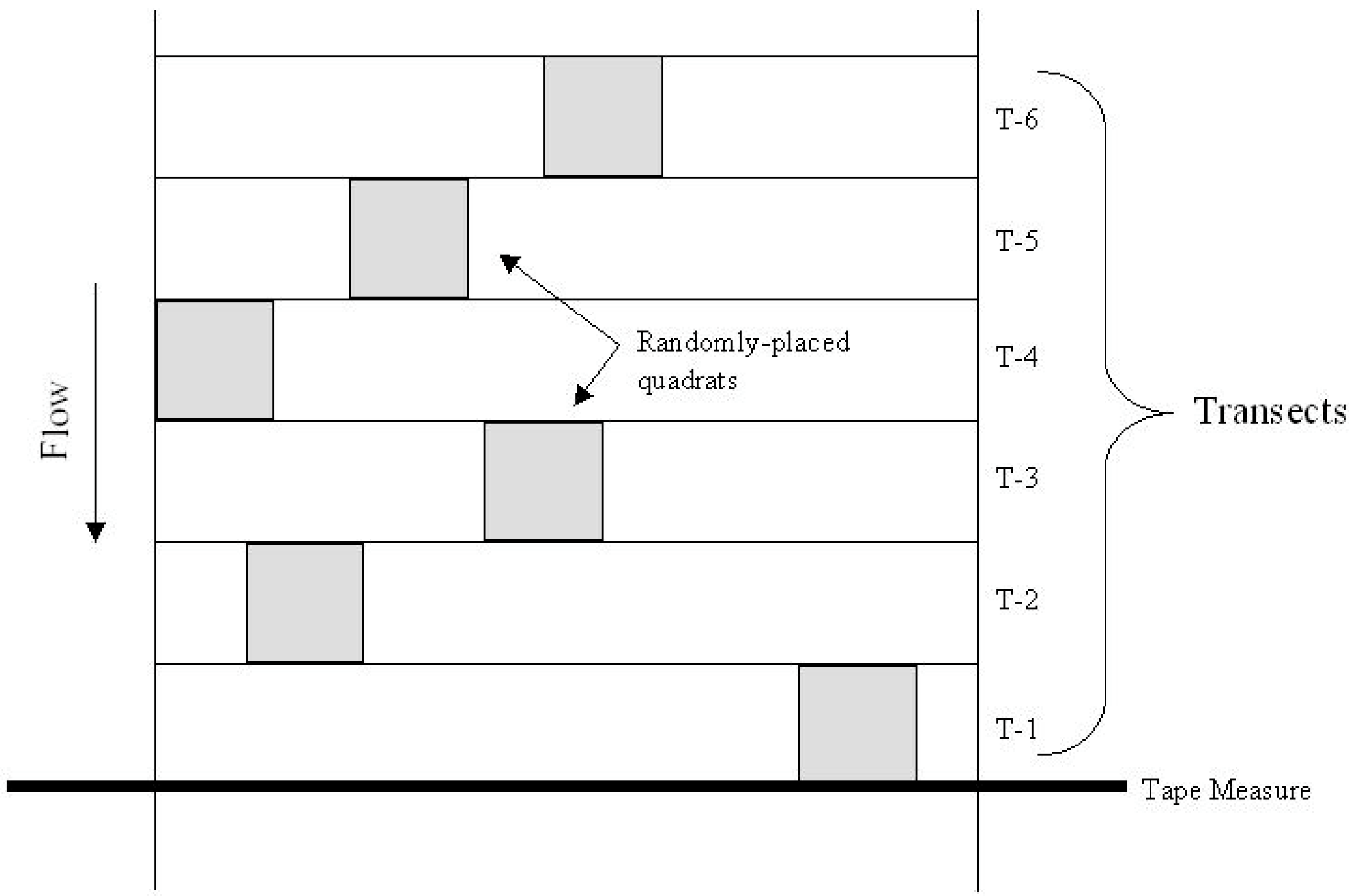


Figure 2: Sediment Sample Grid



protocols: MDNR-FSS-001, Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Considerations (MDNR 2002a); MDNR-FSS-002, Field Sheet and Chain of Custody Record (MDNR 2001b); and MDNR-WQMS-108, Field Analysis of Fecal Coliform Bacteria (MDNR 2002b).

4.5 Quality Assurance/Quality Control (QA/QC)

QA/QC procedures were followed as described in the SMSBPP and in accordance with the Fiscal Year 2003 Quality Assurance Project Plans for "Wasteload Allocations and Other Special Studies" and "Biological Assessment."

5.0 Data Results

5.1 Physiochemical Data

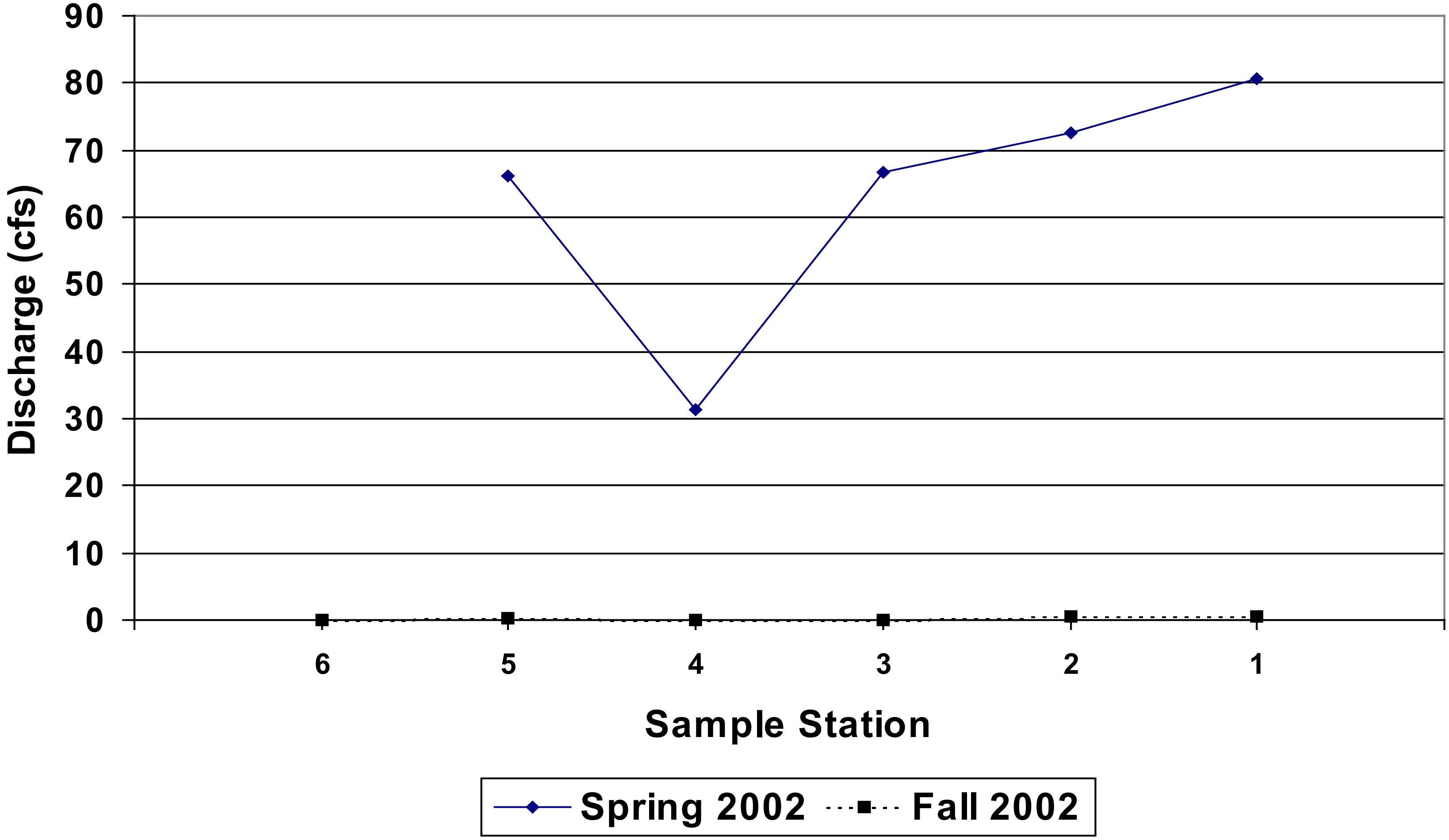
Physical characteristics of each Peruque Creek, North Fork Cuivre River, and South River station are presented in Table 2. Stream widths at Peruque Creek stations ranged from 8 to 24 feet with widths tending to increase while progressing downstream. Peruque Creek stream flow during the spring sample season generally increased in downstream stations with the exception of Station 4, which exhibited less than half the flow of either station upstream or downstream from it (see Figure 3). We are unable to explain this anomaly. Flow during the fall sample season was much reduced compared to spring flow rates in Peruque Creek. Upper stations had been nearly reduced to pools with very little water flowing across riffles. At Station 6, surface flow across riffles had ceased entirely.

Table 2
Physical Characteristics of the Stations

			Spring 2002	Fall 2002
Creek	Station	Avg. Width (ft.)	Flow (cfs)	Flow (cfs)
Peruque Cr.	1	24	80.7	1.02
	2	20	72.5	0.49
	3	23	66.6	0.06
	4	19	31.4	0.13
	5	11	66.2	0.26
	6	8	No data	0.0
NFCuivre River	1	75	54.0	1.69
	2	69	36.0	0.15
South River	1	No data	No data	0.50

In situ water quality measurements are summarized in Tables 3 (Spring 2002) and 4 (Fall 2002). Temperatures among sites varied seasonally, with mean temperatures at Peruque Creek stations higher in the fall (15.8˚C) than spring (4.2˚C). Water temperature at

Figure 3: Peruque Creek Discharge



Peruque Creek Stations 2 and 3 were much higher than at the remaining sites. Portions of Stations 2 and 3 were made up of extended reaches with shallow water and little or no tree canopy. The remaining four stations were mostly shaded. Mean water temperatures during fall 2002 at North Fork Cuivre River were considerably higher than at Peruque Creek. This difference can be attributed to the time of day at which the readings were taken (late afternoon) and to the fact that North Fork Cuivre River is wider than Peruque Creek and has more surface area exposed to sunlight.

Table 3
In situ Water Quality Measurements at all Stations (Spring 2002)

Creek/Station	Parameter				
	Temp. (˚C)	Diss. O_2 (mg/L)	Cond. (µS/cm)	pH	Turb. (NTU)
Peruque #1	3	13.9	262	7.5	42.6
Peruque #2	4	14.3	231	7.8	33.4
Peruque #3	4	13.8	260	7.9	42.1
Peruque #4	6	13.4	243	7.8	37.4
Peruque #5	4	13.3	209	7.7	280
Peruque #6	No data	No data	No data	No data	No data
NFCuivre R #1	4	12.7	383	7.9	28.2
NFCuivre R #2	4	13.9	372	8.1	32.3

Table 4
In situ Water Quality Measurements at all Stations (Fall 2002)

Creek/Station	Parameter				
	Temp. (˚C)	Diss. O_2 (mg/L)	Cond. (µS/cm)	pH	Turb. (NTU)
Peruque #1	15	6.2	411	7.3	21.4
Peruque #2	18.5	10.2	394	7.8	5.04
Peruque #3	20.5	7.16	421	7.7	25.5
Peruque #4	13	7.8	631	7.8	1.32
Peruque #5	14	9.95	1050	8.1	7.22
Peruque #6	14	2.56	527	7.6	41.6
NFCuivre R #1	22	8.35	534	7.7	20.6
NFCuivre R #2	22	8.58	543	7.8	9.93
South River #1	21.5	8.0	470	8.0	4.92

Turbidity levels varied widely among stations during fall 2002. During the spring, turbidity was generally higher and more consistent among sites. A notable exception occurred at Peruque Creek Station 5, downstream from the Wright City wastewater treatment facility, where turbidity was measured at 280 NTUs. This value was nearly seven times higher than the next highest reading during that season.

Conductivity and pH were consistent among sites and seasons with one exception. Conductivity at Peruque Creek Station 5 was 1050 µS/cm during the fall sampling season, almost double that of nearly every other sample location.

Nutrient concentrations as well as chloride concentrations are presented in Table 5 (Spring 2002) and Table 6 (Fall 2002). Ammonia as nitrogen was below the detection limit of 0.05 mg/L during both seasons for all stations at Peruque Creek and North Fork Cuivre River. This parameter was also below detectable limits for South River during the fall season. Nitrate/nitrite levels were generally higher in samples from spring 2002, with mean concentrations at North Fork Cuivre River being nearly triple those at Peruque Creek. Concentrations of TKN during the spring season among all Peruque Creek sites, however, were considerably higher than at North Fork Cuivre River. The lowest TKN reading at Peruque Creek was nearly five times higher than the highest concentration observed at North Fork Cuivre River. Other nutrient parameters varied mostly according to season, except at Peruque Creek Station 5. Concentrations of water chemistry parameters consistent with wastewater discharge (TKN, phosphorus, and chloride) were elevated at this site compared to other sites upstream and downstream.

Table 5
Nutrient Concentrations at all Stations (Spring 2002)

Creek/Station	Parameter				
	NH_3-N	NO_2/NO_3-N	TKN	Total Phos.	Chloride
Peruque #1	*	0.48	0.79	0.13	32.3
Peruque #2	*	0.46	0.78	0.12	22.6
Peruque #3	*	0.47	0.72	0.11	29.9
Peruque #4	*	0.58	0.59	0.14	18.5
Peruque #5	*	0.41	1.27	0.36	20.1
Peruque #6	No data	No data	No data	No data	No data
NFCuivre R #1	*	1.73	0.11	0.11	27
NFCuivre R #2	*	1.63	0.12	0.12	29.4

*below detectable limits

Table 6
Nutrient Concentrations at all Stations (Fall 2002)

Creek/Station	Parameter				
	NH_3-N	NO_2/NO_3-N	TKN	Total Phos.	Chloride
Peruque #1	*	0.13	0.31	0.07	20.9
Peruque #2	*	*	0.23	*	17
Peruque #3	*	*	0.29	0.06	18.6
Peruque #4	*	*	0.27	0.06	53.8
Peruque #5	*	0.49	1.59	1.11	134
Peruque #6	*	*	0.51	0.19	20.7
NFCuivre R #1	*	0.12	0.5	0.13	14.6
NFCuivre R #2	*	0.75	0.3	0.06	24.6
South River #1	*	0.39	*	0.07	29.3

*below detectable limits

5.2 Fecal Coliform Analysis

Fecal coliform bacteria concentration information for Peruque Creek and North Fork Cuivre River is presented in Table 7 (Summer 2002). During the July and September 2002 collection periods, Peruque Creek fecal coliform concentrations were higher at the Pointe Prairie Road monitoring site than the State Road T and Hepperman Road sites. The Pointe Prairie site is located downstream from wastewater treatment facilities (**WWTF**) for Foristell and Wright City. For the single sample collected in August, fecal coliform concentrations were lowest at Pointe Prairie among the three Peruque Creek sites, whereas an extremely high concentration of >6000 colony forming units/100 mL was observed at the State Road T collection site, downstream from the Wright City WWTF.

Table 7
Peruque Creek and North Fork Cuivre River Fecal Coliform Concentrations

Site Description	Collection Date	Discharge (cfs)	Fecal Coliform (cfu/100 mL)
Peruque Creek-State Road T	7-2-02	0.01[1]	30
Peruque Creek-State Road T	7-23-02	0.07[1]	50
Peruque Creek-State Road T	8-13-02	No flow[1]	>6000
Peruque Creek-State Road T	9-4-02	0.23[1]	90
Peruque Creek-Pointe Prairie Rd.	7-2-02	1.66[1]	300
Peruque Creek-Pointe Prairie Rd.	7-23-02	0.17[1]	105
Peruque Creek-Pointe Prairie Rd.	8-13-02	0.72[1]	50
Peruque Creek-Pointe Prairie Rd.	9-4-02	No flow[1]	210
Peruque Creek-Hepperman Rd.	7-2-02	0.58[1]	150
Peruque Creek-Hepperman Rd.	7-23-02	0.49[1]	90
Peruque Creek-Hepperman Rd.	8-13-02	No flow[1]	180
Peruque Creek-Hepperman Rd.	9-4-02	0.05[1]	95
North Fork Cuivre River-Highway 161	7-2-02	3.11	210
North Fork Cuivre River-Highway 161	7-23-02	3.94	440
North Fork Cuivre River-Highway 161	8-13-02	2.71	120
North Fork Cuivre River-Highway 161	9-4-02	1.86	100
North Fork Cuivre River-Co. Rd. 325	7-2-02	0.97	125
North Fork Cuivre River-Co. Rd. 325	7-23-02	4.04	440
North Fork Cuivre River-Co. Rd. 325	8-13-02	1.82	900
North Fork Cuivre River-Co. Rd. 325	8-13-02[2]	1.82	570
North Fork Cuivre River-Co. Rd. 325	9-4-02	0.23	520
North Fork Cuivre River-Co. Rd. 325	9-4-02[2]	0.23	370

[1]Discharge was measured the day prior to fecal coliform sampling.
[2]Duplicate sample.

At North Fork Cuivre River, fecal coliform concentrations were more consistent throughout the summer and were generally higher than the three stations on Peruque Creek. Samples collected in July were similar or slightly higher at Highway 161, the upstream station, when compared to the downstream station at County Road 325. Samples collected from County Road 325 in August and September, however, had substantially higher coliform concentrations than the upstream site.

5.3 Habitat Assessment

Habitat assessment scores were recorded for each sampling station. Results are presented in Table 8. According to the project procedure, for a study site to fully support a biological community, the total score from the physical habitat assessment should be 75% to 100% similar to the total score of the reference site. The mean habitat score for the two North Fork Cuivre River sites was 137.5; when the habitat scores for an additional reference stream were included, the average across all sites was 126. All Peruque Creek stations had habitat scores that exceeded or were within the aforementioned range of similarity. It was therefore inferred that the sites should support comparable biological communities.

Table 8
Reference Streams and Peruque Creek Habitat Assessment Scores

Reference Streams	Habitat Score	Peruque Creek	Habitat Score	% of Mean Ref.
NFCuivre R #1	138	Station #1	148	117%
NFCuivre R #2	137	Station #2	151	120%
North River #1	105	Station #3	138	110%
North River #2	125	Station #4	128	102%
		Station #5	153	121%
		Station #6	108	86%
Mean Ref. Stream Score	**126**			

5.4 Biological Assessment

5.4.1 Comparison of Peruque Creek BMP Sites versus non-BMP Sites

Of the six stations surveyed for macroinvertebrates, we judged four to have adjacent land uses consistent with best management practices (BMPs). The adjoining watersheds at the remaining two sites, Station 3 (Hepperman Road) and Station 4 (State Road T) were impacted by poor land use practices associated with property development at the time of the study. In spite of differences in land use practices among sites within the study reach, there was no direct impact observed with respect to the macroinvertebrate community. Total Taxa and EPT Taxa tended to increase progressing downstream in both spring and fall sample seasons regardless of adjacent land use (Figures 4 and 5). Other biological

Figure 4: Peruque Creek Total Taxa

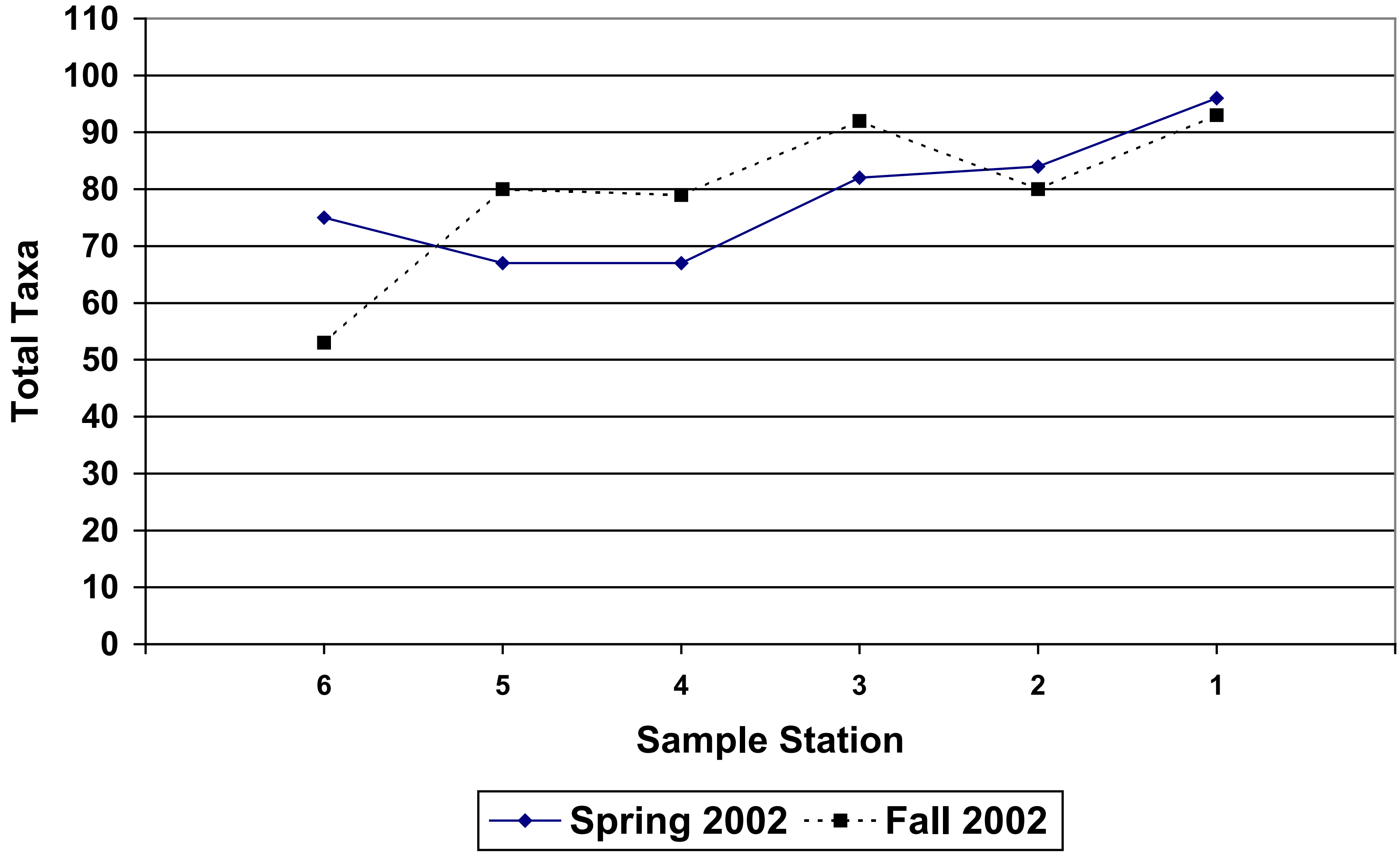
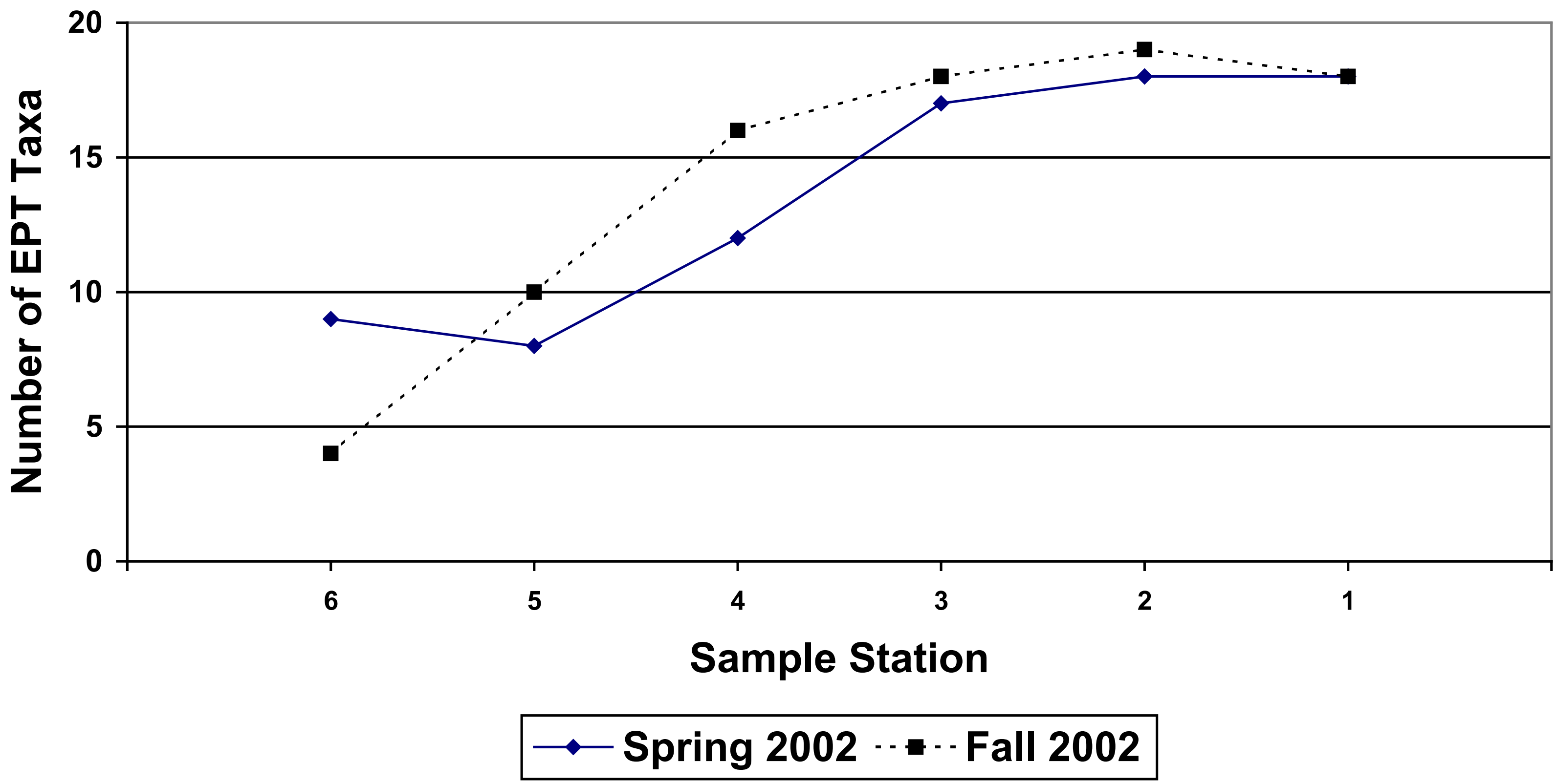


Figure 5: Peruque Creek EPT Taxa



indices and the SCI followed this trend during both sample seasons. Lowest numbers were observed in upstream stations, gradually increasing downstream (Tables 9 and 10).

Table 9
Peruque Creek Metric Values and Scores, Spring 2002 Season, Using Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Biocriteria

Site #	TT	EPTT	BI	SDI	SCI	Support
#6 Value	75	9	8.01	2.66		
#6 Score	3	3	3	3	12	**Partial**
#5 Value	67	8	7.85	2.60		
#5 Score	3	3	3	3	12	**Partial**
#4 Value	67	12	8.19	2.19		
#4 Score	3	3	1	3	10	**Partial**
#3 Value	82	17	7.25	3.05		
#3 Score	5	3	3	3	14	**Partial**
#2 Value	84	18	6.81	3.30		
#2 Score	5	5	3	5	18	**Full**
#1 Value	96	18	7.07	3.37		
#1 Score	5	5	3	5	18	**Full**

Table 10
Peruque Creek Metric Values and Scores, Fall 2002 Season, Using Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Biocriteria

Site #	TT	EPTT	BI	SDI	SCI	Support
#6 Value	53	4	7.77	3.10		
#6 Score	3	1	3	5	12	**Partial**
#5 Value	80	10	7.49	3.07		
#5 Score	5	3	3	5	16	**Full**
#4 Value	79	16	6.93	3.11		
#4 Score	5	3	3	5	16	**Full**
#3 Value	92	18	7.11	3.50		
#3 Score	5	3	3	5	16	**Full**
#2 Value	80	19	6.72	3.29		
#2 Score	5	5	3	5	18	**Full**
#1 Value	93	18	6.54	3.58		
#1 Score	5	3	3	5	16	**Full**

During the spring 2002 sample season, only the two downstream sample sites (Stations 1 and 2) were fully supporting, whereas the remainders were partially supporting. During the fall 2002 sample season, however, all but Station 6 achieved a fully supporting ranking. During fall sampling, Station 6 was nearly devoid of flow and the existing water was restricted to isolated pools.

5.4.2 Comparisons of Peruque Creek and North Fork Cuivre River versus Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Biological Criteria

Metrics calculated for Peruque Creek and North Fork Cuivre River were compared to biological criteria from the PMSD EDU Biocriteria Reference Sites. These criteria are listed for the spring and fall sampling seasons in Tables 11 and 12, respectively. This comparison was made to assess the degree to which using biological criteria was applicable for Peruque Creek and North Fork Cuivre River. Most of the biocriteria reference streams are fourth and fifth order, whereas Peruque Creek and North Fork Cuivre River survey sites were second and third order. Larger streams may have more available habitat and higher numbers of macroinvertebrate taxa and diversity than smaller streams.

Table 11
Biological Criteria for Warm Water Reference Streams in the Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Spring Season

	Score = 5	Score = 3	Score = 1
TT	>78	78-39	38-0
EPTT	>17	17-8	7-0
BI	<6.20	6.20-8.10	8.11-10
SI	>3.19	3.19-1.60	1.50-0

Table 12
Biological Criteria for Warm Water Reference Streams in the Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Fall Season

	Score = 5	Score = 3	Score = 1
TT	>76	76-38	37-0
EPTT	>18	18-9	8-0
BI	<6.34	6.34-8.17	8.18-10
SI	>3.00	3.00-1.50	1.40-0

The four metrics calculated for the spring and fall sample seasons at Peruque Creek (Tables 9 and 10) and North Fork Cuivre River (Tables 13 and 14) were roughly comparable to the biological criteria reference metrics; however some seasonal differences were observed. During the spring season at the upper three stations of Peruque Creek, all four metric values were poorer than the reference metrics. With the exception of the Biotic Index metric, the scores of the downstream two stations exceeded the reference metrics and were the only stations categorized as fully supporting for aquatic life. Each had Stream Condition Index scores of 18. During the spring season at North Fork Cuivre River, only the Total Taxa metric at the upstream station exceeded the reference metrics. Both North Fork Cuivre River sites were categorized as partially supporting for aquatic life.

Table 13
North Fork Cuivre River Metric Values and Scores, Spring 2002 Season, Using Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Biocriteria

Site #	TT	EPTT	BI	SDI	SCI	Support
#2 Value	84	12	7.17	2.87		
#2 Score	5	3	3	3	14	**Partial**
#1 Value	73	13	6.69	2.83		
#1 Score	3	3	3	3	12	**Partial**

Table 14
North Fork Cuivre River Metric Values and Scores, Fall 2002 Season, Using Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Biocriteria

Site #	TT	EPTT	BI	SDI	SCI	Support
#2 Value	72	13	7.33	3.11		
#2 Score	3	3	3	5	14	**Partial**
#1 Value	79	12	7.35	3.23		
#1 Score	5	3	3	5	16	**Full**

During the fall sample season, scores from all but the uppermost Peruque Creek site were sufficient to merit a fully supporting ranking. Relative to the other sites, Peruque Creek Station 6 was lacking in Total Taxa and EPT Taxa, dropping it to a partially supporting ranking. Metrics among North Fork Cuivre River sample sites during the fall season were similar, except that Total Taxa at the upstream site was slightly lower. This difference resulted in the upstream site receiving a partially supporting score, whereas the downstream site was categorized as fully supporting.

5.4.3 Macroinvertebrate Percent and Community Composition

The number of macroinvertebrate total taxa, EPT Taxa, and percent EPT for Peruque Creek and North Fork Cuivre River are presented in Tables 15 and 16. These tables also provide percent composition data for the five dominant macroinvertebrate families at each sample station. The percent of relative abundance data were averaged from the sum

Table 15 : Spring 2002 Peruque Creek and North Fork Cuivre River Macroinvertebrate Composition

	Peruque Creek Test Stations						North Fork Cuivre River Control Stations	
Variable-Station	6	5	4	3	2	1	2	1
Total Taxa	75	67	67	82	84	96	84	73
Number EPT Taxa	9	8	12	17	18	18	12	13
% Ephemeroptera	6.4	6.1	15.7	6.3	9.1	8.9	18.8	18.7
% Plecoptera	0.5	0.3	1.2	6.2	6.2	1.8	0.2	0.8
% Trichoptera	0.5	0.5	1.2	1.4	0.6	1.4	0.7	0.5
% Dominant Families								
Chironomidae	71.4	65.8	70.3	63.4	56.6	56.2	61.1	67.1
Tubificidae	7.9	8.1	2.8	-	-	4.6	9.6	2.5
Elmidae	5.9	11.0	-	-	6.3	8.1	3.4	6.0
Caenidae	4.3	5.0	15.3	4.8	-	3.4	15.2	12.9
Planorbidae	1.0	-	-	-	-	-	-	-
Enchytraeidae	1.0	-	1.3	-	-	-	-	-
Baetidae	1.0	-	-	-	3.7	-	-	3.4
Heptageniidae	1.0	-	-	-		-	2.8	-
Crangonyctidae	-	3.4	-	-	-	-	-	-
Hydrophilidae	-	-	1.5	-	-	-	-	-
Tipulidae	-	-	1.3	-	-	-	-	-
Ceratopogonidae	-	-	-	2.8	-	-	-	-
Lumbricidae	-	-	-	3.7	5.8	-	-	-
Perlodidae	-	-	-	3.3	-	-	-	-
Hyalellidae	-	-	-	-	4.1	3.9	-	-

Table 16 : Fall 2002 Peruque Creek and North Fork Cuivre River Macroinvertebrate Composition

	Peruque Creek Test Stations						North Fork Cuivre River Control Stations	
Variable-Station	6	5	4	3	2	1	2	1
Total Taxa	53	80	79	92	80	93	72	79
Number EPT Taxa	4	10	16	18	19	18	13	12
% Ephemeroptera	2.8	9.9	33.0	29.6	36.0	21.9	22.4	15.0
% Plecoptera	-	-	-	-	-	0.1	-	-
% Trichoptera	0.8	2.2	14.3	2.3	12.3	18.6	1.8	2.5
% Dominant Families								
Chironomidae	38.0	20.8	26.0	27.6	10.7	19.2	27.7	19.2
Elmidae	12.8	12.4	-	5.9	-	8.4	4.3	18.0
Planorbidae	10.5	6.8	-	-	-	-	-	-
Hyalellidae	9.4	-	8.7	8.4	10.9	-	-	-
Physidae	8.5	24.1	-	-	-	-	6.1	7.6
Heptageniidae	-	7.8	-	-	-	-	-	-
Caenidae	-	-	23.4	19.6	18.8	10.1	19.3	9.2
Hydropsychidae	-	-	7.1	-	7.0	8.1	-	-
Philopotamidae	-	-	5.6	-	-	8.4	-	-
Coenagrionidae	-	-	-	5.5	-	-	-	-
Tricorythidae	-	-	-	-	9.6	-	-	-
Baetidae	-	-	-	-	-	-	-	-
Ancylidae	-	-	-	-	-	-	17.3	-
Tubificidae	-	-	-	-	-	-	-	17.3

of the three macroinvertebrate habitats (coarse substrate, nonflow, and rootmat) sampled at each station. Spring 2002 macroinvertebrate samples from Peruque Creek Station 6, the uppermost sample station, contained 75 total taxa and 9 EPT Taxa (Table 15). Peruque Creek Station 1, the most downstream sample station, contained 96 total taxa and 18 EPT Taxa. Midge larvae (Chironomidae) were the dominant taxa at all sites, comprising a smaller percentage of the whole at the lower two stations. Square gill mayflies (Caenidae) were among the top five taxa at all sites except Peruque Creek Station 2. Riffle beetles (Elmidae) and aquatic worms (Tubificidae) both were present among the top five taxa at four of the six sites. Stonefly (Plecoptera) and caddisfly (Trichoptera) taxa were present in all spring samples; however only Station 3 had perlodid stoneflies (Perlodidae) among the five dominant taxa.

During the fall 2002 sample season, total taxa at Peruque Creek Station 6 dropped to 53 and EPT Taxa fell to 4, likely due to a lack of coarse substrate habitat at this site (Table 16). At Station 1, however, total taxa were relatively unchanged at 93 and EPT remained at 18. The proportion that mayflies (Ephemeroptera) and caddisflies contributed to the sample, however, increased greatly in the fall samples. This trend was especially true for the lower four stations where mayflies made up between 21.9 and 36.0 percent of the samples. With the exception of Station 3, caddisflies also were a major contributor to the total count at the lower four stations, comprising between 12.3 to 18.6 percent of samples. Peruque Creek Station 3, where caddisflies comprised 2.3 percent of the total sample, was most similar in this respect to Station 5, where caddisflies made up 2.2 percent of the sample. Chironomids contributed a much lower percentage of samples during the fall, but still were the dominant taxa at all but Station 5 and Station 2. At Station 5, physid snails (Physidae) were the dominant taxa (24.1 percent); caenid mayflies were the dominant taxa at Station 2 with 18.8 percent. Caenid mayflies were second in abundance only to chironomids at each of the four downstream Peruque Creek sample stations, except Station 2 where they were dominant. Elmid beetles, caenid mayflies, and scuds (Hyalellidae) each were among the five dominant taxa at four of the six sample sites. With the exception of a single common stonefly (Perlidae) collected at Peruque Creek Station 1, there were no stoneflies included in any of the fall samples.

Spring 2002 macroinvertebrate samples from North Fork Cuivre River, the control stream, exhibited roughly similar total taxa compared to Peruque Creek as a whole. The number of EPT Taxa was similar to the upper reaches of Peruque Creek where fewer EPT Taxa were documented. The proportions of mayflies in the North Fork Cuivre River samples, however, were much higher than Peruque Creek with mayflies comprising nearly 19 percent of samples at both stations. Chironomids were the dominant taxa at both sites, followed by caenid mayflies. Aquatic worms and riffle beetles also were included among the five dominant taxa. Although stoneflies and caddisflies were represented at both North Fork Cuivre River sites, neither were present in abundance and both comprised less than one percent of individuals in samples.

During the fall 2002 sample season, total taxa and EPT Taxa at North Fork Cuivre River again were comparable to the upper Peruque Creek stations. As was observed at Peruque

Creek fall samples, chironomids were dominant at both sites, but at much lower percentages. Riffle beetles and aquatic worms were nearly as abundant as chironomids at North Fork Cuivre River Station 1. At Station 2, caenid mayflies and limpet snails (Ancylidae) were second and third in abundance, respectively. Caddisflies were present in samples from both sites, but in relatively low abundance. Although several caddisfly genera were found in samples, *Cheumatopsyche*, was dominant among Trichoptera taxa. No stoneflies were collected at North Fork Cuivre River during the fall sample season.

Macroinvertebrate data for three PMSD EDU biocriteria reference streams sampled between spring 1999 and fall 2002 are presented in Table 17. For consistency, two samples from North River, which had been sampled as a glide-pool regime, and a sample collected from South Fabius River, which had no nonflow habitat, were excluded.

Total taxa for the biocriteria reference streams ranged from 78 to 85 during spring and from 66 to 82 during fall samples. Total EPT Taxa ranged from 17 to 22 in spring samples and from 14 to 21 during fall. No distinct trends were apparent among sites with respect to percent Ephemeroptera. Among South River samples, percent Ephemeroptera was slightly higher in fall samples compared to those collected in the spring, but was fairly stable among samples collected in 1999 and 2000. In South River fall 2002 samples, however, mayflies were nearly twice as abundant compared to spring samples of previous years. Mayflies comprised nearly half of individuals in the spring 1999 sample collected at South Fabius River, but were relatively sparse in fall 2001 North River samples. Caddisflies also were consistently higher in fall samples, but stoneflies were absent or nearly absent in the fall. Chironomids were more abundant in spring South River samples and were the dominant taxa in both 1999 seasons and in spring 2000. Chironomids also were the dominant taxa in South Fabius River and North River samples. Stout crawling mayflies (Tricorythidae) were the dominant taxa in South River fall samples, making up 26.1 percent of individuals in 2000 samples and 36.9 percent in 2002 samples. Chironomids and elmid beetles were among the dominant taxa for nearly all samples collected.

The fall 2002 South River sample exhibited some differences compared with samples collected from previous years at the same site. Both total taxa and EPT Taxa were lower, although one mayfly family, Tricorythidae, increased during this season, resulting in a higher relative abundance of mayflies. Also, the relative abundance of tubificid worms increased such that they were among the five dominant taxa.

5.5 Benthic Sedimentation Analysis

Percentage of benthic fine sediment was measured at each sample station on Peruque Creek and North Fork Cuivre River in July 2002. Peruque Creek Station 1 had fewer than the three riffle-pool complexes desired for sediment estimation. Subsequently, sediment estimation was based on a single quadrat at this site. At North Fork Cuivre River Station 2, only two riffle-pool complexes were available for benthic sediment

Table 17: Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU Biocriteria Reference Stream Macroinvertebrate Composition

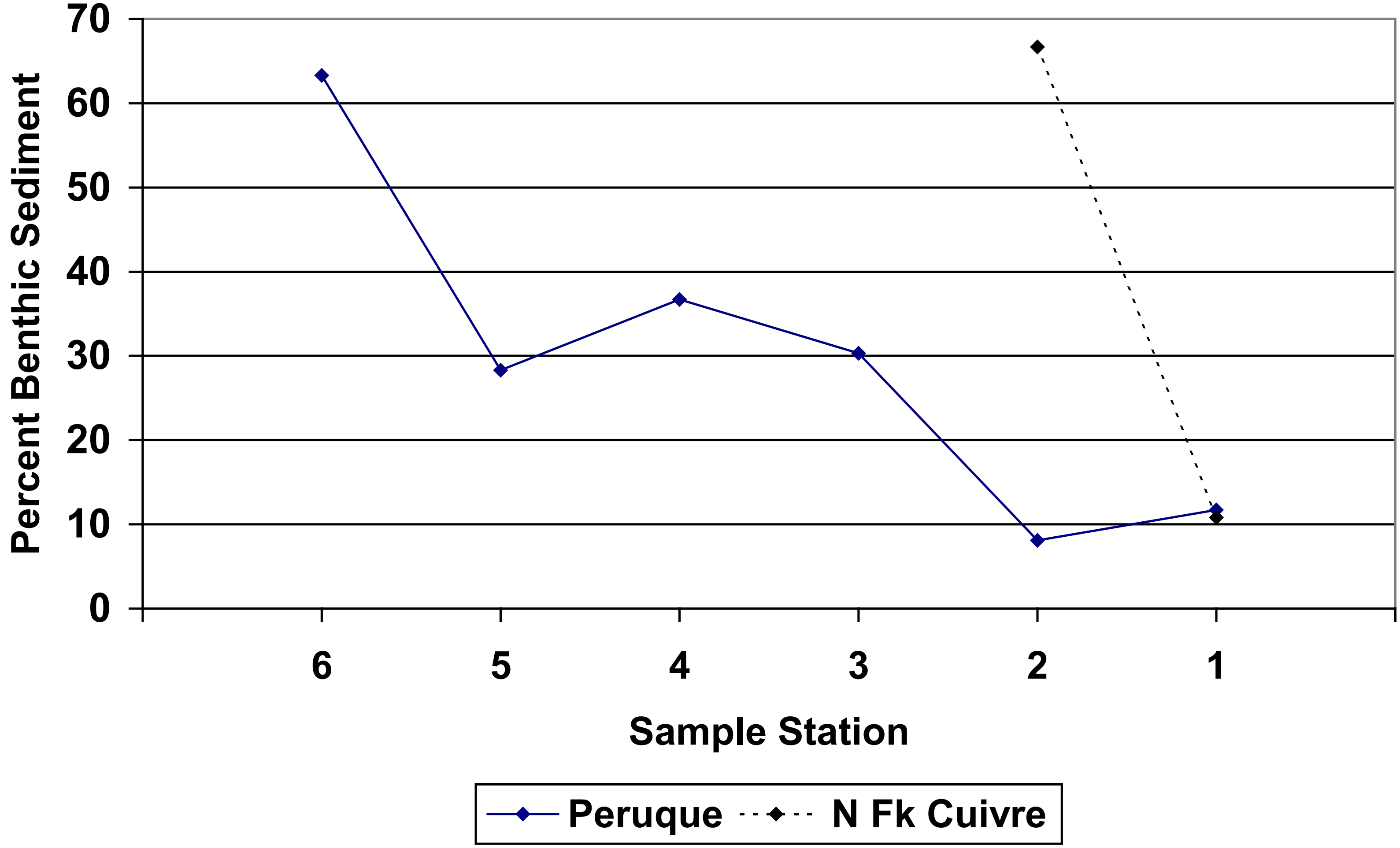
	South River		South Fabius River	South River		North River		South River
Variable-Season	Spring 1999	Fall 1999	Spring 1999	Spring 2000	Fall 2000	Fall 2001 (Station 1)	Fall 2001 (Station 2)	Fall 2002
Total Taxa	82	79	78	85	81	81	82	66
Number EPT	17	18	22	20	18	17	21	14
% Ephemeroptera	23.4	26.6	48.8	20.7	31.7	8.1	17.4	40.2
% Plecoptera	2.8	0.1	2.4	1.1	-	-	-	-
% Trichoptera	5.4	24.3	1.3	5.2	11.8	19.8	12.8	17.5
% Dominant Families								
Chironomidae	34.2	27.1	22.5	46.2	21.5	43.9	33.0	13.1
Elmidae	18.7	7.5	-	9.9	14.1	12.5	12.2	5.7
Caenidae	12.2	7.9	15.9	10.4	-	-	-	-
Tricorythidae	7.1	10.1	-	4.4	26.1	3.2	7.0	36.9
Gammaridae	3.8	-	-	-	-	-	-	-
Philopotamidae	-	10.2	-	-	-	-	-	10.5
Heptageniidae	-	-	9.0	5.1	-	-	-	-
Hydropsychidae	-	-	-	-	4.7	15.9	7.0	-
Tubificidae	-	-	7.7	-	-	-	-	6.7
Hyalellidae	-	-	-	-	6.7	-	10.8	-
Baetidae	-	-	17.8	-	-	-	-	-
Coenagrionidae	-	-	-	-	-	4.2	-	-

estimation. Mean percent fine sediment was calculated for all sites and used for statistical analysis, despite having less than the desired number of observations. Benthic sediment estimates for Peruque Creek and North Fork Cuivre River are presented in Table 18. Among Peruque Creek sample sites, mean percent sediment was highest at Peruque Creek Station 6 (63%) and tended to decrease in downstream stations (Figure 6), with the lowest percentage occurring at Station 2 (8%). Mean sediment percentage at Station 6 was significantly higher than both Stations 1 and 2 ($p<0.05$). Among Peruque Creek non-BMP sites, sedimentation at Station 4 (37%) was only significantly higher than Station 2 ($p<0.05$). No other statistically significant differences occurred among Peruque Creek sites. When using sediment estimates from North Fork Cuivre River Station 1 (11%) as a control to compare with Peruque Creek, only Peruque Creek Station 6 was significantly higher than the control ($p<0.05$).

Table 18
Percentage of Benthic Sediment Observed per Grid-Quadrat at Peruque Creek and North Fork Cuivre River Sample Stations, July 2002.

	Peruque Creek						North Fork Cuivre River	
Grid No.-Quadrat No.	Station 6	Station 5	Station 4	Station 3	Station 2	Station 1	Station 2	Station 1
1-1	100	100	30	0	0	0	90	55
1-2	70	40	45	85	10	0	100	30
1-3	75	95	50	5	5	50	100	15
1-4	10	20	30	5	5	0	100	0
1-5	45	5	100	0	5	0	80	10
1-6	100	5	85	15	10	20	100	15
2-1	75	5	5	70	5	----	90	5
2-2	50	10	10	35	0	----	5	5
2-3	20	15	5	15	100	----	0	5
2-4	35	5	20	100	0	----	5	20
2-5	30	0	80	100	5	----	30	0
2-6	40	0	10	100	0	----	100	15
3-1	100	30	5	5	0	----	----	5
3-2	100	100	10	0	0	----	----	5
3-3	85	5	60	5	0	----	----	5
3-4	100	0	5	0	0	----	----	0
3-5	5	50	15	5	0	----	----	0
3-6	100	25	95	0	0	----	----	5
Mean	**63**	**28**	**37**	**30**	**8**	**12**	**67**	**11**

Figure 6: Peruque Creek and North Fork Cuivre River Benthic Sediment Estimates



Sediment trends at North Fork Cuivre River may be similar to those observed at Peruque Creek. The highest fine sediment estimate was observed at the upstream site, Station 2 (67%), compared to 11% observed at the downstream site at Station 1. The relatively high sedimentation at North Fork Cuivre River Station 2 was comparable only to Peruque Creek Station 6. North Fork Cuivre River Station 2 sedimentation was most similar to the two downstream stations on Peruque Creek.

6.0 Discussion

Although some of the differences among water quality parameters can be attributed to seasonality, results from Peruque Creek and North Fork Cuivre River indicated important differences both among sample stations and between streams. Dissolved oxygen, turbidity, and NO_2+NO_3-N were higher in most spring samples at all sites. Other nutrients were not perceptibly different in spring versus fall samples.

When anomalous water quality results were noted in fall samples, many were associated with Station 5, which was located downstream from the Wright City WWTF. Conductivity, TKN, phosphorus, and chloride readings from Station 5 were all higher than those from samples collected upstream or downstream. Compared to samples collected at other Peruque Creek sites, each of these parameters from Station 5 were considerably higher in the fall samples. During the spring however, TKN and phosphorus were elevated, but chloride was comparable to other sites. Concentrations of NO_2+NO_3-N were higher in spring North Fork Cuivre River samples when compared to Peruque Creek stations. This observation is likely associated with the amount of cattle observed grazing in the watershed.

The highest fecal coliform concentrations consistently occurred at the Pointe Prairie site, which was located downstream of WWTFs from Wright City and Foristell. Based on design flow, the Wright City facility (350,000 gpd) is able to contribute considerably more effluent to Peruque Creek than the Foristell facility (11,700 gpd). With the exception of one extremely high reading of >6000 colony forming units (cfu), however, the fecal coliform concentration was lower by at least half at the State Road T site, which was downstream from the Wright City WWTF but upstream from the Foristell facility. Whether attenuation occurred by the time effluent reached the Hepperman Road site is questionable. Fecal coliform concentrations were actually higher in July and August in samples collected at the Hepperman Road site than at Pointe Prairie, the nearest upstream sample collection site.

Despite flowing through a watershed with greater urban influence than reference streams within the PMSD EDU (11 percent for Peruque Creek versus 1.1 percent for the EDU), habitat scores for Peruque Creek were at least 86 percent of the average of reference and control streams. A total of four Peruque Creek sites were chosen that had no active land disturbance immediately adjacent to the study reach and served as BMP sites. These sites generally had good riparian corridor widths, but other factors such as suitable substrate and water quality influences were variable. The remaining two non-BMP Peruque Creek sites were situated near ongoing land disturbance, both of which were associated with the construction of new housing developments. Land use near Station 4, upstream of State Road T, included the clearing of a hillside for home construction and a stormwater ditch leading from the construction site to Peruque Creek. At the beginning of the study, during the spring 2002 sample season, the bottom of this ditch was approximately five feet higher than the bottom of the creek. When the ditch was observed during the fall 2002 sample season, it had eroded downward nearly two vertical feet. Peruque Creek Station 3 at Hepperman Road was also situated near an ongoing housing development. In addition, a golf course had been built between the subdivision and the creek. The creek at this study site had undergone considerable changes likely due to heavy stormwater runoff during the late spring and summer months of 2002. For example, at the outfall of a discharge pipe (12 to 18 inch diameter) leading from the golf course, stormwater had cut a gully approximately three feet deep through a gravel bar that parallels Peruque Creek on the right descending bank. A silt fence, which appeared to have come from the development site, was observed partially buried in the gully and stretching down into the creek.

Despite the observations described above, land use immediately adjacent to study sites appeared to have little discernible effect on the Peruque Creek macroinvertebrate community at the time of this study. Numbers of total taxa and EPT Taxa tended to increase while progressing downstream, a trend consistent among seasons. During the spring sample season, both non-BMP sites achieved a rating of partially supporting, as did each station upstream. Downstream from these sites, however, the remaining stations were fully supporting for biological life. During the fall season, each of the lower five stations was fully supporting, regardless of land use. Aquatic habitat availability likely played a more important role in determining the overall sustainability score among sites. Sites where macroinvertebrate numbers were poorest tended to have more bedrock as benthic substrate. At these sites, particularly at Stations 5 and 2, substrate types commonly sampled for nonflow and coarse substrate habitats were somewhat sparse. Coupled with habitat availability was the issue of flow status. Although each site except Station 6 (which was reduced to isolated pools) achieved the status of fully supporting, very little flowing water was present at many of the sites during the fall sample season. It is, therefore, curious that so many of the stations along Peruque Creek (i.e., the four upstream stations) only achieved a partially supporting rating during the spring sample season when flow was abundant. One explanation may be that high spring flows had possibly been sufficient to scour the stream bottom prior to sampling, resulting in lower insect numbers at Peruque Creek sites. Another may be that materials that accumulate over the winter on impervious surfaces (e.g. roads and parking lots) may be carried into the creek by runoff associated with snowmelt and early spring rains, which may have a negative effect on the macroinvertebrate community.

Relative to adjacent land use, no changes in benthic sedimentation among study sites was observed. Although erosion associated with land disturbance was observed at two Peruque Creek sample stations, sedimentation was not higher at either site or at downstream stations. Given the changes observed in some stream characters that took place during the spring and summer of 2002 (e.g. elimination of gravel bars, downed trees), it is likely that sediment entering the stream during this time remained entrained through the study reach and was not deposited. In addition, bedrock was common at many of the study sites, which may reduce the amount of instream sediment deposition.

A notable characteristic of the macroinvertebrate data is the large increase Chironomidae taxa contribute to the spring samples compared to fall. Whereas chironomids comprise an average of 23.7 percent of individuals among Peruque Creek fall samples (range 10.7-38.0), they averaged 64 percent in spring samples (range 56.2-71.4). This increase in the proportion of chironomid taxa also was observed in North Fork Cuivre River samples, the local control site. At the bioreference sites for which spring and fall data are available, this trend appears to be variable. During the 2000 season at South River for example, chironomids made up 46.2 percent of samples in spring 2000, but only 21.5 percent in fall. In 1999 there was less of a discrepancy among seasons, with chironomids comprising 34.2 percent of samples in spring and 27.1 percent in fall. Although the relative contribution of chironomids in fall samples was less, they remained among the five most dominant taxa. Mayflies, however, made a more substantial contribution to the sample in fall, especially in the downstream four stations. At Peruque Creek Station 5, the relatively pollution-tolerant physid snails (*Physa* sp.), which have a biotic index value of 9.1 (with 10 being most tolerant), were the dominant taxa. At the remaining downstream stations, chironomids and caenid mayflies were most abundant.

7.0 Summary

1. In determining whether adjacent land practices directly impacted Peruque Creek, none of the factors studied-macroinvertebrate biological metrics and sustainability scores, water chemistry, fecal coliform concentrations, benthic sedimentation, nor habitat scores-were noticeably different at Peruque Creek BMP sites compared to non-BMP sites. Based on our observations, therefore, we are unable to reject the first five null hypotheses of the study. Conclusions for the remaining five hypotheses, comparing Peruque Creek with reference streams within the PMSD EDU, were variable.

2. Water quality samples collected at Peruque Creek Station 5, located downstream from the Wright City WWTF, exhibited higher TKN and phosphorus concentrations than samples collected at other sites. During the fall sample season, each of the following parameters was elevated at Station 5: NO_2+NO_3-N; TKN; phosphorus; and chloride.

3. Water quality samples collected at both North Fork Cuivre River stations had elevated levels of NO_2+NO_3-N during the spring season. Although levels were lower in fall samples, NO_2+NO_3-N concentrations at North Fork Cuivre River remained higher than all Peruque Creek sites except Station 5.

4. Peruque Creek fecal coliform concentrations tended to be highest at the Pointe Prairie monitoring site, which is downstream from both Wright City and Foristell WWTFs.

Fecal coliform levels at North Fork Cuivre River sites were consistently higher than at Peruque Creek.

5. Lack of available habitat and flow appeared to be a dominant factor affecting benthic macroinvertebrates at both Peruque Creek and North Fork Cuivre River.

6. Total taxa and EPT Taxa tended to increase in downstream Peruque Creek stations. Fall sample season trends among sites for these two metrics mirrored those from spring.

7. The Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure found that during spring 2002 the macroinvertebrate community of Peruque Creek Stations 1 and 2 was fully supporting and partially supporting at the remaining upstream four sites. All Peruque Creek sample sites, with the exception of Station 6, were fully supporting during fall 2002. Although the creek at Station 6 was reduced to isolated pools, the macroinvertebrate community was partially supporting.

8. Benthic fine sediment was lower in downstream Peruque Creek stations. Sediment estimates from Station 6, however, were based on a single suitable area within the study reach. This factor may have contributed to an artificially high sediment estimate for this site.

8.0 Literature Cited

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Appendix A

Proposed Bioassessment Study Plan
Peruque Creek
January 16, 2002

Missouri Department of Natural Resources
Assessment Study Proposal
Peruque Creek, St. Charles County
January 16, 2002
Objectives

The Peruque Creek watershed originates in eastern Warren County, Missouri, with the majority occurring in St. Charles County. The downstream reach of this stream is located in a heavily developed urban area. The upper and middle portions of the watershed are rural, but are becoming increasingly urbanized as St. Louis urban sprawl continues westward. Peruque Creek was placed on the 303(d) list due to potential water quality degradation associated with urban development including stormwater runoff and likely detrimental effects on the stream channel and riparian areas. We propose, therefore, to conduct a macroinvertebrate, chemical, and physical assessment of Peruque Creek. Our objectives are to determine: 1) whether there is aquatic life impairment in the most urbanized portions of the creek relative to sections upstream; 2) whether aquatic life in Peruque Creek is impaired relative to that of regional reference streams; and 3) whether this stream is impaired due to nutrification and sedimentation from urban runoff.

Null Hypotheses

1) The macroinvertebrate assemblages will not differ between reaches of Peruque Creek where best management practices (BMPs) are in use in the watershed and reaches where poor management practices are used in the watershed.

2) Water chemistry will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used in the watershed.

3) Fecal coliform concentrations will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used in the watershed.

4) Benthic sediment percentage estimates will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used in the watershed.

5) Measures of habitat quality will not differ between reaches of Peruque Creek where BMPs are in use in the watershed and reaches where poor management practices are used in the watershed.

6) Macroinvertebrate assemblages will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers Ecological Drainage Unit (EDU).

7) Water chemistry will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU.

8) Fecal coliform concentrations will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU.

9) Benthic sediment percentage estimates will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU.

10) Measures of habitat quality will not differ between Peruque Creek and reference streams within the Plains/Mississippi Tributaries between Des Moines and Missouri Rivers EDU.

Background

Streams subjected to urban development are particularly vulnerable to water quality and habitat degradations. Water quality could be reduced by wastewater treatment plant discharges, accidental or deliberate spills, illegal dumping, and sedimentation due to increased runoff. Habitat losses often result from residential or commercial development. It is believed that the pace and extent of development in the area may threaten the biological integrity of Peruque Creek, which flows through St. Charles County. This belief has prompted a joint effort between the Missouri Department of Natural Resources (MDNR) and the Missouri Department of Conservation (MDC) to determine the current status of Peruque Creek. The MDC has collected water quality samples, fish community surveys, and has conducted habitat assessments at sites along Peruque Creek. The MDNR and MDC will continue to collect water quality, bacteriological, and biological samples from the creek.

Study Design

General: The study area includes approximately 14 miles of Peruque Creek. The upstream boundary of the Peruque Creek study area is just south of Wright City at Ruge Park; the downstream boundary is at Duello Road, west of Lake St. Louis. A total of six Peruque Creek stations will be surveyed, one/two in which BMPs are used in the watershed and four/five where poor management practices are in use. The general locations are listed in Table 1 beginning with the most downstream site.

Table 1
Peruque Creek Sample Locations

Sample Site (Station Number)	Geographic Location	Watershed Size (mi^2)
Duello Road (#1)	SW ¼ sec. 32, T. 47 N., R. 2 E.	43
Wilmer Road (#2)	NE ¼ NE ¼ sec. 35, T. 47 N., R. 1 E.	35
Hepperman Road (#3)	Sur. 149, T. 47 N., R. 1 E.	24
State Road T (#4)	W ½ sec. 30, T. 47 N., R. 1 E.	18
Archer Road (#5)	SW ¼ SW ¼ sec. 23, T. 47 N., R. 1 W.	9
Ruge Park (#6)	W ½ sec. 22, T. 47 N., R. 1 W.	5

Peruque Creek is in a geologic and soil transition area where the Ozark/Moreau/Loutre EDU and the Plains/Mississippi tributaries between the Des Moines and Missouri Rivers EDU converge. Biological, chemical, bacteriological, and habitat comparisons will be made between the sample locations on Peruque Creek and two sites on North Fork Cuivre River, a local reference stream. In addition biological, chemical, bacteriological, and habitat comparisons will be made between the stations on Peruque Creek, North Fork Cuivre River, and three regional biocriteria reference streams.

Biological Sampling: Each macroinvertebrate station will consist of a length approximately 20 times the average stream width, and will contain at least two riffle areas. To assess variability among sampling stations, stream discharge measurements, water quality samples, and habitat assessments will be recorded during macroinvertebrate surveys. Sampling will be conducted during spring 2002 (March 15 through April 15) and fall 2002 (September 15 through September 30).

Macroinvertebrates will be sampled according to the guidelines of the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP). Peruque Creek will be considered a "riffle/pool" dominated stream, with samples to be collected from flow over coarse substrate, depositional (non-flow), and rootmat habitats. Each macroinvertebrate sample will be a composite of six subsamples within each habitat. Fish community surveys also have been conducted at each of the six sample sites and that information will be shared with MDNR.

Water Quality Sampling: Water quality samples will be collected on alternate weeks by MDC personnel from March 1, 2002 through September 30, 2002 at three locations on Peruque Creek and two sites on North Fork Cuivre River. The samples will be collected per MDNR-FSS-001 (Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Considerations) and MDNR-FSS-002 (Field Sheet and Chain-of-Custody Record). All water samples will be analyzed for ammonia-nitrogen, nitrite- and nitrate-nitrogen, total Kjeldahl nitrogen, total phosphorus, chloride, turbidity, and total and volatile suspended solids. Stream discharge measurements also will be taken at the time of sample collection using a Marsh-McBirney flow meter per MDNR-FSS-113.

In addition to the collection of water samples by MDC staff, MDNR water quality personnel will collect water samples at the time of each macroinvertebrate sampling event. These samples also will be collected per MDNR-FSS-001 and MDNR-FSS-002. The samples will be analyzed for ammonia-nitrogen, nitrite- and nitrate-nitrogen, total Kjeldahl nitrogen, total phosphorus, chloride, turbidity, and total and volatile suspended solids. Field measurements will be taken at the time of water sample collection and will include pH (per MDNR-FSS-100), temperature (per MDNR-FSS-101), conductivity (per MDNR-FSS-102), dissolved oxygen (per MDNR-FSS-103), and stream discharge using a Marsh-McBirney flow meter (per MDNR-FSS-113).

MDNR water quality personnel also will collect water samples at three sites on Peruque Creek and two sites on North Fork Cuivre River for fecal coliform analysis. They will collect three replicate samples each month from June through September 2002. Samples will be collected four times during this low flow period, at least two weeks apart. All samples will be collected and processed in accordance MDNR-FSS-108 (Field Analysis of Fecal Coliform Bacteria).

MDC personnel will collect water samples twice during storm events. Samples will be collected immediately after rainfall events greater than one inch and analyzed by the MDNR Environmental Service Program (ESP) laboratory for volatile suspended solids and nonfilterable residues. MDNR personnel also will provide technical assistance to MDC personnel regarding collection of these samples.

Benthic Sediment Percentage: To ensure uniformity in estimating benthic sediment percentage, depositional areas will be sampled instream at the upper margins of pools and lower margins of riffle/run habitat. Depths of the sample areas will not exceed two (2.0) feet and water velocity will be less than 0.5 feet per second (fps). A Marsh-McBirney flow meter will be used to ensure that water velocity of the sample area is within this range.

Instream deposits of fine sediment [i.e., less than particle size of approximately 2 mm (coarse sand)] will be estimated for percent coverage per area. A visual method will be used to estimate the percentage of fine sediment. A total of three fine sediment sample areas (grids) will be set up at each water quality/macroinvertebrate sample site. The sample areas will consist of six contiguous transects across the stream. A tape measure will be placed directly on the substrate within each of the six transects using a random number that equates to one-foot increments. The trailing edge of the quadrat will be placed on the random foot increment. Two MDNR water quality personnel will estimate the percentage of the stream bottom covered by fine sediment within each quadrat. If estimated percentages are within ten percent between the MDNR personnel, it will be accepted. If estimates diverge more than ten percent, they will repeat the process until the estimates are within the acceptable margin of error. An average of these two estimates will be recorded and used for analysis.

Habitat Sampling: Stream habitat assessments were conducted by MDC personnel at each of the fish study sites following the Regional Environmental Monitoring and Assessment Program (REMAP) protocol in conducting the assessments.

Laboratory Methods: All water quality samples will be analyzed at the MDNR ESP laboratory. The samples of macroinvertebrates will be processed and identified per MDNR-FSS-209 (Taxonomic Levels for Macroinvertebrate Identification).

Data Recording and Analyses: Macroinvertebrate data will be entered in a Microsoft Access database in accordance with MDNR-WQMS-214 (Quality Control Procedures for Data Processing). Data analysis is automated within the Access database. A total of four standard metrics will be calculated for each sample reach according to the SMSBPP: Total Taxa (TT); Ephemeroptera, Plecoptera, Trichoptera Taxa (EPTT); Biotic Index (BI); and the Shannon Index (SI). Additional metrics, such as Quantitative Similarity Index for Taxa (QSI-T) or Percent Scrapers (PS), may be used to discern differences in taxa between control and impacted stations.

Macroinvertebrate data will be analyzed in three specific ways. First, a comparison of metrics will be made between sample reaches on Peruque Creek where best and poor management practices are in use. Data will be summarized and presented in bar graphs comparing means of the four standard metrics (and other biological parameters) among the six study reaches. Second, Peruque Creek data will be compared to that collected at a local reference stream site (North Fork Cuivre River). Finally, both Peruque Creek and North Fork Cuivre River data will be compared to historic and current data collected at three regional reference sites (North River, South River, and South Fabius River).

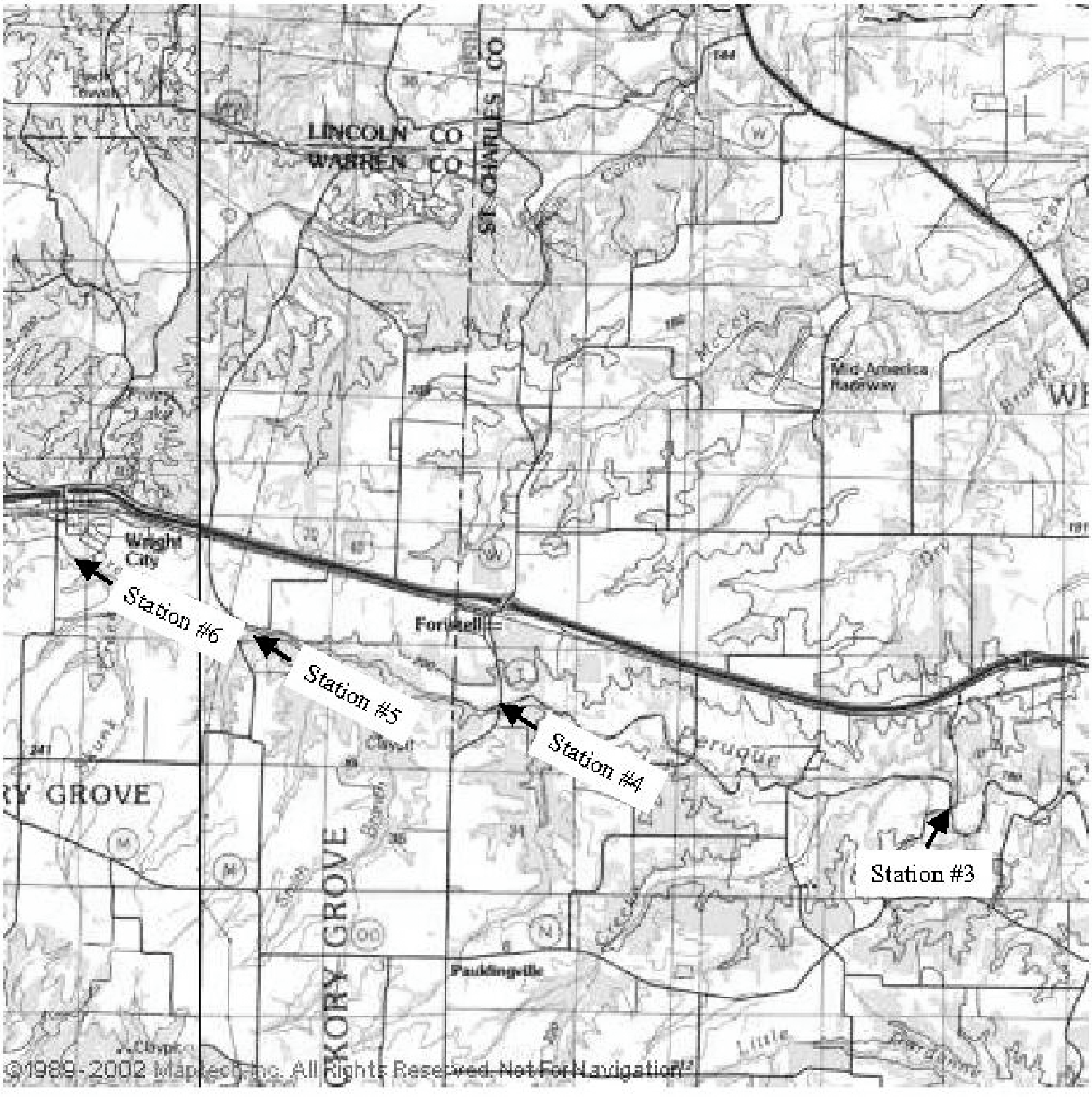
Ordination of macroinvertebrate data may be performed and regression analysis used to examine potential associations with water chemistry and habitat data. Habitat, fish community, and water quality data also will be used to help interpret macroinvertebrate data.

Water quality data will be entered in the Laboratory Information Management System (LIMS) database. Data analysis will be summarized and interpreted using Microsoft Access and Excel software as well as Jandel Scientific software, SigmaStat.

Data Reporting: Results of the study will be summarized and interpreted in report format.

Quality Control: As stated in the various MDNR Project Procedures and Standard Operating Procedures.

Attachments: Map of Peruque Creek sampling stations.



LINCOLN CO
WARREN CO
ST. CHARLES CO
Mid-America Raceway
Wright City
Foristell
Peruque
Paulingsville
RY GROVE
CKORY GROVE
Station #6
Station #5
Station #4
Station #3
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Peruque Creek
St. Charles County, Missouri
Downstream Sampling Stations

Appendix B

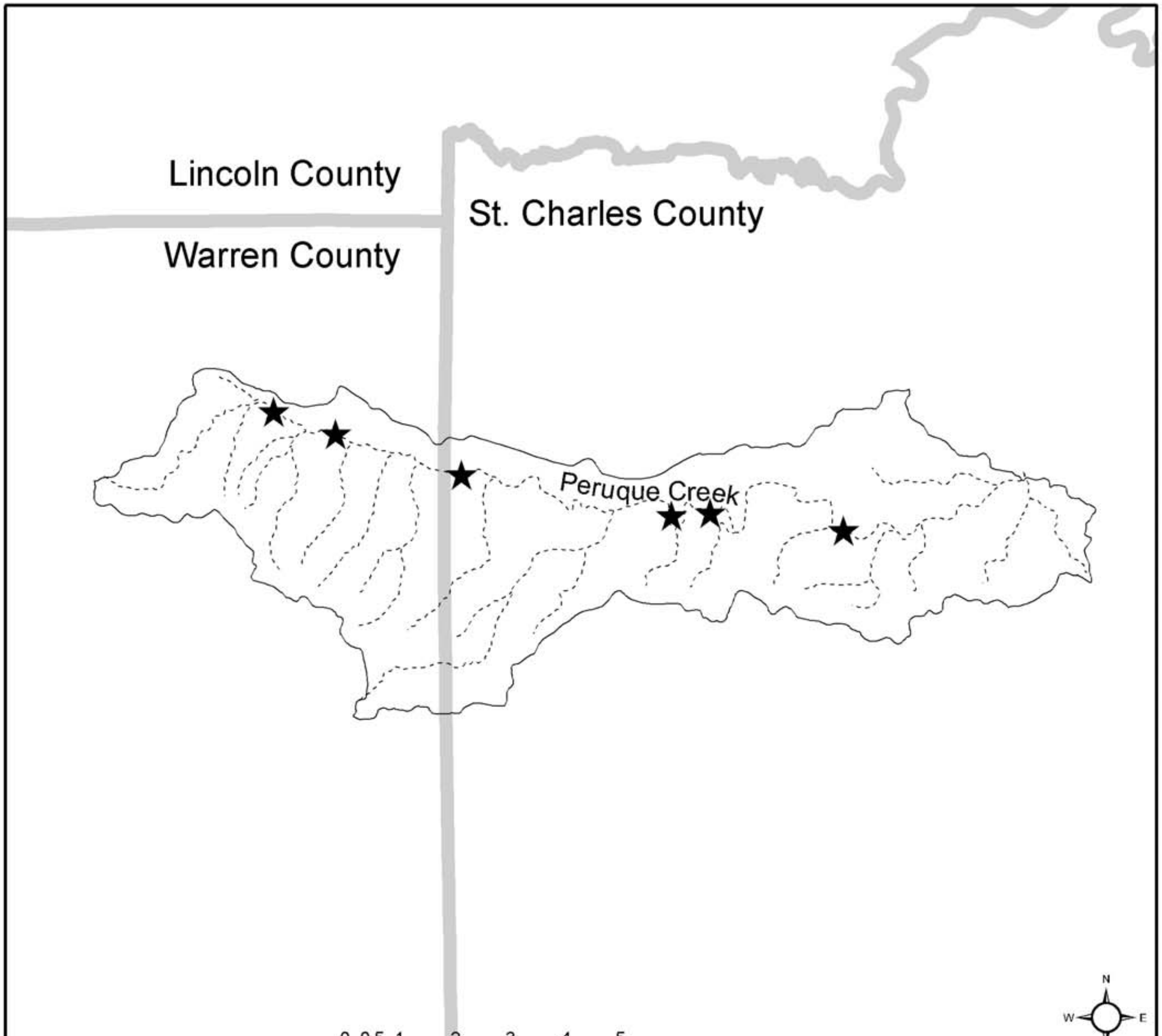
Maps

Peruque Creek
Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU

&

North Fork Cuivre River
Plains/Mississippi Tributaries between the Des Moines and Missouri Rivers EDU

Peruque Creek Study Site



Local Drainage

★ Sampling Location

County Boundary

Local Drainage

Stream/River

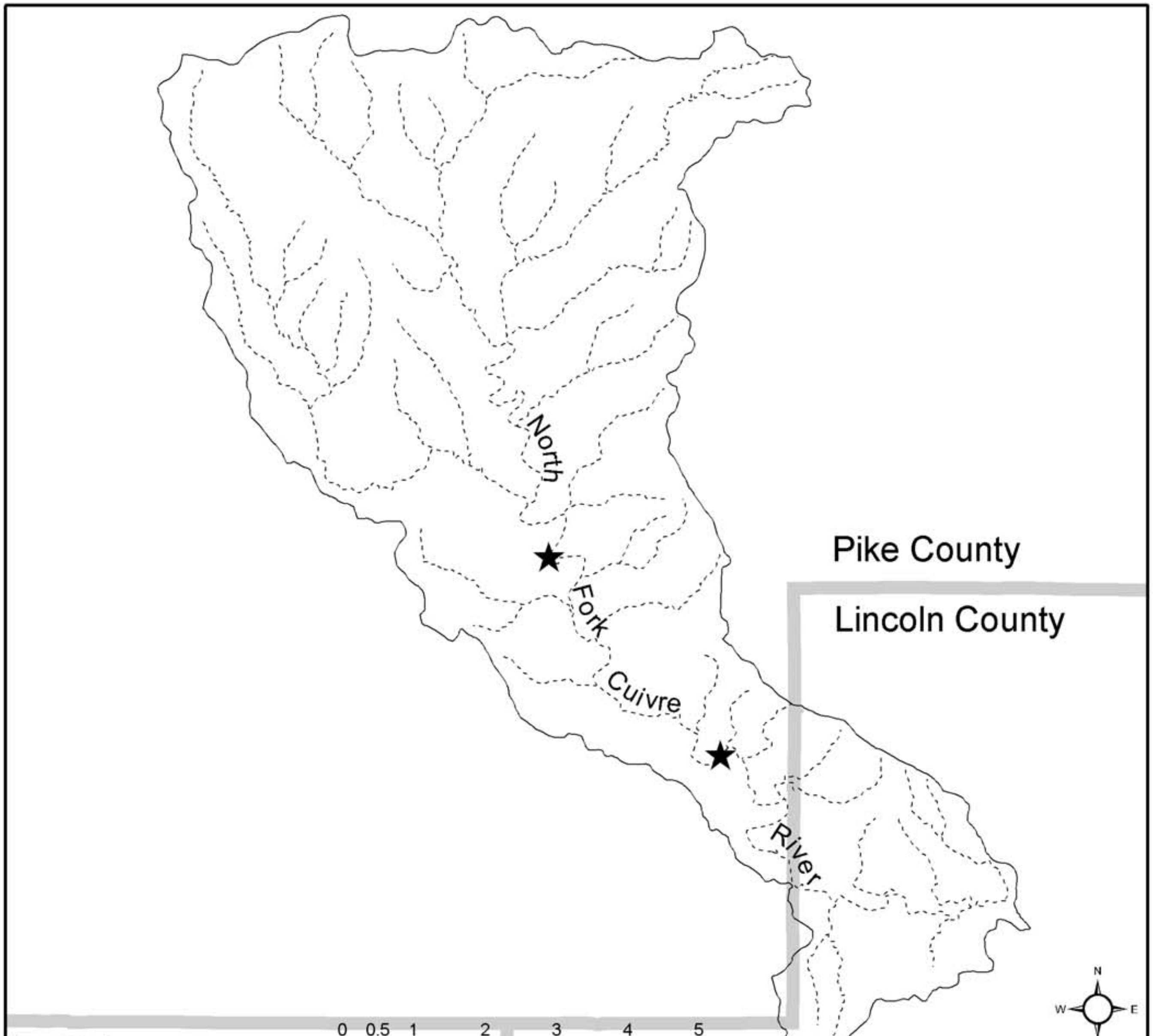
Local Drainage and Biologic Sampling Site Location

Ecolocial Drainage Unit (EDU) - An EDU is an area that contains a unique combination of habitats and organisms. Missouri is divided into 19 EDUs as shown in the inset map below. This site is located in the highlighted EDU.

Local Drainage - The local drainage area, also known as a 14 Digit Hydrologic Unit, is shown in the main map at left. This area is a portion of the local watershed. Missouri is split into over 1500 such units.

Ecological Drainage Unit

North Fork Cuivre River Study Site



Local Drainage

★ Sampling Location

County Boundary

Local Drainage

Stream/River

Local Drainage and Biologic Sampling Site Location

Ecolocial Drainage Unit (EDU) - An EDU is an area that contains a unique combination of habitats and organisms. Missouri is divided into 19 EDUs as shown in the inset map below. This site is located in the highlighted EDU.

Local Drainage - The local drainage area, also known as a 14 Digit Hydrologic Unit, is shown in the main map at left. This area is a portion of the local watershed. Missouri is split into over 1500 such units.

Ecological Drainage Unit

Appendix C

Peruque Creek and North Fork Cuivre River Macroinvertebrate Taxa Lists

Peruque Creek #1: Spring 2002

Taxa	CS	NF	RM
Acarina		3	3
Crangonyx	2		7
Gammarus			-99
Hyalella azteca			48
Erpobdellidae	1		
Berosus	1	6	
Dubiraphia		3	9
Gyretes			1
Hydrobius			1
Hydroporus			1
Peltodytes			1
Scirtes			1
Stenelmis	85	2	2
Orconectes luteus		-99	
Palaemonetes kadiakensis			2
Ablabesmyia		2	
Ceratopogoninae		37	
Chironomus		6	
Cladopelma		1	
Cladotanytarsus	1	8	
Clinocera	4		
Corynoneura		4	9
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	122	4	100
Cryptochironomus	3	10	
Dicrotendipes		1	6
Diplocladius	1		
Gonomyia	16		3
Hemerodromia	1	1	
Hexatoma	4		
Hydrobaenus	150	13	21
Krenopelopia		1	
Labrundinia			1
Nanocladius			4
Ormosia		1	
Orthocladius (Euorthocladius)	3		
Paralauterborniella		1	
Paratanytarsus		2	43
Paratendipes		16	2
Polypedilum convictum grp	2		
Polypedilum halterale grp	2	35	
Polypedilum illinoense grp			8
Polypedilum scalaenum grp		4	
Procladius		2	1
Pseudochironomus	1		1
Rheocricotopus			2
Rheotanytarsus	1		
Simulium	6		
Stempellinella		1	1
Stictochironomus	3	22	
Sympotthastia	1		
Tanytarsus	4	13	32
Thienemannimyia grp.	16	1	3
Tipula	-99		

Peruque Creek #1 (continued): Spring 2002

Tribelos		1	
Tvetenia bavarica grp	5		
Acerpenna	27		4
Caenis latipennis	6	11	17
Caenis punctata			8
Centroptilum			3
Hexagenia limbata		2	
Stenacron	4		
Stenonema femoratum	18	8	3
Ranatra fusca			-99
Caecidotea	11		1
Caecidotea (Blind & Unpigmented)	16		
Ferrissia		1	1
Menetus			7
Physella			1
Lumbricidae	12		
Sialis		-99	
Argia		1	1
Basiaeschna janata		-99	
Calopteryx			-99
Enallagma		1	19
Allocapnia	5		1
Amphinemura	1		1
Hydroperla crosbyi	-99		
Isoperla	11		
Perlesta	3		
Cernotina			1
Cheumatopsyche	-99		
Chimarra	8		
Pycnopsyche			-99
Rhyacophila	1		
Triaenodes			7
Planariidae	2		
Aulodrilus		6	
Branchiura sowerbyi	1	15	
Enchytraeidae	1	1	
Limnodrilus angustipenis		1	
Limnodrilus cervix		2	
Limnodrilus claparedianus		3	
Limnodrilus hoffmeisteri		10	
Tubificidae		19	
Sphaerium	6	4	

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present in Samples

Peruque Creek #2: Spring 2002

Taxa	CS	NF	RM
Branchiobdellida			1
Gordiidae	1		
Acarina	1	2	3
Crangonyx		18	2
Gammarus		2	6
Hyalella azteca			45
Berosus	1	2	
Dubiraphia	1	1	2
Helichus lithophilus			1
Hydroporus			3
Peltodytes			3
Stenelmis	62	1	1
Orconectes luteus	1	1	
Orconectes virilis			-99
Ablabesmyia		1	4
Ceratopogonidae		14	
Chironomus		2	
Cladotanytarsus		10	
Clinocera	8	2	
Corynoneura	12	10	17
Cricotopus bicinctus	1		4
Cricotopus trifascia	18	1	
Cricotopus/Orthocladius	104	29	46
Cryptochironomus		4	
Dicrotendipes	1	3	3
Diptera		1	
Djalmabatista		1	
Eukiefferiella brevicalcar grp	4		
Hexatoma	6		
Hydrobaenus	69	54	47
Nilotanypus	1		
Orthocladius (Euorthocladius)	17	1	
Paralauterborniella		4	
Parametriocnemus	1		
Paratanytarsus	2	4	23
Paratendipes		3	
Phaenopsectra			1
Polypedilum convictum grp	3		
Polypedilum halterale grp		11	
Polypedilum illinoense grp		1	1
Polypedilum scalaenum grp	1		
Prosimulium	3		
Simulium	1		
Stempellinella		1	
Stictochironomus	6	17	
Sympotthastia	1		
Tanytarsus	6	33	5
Thienemanniella	1		2
Thienemannimyia grp.	11	3	3
Tipulidae	1		
Tvetenia	7		
Zavrelimyia	1		
Acerpenna	20	1	4
Caenis latipennis	19		7

Peruque Creek #2 (continued): Spring 2002

Centroptilum		1	14
Hexagenia limbata		-99	
Stenacron	1	1	
Stenonema femoratum	14	14	3
Belostoma			1
Notonecta			1
Caecidotea (Blind & Unpigmented)	1		
Fossaria		1	
Menetus			1
Lumbricidae	62	1	
Corydalus	1		
Argia	3		1
Basiaeschna janata			-99
Enallagma			9
Allocapnia	3		
Amphinemura	4		
Chloroperlidae	2		
Isoperla	31		1
Perlesta	23	1	
Perlinella drymo			2
Cheumatopsyche	1		
Chimarra			1
Hydroptila	2		
Pycnopsyche			1
Rhyacophila	-99		
Triaenodes			1
Enchytraeidae	2		
Limnodrilus hoffmeisteri	1	4	
Tubificidae		9	
Sphaerium	3	1	1

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present in Samples

Peruque Creek #3a: Spring 2002

Taxa	CS	NF	RM
Crangonyx			5
Hyalella azteca		2	26
Erpobdellidae	-99		
Berosus	1	6	2
Dubiraphia		7	7
Hydroporus			1
Paracymus		1	
Peltodytes		1	7
Scirtes			6
Stenelmis	7	7	1
Ablabesmyia		8	8
Ceratopogoninae		31	1
Chaoborus		1	
Chironomus		4	
Cladotanytarsus	8	5	
Clinocera	1	2	
Corynoneura	6	2	32
Cricotopus bicinctus	1		2
Cricotopus trifascia	3		1
Cricotopus/Orthocladius	95	4	56
Demicryptochironomus	1		
Dicrotendipes	1		1
Diptera		2	
Dolichopodidae		1	
Eukiefferiella brevicalcar grp	3		
Glyptotendipes		1	
Gonomyia		3	
Hexatoma	3	3	
Hydrobaenus	226	68	37
Orthocladius (Euorthocladius)	4		
Paralauterborniella		1	
Paratanytarsus	1	2	5
Paratendipes	1	10	
Phaenopsectra		4	2
Polypedilum convictum grp	5		
Polypedilum halterale grp		6	
Polypedilum illinoense grp			3
Polypedilum scalaenum grp	9		
Procladius			1
Prosimulium	3		
Simulium	15		
Stempellinella			1
Stictochironomus		19	
Tabanus	1		
Tanytarsus	11	5	9
Thienemanniella	1		5
Thienemannimyia grp.	9		6
Tipula	-99		
Tvetenia	10		
Acerpenna	6		2
Caenis latipennis	8	9	36
Centroptilum			5
Stenacron		1	
Stenonema femoratum	1		2

Peruque Creek #3a (continued): Spring 2002

Microvelia		1	
Caecidotea		1	
Caecidotea (Blind & Unpigmented)	1		
Ancylidae	1		
Fossaria			3
Physella		2	
Lumbricidae	10	30	1
Argia		2	5
Calopteryx	-99		1
Enallagma		2	18
Nasiaeschna pentacantha			-99
Amphinemura	8		
Chloroperlidae	2		
Clioperla clio			1
Hydroperla crosbyi	1		
Isoperla	35		
Perlesta	16		2
Perlinella drymo			4
Cheumatopsyche	-99		
Chimarra	2		
Ironoquia			1
Pycnopsyche			1
Triaenodes			11
Limnodrilus claparedianus		1	
Limnodrilus hoffmeisteri		9	
Tubificidae		7	1
Corbicula	-99		
Sphaerium		1	

CS = Coarse Substrate Habitat

NF = Non-flow Habitat

RM = Rootmat Habitat

-99 = Present in Samples

Peruque Creek #3b: Spring 2002

Taxa	CS	NF	RM
Acarina			1
Crangonyx		-99	
Hyalella azteca			26
Berosus	3	3	1
Dubiraphia	1	1	1
Peltodytes		3	3
Scirtes			1
Stenelmis	24	1	1
Orconectes virilis			-99
Ablabesmyia		4	7
Ceratopogoninae	1	6	
Cladotanytarsus	4	7	
Clinocera	6	1	
Corynoneura		6	24
Cricotopus trifascia	2		
Cricotopus/Orthocladius	86	16	54
Cryptochironomus		1	
Dicrotendipes	1	2	
Diptera			1
Dolichopodidae		1	
Eukiefferiella brevicalcar grp	1		1
Gonomyia		6	
Hexatoma	11	1	2
Hydrobaenus	170	45	40
Labrundinia			1
Micropsectra			2
Nanocladius	1		
Nilothauma	1		
Orthocladius (Euorthocladius)	10		
Parametriocnemus	3		
Paratanytarsus	1		20
Paratendipes		14	1
Phaenopsectra		1	
Polypedilum convictum grp	3		2
Polypedilum halterale grp		5	
Polypedilum illinoense grp			3
Polypedilum scalaenum grp	3	2	
Pseudochironomus		2	
Rheocricotopus	1		1
Rheotanytarsus	1		1
Simulium	14		1
Stempellinella			1
Stictochironomus		9	
Tabanus	6		
Tanytarsus	12	13	18
Thienemanniella	1		3
Thienemannimyia grp.	10		11
Tvetenia	11		
Acerpenna	13		
Caenis latipennis	7	17	34
Centroptilum		2	2
Leptophlebia			1
Stenacron		2	
Stenonema femoratum	7	5	3

Peruque Creek #3b (continued): Spring 2002

Caecidotea (Blind & Unpigmented)	1		
Ancylidae	3		
Fossaria			1
Physella	1		
Lumbricidae	39	3	
Argia			3
Cordulegaster		1	
Enallagma		1	10
Hagenius brevistylus		1	
Libellulidae			1
Allocapnia	2		1
Amphinemura	11		1
Chloroperlidae	4		
Hydroperla crosbyi	-99		
Isoperla	67		
Perlesta	29		
Perlinella drymo			-99
Cheumatopsyche	9		
Chimarra	26		
Hydropsyche	1		
Pycnopsyche			-99
Triaenodes			3
Enchytraeidae	2	3	1
Limnodrilus hoffmeisteri		1	
Tubificidae	5	6	
Sphaerium	4		

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present in Samples

Peruque Creek #4: Spring 2002

Taxa	CS	NF	RM
Crangonyx	2	-99	2
Hyalella azteca			1
Erpobdellidae	-99		
Berosus	3	3	10
Dubiraphia		2	
Enochrus			1
Gyrinus			1
Peltodytes		1	1
Stenelmis	1		3
Ablabesmyia			2
Ceratopogoninae		12	
Chrysops		1	
Cladotanytarsus	1	1	
Clinocera	3		1
Corynoneura		1	4
Cricotopus bicinctus			1
Cricotopus trifascia		2	
Cricotopus/Orthocladius	22	8	30
Dicrotendipes	1		1
Diplocladius			1
Diptera	1	2	
Eukiefferiella brevicalcar grp	1		
Glyptotendipes			1
Gonomyia	1	3	2
Hexatoma	7	2	
Hydrobaenus	455	63	29
Paratanytarsus			7
Paratendipes	1	35	
Pericoma	1	1	
Polypedilum halterale grp		3	
Polypedilum illinoense grp	1		1
Polypedilum scalaenum grp	3	2	
Pseudochironomus		1	
Pseudosmittia	1	1	
Rheotanytarsus			1
Stictochironomus		58	
Tabanus		1	
Tanytarsus	1	3	14
Thienemanniella	1		1
Thienemannimyia grp.			2
Tvetenia	18		9
undescribed Empididae		1	
Zavrelimyia	1	1	
Caenis latipennis	5	34	132
Caenis punctata		1	
Stenonema femoratum	2	1	1
Aquarius			1
Microvelia			2
Fossaria			3
Lumbricidae			1
Sialis		-99	
Argia			2
Calopteryx			1
Enallagma		-99	2

Peruque Creek #4 (continued): Spring 2002

Amphinemura	1		1
Chloroperlidae	2		
Isoperla	4		
Perlesta	2	1	1
Perlinella drymo			1
Cheumatopsyche			2
Helicopsyche			1
Ironoquia			1
Triaenodes			9
Enchytraeidae	6	4	5
Limnodrilus hoffmeisteri	1	10	
Tubificidae	3	16	2
Sphaerium		2	

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present in Samples

Peruque Creek #5: Spring 2002

Taxa	CS	NF	RM
Branchiobdellida		4	1
Acarina			1
Crangonyx	3	13	23
Erpobdellidae		-99	
Cybister			1
Dubiraphia		1	
Hydrobius			1
Hydroporus			2
Peltodytes		1	5
Stenelmis	118	4	2
Tropisternus			1
Orconectes luteus	-99	-99	
Orconectes virilis			-99
Ablabesmyia		1	3
Ceratopogoninae	3	5	1
Chironomus		1	
Cladotanytarsus	1		
Clinocera	1	1	
Corynoneura	4		6
Cricotopus/Orthocladius	78	24	51
Cryptochironomus	5	1	
Dicrotendipes	1		1
Diptera		2	
Eukiefferiella	1		
Eukiefferiella brevicalcar grp	2		
Glyptotendipes			1
Hexatoma	-99		
Hydrobaenus	227	105	56
Micropsectra			1
Natarsia	2	3	1
Orthocladius (Euorthocladius)	3		
Parametriocnemus	1		1
Paratanytarsus	1		14
Paratendipes	4	24	2
Phaenopsectra			18
Polypedilum halterale grp		3	
Polypedilum illinoense grp			10
Polypedilum scalaenum grp	20	2	
Prosimulium	1		
Stictochironomus	3	32	1
Tabanus	1		
Tanytarsus	12	1	3
Thienemannimyia grp.	9		5
Tribelos			1
Tvetenia	4		
undescribed Empididae	1		
Caenis latipennis	12	21	24
Centroptilum		1	2
Stenacron	1		
Stenonema femoratum	1	4	3
Belostoma			1
Ranatra fusca			1
Ancylidae	2		1
Fossaria		1	

Peruque Creek #5 (continued): Spring 2002

Menetus			3
Physella		1	4
Chauliodes pectinicornis			1
Basiaeschna janata			2
Enallagma	1		1
Isoperla	1		
Perlesta	2		
Cheumatopsyche	2		-99
Ironoquia			4
Enchytraeidae		1	2
Limnodrilus claparedianus		2	
Limnodrilus hoffmeisteri	5	23	1
Tubificidae	26	28	7

CS = Coarse Substrate Habitat

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RM = Rootmat Habitat

-99 = Present in Samples

Peruque Creek #6: Spring 2002

Taxa	CS	NF	RM
Branchiobdellida		1	
Acarina		1	1
Hyalella azteca			4
Erpobdellidae	-99		
Agabus			1
Dubiraphia		5	4
Peltodytes		1	1
Stenelmis	49		5
Orconectes virilis		-99	1
Ablabesmyia		5	15
Ceratopogoninae	4	6	
Chaoborus		1	
Chironomus		11	
Chrysops	-99		
Cladotanytarsus		2	
Clinocera	5		
Corynoneura		2	3
Cricotopus/Orthocladius	106	13	37
Cryptochironomus		1	
Dicrotendipes		3	6
Diptera	1	4	
Eukiefferiella brevicalcar grp	4		
Glyptotendipes		1	
Gonomyia	2		
Hydrobaenus	343	57	
Mesosmittia		1	
Nanocladius		1	5
Natarsia		1	
Parachironomus	1	1	7
Parametriocnemus			1
Paratanytarsus		3	23
Paratendipes		34	
Pericoma		1	
Phaenopsectra			1
Pilaria	1	1	
Polypedilum halterale grp		13	
Polypedilum illinoense grp	1		
Polypedilum scalaenum grp	2	2	
Prosimulium			1
Stempellinella	1		1
Stictochironomus		28	
Tabanus			-99
Tanytarsus	2	4	12
Thienemannimyia grp.	3		4
Tipula	1		
Tvetenia	6		
Zavrelimyia		1	
Caenis latipennis	9	19	18
Caenis punctata		1	
Centroptilum		10	1
Stenonema femoratum	7	2	2
Ferrissia			2
Fossaria		1	1
Menetus			11

Peruque Creek #6 (continued): Spring 2002

Physella	1	-99	1
Lumbriculidae		-99	
Argia		1	1
Basiaeschna janata		-99	
Calopteryx			-99
Enallagma			8
Hetaerina		1	
Ischnura			-99
Libellulidae			2
Nasiaeschna pentacantha			-99
Progomphus obscurus		-99	
Allocapnia	2	1	
Clioperla clio	-99		
Perlesta	2		
Cheumatopsyche	-99		
Triaenodes			5
Enchytraeidae	9	1	1
Limnodrilus cervix		7	
Limnodrilus hoffmeisteri	9	27	
Tubificidae	25	16	1
Sphaerium	1		

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RM = Rootmat Habitat

-99 = Present in Samples

North Fork Cuivre River #1a: Spring 2002

Taxa	CS	NF	RM
Crangonyx			1
Hyalella azteca			9
Berosus	1		
Dubiraphia	1	3	4
Oreodytes		6	
Peltodytes		2	1
Scirtes			1
Stenelmis	71	6	1
Orconectes virilis			-99
Ablabesmyia		5	4
Ceratopogoninae		1	
Chironomus		4	
Chrysops		1	
Cladotanytarsus		22	
Corynoneura	4	3	17
Cricotopus bicinctus	8		7
Cricotopus/Orthocladius	345	9	72
Cryptochironomus	1	2	
Demicryptochironomus	1		
Diamesa	1		
Dicrotendipes	1	8	7
Eukiefferiella brevicalcar grp	10		
Glyptotendipes			2
Gonomyia		1	
Hemerodromia	2		
Hydrobaenus	4	3	7
Lipiniella		4	
Microtendipes		1	1
Nanocladius			1
Ormosia		4	
Orthocladius (Euorthocladius)	18		
Parametriocnemus	2		
Paratanytarsus	4	2	105
Paratendipes	2	17	3
Phaenopsectra		3	2
Polypedilum convictum grp	3		
Polypedilum halterale grp		2	
Polypedilum illinoense grp	1	1	
Polypedilum scalaenum grp	6	7	
Procladius		1	
Rheotanytarsus	2		5
Simulium	3		
Stempellinella	4		
Stictochironomus		59	6
Tabanus	-99		1
Tanytarsus	13	35	33
Thienemanniella	31		10
Thienemannimyia grp.	19	1	4
Tipula	-99		
Acerpenna	47		1
Caenis latipennis	25	55	103
Hexagenia limbata		1	
Stenacron	3	2	
Stenonema femoratum	23		5

North Fork Cuivre River #1a (continued: Spring 2002)

Tricorythodes	1		
Belostoma			-99
Caecidotea			1
Physella			-99
Basiaeschna janata			-99
Enallagma			5
Gomphus		1	
Allocapnia	1		
Hydroperla crosbyi	-99		
Isoperla	7		
Perlesta	4		
Cheumatopsyche	5		
Pycnopsyche			1
Triaenodes			1
Planariidae			1
Branchiura sowerbyi		2	
Enchytraeidae	16	2	2
Limnodrilus hoffmeisteri	1	3	1
Tubificidae	14	14	1

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North Fork Cuivre River #1b: Spring 2002

Taxa	CS	NF	RM
Branchiobdellida		1	
Hyalella azteca			8
Erpobdellidae	-99		
Berosus		3	1
Dubiraphia		5	1
Oreodytes		1	3
Peltodytes		2	1
Scirtes			2
Stenelmis	44	2	4
Orconectes luteus	-99		
Ablabesmyia		8	1
Ceratopogoninae		1	
Chironomus		8	
Cladotanytarsus	1	14	
Cnephia	1		
Corynoneura	13	3	9
Cricotopus bicinctus	2		7
Cricotopus/Orthocladius	282	13	61
Cryptochironomus	1	3	
Dicrotendipes		7	13
Eukiefferiella	1		
Eukiefferiella brevicalcar grp	2		
Glyptotendipes		1	1
Hydrobaenus	7	7	2
Larsia		1	
Microtendipes		1	1
Nanocladius	1		10
Ormosia	1	1	
Orthocladius (Euorthocladius)	17		
Parametriocnemus	3	1	
Paratanytarsus	1	4	64
Paratendipes	2	10	
Phaenopsectra		4	2
Polypedilum convictum grp	3		
Polypedilum halterale grp		11	
Polypedilum illinoense grp	1		4
Polypedilum scalaenum grp	4	5	
Pseudochironomus		2	
Rheotanytarsus	3		3
Stempellinella	1	4	1
Stenochironomus			1
Stictochironomus		50	1
Tabanus	2		
Tanytarsus	13	32	14
Thienemanniella	39		7
Thienemannimyia grp.	21	1	20
Tipula	-99		
Acerpenna	48		
Caenis latipennis	39	63	91
Centroptilum			1
Stenacron	6		
Stenonema femoratum	22	3	2
Microvelia			1
Caecidotea	1		

North Fork Cuivre River #1b (continued): Spring 2002

Menetus			1
Physella			2
Argia			2
Enallagma			15
Progomphus obscurus		-99	
Allocapnia	5	1	
Amphinemura	2		
Hydroperla crosbyi	-99		
Isoperla	5		
Perlesta	1		
Perlinella drymo			-99
Cheumatopsyche	2		
Planariidae			1
Branchiura sowerbyi		2	
Enchytraeidae	11	2	
Limnodrilus hoffmeisteri	1	11	
Tubificidae	4	14	1
Sphaerium	1		

CS = Coarse Substrate Habitat

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RM = Rootmat Habitat

-99 = Present in Samples

North Fork Cuivre River #2: Spring 2002

Taxa	CS	NF	RM
Acarina		4	2
Crangonyx	3		8
Hyalella azteca			2
Erpobdellidae		1	
Berosus	1	4	
Dubiraphia		4	1
Gyrinus			1
Helichus lithophilus	1		
Hydroporus		2	2
Oreodytes		2	-99
Peltodytes		5	1
Stenelmis	36	1	2
Orconectes luteus	-99		-99
Orconectes virilis			-99
Ablabesmyia	1	2	
Ceratopogonidae		1	
Chironomus	6	4	
Chrysops	-99		
Cladotanytarsus		3	
Clinocera	1	1	
Corynoneura	3		18
Cricotopus bicinctus	4		6
Cricotopus trifascia	2		
Cricotopus/Orthocladius	280	13	100
Cryptochironomus	1	1	
Dicrotendipes	1	17	4
Eukiefferiella	1		1
Eukiefferiella brevicalcar grp	8		1
Glyptotendipes	1		
Hydrobaenus	57	4	1
Microtendipes	2	1	1
Nanocladius			1
Ormosia	1		
Orthocladius (Euorthocladius)	37		1
Parametriocnemus	9		
Paratanytarsus	1	1	18
Paratendipes	2	7	1
Phaenopsectra		1	8
Polypedilum convictum grp	6		
Polypedilum halterale grp			1
Polypedilum illinoense grp	1		10
Polypedilum scalaenum grp	19	2	
Procladius		1	
Pseudochironomus	3		
Rheotanytarsus	1		
Simulium			1
Stempellinella		5	1
Stictochironomus	7	3	
Tabanus	1		
Tanytarsus	2	28	12
Thienemanniella	17		24
Thienemannimyia grp.	11	4	5
Tipula	-99	-99	1
Tvetenia			2

North Fork Cuivre River #2 (continued): Spring 2002

Acerpenna	4		2
Caenis latipennis	10	127	61
Hexagenia limbata		4	
Stenonema femoratum	14	12	11
Microvelia		1	
Trichocorixa		1	
Ferrissia	3	1	1
Fossaria			-99
Physella	1	1	8
Lumbricidae	1	1	
Sialis		-99	
Basiaeschna janata			-99
Calopteryx			-99
Enallagma			7
Gomphus		-99	
Libellula		-99	
Allocapnia	1		
Amphinemura	1		
Isoperla	-99		
Perlesta	1		
Glossiphoniidae			1
Cheumatopsyche	6		
Chimarra	2		
Ironoquia			-99
Oecetis	1		
Enchytraeidae	3	1	1
Limnodrilus cervix		5	
Limnodrilus hoffmeisteri		18	
Tubificidae	1	99	2
Sphaerium		1	1

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Peruque Creek #1: Fall 2002

Taxa	CS	NF	RM
Branchiobdellida			1
Acarina	6	4	5
Hyalella azteca			49
Erpobdellidae	-99		
Berosus	1	1	
Coleoptera	1		
Dubiraphia		3	7
Helichus lithophilus	1		
Hydrochus			4
Scirtes			24
Stenelmis sexlineata	90		1
Orconectes luteus	2		
Orconectes virilis			1
Palaemonetes kadiakensis			4
Ablabesmyia	1	6	
Anopheles			3
Ceratopogoninae	10	11	4
Chaoborus		5	
Chironomus		5	
Cladotanytarsus		2	
Clinotanypus			1
Corynoneura	1		3
Cricotopus/Orthocladius	1		1
Cryptochironomus	1	2	
Culex			1
Dicrotendipes		8	2
Diplocladius	1		
Diptera	1		
Glyptotendipes		8	12
Hemerodromia	4	1	
Hexatoma	2		
Labrundinia			6
Microchironomus		2	
Nanocladius	1		
Nilotanypus	3		
Parachironomus		1	10
Phaenopsectra		1	
Polypedilum	1		
Polypedilum convictum grp	47		2
Polypedilum fallax grp	1		
Polypedilum halterale grp		5	
Polypedilum illinoense grp	9		2
Polypedilum scalaenum grp	3		
Procladius		8	
Rheotanytarsus	3		
Stenochironomus	1		2
Stictochironomus		2	
Tabanus	-99		-99
Tanypus		5	
Tanytarsus	22	5	8
Thienemannimyia grp.	23		3
Tipula	-99		
undescribed Empididae	3		
Acerpenna	47		

Peruque Creek #1 (continued): Fall 2002

Apobaetis		13	
Baetis	1		
Caenis latipennis	8	75	38
Callibaetis		1	3
Choroterpes	2		
Hexagenia limbata		9	
Procloeon		1	1
Stenacron	5	1	5
Stenonema femoratum	28	7	2
Tricorythodes	11	5	
Corixidae		12	
Microvelia			2
Neoplea			1
Caecidotea	1		
Caecidotea (Blind & Unpigmented)		1	
Ancylidae	1		
Menetus		3	38
Physella		2	6
Lumbricidae	6		
Chauliodes pectinicornis	-99		
Corydalus	-99		
Sialis	-99		
Argia	5	1	8
Enallagma			18
Libellula		1	
Nasiaeschna pentacantha			1
Perlidae	1		
Cheumatopsyche	94		3
Chimarra	96	5	
Hydroptila	2	1	
Orthotrichia			4
Polycentropodidae			1
Triaenodes			17
Planariidae	45	2	7
Aulodrilus		3	
Branchiura sowerbyi	2	34	
Tubificidae	3	11	
Corbicula	18	1	
Sphaerium	1		

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Peruque Creek #2: Fall 2002

Taxa	CS	NF	RM
Acarina	6	4	1
Hyalella azteca			142
Berosus	35	2	10
Dubiraphia		1	10
Macronychus glabratus			1
Psephenus herricki	13		
Scirtes			22
Stenelmis	41		
Ablabesmyia		3	2
Anopheles			1
Ceratopogoninae	3	25	1
Chironomus		2	
Cladopelma		1	
Cladotanytarsus	1	13	
Corynoneura	2		
Cricotopus bicinctus	2		
Cricotopus/Orthocladius	2		3
Dicrotendipes	1	2	1
Diptera	1		
Forcipomyiinae	2		
Hemerodromia	6		
Hexatoma	-99		
Labrundinia		1	1
Nanocladius	1	1	1
Paralauterborniella		1	
Paraphaenocladius		2	
Paratanytarsus			5
Paratendipes		3	
Pentaneura	1		
Phaenopsectra			2
Polypedilum convictum grp	6		1
Polypedilum halterale grp		10	
Polypedilum illinoense grp	5	1	2
Polypedilum scalaenum grp	1	4	
Procladius		1	
Rheocricotopus	1		
Rheotanytarsus	12		
Stempellinella		1	
Stictochironomus	1	9	
Sublettea		1	
Tabanus	1		
Tanytarsus	5	6	10
Thienemannimyia grp.	7	1	
Tipula	-99		
undescribed Empididae	1		
Acentrella	8		
Acerpenna	22		
Baetis	52		
Caenis latipennis	62	156	27
Callibaetis			1
Centroptilum		2	1
Stenacron	2		
Stenonema femoratum	10	1	1
Tricorythodes	124		1

Peruque Creek #2 (continued): Fall 2002

Rhagovelia	4		
Ancylidae	6	2	21
Fossaria	11	1	4
Menetus	3		12
Physella	15		3
Lumbricidae	11		-99
Corydalus	-99		
Argia	46		9
Basiaeschna janata			-99
Enallagma	2		13
Erythemis			-99
Cheumatopsyche	87		2
Chimarra	32		
Helicopsyche	7		1
Hydropsyche	2		
Hydroptila	5	1	3
Nectopsyche	4		
Oecetis	7		1
Oxyethira		1	1
Phryganeidae		1	
Triaenodes			6
Planariidae	5		1
Aulodrilus		11	
Tubificidae	1	6	
Corbicula	17	-99	-99
Sphaeriidae	1		

CS = Coarse Substrate Habitat
NF = Non-flow Habitat
RM = Rootmat Habitat
-99 = Present in Samples

Peruque Creek #3: Fall 2002

Taxa	CS	NF	RM
Acarina	15	4	2
Hyalella azteca		2	88
Berosus	7	1	
Dubiraphia	2	2	16
Helichus lithophilus	2		2
Macronychus glabratus			1
Psephenus herricki	2		
Scirtes			2
Stenelmis	37	1	4
Tropisternus	1		
Orconectes luteus	-99		-99
Orconectes virilis			1
Palaemonetes kadiakensis			1
Ablabesmyia	2	2	1
Ceratopogoninae	16	34	3
Chironomus		39	
Cladopelma		5	
Cladotanytarsus		4	
Corynoneura			2
Cricotopus bicinctus	1		
Cricotopus/Orthocladius	3		
Cryptochironomus	1		
Dasyheleinae	3		
Dicrotendipes	3	13	2
Dolichopodidae	1		
Einfeldia		4	
Endochironomus			1
Glyptotendipes		2	2
Hemerodromia	6		
Hexatoma	3		
Labrundinia		5	5
Nanocladius	2	2	2
Nilotanypus	3		1
Parakiefferiella		1	
Paratanytarsus		4	18
Pentaneura	2		
Phaenopsectra		1	
Polypedilum convictum grp	19		10
Polypedilum halterale grp	1	4	
Polypedilum illinoense grp	7	1	4
Polypedilum scalaenum grp	1		
Procladius		2	
Pseudochironomus	1		
Rheotanytarsus	6		2
Stempellinella	2	3	
Stenochironomus			1
Stictochironomus		18	
Sublettea	1		
Tabanus	-99		1
Tanypus		2	
Tanytarsus	28	13	12
Thienemannimyia grp.	5		14
Tipula	1		
Tribelos			1

Peruque Creek #3 (continued): Fall 2002

undescribed Empididae	3		1
Zavreliella		2	
Zavrelimyia	1		
Acerpenna	22		1
Apobaetis		7	
Baetis	11		5
Caenis latipennis	182	12	15
Callibaetis		1	
Heptageniidae	5	1	1
Hexagenia limbata	2		1
Leptophlebiidae	2		
Procloeon		2	
Stenacron	12		7
Stenonema femoratum	13	6	2
Tricorythodes	5		1
Neoplea			1
Trepobates		1	
Ancylidae	2		5
Menetus	1	4	13
Physella	25	2	2
Lumbricidae	9	2	3
Corydalus	-99		
Argia	12		31
Enallagma	4		12
Libellulidae			2
Pachydiplax longipennis			-99
Cernotina			1
Cheumatopsyche	4		5
Hydroptila	1		
Oecetis	3		
Orthotrichia			1
Triaenodes			10
Planariidae			17
Aulodrilus		1	
Enchytraeidae	1		
Limnodrilus hoffmeisteri		1	1
Tubificidae	7	4	3
Sphaerium	1		

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-99 = Present in Samples

Peruque Creek #4: Fall 2002

Taxa	CS	NF	RM
Acarina	1	4	1
Hyalella azteca		100	1
Erpobdellidae	-99		
Berosus	11	7	2
Dubiraphia			7
Helichus lithophilus	1		
Psephenus herricki	4		
Scirtes			9
Stenelmis	19	5	2
Orconectes luteus		-99	
Orconectes virilis			-99
Ablabesmyia		2	1
Ceratopogoninae	4	8	
Chironomus		6	1
Chrysops		1	
Cladotanytarsus	1		
Corynoneura	1	2	
Culex			1
Dicrotendipes	1	6	2
Einfeldia		1	
Forcipomyiinae	1		
Hemerodromia	2		
Hexatoma	-99		
Kiefferulus		2	3
Krenosmittia			1
Labrundinia	1	1	9
Microtendipes	2		2
Nilotanypus	5		1
Parachironomus			1
Paramerina			1
Parametriocnemus	4		
Paraphaenocladius		1	
Paratanytarsus	2		49
Paratendipes			1
Phaenopsectra			2
Polypedilum convictum grp	16		
Polypedilum illinoense grp			1
Polypedilum scalaenum grp	106	3	
Pseudochironomus		1	
Rheotanytarsus	2		
Simulium	1		
Stempellinella	5	1	
Stictochironomus		5	
Tabanus	2		
Tanytarsus	13	6	7
Thienemannimyia grp.	17	1	6
Tipula	1		
undescribed Empididae	5	3	
Acentrella	1		
Acerpenna	37		1
Baetis	20		
Caenis latipennis	73	184	15
Paracloeodes			1
Stenacron	3		

Peruque Creek #4 (continued): Fall 2002

Stenonema femoratum	34	6	5
Tricorythodes	4		
Microvelia			1
Ranatra nigra		-99	
Ancylidae	2	1	11
Fossaria			3
Menetus			12
Physella	18	7	7
Argia	1		1
Enallagma			4
Erythemis			3
Ischnura		1	
Libellula	-99	1	
Stylogomphus albistylus	4		
Glossiphoniidae			1
Cheumatopsyche	81		1
Chimarra	63		2
Helicopsyche	3		
Hydropsyche			1
Hydroptila	3		
Nectopsyche	1		
Oecetis	3	3	
Triaenodes			6
Planariidae			24
Tubificidae	1	2	1

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-99 = Present in Samples

Peruque Creek #5: Fall 2002

Taxa	CS	NF	RM
Branchiobdellida			2
Chordodidae			1
Acarina		23	7
Crangonyx	1		
Hyalella azteca	1		42
Erpobdellidae	-99		
Berosus	18	7	1
Dubiraphia		3	27
Enochrus	2		
Helichus basalis	1		
Peltodytes			-99
Psephenus herricki	1		
Scirtes			3
Stenelmis	117	1	12
Orconectes virilis	-99		1
Ablabesmyia		3	3
Anopheles			2
Ceratopogoninae	1	2	
Chironomus		20	
Chrysops		2	
Cladotanytarsus		20	
Cricotopus bicinctus	1		
Cryptochironomus		4	
Culex			1
Dicrotendipes			4
Diptera			1
Forcipomyiinae	1	1	
Hemerodromia	3		
Labrundinia	4	2	
Larsia	1		
Microtendipes	2	1	1
Nanocladius			1
Nilotanypus	5		1
Parachironomus			2
Paraphaenocladius	1		
Paratanytarsus	2	1	12
Paratendipes		3	1
Polypedilum convictum grp	28		
Polypedilum halterale grp		4	
Polypedilum illinoense grp	5		
Polypedilum scalaenum grp		6	
Procladius		4	
Pseudosmittia		2	
Rheotanytarsus	2		
Simulium	2		
Stempellinella		1	
Stictochironomus		11	
Tanytarsus	69	15	7
Thienemannimyia grp.	18	1	
Tipula	4		
Caenis latipennis	1	24	
Hexagenia limbata		1	
Stenacron	16	3	
Stenonema femoratum	71	7	4

Peruque Creek #5 (continued): Fall 2002

Corixidae		4	
Microvelia	1		
Trepobates		1	
Ancylidae	29	26	7
Fossaria	1	4	3
Menetus	4	2	82
Physella	237	40	33
Lumbricidae	1		
Argia			1
Calopteryx	3		
Enallagma			3
Ischnura			1
Nasiaeschna pentacantha		1	
Pachydiplax longipennis			-99
Progomphus obscurus		-99	
Stylogomphus albistylus	2		
Cheumatopsyche	16		
Chimarra		1	
Helicopsyche	2		1
Oecetis		2	2
Phryganeidae		1	
Triaenodes			3
Planariidae			39
Limnodrilus hoffmeisteri	2		
Tubificidae	26	17	1
Sphaerium	1	1	

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Peruque Creek #6: Fall 2002

Taxa	NF	RM
Acarina	1	10
Hyalella azteca	3	61
Berosus	1	2
Dubiraphia	5	79
Scirtes	1	9
Stenelmis	2	1
Ablabesmyia	2	4
Anopheles	1	
Ceratopogoninae	30	3
Chaoborus	1	
Chironomus	55	6
Cladotanytarsus	5	
Cryptochironomus	3	
Cryptotendipes	1	
Culex		2
Dicrotendipes	16	24
Diptera	1	
Glyptotendipes	1	19
Labrundinia		5
Parachironomus	1	6
Paraphaenocladius	2	
Paratanytarsus	2	8
Phaenopsectra		1
Polypedilum halterale grp	16	
Polypedilum illinoense grp	5	4
Procladius	19	
Pseudochironomus	1	
Stictochironomus	20	
Tabanus	1	
Tanypus	1	
Tanytarsus	29	2
Caenis latipennis	8	7
Procloeon	2	
Stenonema femoratum		2
Neoplea	1	1
Trepobates	1	
Ancylidae		2
Menetus	1	70
Physella	20	38
Argia	1	10
Basiaeschna janata		-99
Enallagma		5
Hetaerina		1
Libellulidae	1	
Nasiaeschna pentacantha		2
Pachydiplax longipennis		1
Perithemis	-99	-99
Glossiphoniidae		-99
Triaenodes		6
Aulodrilus		1
Limnodrilus hoffmeisteri	3	
Tubificidae	20	1
Sphaerium	2	

NF = Non-flow Habitat

RM = Rootmat Habitat

-99 = Present in Samples

North Fork Cuivre River #1a: Fall 2002

Taxa	CS	NF	RM
Acarina		6	7
Erpobdellidae	-99	-99	
Berosus	9	2	30
Dubiraphia		8	11
Enochrus	5		
Helichus lithophilus			3
Scirtes	1		12
Stenelmis	206	2	7
Ablabesmyia	15	1	
Anopheles			1
Ceratopogoninae	4	16	
Chironomus		13	
Chlorotabanus			-99
Cladopelma		1	
Cladotanytarsus	1	5	
Cricotopus bicinctus	2		
Cricotopus/Orthocladius	3		
Cryptochironomus	1		
Culex			1
Dasyheleinae	1	1	
Demicryptochironomus	2		
Dicrotendipes	1	1	4
Diptera			1
Dolichopodidae	1		
Ephydridae	1		
Forcipomyiinae	2		
Glyptotendipes	2		9
Hemerodromia	2		
Labrundinia	1		5
Nilotanypus	2		
Parachironomus			2
Paratanytarsus			5
Paratendipes	1		
Pentaneura	2		
Polypedilum	1		1
Polypedilum convictum grp	16		
Polypedilum halterale grp	1	9	
Polypedilum illinoense grp	18	1	1
Polypedilum scalaenum grp	15	2	
Procladius		7	1
Rheotanytarsus	13		
Stempellinella	1	1	
Stictochironomus	1	1	
Tabanus	2		
Tanytarsus	46	11	4
Thienemanniella	1		
Thienemannimyia grp.	16		2
Caenis latipennis	97	18	4
Callibaetis			1
Choroterpes	1		
Hexagenia		1	
Procloeon		4	
Stenonema femoratum	3		
Tricorythodes	65	1	

North Fork Cuivre River #1a (continued): Fall 2002

Microvelia			1
Caecidotea (Blind & Unpigmented)	1		
Ancylidae	9	1	4
Menetus			72
Physella	76	2	21
Argia	1		14
Enallagma		1	9
Erythemis			-99
Gomphidae		1	
Gomphus			1
Macromia			-99
Nasiaeschna pentacantha			-99
Glossiphoniidae		1	
Ceratopsyche	1		
Cheumatopsyche	28	1	
Nectopsyche			1
Oecetis	1		
Pycnopsyche			-99
Planariidae			26
Aulodrilus		12	1
Branchiura sowerbyi	2	41	1
Limnodrilus cervix		2	
Limnodrilus hoffmeisteri		22	
Tubificidae	6	134	4
Sphaerium	3	3	7

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North Fork Cuivre River #1b: Fall 2002

Taxa	CS	NF	RM
Chordodidae	-99		
Acarina	1	10	5
Hyalella azteca			1
Berosus	9	3	28
Dubiraphia		3	16
Enochrus	2		
Helichus lithophilus	9		
Macronychus glabratus			5
Paracymus	1		
Scirtes			6
Stenelmis	183	3	9
Ablabesmyia	5	1	1
Anopheles			1
Axarus	1		
Ceratopogoninae	8	9	
Chaoborus		2	
Chironomus		15	
Cladotanytarsus	3	16	
Cricotopus/Orthocladius	2		
Cryptochironomus	14	3	
Dasyheleinae		1	
Demicryptochironomus	3		
Dicrotendipes	2	1	6
Diptera	2	1	
Forcipomyiinae	2	1	
Glyptotendipes			15
Hemerodromia	1		
Labrundinia			9
Nanocladius		1	1
Nilotanypus	1		
Parachironomus			5
Paratanytarsus		2	19
Paratendipes	5	1	
Phaenopsectra			2
Polypedilum convictum grp	40		
Polypedilum halterale grp	1	10	
Polypedilum illinoense grp	27		1
Polypedilum scalaenum grp	24	2	
Procladius		4	
Pseudochironomus		1	
Rheotanytarsus	6		
Stempellinella	3	5	
Stictochironomus		1	
Tabanus	4		
Tanypus		1	
Tanytarsus	73	36	18
Thienemanniella	1		1
Thienemannimyia grp.	10		1
Caenis latipennis	131	39	15
Choroterpes	1		
Procloeon		2	
Stenacron	2		1
Stenonema femoratum	19	3	
Tricorythodes	32		

North Fork Cuivre River #1b (continued): Fall 2002

Ancylidae	6		14
Menetus		1	102
Physella	44	6	29
Argia	4		14
Enallagma	1		41
Gomphus		3	
Libellulidae		1	
Progomphus obscurus		-99	
Cheumatopsyche	17		
Chimarra	1		
Hydroptila			1
Nectopsyche		1	1
Nyctiophylax			1
Oecetis	1		2
Pycnopsyche			1
Triaenodes			1
Planariidae			55
Branchiura sowerbyi	2	13	
Enchytraeidae	1		
Limnodrilus cervix		5	
Limnodrilus hoffmeisteri		12	
Tubificidae	4	101	

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North Fork Cuivre River #2: Fall 2002

Taxa	CS	NF	RM
Acarina	18	21	6
Berosus	20	1	16
Dubiraphia		1	11
Enochrus	6		1
Helichus lithophilus			3
Macronychus glabratus			1
Scirtes			11
Stenelmis sexlineata	36	1	2
Ablabesmyia	5	5	1
Anopheles			1
Ceratopogoninae	10	6	
Chironomus	2	35	
Cladotanytarsus	11	11	1
Corynoneura			1
Cryptochironomus		2	
Dicrotendipes	2	6	
Labrundinia		1	6
Microtendipes	1		
Nilotanypus	5		
Paracladopelma		1	
Paratanytarsus			15
Paratendipes	4	1	
Pentaneura	1		
Phaenopsectra			1
Polypedilum convictum grp	16		1
Polypedilum halterale grp		2	
Polypedilum illinoense grp	15	1	3
Polypedilum scalaenum grp	58	2	
Procladius	1	5	
Pseudochironomus	2		
Rheotanytarsus	6	1	
Stempellinella	10	1	
Stenochironomus			1
Tabanus	1		
Tanytarsus	68	6	1
Thienemannimyia grp.	12		7
undescribed Empididae	13		
Baetidae	1		
Caenis latipennis	99	101	34
Procloeon		2	
Stenacron	3		1
Stenonema femoratum	9	1	8
Tricorythodes	13		
Microvelia			2
Rhagovelia	1		
Trepobates		1	
Ancylidae	17	38	155
Fossaria	5		2
Menetus	5	9	4
Physella	50	1	24
Lumbricidae	1		
Argia	-99	1	6
Basiaeschna janata			-99
Calopteryx	-99		1

North Fork Cuivre River #2 (continued): Fall 2002

Enallagma			28
Erythemis			1
Gomphus		-99	
Ischnura			1
Macromia			-99
Somatochlora		-99	
Cheumatopsyche	7		
Chimarra	8		
Helicopsyche	1		
Hydroptila			1
Nectopsyche			2
Oecetis		1	
Triaenodes			2
Aulodrilus		13	
Enchytraeidae	1		
Limnodrilus hoffmeisteri		2	
Tubificidae	5	22	
Sphaerium		1	1

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