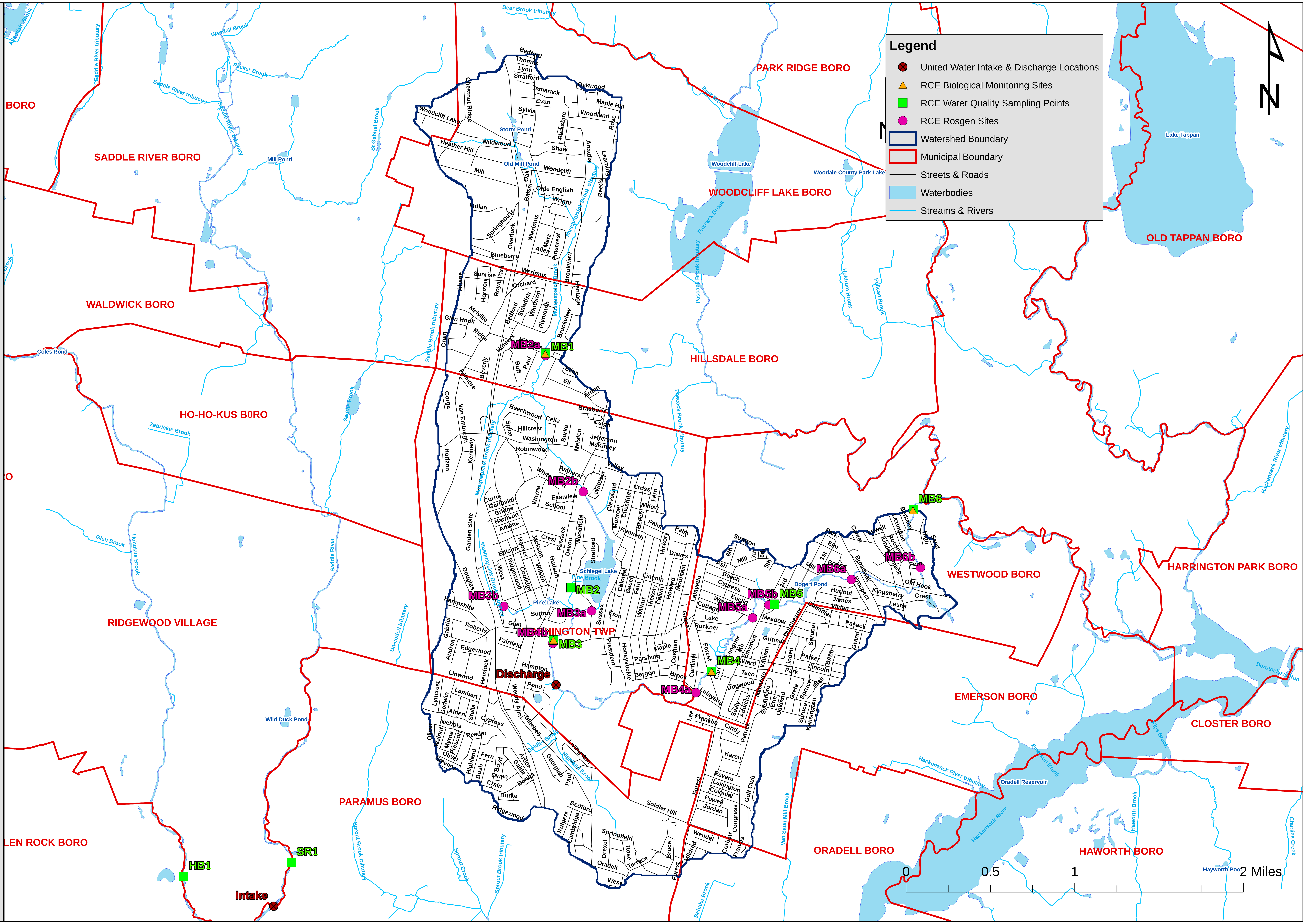
Musquapsink Brook Watershed Restoration & Protection Plan: OVERVIEW MAP



Summary
Musquapsink Brook Watershed Restoration and Protection Plan

Introduction

The Musquapsink Brook is a tributary of the Pascack Brook, which flows along the New York/New Jersey State line to its confluence with the Oradell Reservoir, which provides drinking water for an estimated 800,000 residents of Bergen and Hudson counties. The watershed area is predominantly urbanized, causing degradation of stream health and threatening the Category One waters to which the Musquapsink Brook flows.

The development of the Musquapsink Brook Watershed Restoration and Protection Plan was funded by the 319(h) Program administered through the Division of Watershed Management of the New Jersey Department of Environmental Protection (NJDEP). Working with the Bergen County Department of Health Services, Fairleigh Dickinson University, and United Water New Jersey, the Rutgers Cooperative Extension Water Resources Program has created this plan to achieve the following watershed goals:

- Initiate effective projects to improve the quality of the Musquapsink Brook Watershed.
- Increase awareness about water quality issues and promote watershed stewardship.
- Improve the quality of life in and around the Musquapsink Brook Watershed.

The NJDEP Integrated Water Quality Monitoring and Assessment Report indicates that the Musquapsink Brook is not attaining appropriate water quality standards for total phosphorus and bacterial contamination. The NJDEP has listed the Musquapsink Brook on New Jersey's 303(d) list of impaired waters. Total maximum daily loads (TMDLs) have been developed by the United States Environmental Protection Agency requiring a 10.9% reduction in total phosphorus loadings and a 96% reduction in fecal coliform loadings in the watershed. Cited sources include urban runoff and habitat modification.

The Musquapsink Brook Watershed Restoration and Protection Plan provides an overview of the status of the stream and provides suggestions for restoration and protection and a process of implementation. The Rutgers Cooperative Extension Water Resources Program proposes to use this plan to implement best management practices (BMPs) via community involvement in demonstration projects and through available grants or other funding sources.

Stream Impairments and Causes

Impervious Cover

The Musquapsink Brook Watershed is nearly 85% urban, with very little agricultural land use. Nonpoint source pollution is therefore largely associated with roads, buildings, pavement, and generally compacted landscapes with impaired drainage. Pollutants of concern include: sediment; oil, grease and toxic chemicals from motor vehicles; pesticides and nutrients from lawns and gardens; bacteria and nutrients from wildlife or pet waste; road salts; heavy metals from roof shingles, motor vehicles and other sources; and thermal pollution from dark impervious surfaces such as streets and rooftops. As these pollutants, generated by urban development and wildlife, accumulate on the land surface, hydrological processes such as runoff and percolation during a storm event eventually transport these contaminants into nearby streams and groundwater. The urban land use has caused significant hydrological alteration and thus accelerated the speed and extent of pollutant transportation from sources to the stream. The aggregate contribution of all nonpoint sources of pollution to the Musquapsink Brook has severely degraded surface water quality over time.

Erosion and Downcutting

Visual assessments and channel analyses of the Musquapsink Brook indicate that approximately 80% of the stream reaches assessed are unstable and are characterized by disturbance, incision, and excessive downcutting, which liberates sediment and alters the floodplain. Woody vegetation near the water line has been removed due to unstable bank conditions. In most cases, the downcutting and widening can be linked to impervious cover that is directly connected to the stream, resulting in flashy hydrology.

A significant feature to note is a historic mill dam located in Westwood, New Jersey. Bogert's Pond is created by this dam and is surrounded by residential neighborhoods. Impounded waters are subject to frequent floods, destabilizing river banks formerly subjected only to occasional high waters for short periods of time. This causes erosion and downcutting both upstream and downstream of the dam. Unstable, eroding streambanks and entrenched profiles are typical of the segments of stream most closely connected to the mill dam.

Benthic Macroinvertebrates

Biological assessments have become an important tool for managing water quality to meet the goals of the Clean Water Act. The benthic macroinvertebrate community occurring within the Musquapsink Brook Watershed is under some type of stress as evidenced by the extremely low numbers of organisms collected and by sensitive taxa being markedly diminished. Also, the types of organisms found within the study area are indicative of some organic pollution and habitat assessments revealed suboptimal to marginal conditions. Candidate causes of impairment within the Musquapsink Brook Watershed include:

1. Elevated nutrient levels (i.e., total phosphorus)
2. Elevated bacteria levels (i.e., fecal coliform and *E. coli*)
3. Degraded instream habitat
4. Altered hydrology
5. Toxicants.

Leaking Infrastructure

Microbial source tracking (MST) are a series of methods employed to determine sources of microbial pollution, whether from bacteria or other pathogens. A tiered approach to microbial source tracking (MST) was conducted within the watershed as part of this study. Human-related *Bacteroides* were detected at several locations within the watershed. The study was intended to provide Bergen County and its included townships with the initial information they need for targeted investigation into sanitary sewer releases to the Brook. Aging/leaking/failing infrastructure may be a likely source of the elevated bacteria levels observed within the watershed.

Recommendations for Best Management Practices

The main objective of the watershed restoration and protection plan is to prioritize the implementation of various best management practices. For this project, water quality data and flow data were collected at six sampling locations within the Musquapsink Brook Watershed. Synthesis of this data, in conjunction with the results of the visual assessments and MST studies, indicate that the most downstream portions of the watershed are the most severely impaired. Municipalities within this priority region include the Borough of Emerson, Borough of Paramus, Borough of Westwood, and Washington Township. The major emphasis of the remediation strategies is to retain stormwater runoff and loadings by disconnection of impervious surfaces, riparian corridor restoration, implementing goose/waterfowl deterrents, and initiating or enhancing education for students, homeowners, businesses, etc. on the proper management techniques for runoff and pollutant control. Watershed-wide strategies should readily produce enhancements to the flow regime and water quality throughout the Musquapsink Brook Watershed.

Priority recommendations include:

- Disconnection of impervious cover with rain gardens, rain barrels, green streets, and permeable pavement to capture, treat, and infiltrate stormwater runoff from these surfaces. Concept designs incorporating these features are included in the report for Washington Green Townhomes in Washington Township, Berkeley Elementary School in the Borough of Westwood, and for Haines Street in the Borough of Emerson.

- Restoration of riparian buffers along stream segments and ponds to prohibit waterfowl from entering the stream and filter stormwater flows. Several of these areas should be examined for possible reconnection to the floodplain. Once reconnected to the floodplain, flood waters will move much slower downstream and receive treatment by floodplain vegetation. Concept designs incorporating the restoration of riparian buffers are included in the report for Gritman Park and a segment of stream along 3rd Avenue, both in the Borough of Westwood.

- A Pond Management Plan should be developed for Bogert's Pond and should include a sediment survey, recommendations for land use practices, and options for dam removal. This may improve issues associated with flooding and erosion in the Musquapsink Brook Watershed.

- Three general areas should be evaluated for sources of human-related bacterial contamination in Westwood Borough and Washington Township. Maintenance and inspection records of water and wastewater infrastructure should be reviewed for each of these areas. Video inspections, smoke testing, or dye testing to determine infrastructure conditions may also be considered.

- True source reduction is exceedingly enhanced by watershed-wide information and educational programs that will bring about a true change of behavior. Programs addressing the use of the land, streamside living, landscaping practices and how it impacts the waterways can be distributed by Rutgers Cooperative Extension, Bergen SWAN, and many other entities. Targeted audiences would include homeowners, businesses, students, and municipal officials.

The list of recommendations provides a guide for potential projects to be implemented to improve surface water quality and improve the overall health of the Musquapsink Brook Watershed. Key in successfully implementing these projects in the watershed will be working closely with NJDEP, municipalities, and nonprofit groups to develop a goal-oriented schedule and time table. This plan is intended to be a guide for the project partners as they work to achieve water quality improvements in the watershed. The study and recommendations should be viewed as a working document and periodically updated as new issues arise, new data is collected, and when projects have been successfully completed. Modeling and monitoring will be key components in the assessment of restoration project successes. The RCE Water Resources Program is always available to work with stakeholders to implement stormwater management strategies throughout the watershed.

MUSQUAPSINK BROOK WATERSHED RESTORATION AND PROTECTION PLAN

FINAL

Developed by the Rutgers Cooperative Extension Water Resources Program
Funded by the New Jersey Department of Environmental Protection
RP 07-002

December 11, 2012

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1. Acknowledgements

The Musquapsink Brook Watershed Restoration and Protection Plan was developed by the Rutgers Cooperative Extension Water Resources Program and was funded by the **New Jersey Department of Environmental Protection** (NJDEP) through the 319(h) Grants for Nonpoint Source Pollution Control under Grant #RP 07-002. This document has been produced by the Rutgers Cooperative Extension Water Resources Program (www.water.rutgers.edu).

This document represents the culmination of efforts from all project partners. The Rutgers Cooperative Extension Water Resources Program would like to thank **Marion McClary, Ph.D.**, Associate Professor of Biological Sciences Co-Director, School of Natural Sciences at Fairleigh Dickinson University, who collected and analyzed the biological monitoring data; the **Bergen County Department of Health Services**, who assisted with water quality sampling and fieldwork; **Arnold Vernick, P.E.**, project manager on behalf of the Bergen County Department of Health Services; and **Raymond Cywinski** of United Water New Jersey, who served as project liaison between local watershed organizations, Rutgers University, and Bergen County.

The *Musquapsink Brook Watershed Restoration and Protection Plan* maps were developed using NJDEP Geographic Information System (GIS) digital data, but this secondary product has not been verified by NJDEP and is not State-authorized.

2. Executive Summary

The Musquapsink Brook Watershed Restoration and Protection Plan characterizes the watershed and provides insight into the problems facing the waterway and potential solutions. The Musquapsink Brook is a tributary of the Pascack Brook, which flows along the New York/New Jersey State line to its confluence with the Oradell Reservoir, which provides drinking water for an estimated 800,000 residents of Bergen and Hudson counties.

The watershed area is predominantly urbanized. This intensive land use has caused degradation of stream health, threatening the Category One waters to which the Musquapsink Brook flows. With the introduction of enhanced stormwater management, this watershed can continue these land use practices while achieving sustainability and improved water quality. Management measures that will minimize stormwater runoff will be essential to reducing phosphorus and fecal bacteria loads that now degrade the quality of the surface waters within the watershed.

Working with the Bergen County Department of Health Services, Fairleigh Dickinson University, and United Water New Jersey, the Rutgers Cooperative Extension Water Resources Program has created this plan to provide recommended implementation projects, measureable milestones and suggestions for technical assistance and funding. Along with site specific projects, watershed wide educational components will be essential for obtaining designated use goals for the future.

3. Introduction

The development of the Musquapsink Brook Watershed Restoration and Protection Plan is funded by the Federal Clean Water Act Section 319(h) Program administered through the Division of Watershed Management of the New Jersey Department of Environmental Protection (NJDEP). The project began in September 2006 and was granted an extended deadline of June 30, 2012. This chapter describes the general background of the planning area, the project organizational structure, and the purpose of the watershed restoration and protection plan.

3.1 Background

The Musquapsink Brook Watershed, located above U.S. Geological Survey (USGS) streamflow gauge #01377499 at River Vale, is approximately 6.9 square miles (about 4,407 acres) in area. The Musquapsink Brook Watershed is located in Bergen County and encompasses part of Woodcliff Lake Borough, Saddle River Borough, Hillsdale Borough, Washington Township, Westwood Borough, Emerson Borough, Paramus Borough, and Oradell Borough. Musquapsink Brook is approximately 7.3 river miles from the headwaters in Woodcliff Lake Borough to its confluence with the Pascack Brook at the border between Westwood and River Vale, New Jersey. The largest surface water body in the drainage area is Schlegel Lake, which encompasses 27.0 acres (Figure 3.1).

Under certain conditions, United Water of New Jersey diverts water from the Saddle River to the Oradell Reservoir through the Musquapsink Brook (Figure 3.1). The United Water of New Jersey records show that during the surface water sampling period (June 1, 2007 and December 31, 2007) a total of 551 million gallons of river water was transferred.

The NJDEP funded a characterization and assessment for Watershed Management Area 5 (WMA5) in which the Musquapsink Watershed is located. The WMA5 report was released in 2005 and analyzed data for the entire the WMA5 to identify concerns with land-based runoff; groundwater and water supply issues; point and nonpoint sources; and important natural resources.

Based upon numerous monitoring sources including the NJDEP Ambient Biomonitoring Network (AMNET) and the NJDEP and the USGS, the Musquapsink Brook is a moderately-to-severely impaired waterway. According to the 2010 *New Jersey Integrated Water Quality Monitoring and Assessment Report,* the Musquapsink Brook (reported as ‘Pascack Brook (below Westwood gage)’) is reported to not support the following designated:

- Agricultural Water Supply: impairment due to total dissolved solids;
- Aquatic Life: impairments due to low dissolved oxygen, pH, and total phosphorus;
- Primary Contact Recreation: impairment due to fecal coliform;
- Public Water Supply: impairment due to arsenic.

A TMDL was established in 2002 for the Musquapsink Brook requiring a 96% reduction in fecal coliform load for 7.3 miles of stream. In 2005, a TMDL for total phosphorus (TP) was established for the same 7.3 mile stretch of stream. This TMDL requires a 21.43% reduction in total phosphorus TP loadings from medium/high density residential, low density/rural residential, commercial, industrial, and mixed urban/other urban land uses to achieve an overall 10.9% reduction in TP loadings to the Musquapsink Brook. Additional aquatic life surface water quality impairments will need to be addressed through the TMDL process.

The NJDEP Bureau of Biological & Freshwater Monitoring maintains one AMNET station within the Musquapsink Brook Watershed (Station AN0206, Westwood, NJ). This station, located at Harrington Avenue, has been sampled in July of 1993, 1998, and 2003. For each of the three sampling rounds, the Musquapsink Brook was rated as a moderately impaired site, characterized by reduced macroinvertebrate taxa richness.

3.2 Partnerships and Accomplishments

Development of the Musquapsink Brook Watershed Restoration Plan is a multi-disciplinary and multi-agency collaborative effort. The partner agencies that have collaborated include Bergen County Department of Health Services, Fairleigh Dickenson University, United Water of New Jersey, and Bergen Save the Watershed Action Network (Bergen SWAN).

3.3 Purpose of this Plan

This watershed restoration and protection plan is the culmination of results obtained from the completion of project tasks and objectives. This plan will detail the management measures needed to achieve the necessary reduction in fecal coliform and total phosphorus loadings. In addition, this plan will provide an education component for education and outreach to enhance the public's understanding of the project and its goals. Schedules and measurable milestones for project implementation will also be included.

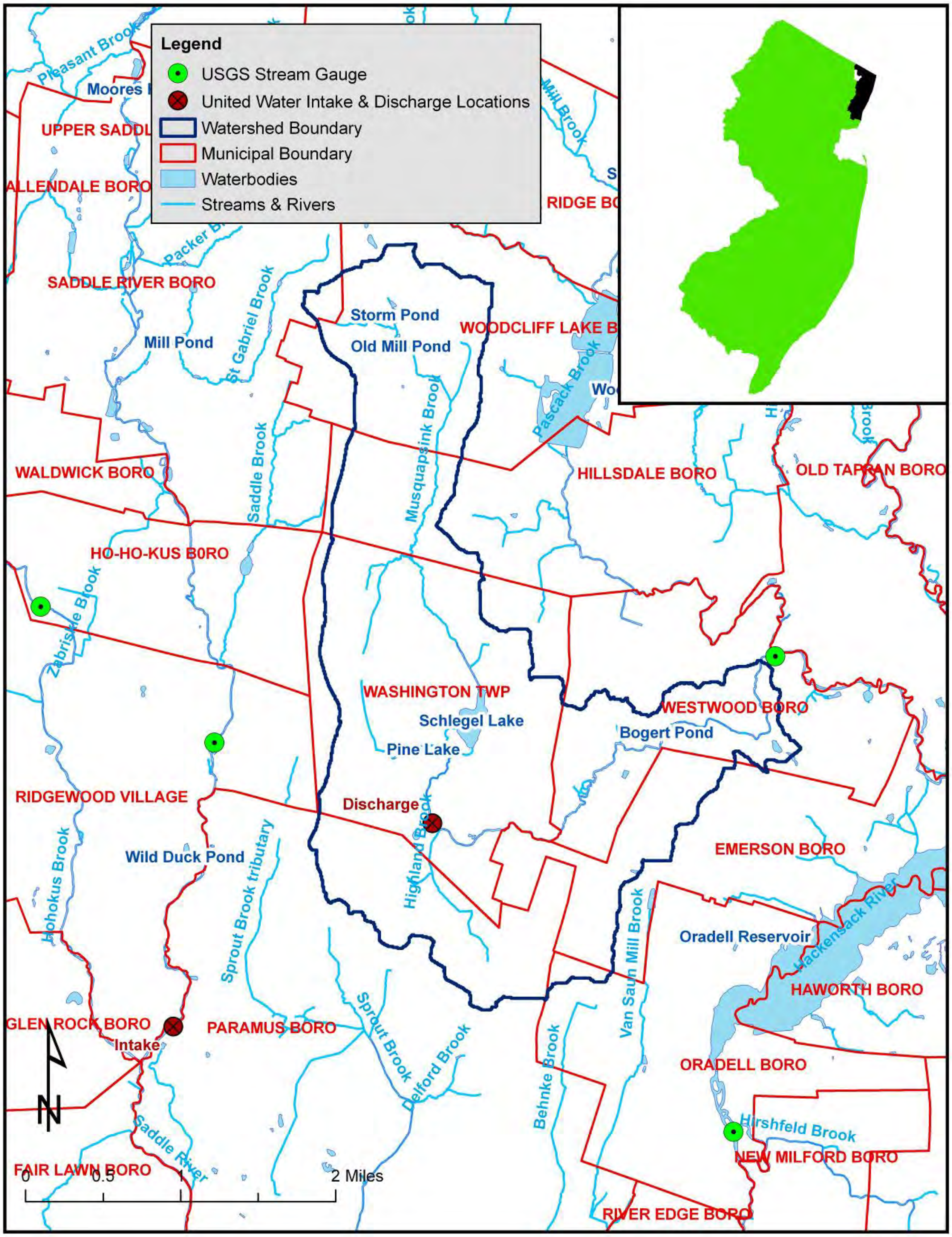

Figure 3.1: Municipalities and Waterbodies Located within the Musquapsink Brook Watershed

4. Musquapsink Brook Watershed

4.1 Physical Characteristics

4.1.1 Geography and Topography

The Musquapsink Brook Watershed is located in Bergen County in the northeastern part of New Jersey. The headwaters of the Musquapsink Brook are located in Woodcliff Lake Borough. The 7.3 miles of stream flow through Hillsdale Borough, Washington Township, and Paramus Borough, to its confluence with the Pascack Brook in Westwood Borough. The watershed area itself is approximately 6.9 square miles (about 4,407 acres) and also includes portions of Saddle River, Emerson and Oradell Boroughs. The geographic location is shown in Figure 4.1.

The highest elevations within the watershed are at approximately 407 feet above mean sea level (AMSL). The lowest elevations are around 28.9 feet AMSL. Figure 4.2 shows the spatial distribution of elevation within the watershed.

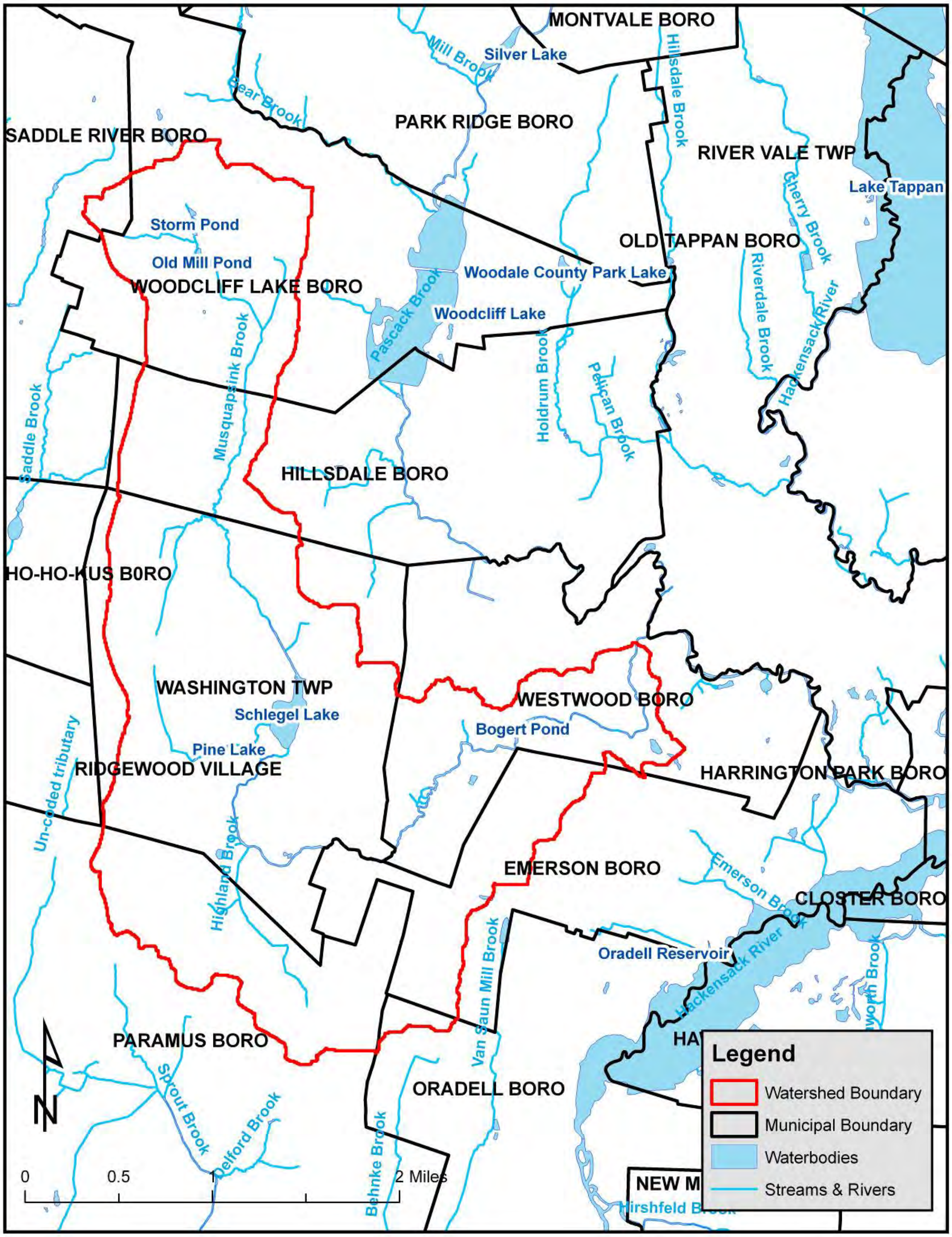

Figure 4.1: Geographic Location of the Musquapsink Brook Watershed

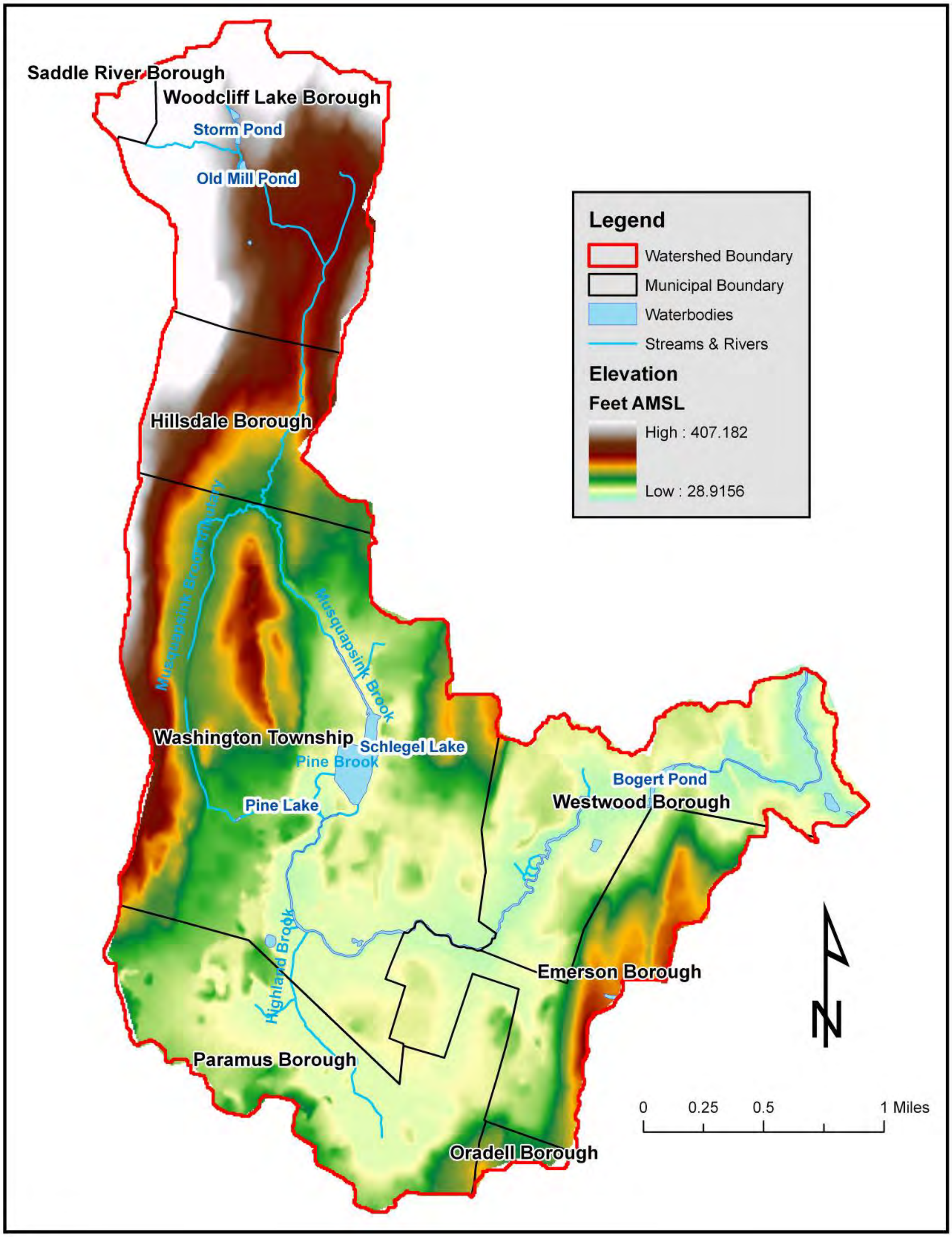

Figure 4.2: Spatial Distribution of Elevation within the Musquapsink Brook Watershed

4.1.2 Demographics

The Musquapsink Brook flows through eight municipalities all located within Bergen County (Figure 4.1). Demographic data for these municipalities were obtained from the United States Census Bureau 2010 census.

Bergen County has a population of 905,116 people, which is a 2.4% increase in the population from 2000 (884,118). The majority of the people in Bergen County are White (71.9%) with the next highest race are Hispanics/Latinos (16.1%). There are 352, 388 housing units in the county and the median household income is $81,708. Similar data is presented in Table 4.1 for each municipality in the Musquapsink Brook Watershed.

Table 4.1: Summary of 2010 United States Census Bureau data

Municipality	2010 Population	2000 Population	% Population Change	Housing Units	Median Household Income
Emerson Borough	7,401	7,197	+2.8	2,552	$99,292
Hillsdale Borough	10,219	10,087	+1.3%	3,567	$116,021
Oradell Borough	7,978	8,047	-0.9%	2,831	$123,750
Paramus Borough	26,342	25,737	+2.4%	8,915	$104,986
Saddle River Borough	3,152	3,201	-1.5%	1,341	$97,167
Washington Borough	9,102	8,938	+1.8%	3,341	$117,394
Westwood Borough	10,908	10,999	-0.8%	4,636	$79,133
Woodcliff Lake Borough	5,730	5,745	-0.3%	1,980	$150,404

4.1.3 Climate

The Musquapsink Brook Watershed lies in the Central Climate Zone of New Jersey. According to the Office of the New Jersey State Climatologist, the extensive urbanization in this zone results in a noticeable heat island effect. The concentration of buildings and paved surfaces retains heat, affecting the local temperatures. The observed night-time temperatures in heavily developed parts of the zone are regularly warmer than surrounding suburban and rural areas. The northern edge of the Central Zone is often the boundary between freezing and non-freezing precipitation in the winter months.

Based on recorded observations from years 1981-2010 for Northern New Jersey, the Musquapsink Brook Watershed receives, on average, 49.37 inches of precipitation annually (Table 4.2). The mean temperature is 51.6 degrees Fahrenheit (^{o}F) from 1981-2010 (Table 4.2).

Table 4.2: Total Precipitation and Mean Temperature for Northern New Jersey (includes Bergen County)

Year	Total Precipitation (inches)	Departure from Normal (inches)	Mean Temperature (°F)	Departure from Normal (°F)
1981	40.93	-8.86	50.1	-0.8
1982	42.20	-7.59	50.0	-0.9
1983	64.30	+14.51	51.3	+0.4
1984	54.68	+4.89	50.8	-0.1
1985	42.66	-7.13	51.0	+0.1
1986	50.33	+0.54	50.7	-0.2
1987	47.90	-1.89	50.9	0.0
1988	44.20	-5.59	50.2	-0.7
1989	55.23	+5.44	50.0	-0.9
1990	56.19	+6.40	53.0	+2.1
1991	42.64	-7.15	53.3	+2.4
1992	44.17	-5.62	50.2	-0.7
1993	45.58	-4.21	51.0	+0.1
1994	48.56	-1.23	50.9	0.0
1995	42.41	-7.38	51.1	+0.2
1996	62.96	+13.17	50.4	-0.5
1997	43.25	-6.54	50.6	-0.3
1998	44.05	-5.74	54.0	+3.1
1999	48.99	-0.80	52.6	+1.7
2000	46.22	-3.57	50.4	-0.5
2001	36.96	-12.83	52.4	+1.5
2002	47.44	-2.35	53.0	+2.1
2003	62.41	+12.62	50.5	-0.4
2004	52.71	+2.92	51.8	+0.9
2005	52.14	+2.35	53.1	+2.2
2006	55.05	+5.26	54.4	+3.5
2007	55.85	+6.06	52.8	+1.9
2008	51.35	+1.56	52.9	+2.0
2009	50.35	+0.56	51.8	+0.9
2010	49.31	-0.48	53.9	+3.0
MEAN	49.37	-0.42	51.6	+0.7

4.1.4 Geology

The Musquapsink Brook Watershed is located wholly within the Piedmont Plain physiographic province of New Jersey. The Passaic Formation (formerly known as the Brunswick Formation) is the dominant bedrock unit in the Watershed. The Passaic Formation consists of reddish brown, thin-bedded to thick-bedded shale, siltstone, and very fine-grained to coarse-grained sandstone. It is defined as a reddish-brown shale, siltstone and mudstone with a few green and brown shale interbeds; red and dark-gray interbedded argillites occur near the base of the geologic unit. There are also conglomerate and sandstone beds within the formation. See Figure 4.3 for the spatial distribution of bedrock in the Musquapsink Brook Watershed.

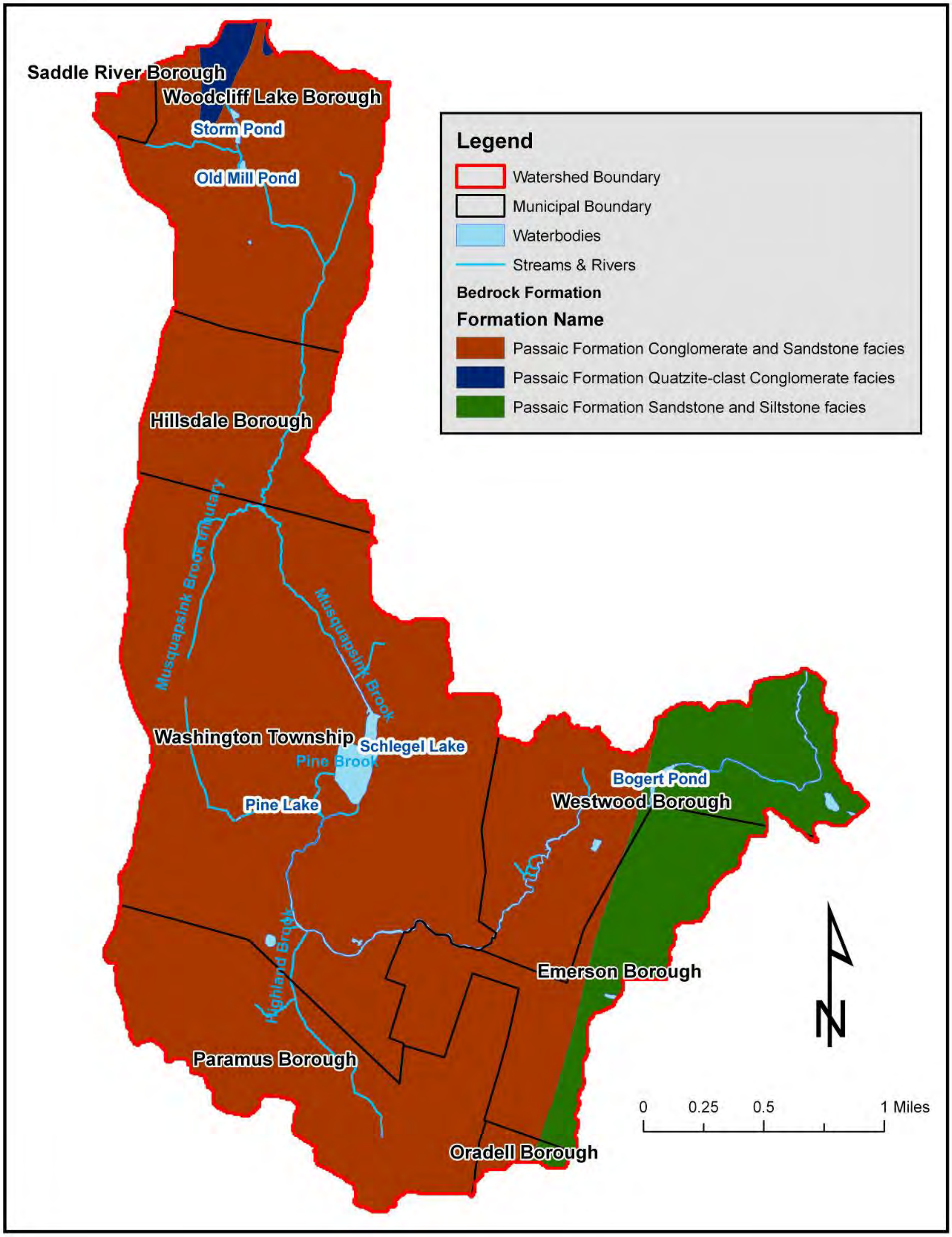

Figure 4.3: Bedrock Formations within the Musquapsink Brook Watershed

The fine-grained sandstones, shales, and thin-bedded siltstones of the Passaic Formation serve as the primary water-bearing layers. Massive siltstone beds often confine these layers. In the Passaic Formation, vertical to near vertical joints may interconnect water-bearing layers. The New Jersey Geological Survey ranks the Passaic Formation as a 'C' aquifer indicating that these rocks have moderate capacity to support major water-supply wells.

4.1.5 Soils

Major soils types in the watershed are: Dunellen-Urban land complex (DuuA, DuuB, DuuC, and DuuD; 26.7%), Wethersfield-Urban land complex (WeuB, WeuC, WeuD; 21.6%), and Udorthents (UdwB, UdwuB; 11.8%). These three soil types account for 60.1% of the Musquapsink Brook Watershed soils. The details of their area distribution are presented in Figure 4.4 and described in Table 4.3.

According to the 1995 Soil Survey of Bergen County, New Jersey, the Dunellen-Urban land complexes consist of 55% Dunellen soil, 30% urban land, and 15% included soils (silt and/or fine sand layers in subsoils and substratum). Typically, the surface layer of the Dunellen soil is characterized by 5 inches of very dark grayish brown loam. The subsoil is brown loam about 21 inches thick. The substratum extends to a depth of 66 inches or more and is characterized by stratified reddish brown gravelly sand, sand, and loamy sand. Urban land consists of areas in which the surface is covered by parking lots, patios, paved walkways, buildings, and other structures. Surface runoff is rapid. Permeability is moderate in the subsoil layer and rapid in the substratum. The available water capacity and hazard of erosion is moderate for this soil layer. The high water table is located at a depth greater than 6 feet in this soil complex. Depth to bedrock is greater than 60 inches.

The Wethersfield-Urban land complexes consist of 55% Wethersfield soil, 30% urban land, and 15% included soils. The surface of the Wethersfield soil is dark brown gravelly loam about 8 inches thick. The subsoil is characterized by an upper 10 inches of yellowish brown gravelly loam and a lower 8 inches of brown gravelly loam. The substratum extends to a depth of 65 inches or more and is characterized by reddish yellow gravelly fine sandy loam that is very firm in place. Surface runoff is moderate. Permeability is moderate in the subsoil and slow in the substratum. The water table is seasonally high from February through April for this soil type, with a depth ranging from 1.5 to 2.5 feet. Depth to bedrock is greater than 60 inches.

The Udorthents, wet substratum units, are located on upland stream terraces in drainageways and in areas of marine or estuarine deposits. Udorthents and urban lands are typically so intricately mixed that they are not mapped separately. Udorthent areas have been filled and smoothed or otherwise extensively disturbed to a depth of three feet or more. In most areas the original soils are presumed to have been deep, somewhat poorly drained soils that were subjected to flooding or prolonged ponding. The fill material generally consists of a mixture of soil material and stone, boulders, or rubble. Urban land consists of areas in which the surface is covered by parking lots, patios, paved walkways, buildings, and other structures.

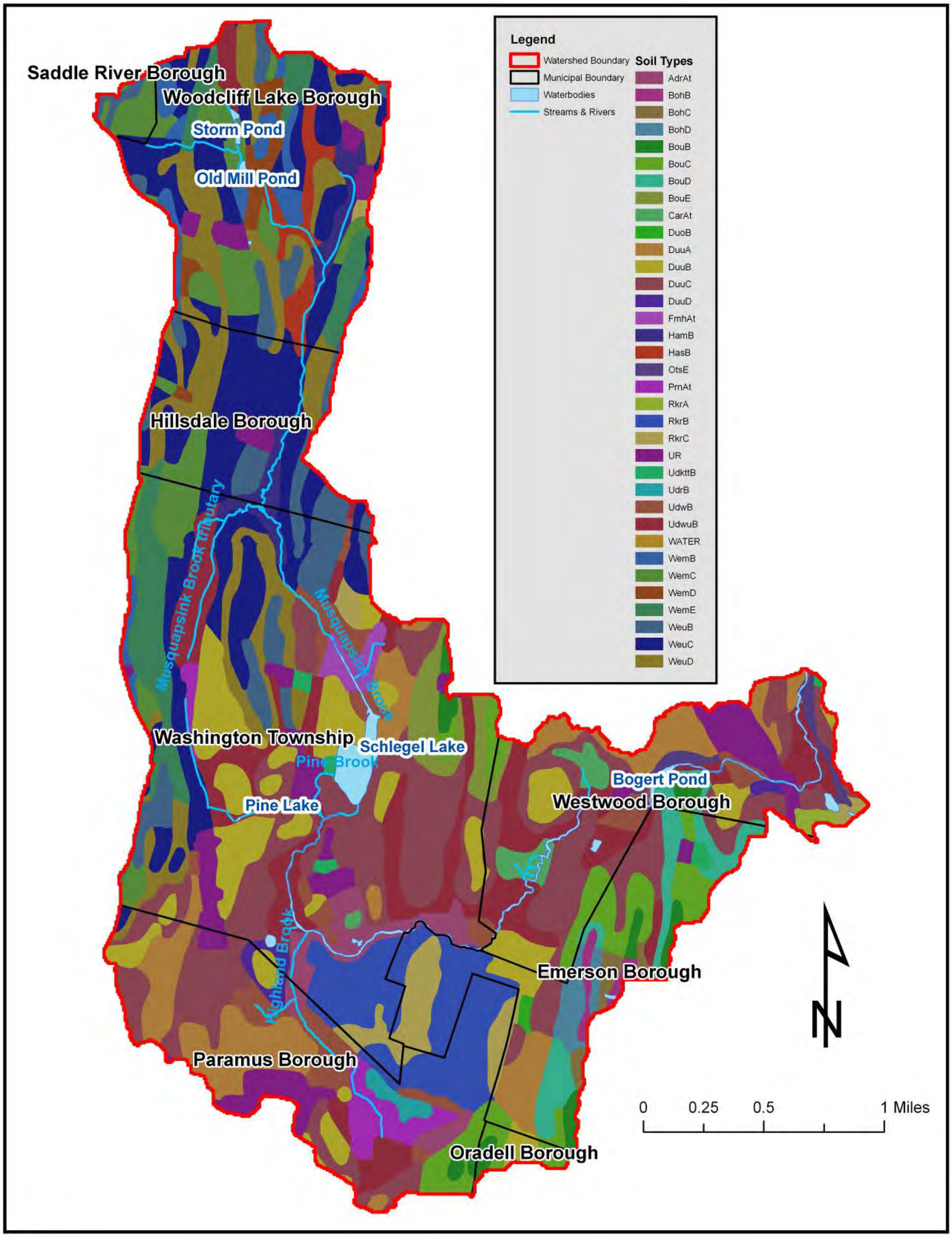

Figure 4.4: Soil Types within the Musquapsink Brook Watershed

Table 4.3: Summary of Soil Types Shown in Figure 4.4 (Soil Survey Geographic (SSURGO) Database, 2010)

Map Unit Symbol	Soil Name	Acres	Percent
AdrAt	Adrian muck, 0 to 2 percent slopes, frequently flooded	82	1.9%
BohB	Boonton moderately well drained gravelly loam, 3 to 8 percent slopes	17	0.4%
BohC	Boonton moderately well drained gravelly loam, 8 to 15 percent slopes	20	0.5%
BohD	Boonton moderately well drained gravelly loam, 15 to 25 percent slopes	30	0.7%
BouB	Boonton-Urban land complex, 0 to 8 percent slopes	50	1.1%
BouC	Boonton-Urban land complex, 8 to 15 percent slopes	149	3.4%
BouD	Boonton-Urban land complex, 15 to 25 percent slopes	84	1.9%
BouE	Boonton-Urban land complex, 25 to 45 percent slopes	63	1.4%
CarAt	Carlisle muck, 0 to 2 percent slopes, frequently flooded	36	0.8%
DuoB	Dunellen loam, 3 to 8 percent slopes	5	0.1%
DuuA	Dunellen-Urban land complex, 0 to 3 percent slopes	264	6.0%
DuuB	Dunellen-Urban land complex, 3 to 8 percent slopes	307	7.0%
DuuC	Dunellen-Urban land complex, 8 to 15 percent slopes	588	13.3%
DuuD	Dunellen-Urban land complex, 15 to 25 percent slopes	19	0.4%
FmhAt	Fluvaquents, loamy, 0 to 3 percent slopes, frequently flooded	27	0.6%
HamB	Haledon gravelly loam, 3 to 8 percent slopes	61	1.4%
HasB	Haledon-Urban land complex, 3 to 8 percent slopes	48	1.1%
OtsE	Otisville gravelly loamy sand, 25 to 35 percent slopes	24	0.5%
PrnAt	Preakness silt loam, 0 to 3 percent slopes, frequently flooded	55	1.2%
RkrA	Riverhead sandy loam, 0 to 3 percent slopes	8	0.2%
RkrB	Riverhead sandy loam, 3 to 8 percent slopes	213	4.8%
RkrC	Riverhead sandy loam, 8 to 15 percent slopes	93	2.1%
UdkttB	Udorthents, loamy, 0 to 8 percent slopes, frequently flooded	15	0.3%
UdrB	Udorthents, refuse substratum, 0 to 8 percent slopes	14	0.3%
UdwB	Udorthents, wet substratum, 0 to 8 percent slopes	137	3.1%
UdwuB	Udorthents, wet substratum-Urban land complex	381	8.6%
UR	Urban land	203	4.6%
WATER	Water	33	0.7%
WemB	Wethersfield gravelly loam, 3 to 8 percent slopes	67	1.5%
WemC	Wethersfield gravelly loam, 8 to 15 percent slopes	181	4.1%
WemD	Wethersfield gravelly loam, 15 to 25 percent slopes	36	0.8%
WemE	Wethersfield gravelly loam, 25 to 35 percent slopes	147	3.3%
WeuB	Wethersfield-Urban land complex, 3 to 8 percent slopes	185	4.2%
WeuC	Wethersfield-Urban land complex, 8 to 15 percent slopes	470	10.7%
WeuD	Wethersfield-Urban land complex, 15 to 25 percent slopes	295	6.7%
TOTAL		4,407	100%

Soils that are described as ‘frequently flooded’ (Table 4.3) are soils in which flooding is likely to occur often under usual weather conditions (more than 50 percent chance in any year, or more than 50 times in 100 years). There are 215 acres of these soils in the Musquapsink Brook Watershed (Table 4.3).

4.1.6 Streams and Groundwater

The Musquapsink Brook is a tributary of the Pascack Brook, which flows along the New York/New Jersey State line to its confluence with the Oradell Reservoir. The Reservoir is managed by United Water of New Jersey and provides drinking water for an estimated 800,000 residents of Bergen and Hudson counties (United Water, 2010). The Pascack Brook and its tributaries are classified as FW2-NT (C1), or freshwater (FW) non-trout (NT) category one (C1) in the 2010 N.J.A.C. 7:9B New Jersey Surface Water Quality Criteria. “FW2” refers to water bodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. “NT” means those freshwaters that have not been designated as trout production or trout maintenance. NT waters are not suitable for trout due to physical, chemical, or biological characteristics, but can support other fish species. “C1” refers to those waters designated for protection from measurable changes in water quality based on exceptional ecological significance, exceptional recreational significance, exceptional water supply significance or exceptional fisheries resource(s) to protect their aesthetic value (color, clarity, scenic setting) and ecological integrity (habitat, water quality and biological functions) (NJDEP, 2010). The C1 classification for the Musquapsink Brook and Pascack Brook are due to their significance as sources for the Oradell Reservoir.

4.2 Critical Source Areas

4.2.1 Wetlands

According to state Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A), a wetland is any “area that is inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions, commonly known as hydrophytic vegetation; provided, however, that the [NJDEP], in designating a wetland, shall use the three-parameter approach (that is, hydrology, soils and vegetation)” (NJDEP, 2009). These wetlands include tidally influenced wetlands which have not been included on a promulgated map pursuant to the Wetlands Act of 1970 (N.J.S.A. 13:9A-1 et seq).

Generally, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface (Cowardin, 1979). Wetlands include swamps, marshes, bogs, and similar areas. The NJDEP Land Use Regulation program primarily regulates wetlands in New Jersey. NJDEP has adopted the federal wetlands program, and thus is the lead regulating agency. The U.S. Army Corps of Engineers (USACOE) and NJDEP both have jurisdiction over tidal wetlands, navigable waters and wetlands located within 1,000 feet of navigable waterways. New Jersey protects wetlands and transition areas under the New Jersey Freshwater Wetlands Protection Act

(NJDEP, 1998). The federal Clean Water Act, Section 404 (33 U.S.C. 1344) is enforced by the USACOE and regulates navigable waters, tributaries of navigable waters and wetlands.

NJDEP developed and maintains two types of wetlands information for general planning and regulatory purposes. The first is the delineated wetlands in the NJDEP land use/cover change databases. The second is the linear wetlands database derived from the freshwater wetlands data generated under the New Jersey Freshwater Wetlands Mapping Program. The linear wetlands are intended to serve as a resource for analysis rather than regulatory delineations. The Musquapsink Brook Watershed contains approximately 8.6 miles of linear wetlands and 199.4 acres of delineated wetlands. Over 89% of the delineated wetland area is categorized as Deciduous Wooded Wetlands (Table 4.4). See Figure 4.5 below for the spatial distribution of linear and delineated wetlands within the watershed. Table 4.4 provides a list of wetland types and coverage (in acres) within the Musquapsink Brook Watershed.

Table 4.4: Wetland Types and Coverage within the Musquapsink Brook Watershed (NJDEP Land Use/Land Cover Database, 2007)

Wetland Type	Area (acres)	Percent of Wetland Area
Agricultural Wetlands (Modified)	2.4	1.2%
Deciduous Scrub/Shrub Wetlands	5.1	2.6%
Deciduous Wooded Wetlands	178.3	89.4%
Disturbed Wetlands	3.2	1.6%
Herbaceous Wetlands	0.5	0.2%
Managed Wetland In Built-Up Maintained Recreational Area	5.2	2.6%
Managed Wetland In Maintained Lawn Greenspace	4.2	2.1%
Mixed Wooded Wetlands (Deciduous Dominated)	0.5	0.2%
TOTAL	199.4	100%

Wetlands provide important hydrological functions, such as filtering pollutants from stormwater runoff, acting as storage areas for flood waters, protecting stream banks from erosion, providing habitat for wildlife, and providing recreational opportunities for humans. The delineated wetlands represent only about 4.5% of the land area in the Musquapsink Watershed. The loss of wetlands to urbanization significantly alters the watershed hydrology and contributes to water quality and quantity problems observed in the Musquapsink Brook Watershed.

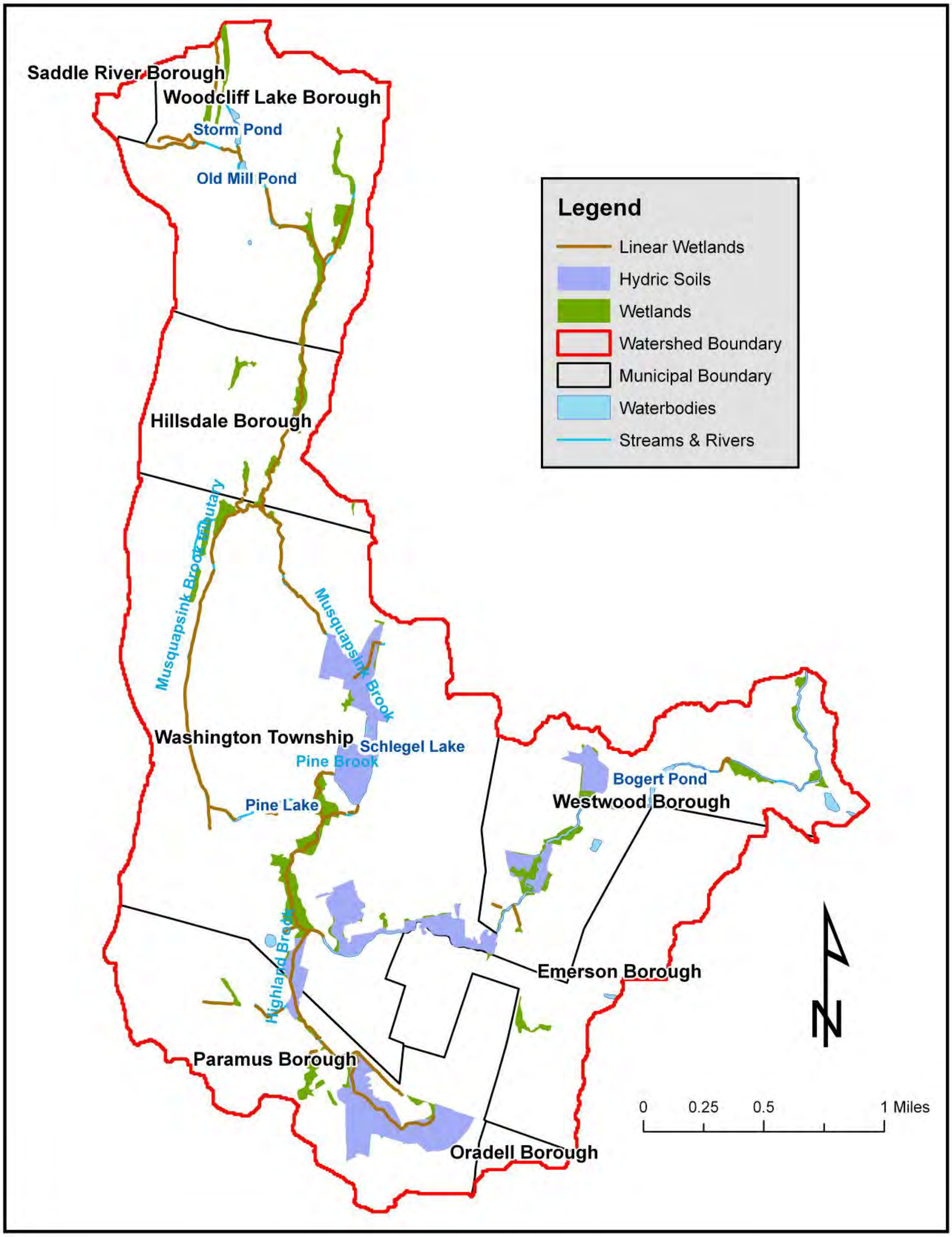

Figure 4.5: Linear and Delineated Wetlands within the Musquapsink Brook Watershed

4.2.2 Hydric Soils

The New Jersey Freshwater Wetlands Protection Act Rules (N.J.A.C. 7:7A) defines hydric soils as soils that in their "undrained condition is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions that favor the growth and regeneration of hydrophytic vegetation" (NJDEP, 2009). Hydric soils are commonly associated with wetland areas and are strongly influenced by the presence of water. Wetland conditions may exist without the presence of hydric soils.

There are four different hydric soil types in the Musquapsink Brook Watershed, with coverage of approximately 189 acres as presented in Table 4.5. The spatial distribution of hydric soils is presented in Figure 4.5 above. These are the same soils that are described as 'frequently flooded' in Table 4.3.

Table 4.5: Hydric Soil Types and Coverage within the Musquapsink Brook Watershed (SSURGO Database, 2010)

Description	Area (acres)
Adrian muck	81.8
Carlisle muck	36.6
Fluvaquents, loamy	27.3
Preakness silt loam	55.0
Udorthents, loamy	15.1
TOTAL	215.8

4.2.3 Riparian Areas

Riparian areas, or riparian zones, are areas of land and vegetation within and adjacent to a regulated water, but not man-made lagoons, stormwater management basin, or oceanfront barrier island, spit or peninsula, nor along the Atlantic Ocean (NJDEP, 2010). Riparian areas are best as undeveloped areas adjacent to streams that are either within the 100-year floodplain, contain hydric soils, contain streamside wetlands and associated transition areas, or are within a 150-foot or 300-foot wildlife passage corridor on both sides of a stream. Riparian zones are important natural filters of stormwater runoff, protecting aquatic environments from excessive sedimentation, pollutants, and erosion. They supply shelter and food for many aquatic animals and also provide shade, an important part of stream temperature regulation. Because the streams within the Musquapsink Brook Watershed are designated as "C1," New Jersey regulations require a 300 foot buffer on either side of the waterway (NJDEP, 2010). Approximately 1,444 acres of land are designated as riparian area in the Musquapsink Brook Watershed using the 300 foot buffer rule (Figure 4.6).

Riparian zones are instrumental in water quality improvement for both surface runoff and water flowing into streams through subsurface or groundwater flow. The decrease of riparian areas in the Musquapsink Brook Watershed due to urbanization has contributed to poor surface water quality conditions and increased streambank erosion.

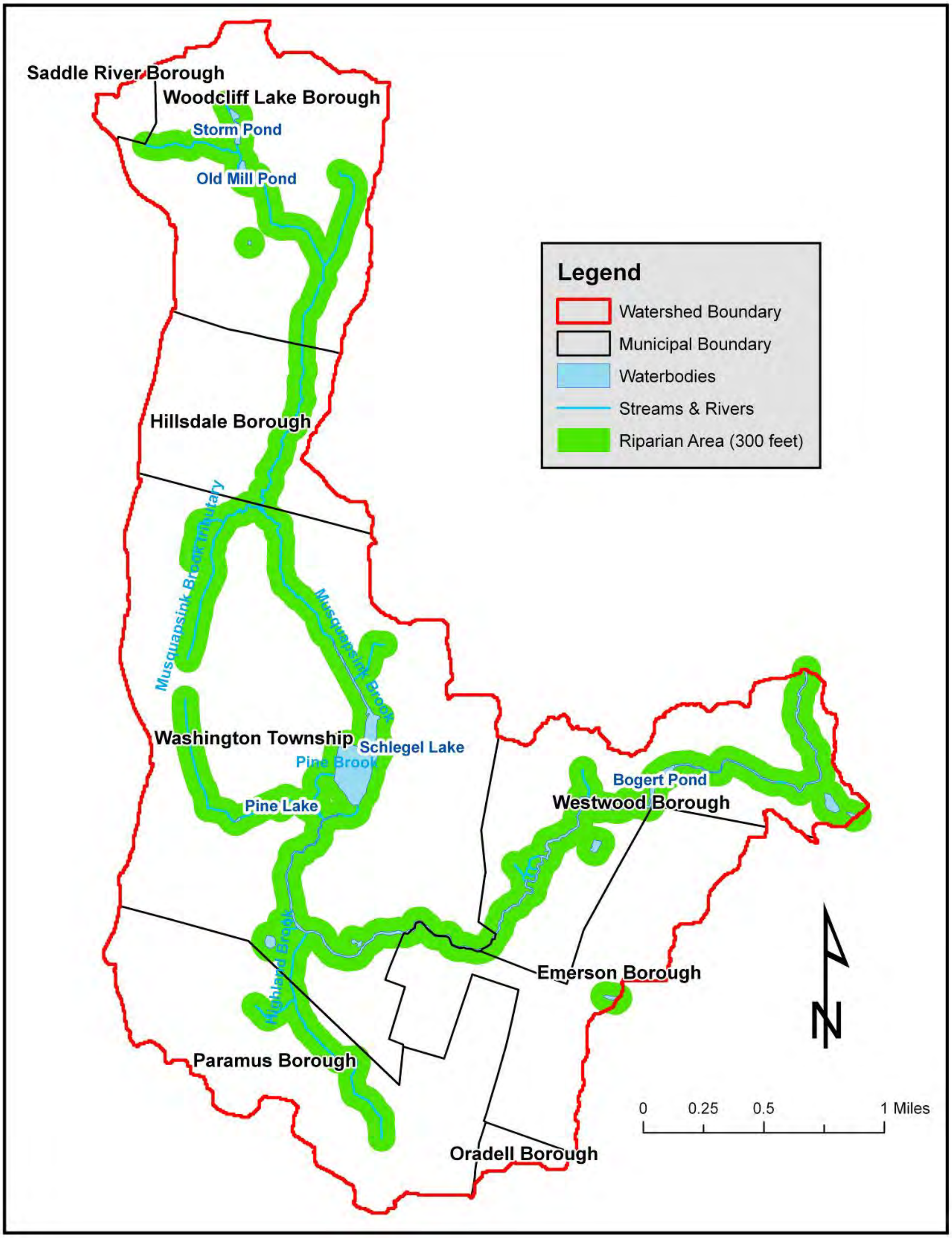

Figure 4.6: Riparian Areas within the Musquapsink Brook Watershed

4.3 Land Use

The land uses in this watershed are classified under six broad land use categories including agriculture, barren, forest, urban, water and wetlands; these are further defined by 50 subcategories of land use following a 4-digit land use classification code based on a modified Anderson Land Classification system (Anderson *et al*., 1976). Table 4.6 presents the area and percentages of land uses in the Musquapsink Brook Watershed in 1995, 2002, and 2007. The extent distribution of land use types for the year 2007 is displayed in Figure 4.7.

Table 4.6: Area and Percentage of Land Uses within the Musquapsink Brook Watershed (NJDEP Land Use/Land Cover Database)

Land Use	1995		2002		2007	
	Acres	Percent	Acres	Percent	Acres	Percent
Agriculture	23.2	0.5%	23.4	0.5%	19.7	0.4%
Barren	14.6	0.3%	9.4	0.2%	3.0	0.1%
Forest	427.7	9.7%	438.0	10.0%	405.6	9.2%
Urban	3,647.4	83.1%	3,653.7	83.2%	3,705.4	84.4%
Water	50.9	1.2%	58.5	1.3%	56.9	1.3%
Wetlands	226.2	5.2%	207.0	4.7%	199.4	4.5%
TOTAL	4,390	100%	4,390	100%	4,390	100%

Of the 84.4% of the land use designated as urban in 2007 Table 4.6), 49.1%, or 1,821.3 acres (or 2.8 square miles), is classified as single residential, medium density, defined by the NJDEP as residential urban/suburban neighborhoods greater than 1/8 acre and up to and including 1/2 acre lots. These areas generally contain impervious surface areas of approximately 30% to 35%. Urban land use also includes land utilized for commercial, industrial and transportation purposes (Anderson *et al*., 1976). Table 4.7 provides further information on the types of urban land use in the Musquapsink Brook Watershed.

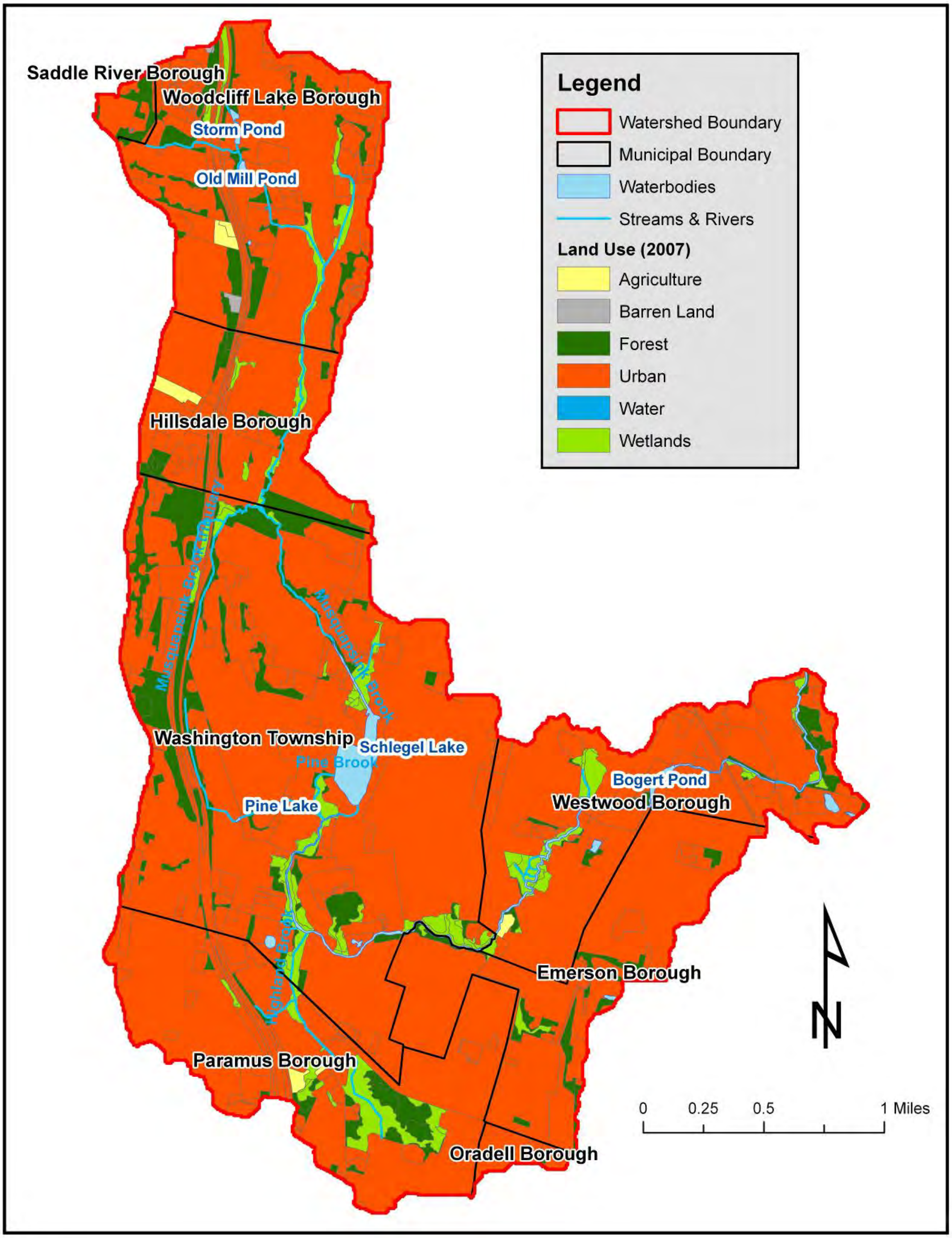

Figure 4.7: Spatial Distribution of Land Use Types within the Musquapsink Brook Watershed

Table 4.7: Urban Land Uses in the Musquapsink Brook Watershed

2007 Urban Land Use	Acres	Percent Cover
Athletic Fields (Schools)	64.2	1.73%
Cemetery	308.8	8.31%
Commercial/Services	168.5	4.58%
Major Roadway	68.2	1.83%
Mixed Urban or Built-Up Land	1.9	
Other Urban or Built-Up Land	128.4	3.51%
Railroads	3.2	0.09%
Recreational Land	70.8	1.90%
Residential, High Density or Multiple Dwelling	86.8	2.34%
Residential, Rural, Single Unit	66.0	1.78%
Residential, Single Unit, Low Density	911.0	24.52%
Residential, Single Unit, Medium Density	1,821.3	49.26%
Stormwater Basin	2.2	0.06%
Transportation/Communication/Utilities	4.1	0.11%
TOTAL	3,705.4	100%

5. Causes and Sources of Pollution

5.1 Hydrological Alteration

The loss of wetlands and riparian areas to development has resulted in significant hydrological alterations in the Musquapsink Brook Watershed. Extensive urbanization has direct impacts on both water quality and quantity. The increase of impervious surface coverage (i.e., rooftops, driveways, roads, parking lots) results in decreased infiltration of stormwater and increased surface runoff. This runoff, when managed improperly, is a major pathway for the transportation of pollutants such as debris, fertilizer, bacteria, and/or sediment. These pollutants are washed directly into the Brook, ultimately degrading the surface water quality and necessitating the development of TMDLs. Stormwater runoff also causes recurrent flooding problems in many municipalities, the destruction of habitat along the streambank, and may contribute to manhole discharges.

The Brook is dammed at three locations, two of which are along Musquapsink Brook and one along Pine Brook (Figure 5.1). The two Musquapsink Brook dams create Schlegel Lake and Bogert Pond, both of which are recreational lakes. Schlegel Lake is the largest waterbody in the watershed covering 27.0 acres. The Pine Brook dam creates Pine Lake, a 0.6 acre waterbody in Washington Township (Figure 5.1). All of the dams are privately owned.

5.2 Surface Water Quality

5.2.1 Designated Uses and Impairments

NJDEP (2011) designated the Musquapsink Brook (listed as a tributary to the Pascack Brook) as FW2-NT(C1). "FW2" refers to the freshwater bodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "NT" means those freshwaters are not suitable for trout production or trout maintenance due to their physical, chemical, or biological characteristics. "NT" streams may support other fish species. "C1" refers to its designation for protection from measurable changes in water quality based on exceptional water supply significance as a tributary to the Oradell Reservoir.

According to the designated use of FW2-NT(C1) waters, the New Jersey Surface Water Quality Standards (last amended on April 4, 2011) presented in Table 5.1 below are applicable to the Musquapsink Brook Watershed. Note that the FW2 designation applies to all streams and waterbodies in the watershed, an encompass waterways categorized as C1, as well. At the time of this project's initiation, fecal coliform was the accepted measure indicating pathogen pollution for New Jersey freshwaters. Since then, the fecal coliform standard has been replaced by an *E. coli* standard. Because the TMDL established by New Jersey refers to fecal coliform, both fecal coliform and *E. coli* were measured during sampling events in the Musquapsink Brook Watershed.

Table 5.1: New Jersey Surface Water Quality Standards for Different Substances and Surface Waters (NJDEP, 2011)

Substance	Surface Water Classification	Standards
Total Phosphorus (mg/L)	FW2 Streams	Total Phosphorus shall not exceed 0.1 in any stream, unless watershed-specific translators are established pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable.
	FW2 Lakes	Concentrations of total P shall not exceed 0.05 in any lake, pond or reservoir, or in a tributary at the point where it enters such bodies of water, unless watershed-specific translators are developed pursuant to N.J.A.C. 7:9B-1.5(g)2 or if the Department determines that concentrations do not render the waters unsuitable.
Fecal Coliform* (col/100 mL)	FW2	Shall not exceed geometric average of 200/100 mL, nor should more than 10% of the total samples taken during any 30-day period exceed 400/100 mL.
E. coli (col/100 mL)	FW2	Shall not exceed a geometric mean of 126/100 mL or a single sample maximum of 235/100 mL.

*This standard has been replaced by *E. coli*.

In accordance with Section 305(b) of the Clean Water Act, New Jersey addresses the overall water quality of the State's waters and identifies impaired waterbodies through the development of a document referred to as the *Integrated List of Waterbodies*. Within this document are lists that indicate the presence and level of impairment for each waterbody monitored. It is recommended by the EPA that this list be a guideline for water quality management actions that will address the cause of impairment. The 2010 *New Jersey Integrated Water Quality Monitoring and Assessment Report* lists the Musquapsink Brook (reported as 'Pascack Brook (below Westwood gage) as not supporting the following uses: agricultural water supply use due to total dissolved solids; aquatic life use due to dissolved oxygen, pH, and TP; primary contact recreational use due to fecal coliform; and, public water supply use due to arsenic.

A total maximum daily load was established in 2002 for the Musquapsink Brook requiring a 96% reduction in fecal coliform load for 7.3 miles of stream. In 2005, a TMDL for total phosphorus was established for the same 7.3 mile stretch of stream. This TMDL requires a 21.43% reduction in total phosphorus loadings from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forest, and agricultural lands. Additional aquatic life surface water quality impairments will also need to be addressed through the TMDL process.

The NJDEP Bureau of Biological & Freshwater Monitoring maintains one AMNET station within the Musquapsink Brook Watershed (Station AN0206, Westwood, NJ) (Figure 5.1). This station, located at Harrington Avenue, was sampled in July of 1993, 1998, and 2003. For each of the three sampling rounds, the Musquapsink Brook was rated as a moderately impaired site, characterized by reduced macroinvertebrate taxa richness.

A fourth round of sampling was conducted in 2008, but AMNET data for this round were not available at the time of publication.

5.2.2 Monitoring Stations

To better understand the causes and sources of the water pollution in the watershed, surface water samples were regularly collected from eight water quality monitoring stations over a six-month time frame in 2007. These stations are depicted in Figure 5.1. Note that MB2 serves as a monitoring site for Schlegel Lake and is not included in catchment area calculations (Chapter 6). Six stations are located on the Musquapsink Brook, and two are located adjacent to the United Water Transfer intake on Saddle River and the Ho-Ho-Kus Brook, respectively. The station site descriptions are identified in Table 5.2.

Table 5.2: Water Quality Monitoring Location IDs and Descriptions

Site ID	Site Description
MB1	Musquapsink Brook at Hillside Ave, Hillsdale
MB2	Musquapsink Brook at Woodfield Ave, Washington
MB3	Musquapsink Brook at Ridgewood Ave, Washington
MB4	Musquapsink Brook at Forest Ave, Westwood
MB5	Musquapsink Brook at Third Ave, Westwood
MB6	Musquapsink Brook at Harrington Ave, Westwood
SR1	Saddle River at Grove St, border of Paramus and Ridgewood
HB1	Ho-Ho-Kus Brook at Grove St, border of Paramus and Ridgewood

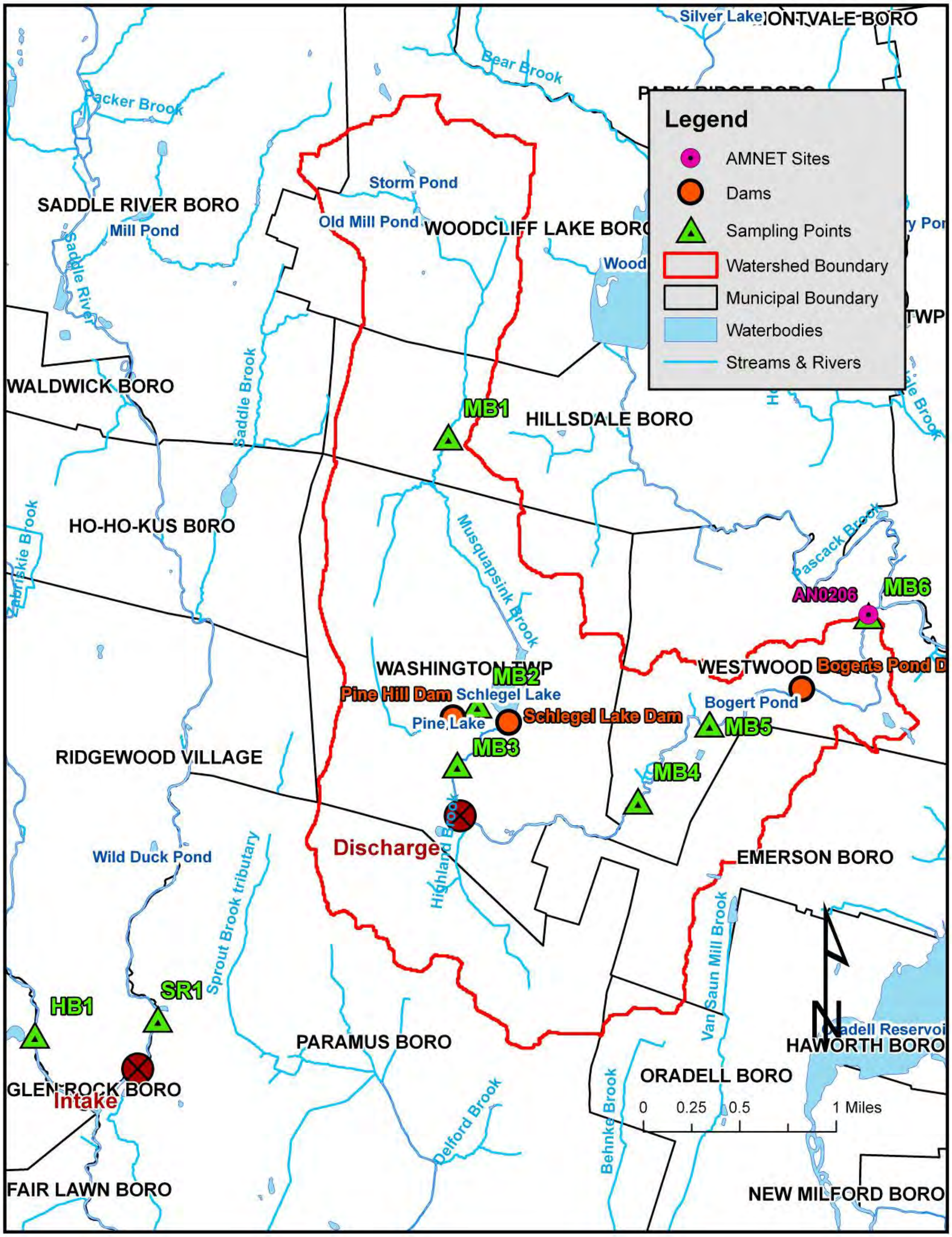

Figure 5.1: Water Quality Sampling Location Map

5.2.3 Monitoring Events

Project partners, including NJDEP, Rutgers Cooperative Extension Water Resources Program, and the Bergen County Department of Health Services, began water quality monitoring on May 25, 2007. As per the NJDEP-approved Quality Assurance Project Plan (QAPP), *in situ* measurements of pH, dissolved oxygen (DO), and temperature were collected. Stream velocity and depth were measured along transects laid across the stream at each sampling station. Using this information, flow (Q) was calculated. Water samples were collected and analyzed by two separate laboratories. The Bergen County Utility Authority conducted analyses for total phosphorus (TP), dissolved orthophosphate phosphorus, ammonia-nitrogen, Total Kjeldahl Nitrogen (TKN), nitrate-nitrogen, nitrite-nitrogen, total suspended solids (TSS), and fecal coliform. Garden State Laboratories analyzed the samples for *E. coli*.

Water quality monitoring included two different types of sampling events: regular and bacteria only. Regular monitoring, which included analysis for all parameters, occurred from May 25, 2007 through October 25, 2007. These events were monitored for TP, dissolved orthophosphate phosphorus, ammonia-nitrogen, TKN, nitrate-nitrogen, nitrite-nitrogen, TSS, fecal coliform, and *E. coli* and had no specific weather conditions directing the sample collection. Bacteria-only monitoring was conducted in the months of June, July, August, and September 2007, again without conditions set by the weather. The bacteria-only sampling entailed collecting three additional samples in each of those months for pathogen analysis. Flow was measured, and *in situ* samples were collected during these events. Specific dates and the corresponding types of monitoring events are presented in Table 5.3.

Table 5.3: Types of Monitoring Events for Each Sampling Date

Date	Regular Monitoring for all Parameters	Bacteria Only Monitoring
5/24/2007	X	
5/31/2007	X	
6/7/2007	X	
6/14/2007		X
6/19/2007		X
6/21/2007	X	
6/28/2007		X
7/5/2007	X	
7/12/2007		X
7/24/2007		X
7/26/2007		X
8/2/2007	X	
8/9/2007		X
8/16/2007	X	
8/23/2007		X
8/30/2007		X
9/13/2007		X
9/27/2007		X
10/10/2007	X	
10/11/2007	X	
10/25/2007	X	

(shaded box) Indicates Storm Sampling Event

5.2.4 Summary of Water Quality Data

To evaluate the health of the Musquapsink Brook at all the stations, the monitoring results were compared to the designated water quality standards. The USEPA Guidance for the Preparation of the Comprehensive State Water Quality Assessments (1997) advises that an acceptable frequency for water quality results to exceed criteria is 10% of samples. In the 2010 Integrated Water Quality Monitoring and Assessment Methods, NJDEP further states that a minimum of eight samples collected quarterly over a two-year period are required to confirm quality of waters. Therefore, if a waterbody has a minimum of eight samples collected quarterly over a two-year period with more than 10% of the samples exceeding the water quality criteria for a certain parameter, the waterbody is considered “impaired” for that parameter.

By applying this rule to the water quality data, it is possible to identify which stations are impaired for each parameter that has been identified as a concern in the scope of this project– TP, fecal coliform, and *E. coli*. The applicable water quality standards for this project are detailed in Table 5.1 above, and the percent of samples that exceeded these standards are given in Table 5.4 below.

Table 5.4: Summary of Water Quality Data Collected in this Planning Effort and Comparison to Water Quality Standards

Monitoring Station ID	**Total Phosphorus (mg/L)**					
	Water Quality Standard (WQS)	*Count*	*Minimum*	*Average*	*Maximum*	*% Not Satisfying WQS*
MB1	0.1	11	0.01	0.09	0.16	45%
MB2	0.1	11	0.05	0.07	0.13	18%
MB3	0.1	11	0.01	0.06	0.13	9%
MB4	0.1	11	0.01	0.10	0.35	45%
MB5	0.1	11	0.01	0.12	0.35	45%
MB6	0.1	11	0.01	0.12	0.29	55%
SR1	0.1	11	0.01	0.07	0.13	27%
HB1	0.1	10	0.91	1.63	2.20	100%
	Fecal Coliform (col/100mL)					
MB1	200	23	200	3479	28000	96%
MB2	200	23	60	1481	12000	87%
MB3	200	23	120	3706	44000	91%
MB4	200	23	410	5530	49000	100%
MB5	200	23	106	6627	58000	91%
MB6	200	23	500	10373	70000	100%
SR1	200	23	110	5550	39000	91%
HB1	200	23	200	7270	41000	96%
	***E. coli* (col/100mL)**					
MB1	235	23	170	2645	16000	91%
MB2	235	23	60	480	2200	65%
MB3	235	23	160	1897	7800	96%
MB4	235	23	160	4809	25000	96%
MB5	235	23	120	6090	33000	96%
MB6	235	23	210	5202	38000	96%
SR1	235	22	380	2860	23000	100%
HB1	235	22	410	3150	22000	100%

Tabulated water quality monitoring data are provided in the data report (Appendix A). Data has also been graphed with corresponding surface water quality standards and daily precipitation records for Bergen County. These graphs are provided in the appendices of the data report.

5.2.5 Biological Monitoring Data

Biological monitoring data is available for the Musquapsink Brook Watershed as part of the **Am**bient Biological Monitoring **Net**work (AMNET), which is administered by the New Jersey Department of Environmental Protection (NJDEP). The NJDEP has been monitoring the biological communities of the State's waterways since the early 1970's, specifically the benthic macroinvertebrate communities. Benthic macroinvertebrates are primarily bottom-dwelling (benthic) organisms that are generally ubiquitous in freshwater and are macroscopic. Due to their important role in the food web, macroinvertebrate communities reflect current perturbations in the environment. There are several advantages to using macroinvertebrates to gauge the health of a stream. First, macroinvertebrates have limited mobility, and thus, are good indicators of site-specific water conditions. Also, macroinvertebrates are sensitive to pollution, both point and nonpoint sources; they can be impacted by short-term environmental impacts such as intermittent discharges and contaminated spills. In addition to indicating chemical impacts to stream quality, macroinvertebrates can gauge non-chemical issues of a stream such as turbidity and siltation, eutrophication, and thermal stresses. Finally, macroinvertebrate communities are a holistic overall indicator of water quality health, which is consistent with the goals of the Clean Water Act (NJDEP, 2007). These organisms are normally abundant in New Jersey freshwaters and are relatively inexpensive to sample.

New Jersey Impairment Score (NJIS)

The AMNET program began in 1992 and is currently comprised of more than 800 stream sites with approximately 200 monitoring locations in each of the five major drainage basins of New Jersey (i.e., Upper and Lower Delaware, Northeast, Raritan, and Atlantic). These sites are sampled once every five years using a modified version of the USEPA Rapid Bioassessment Protocol (RBP) II (NJDEP, 2007). To evaluate the biological condition of the sampling locations, several community measures have been calculated by the NJDEP from the data collected and include the following:

1. Taxa Richness: Taxa richness is a measure of the total number of benthic macroinvertebrate families identified. A reduction in taxa richness typically indicates the presence of organic enrichment, toxics, sedimentation, or other factors.

2. EPT (Ephemeroptera, Plecoptera, Trichoptera) Index: The EPT Index is a measure of the total number of Ephemeroptera, Plecoptera, and Trichoptera families (i.e., mayflies, stoneflies, and caddisflies) in a sample. These organisms typically require clear moving water habitats.

3. % EPT: Percent EPT measures the numeric abundance of the mayflies, stoneflies, and caddisflies within a sample. A high percentage of EPT taxa is associated with good water quality.

4. % CDF (percent contribution of the dominant family): Percent CDF measures the relative balance within the benthic macroinvertebrate community. A healthy community is characterized by a diverse number of taxa that have abundances somewhat proportional to each other.

6. Family Biotic Index: The Family Biotic Index measures the relative tolerances of benthic macroinvertebrates to organic enrichment based on tolerance scores assigned to families ranging from 0 (intolerant) to 10 (tolerant).

This analysis integrates several community parameters into one easily comprehended evaluation of biological integrity referred to as the New Jersey Impairment Score (NJIS). The NJIS was established for three categories of water quality bioassessment for New Jersey streams: non-impaired, moderately impaired, and severely impaired. A non-impaired site has a benthic community comparable to other high quality "reference" streams within the region. The community is characterized by maximum taxa richness, balanced taxa groups, and a good representation of intolerant individuals. A moderately impaired site is characterized by reduced macroinvertebrate taxa richness, in particular the EPT taxa. Changes in taxa composition result in reduced community balance and intolerant taxa become absent. A severely impaired site is one in which the benthic community is significantly different from that of the reference streams. The macroinvertebrates are dominated by a few taxa which are often very abundant. Tolerant taxa are typically the only taxa present. The scoring criteria used by the NJDEP are as follows:

- non-impaired sites have total scores ranging from 24 to 30,
- moderately impaired sites have total scores ranging from 9 to 21, and
- severely impaired sites have total scores ranging from 0 to 6.

It is important to note that the entire scoring system is based on comparisons with reference streams and a historical database consisting of 200 benthic macroinvertebrate samples collected from New Jersey streams. While a low score indicates "impairment," the score may actually be a consequence of habitat or other natural differences between the subject stream and the reference stream.

Starting with the second round of sampling under the AMNET program in 1998 for the Passaic Region, habitat assessments were conducted in conjunction with the biological assessments. The habitat assessment, which was designed to provide a measure of habitat quality, involves a visually based technique for assessing stream habitat structure. The habitat assessment is designed to provide an estimate of habitat quality based upon qualitative estimates of selected habitat attributes. The assessment involves the numerical scoring of ten habitat parameters to evaluate instream substrate, channel morphology, bank structural features, and riparian vegetation. Each parameter is scored and summed to produce a total score which is assigned a habitat quality category of optimal, sub-optimal, marginal, or poor. Sites with optimal/excellent habitat conditions have total scores ranging from 160 to 200; sites with suboptimal/good habitat conditions have total scores ranging from 110 to 159; sites with marginal/fair habitat conditions have total scores ranging from 60 to 109, and sites with poor habitat conditions have total scores less than 60. The findings from the habitat assessment are used to interpret survey results and identify obvious constraints on the attainable biological potential within the study area.

The NJDEP Bureau of Freshwater & Biological Monitoring maintains one AMNET station within the project area (i.e., Station AN0206 – Musquapsink Brook, Harrington Avenue, Westwood Borough, in Bergen County). This station corresponds with the water quality monitoring station MB6 (Figure 5.1). Station AN0206 was sampled by NJDEP in 1993, 1998, and 2003 under the AMNET program. Findings from the AMNET program are summarized in Table 5.5. A fourth round of sampling was conducted in 2008, but data were unavailable at the time of publication of this plan. The biological condition over the years has been assessed as being moderately impaired, and the habitat has ranged from marginal to sub-optimal within the Musquapsink Brook Watershed.

Table 5.5: Summary of NJDEP Ambient Biological Monitoring Network Results (NJDEP, 1994; NJDEP, 2000; NJDEP, 2008)

Station	Date	Biological Condition (Score)	Habitat Assessment (Score)
AN0206	7/6/1993	Moderately Impaired (9)	~
AN0206	7/9/1998	Moderately Impaired (15)	Marginal (104)
AN0206	7/1/2003	Moderately Impaired (15)	Suboptimal (147)

Given these aquatic life impairments, an additional biological assessment was proposed as part of the data collection needed to prepare a comprehensive watershed restoration plan for the Musquapsink Brook. A biological assessment was conducted by Marion McClary, Jr., Ph.D., Associate Director of Biological Sciences at Fairleigh Dickinson University and project partner, in the late summer of 2007 at MB1 (Musquapsink Brook at Hillside Avenue, Hillsdale), MB3 (Musquapsink Brook at Ridgewood Avenue, Washington), MB4 (Musquapsink Brook at Forest Avenue, Westwood), and at MB6 (AMNET Station AN0206, Musquapsink Brook at Harrington Avenue, Westwood). The 2007 biological assessment conducted by Dr. McClary is summarized in the Musquapsink Brook Benthic Data Report and Musquapsink Brook Benthic Species List provided in Appendix A of the Musquapsink Brook Watershed Restoration and Protection Plan Data Report. The 2007 assessment revealed that the biological condition within the Musquapsink Brook Watershed had degraded to a severely impaired condition. Marginal to sub-optimal habitat conditions were found within the watershed. There was such a paucity of benthic organisms found that less than 100 specimens were collected from the four sampling locations combined, prohibiting the calculation of the various metrics needed for the NJIS score.

<u>High Gradient Macroinvertebrate Index (HGMI)</u>

New Jersey's benthic macroinvertebrate communities can be grouped into three distinct groupings based on geographical regions: high gradient (above the Fall Line), low gradient (Coastal Plain excluding the Pinelands), and Pinelands. A multimetric index has been developed, using genus level taxonomic identifications, for each distinct region. The NJIS described and presented above is a single index used statewide that is based on family level taxonomic identifications. The NJDEP, in 2009, began using the multimetric indices for each distinct region. The index appropriate to use within the Musquapsink Brook Watershed is the High Gradient Macroinvertebrate Index (HGMI). The HGMI is comprised of the following metrics: total number of genera, percent genera that are not insects, percent sensitive EPT genera, number of scraper genera, Hilsenhoff Biotic Index, number of New Jersey TALU attribute 2 genera, and number of New Jersey TALU attribute 3 genera. Excellent sites have total scores greater than or equal to 63 and are characterized as having minimal changes in the structure of biological community and having minimal changes in ecosystem function. Good sites have total scores ranging from 42-63 and are characterized as having some evident changes in the structure of the biological community and having minimal changes in ecosystem function. Fair sites have total scores ranging from 21-42 and are characterized as having moderate to major changes in the structure of the biological community and having moderate changes in ecosystem function. Poor sites have total scores of <21 and are characterized by extreme changes in the structure of the biological community and a major loss of ecosystem function.

HGMI scores for Station AN0206 (MB6) were reported as 13.75 for the July 2003 AMNET sampling (Round 3) and 18.67 for the 2008 AMNET sampling (Round 4) by NJDEP at http://www.state.nj.us/dep/wms/bfbm under *AMNET Stations Result Comparisons for Round 2 to 4*. These scores correspond to a poor assessment. A poor assessment under the HGMI falls below the acceptable regulatory range, and a site assessed as poor using the HGMI would be considered impaired from a Federal Clean Water Act perspective and not attaining the aquatic life use. Again, given the paucity of organisms collected, the HGMI could not be calculated from the data collected as part of the 2007 assessment conducted by Dr. McClary.

5.2.6 Stressor Identification

Biological assessments have become an important tool for managing water quality to meet the goal of the Clean Water Act (i.e., to maintain the chemical, physical, and biological integrity of the nation's water). However, although biological assessments are a critical tool for detecting impairment, they do not identify the cause or causes of the impairment. The USEPA developed a process, known as the Stressor Identification (SI) process, to accurately identify any type of stressor or combination of stressors that might cause biological impairment (USEPA, 2000). The SI process involves the critical review of available information, the formation of possible stressor scenarios that may explain the observed impairment, the analysis of these possible scenarios, and the formation of conclusions about which stressor or combination of stressors are causing the impairment. The SI process is iterative, and in some cases additional data may be needed to identify the stressor(s). In addition, the SI process provides a structure or a method for assembling the scientific evidence needed to support any conclusions made about the stressor(s). When the cause of a biological impairment is identified, stakeholders are then in a better position to locate the source(s) of the stressor(s) and are better prepared to implement the appropriate management actions to improve the biological condition of the impaired waterway.

The benthic macroinvertebrate community occurring within the Musquapsink Brook Watershed is apparently under some type of stress as evidenced by the extremely low numbers of organisms collected and by sensitive taxa (i.e., EPT taxa) being markedly diminished. Also, the types of organisms found within the study area are indicative of some organic pollution (Hilsenhoff, 1988). In addition, the habitat assessment revealed sub-optimal habitat to marginal conditions which may also account for the impaired condition of the community within the study area.

Candidate causes of impairment within the Musquapsink Brook Watershed include:

1. Elevated nutrient levels (i.e., total phosphorus)
2. Elevated bacteria levels (i.e., fecal coliform and *E. coli*)
3. Degraded instream habitat
4. Altered hydrology
5. Toxicants.

Analysis/Evaluation of Candidate Causes:

Elevated nutrient levels and elevated bacteria levels: The role of elevated nutrients and elevated bacteria levels in impairing the biological community was indicated by continual and persistent exceedances of the surface water quality criteria for phosphorus and bacteria throughout the watershed during the surface water quality monitoring portion of this study. Surface water quality samples were collected from stations within the Musquapsink Brook Watershed over a six month sampling time frame from May 2007 through October 2007, demonstrating a co-occurrence of these candidate causes within the watershed. Approximately 83% of the designated land use within the watershed is urban and comprised of residential (medium and low density), commercial, and roadway land use/land cover types. Stormwater runoff from these land uses is a likely source of elevated nutrients. In addition, microbial source tracking (MST) was conducted within the watershed as part of this study. Human related *Bacteroides* were detected at several locations within the watershed. Aging/leaking/failing infrastructure may be a likely source of the elevated bacteria levels observed within the watershed.

Degraded habitat: The role of degraded habitat in impairing the biological community within the watershed was indicated by the assessed sub-optimal to marginal habitat conditions within the watershed. Also, out of the 38 stream reaches evaluated using SVAP, 18 were rated as only fair and 15 were rated as poor. A likely source observed within the watershed for degraded habitat conditions includes channelization, which reduces channel diversity and promotes a uniform flow regime and ultimately reduces habitat diversity. Another likely source is stormwater outfalls which can increase erosion and scour leading to reduced channel diversity, homogenous flow regime, and unstable habitat. An additional source observed within the watershed is a decreased riparian vegetative zone (i.e., riparian buffer) which leads to increased stream temperatures, depressed dissolved oxygen levels, unstable banks, and an overall reduction in habitat complexity.

Altered hydrology: The role of altered hydrology in impairing the biological community within the watershed was indicated by reduced channel and habitat diversity, a slow and homogenous flow regime, and a potential reduction in baseflow. A likely source for altered hydrology observed within the watershed includes channelization, which reduces channel diversity and therefore promotes a uniform flow regime. Another likely source for altered hydrology observed within the watershed would include stormwater outfalls. Stormwater outfalls can increase erosion and scour leading to reduced channel diversity and homogenous flow regime.

The United Water of New Jersey water diversion from the Saddle River in Paramus Borough which discharges into the Musquapsink Brook in Washington Township may also have an impact on the biological community. According to the USGS Water-Data Report 2007, from May through October 2007, the diversion averaged, 3.27 cubic feet per second. This additional flow to the Musquapsink Brook may also be responsible for increased erosion and scour, similar to stormwater outfalls.

Toxicants: The role of toxicants in impairing the biological community was indicated by the observation of very few macroinvertebrates at each sampling station. Less than 100 organisms were collected from the four sampling locations combined during the 2007 assessment by Dr. McClary. Monitoring for pesticides and herbicides as possible toxicants is recommended in the future given the urban nature of the watershed.

5.2.7 Microbial Source Tracking

Microbial source tracking (MST) are a series of methods employed to determine sources of microbial pollution, whether from bacteria or other pathogens such as viruses and protozoa (Simpson et al. 2002). MST is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical), and chemical methods (e.g., caffeine or optical brighteners) to identify the origin of fecal pollution (Simpson et al. 2002; Scott et al. 2002; Stoeckel and Harwood 2007).

To gain a better understanding of the sources of contaminants of human origin, tiered approaches can be applied to microbial source tracking studies. Tiered approaches study multiple levels, multiple scales, or multiple parameters with increasing focus as one moves through each tier. This has been recommended by investigators as a successful means of tracking fecal contamination sources (Boehm et al. 2003; Stewart et al. 2003; Noble et al. 2006; Cao et al. 2009). The tiered approach can aid watershed management in abating the most significant sources of fecal bacteria (or other pollutant of concern) (Noble et al. 2006). Objectives and tasks are developed in this approach so that appropriate management practices are implemented and resources are allocated efficiently and economically throughout a watershed.

To track down potential sources of human-related fecal contamination, a tiered sampling approach was used. Tiered approaches study multiple levels, multiple scales, or measuring multiple parameters with increasing focus as one moves through each tier. Three tiers have been identified in which each tier uses a different method of bacterial contamination detection. The tiered sampling scheme for determining human sources as part of the Musquapsink Brook Watershed Restoration and Protection Plan is outlined below:

<u>Tier 1: Screening for fecal coliform contamination</u>
Surface water quality sampling was performed during both wet and dry weather conditions to determine the presence of fecal contamination.

Table 5.4 provides a summary of the results of surface water quality sampling analyses. Depending upon the sampling station, 87% to 100% of the samples collected in the Musquapsink Brook Watershed exceed the surface water quality standard for fecal coliform (Table 5.4).

<u>Tier 2: Location of human and non-human fecal “hot spots”</u>
MST sampling and qPCR analysis were used to differentiate between human and non-human sources of bacterial loadings to surface waters.

MST techniques typically report fecal contamination source as a percentage of targeted bacteria. One of the most promising targets for MST is *Bacteroides*, a genus of obligately anaerobic, gram-negative bacteria that are found in all mammals and birds. *Bacteroides* comprise up to 40% of the amount of bacteria in feces and 10% of the fecal mass. Due to large quantities of *Bacteroides* in feces, they are an ideal target organism for identifying fecal contamination

(Layton et al. 2006). In addition, *Bacteroides* have been recognized as having broad geographic stability and distribution in target host animals and are a promising microbial genus for differentiating fecal sources (USEPA 2005; Dick et al. 2005; Layton et al. 2006).

Three sets of primers (targets) were used to quantify *Bacteroides* from 1) all sources of *Bacteroides* ("AllBac"), 2) human sources ("HuBac"), and 3) bovine sources of *Bacteroides* ("BoBac") using quantitative real-time polymerase chain reaction (qPCR). Two sets of surface water quality samples were collected in the Musquapsink Brook Watershed during July and August of 2008 and analyzed for the three target sequences. Human-related *Bacteroides* were detected at sampling locations MB2, MB4, MB5, and MB6 for at least one MST sampling event (August 21, 2008). See Figures 5.2 and 5.3 for *Bacteroides* quantifications at all sampling sites.

The Musquapsink Brook Watershed is a highly-urbanized watershed with little agriculture within its boundaries. The MST results confirmed this with no detections of agriculturally-derived bovine *Bacteroides* (BoBac) in either July or August sampling event (Figures 5.2 and 5.3).

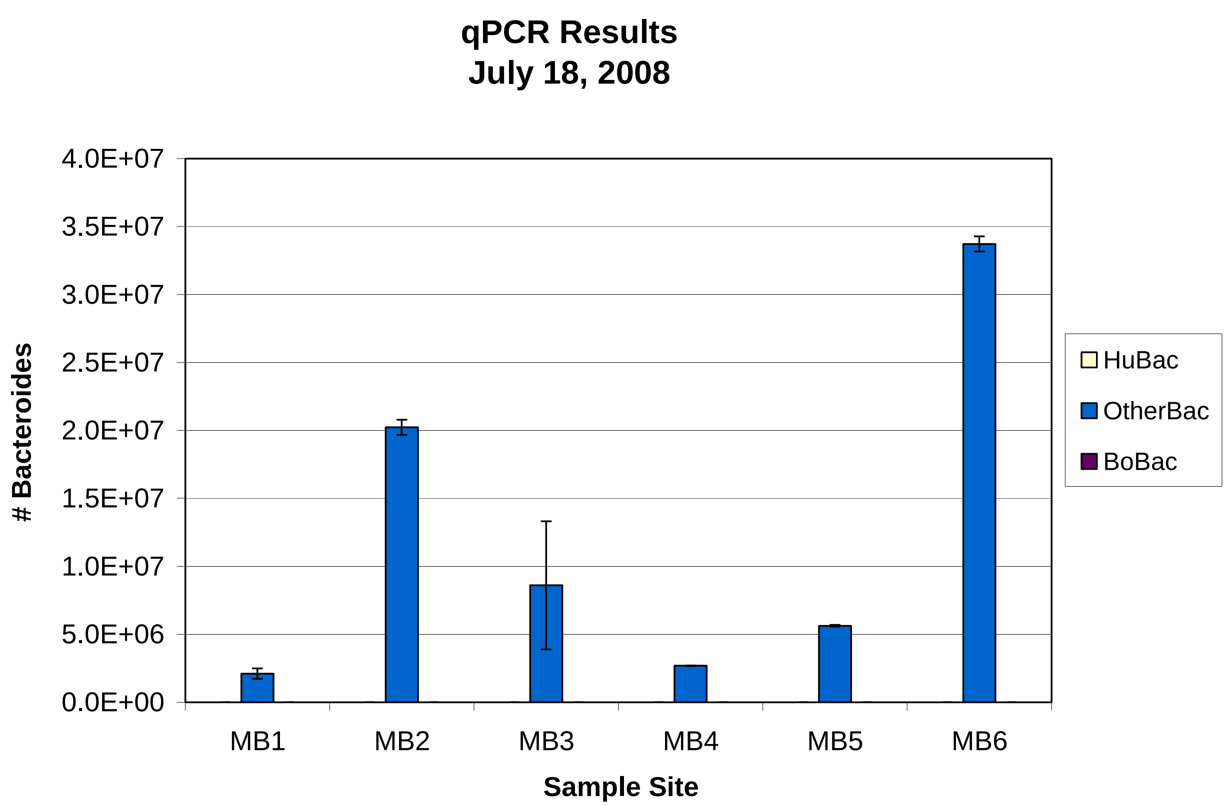

Figure 5.2: *Bacteroides* Quantifications at Each Sampling Site on July 18, 2008

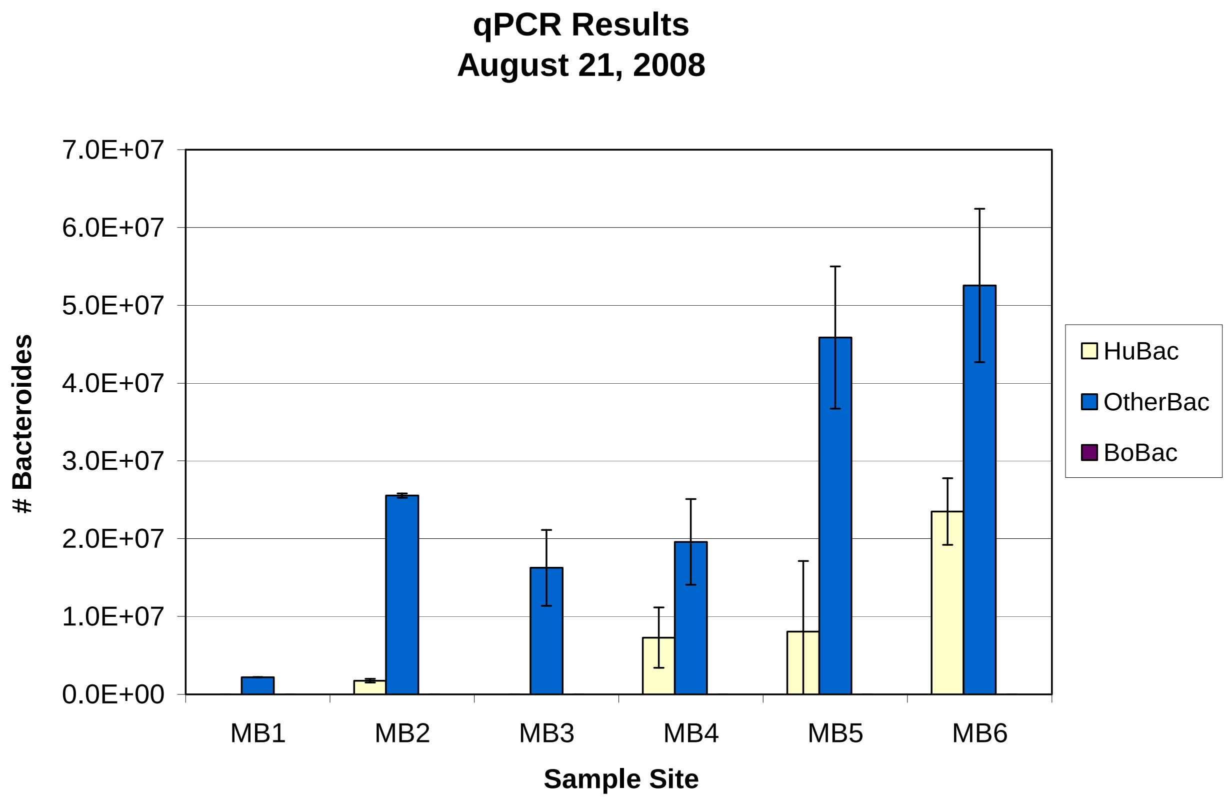

Figure 5.3: *Bacteroides* Quantifications at Each Sampling Site on August 21, 2008

Tier 3: Source tracking with optical brighteners

Another source tracking method to identify *human* bacterial contamination in surface water is the fluorometric detection of optical brighteners. Optical brighteners are compounds added to laundry detergents and soaps, and have no natural sources. Because household plumbing systems combine effluent from washing machines and toilets, optical brighteners are associated with human sewage in sewer lines, septic systems and wastewater treatment plants (Hartel et al., 2007). Their presence in surface water, therefore, can be an indicator of an illicit connection, leaking collection pipes, or contamination from other wastewater discharges.

Fluorometric analysis was used to detect the presence of optical brighteners in the stream. Optical brightener data was correlated with *in-situ* stream measurements to verify sewer discharges. These compounds enter an excited state when exposed to UV light (360-365nm range) and emit light in the blue range (400-440nm). Fluorescence of these compounds can be measured with a fluorometer.

Two rounds of optical brightener sampling and fluorometric analysis were completed between May and August 2010 during dry conditions (no recorded precipitation within 48 hours of sampling event). Initially, there were 16 sites sampled (Figure 5.4). Two additional sites were added for the August sampling event. The locations of sampling sites for both events are provided in Appendix B. Fluorometric analysis results and *in situ* pH, DO, and temperature readings are also reported in Appendix B. Average fluorometric readings for the collected samples are presented in Figure 5.5 below.

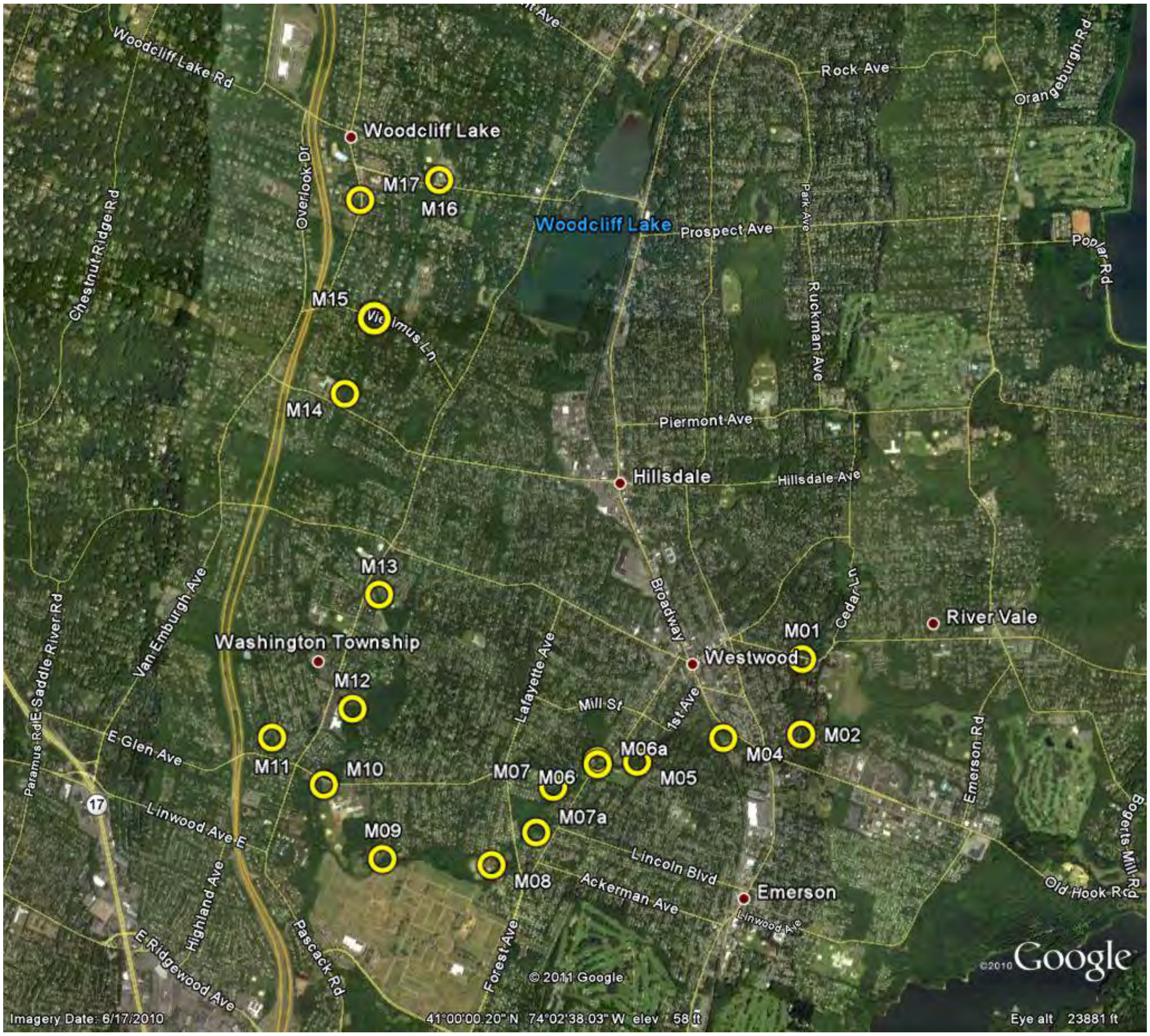

Figure 5.4: Sampling sites for Optical Brighteners in the Musquapsink Brook Watershed

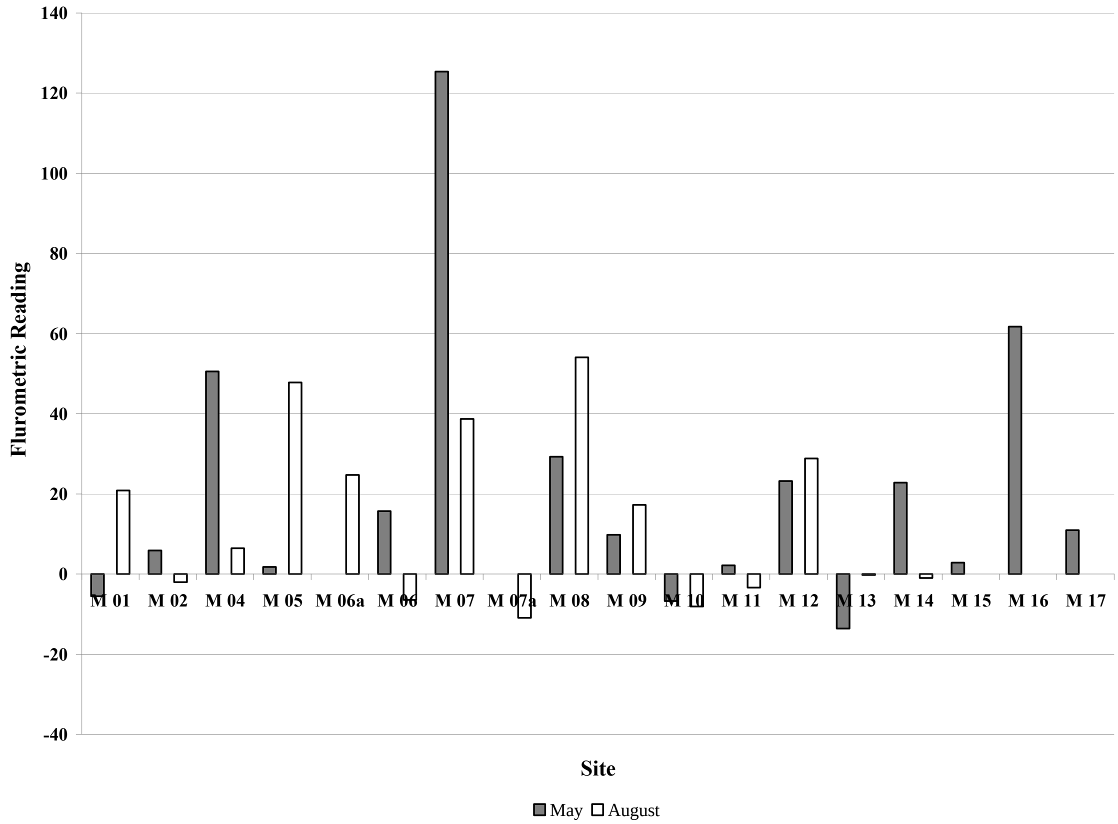

Figure 5.5: Average Fluorometric Readings for Samples Collected in May and August, 2010

<u>Recommendations</u>

Modeled on a similar optical brightener study conducted by the University of North Carolina (Tavares et al, 2008), bacteria source trackdown was achieved by comparing fecal coliform concentration and MST sampling results to average optical brightener levels at each sampling location. Refer to Table 5.6 for summary of this data.

Table 5.6: Summary of Results for Optical Brightener Levels for Each Subwatershed

Subwatershed	Average Fecal Concentration (col/100ml)	MST Human Source Detection	Optical Brightener Sampling Site	Optical Brightener Level[1]
MB1	3,479	No	M14	Low
			M15	Low
			M16	High
			M17	Low
MB2	1,481	Yes	M12	High
			M13	Low
MB3	3,706	No	M11	Low
MB4	5,530	Yes	M08	High
			M09	Low
			M10	Low
MB5	6,627	Yes	M06	Low
			M06a	High
			M07	High
			M07a	Low
MB6	10,373	Yes	M01	Low
			M02	Low
			M04	High
			M05	High

[1]"High" Optical Brightener Level indicates that, for sites sampled in both May and August, at least one fluorometric reading was above 20 and both events yielded samples positive for optical brightener presence. For sites with only one sampling event, "High" indicates a fluorometric reading above 40. All other scenarios indicate "Low" Optical Brightener Levels.

The tiered approach study was intended to provide Bergen County and its included townships with the initial information they need for targeted investigation into sanitary sewer releases to the Brook. Based on the results provided in Table 5.6, the Rutgers Cooperative Extension Water Resources Program recommends that three general areas be evaluated for sources of human-related bacterial contamination in Westwood Borough and Washington Township. Figure 5.6 contains maps of the identified regions. Maintenance and inspection records of water and wastewater infrastructure should be reviewed for each of these areas. Video inspections, smoke testing, or dye testing to determine infrastructure conditions may also be considered.

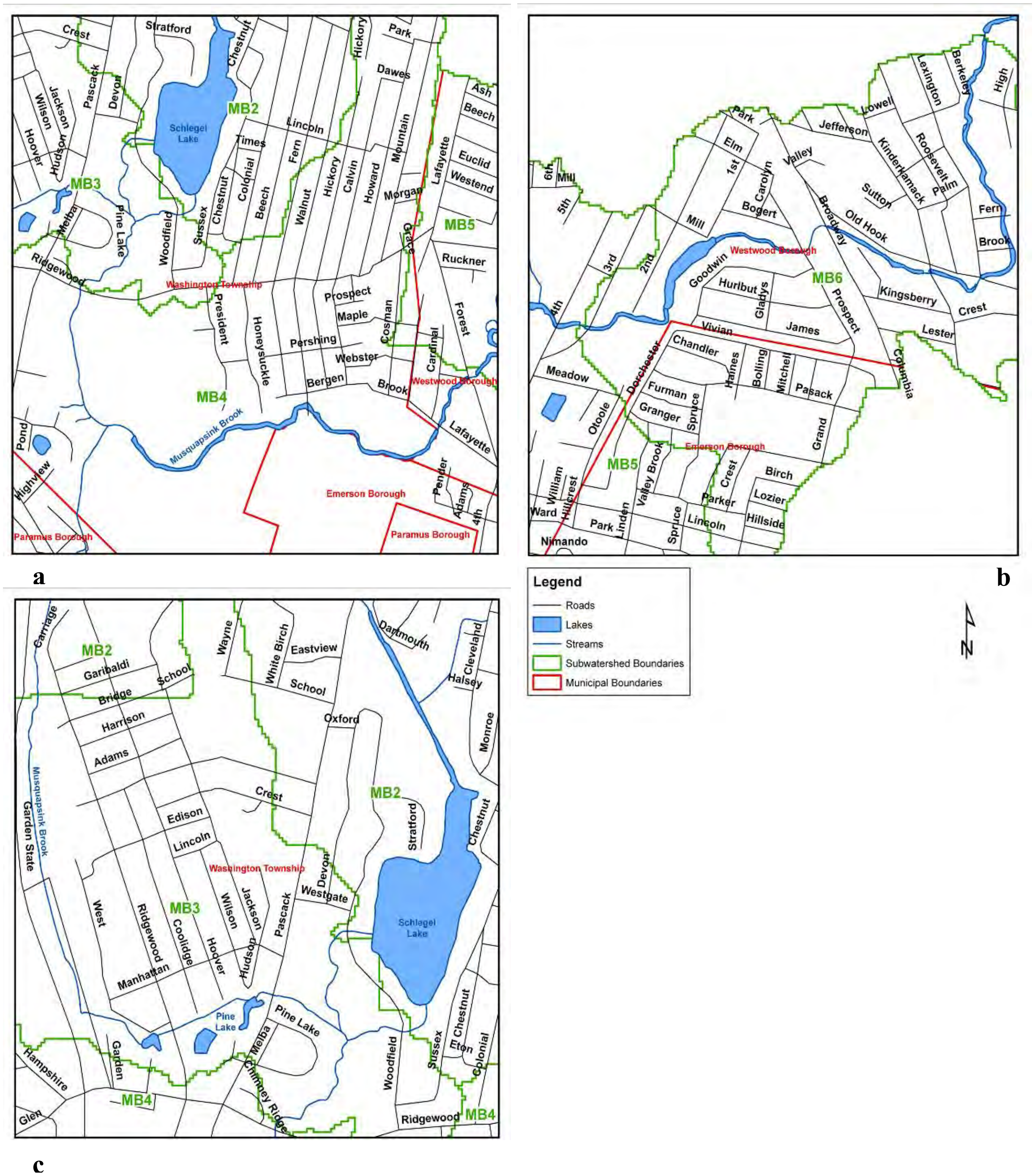

Figure 5.6 Regions identified for further trackdown of human-source bacterial contamination of surface water (a) Stream segment between Forest Avenue and Pascack Road, Washington Township (b) Stream segment between 4th Avenue and Old Hook Road, Westwood Borough (c) Stream segment along Pascack Road, between Sutton Way and Eastview Terrace, Washington Township

While optical brightener detection by fluorometry shows promise as a method of MST in watershed restoration planning, additional field sampling and comparisons with other methods need to be conducted to determine its effectiveness in watershed management. To this effect, it is important to note that the results of this study are preliminary in nature. Further data collection is necessary before infrastructure investigations are carried out, as the scope of this project (nonpoint source identification) did not provide for the intensive trackdown of wastewater infrastructure failures. Only two rounds of MST sampling were conducted for both qPCR analysis and optical brightener detection by fluorometry. At the time, avian primers were not available for qPCR analysis. Since geese have been identified as a major source of bacterial contamination, this study would be greatly enhanced with data separating avian versus human sources.

Additional lab and field work also need to be conducted to verify the results of the optical brightener detection by fluorometry. This would involve evaluating different excitation wavelengths and determining how best to account for both natural and anthropogenic sources of fluorescent compounds, such as those produced by organic material, newspapers, and cigarette butts. The best approach to this issue is to collect samples where these substances are present, and scan wavelengths to see where fluorescence occurs. Oil-based compounds from oil spills could also potentially contribute chemicals that fluoresce, and lab studies where oils are added to water could be performed to examine this issue. Seasonality is another confounding factor that should be investigated, as there may be particular times of the year when fluorescent signals are more prevalent, and if so, these times should be identified. As fluorescence technology emerges as a source-tracking tool, it would also be valuable to study how well fluorescence is removed by sediment in riverbeds. Such information would be helpful in making decisions regarding where to sample for fluorescence in water bodies and how to interpret fluorescence after it has been found (Hagedorn, et al., 2008).

5.3 Nonpoint Sources

Nonpoint sources of water pollution derive from many different contaminants and landscapes. The extent and locations of these contaminant sources cannot be easily identified due to their diffuse nature, making them difficult to regulate and even more difficult to rectify.

The Musquapsink Brook Watershed is highly urbanized, with very little agricultural land use. Nonpoint source pollution is therefore largely associated with roads, buildings, pavement, and generally compacted landscapes with impaired drainage. Pollutants of concern include: sediment; oil, grease and toxic chemicals from motor vehicles; pesticides and nutrients from lawns and gardens; bacteria and nutrients from wildlife or pet waste; road salts; heavy metals from roof shingles, motor vehicles and other sources; and thermal pollution from dark impervious surfaces such as streets and rooftops are all pollutant concerns within the watershed. As these pollutants, generated by urban development and wildlife, accumulate on the land surface, hydrological processes such as runoff and percolation during a storm event will eventually transport these contaminants into nearby streams and groundwater. The urban land use has caused significant hydrological alteration and thus accelerated the speed and extent of pollutant transportation from sources to stream. The aggregate contribution of all nonpoint sources to the Musquapsink Brook has severely degraded surface water quality over time.

Specifically, sources of fecal contamination most likely include failing infrastructure or septic systems, incorrect disposal of domestic pet waste, and waste from waterfowl populations. Phosphorus impairments may be due to excessive fertilizer applications in residential neighborhoods, resulting in stormwater runoff with high nutrient concentrations. Highway runoff during storm events may also contribute to phosphorus loads (Flint and Davis, 2007). Atmospheric deposition of phosphorus and nitrogen and other airborne pollutants onto impervious surfaces may also contribute largely to stormwater runoff loadings.

5.4 Point Sources

According to the regulation in the United States, generally point sources include municipal wastewater (sewage), industrial wastewater discharges, municipal separate storm sewer systems (MS4) and industrial stormwater discharges (Public Law 100-4. 1987). These facilities are required to obtain New Jersey Pollution Discharge Elimination System (NJPDES) permits or state/local permits. All municipalities within the Musquapsink Brook Watershed have MS4s and state permits for stormwater discharges. There are no NJPDES-permitted surface water discharges within the Watershed.

In addition, there are 10 known contaminated sites in the Musquapsink Brook Watershed (Table 5.7). Many of these sites have groundwater contamination associated with them and some have soil or other media contaminated by a substance release (Table 5.7). While the specifics of the source and type of contaminants from these sites are regulated by the NJDEP, they are included here as a possible reason for some of water quality issues not explained by monitoring conducted by the RCE Water Resources Program as part of this restoration planning effort. Confirmation of these known contaminated sites as potential sources of water quality impairments cannot be made at this time. However, future monitoring could be focused on determining the impact of these sites.

Table 5.7: Known contaminated sites (2009) located within the Musquapsink Brook Watershed

Site Name	Site Address	Status	Remedial Level	Municipality
Soldier Hill Redevelopment	Soldier Hill Road	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Paramus Borough
91 4th Avenue	91 4th Avenue	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Westwood Borough
Westwood Amoco	100 Kinderkamack Road	Active	C2: Formal Design - Known Source or Release with GW Contamination	Westwood Borough
Washington Town Center	285 Pascack Road	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Washington Township
Lukoil #57301	290 Pascack Road	Active	C2: Formal Design - Known Source or Release with GW Contamination	Washington Township
Park Ridge Well #15	Old Mill Pond Road	Active	C3: Multi-Phased RA - Unknown or Uncontrolled Discharge to Soil or GW	Woodcliff Lake Borough
Washington Township	350 Hudson Avenue	Active	C2: Formal Design - Known Source or Release with GW Contamination	Washington Township
Sky's Trading, LLC	700 Pascack Road	Active	C2: Formal Design - Known Source or Release with GW Contamination	Washington Township
43 Brookview Terrace	43 Brookview Terrace	Active	C1: No Formal Design - Source Known or Identified-Potential GW Contamination	Hillsdale Borough
Woodcliff Lake Friendly Service	223 Woodcliff Avenue	Active	C2: Formal Design - Known Source or Release with GW Contamination	Woodcliff Lake Borough

5.5 Erosion and Sedimentation

The Rosgen Stream Classification System and Simon's 1989 Channel Evolution Model were used to assess streams and tributaries in the Musquapsink Brook Watershed. Based on the simplified Rosgen analysis, several typical stream types were identified. Results are presented in Table 5.7. The geographical location of sites evaluated for the Rosgen Stream Classification analysis and the Channel Evolution Model are depicted in Figure 5.7. Low flow conditions in subwatershed MB1 prevented complete analysis and stream classification. This portion of stream is not addressed in this section of the Plan.

A significant feature to note is a historic mill dam located in Westwood, New Jersey. Bogert Pond is created by this dam and is surrounded by residential neighborhoods. Impounded waters are subject to frequent floods, destabilizing river banks formerly subjected only to occasional high waters for short periods of time. This causes erosion and downcutting both upstream and downstream of the dam. Sediment deposition at the dam site also causes further erosion downstream. Because there is no bed load just below a dam, the streambed erodes, increasing silt. If there is no equilibrium between bedload entering a stretch of river and leaving it, a river will cut into its streambed and deepen. Such is the case with the Musquapsink Brook, as indicated by findings from both the Rosgen Stream Classification and Channel Evolution Model analysis. Unstable, eroding streambanks and entrenched profiles are typical of MB4, MB5, and MB6, the subwatersheds that contain the segments of stream most closely connected to the mill dam. A Pond Management Plan should be developed for Bogert Pond and should include a sediment survey, recommendations for land use practices, and options for dam removal. This may improve issues associated with flooding and erosion in the Musquapsink Brook Watershed. See project MB6_We_a in Appendix C for further information on this site.

Stream classification based on morphology is meant to provide a common ground for understanding current stream conditions and potential stream conditions in varying settings with vastly different influences. Rosgen stream classification is one such morphology-based analysis. Figure 5.8 depicts the different stream types and characteristics. Type B is a moderately entrenched, moderate gradient, riffle dominated channel with frequently spaced pools. This stream type is very stable in plan and profile with stable banks. Type C is a low-gradient, meandering stream containing point-bars, riffle/pools, and alluvial channels within a broad, well-defined floodplain. This type of stream is fairly stable in plan and profile. Type D streams are multiple-channel systems that typically do not have a boulder or bedrock channel bed. Type G is an entrenched "gulley" step/pool stream with low width/depth ratio on moderate gradients. This type of stream is unstable with grade control problems and high bank erosion rates (Rosgen, 1994).

Table 5.8: Rosgen Stream Classifications for Musquapsink Brook Watershed

	MB1a	MB1b	MB2a	MB2b	MB3a	MB3b	MB4a	MB4b	MB5a	MB5b	MB6a	MB6b
Single Threaded Channels		Yes	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Entrenchment Ratio			Entrenched	Moderate	Slight	Slight	Moderate	Moderate	Entrenched	Entrenched	Entrenched	Moderate
Width/Depth Ratio	12		<12	>12	>12	<12	>12	<12	<12	<12	>12	>12
Sinuosity							1.586	1.586	1.510	1.510	1.618	1.618
Stream Type			G	DA	C	DA	B	F	G	C	B	B
Slope							0.0006		0.0013	0.0008	0.005	0.0005
Channel Material	Silt/Clay	Clay/Silt	Cobble	Clay/Silt	Boulders	Clay/Silt	Silt/Clay	Sand/Cobble	Clay/Silt	Clay/Silt	Cobble	Clay/Silt
Stream Classification			G3	DA6	C2	DA6	B6c	F3	G6c	C6c	B3c	B6c

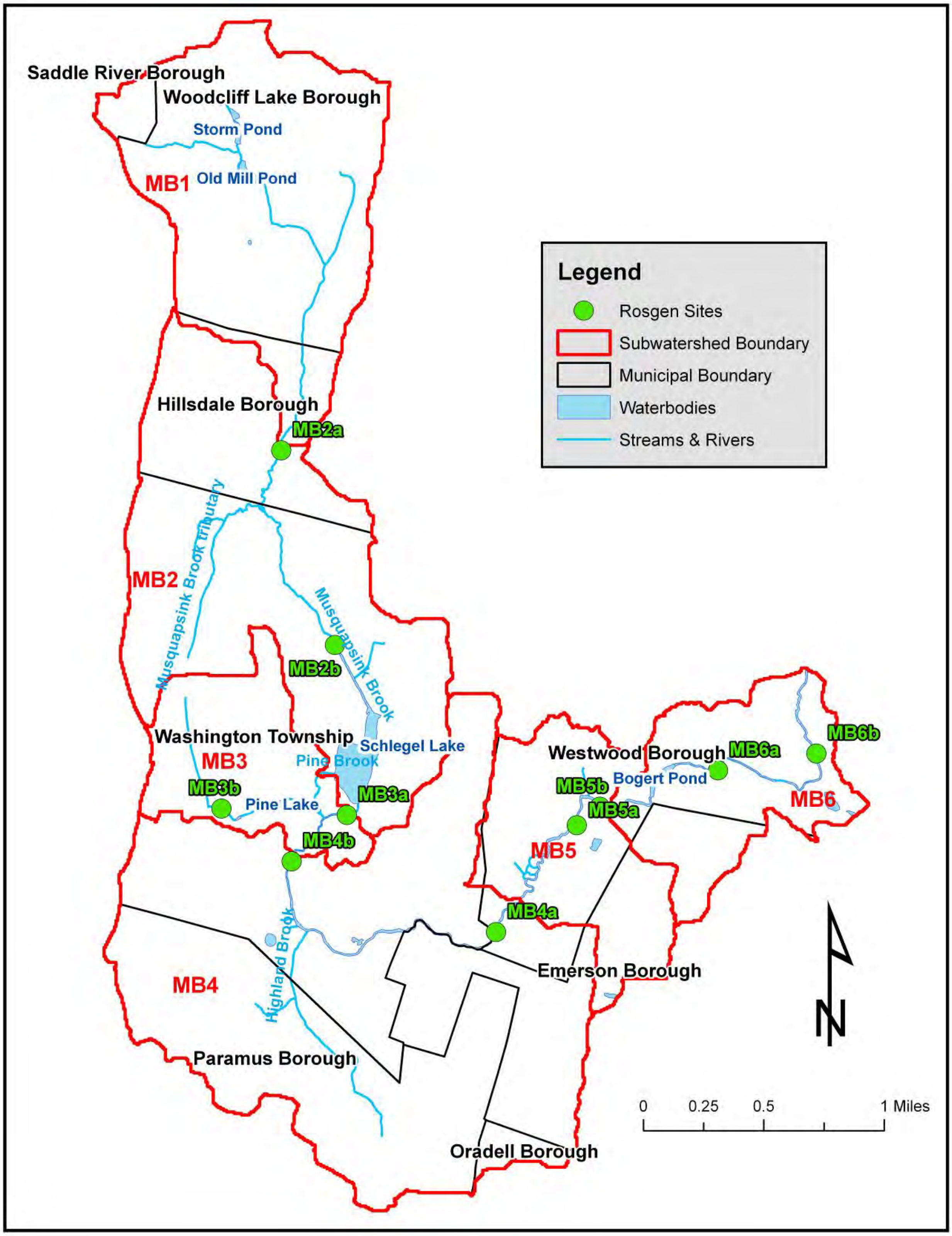

Figure 5.7: Musquapsink Brook Watershed Sites for Rosgen Stream Classification Analysis

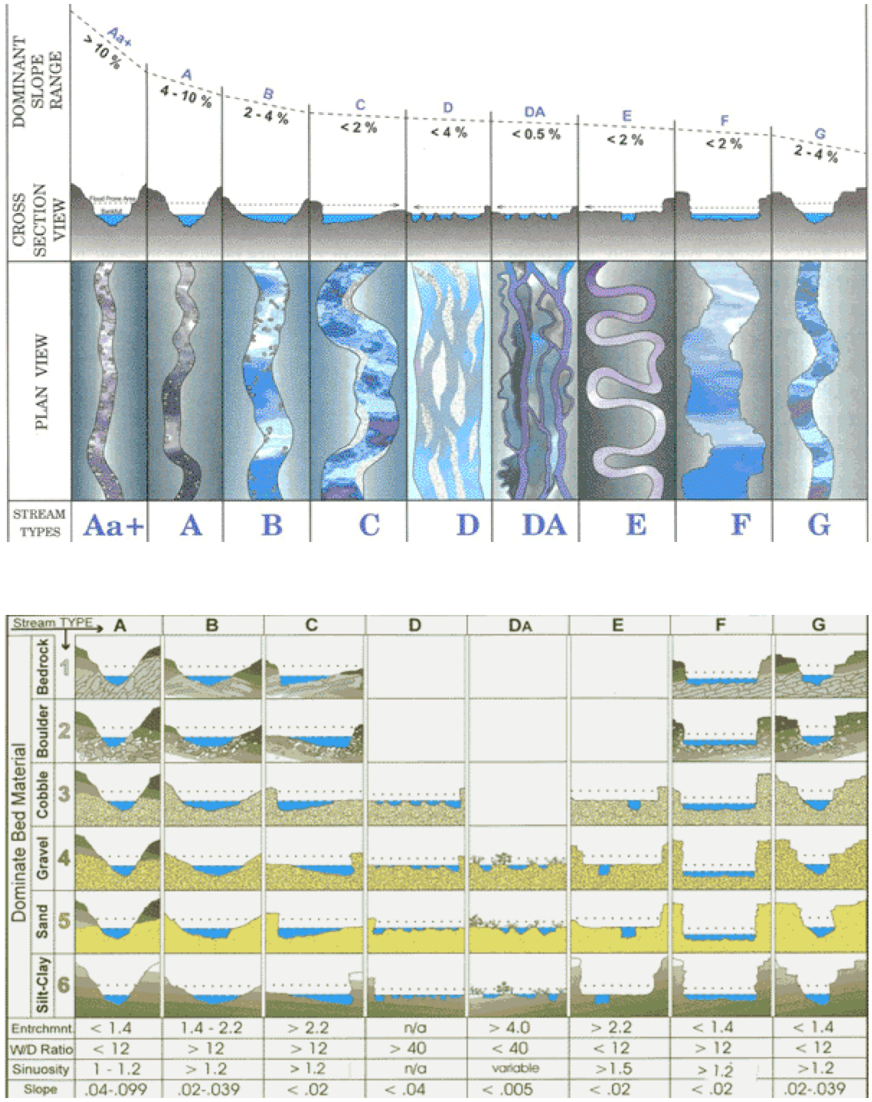

Figure 5.8: Rosgen Stream Classification Cross Section, Plan and Profile Views (Rosgen, 1994)

Simon's Channel Evolution Model describes a stream's erosive evolution in six stages, starting with a stable, undisturbed channel (Stage I) and ending with a refilled channel (Stage VI). In between, the stream is disturbed by some large-scale event, eroded, and then re-stabilized. Table 5.9 provides information on the channel evolution conditions in the Musquapsink Brook Watershed. Approximately 80% of the stream reaches assessed are unstable and fall under Stages II and III, characterized by disturbance and incision, respectively. Stage II stream reaches typically have altered channel hydrology and modified sediment input. Woody vegetation near the water line has been removed due to unstable bank conditions. Stage III stream reaches are characterized by excessive downcutting, which liberates sediment and alters the bankfull floodplain (Simon and Downs, 1995).

Observations noted in the Channel Evolution Model evaluation reflect the impacts of the high percentage of urban land use in the Musquapsink Brook Watershed. Streams in Stage II or III are most likely suffering from higher peak stormwater flows from urban land use in the upper watershed. In most cases, the downcutting and widening seen in Stages II and III can be linked to impervious cover that is directly connected to the stream, resulting in flashy hydrology. Furthermore, these unstable reaches can contribute a significant amount of sediment to the stream.

Table 5.9: Channel Evolution Evaluations for Musquapsink Brook Watershed

Site	Sub Watershed	Stage	Description and Observations
MB1a	MB1	-	-
MB1b	MB1	-	-
MB2a	MB2	II	Unstable. Bank slopes of stream are very steep with obvious headcutting occurring. Cultural features are exposed and sediment accumulation in stream.
MB2b	MB2	V	Stable. Well developed baseflow and bankfull channel, along with one stream bank slopes less than 1:1. Floodplain features are easily identified, and one terrace is apparent. A point bar is also present, due to low flow and excess sediment conditions.
MB3a	MB3	III	Unstable. Stream is widening due to stream bank sloughing; the sloughed material is being eroded creating vertical bank slopes. Erosion is especially prevalent on the insides of bends due to fast moving water.
MB3b	MB3	I	Stable. Well developed base flow and bank full channel, in addition to predictable streambed morphology. Floodplain features are easily identified, and there is one terrace apparent.
MB4a	MB4	II	Unstable. Bank slopes are steep with head cuts and exposed cultural features present. There's also some algae and aquatic vegetation.
MB4b	MB4	II	Unstable. Easily identifiable incisions on both banks of stream, in addition to exposed cultural features and considerable amount of sediment deposits in stream.
MB5a	MB5	II	Unstable. Slow moving stream with a storm drain pipe directed from the street on the side. It is very deep in the middle, with steep banks that contain incision and exposed roots.
MB5b	MB5	III	Unstable. Waterfowl present; at least 15 geese and 15 ducks are present. A corresponding amount of feces is on the right bank with very little to no buffer. The site is at a bend in the stream where there is heavy erosion on the inside, making it very deep there. The bank is sloughing, making it almost vertical.
MB6a	MB6	III	Stable. Riprap-lined channel. The banks are steep, and the stream is shallow but fast moving. Some incision is present.
MB6b	MB6	III	Left side of stream is residential with heavy erosion. Bank would be vertical if rocks weren't placed there to prevent further sloughing. Right bank is stable, with some headcutting.

5.6 Stream Visual Assessment Protocol (SVAP) Data

SVAP was developed by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture to assess the health of the stream, identify pollutant sources, and identify potential management measures to control these pollutant sources based on visual inspection of instream physical and biological characteristics. The assessment is based on a three-page worksheet modified for New Jersey by the Rutgers Cooperative Extension Water Resource Program. SVAP assesses a set of 15 stream condition indicators and assigns each indicator a numerical score relative to reference conditions. The specific indicators include channel condition, hydrologic alteration, riparian zone, bank stability, water appearance, nutrient enrichment, barriers to fish movement, instream fish cover, pools, insect/invertebrate habitat, canopy cover, manure presence, riffle embeddedness, and macroinvertebrates observed if applicable. The score for each element is assessed on a scale of 1 to 10, with one being the worst and ten being the best. The scores of the 15 elements at each site are averaged to give an overall rating for that assessed stream reach. A score of less than 6.0 is considered “Poor,” a score of 6.0 to 7.49 is considered “Fair,” and a score above 7.5 is considered “Good.” The numerical assessment is complemented by photographs and drawings of the stream site, as well as notes on visual observations of unusual or unsightly occurrences such as dumping, manure, runoff or outfall pipes, etc.

Thirty eight stream reaches were evaluated in the Musquapsink Brook Watershed; the stream reaches and the average SVAP scores are identified in Figure 5.9. The average overall SVAP score was 6.7, a “fair” score (Table 5.10). Canopy cover was the highest scoring element (average of 8.4), and instream fish cover was the lowest scoring element (average of 5.2). No assessed stream reach received a score of “excellent,” five reaches were rated as “good,” and eighteen were rated as “fair.” The remaining fifteen reaches were rated as “poor.” The reaches that were rated as poor are located along the entire length of the Musquapsink Brook.

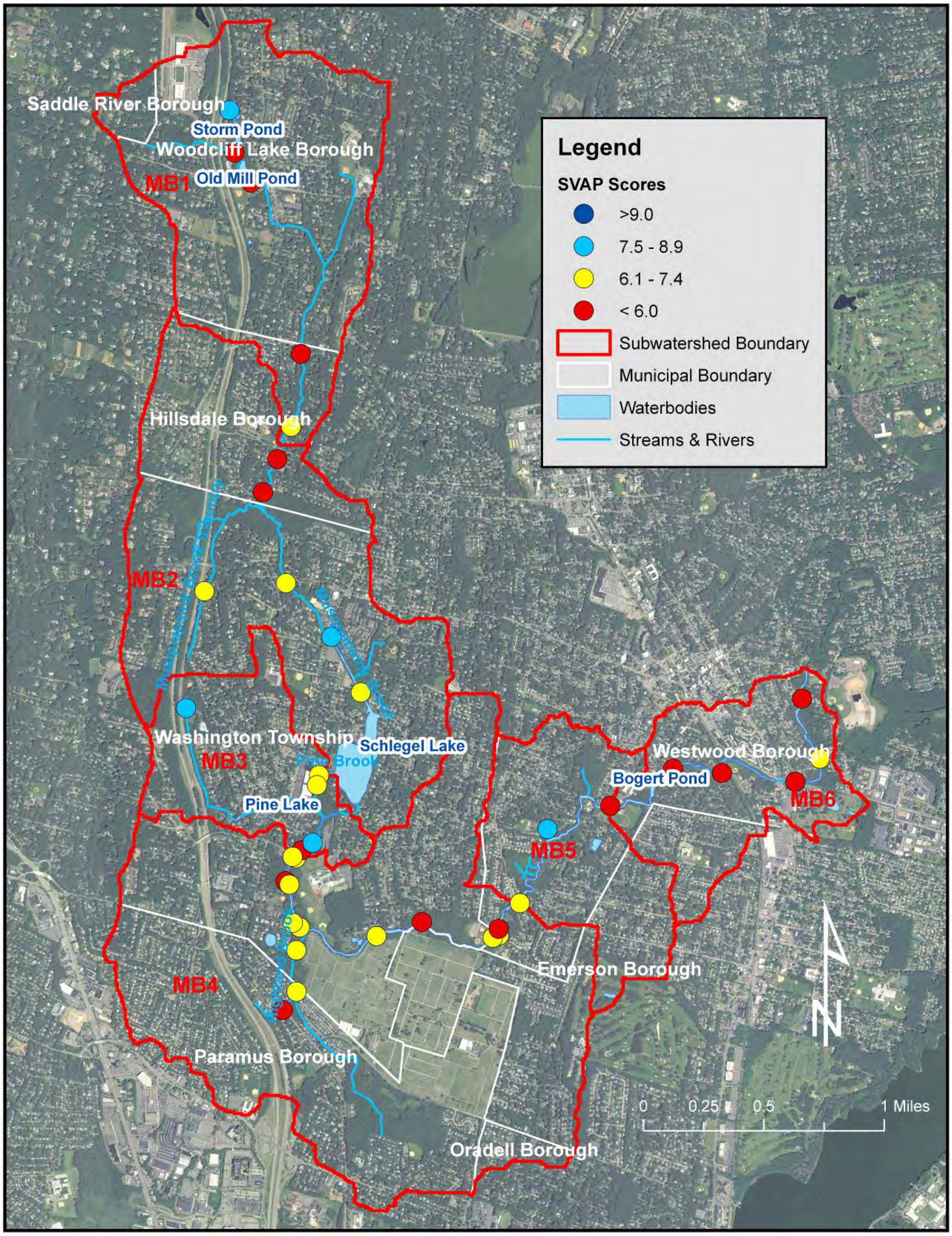

Figure 5.9: Stream Visual Assessment Reaches with Scores in the Musquapsink Brook Watershed

Table 5.10: SVAP Assessment Elements and Data for Musquapsink Brook Watershed

	Channel Condition	**Hydrologic Alteration**	**Riparian Zone left bank**	**Riparian Zone right bank**	**Bank Stability left bank**	**Bank Stability right bank**	**Water Appearance**	**Nutrient Enrichment**	**Barriers to Fish Movement**
# of scores	38	20	38	38	38	38	38	38	38
minimum value	1	1	1	1	1	1	3	3	0
maximum value	10	10	10	10	10	10	10	10	10
average	6.4	6.7	7.3	6.3	5.8	5.8	7.6	7.4	5.5
	Instream Fish Cover	**Pools**	**Invertebrate Habitat**	**Canopy Cover**	**Manure Presence**	**Riffle Embeddedness**	**Water Appearance & Nutrient Enrichment Averages**		**Tiered Assessment Averages***
# of scores	38	38	38	38	NA	20	38		36
minimum value	0	1	3	1	NA	0	3		1.5
maximum value	8	8	10	10	NA	10	10		10
average	5.2	6.3	7.9	8.4	NA	6.0	7.5		6.7
	Overall Average - left bank		***Overall Average - right bank***		***Overall Site Average***				
# of scores	***35***		***35***		***35***				
minimum value	***1.3***		***1.3***		***1.3***				
maximum value	***9.7***		***9.7***		***9.7***				
average	***6.7***		***6.6***		***6.7***				

** "Tiered Assessment Averages" refers collectively to Hydrologic Alteration, Channel Condition, Riparian Zones left and right, Bank Stability left and right, Water Appearance, and Nutrient Enrichment.*

5.6.1 Using the SVAP Data

SVAP scores have been evaluated as individual assessment elements and combined with other data collected as part of this restoration planning effort. The SVAP results were compared to land use, soil characteristics, slope and stream gradient, and water quality monitoring results to determine the quality of waters within the Musquapsink Brook Watershed. The SVAP scores, information on pipes, ditches, photos, and remediation notes have been used to identify sources of pollution and potential opportunities for improved management.

6. Estimated Loading Targets and Priorities

6.1. Loading Targets

Load reduction targets will adhere to the TMDL approved by the USEPA. In this plan, reduction targets are defined by the total pollutant load reductions that are required to satisfy the water quality standards for the non-trout FW2 streams. These targets will dictate the management plans developed for the Musquapsink Brook Watershed.

As stated previously, a TMDL was established in 2002 for the Musquapsink Brook requiring a 96% reduction in fecal coliform load. In 2005, a TMDL for total phosphorus was established and requires a 10.9% reduction in total phosphorus loadings from medium/high density residential, low density/rural residential, commercial, industrial, mixed urban/other urban, forested, and agricultural lands.

6.2. Priority Ranking

One of the goals of the watershed restoration and protection plan is to prioritize the implementation of various best management practices. For this project, water quality data and flow data were collected at six sampling locations. Each of these sampling locations represents the outlet of a subwatershed within the Musquapsink Brook Watershed. To identify which subwatershed was contributing the most pollution to the Musquapsink Brook, data from each of these sampling locations was used to determine the annual pollutant load leaving each of the subwatersheds. Average loading rates of fecal coliform, *E. coli*, and phosphorus were calculated for MB1, MB3, MB4, MB5, and MB6. Data at MB2 was analyzed and used for the monitoring of Schlegel Lake, but was not included in the final loading rate calculations. The subwatersheds were then ranked by their annual pollutant load.

The two primary pollutants of concern in the Musquapsink Brook Watershed are total phosphorus and fecal coliform, an indicator of pathogen contamination. Flow and pollutant concentration from each sampling event were used to calculate the daily load at each sampling location. The annual total load for each subwatershed was determined by averaging the daily loads and multiplying this average daily load by 365 days (number of day in a year). For total phosphorus this provides an annual load in kg/year. For fecal coliform, this calculation provided an annual load in colonies per year. At the time of this project's initiation, fecal coliform was the accepted measure indicating pathogen pollution for New Jersey freshwaters. Since then, the fecal coliform standard has been replaced by an *E. coli* standard. Because the TMDL established refers to fecal coliform, both fecal coliform and *E. coli* loading rates were calculated.

The differentiation between 'wet' and 'dry' weather sampling can be used to improve the understanding of the impact of stormwater on pollutant concentrations. To more accurately determine which monitoring events were collected under wet conditions when the stream velocities exceeded baseflow conditions, the HYSEP procedure was used. HYSEP is a data analysis program developed by the USGS to separate river flow into baseflow and storm-flow (Sloto and Crouse, 1996). Normally, this model would be applied to a daily discharge monitoring station within the watershed; however, daily discharge is not recorded by the USGS in the Musquapsink Brook Watershed. Instead, USGS monitoring station 01377500, Pascack Brook at Westwood, which is just downstream of the confluence of the Musquapsink Brook and the Pascack Brook, was chosen. Although it would be preferable to use a flow gauge in the target watershed, the watershed does drain to the Pascack Brook, and the remainder of the drainage area is adjacent to the Musquapsink Brook watershed. The analysis was completed for the Pascack Brook over the length of the field sampling program. A 10% error bar was applied to the baseflow since these data are collected in a watershed other than the Musquapsink Brook. When flow was more than 10% greater than baseflow and rain occurred on the day of or the day preceding sampling, the event was considered as storm-related flow and assigned the term "wet."

Average annual loading rates for these three parameters during both wet weather and dry weather conditions are presented in Table 6.1. The annual loads were then normalized by the area of each of the individual subcatchments. These loading rates are presented in Table 6.2.

Table 6.1: Annual Loading Rates for Individual Subwatersheds

Subwatershed	Fecal Coliform (Colonies/Year)		*E. coli* (Colonies/Year)		Total Phosphorus (Kg/Year)	
	Wet	Dry	Wet	Dry	Wet	Dry
MB1	8.76E+13	3.91E+12	7.33E+13	1.88E+12	5.00E+01	3.15E+01
MB3	2.50E+13	4.36E+12	6.85E+12	2.86E+12	2.66E+01	3.88E+01
MB4	5.31E+14	9.17E+13	5.53E+14	6.26E+13	5.09E+02	1.56E+03
MB5	4.29E+14	-1.48E+13	4.99E+14	6.68E+13	6.92E+02	7.29E+01
MB6	9.59E+14	-5.44E+12	2.50E+14	5.05E+13	1.67E+02	-9.33E+02

Table 6.2: Annual Loading Rates Normalized to Area for Individual Subwatersheds

Subwatershed	Fecal Coliform (Colonies/Acre/Year)		*E. coli* (Colonies/Acre/Year)		Total Phosphorus (Kg/Acre/Year)	
	Wet	Dry	Wet	Dry	Wet	Dry
MB1	1.12E+11	5.00E+09	9.37E+10	2.41E+09	6.40E-02	4.03E-02
MB3	7.99E+10	1.40E+10	2.19E+10	9.14E+09	8.51E-02	1.24E-01
MB4	3.37E+11	5.81E+10	3.51E+11	3.97E+10	3.23E-01	9.91E-01
MB5	1.17E+12	-4.03E+10	1.36E+12	1.82E+11	1.88E+00	1.98E-01
MB6	2.47E+12	-1.40E+10	6.46E+11	1.30E+11	4.32E-01	-2.41E+00

Fecal coliform counts increase by 48% from station MB3 to MB4 during wet weather events and by over 56% during dry weather. This increase may be due to the discharge of the United Water intake from Saddle River and Ho-Ho-Kus Brook into the Musquapsink Brook Watershed, which occurs directly upstream of the MB4 sampling site. There is a 62% increase in fecal coliform counts between MB5 and MB6 during wet weather conditions, while average dry weather counts decrease, indicating that a significantly large pathogen source is impacting the stream via surface runoff or point source pollution within the MB6 subwatershed.

Total phosphorus loadings during wet weather conditions are most significant in MB4, MB5, and MB6. In subwatersheds MB5 and MB6, total phosphorus loads are dominated by stormwater runoff events, with over 90% of the annual load being contributed during wet weather conditions. Subwatersheds MB4 and MB5 also have total phosphorus loadings during baseflow conditions. Only in subwatershed MB4 do total phosphorus loadings from groundwater discharge exceed those from stormwater runoff.

The calculated annual loads and loading rates were used to rank the subwatersheds. Because stormwater best management practices and implementation projects typically target pollutant loading reductions during wet weather conditions, rankings are based on wet weather loadings.

The subwatershed with the highest loading rate was given one (1) point, the next highest was given two (2) and so on. This method was repeated for the area-normalized loading rate. The points were combined, and the subwatersheds were ranked highest to lowest according to their total points (maximum of 10 points, with lower values indicating highest loading impact). The results of the ranking process are shown in Tables 6.3a, b, and c. The loading rates show which subwatershed is contributing the most pollutants into the stream. The area normalized loading rates show which subwatershed is contributing the most pollutant per acre. Combining both parameters ensures that the subwatersheds with the highest priority are those where the greatest impact can be had with the least amount of implementation. For all three pollutants of concern in the Musquapsink Brook Watershed, loadings from subwatersheds MB4, MB5, and MB6 are the top three contributors to water quality impairments.

Table 6.3a.b.c: Summation of Rankings for Loadings and Area- Normalized Loadings

	a. Fecal Coliform		
Subwatershed	**Ranking of Annual Loading**	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	4	8
MB3	5	5	10
MB4	2	3	5
MB5	3	2	5
MB6	1	1	2

	b. *E. coli*		
Subwatershed	**Ranking of Annual Loading**	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	4	8
MB3	5	5	10
MB4	1	3	4
MB5	2	1	3
MB6	3	2	5

Subwatershed	c. Total Phosphorus		
	Ranking of Annual Loading	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	5	9
MB3	5	4	9
MB4	2	3	5
MB5	1	1	2
MB6	3	2	5

The final step in this analysis was to combine the priority rankings for total phosphorus, fecal coliform and *E. coli* to create an overall ranking for each subwatershed. These rankings will help prioritize the implementation of stormwater best management practices. Tables 6.4 a, b, and c summarize overall rankings for total phosphorus, fecal coliform and *E. coli*. Subwatersheds of top priority are in bold.

The prioritization and ranking reflect the conclusions drawn from the surface water quality sampling results; the Rosgen Analysis; and Channel Evolution Model evaluations. The downstream portion (subwatersheds MB4, MB5, and MB6) of the Musquapsink Brook Watershed is the most significantly impaired, with pollutant loadings due largely to human activities, potential infrastructure failures, and unstable stream conditions. Areas in these segments of the watershed will be targeted for BMP implementation.

Tables 6.4 a,b,c: Priority Watersheds by Surface Water Quality Parameter

Subwatershed	a. Fecal Coliform		
	Ranking of Annual Loading	**Ranking of Area-Normalized Annual Loading**	**Total Ranking**
MB1	4	4	4
MB3	5	5	5
MB4	2	3	3
MB5	3	2	**2**
MB6	1	1	**1**

Subwatershed	b. *E. coli*		
	Ranking of Annual Loading	Ranking of Area-Normalized Annual Loading	Total Ranking
MB1	4	4	4
MB3	5	5	5
MB4	1	3	**2**
MB5	2	1	**1**
MB6	3	2	3

Subwatershed	c. Total Phosphorus		
	Ranking of Annual Loading	Ranking of Area-Normalized Annual Loading	Total Ranking
MB1	4	5	5
MB3	5	4	4
MB4	2	3	3
MB5	1	1	**1**
MB6	3	2	**2**

7. Nonpoint Source Pollution Management Measures

The Musquapsink Brook Watershed Restoration and Protection Plan is dedicated to projects and efforts to control nonpoint source pollution. In the Musquapsink Brook Watershed, fecal coliform (*E. coli* as replacement standard) and TP are of greatest concern. Implementation of the suggested projects will aid in achieving the goals set up in the appropriate TMDLs. These projects have been prioritized based on a subwatershed basis, percent removal of pollutants, impact on the watershed's discharge quality, overall cost-effectiveness, and best professional judgment. Projects aim to reduce connected impervious cover, improve riparian buffers, control geese access to streams, and improve stakeholder knowledge on the importance of stormwater management.

7.1 Load Reduction Scenarios

Load reduction targets will adhere to those recommended by USEPA-approved TMDLs for the Musquapsink Brook Watershed. Based on the calculated annual loadings and priority rankings of the subwatersheds provided in Chapter 6 of this report, targeted reductions in TP and fecal coliform in the downstream portions of the watershed will likely have the most measurable effect on overall watershed loadings. Best management practices (BMPs) will be recommended for all subwatersheds, with a specific focus on implementation in subwatersheds MB4, MB5, and MB6.

7.1.1 Total Phosphorus

The 2005 TMDL load allocation for total phosphorus requires a 10.9% reduction in current loadings to the Musquapsink Brook. According to the calculations provided in Table 11 of the TMDL report for the Musquapsink Brook, the 10.9% load reduction equates to 641 kg/year reduction in total phosphorus loadings for the entire watershed. Since there are not significant point sources identified as contributing to the overall water quality exceedances in this watershed, source reduction needs to be allocated to nonpoint sources. Stormwater is considered a nonpoint source, although MS4s are a regulated point source for both Tier A and Tier B municipalities. Due to the fact that the origin of stormwater is from diffuse sources that run off of the land area, solutions will be determined while the pollutant is still considered nonpoint. Land use in each of the targeted subwatersheds has been evaluated for aerial loading and is a key determinant of recommended BMP types. Tables 7.1 a, b, and c provide information on calculated TP loading rates in the watershed.

Table 7.1: Total Phosphorus Loading Analysis According to 2007 Land use/Land cover Data for the Priority Subwatersheds in the Musquapsink Brook Watershed

a.

Land use: Subwatershed MB4	**Coverage Area** acre	**Export Coefficient** kg/acre/year	**Annual Load** kg/year	**% Total Load**
Agriculture	7.2	0.61	4.4	0.54%
Forest/Water/Wetlands	196.0	0.04	7.9	0.99%
Urban: Recreational	26.9	0.01	0.3	0.04%
Urban: Residential-High, Medium	777.6	0.65	503.5	62.85%
Urban: Residential-Low, Rural	155.9	0.28	44.2	5.51%
Urban: Cemetery	293.4	0.45	130.6	16.31%
Urban: Athletic Fields	25.9	0.45	11.5	1.44%
Urban: Commercial	28.5	0.97	27.7	3.46%
Urban: Other	59.4	0.45	26.4	3.30%
Atmospheric Deposition (Direct)	1570.8	0.03	44.5	5.55%

b.

Land use: Subwatershed MB5	**Coverage Area** acre	**Export Coefficient** kg/acre/year	**Annual Load** kg/year	**% Total Load**
Forest/Water/Wetlands	45.6	0.04	1.8	0.90%
Urban: Recreational	14.0	0.01	0.2	0.08%
Urban: Residential-High, Medium	283.9	0.65	183.8	89.14%
Urban: Residential-Low, Rural	13.3	0.28	3.8	1.83%
Urban: Athletic Fields	3.9	0.45	1.7	0.84%
Urban: Commercial	2.7	0.97	2.6	1.25%
Urban: Other	4.2	0.45	1.9	0.91%
Atmospheric Deposition (Direct)	367.6	0.03	10.4	5.05%

c.

Land use: Subwatershed MB6	**Coverage Area** acre	**Export Coefficient** kg/acre/year	**Annual Load** kg/year	**% Total Load**
Forest/Water/Wetlands	38.0	0.04	1.5	0.66%
Urban: Recreational	5.2	0.01	0.1	0.03%
Urban: Residential-High, Medium	250.6	0.65	162.3	69.33%
Urban: Residential-Low, Rural	17.5	0.28	4.9	2.11%
Urban: Cemetery	15.4	0.45	6.8	2.92%
Urban: Athletic Fields	13.8	0.45	6.2	2.63%
Urban: Commercial	38.6	0.97	37.5	16.00%
Urban: Other	8.6	0.45	3.8	1.63%
Atmospheric Deposition (Direct)	387.6	0.03	11.0	4.69%

The export coefficients used in this analysis were provided by NJDEP using the Loading Coefficient Analysis and Selection Tool (LCAST) database of export coefficients (Al-Ebus 2003; NJDEP 2001). The export coefficient for recreational areas, which was not provided by NJDEP, was determined by the average of values presented in LCAST. The unit area phosphorus loading from atmospheric deposition, applied as a direct load, was based on a statewide value from the New Jersey Atmospheric Deposition Network (Eisenreich and Reinfelder 2001). To achieve a TP load reduction of 641 kg/year, nonpoint source management measures will aim to remove a significant portion of TP load from subwatersheds MB4, MB5, and MB6. Cemeteries, medium-high density residential areas, athletic fields, and commercial/service areas will be targeted for BMP implementation. See Table 7.2 below for targeted land use and the proposed area to be treated by BMPs.

Table 7.2: BMP Implementation Scenario and TP Load Reductions

a.

Land use: Subwatershed MB4	Coverage Area	Annual Load	TP Removal by BMP	Area Treated by BMP	Total TP Load Reduction
	acre	kg/year	%	acre	kg/year
Urban: Residential-High, Medium	777.6	503.5	60	500	195
Urban: Residential-Low, Rural	155.9	44.2	60	100	16.8
Urban: Cemetery	293.4	130.6	60	290	78.3

b.

Land use: Subwatershed MB5	Coverage Area	Annual Load	TP Removal by BMP	Area Treated by BMP	Total TP Load Reduction
	acre	kg/year	%	acre	kg/year
Urban: Residential-High, Medium	283.9	183.8	60	200	78
Urban: Residential-Low, Rural	13.3	3.8	60	8	1.344
Urban: Commercial	2.7	2.6	60	2	1.164

c.

Land use: Subwatershed MB6	Coverage Area	Annual Load	TP Removal by BMP	Area Treated by BMP	Total TP Load Reduction
	acre	kg/year	%	acre	kg/year
Urban: Residential-High, Medium	250.6	162.3	60	200	78
Urban: Commercial	38.6	37.5	60	25	14.55
Urban: Cemetery	15.4	6.8	60	15	4.05
Urban: Athletic Fields	13.8	6.2	60	10	2.7

Assuming the installed BMPs will achieve a 60% removal of TP from stormwater runoff, the extent of implementation proposed in Table 7.2 will yield a total reduction of 470 kg TP/year. This accounts for 73% of total TP loading reductions required by the TMDL. The totals in Table 7.2 do not account for reductions in atmospheric deposition contributions.

7.1.2 Fecal Coliform/E. coli

Fecal coliform and *E. coli* are present in high concentrations in the Musquapsink Brook Watershed. The main sources of total coliform are wildlife and domestic pet waste, and, to a lesser extent, from human inputs. The 2003 TMDL established for fecal coliform requires a 96% reduction in loadings to the watershed and requires that no sample exceeds a 200 col/100 mL maximum concentration. Since the initiation of this project, the indicator organism of bacterial quality has changed for freshwaters in New Jersey to the use of *E. coli*. The newly adopted water quality criterion for *E. coli* requires that no sample exceeds a 236 col/100 mL maximum concentration. All sampling stations violated the water quality criteria for both fecal coliform and *E. coli* for all sampling events.

Surface water quality sampling results indicate that pathogen loading to the brook occurs during both wet and dry events. Furthermore, MST data and fluorometric detection of optical brighteners indicate human sources of pathogenic contamination are present in the Musquapsink Brook Watershed. The potential for human fecal matter in streams is a serious public health threat and needs to be addressed. Discharge of untreated sewage in the Musquapsink Brook, broken sanitary sewer pipes, illicit connections, or failing septic systems may be contributing to the human sources detected during MST sampling. The majority of properties within the Musquapsink Brook Watershed are on community sewer systems. Further investigation into the exact type of problems leading to bacterial contamination is required before strategies for remediation can be evaluated. One method is to videotape the sanitary sewer lines to identify breaks that might allow wastewater to leak from the sewer lines and discharge into local waterways. Although the focus of this restoration and protection plan is on nonpoint sources of pollution, point sources that can create bacterial contamination of waters in the Musquapsink Brook Watershed, such as faulty wastewater treatment facilities and leaking septic systems, require further evaluation to successfully improve water quality.

All subwatersheds in the Musquapsink Brook Watershed should be considered for control of bacterial contamination due to the high number of samples that violated the water quality criteria for fecal coliform and *E. coli* (Table 5.4). Particular focus should be placed on MB4, MB5, and MB6 where preliminary MST data indicates the highest likelihood of human source pathogenic contamination (Table 5.6 and Figure 5.5). Control and reduction of pathogen contamination presents several challenges, however. Indicator organisms like fecal coliform and *E. coli* are solely indicators of fecal pollution and are not a direct measure of the amount of fecal contamination. Also, the measurement of fecal coliform and *E. coli* does not identify specific sources as these bacteria are found in many mammals. Further bacteria source trackdown is recommended prior to the implementation of remediation strategies for pathogen loading reductions.

Loading coefficients have not been created for fecal coliform or *E. coli*, making estimation of load reductions by this method inappropriate (NJDEP, 2004). Estimation of fecal coliform and *E. coli* is further made difficult due to multiple sources of fecal contamination (wildlife feces, improper pet waste disposal, leaking septic systems, faulty sewer infrastructure) having different bacteria concentrations and loading rates. For example, Canada geese (*Branta canadensis*) have been noted as a possible source of fecal contamination in the Musquapsink Brook Watershed. The number of geese seen during field visits will vary for each site visit, due to the migratory nature of these animals. This makes proper enumeration of potential fecal loads extremely difficult to achieve. Beyond the ability to estimate bacterial loads from sampling data, estimation of bacterial loadings needs to be performed on a site by site basis to determine the impact of proposed water quality improvement projects. While rain gardens have been found to remove 90% of fecal coliform from stormwater runoff (Rusciano and Obropta, 2007) other measures described in this report (such as pervious pavement and rain barrels) do not have available information on bacteria removal rates.

7.2 Urban Best Management Practices

As the population within the Musquapsink Brook Watershed has remained fairly stable and land use has not changed significantly in recent years, the observed impacts to the Musquapsink Brook and within the watershed are not likely due to recent changes in the landscape. Similarly, the scope for future land use changes is limited as it has already reached capacity for development. Therefore, restoration and protection efforts need to focus on changes that can be accomplished within the current land use and environmental framework. This may include a combination of both institutional and structural controls. All proposed recommendations will function to decrease stormwater flows, increase infiltration, and ultimately reduce pollutant loading so that the Musquapsink Brook meets the water quality criteria for its designated uses.

7.2.1 Rain Gardens

Designating areas within the watershed for increased stormwater infiltration is one method to reduce stormwater flow and does not require setting aside large tracts of land for construction. The general theory is to provide portions of the landscape where stormwater typically flows overland, and changing the nature of the surface such that some of the stormwater load is allowed to infiltrate into the ground. This requires permeable soils that allow stormwater to quickly seep into the ground surface before becoming saturated to the point of inefficiency. This recommendation is different from a detention/retention basin as it could spread the load of stormwater control over a large number of smaller infiltration areas, including personal property in the form of rain gardens or infiltration strips.

Rain gardens can be a simple and easily implemented BMP for private land owners. Increased infiltration could also be employed on property right-of-ways where stormwater overland flow occurs. A rain garden is a landscaped, shallow depression designed to capture, treat, and infiltrate stormwater at the source before it reaches to a stormwater infrastructure system or a stream. Plants used in the rain garden help retain pollutants that could otherwise degrade nearby waterways. Rain gardens are becoming popular in suburban and urban areas. These systems not only improve water quality, but also help homeowners minimize the need for watering and fertilizing large turf grass areas and promote groundwater recharge. If designed properly, these systems improve the aesthetics of the urban/suburban neighborhoods through the use of flowering native plants and attractive trees and shrubs. See Figure 7.1 below for an example of a flourishing rain garden capturing rooftop runoff.

Figure 7.1: Example of a Rain Garden installed at the Rutgers Cooperative Extension of Burlington County, NJ in the Lower Delaware Watershed

A typical rain garden is designed to capture, treat and infiltrate the water quality storm of 1.25 inches of rain from a 1,000 square foot impervious area from an individual lot (i.e., a 25 foot by 40 foot roof for a house or a 20 foot wide by 50 foot long driveway). By collecting runoff generated by the first 1.25 inches of rainfall, the rain garden prevents the "first flush" of runoff from entering the stream, which characteristically has the highest concentration of contaminants. For the water quality storm of 1.25 inches of rainfall, the rain garden needs to be 10 foot by 20 foot and six inches deep. Since 90% of all rainfall events are less than one inch, rain gardens are able to treat and recharge the majority of runoff from these storms. It is fair to assume, if designed correctly, rain gardens will reduce the pollutant loading from a drainage area by 90 percent wherever they are installed. Furthermore, they will reduce stormwater runoff volumes and reduce the flashy hydrology of local streams. This reduction of flashy hydrology will minimize stream bank erosion and stream bed scour, thereby reducing TSS and phosphorus loads in the waterway. According to Rusciano and Obropta (2007), rain gardens are found to remove 90 percent of fecal coliform from stormwater runoff.

Rain gardens can be installed almost anywhere. Ideally the best installation sites are those where the soils are well-drained so that an underdrain system is not required. However, any diversion runoff and filtration through native vegetation in the watershed would help reduce pollutant loading to the stream.

7.2.2 Permeable Pavement

Reduction of impervious surfaces with the installation of permeable or pervious surfaces is another BMP that can help reduce stormwater flow, increase groundwater recharge and improve water quality. Pervious surfaces can include asphalt, concrete, or even interlocking concrete blocks with soil and grass growing within the voids. These surfaces allow water to pass through the surface into an underlying reservoir (stones or gravel) that provides temporary runoff storage until infiltration to the subsurface soils can occur. Figure 7.2 demonstrates the ability of pervious concrete to infiltrate stormwater runoff as opposed to causing sheet flow like the impervious counterpart. Primary applications for these surfaces are low traffic or parking areas that do not see a high volume of vehicular traffic but have significant areas of impervious surfaces (Hun-Dorris 2005).

Figure 7.2: Example of previous concrete allowing water to flow through it[1]

7.2.3 Green Streets

Roadways cover a significant percentage of land in most urban communities, and thus offer a unique opportunity for stormwater management. Green streets can include combinations of features such as vegetated curb extensions, flow-through planter boxes, and permeable paving to reduce stormwater flow and improve water quality (USEPA, 2009).

A curb extension is an angled narrowing of a roadway with a concurrent widening of the sidewalk space. Rain gardens can be incorporated into these extensions to capture stormwater flow from streets. Flow-through planter boxes are long, narrow landscaped areas with vertical walls and flat bottoms open to the underlying soil. They allow for increased stormwater storage volume in minimal space. The plants and topsoil within the boxes contribute to stormwater filtering and treatment for improved water quality. Planters may also incorporate street trees. Figures 7.3 and 7.4 show common applications of green street features in Portland, Oregon.

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[1] "Pervious Concrete Pavement". September 2009. U.S. Environmental Protection Agency. < http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=137&minmeasure=5>.

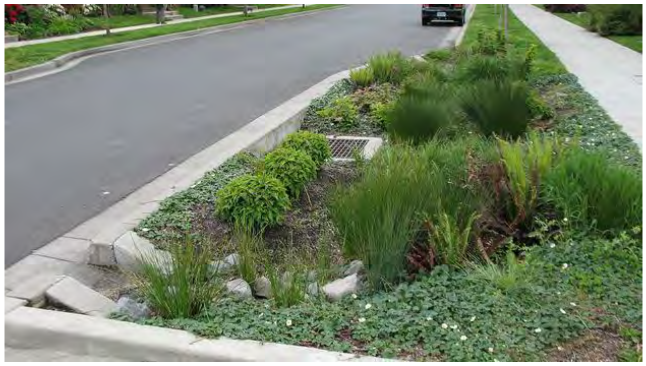

Figure 7.3: Example of a Green Street with incorporation of a Curb Extension and Rain Garden in Portland, OR[2]

Figure 7.4: Example of a Green Street with incorporation of a flow-through planter in Portland, OR[2]

7.2.4 Rain Barrels

An additional recommendation that may help reduce a limited volume of stormwater flow from personal properties is the installation of rain barrels at roof gutter down spouts. Considering that a vast majority of the watershed is occupied by residential properties, there is a large total surface area of roofs that contribute to impervious surface runoff. While many gutter systems drain to lawns where infiltration can occur, a significant portion of drainage systems were observed that drain runoff directly to street curbs and therefore directly to the Musquapsink Brook. With education and awareness, rain barrels could become part of an overall approach for homeowner action. Figure 7.5 shows an example of an installed rain barrel collecting stormwater from a residential rooftop.

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[2] "Curb Bump-Out Rain Garden". May 2009. Flickr. 2011. <http://www.flickr.com/photos/dcgreeninfrastructure/5036625486/in/photostream>.

Figure 7.5: Example of an installed Rain Barrel in the Lower Delaware Watershed

7.2.5 Bank Stabilization and Riparian Buffer Restoration

As presented in Chapter 4 of this plan, there are a number of areas along the Musquapsink Brook where steep and unstable or unvegetated banks are eroding. Figure 7.6 illustrates an example of these conditions in the watershed. There are several bank stabilization methods that alleviate excessive sedimentation and allow for the interception of direct storm flow. The installation and planting of native riparian plant species in unvegetated areas of the Musquapsink Brook Watershed would stabilize the exposed and eroding bank areas and reduce the sediment load. This form of bank stabilization can be conducted in a relatively cost-effective manner. See Figure 7.7 for an example of installed live stakes and coir fiber mat for erosion control and stabilization.

Figure 7.6: Example of an Eroded and Unstable Streambank in Musquapsink Brook Watershed

Increased buffer areas in the riparian corridor can reduce both stormwater flow and pollutant loading. Riparian zones are recognized for their ability to perform a variety of functions, including erosion control by regulating sediment storage; stabilizing stream channels; serving as nutrient sinks; reducing flood peaks; and serving as key recharge points for renewing groundwater supplies. They create better macroinvertebrate habitat within the stream by increasing canopy cover and reducing water temperatures.

Additionally, riparian buffers can also deter geese and other waterfowl from entering the waterway.

Figure 7.7: Erosion control and streambank stabilization with live stake plant material, North Carolina[3]

Finally, there are sections of the Musquapsink Brook where down-cutting is occurring. This is the deepening of the river so that it loses its ability to rise beyond its banks into the floodplain. This disconnection from the floodplain makes the stream flow much faster during storm events and limits its ability to provide stormwater detention in its floodplains. Several of these areas should be examined for possible reconnection to the floodplain. Once reconnected to the floodplain, flood waters will move much slower downstream and receive treatment by floodplain vegetation. Caution needs to be taken in these reconnection projects so as to not put infrastructure and buildings in danger as a result of flood waters.

7.3 Site Specific Restoration Projects

The major emphasis of the remediation strategies is to retain stormwater runoff and loadings by disconnection of impervious surfaces, riparian corridor restoration, implementing goose/waterfowl deterrents, and initiating or enhancing education for students, homeowners, businesses, etc. on the proper management techniques for runoff and pollutant control. Watershed-wide strategies should readily produce enhancements to the flow regime and water quality throughout Musquapsink Brook Watershed. Site-specific strategies should provide localized remediation for sources of stormwater runoff and the associated contaminants while also serving as a demonstration for universal application to foster a more effective restoration and protection program.

For each subwatershed, BMP opportunities were identified in each municipality. The figures that illustrate theses opportunities are presented in Appendix C. Each site was field inspected and a brief description of the site and possible BMPs are also presented in Appendix C. Each potential project was given a unique identification code. In Tables 7.3 through 7.26, information for each project is presented including site description, land use, area of project, existing pollutant loading from each project site as calculated using aerial loading coefficients, recommended management measures and BMP type, estimated implementation costs, and load reductions anticipated by the BMP. Aerial loading coefficients were used to determine the load reductions for total phosphorus, total nitrogen, and total suspended solids. These loading coefficients were multiplied by the

[3] Charlotte-Mecklenburg Storm Water Services

area disconnected for each of the identified project sites. Annual pollutant loading reductions and water quantity reductions are based on 90% volume reductions as management measures are designed to capture all runoff from two-year rainfall events and are estimated to capture 90% of the annual rainfall (44.1 inches in Bergen County).

7.3.1 Subwatershed MB1

Borough of Woodcliff Lake

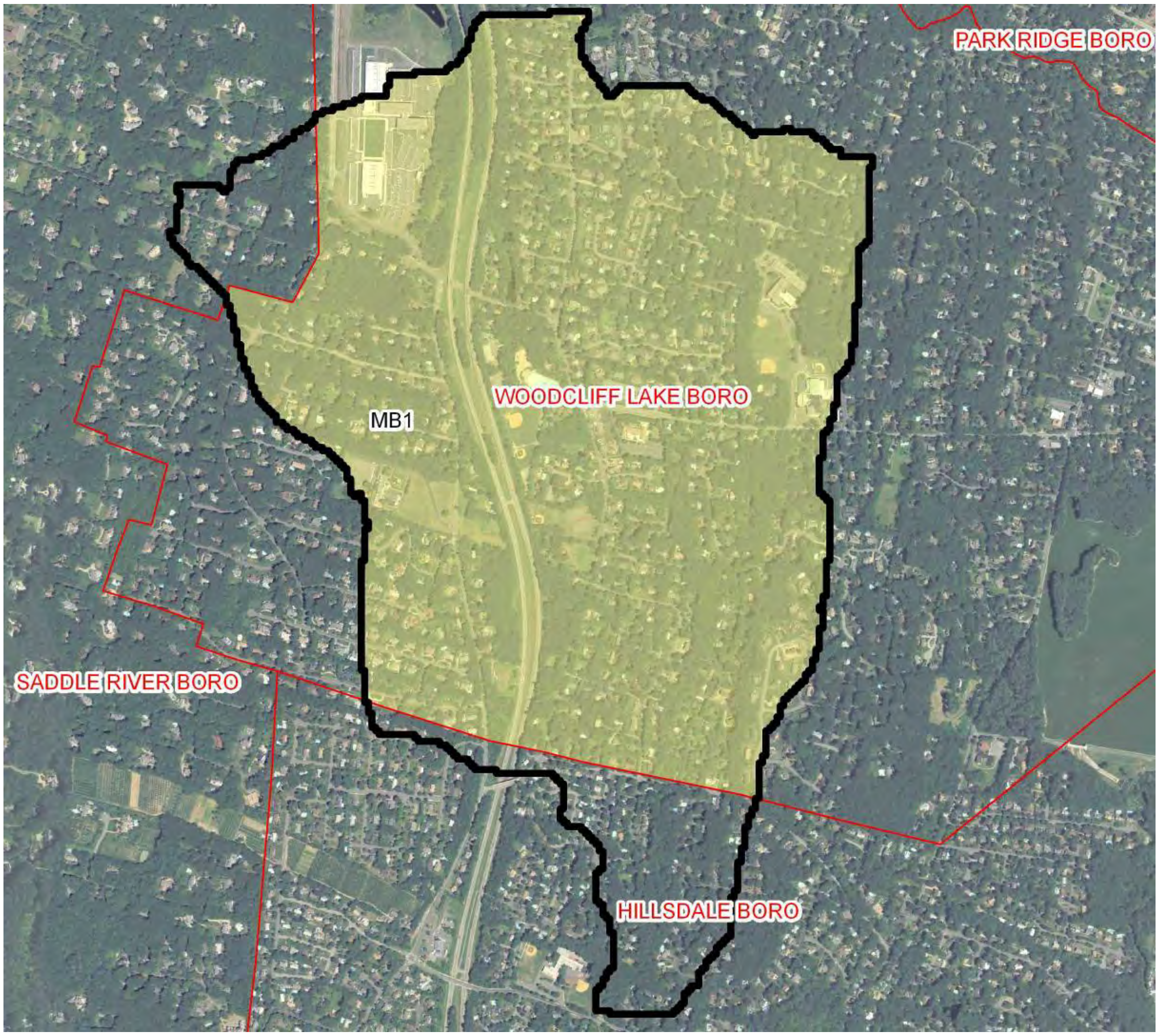

Figure 7.8 Aerial View of Subwatershed MB1, Borough of Woodcliff Lake Study Area

Table 7.3 Projects Identified in Subwatershed MB1, Borough of Woodcliff Lake with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB1_WL	a	COMMERCIAL (PARKING)	25	53	47	550	495	5,000	4,500	27
MB1_WL	b	RESIDENTIAL	50	30	27	250	225	5,000	4,500	54
MB1_WL	c	RESIDENTIAL	38	23	21	190	171	3,800	3,420	41
MB1_WL	d	RESIDENTIAL	124	174	156	1,860	1,674	17,360	15,624	134
MB1_WL	e	RECREATIONAL	8	8	7	80	72	960	864	9
MB1_WL	f	RECREATIONAL	16	16	14	160	144	1,920	1,728	17
MB1_WL	g	COMMERCIAL (PARKING)	1	2	2	22	20	200	180	1
		Total	262	303	273	3,090	2,781	34,040	30,636	282
		Total Impervious Cover (Acres)	73							

Table 7.4 BMP Management Measures for Project Locations in Subwatershed MB1, Borough of Woodcliff Lake

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB1_WL	a	Car Dealership	Disconnection of Parking Lot	Rain Garden Pervious Asphalt	$12,000-$720,000
MB1_WL	b	Residential Neighborhood	Disconnection of Roadway	Rain Garden	$2,000
MB1_WL	c	Residential Neighborhood	Disconnection of Roadway	Pervious Asphalt	$300,000
MB1_WL	d	Residential Neighborhood	Disconnection of Roadway, Rooftops Educational Programs	Rain Garden Grassed Swales Rain Barrels	$6,000-$20,000
MB1_WL	e	Park	Disconnection of Parking Lot, Rooftop	Rain Garden Pervious Asphalt	$2,000-$100,000
MB1_WL	f	School	Disconnection of Parking Lot	Rain Garden	$2,000
MB1_WL	g	Church	Disconnection of Parking Lot	Pervious Asphalt	$450,000

7.3.2 Subwatershed MB2

Hillsdale Borough

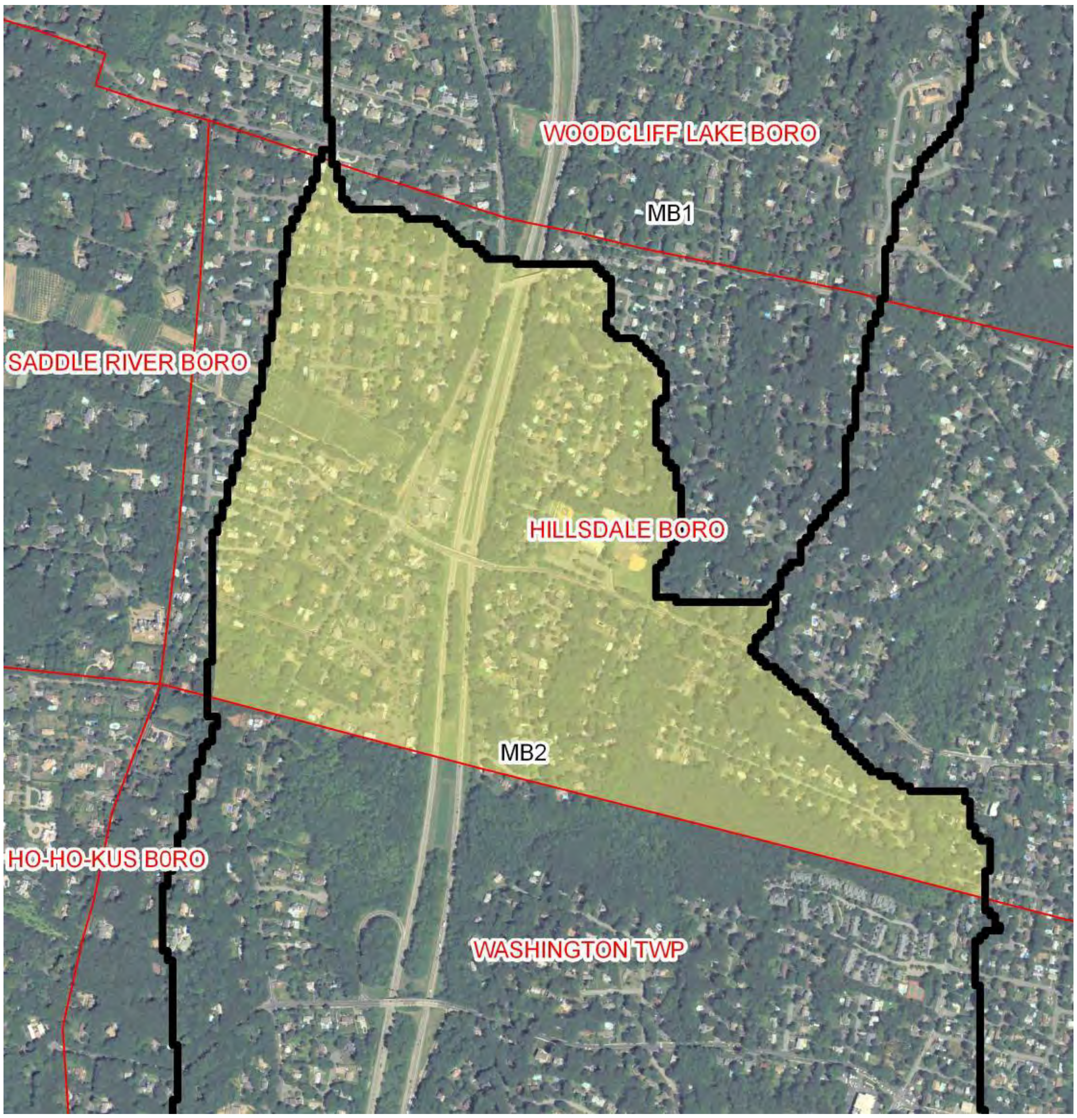

Figure 7.9 Aerial View of Subwatershed MB2, Hillsdale Borough Study Area

Table 7.5 Projects Identified in Subwatershed MB2, Hillsdale Borough with Load Reduction Scenarios

Project ID		LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB2_H	a	COMMERCIAL (PARKING)	3	6	6	66	59	600	540	3
MB2_H	b	RESIDENTIAL	40	24	22	200	180	4,000	3,600	43
MB2_H	c	RESIDENTIAL	32	19	17	160	144	3,200	2,880	34
MB2_H	d	RECREATIONAL (SCHOOL)	8	8	7	80	72	960	864	9
		Total	83	58	52	506	455	8,760	7,884	89
		Total Impervious Cover (Acres)	19							

Table 7.6 BMP Management Measures for Project Locations in Subwatershed MB2, Hillsdale Borough

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB2_H	a	Business	Disconnection of Parking Lot	Pervious Asphalt Planter Boxes	$150,000
MB2_H	b	Residential Neighborhood	Disconnection of Rooftop Educational Programs	Rain Gardens Rain Barrels	$10,000-$20,000
MB2_H	c	Residential Neighborhood	Disconnection of Roadway	Green Streets	$1,540,000
MB2_H	d	School	Disconnection of Parking Lot	Rain Garden	$2,000-$4,000

Washington Township

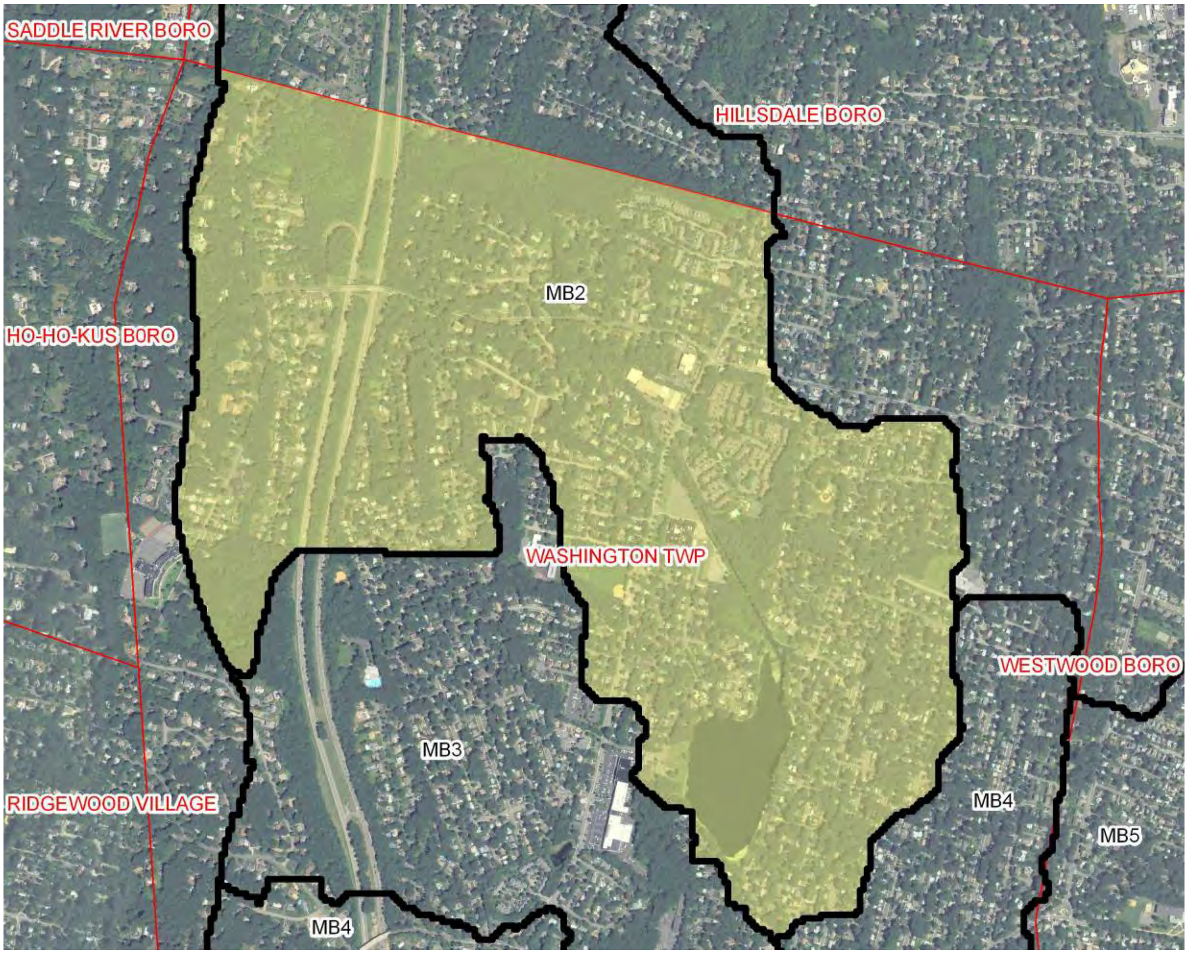

Figure 7.10 Aerial View of Subwatershed MB2, Washington Township Study Area

Table 7.7 Projects Identified in Subwatershed MB2, Washington Township with Load Reduction Scenarios

Project ID		LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB2_Wa	a	COMMERCIAL	8	17	15	176	158	1,600	1,440	9
MB2_Wa	b	COMMERCIAL	7	15	13	154	139	1,400	1,260	8
MB2_Wa	c	COMMERCIAL	1	2	2	22	20	200	180	1
MB2_Wa	d	RESIDENTIAL	18	11	10	90	81	1,800	1,620	19
MB2_Wa	e	RESIDENTIAL	35	21	19	175	158	3,500	3,150	38
MB2_Wa	f	RESIDENTIAL	12	7	6	60	54	1,200	1,080	13
MB2_Wa	g	RESIDENTIAL	27	16	15	135	122	2,700	2,430	29
MB2_Wa	h	RECREATIONAL (SCHOOL)	6	6	5	60	54	720	648	6
		Total	114	95	85	872	785	13,120	11,808	123
		Total Impervious Cover (Acres)	50							

Table 7.8 BMP Management Measures for Project Locations in Subwatershed MB2, Washington Township

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB2_Wa a	Recreation	Disconnection of Parking Lot	Naturalize basin, swale Rain garden Pervious pavement	$12,100
MB2_Wa b	Commercial	Disconnection of Parking Lot	Pervious Pavement	$100,000
MB2_Wa c	Commercial	Disconnection of Parking Lot	Pervious Pavement Rain gardens	$96,200
MB2_Wa d	Residential	Disconnection of Rooftop	Rain barrels Green Alleyway	$70,680
MB2_Wa e	Residential	Disconnection of Rooftop	Rain Gardens Rain Barrels	$22,000
MB2_Wa f	Residential	Disconnection of Rooftop	Rain Gardens Rain Barrels Naturalize Basin, Swale	$22,040
MB2_Wa g	Park	Disconnection of Parking Lot	Rain Garden Shoreline Stabilization	$3,300
MB2_Wa h	School	Disconnection of Parking Lot	Rain Garden Pervious Pavement	$50,400

7.3.3 Subwatershed MB3

<u>Washington Township</u>

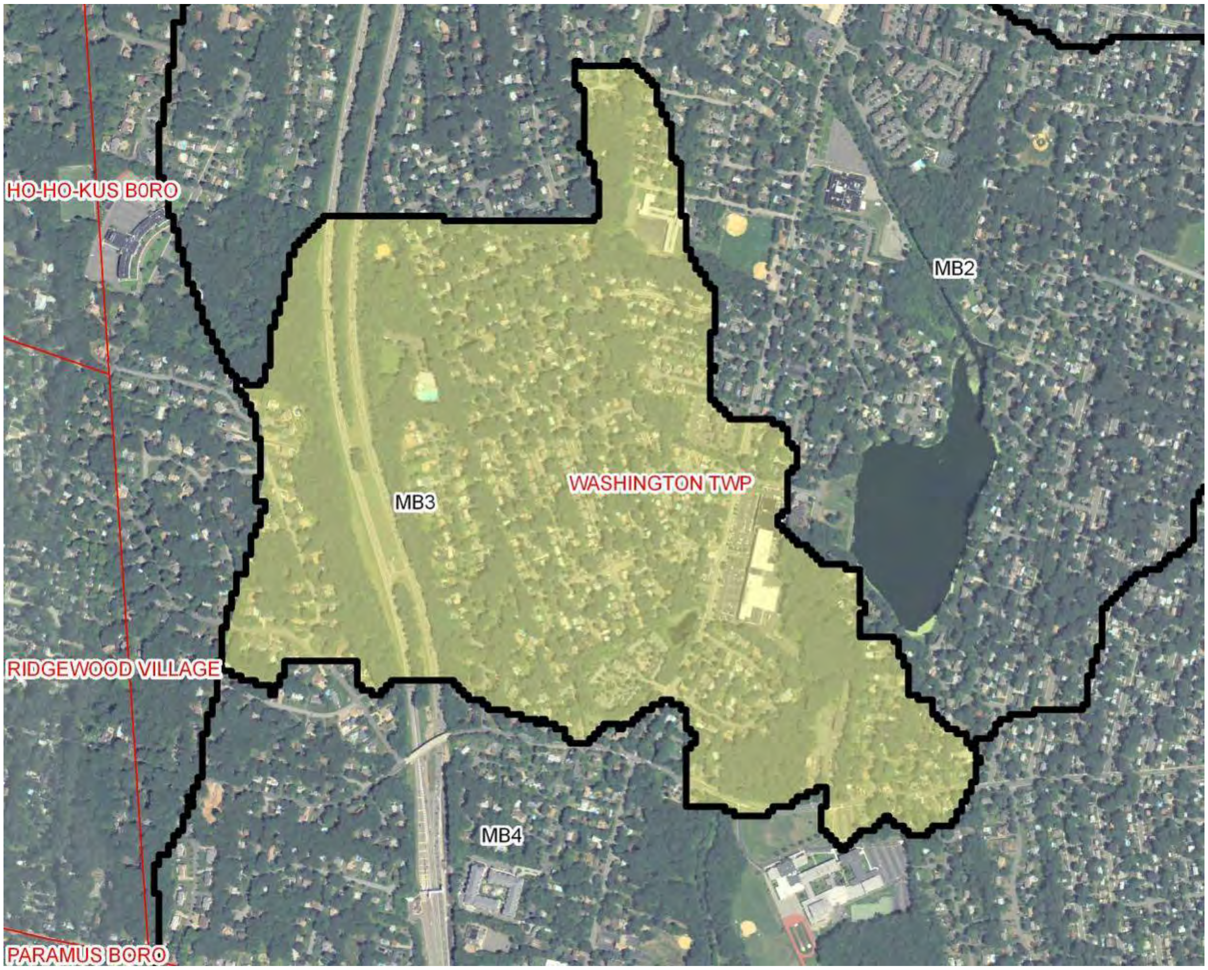

Figure 7.11 Aerial View of Subwatershed MB3, Washington Township Study Area

Table 7.9 Projects Identified in Subwatershed MB3, Washington Township with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB3_Wa	a	COMMERCIAL (PARKING)	14	29	26	308	277	2,800	2,520	15
MB3_Wa	b	COMMERCIAL (PARKING)	3	6	6	66	59	600	540	3
MB3_Wa	c	RESIDENTIAL	4	2	2	20	18	400	360	4
MB3_Wa	d	RESIDENTIAL	9	5	5	45	41	900	810	10
MB3_Wa	e	RESIDENTIAL	11	7	6	55	50	1,100	990	12
MB3_Wa	f	RESIDENTIAL	37	22	20	185	167	3,700	3,330	40
MB3_Wa	g	RECREATIONAL	3	3	3	30	27	360	324	3
MB3_Wa	h	RECREATIONAL (SCHOOL)	4	4	4	40	36	480	432	4
		Total	85	79	71	749	674	10,340	9,306	92
		Total Impervious Cover (Acres)	40							

Table 7.10 BMP Management Measures for Project Locations in Subwatershed MB3, Washington Township

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost ($)
MB3_Wa a	Commercial	Disconnection of Parking lot	Rain Garden/Pervious Asphalt/Swale/Increase buffer	$156,800
MB3_Wa b	Church	Disconnection of Parking lot	Disconnect downspouts/Rain Gardens	$840
MB3_Wa c	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels	$11,680
MB3_Wa d	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$33,900
MB3_Wa e	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$13,500
MB3_Wa f	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$79,800
MB3_Wa g	Recreation	Disconnection of Parking lot, Rooftop	Pervious Asphalt, Increase Buffer	$106,000
MB3_Wa h	School	Disconnection of Rooftops, Parking lot	Rain Gardens, Pervious Asphalt, Swales	$102,000

7.3.4 Subwatershed MB4

Borough of Emerson

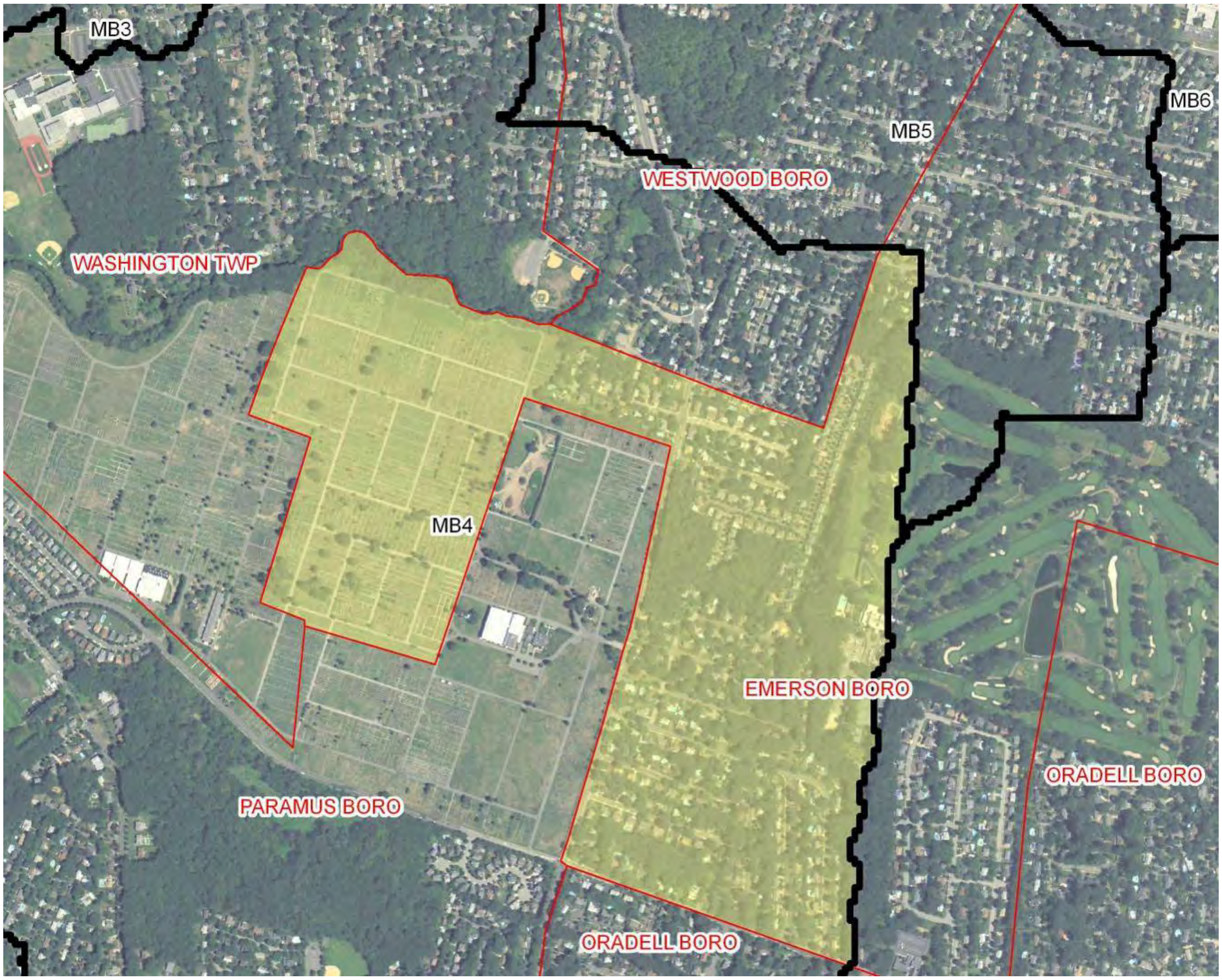

Figure 7.12 Aerial View of Subwatershed MB4, Borough of Emerson Study Area

Table 7.11 Projects Identified in Subwatershed MB4, Borough of Emerson with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_E	a	CEMETERY	82	82	74	820	738	9,840	8,856	88
MB4_E	b	RESIDENTIAL	27	16	15	135	122	2,700	2,430	29
MB4_E	c	RESIDENTIAL	61	37	33	305	275	6,100	5,490	66
MB4_E	d	RECREATIONAL	17	17	15	170	153	2,040	1,836	18
		Total	187	152	137	1,430	1,287	20,680	18,612	202
		Total Impervious Cover (Acres)	38							

Table 7.12 BMP Management Measures for Project Locations in Subwatershed MB4, Borough of Emerson

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_E	a	Cemetery	Disconnection of Roadways	Flow-Through Planter Boxes	$60,000
MB4_E	b	Residential	Disconnect Rooftops	Rain Gardens/Rain Barrels	$39,600
MB4_E	c	Residential	Disconnect Rooftops, Roadways	Rain Gardens/Rain Barrels/Swales	$73,400
MB4_E	d	Golf Club	Disconnect Parking Lot	Pervious Pavement	$200,000

Borough of Paramus

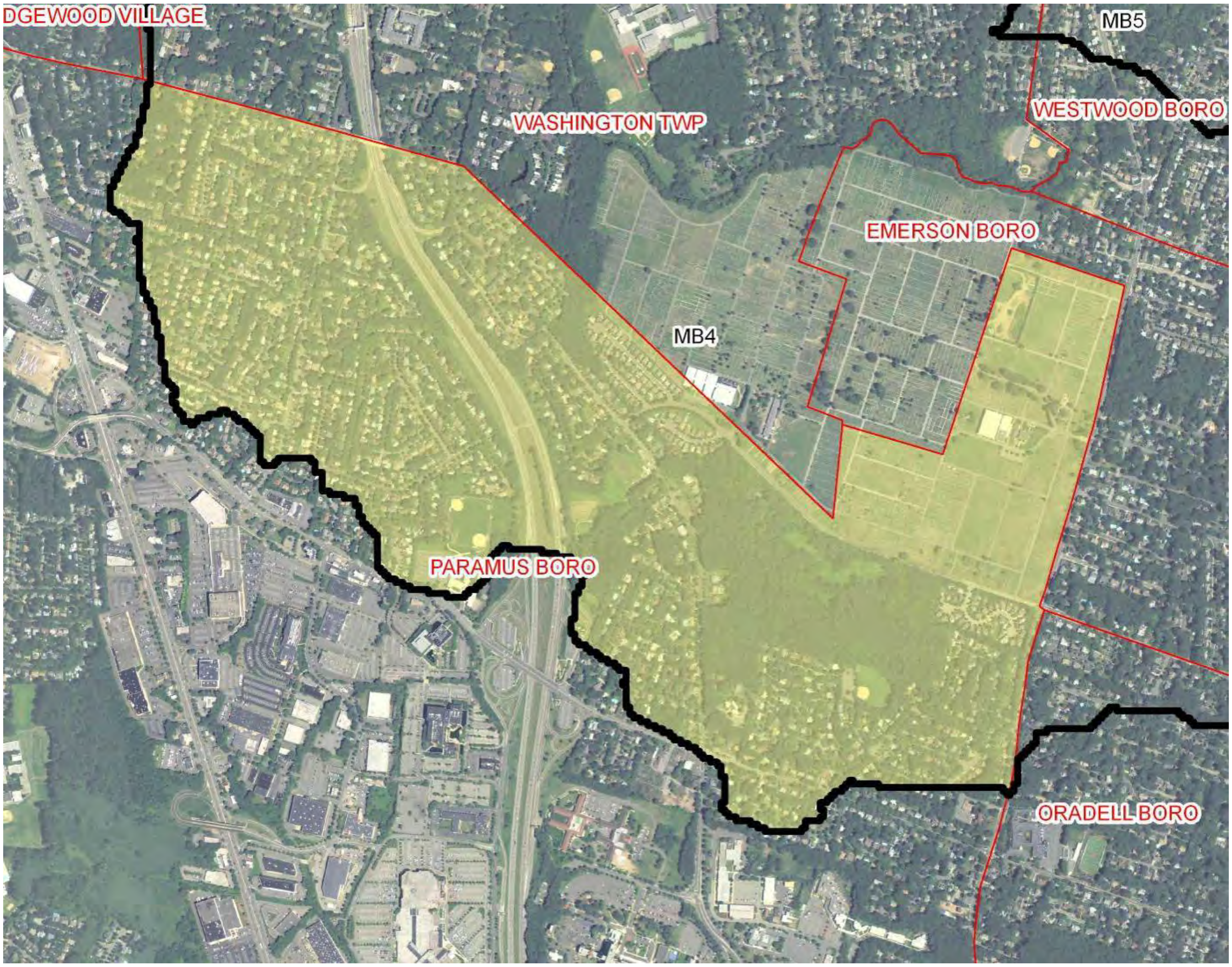

Figure 7.13 Aerial View of Subwatershed MB4, Borough of Paramus Study Area

Table 7.13 Projects Identified in Subwatershed MB4, Borough of Paramus with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_P	a	CEMETERY	100	100	90	1,000	900	12,000	10,800	108
MB4_P	b	RESIDENTIAL	42	25	23	210	189	4,200	3,780	45
MB4_P	c	RESIDENTIAL	22	13	12	110	99	2,200	1,980	24
MB4_P	d	RESIDENTIAL	86	52	46	430	387	8,600	7,740	93
MB4_P	e	RESIDENTIAL	29	17	16	290	261	3,480	3,132	31
MB4_P	f	RECREATIONAL (SCHOOL)	12	12	11	120	108	1,440	1,296	13
MB4_P	g	RESIDENTIAL	14	8	8	70	63	1,400	1,260	15
		Total	305	228	205	2,230	2,007	33,320	29,988	329
		Total Impervious Cover (Acres)	81							

Table 7.14 BMP Management Measures for Project Locations in Subwatershed MB4, Borough of Paramus

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_P	a	Cemetery	Disconnection of Roadways	Flow-Through Planter Boxes	$65,000
MB4_P	b	Residential	Disconnection of Rooftops	Rain Gardens/Rain Barrels	$17,600
MB4_P	c	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$17,600
MB4_P	d	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$89,600
MB4_P	e	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$164,000
MB4_P	f	School	Disconnection of Parking Lot	Rain Gardens/Pervious Pavement	$244,600
MB4_P	g	Residential	Disconnection of Rooftops	Rain Gardens/Rain Barrels	$19,800

Washington Township

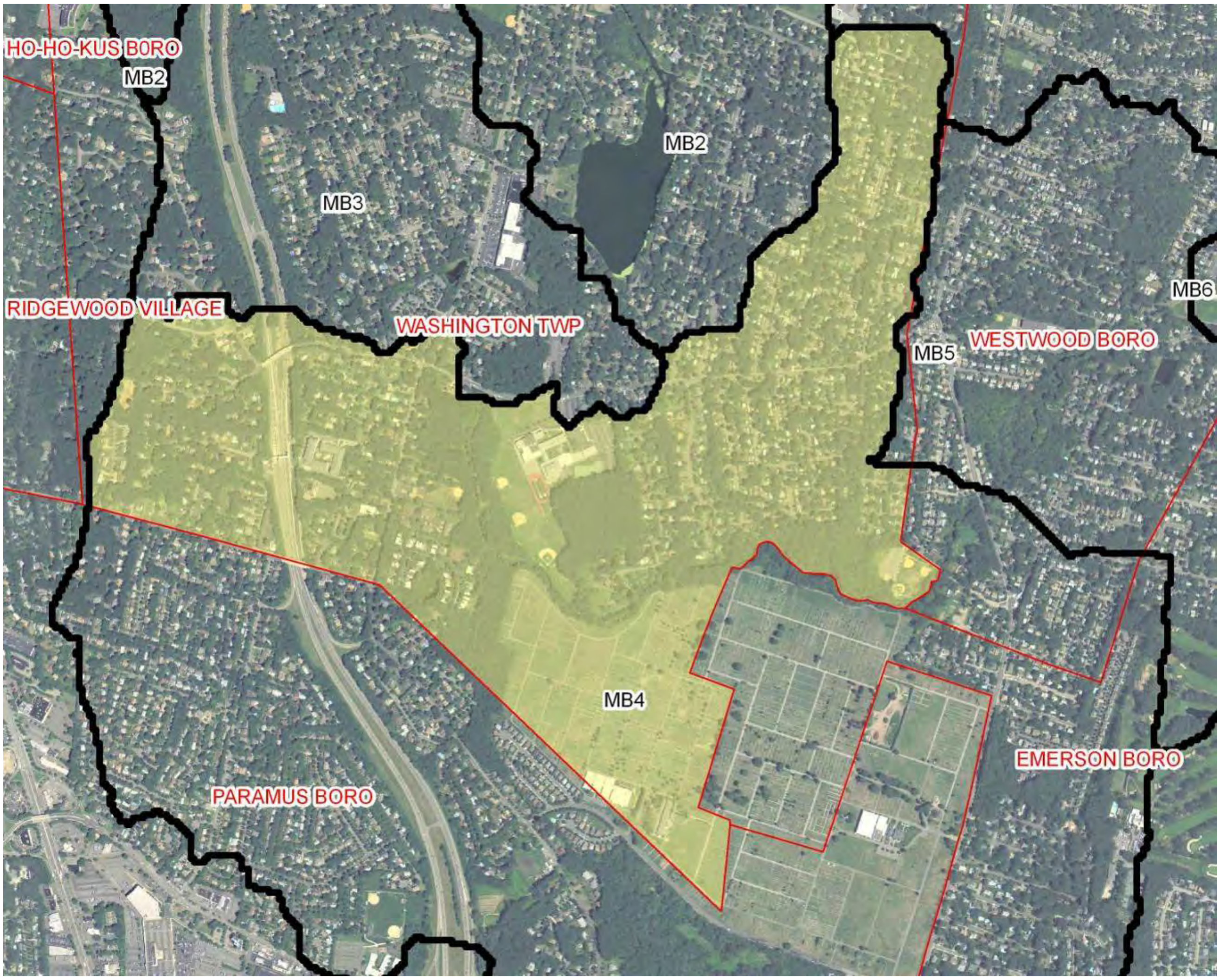

Figure 7.14 Aerial View of Subwatershed MB4, Washington Township Study Area

Table 7.15 Projects Identified in Subwatershed MB4, Washington Township with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_Wa	a	CEMETERY	89	89	80	890	801	10,680	9,612	96
MB4_Wa	b	COMMERCIAL (PARKING)	3	6	6	66	59	600	540	3
MB4_Wa	c	COMMERCIAL (PARKING)	4	8	8	88	79	800	720	4
MB4_Wa	d	COMMERCIAL (PARKING)	2	4	4	44	40	400	360	2
MB4_Wa	e	RESIDENTIAL	14	8	8	70	63	1,400	1,260	15
MB4_Wa	f	RESIDENTIAL	3	2	2	15	14	300	270	3
MB4_Wa	g	RESIDENTIAL	73	44	39	365	329	7,300	6,570	79
MB4_Wa	h	RECREATIONAL	3	3	3	30	27	360	324	3
MB4_Wa	i	RECREATIONAL (SCHOOL)	27	27	24	270	243	3,240	2,916	29
		Total	218	192	173	1,838	1,654	25,080	22,572	235
		Total Impervious Cover (Acres)	55							

Table 7.16 BMP Management Measures for Project Locations in Subwatershed MB4, Washington Township

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_Wa a	Cemetery	Disconnection of Roadways	Flow-Through Planter Boxes Rain Garden	$50,800
MB4_Wa b	Public Building	Disconnection of Parking Lot	Rain Garden	$1,600
MB4_Wa c	Church	Disconnection of Rooftops, Roadways	Rain Garden	$800
MB4_Wa d	Commercial	Disconnection of Parking Lot	Pervious Asphalt	$150,000
MB4_Wa e	Recreation	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$12,600
MB4_Wa f	Residential	Disconnection of Rooftops	Cluster Rain Gardens	$20,000
MB4_Wa g	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt	$532,800
MB4_Wa h	Recreation	Disconnection of Roadways	Increase Buffer	$8,000
MB4_Wa i	School	Disconnect Parking Lot, Rooftops	Rain Garden/Pervious Pavement	$151,000

Borough of Westwood

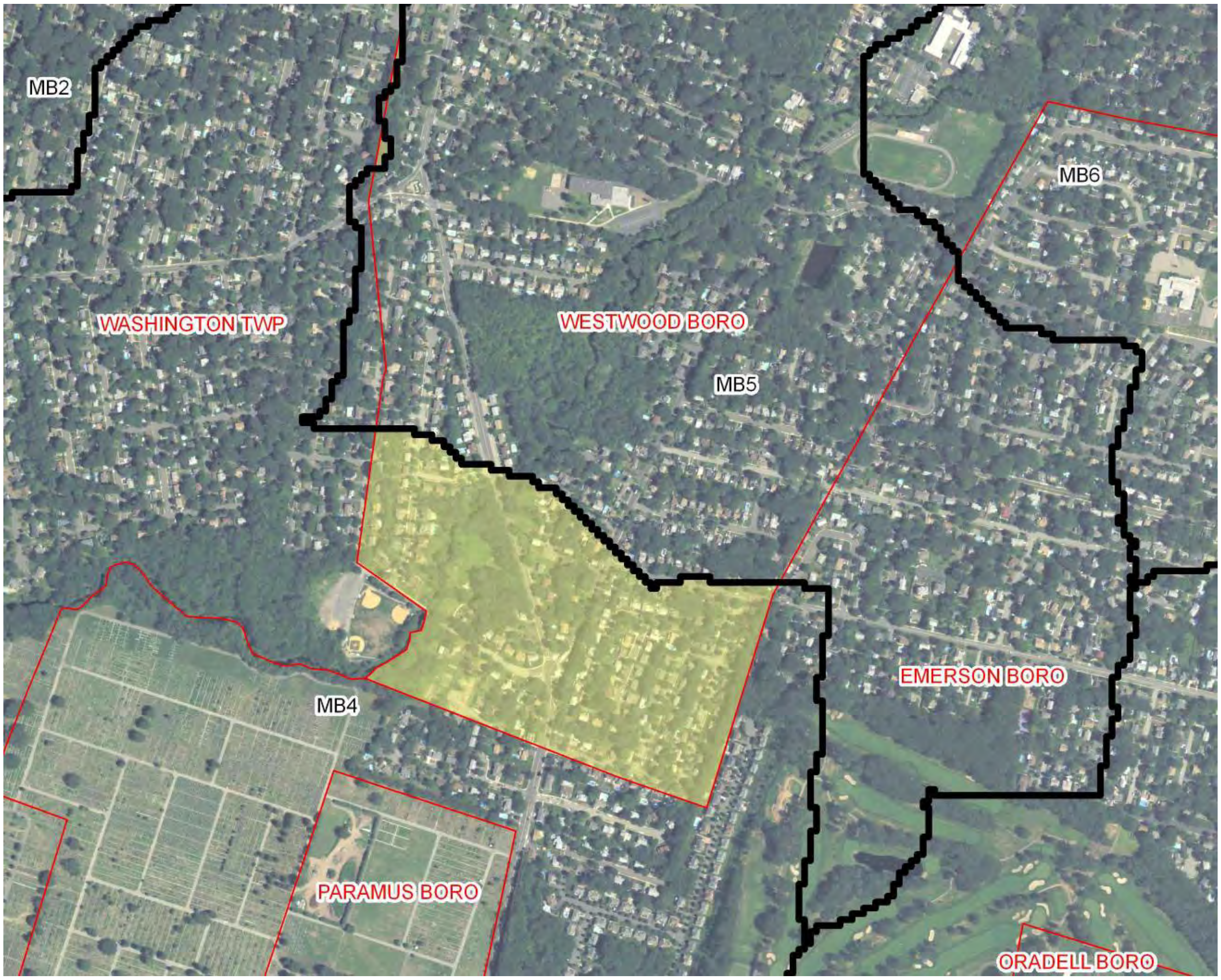

Figure 7.15 Aerial View of Subwatershed MB4, Borough of Westwood Study Area

Table 7.17 Projects Identified in Subwatershed MB4, Borough of Westwood with Load Reduction Scenarios

Project ID	LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB4_We a	RESIDENTIAL	19	11	10	95	86	1,900	1,710	20
MB4_We b	RESIDENTIAL	8	5	4	40	36	800	720	9
	Total	27	16	15	135	122	2,700	2,430	29
	Total Impervious Cover (Acres)	10							

Table 7.18 BMP Management Measures for Project Locations in Subwatershed MB4, Borough of Westwood

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB4_We a	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt/Swales	$225,000
MB4_We b	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt/Swales	$157,300

7.3.5 Subwatershed MB5

Borough of Emerson

Figure 7.16 Aerial View of Subwatershed MB5, Borough of Emerson Study Area

Table 7.19 Projects Identified in Subwatershed MB5, Borough of Emerson with Load Reduction Scenarios

Project ID	LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB5_E a	RESIDENTIAL	17	10	9	85	77	1,700	1,530	18
MB5_E b	RESIDENTIAL	11	7	6	55	50	1,100	990	12
	Total	28	17	15	140	126	2,800	2,520	30
	Total Impervious Cover (Acres)	12							

Table 7.20 BMP Management Measures for Project Locations in Subwatershed MB5, Borough of Emerson

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB5_E a	Residential	Disconnect Rooftops, Roadways	Rain Gardens/Rain Barrels/Pervious Asphalt	$659,200
MB5_E b	Residential/Recreation	Disconnect Roadways, Rooftops	Rain Garden	$17,600

Borough of Westwood

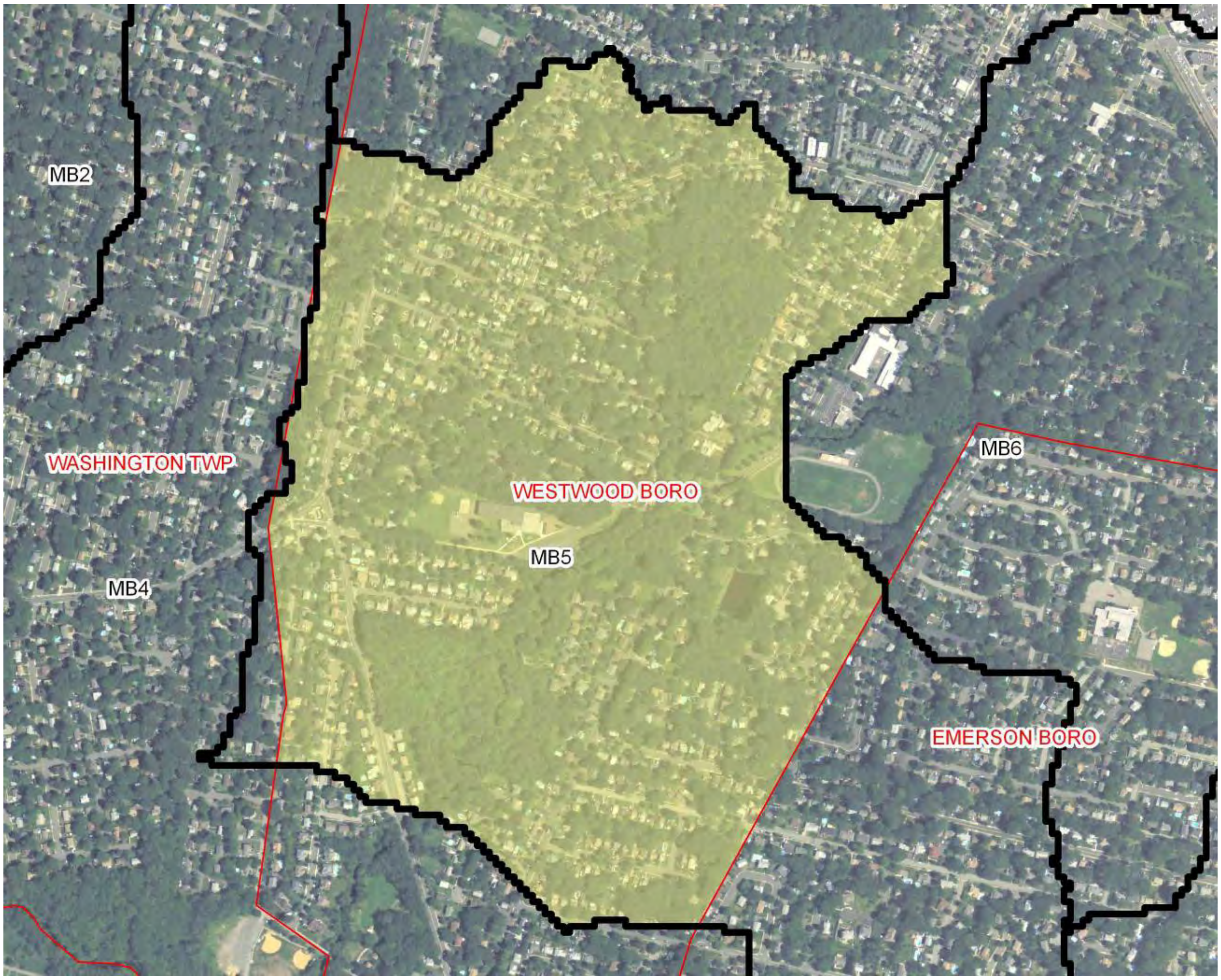

Figure 7.17 Aerial View of Subwatershed MB5, Borough of Westwood Study Area

Table 7.21 Projects Identified in Subwatershed MB5, Borough of Westwood with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB5_We	a	RESIDENTIAL	6	4	3	30	27	600	540	6
MB5_We	b	RESIDENTIAL	3	2	2	15	14	300	270	3
MB5_We	c	RESIDENTIAL	20	12	11	100	90	2,000	1,800	22
MB5_We	d	RESIDENTIAL	7	4	4	35	32	700	630	8
MB5_We	e	RESIDENTIAL	10	6	5	50	45	1,000	900	11
MB5_We	f	RESIDENTIAL	3	2	2	15	14	300	270	3
MB5_We	g	RESIDENTIAL	14	8	8	70	63	1,400	1,260	15
MB5_We	h	RECREATIONAL	1	1	1	10	9	120	108	1
MB5_We	i	RECREATIONAL (SCHOOL)	6	6	5	60	54	720	648	6
		Total	70	45	40	385	347	7,140	6,426	75
		Total Impervious Cover (Acres)	24							

Table 7.22 BMP Management Measures for Project Locations in Subwatershed MB5, Borough of Westwood

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB5_We a	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$183,200
MB5_We b	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$93,600
MB5_We c	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$211,000
MB5_We d	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$152,800
MB5_We e	Recreation	Disconnection of Roadways	Increase Buffer	$77,760
MB5_We f	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$76,600
MB5_We g	Residential	Disconnection of Roadways, Rooftops	Rain Gardens/Rain Barrels/Pervious Asphalt	$906,000
MB5_We h	Recreation	Riparian Buffer Restoration	Increase Buffer	$20,000
MB5_We i	School	Disconnect Roadways, Rooftops	Rain Garden	$800

7.3.6 Subwatershed MB6

<u>Borough of Emerson</u>

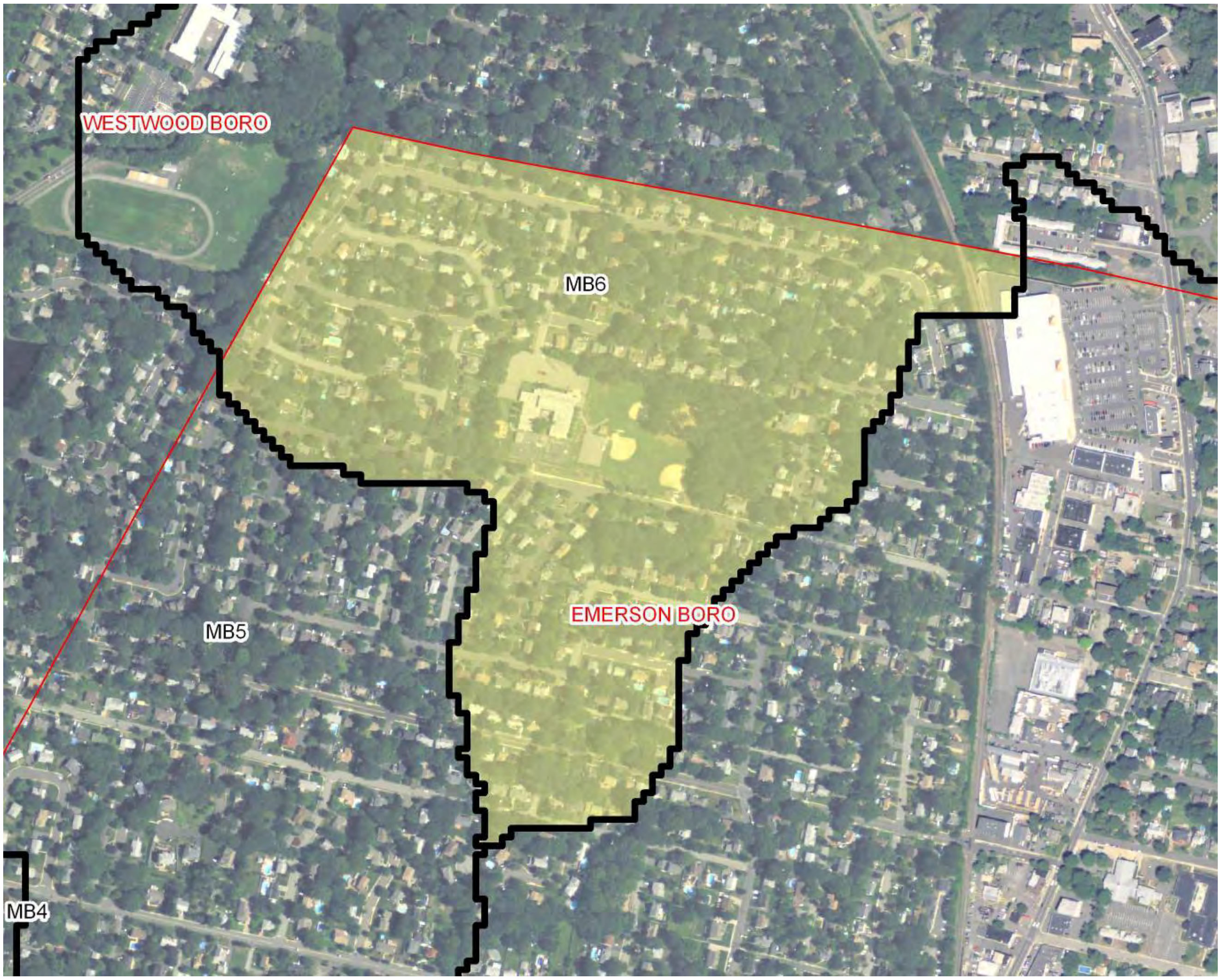

Figure 7.18 Aerial View of Subwatershed MB6, Borough of Emerson Study Area

Table 7.23 Projects Identified in Subwatershed MB6, Borough of Emerson with Load Reduction Scenarios

Project ID	LANDUSE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB6_E a	RESIDENTIAL	19	11	10	95	86	1,900	1,710	20
MB6_E b	RECREATIONAL (SCHOOL)	7	7	6	70	63	840	756	8
	Total	26	18	17	165	149	2,740	2,466	28
	Total Impervious Cover (Acres)	9							

Table 7.24 BMP Management Measures for Project Locations in Subwatershed MB6, Borough of Emerson

Project ID	Site Description	Management Measure	Type of BMP	Estimated Cost
MB6_E a	Residential	Disconnect Roadways	Green Street	$65,000
MB6_E b	School	Disconnect Rooftops	Rain Garden/Rain Barrels	$37,400

Borough of Westwood

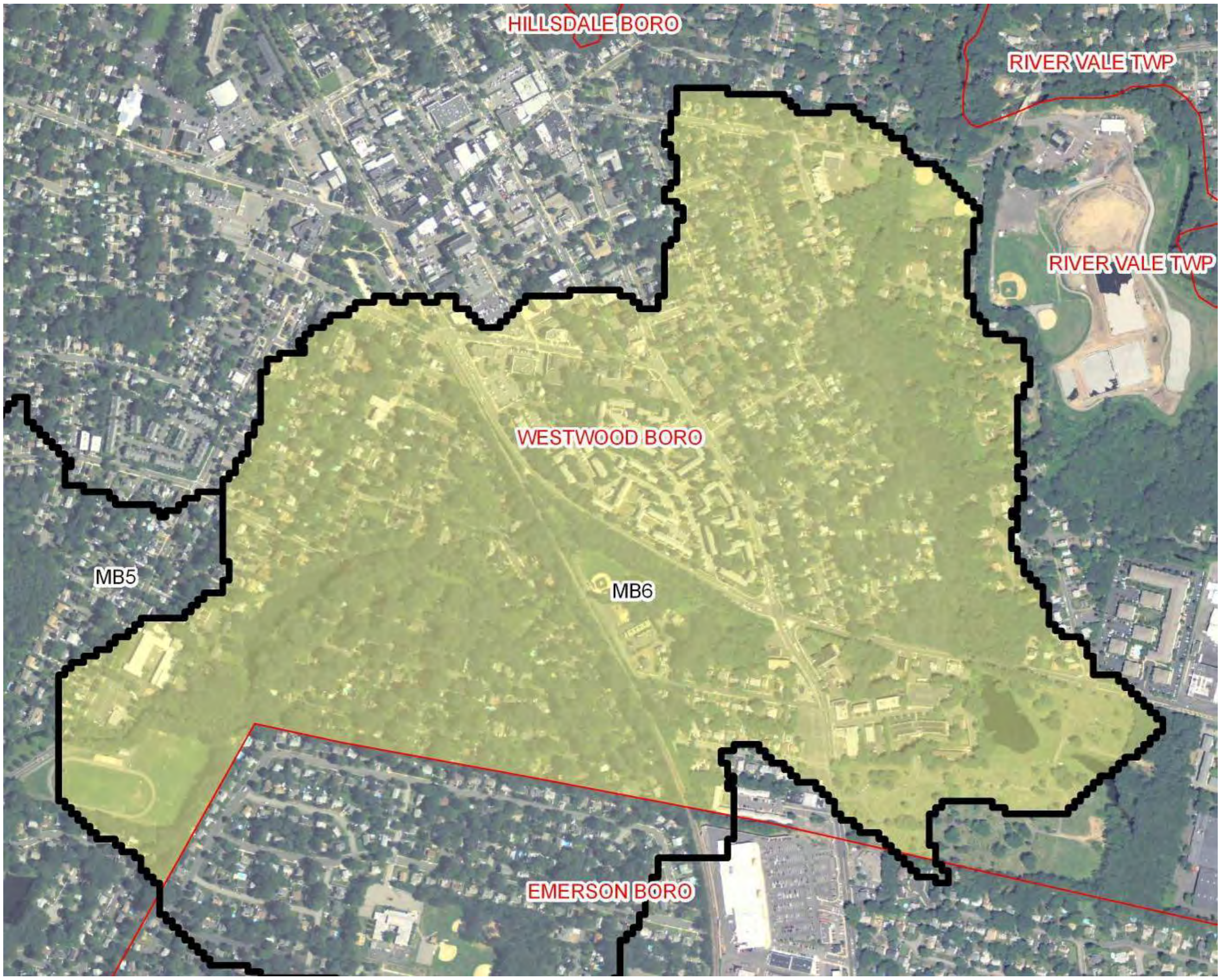

Figure 7.19 Aerial View of Subwatershed MB6, Borough of Westwood Study Area

Table 7.25 Projects Identified in Subwatershed MB6, Borough of Westwood with Load Reduction Scenarios

Project ID		LAND USE	AREA ACRES	Calculated TP Load lbs/yr	Estimated TP Removal by BMP lbs/yr	Calculated TN Load lbs/yr	Estimated TN Removal by BMP lbs/yr	Calculated TSS Load lbs/yr	Estimated TSS Removal by BMP lbs/yr	Estimated Water Quantity Reduction Mgal/yr
MB6_We	a	RESIDENTIAL	4	2	2	20	18	400	360	4
MB6_We	b	COMMERCIAL	10	21	19	220	198	2,000	1,800	11
MB6_We	c	RESIDENTIAL	4	6	5	20	18	400	360	4
MB6_We	d	COMMERCIAL	3	6	6	66	59	600	540	3
MB6_We	e	COMMERCIAL	3	6	6	66	59	600	540	3
MB6_We	f	COMMERCIAL	4	8	8	88	79	800	720	4
MB6_We	g	COMMERCIAL	3	6	6	66	59	600	540	3
MB6_We	h	RESIDENTIAL	15	9	8	75	68	1,500	1,350	16
MB6_We	i	RESIDENTIAL	4	2	2	20	18	400	360	4
		Total	50	68	61	641	577	7,300	6,570	54
		Total Impervious Cover (Acres)	25							

Table 7.26 BMP Management Measures for Project Locations in Subwatershed MB6, Borough of Westwood

Project ID		Site Description	Management Measure	Type of BMP	Estimated Cost
MB6_We	a	Recreation	Disconnection of Roadways	Increase Buffer	$10,000
MB6_We	b	Commercial	Disconnection of Parking Lot	Pervious Asphalt	$95,000
MB6_We	c	Residential	Disconnection of Parking Lot, Rooftops	Rain Gardens/Rain Barrels	$12,500
MB6_We	d	Commercial	Disconnection of Parking Lot	Pervious Asphalt	$75,000
MB6_We	e	Commercial	Disconnection of Parking Lot	Pervious Asphalt/Increase Buffer	$99,500
MB6_We	f	School	Disconnection of Parking Lot	Rain Gardens	$2,200-$5,500
MB6_We	g	School	Disconnection of Rooftop, Parking Lot	Rain Gardens/Permeable Pavement/Green Roof	$90,000-$200,000
MB6_We	h	Residential	Disconnection of Rooftop	Rain Gardens/Rain Barrels	$26,500
MB6_We	i	Residential	Disconnection of Rooftops, Roadways	Rain Gardens/Rain Barrels/Increase Buffer	$17,500-$120,000

7.4 BMP Concept Designs

BMP concept designs for five (5) priority projects located in subwatersheds MB4, MB5, and MB6 are included in Appendix D of this report and provide the following project information:

- Summary of current conditions at the location or in the watershed
- Anticipated pollutant removal
- Potential funding sources and project partners.
- An estimate of cost

These projects have been prioritized based on a subwatershed basis, percent removal of pollutants, impact on the watershed's discharge quality, overall cost-effectiveness, and best professional judgment. Projects aim to reduce connected impervious cover, improve riparian buffers, control geese access to streams, and improve stakeholder knowledge on the importance of stormwater management.

7.5 Point Source Recommendations

Although the primary focus of this plan is addressing nonpoint source pollution, microbial source tracking was completed and human bacterial contamination was detected, particularly in subwatersheds MB4, MB5, and MB6. Even though the significance of human sources compared to other sources is unknown (see *Section 7.1.2*), it is highly recommended that further study be completed to better track down and then remediate these human sources. A common practice among sewage authorities is to videotape the sanitary sewer lines to identify breaks that might allow wastewater to leak. Municipalities in MB4, MB5, and MB6 should consider videotaping sewer lines and possibly installing liners in areas where leaks are detected. Further investigation into the sanitary sewer systems within the Musquapsink Brook Watershed is suggested.

8. Information and Education

Although site specific projects will address the physical nature of the nonpoint source entry into the waterway, true source reduction is exceedingly enhanced by watershed wide information and educational programs that will bring about a true change of behavior. Programs addressing the use of the land, streamside living, landscaping practices and how it impacts the waterways can be distributed by Rutgers Cooperative Extension, Bergen SWAN, and many other entities.

The Musquapsink Brook Watershed would benefit from the implementation of extension programs similar to New Hampshire's "Landscaping at the Water's Edge" program. "Landscaping at the Water's Edge" was developed by a team of water resource and horticulture specialists to train landscapers and decision makers in ecological landscape practices for protection of water quality in lakes, rivers, streams, and coastal areas. Through collaboration with the USDA NIFA Regional Water Center for Northeast States and Caribbean Islands, a pilot training session has already been offered in New Jersey with great success. States such as Pennsylvania and Virginia also have their own versions of “Streamside Living” educational programs that could be used as models for the development of programs specific to New Jersey needs and conditions. The extension programs should include pertinent information on: limiting the use of pesticides, herbicides, and fertilizer; establishing a no-mow zone along banks; protecting storm drains from debris; planting native trees, shrubs, perennials and grasses; and identifying and removing invasive plants. The curriculum should also include the state and local regulations.

Rutgers Cooperative Extension Water Resources Program offers extension programs that would benefit homeowners, landscapers, and local officials in the Musquapsink Brook Watershed. Descriptions are provided below:

- *Stormwater Management in Your Backyard* program was developed by the Rutgers Cooperative Extension Water Resources Program in collaboration with the USDA Regional Water Program and New Jersey Sea Grant. The program provides educational lectures, hands-on training, and community-level outreach for homeowners and other groups on the topics of water quality issues and management practices such as rain gardens and rain barrels. County Master Gardener and Environmental Steward volunteers play an important role in many aspects of the program;
- *Stormwater Management in Your School Yard* educational program is designed to provide fourth and/or fifth grade students with an opportunity to apply their science, math, and communication skills to real-world environmental problems through the building of a rain garden on the school’s campus. The main focus of the *Stormwater Management in Your School Yard* program curriculum is rain gardens. However, topics such as water, soil, and plant ecology are presented, and connections between these topics and rain gardens are introduced and discussed with the students;
- *Rain Barrel Workshops* are designed to teach participants how to build their own rain barrel and learn how to install it at home. A rain barrel is placed under a downspout next to a house to collect rain water from the roof. The barrel holds approximately 50 gallons of water which can be used to water gardens. The use of collected rain water can save money on water bills, prevent basement flooding, and reduce flooding in local rivers and streams.

Many of these programs have been developed and tested with great success throughout New Jersey. Some may have to be adapted to the specific conditions and issues affecting the Musquapsink Brook Watershed prior to being delivered. Depending on the scope of the need for these programs, additional funding will have to be acquired by the RCE Water Resources Program to deliver the appropriate programs.

9. Implementation Plan and Measurable Milestones

The list of recommendations provides a guide for potential projects to be implemented to improve surface water quality and improve the overall health of the Musquapsink Brook Watershed. Key in successfully implementing these projects in the watershed will be working closely with NJDEP, municipalities, and nonprofit groups to develop a goal-oriented schedule and time table. This plan is intended to be a guide for the project partners as they work to achieve water quality improvements in the watershed. The study and recommendations should be viewed as a working document and periodically updated as new issues arise, new data is collected, and when projects have been successfully completed. Modeling and monitoring will be key components in the assessment of restoration project successes.

Five years after the acceptance of an implementation plan, a detailed evaluation should be conducted to quantify the improvements attained in the watershed with respect to water quality. Based upon this evaluation, the priorities in the plan can be modified to further refine the recommendations for management measures, which are needed to ultimately attain the goal of the plan. The project partners should work together to secure funding for this effort.

10. Estimated Budget, Source of Funding, and Technical Assistance

The implementation of the proposed BMPs could be funded through various federal, state and local programs that provide cost-share for implementation. The NJDEP 319(h) program is a viable source of funding for these efforts. In addition, utility companies may also be able to provide monetary contributions and technical assistance. United Water donates close to $1.5 million each year in direct contributions and in-kind services to nonprofit groups across the country who are dedicated to the environment, education, and humanitarian services.

11. Conclusions

The Musquapsink Brook is a valuable resource for New Jersey as it ultimately drains to a reservoir that provides drinking water for an estimated 800,000 residents of Bergen and Hudson counties. Urbanization threatens the water resources within this watershed and management measures have not been implemented to mitigate the impacts of development. The pollutants entering the waterways of the Musquapsink Brook Watershed serve to impair its uses, including recreational uses and the macroinvertebrate habitat. This plan provides cost effective solutions to improve water quality while maintaining the character of the watershed. It is in the best interest of future generations to create a system of sustainable water resources that will provide for all the needs of the watershed.

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APPENDICES

APPENDIX A

Musquapsink Brook Watershed Restoration and Protection Plan Data Report

Musquapsink Brook Watershed Restoration and Protection Plan:

DATA REPORT

Developed by the Rutgers Cooperative Extension Water Resources Program

Funded by the New Jersey Department of Environmental Protection
RP 07–002

August 2011

Acknowledgements

This document has been produced by the Rutgers Cooperative Extension (RCE) Water Resources Program (more information at www.water.rutgers.edu). Data collection was carried out by staff from the RCE Water Resources Program and project partners including the Bergen County Health Department, the Bergen County Utilities Authority, and Marion McClary, Jr., Ph.D. of Fairleigh Dickinson University.

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Watershed Overview

The Musquapsink Brook Watershed, located above U.S. Geological Survey (USGS) streamflow gauge #01377499 at River Vale, is approximately nine square miles in size and is dominated by urban land uses (Figure 1). The New Jersey Department of Environmental Protection (NJDEP) 2002 land use data identifies the urban land uses as primarily consisting of residential (medium and low density), commercial, and roadways (Figure 2). The remainder of the land use consists of forest, wetlands, water bodies, agriculture, and barren land (NJDEP, 2007).

The Musquapsink Brook Watershed encompasses part of Woodcliff Lake Borough, Saddle River Borough, Hillsdale Borough, Washington Township, Westwood Borough, Emerson Borough, Paramus Borough, and Oradell Borough (Figure 3). The Musquapsink Brook is approximately 6.6 river miles from the headwaters to its confluence with the Pascack Brook. The largest surface water body in the drainage area is Schlegel Lake, which encompasses 26.5 acres.

Under certain conditions, United Water of New Jersey (UWNJ) diverts water from the Saddle River to the Oradell Reservoir through the Musquapsink Brook. UWNJ records show that during the period between June 1, 2007 and December 31, 2007 a total of 551 million gallons of river water was transferred.

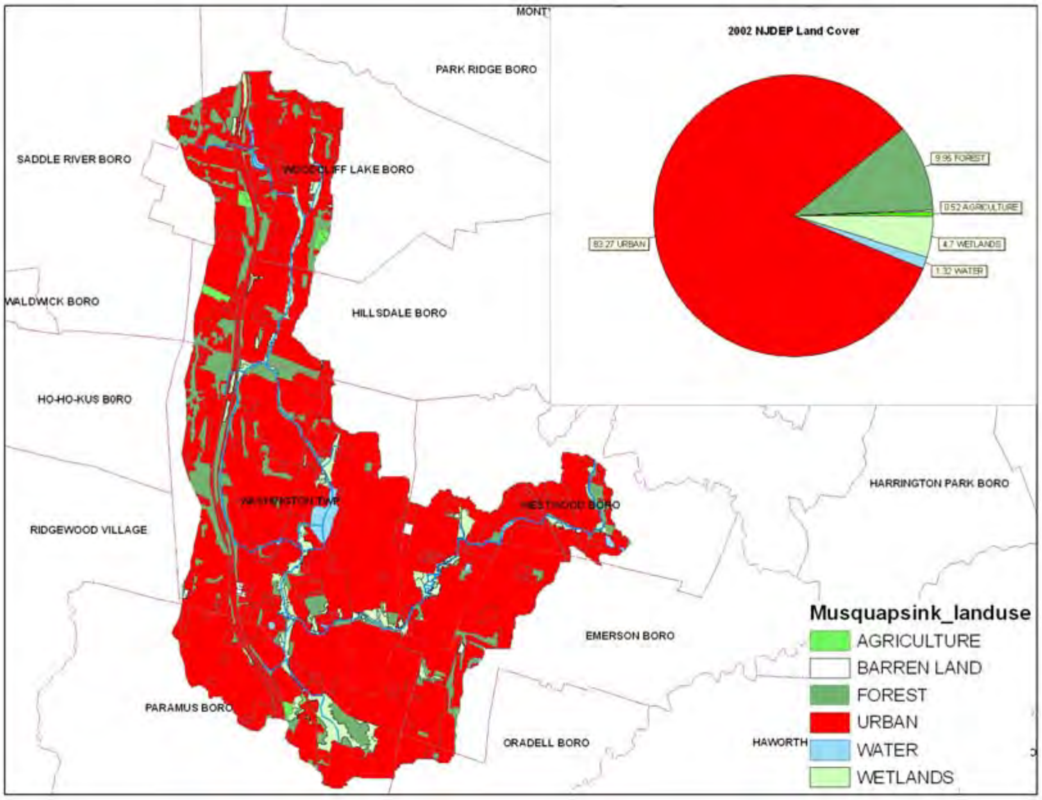


Figure 1: Land use/ land cover map

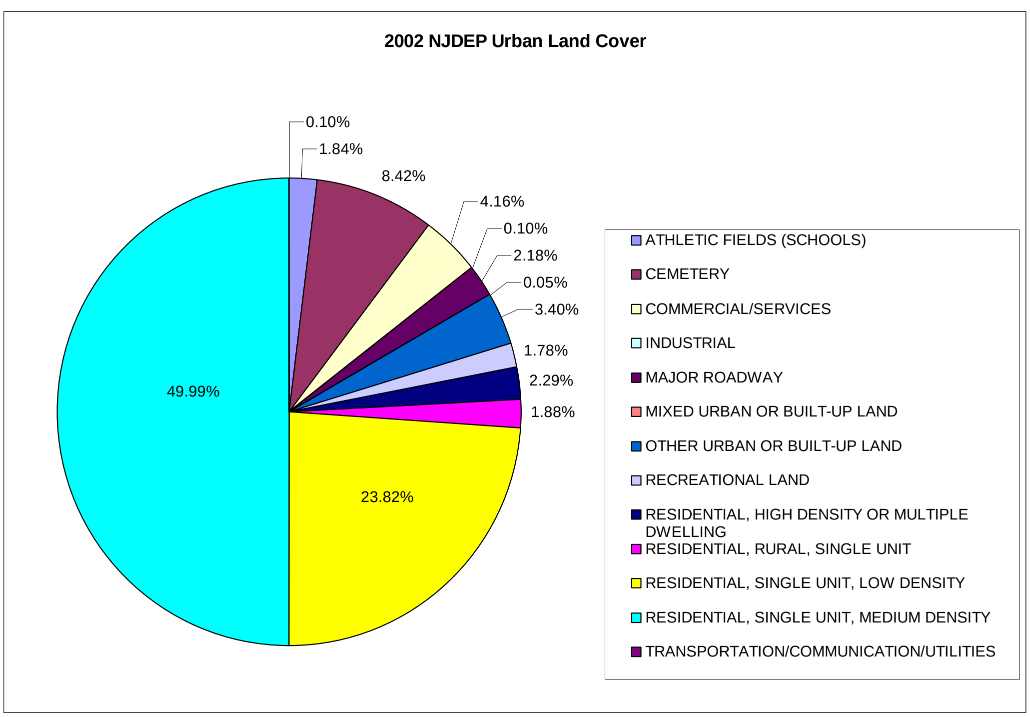


Figure 2: Land use/ land cover types and relative distribution

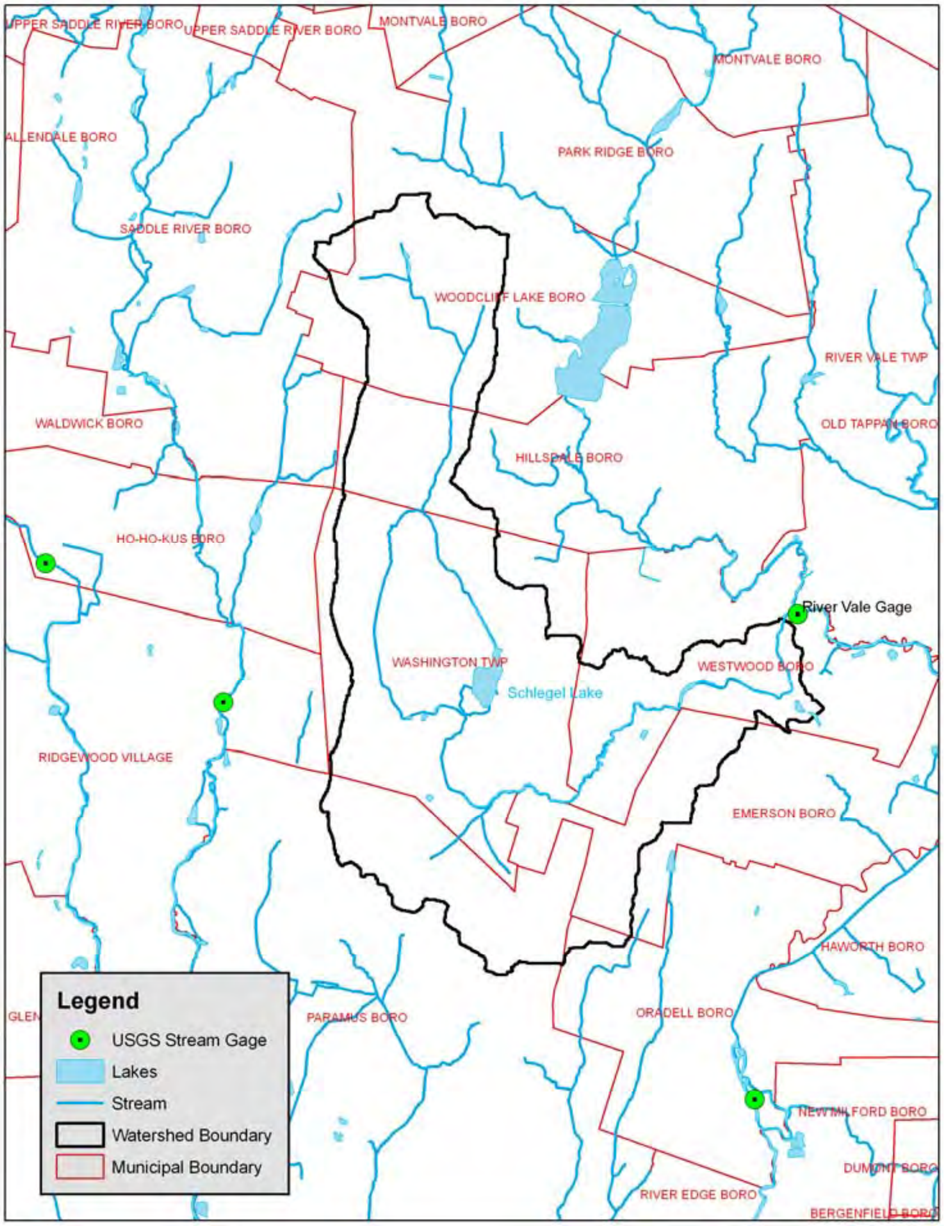


Figure 3: Municipalities and waterbodies located within the Musquapsink Brook Watershed

Project Background and the TMDL Development Process

The development of the Musquapsink Brook Watershed Restoration and Protection Plan was funded in 2007 by the NJDEP (RP 07-002). The project has been established to address a fecal coliform impairment that has been identified in the total maximum daily load (TMDL) developed based on data collected in the Musquapsink Brook at the US Geological Survey (USGS) monitoring station at River Vale (USGS 01377499).

TMDLs are developed by the NJDEP, and approval is given by the US Environmental Protection Agency (USEPA). In accordance with Section 305(b) of the Clean Water Act, New Jersey addresses the overall water quality of the State's waters and identifies impaired waterbodies through the development of a document referred to as the *Integrated List of Waterbodies* (NJDEP, 2006). Within this document are lists that indicate the presence and level of impairment for each waterbody monitored. The lists are defined as follows:

- **Sublist 1** suggests that the waterbody is meeting water quality standards.
- **Sublist 2** states that a waterbody is attaining some of the designated uses, and no use is threatened. Furthermore, Sublist 2 suggests that data are insufficient to declare if other uses are being met.
- **Sublist 3** maintains a list of waterbodies where no data or information are available to support an attainment determination.

- **Sublist 4** lists waterbodies where use attainment is threatened and/or a waterbody is impaired; however, a TMDL will not be required to restore the waterbody to meet its use designation.
    - **Sublist 4a** includes waterbodies that have a TMDL developed and approved by the USEPA, that when implemented, will result in the waterbody reaching its designated use.
    - **Sublist 4b** establishes that the impaired reach will require pollutant control measurements taken by local, state, or federal authorities that will result in full attainment of designated use.
    - **Sublist 4c** states that the impairment is not caused by a pollutant, but is due to factors such as instream channel condition and so forth. It is recommended by the USEPA that this list be a guideline for water quality management actions that will address the cause of impairment.
- **Sublist 5** clearly states that the water quality standard is not being attained and requires a TMDL.

Biological monitoring data is available for one location at the outlet of the Musquapsink Brook as part of the **Am**bient Biological Monitoring **Net**work (AMNET), which is administered by the NJDEP. Based upon AMNET and other monitoring sources, water quality impairments have been identified in the Musquapsink Brook. According to the *New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report,* the Musquapsink Brook has been cited with the following listings:

- Sublist 3 - No data or information are available to support attainment determination: cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc;

- Sublist 4 - Attainment is threatened or waterbody is impaired; a TMDL has been developed and/or approved or pollution control measures do not require a TMDL: fecal coliform;
- Sublist 5 - Water quality standard is not being attained and requires a TMDL: aquatic life, total phosphorus, and arsenic. **Arsenic will be addressed by the NJDEP and will not be a focus of this project.**

Based on the TMDL prepared for the Musquapsink Brook at River Vale, USGS 01377499, a 96% reduction in fecal coliform load for 6.6 miles of stream is needed (NJDEP, 2003). Additional aquatic life and total phosphorus surface water quality impairments will also need to be addressed through the TMDL process.

Biological Monitoring Data

Biological monitoring data is available for the Musquapsink Brook Watershed as part of the AMNET program administered by NJDEP. The NJDEP has been monitoring the biological communities of the State's waterways since the early 1970's, specifically the benthic macroinvertebrate communities. Benthic macroinvertebrates are primarily bottom-dwelling (benthic) organisms that are generally ubiquitous in freshwater and are macroscopic. Due to their important role in the food web, macroinvertebrate communities reflect current perturbations in the environment. There are several advantages to using macroinvertebrates to gauge the health of a stream. Macroinvertebrates have limited mobility, and thus, are good indicators of site-specific water conditions. Macroinvertebrates are sensitive to pollution, both point and nonpoint sources; they can be impacted by short-term environmental impacts such as intermittent discharges and contaminated spills. In addition to indicating chemical impacts to stream quality, macroinvertebrates can gauge non-chemical issues of a stream such as turbidity and siltation, eutrophication, and thermal stresses. Macroinvertebrate communities are a holistic overall indicator of water quality health, which is consistent with the goals of the

Clean Water Act (NJDEP, 2007a). Finally, these organisms are normally abundant in New Jersey freshwaters and are relatively inexpensive to sample.

New Jersey Impairment Score (NJIS)

The AMNET program began in 1992 and is currently comprised of more than 800 stream sites with approximately 200 monitoring locations in each of the five major drainage basins of New Jersey (i.e., Upper and Lower Delaware, Northeast, Raritan, and Atlantic). These sites are sampled once every five years using a modified version of the USEPA Rapid Bioassessment Protocol (RBP) II (NJDEP, 2007a). To evaluate the biological condition of the sampling locations, several community measures have been calculated by the NJDEP from the data collected and include the following:

1. Taxa Richness: Taxa richness is a measure of the total number of benthic macroinvertebrate families identified. A reduction in taxa richness typically indicates the presence of organic enrichment, toxics, sedimentation, or other factors.

2. EPT (Ephemeroptera, Plecoptera, Trichoptera) Index: The EPT Index is a measure of the total number of Ephemeroptera, Plecoptera, and Trichoptera families (i.e., mayflies, stoneflies, and caddisflies) in a sample. These organisms typically require clear moving water habitats.

3. % EPT: Percent EPT measures the numeric abundance of the mayflies, stoneflies, and caddisflies within a sample. A high percentage of EPT taxa is associated with good water quality.

4. % CDF (percent contribution of the dominant family): Percent CDF measures the relative balance within the benthic macroinvertebrate community. A healthy community is characterized by a diverse number of taxa that have abundances somewhat proportional to each other.

5. Family Biotic Index: The Family Biotic Index measures the relative tolerances of benthic macroinvertebrates to organic enrichment based on tolerance scores assigned to families ranging from 0 (intolerant) to 10 (tolerant).

This analysis integrates several community parameters into one easily comprehended evaluation of biological integrity referred to as the New Jersey

Impairment Score (NJIS). The NJIS was established for three categories of water quality bioassessment for New Jersey streams: non-impaired, moderately impaired, and severely impaired. A non-impaired site has a benthic community comparable to other high quality "reference" streams within the region. The community is characterized by maximum taxa richness, balanced taxa groups, and a good representation of intolerant individuals. A moderately impaired site is characterized by reduced macroinvertebrate taxa richness, in particular the EPT taxa. Changes in taxa composition result in reduced community balance and intolerant taxa become absent. A severely impaired site is one in which the benthic community is significantly different from that of the reference streams. The macroinvertebrates are dominated by a few taxa which are often very abundant. Tolerant taxa are typically the only taxa present. The scoring criteria used by the NJDEP are as follows:

- non-impaired sites have total scores ranging from 24 to 30,
- moderately impaired sites have total scores ranging from 9 to 21, and
- severely impaired sites have total scores ranging from 0 to 6.

It is important to note that the entire scoring system is based on comparisons with reference streams and a historical database consisting of 200 benthic macroinvertebrate samples collected from New Jersey streams. While a low score indicates "impairment," the score may actually be a consequence of habitat or other natural differences between the subject stream and the reference stream.

Starting with the second round of sampling under the AMNET program in 1998 for the Northeast Basin, habitat assessments were conducted in conjunction with the biological assessments. The first round of sampling under the AMNET program did not include habitat assessments. The habitat assessment, which was designed to provide a measure of habitat quality, involves a visually based technique for assessing stream habitat structure. The habitat assessment is designed to provide an estimate of habitat quality based upon qualitative estimates of selected habitat attributes. The assessment involves the numerical scoring of ten habitat parameters to evaluate instream substrate, channel morphology, bank structural features, and riparian vegetation. Each parameter is scored and summed to produce a total score which is assigned a habitat quality category of optimal, sub-optimal, marginal, or poor. Sites with optimal/excellent habitat conditions have total scores ranging from 160 to 200; sites with suboptimal/good habitat conditions have total scores ranging from 110 to 159; sites with marginal/fair habitat conditions have total scores ranging from 60 to 109, and sites with poor habitat conditions have total scores less than 60. The findings from the habitat assessment are used to interpret survey results and identify obvious constraints on the attainable biological potential within the study area.

The NJDEP Bureau of Freshwater & Biological Monitoring maintains one AMNET station within the project area (i.e., Station AN0206 – Musquapsink Brook, Harrington Avenue, Westwood Borough, Bergen County). This station corresponds with the water quality monitoring station MB6. Station AN0206 was sampled by NJDEP in 1993, 1998, and 2003 under the AMNET program. Findings from the AMNET program are summarized in Table 1. The biological condition over the years has been assessed as being moderately impaired, and the habitat has ranged from marginal to sub-optimal within the Musquapsink Brook Watershed.

Table 1: Summary of NJDEP Ambient Biological Monitoring Network results (NJDEP, 1994; NJDEP, 2000; NJDEP, 2008)

Station	Date	Biological Condition (Score)	Habitat Assessment (Score)
AN0206	7/6/1993	Moderately Impaired (9)	~
AN0206	7/9/1998	Moderately Impaired (15)	Marginal (104)
AN0206	7/1/2003	Moderately Impaired (15)	Suboptimal (147)

The 2007 Biological Assessment by Marion McClary, Jr., Ph.D.

Given these aquatic life impairments, an additional biological assessment was proposed as part of the data collection needed to prepare a comprehensive watershed restoration and protection plan for the Musquapsink Brook. A biological assessment was conducted by Marion McClary, Jr., Ph.D., Associate Director of Biological Sciences at Fairleigh Dickinson University and project partner, in the late summer of 2007 at MB1 (Musquapsink Brook at Hillside Avenue, Hillsdale), MB3 (Musquapsink Brook at Ridgewood Avenue, Washington), MB4 (Musquapsink Brook at Forest Avenue, Westwood), and at MB6 (AMNET Station AN0206, Musquapsink Brook at Harrington Avenue, Westwood). The 2007 biological assessment conducted Dr. McClary is summarized in the Musquapsink Brook Benthic Data Report and Musquapsink Brook Benthic Species List provided in Appendix A of the Musquapsink Brook Watershed Restoration Plan Data Report. The 2007 assessment revealed that the biological condition within the Musquapsink Brook Watershed had degraded to a severely impaired condition. Marginal to sub-optimal habitat conditions were found within the watershed.

There was such a paucity of benthic organisms found that less than 100 specimens were collected from the four sampling locations combined, prohibiting the calculation of the various metrics needed for the NJIS score.

Stream Visual Assessment Protocol (SVAP) Data Collected in the Musquapsink Brook Watershed

Introduction to SVAP

Among the hierarchy of tools used to characterize watershed health, the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Stream Visual Assessment Protocol (SVAP) is one method that fills this need. SVAP was originally developed for use by the landowner (USDA, 1998), but it has proved to also be useful by those familiar with the river system and flooding occurrences. The protocol provides an outline on how to quantitatively score in-stream and riparian qualities that includes water appearance, channel condition, and riparian health. There are 10 primary SVAP elements:

- channel condition,
- hydrologic alternation,
- riparian zone,
- bank stability,
- water appearance,
- nutrient enrichment,
- barriers to fish movement,
- instream fish cover,
- presence of pools, and
- invertebrate habitat

In addition, there are elements that should only be scored if applicable. These are canopy cover, manure presence, salinity, riffle embeddedness, and observed macroinvertebrates. Elements are scored 1 to 10 (poor to excellent) with the exception of observed macroinvertebrates, which uses a scale ranging from 1 to 15. The range of scores is qualitatively described as follows:

- < 6.0 is Poor;
- 6.1-7.4 is Fair;
- 7.5-8.9 is Good;
- 9.0 is Excellent.

The SVAP data sheet was modified to include other reach features that could aid pollution source trackdown in the Musquapsink Brook Watershed. These reach features include the identification of pipes and ditches, details as to erosion or impairment caused by the pipes or ditches, and access to stream reach for restoration. Additionally, all assessed reaches were photo-documented, and a sketch was made denoting important reach characteristics.

SVAP in the Musquapsink Brook Watershed

The visual assessment process in the Musquapsink Brook Watershed began in April 2007. In March 2006, all project partners were trained in using SVAP at the RCE Water Resources Program's SVAP Workshop. The training workshop consisted of a full day of SVAP introduction and use, and the workshop included presentations in a classroom setting and group and paired exercises in the field. Additional training included instructions on how to use the RCE online database entry system for the SVAP data. The Bergen County Department of GIS (geographic information systems) also developed an application to fill out SVAP data on a hand held ArcPad unit, which was used for this project. The Musquapsink Brook watershed was then divided into a grid; grids were assigned to the participating project partners.

Considerations were agreed upon at the onset of the assessment effort. Macroinvertebrates observed were not scored through this SVAP process, since macroinvertebrate data would be collected as part of the NJDEP-approved sampling plan for this project. Also, the manure presence element was expanded to include signs of waterfowl, pet, and wildlife waste. This category is only scored when the presence of manure or animal waste is visible within the reach, which includes the floodplain for that particular reach. As per the SVAP protocol and the agreed upon revisions, the following rules apply:

- A score of “1” indicates that extensive amount of manure is on the banks or in the stream, or, untreated human waste discharge pipes are present.
- A score of “3” indicates occasional manure in the stream, or there is a waste storage structure located on the floodplain.
- A score of “5” indicates evidence of waterfowl, wildlife, or domestic pet access to riparian zone.

Only one reach was scored for manure presence out of the 38 reaches assessed; this location is shown in Figure and had a manure presence score of 3 indicating occasional manure in the stream, or there is a waste storage structure located on the floodplain.

Figure 4: Manure presence at 3rd Street in the Musquapsink Brook Watershed

SVAP Data

Thirty eight stream reaches were evaluated in the Musquapsink Brook Watershed; the stream reaches and the average SVAP scores are identified in Figure . The average overall SVAP score was 6.7, a "fair" score (Table 2). Canopy cover was the highest scoring element (average of 8.4), and instream fish cover was the lowest scoring element (average of 5.2). No assessed stream reach received a score of "excellent," five reaches were rated as "good" and eighteen were rated as "fair" (Table 2). The remaining fifteen reaches were rated as "poor." The reaches that were rated as poor were located along the entire length of the Musquapsink Brook (Figure 5). Tabulated SVAP data are provided in Appendix B.

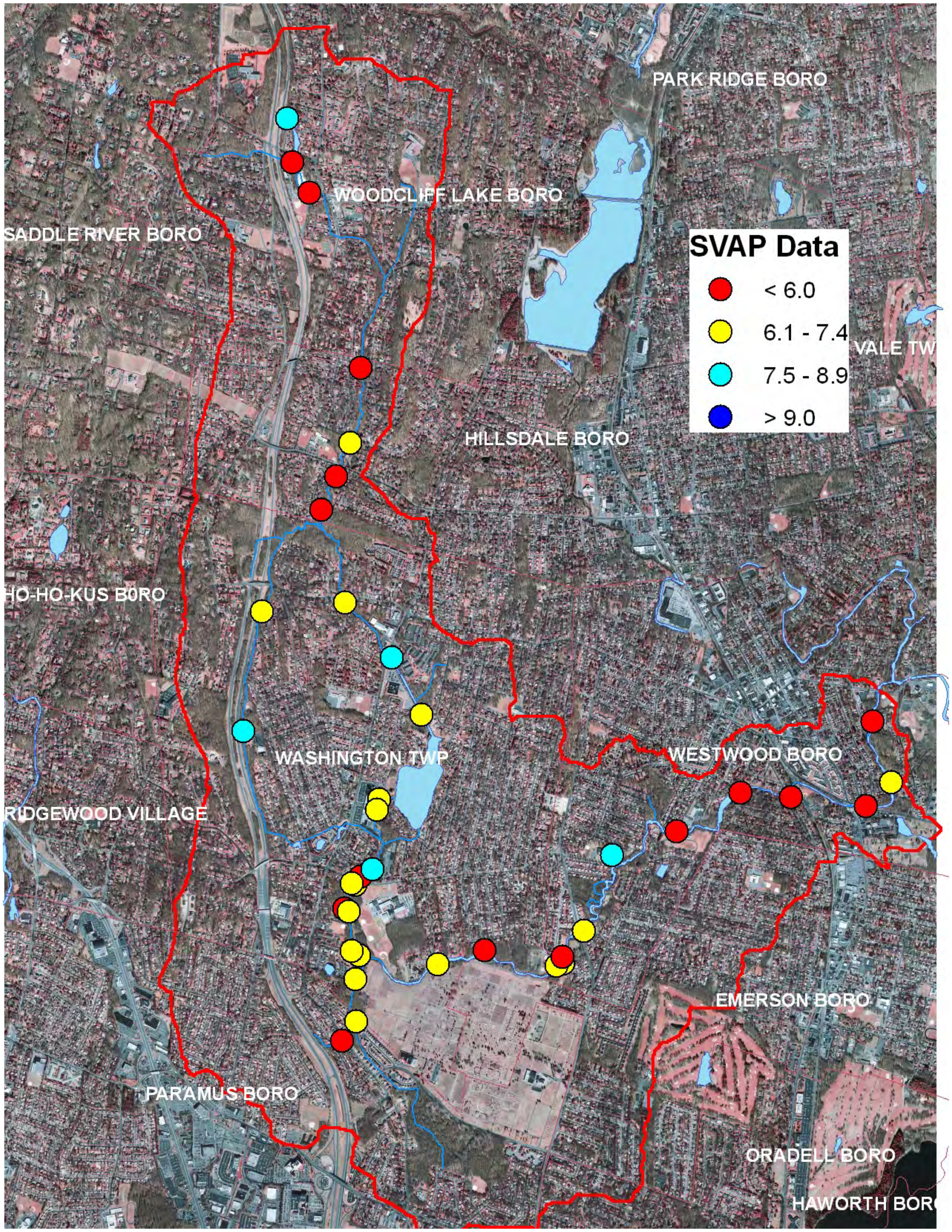


Figure 5: Stream visual assessment reaches with scores in the Musquapsink Brook Watershed

Table 2: SVAP assessment elements and data

	Channel Condition	Hydrologic Alteration	Riparian Zone left bank	Riparian Zone right bank	Bank Stability left bank	Bank Stability right bank	Water Appearance	Nutrient Enrichment	Barriers to Fish Movement
# of scores	38	20	38	38	38	38	38	38	38
minimum value	1	1	1	1	1	1	3	3	0
maximum value	10	10	10	10	10	10	10	10	10
average	6.4	6.7	7.3	6.3	5.8	5.8	7.6	7.4	5.5

	Instream Fish Cover	Pools	Invertebrate Habitat	Canopy Cover	Manure Presence	Riffle Embeddedness	Water Appearance & Nutrient Enrichment Averages	Tiered Assessment Averages*
# of scores	38	38	38	38	NA	20	38	36
minimum value	0	1	3	1	NA	0	3	1.5
maximum value	8	8	10	10	NA	10	10	10
average	5.2	6.3	7.9	8.4	NA	6.0	7.5	6.7

	Overall Average - left bank	*Overall Average - right bank*	*Overall Site Average*
# of scores	***35***	***35***	***35***
minimum value	***1.3***	***1.3***	***1.3***
maximum value	***9.7***	***9.7***	***9.7***
average	***6.7***	***6.6***	***6.7***

** "Tiered Assessment Averages" refers collectively to Hydrologic Alteration, Channel Condition, Riparian Zones left and right, Bank Stability left and right, Water Appearance, and Nutrient Enrichment.*

Using the SVAP Data

SVAP scores will be evaluated as individual assessment elements and combined with other data collected as part of this restoration planning effort. The SVAP results will be compared to land use, soil characteristics, slope and stream gradient, and water quality monitoring results to determine the quality of waters within the Musquapsink Brook Watershed. The SVAP scores, information on pipes, ditches, photos, and remediation notes will be used to identify sources of pollution and potential opportunities for improved management.

Water Quality Sampling Overview

Project partners, including NJDEP, the RCE Water Resources Program, and the Bergen County Department of Health Services, began water quality monitoring on May 25, 2007. As per the approved Quality Assurance Project Plan (QAPP) provided in Appendix C, *in situ* measurements of pH, dissolved oxygen (DO), and temperature were collected. Stream velocity and depth were measured across the transect of the stream at each sampling station. Using this information, flow rate was calculated for each event where access to the stream was deemed safe. Water samples were collected and analyzed by two separate laboratories. The Bergen County Utility Authority conducted analyses for total phosphorus (TP), dissolved orthophosphate phosphorus (PO_4^{3-}), ammonia-nitrogen (NH_3-N), total kjeldahl nitrogen (TKN), nitrate-nitrogen (NO_3-N), nitrite-nitrogen (NO_2-N), total suspended solids (TSS), and fecal coliform. Garden State Laboratories analyzed samples for *Escherichia coli* (*E. coli*).

Water quality monitoring included two different types of sampling events, regular and bacteria only. Regular monitoring, which included analysis for all parameters, occurred from May 25, 2007 through October 25, 2007. These events were monitored for total phosphorus, dissolved orthophosphate phosphorus, ammonia-nitrogen, TKN, nitrate-nitrogen, nitrite-nitrogen, total suspended solids, fecal coliform, and *E. coli* and had no specific weather conditions directing the sample collection. Bacteria-only monitoring was conducted in the summer months of June, July, and August 2007, again without conditions set by the weather. The bacteria-only sampling entailed collecting three additional samples in each of those months. Flow was measured, and *in situ* measurements were taken during these events. The dates and the types of monitoring events are summarized in Table 3.

Three storm events were supposed to be collected as part of this project. Due to the weather patterns and timing of storms during the six months of monitoring, only one storm event was encountered that would meet the requirements of the approved QAPP. Surface water samples collected during this storm were taken twice on October 10, 2007 and one the following morning on October 11, 2007. In addition to the one storm sampling event, several sampling events were representative of 'wet' conditions in the watershed.

To more accurately determine which monitoring events were collected under wet conditions when the stream velocities exceeded baseflow conditions, the HYSEP procedure was used. HYSEP is a data analysis program developed by the USGS to separate river flow into baseflow and storm-flow (Sloto and Crouse, 1996). Normally, this model would be applied to a daily discharge monitoring station within the watershed;

Table 3: Water quality monitoring events

Date	Weather	Regular Monitoring for all Parameters	Bacteria Only Monitoring
5/24/2007	Dry	X	
5/31/2007	Wet	X	
6/7/2007	Dry	X	
6/14/2007	Dry		X
6/19/2007	Dry		X
6/21/2007	Dry	X	
6/28/2007	Wet		X
7/5/2007	Wet	X	
7/12/2007	Wet		X
7/24/2007	Wet		X
7/26/2007	Dry		X
8/2/2007	Dry	X	
8/9/2007	Wet		X
8/16/2007	Wet	X	
8/23/2007	Wet		X
8/30/2007	Wet		X
9/13/2007	Wet		X
9/27/2007	Dry		X
10/10/2007	Storm	X	
10/11/2007	Storm	X	
10/25/2007	Wet	X	

however daily discharge is not recorded by the USGS in the Musquapsink Brook Watershed. Instead, USGS monitoring station 01377500, Pascack Brook at Westwood, which is just downstream of the confluence of the Musquapsink Brook and the Pascack Brook, was chosen. Although it would be preferable to use a flow gauge in the target watershed, the watershed does drain to the Pascack Brook, and the remainder of the drainage area is adjacent to the Musquapsink Brook watershed. The analysis was completed for the Pascack Brook over the length of the field sampling program. A 10% error bar was also applied to the baseflow since these data are collected in a watershed other than the Musquapsink Brook. When flow was more than 10% greater than baseflow and rain occurred on the day of or the day preceding sampling, the event was considered as storm-related flow and assigned the term “wet” in Table 3.

Surface water samples from eight water quality monitoring stations were regularly collected over the six-month sampling time frame. These stations are depicted in Figure 6. Six stations were located on the Musquapsink Brook, and two were located adjacent to the UWNJ transfer intake located at the confluence of the Saddle River and the Ho Ho Kus Brook. The stations are identified in Table 4 .

A record of the water transfers to the Musquapsink Brook was obtained from UWNJ. It shows that transfers were made on 188 days out of the 214 day interval between June 1, 2007 and December 31, 2007. The total volume of water transferred was 551 million gallons. Figure 7 shows the water transfer record.

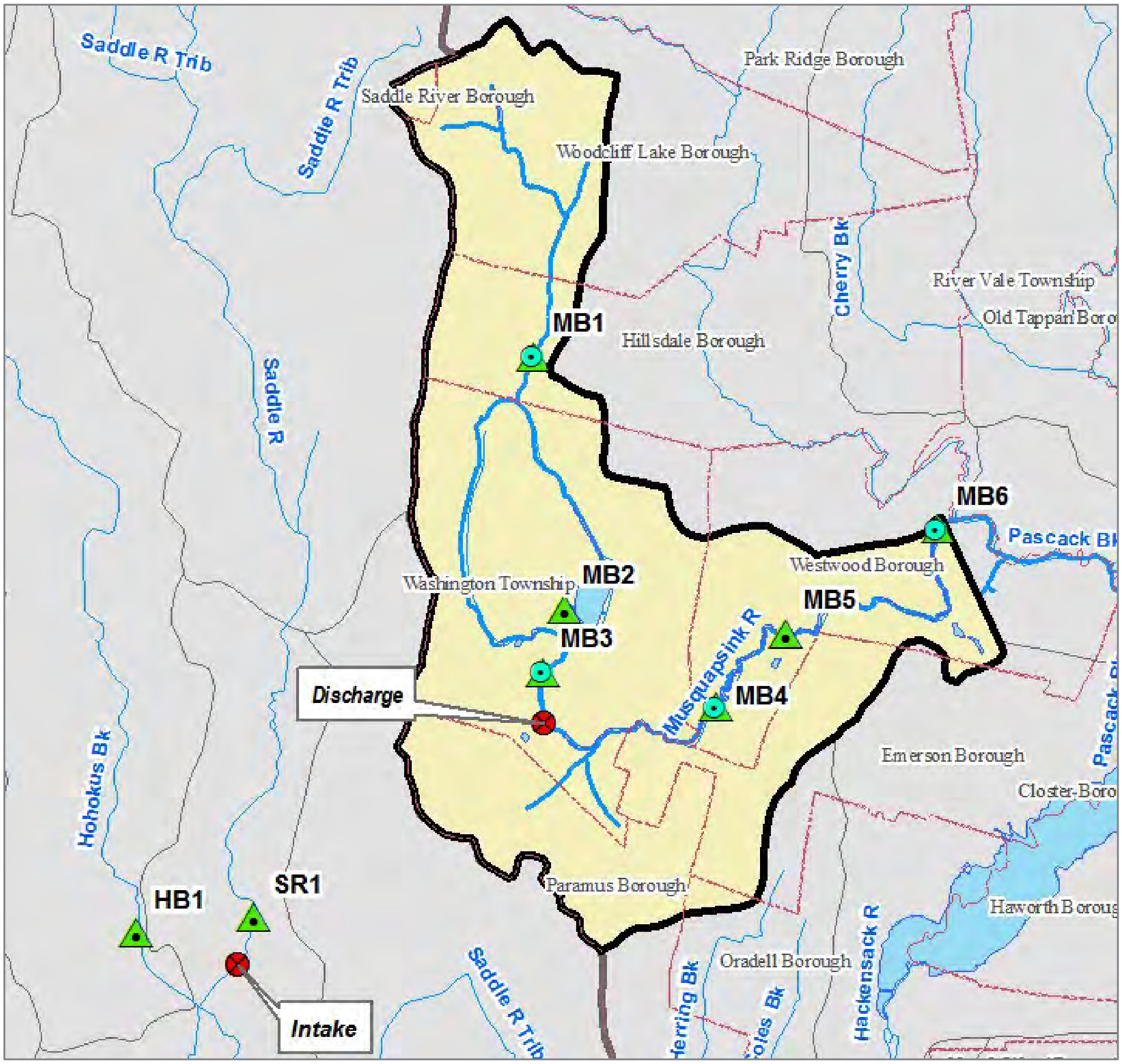


Figure 6: Water quality sampling location map

Table 4: Water quality monitoring location IDs and descriptions

Site ID	Site Description
MB1	Musquapsink Brook at Hillside Ave, Hillsdale
MB2	Musquapsink Brook at Woodfield Ave, Washington
MB3	Musquapsink Brook at Ridgewood Ave, Washington
MB4	Musquapsink Brook at Forest Ave, Westwood
MB5	Musquapsink Brook at Third Ave, Westwood
MB6	Musquapsink Brook at Harrington Ave, Westwood
SR1	Saddle River at Grove St, border of Paramus and Ridgewood
HB1	Ho Ho Kus Brook at Grove St, border of Paramus and Ridgewood

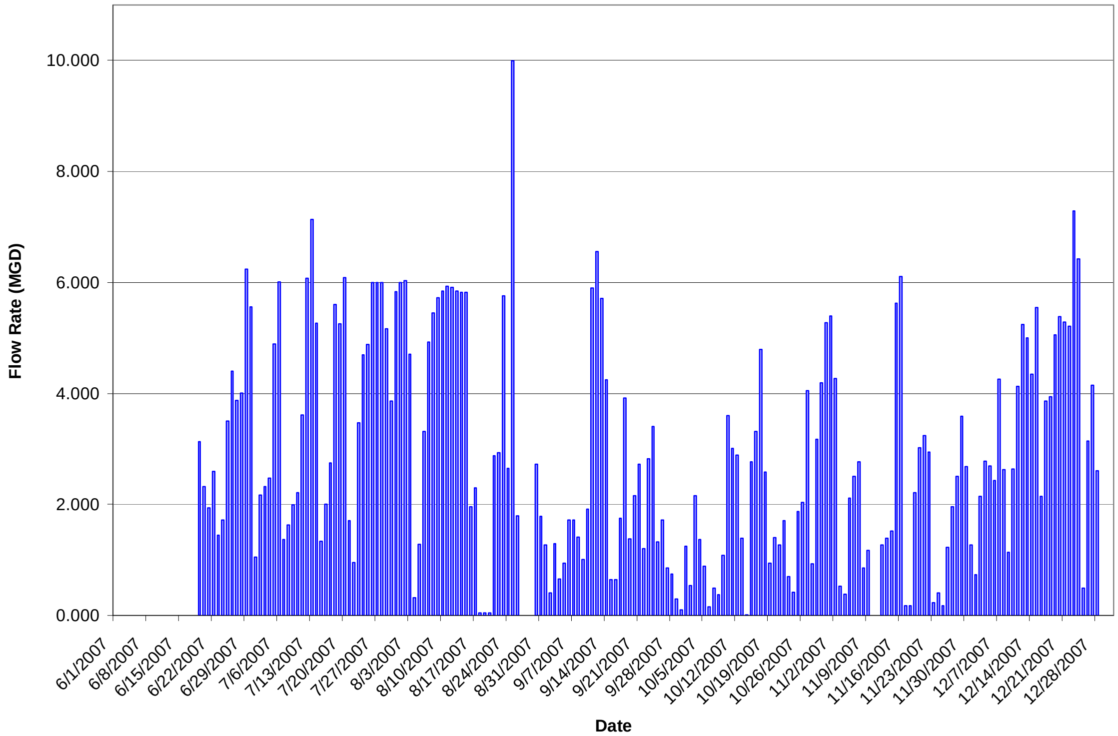


Figure 7: UWNJ transfer record

Data Results and Comparison to Water Quality Criteria

To evaluate the health of the Musquapsink Brook at all the stations, the monitoring results were compared to the designated water quality criteria. Water quality criteria are developed according to the designated uses of the waterbody. The Musquapsink Brook is classified as FW2-NT, or freshwater (FW) non trout (NT). "FW2" refers to waterbodies that are used for primary and secondary contact recreation; industrial and agricultural water supply; maintenance, migration, and propagation of natural and established biota; public potable water supply after conventional filtration treatment and disinfection; and any other reasonable uses. "NT" means those freshwaters that have not been designated as trout production or trout maintenance. NT waters are not suitable for trout due to physical, chemical, or biological characteristics, but NT waters can support other fish species (NJDEP, 2006a). Furthermore, the Musquapsink Brook is a Category One antidegradation waterbody due to its discharge to the Oradell Reservoir, which is a potable water supply.

The USEPA Guidance for the Preparation of the Comprehensive State Water Quality Assessments (USEPA, 1997) advises that an acceptable frequency for water quality results to exceed criteria is 10% of samples. NJDEP has further stated that a minimum of eight samples collected quarterly over a two-year period are required to confirm quality of waters. Therefore, if a waterbody has a minimum of eight samples collected quarterly over a two-year period with more than 10% of the samples exceeding the water quality criteria for a certain parameter, the waterbody is considered "impaired" for that parameter. By applying this rule to the water quality data, it is possible to identify which stations are impaired for each parameter that has been identified as a concern to the project – total phosphorus, fecal coliform, and *E. coli*. The applicable water quality criteria for this project are detailed in Table 5, and the percent of samples that exceeded these standards are given in Table 6. At the time of this project's initiation, fecal coliform was the accepted measure indicating pathogen pollution for New Jersey freshwaters. Since then, the fecal coliform criterion has been replaced by an *E. coli* criterion. Since the TMDL refers to fecal coliform, both fecal and *E. coli* were measured.

Tabulated water quality monitoring results are provided in Appendix D. Water quality monitoring data have also been graphed with surface water quality criterion; these graphs are available in Appendix E.

Table 5: Water quality criteria according to N.J.A.C. 7:9B (NJDEP, 2006a)

Substance	Surface Water Classification	Criteria
TP (mg/L)	FW2 Streams	Except as necessary to satisfy the more stringent criteria in accordance with "Lakes" (above) or where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3, phosphorus as total P shall not exceed 0.1 in any stream, unless it can be demonstrated that total P is not a limiting nutrient and will not otherwise render the waters unsuitable for the designated uses.
	FW2 Lakes	Phosphorus as total P shall not exceed 0.05 in any lake, pond, or reservoir, or in a tributary at the point where it enters such bodies of water, except where watershed or site-specific criteria are developed pursuant to N.J.A.C. 7:9B-1.5(g)3.
Fecal Coliform (Col/100 mL)	FW2	Shall not exceed geometric average of 200/100 mL, nor should more than 10% of the total samples taken during any 30-day period exceed 400/100 mL.
E. coli (Col/100 mL)	FW2	Shall not exceed a geometric mean of 126/100 mL or a single sample maximum of 235/100 mL.

Table 6: Summary of water quality data collected and comparison to water quality criteria

Monitoring Station ID	**TP (mg/L)**					
	criterion	*count*	*minimum*	*maximum*	*average*	*% not satisfying criterion*
MB1	0.1	6	0.05	0.14	0.08	44
MB2	0.1	7	0.05	0.11	0.07	10
MB3	0.1	7	0.03	0.09	0.06	0
MB4	0.1	7	0.03	0.35	0.11	50
MB5	0.1	6	0.06	0.35	0.17	60
MB6	0.1	7	0.04	0.19	0.10	50
SR1	0.1	7	0.01	0.11	0.05	30
HB1	0.1	7	0.91	2.20	1.77	90
Fecal Coliform (col/100mL)						
MB1	200	23	200	28,000	3,479	*96*
MB2	200	23	60	12,000	1,481	*87*
MB3	200	23	120	44,000	3,706	*91*
MB4	200	23	410	49,000	5,530	*100*
MB5	200	23	106	58,000	6,627	*100*
MB6	200	22	500	70,000	8,117	*100*
SR1	200	23	110	39,000	5,550	*87*
HB1	200	23	200	41,000	7,270	*91*
***E. coli* (col/100mL)**						
MB1	235	23	170	16,000	2,639	*91*
MB2	235	23	60	2,200	480	*65*
MB3	235	23	160	7,800	1,897	*96*
MB4	235	23	160	25,000	4,809	*96*
MB5	235	23	120	33,000	6,090	*96*
MB6	235	23	210	38,000	5,202	*96*
SR1	235	22	380	23,000	2,860	*100*
HB1	235	22	410	22,000	3,150	*100*

MST Data in the Musquapsink Brook Watershed

Microbial source tracking (MST) techniques have recently been developed that have the ability to identify the origin of fecal pollution. MST is the concept of applying microbiological, genotypic (molecular), phenotypic (biochemical), and chemical methods to identify the origin of fecal pollution (USEPA, 2005). MST techniques typically report fecal contamination source as a percentage of targeted bacteria. One of the most promising targets for MST is group *Bacteroides,* a genus of obligately anaerobic, gram-negative bacteria that are found in all mammals and birds. *Bacteroides* comprise up to 40% of the amount of bacteria in feces and 10% of the fecal mass. Due to the large quantity of *Bacteroides* in feces, they are an ideal target organism for identifying fecal contamination (Layton *et al.*, 2006). In addition, *Bacteroides* have been recognized as having broad geographic stability and distribution in target host animals and are a promising microbial species for differentiating fecal sources (USEPA, 2005; Dick *et al.*, 2005; Layton *et al.*, 2006).

Three sets of PCR primers (targets) were used to quantify *Bacteroides* from 1) all sources of *Bacteroides* ("AllBac"), 2) human sources ("HuBac"), and 3) bovine sources of *Bacteroides* ("BoBac"). This assay is based on published results from a study sponsored by the Tennessee Department of Environmental Conservation (Layton *et al*., 2006).

Methods

Samples were collected in sterile bottles at all six monitoring sites and held at 4˚C until processing. On one sampling occasion, additional samples were collected at stations HR1 and SR1. A 100 mL aliquot of each sample was filtered aseptically onto a membrane filter and DNA was extracted from total filtered biomass using a DNeasy® tissue kit (Qiagen). The protocol used is a modification of the procedure found in the DNeasy Tissue Handbook (Qiagen, 2004).

After extraction, all DNA samples were quantified by spectroscopy (Beckman DU 640) at 260 and 280 nm then diluted in sterile water to a concentration of 1 µg/mL.

This diluted DNA was used as the template for quantitative, real-time PCR reactions to measure the number of *Bacteroides* present.

The number of *Bacteroides* was measured using a TaqMan® based assay using Applied Biosystems reagents and standard conditions on an Applied Biosystems 7300 Real-Time PCR system. Three target sequences were measured. These targets indicate the total number of *Bacteroides* (AllBac) as well as the number of specifically human-sourced (HuBac) and bovine-sourced (BoBac) *Bacteroides*. The copy number of each target was calculated by comparison to a standard curve made with plasmids containing human- or bovine-sourced target 16S RNA genes amplified with the primers Bac 32f and Bac 708r (Bernhard and Field, 2000). Dilutions of plasmid DNA provided standard curves which were linear from 10 to 100,000 copies per µL. Figure presents individual standard curves plotting log copy number vs. threshold cycle (Ct) for AllBac (a), Hubac (b), and BoBac (c) primer sets. All primers and probes were taken from Layton *et al.* (2006) or Bernhard and Field (2000) (Table 7).

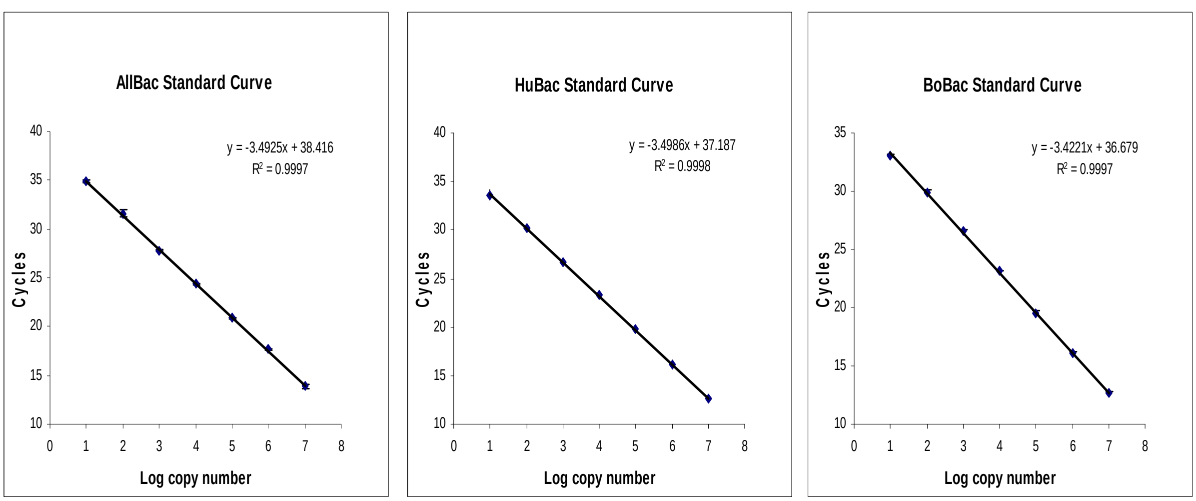


Figure 8: Standard curves for quantification of *Bacteroides*

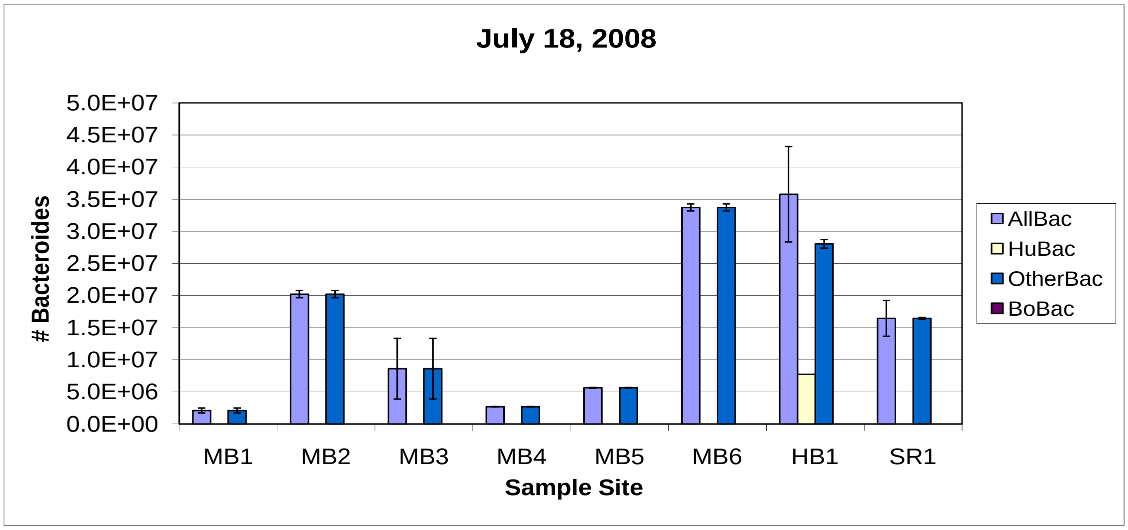
Table 7: Primers and probes used for the MST effort

PCR Primers	
HuBac 566f	5' GGG TTT AAA GGG AGC GTA GG 3'
HuBac 692r	5' CTA CAC CAC GAA TTC CGC CT 3'
BoBac 367f	5' GAA GRC TGA ACC AGC CAA GTA 3'
BoBac 467r	5' GCT TAT TCA TAC GGT ACA TAC AAG 3'
AllBac 296f	5' GAG AGG AAG GTC CCC CAC 3'
AllBac 412r	5' CGC TAC TTG GCT GGT TCA G 3'
Bac 32f	5' AAC GCT AGC TAC AGG CTT 3'
Bac 708r	5' CAA TCG GAG TTC TTC GTG 3'
TaqMan Probes	
BoBac402Tman	5' 6FAM TGA AGG ATG AAG GTT CTA TGG ATT GTA AAC TT TAMRA 3'
HuBac594Tman	5' 6FAM TAA GTC AGT TGT GAA AGT TTG CGG CTC TAMRA 3'
AllBac375Tman	5' VIC CCA TTG ACC AAT ATT CCT CAC TGC TGC CT TAMRA 3'

Results of qPCR and Source Detection

The Musquapsink Brook Watershed is an urban watershed with no cattle within its boundaries, and the MST confirmed this with no detections of bovine-related *Bacteroides* in any sample. Human-related *Bacteroides* were detected in MB2, MB4, MB5, MB6, and HB1 on at least one sampling occasion (Figure 9). Pollution sources could be determined by the frequency of detection of specific markers at particular sampling locations (

Table 8). These data show that certain stations (MB2, MB4, MB5, MB6, and HB1) have a higher incidence of contamination with human feces.



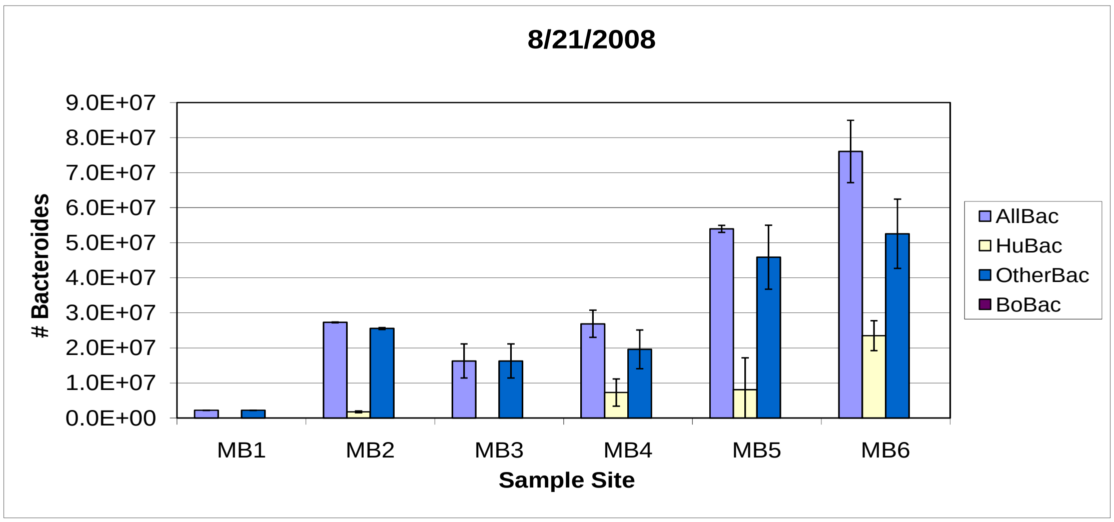


Figure 9: Sample data showing the numbers of *Bacteroides* detected by the three primer sets on two days of sampling

Table 8: Frequency of detection of AllBac, HuBac (human), or BoBac (bovine) target sequences

	% of Samples Containing Target Sequence							
	MB1	MB2	MB3	MB4	MB5	MB6	HB1	SR1
AllBac	100	100	100	100	100	100	100	100
HuBac	0	50	0	50	50	50	50	0

Data Summary

The data show a variety of water quality concerns in the Musquapsink Brook Watershed. The AMNET macroinvertebrate results show moderate impairments to the biological communities within the watershed (Table 1). The biological community may be impacted by environmental stressors or degraded habitat. Habitat quality may be low due to physical alterations as observed during SVAP assessments conducted throughout the watershed. Overall quality of the streams was assessed as "fair" but individual element scores ranged from "poor" to "good" (Table 2). Further analysis of this data may help to explain what physical factors (i.e., erosion, habitat structure, and water availability) may be responsible for the composition of the macroinvertebrate communities seen in the watershed.

While the biological monitoring and SVAP assessments shed light on watershed quality, surface water monitoring provides possible reasons for this quality. Results indicate that total phosphorus and fecal coliform concentrations, and pH levels are in violation of water quality criteria established by the NJDEP (Table 6). All eight (8) monitoring locations were in violation of both pH and total phosphorus water quality criteria in greater than 10% of the samples (Table 6). All eight (8) stations were also in violation of the fecal coliform water quality criterion (Table 6). Tracking of bacterial sources within the watershed indicate a higher human contribution to bacteria at stations MB2, MB4, MB5, MB6, and HB1 (Table 8).

Water quality data will be combined with land use data analyses to determine sources of pollutants. A full analysis of data will be conducted and presented in the Musquapsink Brook Watershed Restoration and Protection Plan.

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Appendix A: Musquapsink Brook Benthic Data Report & Species List, Marion McClary, Jr., Ph.D., Fairleigh Dickinson University

Musquapsink Brook Benthic Data Report

Prepared by:

Marion McClary, Jr., Ph.D.
Associate Professor of Biological Sciences
Associate Director of Biological Sciences
Fairleigh Dickinson University

for

Rutgers Cooperative Extension Water Resources Program
as part of
RP07-002 Musquapsink Brook Watershed
Restoration and Protection Plan

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Biological Monitoring Materials and Methods

Upon arrival at the sampling location, the end of a tape measure was placed and held below any road or bridge crossing that was present and stretched 100 meters upstream to minimize the effect of the road or bridge on stream velocity, depth, and overall habitat quality as per the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. At this location, 100 meters upstream of the road or bridge crossing, the tape measure was again placed and held and stretched 100 meters upstream to include a 100 meter reach that was representative of the characteristics of the stream (the study area). Other road or bridge crossings were avoided. If this was not possible, the tape measure was placed and held below this road or bridge crossing and the aforementioned procedure was repeated until road and bridge crossing could be avoided. There were no major tributaries discharging to the stream in the study area as suggested by the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. The tape measure was left in the study area for sampling.

Before sampling the physical/chemical field sheet (Chapter 5; Appendix A-1, Form 1 of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition) was completed to document the site description, weather conditions, and land use. After sampling this information was reviewed for accuracy and completeness.

The straight-away portions of the sampling reach were photographed with a digital camera starting downstream and ending upstream (with the exception of MB6 which was done in the reverse direction) to include in-stream attributes (e.g. riffles, falls, fallen trees, pools, bends, etc.) and important structures, plants, and attributes of the bank and near stream areas. If the sampling reach had curves, the "straight-away portions of each curve" were photographed. This means more photographs were taken of sampling reaches that had more curves because each "straight-away segment of the curve" received a photograph, and fewer photographs were taken of sampling reaches that had less curves.

Two sampling procedures were used. One procedure was used depending upon if the habitat was a single habitat or a multihabitat. Habitats that had a very slow current or were greater than 1 ft deep, and lacked riffles were considered to be multihabitats and a multihabitat approach was used for them. Habitats that were 1 ft deep or less and had riffles and runs were considered single habitats. The second procedure was used for all habitats whether they were single or multihabitats. For single habitats with riffles and runs, all riffle and run areas within the 100-m reach were candidates for sampling macroinvertebrates. A composite sample was taken from individual sampling spots in the riffle and runs representing different velocities.

Field Sampling Procedures for Single Habitat

Sampling began at the downstream end of the reach and proceeded upstream. Sampling was done in triplicate. The first replicate (A) was done along the bank on the right. The second replicate (B) was done along the bank on the left. The third replicate

(C) was done in the middle of the channel. For sampling, a surber sampler (0.3 m x 0.3 m with a mesh size of 500 μ) was placed horizontally on cobble substrate and 2 or 3 kicks (use of the toe or heel of the boot to dislodge the upper layer of cobble or gravel and to scrape the underlying bed) were done at various velocities in the riffle or series or riffles. Larger substrate particles were picked up and rubbed by hand to remove attached organisms. The net on the vertical section of the frame captured the dislodged organisms from the sampling area.

The kicks collected from three different locations in the cobble substrate were composited to obtain a single homogenous sample for each replicate. After each kick, the collected material was washed by running clean stream water through the net 2 to 3 times until the water was clear. Large debris was removed after rinsing and inspecting for organisms. Any organisms found were placed into a sample container.

The sample in the net was transferred to a sample container and enough 95 percent ethanol was added to cover the sample. Forceps were used to remove organisms from the net. A label indicating the date, stream name and sampling location was placed on the sample container. This information was recorded in the "Sample log" (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

The top portion of the "Benthic Macroinvertebrate Field Data Sheet" (Appendix A-3, Form 1) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

The percentage of each habitat type in the reach was recorded, and the sampling gear used and the conditions of the sampling, e.g. high flows, treacherous rocks, difficult access to the stream, or anything that would indicate adverse sampling conditions were noted.

Observations of aquatic flora and fauna were documented and qualitative estimates of macroinvertebrate composition and relative abundance as a cursory estimate of ecosystem health and to check adequacy of sampling were made.

Habitat assessment (Appendix A-1, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was performed after sampling was completed by walking the reach.

The samples were returned to the laboratory and the log-in form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

After sampling was completed at the site, all nets, pans, and etc. that came in contact with a sample was rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found were placed in the sample containers. The equipment was examined again prior to use at the next sampling site.

<u>Field Sampling Procedures for Multihabitat</u>

Different types of habitat were sampled in approximate proportion to their representation of surface area of the total macroinvertebrate habitat in the reach. For example, if snags comprised 50% of the habitat in a reach and riffles comprised 20%, then 10 kicks were done in snag material and 4 kicks were done in riffle areas. The remainder of the kicks (6) would be done in any remaining habitat type. Habitat types contributing less than 5% of the stable habitat in the stream were not sampled. In this case, the remaining kicks were allocated proportionately among the predominate substrates. The number of kicks done in each habitat was recorded on the field data sheet.

Sampling began at the downstream end of the reach and proceeded upstream. Sampling was done in triplicate. The first replicate (A) was done along the bank on the right. The second replicate (B) was done along the bank on the left. The third replicate (C) was done in the middle of the channel. A total of 20 kicks were done over the length of the reach. A kick was a stationary sampling accomplished by positioning a D-frame dip net (0.3 m width and 0.3 m height and shaped as a "D" with a mesh size of 500 μ) and disturbing the substrate for a distance of 0.5 m upstream of the net.

Kicks collected from the multiple habitats were composited to obtain a single homogenous sample for each replicate. After every 3 kicks or more if necessary, the collected material was washed by running clean stream water through the net two to three times. Large debris was removed after rinsing and inspecting for organisms. Any organisms found were placed into a sample container.

The sample in the net was transferred to a sample container and enough 95 percent ethanol was added to cover the sample. Forceps were used to remove organisms from the net. A label indicating the date, stream name and sampling location was placed on the sample container. This information was recorded in the "Sample log" (Appendix

A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

The top portion of the “Benthic Macroinvertebrate Field Data Sheet” (Appendix A-3, Form 1) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

The percentage of each habitat type in the reach was recorded, and the sampling gear used and the conditions of the sampling, e.g. high flows, treacherous rocks, difficult access to the stream, or anything that would indicate adverse sampling conditions were noted.

Observations of aquatic flora and fauna were documented and qualitative estimates of macroinvertebrate composition and relative abundance as a cursory estimate of ecosystem health and to check adequacy of sampling were made.

Habitat assessment (Appendix A-1, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was performed after sampling was completed by walking the reach.

The samples were returned to the laboratory and the log-in form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

After sampling was completed at the site, all nets, pans, and etc. that came in contact with a sample was rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found were placed in the sample containers. The equipment was examined again prior to use at the next sampling site.

Coarse Particulate Organic Matter (CPOM) Sampling Procedures

Sampling began at the downstream end of the reach and proceeded upstream. Sampling was done in triplicate. The first replicate (D) was done along the bank on the right. The second replicate (E) was done along the bank on the left. The third replicate (F) was done in the middle of the channel. Three grab type samples were collected for each replicate. These samples were sorted in the field, composited (i.e., the contents from the three grab samples from each site was combined into a single container) for each replicate, and preserved in 80% ethanol for later subsampling, identification and enumeration.

A composite collection of a variety of CPOM forms (e.g., leaves, needles, twigs, bark, or fragments of these) was collected for each replicate. The material was sampled in depositional areas, such as pools and along snags and undercut banks. The CPOM sample was processed using a U.S. Standard No. 30 sieve, and added to the composite of the replicate grab samples for each site.

A label indicating the date, stream name and sampling location was placed on the sample container. This information was recorded in the "Sample log" (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition.

The top portion of the "Benthic Macroinvertebrate Field Data Sheet" (Appendix A-3, Form 1) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable

Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

The percentage of each habitat type in the reach was recorded, and the sampling gear used and the conditions of the sampling, e.g. high flows, treacherous rocks, difficult access to the stream, or anything that would indicate adverse sampling conditions were noted.

The samples were returned to the laboratory and the log-in form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition was completed.

After sampling was completed at the site, the sieve was rinsed thoroughly, examined carefully, and picked free of organisms or debris. Any additional organisms found were placed in the sample containers. The sieve was examined again prior to use at the next sampling site.

Laboratory Processing For Macroinvertebrate Samples

All samples were dated and recorded in the "Sample Log" notebook or on sample log form (Appendix A-3, Form 2) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition in the laboratory. All information from the sample container label was included on the sample log sheet. All samples were sorted in a single laboratory to enhance quality control.

The identity and number of organisms were recorded on the Laboratory Bench Sheet (Appendix A-3, Form 3) of the Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition. The life stage of the organisms, the taxonomist's initials and the Taxonomic Certainty Rating (TCR) was recorded as a measure of confidence.

The back of the bench sheet was used to explain certain TCR ratings or condition of organisms. Other comments were included to provide additional insights for data interpretation.

A 100-organism subsample of the benthic macroinvertebrate composite sample from each sampling site was to be taken into the laboratory according to the methods outlined in the Rapid Bioassessment Protocol used by the NJDEP Bureau of Freshwater and Biological Monitoring. With the exception of chironomids and oligochaetes, benthic macroinvertebrates were to be identified to genus. Chironomids were to be identified to subfamily as a minimum, and oligochaetes were to be identified to family as a minimum.

Each individual organism was to be assigned a number and 100 numbers were to be randomly selected out of a hat. The organisms assigned to these numbers were to be the randomly selected sub-sample. Taxa richness (total families) was to be determined by totaling each different family represented in the sub-sample. The EPT (*Ephemeroptera*, *Plecoptera*, and *Trichoptera* orders; mayflies, stoneflies, and caddisflies) Index was to be determined by adding each individual EPT family in the sub-sample. Percent dominance was to be determined by the family that has the greatest number of individuals in the sub-sample. Percent EPT was to be determined by adding the total number of individuals found in all EPT families in the sub-sample. A Modified Family Biotic Index (FBI) was to be determined by $FBI = \Sigma x_i t_i / n$ where x_i = number of individuals within a family, t_i = tolerance value of a family (in appendix B, Tables C-1 and C-2 of the NJDEP guide), and n = total number of organisms within the sub-sample (100). Taxa richness, EPT Index, percent dominance, percent EPT, and FBI were to be assigned a biometric score of 0, 3, or 6 (in Table 1 of the NJDEP guide) and totaled. A score of 24-30 means the Musquapsink Brook is not impaired, 9-21 means it is moderately impaired, and 0-6 means it is severely impaired. A good or bad land assessment moves a score between a range up or down.

The measurement of physicochemical parameters was also conducted concurrent with the benthic macroinvertebrate sampling. These parameters, pH, temperature, dissolved oxygen, and total dissolved solids (TDS) were conducted by Rutgers University.

For archiving samples, specimen vials, (grouped by station and date), were placed in jars with a small amount of denatured 70% ethanol and tightly capped. The ethanol levels in these jars was examined periodically and replenished as needed. A stick-on label was placed on the outside of the jar indicating sample identifier and date.

Biological Monitoring Results and Discussion

Physical characterization/water quality

The stations sampled in the Musquapsink Brook became deeper moving from an upstream to a downstream location. Station MB1, the most upstream sampling site, is composed of mainly bedrock and had the least amount of water of the other stations (Table 1). Station MB3, further downstream, has more water than MB1 and was composed of sediment and rocks (Table 2). Station MB6, even further downstream, has more water than MB3 and it too has sediment and rocks unlike station MB1 which lacks sediment (Table 3). Station MB4, the most downstream sampling site, had the most water and was also the slowest moving of the other sites. It was the only site that lacked riffles (Table 4). Tables 1-4 also include information about the stream such as weather conditions during sampling, watershed features, riparian vegetation, instream features, large woody debris, aquatic vegetation, water quality, and sediment and substrate characteristics. The photographs of each station are immediately after the table. The table indicates the number of pages that contain the photographs.

Table 1. Physical characterization/water quality field data sheet for MB1.

Stream Name: Musquapsink Brook	
Station #: MB1	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 8/30/07 Time: 8:28 am
Weather conditions:	Clear/sunny, no heavy rain in the last 7 days
Site location/photographs	See the next 3 pages
Watershed features	Predominant surrounding land use: forest and residential, no evidence of local watershed NPS pollution, moderate evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Trees are the dominant type
Instream features	Estimated reach length: 100 m, width: 2 m, stream depth: < 0.3 m, canopy cover: partly shaded, 40 riffle, 20% pool, 40% run, channelized, no dam present
Large woody debris	LWD: 0 m^2
Aquatic vegetation	0% of the reach with aquatic vegetation
Water quality	No water odors, no surface oils, clear
Sediment/substrate	No odors, no oils, no deposits
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 70%	Detritus: 5%
Boulder: 5%	
Cobble: 20%	Muck-Mud: 0%
Gravel: 5%	
Sand: 0%	Marl: 0%
Silt: 0%	
Clay: 0%	

Table 2. Physical characterization/water quality field data sheet for MB3.

Stream Name: Musquapsink Brook	
Station #: MB3	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 8/30/07 Time: 11:07 am
Weather conditions:	70% cloud cover, clear/sunny, heavy rain in the last 7 days, air temperature: 22 ^{o} C
Site location/photographs	See the next 4 pages
Watershed features	Predominant surrounding land use: residential, no evidence of local watershed NPS pollution, moderate evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Trees and shrubs are the dominant type
Instream features	Estimated reach length: 100 m, width: 5 m, stream depth: < 0.3 m, canopy cover: partly shaded, 30% riffle, 30% pool, 30% run, channelized, no dam present
Large woody debris	LWD: 1 m^2
Aquatic vegetation	0% of the reach with aquatic vegetation
Water quality	No water odors, surface oils, slightly turbid
Sediment/substrate	No odors, no oils, trash
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 0%	Detritus: 60%
Boulder: 0%	
Cobble: 20%	Muck-Mud: 0%
Gravel: 20%	
Sand: 20%	Marl: 0%
Silt: 20%	
Clay: 20%	

Table 3. Physical characterization/water quality field data sheet for MB6.

Stream Name: Musquapsink Brook	
Station #: MB6	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 9/13/07 Time: 9:30 am
Weather conditions:	Clear/sunny, heavy rain in the last 7 days, air temperature: 75 ^{o} F
Site location/photographs	See the next 3 pages
Watershed features	Predominant surrounding land use: residential, no evidence of local watershed NPS pollution, no evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Trees and shrubs are the dominant type
Instream features	Estimated reach length: 100 m, width: 7 m, stream depth: 0.3 m, canopy cover: partly shaded, 20% riffle, 40% pool, 20% run, not channelized, no dam present
Large woody debris	LWD: 1 m^2
Aquatic vegetation	0% of the reach with aquatic vegetation
Water quality	No water odors, no surface oils, slightly turbid to turbid
Sediment/substrate	No odors, no oils, trash
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 0%	Detritus: 20%
Boulder: 5%	
Cobble: 15%	Muck-Mud: 0%
Gravel: 20%	
Sand: 20%	Marl: 10%
Silt: 20%	
Clay: 20%	

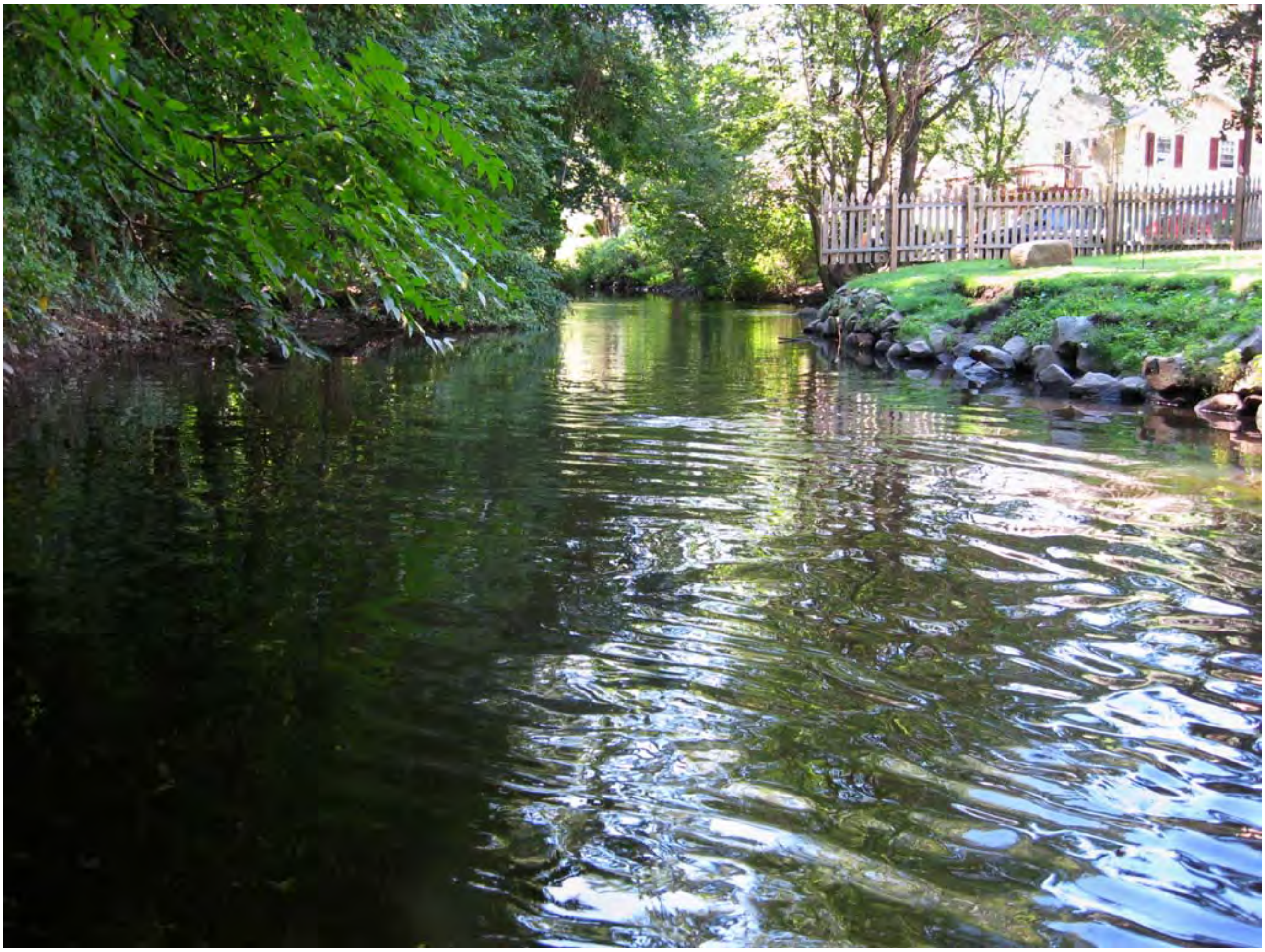

Table 4. Physical characterization/water quality field data sheet for MB4.

Stream Name: Musquapsink Brook	
Station #: MB4	
Investigator: Dr. Marion McClary and students	
Form completed by: Dr. Marion McClary and students	Date: 9/13/07 Time: 11:30 am
Weather conditions:	Clear/sunny, heavy rain in the last 7 days, air temperature: 78 ^{o} F
Site location/photographs	See the next 4 pages
Watershed features	Predominant surrounding land use: park, no evidence of local watershed NPS pollution, no evidence of local watershed erosion
Riparian vegetation (18 meter buffer)	Shrubs are the dominant type
Instream features	Estimated reach length: 100 m, width: 8 m, stream depth: > 1 m, canopy cover: partly shaded, 100% run, channelized, no dam present
Large woody debris	LWD: 1 m^2
Aquatic vegetation	Rooted emergent (70%), rooted submergent (30%) are dominant, 100% of the reach with aquatic vegetation
Water quality	No water odors, no surface oils, turbid
Sediment/substrate	No odors, no oils, no deposits
Inorganic substrate components % composition in reach (should add up to 100%)	Organic substrate components % composition in sampling area (does not necessarily add up to 100%)
Bedrock: 0%	Detritus: 10%
Boulder: 0%	
Cobble: 0%	Muck-Mud: 90%
Gravel: 0%	
Sand: 0%	Marl: 0%
Silt: 50%	
Clay: 50%	

Benthic Macroinvertebrates

Because station MB1 was shallow and had riffles (see Table 1), a surber was used to collect macroinvertebrates. An average of 0 (absent/not observed) were collected from MB1 using this technique and grab samples (Table 5).

Because MB3 was shallow and had riffles (see Table 2), a surber was used to collect macroinvertebrates. An average of 1 (rare) was collected from MB3 using this technique and grab samples (Table 6). Of the macroinvertebrates collected, the most abundant was an average of 1 (rare) which was found for Coleoptera and Trichoptera (Table 6).

Because MB6 was shallow and had riffles (see Table 3), a surber was used to collect macroinvertebrates. An average of 2 (common) was collected from MB6 using this technique and grab samples (Table 7). Of the macroinvertebrates collected, the most abundant was an average of 1 (rare) which was found for Amphipoda, Coleoptera and Chironomidae (Table 7).

Because station MB4 was deep and lacked riffles (see Table 4), a D frame dip was used to collect macroinvertebrates. An average of 1 (rare) was collected from MB4 using this technique and grab samples (Table 8). Of the macroinvertebrates collected, the most abundant was an average of 1 (rare) which was found for Anisoptera and Zygoptera (Table 8).

Table 5. Benthic macroinvertebrate field data sheet for MB1.

Stream Name: Musquapsink Brook								
Station #: MB1								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				0s				0vb
Sample collection: d = d frame, s = surber, g = grab	s	s	s		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes	0	0	0	0	0	0	0	0
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	0	0	0	0	0	0	0	0
Fish	0	0	0	0	0	0	0	0
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	0	0
Gastropoda	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Anisoptera	0	0	0	0	0	0	0	0
Zygoptera	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	0	0	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	0
Ephemeroptera	0	0	0	0	0	0	0	0
Trichoptera	0	0	0	0	0	0	0	0
Other (Nematocera)	0	0	0	0	0	0	0	0

Table 6. Benthic macroinvertebrate field data sheet for MB3.

Stream Name: Musquapsink Brook								
Station #: MB3								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				30s				0vb
Sample collection: d = d frame, s = surber, g = grab	s	s	s		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes	0	0	0	0	0	0	0	0
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	0	1	3	1.3	1	1	2	1.3
Fish	0	0	0	0	0	0	0	0
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	1	0	0	0.3
Amphipoda	0	0	0	0	0	0	1	0.3
Decapoda	0	0	1	0.3	1	0	0	0.3
Gastropoda	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Anisoptera	0	0	0	0	0	0	0	0
Zygoptera	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	0	1	2	1	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	0	0	1	0.3	0	1	2	1
Ephemeroptera	0	0	0	0	0	0	0	0
Trichoptera	0	0	2	0.7	0	0	0	0
Other (Nematocera)	0	0	0	0	0	0	0	0

Table 7. Benthic macroinvertebrate field data sheet for MB6.

Stream Name: Musquapsink Brook								
Station #: MB6								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				30s				50vb
Sample collection: d = d frame, s = surber, g = grab	s	s	s		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes	0	0	0	0	0	0	0	0
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	2	2	2	2	1	3	2	2
Fish	0	0	0	0	0	0	0	0
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0
Amphipoda	1	1	0	0.7	1	2	1	1.3
Decapoda	1	0	0	0.3	0	0	0	0
Gastropoda	0	0	0	0	0	0	0	0
Bivalvia	0	0	1	0.3	0	1	0	0.3
Anisoptera	0	0	0	0	0	1	0	0.3
Zygoptera	0	0	0	0	0	0	0	0
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	2	0	0	0.7	0	0	1	0.3
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	0	1	1	0.7	0	1	1	0.7
Ephemeroptera	0	1	0	0.3	0	0	0	0
Trichoptera	0	0	0	0	0	1	0	0.3
Other (Nematocera)	0	0	0	0	0	0	0	0

Table 8. Benthic macroinvertebrate field data sheet for MB4.

Stream Name: Musquapsink Brook								
Station #: MB4								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
Habitat types: % c = cobble, s = snags, vb = vegetated banks, s = sand, sm = submerged veg.				20s				100 Vb
Sample collection: d = d frame, s = surber, g = grab	d	d	d		g	g	g	
Qualitative listing of aquatic biota: 0 = absent/not observed, 1 = 1-3, 2 = 3-9, 3 = > 10, 4 = > 50 orgs.								
Periphyton	0	0	0	0	0	0	0	0
Filamentous algae	0	0	0	0	0	0	0	0
Macrophytes	0	0	0	0	0	0	0	0
Slimes	0	0	0	0	0	0	0	0
Macroinvertebrates	1	1	1	1	1	1	0	0.7
Fish	0	0	0	0	0	0	0	0
Field observations of macrobenthos: 0 = absent/not observed, 1 = rare (1-3), 2 = common (3-9), 3 = abundant (>10), 4 = dominant (>50 organisms)								
Porifera	0	0	0	0	0	0	0	0
Hydrozoa	0	0	0	0	0	0	0	0
Platyhelminthes	0	0	0	0	0	0	0	0
Turbellaria	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0
Oligochaeta	0	0	0	0	0	0	0	0
Isopoda	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0	0	0
Decapoda	0	0	0	0	0	0	0	0
Gastropoda	0	0	0	0	0	0	0	0
Bivalvia	0	0	0	0	0	0	0	0
Anisoptera	1	1	0	0.7	0	0	0	0
Zygoptera	0	0	1	0.3	1	1	0	0.7
Hemiptera	0	0	0	0	0	0	0	0
Coleoptera	1	0	0	0.3	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0
Sialidae	0	0	0	0	0	0	0	0
Corydalidae	0	0	0	0	0	0	0	0
Tipulidae	0	0	0	0	0	0	0	0
Empididae	0	0	0	0	0	0	0	0
Simuliidae	0	0	0	0	0	0	0	0
Tabanidae	0	0	0	0	0	0	0	0
Culicidae	0	0	0	0	0	0	0	0
Chironomidae	0	0	0	0	0	0	0	0
Ephemeroptera	0	0	0	0	0	0	0	0
Trichoptera	0	0	0	0	0	0	0	0
Other (Nematocera)	0	0	0	0	0	0	0	0

Habitat assessment

Station MB1 is poor for epifaunal substrate/available cover, optimal for embeddedness, marginal for velocity/depth regime, optimal for sediment deposition and marginal for channel flow status for an overall score of marginal (Table 9).

MB3 is suboptimal for epifaunal substrate/available cover, marginal for embeddedness, suboptimal for velocity/depth regime, optimal for sediment deposition and suboptimal for channel flow status for an overall score of suboptimal (Table 10).

MB6 is suboptimal for epifaunal substrate/available cover, poor for embeddedness, suboptimal for velocity/depth regime, optimal for sediment deposition and optimal for channel flow status for an overall score of suboptimal (Table 11)

Station MB4 is marginal for epifaunal substrate/available cover, poor for embeddedness, poor for velocity/depth regime, optimal for sediment deposition and optimal for channel flow status for an overall score of marginal (Table 12).

MB6 having an overall score of suboptimal (Table 11) may be the reason why it was the only station to have a macroinvertebrate collection average of 2 (the number of macroinvertebrates collected is common) (Table 7). When considering the type of macroinvertebrates present, all stations, including MB6, have a collection average of 1 (the number in the different types of macroinvertebrates is rare) or 0 (the macroinvertebrates are absent/not observed). This suggests a lack of diversity or a lack in general. Like MB6, MB3 also has an overall habitat assessment score of suboptimal (Table 10) but it does not have a macroinvertebrate collection average of 2 (Table 6) like MB6. This suggests that the problem is not entirely related to the habitat.

Table 9. Habitat assessment field data sheet for MB1.

Stream Name: Musquapsink Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking. 0
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space. 20	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low). 10	Dominated by 1 velocity/depth regime (usually slow-deep).
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. 20	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed. 10	Very little water in channel and mostly present as standing pools.

Table 10. Habitat assessment field data sheet for MB3.

Stream Name: Musquapsink Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale). 14	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment. 6	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes). 13	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. 20	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed. 11	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

Table 11. Habitat assessment field data sheet for MB6.

Stream Name: Musquapsink Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale). 13	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. 5
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes). 15	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. 20	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed. 20	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

Table 12. Habitat assessment field data sheet for MB4.

Stream Name: Musquapsink Brook				
Habitat parameter	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal substrate/ available cover Score:	Greater than 70% of substrate favorable for the epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed. 10	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
2. Embeddedness Score:	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment. 0
3. Velocity/depth regime Score:	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep). 5
4. Sediment deposition Score:	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition. 20	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constructions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
5. Channel flow status Score:	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed. 20	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.

Benthic Macroinvertebrates

At MB1 no macroinvertebrates were found (Table 13).

At MB3, the Hydropsychidae, the Gammaridae and the Chironomidae averaged 1 individual followed by the Asellidae with 0.3 (Table 14).

At MB6, the Gammaridae averaged 3 individuals by grab samples and 1 individual with the surber followed by the Elmidae, the Chironomidae and the Gomphidae with 1 (Table 15).

At MB4, the Coenagrionidae averaged 1 individual followed by the Psephenidae with 0.3 (Table 16).

Due to the inability of obtaining a 100-organism subsample, even if combining replicates A-C with D-F which could not be done because different techniques were used in replicates A-C and D-F, taxa richness, EPT Index, percent dominance, percent EPT, and FBI were not calculated for a score. This suggests that Musquapsink Brook should receive the most severe level of biological impairment.

Table 13. Benthic macroinvertebrate field data sheet for MB1.

Stream Name: Musquapsink Brook								
Station #: MB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda	0	0	0	0	0	0	0	0
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera	0	0	0	0	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other	0	0	0	0	0	0	0	0

Table 14. Benthic macroinvertebrate field data sheet for MB3.

Stream Name: Musquapsink Brook								
Station #: MB3								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae	0	0	0	0	1	0	0	0.3
# of Amphipoda, Gammaridae	0	0	0	0	0	0	2	0.7
# of Decapoda, Cambaridae	0	0	1	0.3	1	0	0	0.3
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae	0	0	4	1.3	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, beetle larva	0	1	3	1.3	0	0	0	0
Elmidae	0	0	1	0.3	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Nematocera, Chironomidae	0	0	1	0.3	0	1	4	1.7

Table 15. Benthic macroinvertebrate field data sheet for MB6.

Stream Name: Musquapsink Brook								
Station #: MB6								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae	0	1	0	0.3	0	0	0	0
# of Amphipoda, Gammaridae	1	3	0	1.3	2	5	1	2.7
# of Decapoda, Cambaridae	1	0	0	0.3	0	0	0	0
# of Ephemeroptera, Baetidae	0	2	0	0.7	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae	0	0	0	0	0	1	0	0.3
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, beetle larva	7	0	0	2.3	0	0	0	0
Elmidae	1	0	0	0.3	0	0	2	0.7
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda, Corbiculidae	0	0	3	1	0	1	0	0.3
# of Other, Nematocera, Chironomidae	0	2	1	1	0	1	1	0.7
Anisoptera, Gomphidae	0	0	0	0	0	2	0	0.7

Table 16. Benthic macroinvertebrate field data sheet for MB4.

Stream Name: Musquapsink Brook								
Station #: MB4								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda	0	0	0	0	0	0	0	0
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Psephenidae	1	0	0	0.3	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Anisoptera	1	1	0	0.7	0	0	0	0
Zygoptera, Coenagrionidae	0	2	1	1	2	2	0	1.3

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Musquapsink Brook Benthic Species List

Prepared by:

Marion McClary, Jr., Ph.D.
Associate Professor of Biological Sciences
Associate Director of Biological Sciences
Fairleigh Dickinson University

for

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Restoration and Protection Plan

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Table 1. Benthic macroinvertebrate field data sheet for MB1.

Stream Name: Musquapsink Brook								
Station #: MB1								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda	0	0	0	0	0	0	0	0
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera	0	0	0	0	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other	0	0	0	0	0	0	0	0

Table 2. Benthic macroinvertebrate field data sheet for MB3.

Stream Name: Musquapsink Brook								
Station #: MB3								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae, *Caecidotea* sp.	0	0	0	0	1	0	0	0.3
# of Amphipoda, Gammaridae,	0	0	0	0	0	0	2	0.7
Gammarua fasciatus								
# of Decapoda, Cambaridae	0	0	1	0.3	1	0	0	0.3
Orconectes virilis								
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae,	0	0	4	1.3	0	0	0	0
Hydropsyche sp.								
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, beetle larva	0	1	3	1.3	0	0	0	0
Elmidae, *Dubiraphia* sp.	0	0	1	0.3	0	0	0	0
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Nematocera, Chironomidae,	0	0	1	0.3	0	1	4	1.7
Axarus sp.								

Table 3. Benthic macroinvertebrate field data sheet for MB6.

Stream Name: Musquapsink Brook								
Station #: MB6								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda, Asellidae, *Caecidotea* sp.	0	1	0	0.3	0	0	0	0
# of Amphipoda, Gammaridae,	1	3	0	1.3	2	5	1	2.7
Gammarus fasciatus								
# of Decapoda, Cambaridae,	1	0	0	0.3	0	0	0	0
Orconectes virilis								
# of Ephemeroptera, Baetidae, *Callibaetis* sp.	0	2	0	0.7	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera, Hydropsychidae,	0	0	0	0	0	1	0	0.3
Hydropsyche sp.								
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, *Optioservus* sp.	7	0	0	2.3	0	0	0	0
Elmidae, *Dubiraphia* sp.	1	0	0	0.3	0	0	2	0.7
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda, Corbiculidae,	0	0	3	1	0	1	0	0.3
Corbicula fluminea								
# of Other, Nematocera, Chironomidae,	0	2	1	1	0	1	1	0.7
Axarus sp.								
Anisoptera, Gomphidae, *Hagenius* sp.	0	0	0	0	0	2	0	0.7

Table 4. Benthic macroinvertebrate field data sheet for MB4.

Stream Name: Musquapsink Brook								
Station #: MB4								
Investigator: Dr. Marion McClary and students								
A-C are replicates, D-F are replicates	A	B	C	Ave.	D	E	F	Ave.
# of Oligochaeta	0	0	0	0	0	0	0	0
# of Hirudinea	0	0	0	0	0	0	0	0
# of Isopoda	0	0	0	0	0	0	0	0
# of Amphipoda	0	0	0	0	0	0	0	0
# of Decapoda	0	0	0	0	0	0	0	0
# of Ephemeroptera	0	0	0	0	0	0	0	0
# of Plecoptera	0	0	0	0	0	0	0	0
# of Trichoptera	0	0	0	0	0	0	0	0
# of Hemiptera	0	0	0	0	0	0	0	0
# of Megaloptera	0	0	0	0	0	0	0	0
# of Coleoptera, Psephenidae,	1	0	0	0.3	0	0	0	0
Psephenus herricki								
# of Diptera	0	0	0	0	0	0	0	0
# of Gastropoda	0	0	0	0	0	0	0	0
# of Pelecypoda	0	0	0	0	0	0	0	0
# of Other, Anisoptera, *Hagenius* sp.	1	1	0	0.7	0	0	0	0
Zygoptera, Coenagrionidae, *Argia* sp.	0	2	1	1	2	2	0	1.3

References

NWCC Technical Note 99-1, Stream Visual Assessment Protocol, December 1998. 2 pgs.

Peckarsky, B.L., Fraissinet, P.R., Penton, M.A., and Conklin, Jr., D.J. 1990. Freshwater Macroinvertebrates of Northeastern North America. Cornell University Press. Ithaca, N.Y. 442 pgs.

Rawlyk, W. 1998. The Common Benthic Macroinvertebrates of New Jersey Streams: A Field Guide to Family Level Identification. William Rawlyk. 101 pgs.

Appendix B: Tabulated Stream Visual Assessment Protocol (SVAP) Data

REACH LOCATION	DATE	HYDROLOGIC ALTERATATION	CHANNEL CONDITION	RIPARIANZONE 1	RIPARIAN ZONE 2	BANKSTABILITY	BANKSTABILITY 2	WATER APPEARANCE	NUTRIENT ENRICHMENT	FISH BARRIER	INSTREAM FISHCOVER	POOLS	INVERTEBRATES	CANOPY COVER	MANURE PRESENCE	SALINITY	RIFFLE EMBEDEDNESS	MACROINVERTEBRATES	SITE AVERAGE
E3R005	6/29/07	NA	3	3	1	6	6	5	4	1	3	5	5	1	NA	NA	NA	NA	3.5
GB2R001	5/10/07	1	1	1	3	1	1	10	8	1	8	1	7	7	NA	NA	9	NA	4.7
E4R007	6/29/07	NA	3	5	3	5	7	7	7	7	5	3	7	1	NA	NA	NA	NA	5.0
GD2R001	5/10/07	5	3	5	1	3	5	10	8	1	3	1	7	7	NA	NA	10	NA	5.2
F2R005	7/3/07	NA	7	10	6	7	3	3	7	10	3	3	3	3	NA	NA	NA	NA	5.2
E3R004	6/29/07	NA	5	4	3	3	3	3	3	8	7	7	8	7	NA	NA	NA	NA	5.2
E4R006	6/29/07	NA	1	2	2	3	3	7	7	7	7	5	7	7	NA	NA	NA	NA	5.3
E4R009	6/29/07	NA	6	6	2	2	2	5	6	7	5	3	7	10	NA	NA	NA	NA	5.5
GD2R002	5/10/07	3	1	4	10	1	2	10	9	3	8	3	7	8	NA	NA	9	NA	5.6
GC2R001	4/30/07	5	8	4	8	3	3	10	9	1	3	1	7	8	NA	NA	8	NA	5.7
ge3r002	6/13/07	10	10	8	3	10	7	7	7	1	5	5	3	1	NA	NA	0	NA	5.7
G1R002	7/6/07	NA	1	3	3	7	7	8	7	6	5	5	6	10	NA	NA	NA	NA	5.8
F2R002	7/3/07	NA	6	10	6	8	6	8	7	8	3	5	3	3	NA	NA	NA	NA	5.8
GB2R002	5/10/07	7	7	1	1	5	5	10	10	1	8	1	10	1	NA	NA	10	NA	5.9
GF2R001	5/15/07	7	8	10	10	8	3	3	3	10	5	1	3	10	NA	NA	0	NA	6.0
G1R001	7/6/07	NA	3	8	6	3	5	8	8	5	5	7	7	7	NA	NA	NA	NA	6.1
F3R001	6/29/07	NA	6	5	6	4	4	7	3	7	8	7	7	7	NA	NA	NA	NA	6.2
ge2r002	6/13/07	7	7	9	8	8	9	7	7	4	5	5	7	3	NA	NA	5	NA	6.2
F3R002	6/29/07	NA	7	7	3	7	3	7	7	8	3	6	7	7	NA	NA	NA	NA	6.2
F2R003a	7/6/07	NA	8	10	10	5	2	5	5	7	5	3	7	10	NA	NA	NA	NA	6.4
gf2r004	6/13/07	8	9	10	10	10	9	7	7	3	3	3	3	8	NA	NA	0	NA	6.5

REACH LOCATION	DATE	HYDROLOGIC ALTERATATION	CHANNEL CONDITION	RIPARIANZONE 1	RIPARIAN ZONE 2	BANKSTABILITY	BANKSTABILITY 2	WATER APPEARANCE	NUTRIENT ENRICHMENT	FISH BARRIER	INSTREAM FISHCOVER	POOLS	INVERTEBRATES	CANOPY COVER	MANURE PRESENCE	SALINITY	RIFFLE EMBEDEDNESS	MACROINVERTEBRATES	SITE AVERAGE
GD2R002	5/15/07	8	7	8	10	10	10	10	9	1	5	1	3	10	NA	NA	0	NA	6.6
F2R003b	7/6/07	NA	8	10	7	5	5	9	8	8	5	1	7	7	NA	NA	NA	NA	6.7
ge3r001	6/13/07	10	10	8	5	10	10	7	8	10	5	3	3	1	NA	NA	0	NA	6.7
F2R001	7/3/07	NA	7	5	8	4	7	9	8	8	5	3	7	8	NA	NA	NA	NA	6.7
GC2R002	4/30/07	8	8	10	5	8	8	9	9	3	3	1	7	9	NA	NA	10	NA	6.9
E4R008	6/29/07	NA	7	9	5	5	5	5	7	8	7	5	8	10	NA	NA	NA	NA	6.9
F2R004	7/3/07	NA	9	8	3	5	7	3	7	10	6	7	7	9	NA	NA	NA	NA	7.0
F2R003	7/3/07	NA	5	9	9	9	8	3	7	10	7	8	7	6	NA	NA	NA	NA	7.1
ge2r003	6/13/07	5	8	8	10	6	6	10	8	1	8	7	7	7	NA	NA	10	NA	7.2
ge2r004	6/13/07	7	8	8	10	7	8	10	9	3	5	1	7	10	NA	NA	10	NA	7.2
gf2r003	6/13/07	3	8	9	10	5	5	10	9	3	5	8	7	10	NA	NA	10	NA	7.3
GD2R001	5/15/07	7	8	10	10	2	8	10	9	10	5	1	3	10	NA	NA	10	NA	7.4
GA2R001	5/10/07	8	7	10	10	4	8	10	8	1	8	3	10	10	NA	NA	10	NA	7.5
F3R003	6/29/07	NA	8	10	7	7	7	7	7	8	7	7	7	10	NA	NA	NA	NA	7.7
GE2R002	5/15/07	9	7	10	8	10	10	10	10	0	0	1	3	10	NA	NA	0	NA	7.7
GE2R001	5/15/07	8	8	10	7	10	8	10	9	10	3	1	7	10	NA	NA	8	NA	7.8
GF2R002	5/15/07	8	10	10	10	5	5	10	10	10	8	3	7	10	NA	NA	0	NA	8.3

Appendix C: Quality Assurance Project Plan, RP 07-002 Musquapsink Brook Watershed Restoration Plan, Rutgers Cooperative Extension Water Resources Program

QUALITY ASSURANCE PROJECT PLAN

RP07-002 MUSQUAPSINK BROOK WATERSHED RESTORATION PLAN

Rutgers Cooperative Extension Water Resources Program

January 8, 2007

Revised & Resubmitted April 12, 2007

Revised & Resubmitted May 15, 2007

QUALITY ASSURANCE PROJECT PLAN

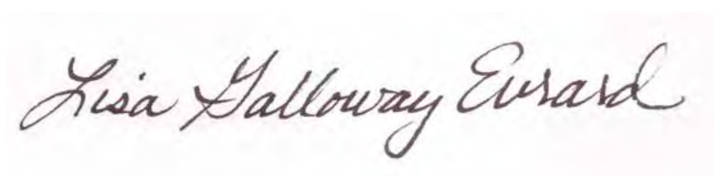
RP07-002 MUSQUAPSINK BROOK WATERSHED RESTORATION PLAN

Rutgers Cooperative Extension Water Resources Program

Applicant/ Project Officer:	Christopher C. Obropta, Ph.D., P.E. Rutgers Cooperative Extension Water Resources Program 14 College Farm Road – 2nd Floor New Brunswick, NJ 08901-8551 732-932-9800 x 6209 (phone); 732-932-8644 (fax) obropta@envsci.rutgers.edu

Signature Date

QA Officers:	Lisa Galloway Evrard Rutgers Cooperative Extension Water Resources Program 14 College Farm Road – 2nd Floor New Brunswick, NJ 08901-8551 732-932-9800 x 6130 (phone); 732-932-8644 (fax) evrard@rci.rutgers.edu



Signature Date

NJDEP Main Point of Contact:	Michele Bakacs Watershed Management Area 5 Manager Division of Watershed Management New Jersey Department of Environmental Protection 401 East State Street P.O. Box 418 Trenton, New Jersey 08625-0418 609-292-9247 (phone); 609-633-0750 (fax) Michele.Bakacs@dep.state.nj.us

Signature Date

NJDEP Additional Data Quality Review:	Beth Torpey Division of Watershed Management New Jersey Department of Environmental Protection 401 East State Street P.O. Box 418 Trenton, New Jersey 08625-0418 609-633-1471 (phone); 609-633-0750 (fax) ***Beth.Torpey@dep.state.nj.us***

Signature Date

NJDEP Office of Quality Assurance:	Marc Ferko Research Scientist Office of Quality Assurance New Jersey Department of Environmental Protection 9 Ewing Street P.O. Box 424 Trenton, NJ 08625-0418 609-292-3950 (phone); 609-777-1774 (fax) Marc.Ferko@dep.state.nj.us

Signature Date

1. Project Name: Musquapsink Brook
Watershed Restoration Plan

Requested By: Michele Bakacs
New Jersey Department of Environmental Protection

2. This project has been initiated by the New Jersey Department of Environmental Protection to collect data needed to prepare a comprehensive watershed restoration plan for the Musquapsink Brook.

3. Date Project Requested: January 2007

4. Date Project Initiated: May 2007

5. Project Officer: Christopher C. Obropta, Ph.D., P.E.
Rutgers Cooperative Extension Water Resources Program

6. QA Officer: Lisa Galloway Evrard
Rutgers Cooperative Extension Water Resources Program

7. Project Description:

A. Objective and Scope

The proposed watershed study area is the Musquapsink Brook Watershed of Watershed Management Area 5 (WMA 5). The Musquapsink Brook Watershed, Hydrologic Unit Code 02030103170020, is approximately nine square miles in size. Based upon numerous monitoring sources, including the New Jersey Department of Environmental Protection (NJDEP) Ambient Biomonitoring Network (AMNET) program and the NJDEP/United States Geological Survey (USGS) water quality monitoring network, water quality impairments exist in the Musquapsink Brook Watershed.

According to the *New Jersey 2004 Integrated Water Quality Monitoring and Assessment Report,* the Musquapsink Brook maintains the following listings:

- Sublist 3 - No data or information are available to support attainment determination: cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc;
- Sublist 4 - Attainment is threatened or waterbody is impaired; a TMDL has been developed and/or approved or pollution control measures do not require a TMDL: fecal coliform;
- Sublist 5 - Water quality standard is not being attained and requires a TMDL: aquatic life, total phosphorus, and arsenic.

According to the recently adopted 2006 Integrated List, which uses a HUC-14 based water quality impairment listing methodology, the Musquapsink Brook Watershed (HUC 02030103170020), maintains the following listings:

- Sublist 4 for fecal coliform, phosphorus (primary recreation)

- Sublist 5 for drinking water, agricultural use, total dissolved solids (TDS), arsenic, aquatic life (general).

Based on the Total Maximum Daily Load (TMDL) prepared for the Musquapsink Brook at River Vale, USGS 01377499, a 96% reduction in fecal coliform load for 6.6 miles of stream is needed. Additional aquatic life and total phosphorus surface water quality impairments will also need to be addressed through the TMDL process.

B. Data Usage

The data collected in accordance with this Quality Assurance Project Plan (QAPP) will help describe both dry weather and wet weather water quality conditions. These data will provide the information needed to identify and quantify sources of pollution so that appropriate management practices can be implemented to minimize these sources.

C. Monitoring Network Design and Rationale

Sampling Locations:

A draft of this QAPP was forwarded to various stakeholders by Michele Bakacs on 2/16/07 for review and comment. In addition, an overview of the QAPP, in particular a review of all the sampling locations for the study, was presented by the Rutgers Cooperative Extension Water Resources Program at the Northeast NJ Watershed Alliance March meeting on 3/6/07 for review and comment. An additional presentation regarding addressing fecal contamination in the watershed was presented by the Rutgers Cooperative Extension Water Resources Program at the Northeast NJ Watershed Alliance April meeting on 4/10/07 for review and comment.

The sampling locations, following the above referenced presentations, are shown in Attachment A. The eight sampling stations throughout the watershed are as follows:

Musquapsink Brook Proposed Water Quality Stations			
Station ID	Station Name	Northing	Easting
SR1	Saddle River at Grove St., Ridgewood, NJ	604,246	775,678
HB1	Hohokus Brook at Saddle River County Park, Ridgewood, NJ	600,871	775,240
MB1	Musquapsink Brook at Hillsdale Ave, Hillsdale, NJ	612,208	791,635
MB2	Musquapsink Brook at Woodfield, below Schlegel Lake, Washington, NJ	613,070	784,469
MB3	Musquapsink Brook at Ridgewood Ave, Washington, NJ	612,454	782,650
MB4	Musquapsink Brook at Forest Ave, Westwood, NJ	617,409	781,658
MB5	Musquapsink Brook at Third Ave, Westwood, NJ	619,373	783,768
MB6	Musquapsink Brook at Harrington Avenue, Westwood, NJ	623,729	786,736

A WAAS-enable Garmin Rino 120 GPS (global positioning system) unit will be used to locate and identify the sampling locations. Sampling locations will be marked with stakes and surveying tape ***or flags***. Field personnel will take GPS readings in the field to aid in verifying the correct sampling locations during the first sampling event.

Basis for Sampling Locations:
Surface water quality sampling will be conducted to assess the loading inputs of nutrients, total suspended solids and bacteria to the Musquapsink Brook, as well as the movement of nutrients, total suspended solids and bacteria from basin to basin to identify and quantify the sources of pollution under dry weather and wet weather conditions. Biological sampling will be conducted so that the benthic macroinvertebrate community can be better characterized, compared, and evaluated for biological integrity within the study area.

- Location SR1 - Saddle River at Grove Street, Ridgewood was selected to monitor the Saddle River upstream of the United Water interbasin transfer site.
- Location HB1 – Hohokus Brook at Saddle River County Park, Ridgewood was selected to monitor the Hohokus Brook upstream of the United Water interbasin transfer location.
- Location MB1 – Musquapsink Brook at Hillsdale Avenue, Hillsdale was selected to yield water quality information on the headwaters of the Musquapsink Brook.
- Location MB2 – Musquapsink Brook at Woodfield Avenue, Washington was selected to yield water quality information on Musquapsink Brook just downstream of the spillway/discharge from Schlegel Lake and upstream from the interbasin discharge point.
- Location MB3 – Musquapsink Brook at Ridgewood Avenue, Westwood was selected to yield water quality information on the Musquapsink Brook below the interbasin transfer.
- Location MB4 – Musquapsink Brook at Forest Avenue, Westwood was selected to yield water quality information on the Musquapsink Brook downstream from the confluence with an unnamed tributary to the Musquapsink.
- Location MB5 – Musquapsink Brook at Third Avenue, Westwood was selected to yield water quality information on the Musquapsink Brook as the stream flows further downstream through the watershed and to monitor any inputs from the large duck and goose population in this area, as well as drainage from the Beth El and Cedar Park Cemeteries.
- Location MB6 – Musquapsink Brook at Harrington Avenue, Westwood was selected to yield water quality information on the Musquapsink Brook at the most downstream location within the study area prior to the confluence with Pascack Brook.

Temporal and Spatial Aspects:
Biweekly Surface Water Sampling
Surface water quality samples will be collected from all sampling locations in a downstream to upstream order to avoid disturbances to downstream water column samples twice a month, independent of weather, from May through October 2007 (12 events). Three additional surface water quality samples will be collected from all sampling locations in June, July, and August 2007 for fecal coliform and *Eschericia coli* (*E. coli*) analyses (nine additional sampling events). These nine additional sampling events will be independent of precipitation and will allow for a total of five fecal coliform, as well as five *E. coli* analyses at all sampling locations within a 30 day period during the warmer summer months. NJDEP considers the warm weather sampling months to fall between Memorial Day (i.e., May 28, 2007) and Labor Day (i.e., September 3, 2007).

All scheduling is subject to the natural occurrence of appropriate stream flow conditions (i.e., non-flooding conditions). In accordance with the Field Sampling Procedures Manual (See

Section 6.8.1.1, Chapter 6D – page 59 of 188), field personnel will not wade into flowing water when the product of depth (in feet) and velocity (in feet per second) equals ten or greater to ensure the health and safety of all field personnel. If the stream flow conditions preclude entry into the stream, samples will be collected from the closest bridge crossing to that location or from the stream bank.

Bacteriology samples will be collected directly into a bacteriological sample container in accordance with the methods outlined in section 6.8.2.2.7 of the Field Sampling Procedures Manual (See Chapter 6D - page 67 of 188). Composite samples will not be collected for bacteriology samples.

For the most part, the Musquapsink Brook and its tributaries are uniformly mixed, which warrants grab sampling (See Section 6.8.2.2.3, Chapter 6D-Page 66 of 188 of the Field Sampling Procedures Manual). A single grab sample will be collected at all locations where the stream width is six feet or less. At stream locations with a width greater than six feet, a minimum of three subsurface grab samples (i.e., quarter points) will be collected at equidistant points across the stream. The number of individual samples in a composite varies with the width of the stream being sampled. Horizontal intervals will be at least one foot wide (See Section 6.8.2.2.2, Chapter 6D – Page 64 of 188 of the Field Sampling Procedures Manual). These grab samples then will be composited in a larger volume container from which the desired volume will be transferred to the sample bottles. A dedicated large volume container will be assigned to each sample location.

Field equipment used for surface water quality sample collection (i.e., bottles and buckets) will be decontaminated/cleaned in the laboratory prior to each sampling event. A dedicated large volume container will be assigned to each sample location. Prior to each sampling event, the large volume containers will be decontaminated in the laboratory using the following procedures in accordance with the Field Sampling Procedures Manual (See Chapter 2A – Page 10 of 61): 1) laboratory grade glassware detergent plus tap water wash, 2) generous tap water rinse, 3) distilled/deionized water rinse, 4) 10% nitric acid rinse, 5) distilled/deionized water rinse. Note that the samples collected will not be analyzed for metals or organics. Also, field equipment decontamination water will be disposed of in accordance with the laboratory's Standard Operating Procedures and Quality Assurance Manual.

Wet Weather Surface Water Sampling

Three wet weather sampling events, at a minimum, will be conducted between May and October 2007 at each station. The wet weather samples for this plan will be in addition to the 12 biweekly surface water sampling events described above. Collection of stormwater samples will begin at the onset of the storm (i.e., a storm predicted to produce a minimum of ½ inch of precipitation), and an attempt will be made to span the course of the event. By using this method of sampling, the samples should accurately reflect loading for the entire event. A priority will be to acquire first flush samples. Flow will be measured along with concentrations to quantify loading for selected parameters. A total of three samples will be obtained between the onset of the storm and the time when the flow reaches the pre-storm level, unless impractical, at each station during each storm event. At each station, the samples obtained for the entire event will be flow-weight composited to provide one sample from each station, with the exception of fecal coliform and *E. coli*, which will require analysis of each individual grab sample. Rainfall data will be collected from a rain gauge that will be installed in the watershed.

If three samples can not be collected between the onset of the storm and the time when the flow reaches the pre-storm level, then the sampling event will not count as a wet weather surface water sampling event. If three ½ inch storm events are not captured between May - October 2007, the Water Resources Program, after consultation with the Department, may have to defer the Wet Weather Surface Water Sampling portions of the study to May – October 2008. Attempts will be made to conduct this portion of the study as early on in the study period as possible. Regarding time for collection of the first flush samples, the Water Resources Program will attempt to capture the first flush using the expected or anticipated rising limb of the hydrograph. The actual point on the hydrograph will have to be confirmed after sample completion.

Biological Sampling

Samples of the benthic macroinvertebrate community will be collected in accordance with the Rapid Bioassessment Protocol (RBP) procedure used by the NJDEP Bureau of Freshwater and Biological Monitoring, which is based on USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (EPA 841-B-99-002 Nov. 1999). A multihabitat sampling approach, concentrating on the most productive habitat of the stream plus coarse particulate organic matter (CPOM) or leaf litter, will be used. Benthic macroinvertebrates will be collected from four locations (i.e., MB1, MB3, MB4, and MB6) once in either early summer or late summer as described in Attachment B. The biological sampling locations were selected to bracket the upstream and downstream boundaries of the study areas, as well as to characterize as much of the study area as possible since there are no AMNET monitoring locations on the Musquapsink Brook. In addition, locations with comparable substrate, canopy coverage, and flow conditions were selected within the study area for data comparability.

Summary of Monitoring Network Design and Rational – Temporal and Spatial Aspects

Type:	Biweekly Surface Water Sampling	Additional Bacteriology Sampling	Wet Weather Surface Water Sampling	Biological Sampling
Frequency:	Two (2) times a month from May - October 2007 (12 events)	Three (3) times, in addition to biweekly samples, in June, July, & August 2007 (9 events)	Three (3) times between May - October 2007 (3 events)	One (1) time in either early summer or late summer (1 event)
Parameters:	pH, temperature, dissolved oxygen, stream width, stream depth, stream velocity, ammonia-N, nitrate-N, nitrite-N, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate phosphorus, total suspended solids, fecal coliform, *E. coli*	Stream width, stream depth, stream velocity, fecal coliform, *E. coli*	pH, temperature, dissolved oxygen, stream width, stream depth, stream velocity, ammonia-N, nitrate-N, nitrite-N, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate phosphorus, total suspended solids, fecal coliform, *E. coli*	pH, temperature, dissolved oxygen, stream width, stream depth, stream velocity, total dissolved solids, benthic macroinvertebrate survey, habitat assessment
Sampling Locations:				
SR1	X	X	X	
HB1	X	X	X	
MB1	X	X	X	X
MB2	X	X	X	
MB3	X	X	X	X
MB4	X	X	X	X
MB5	X	X	X	
MB6	X	X	X	X

D. Monitoring Parameters

Surface water quality sample collection will be conducted by the Rutgers Cooperative Extension Water Resources Program (RCE WRP). Stream width, stream depth, and stream velocity will be measured in accordance with the methods outlined in Attachment C by the RCE WRP. *In situ* measurements of pH, temperature, and dissolved oxygen will be conducted by the Rutgers EcoComplex Laboratory (NJDEP Certified Laboratory #03019). Collected samples will be analyzed for fecal coliform, ammonia-nitrogen, total Kjeldahl nitrogen, total phosphorus, dissolved orthophosphate phosphorus, and total suspended solids by Bergen County Utilities Authority (NJDEP Certified Laboratory #02268). Collected samples will also be analyzed for nitrate-nitrogen, nitrite-nitrogen, and total dissolved solids by Hampton Clarke Veritech (NJDEP Certified Laboratory #14622) via the Bergen County Utilities Authority. In addition, collected samples will be analyzed for *E. coli* by Garden State Laboratories (NJDEP Certified Laboratory #20044).

Biological sampling will include benthic macroinvertebrate grab/jab type sampling, along with the collection of CPOM. Physicochemical measurements will include total dissolved solids and *in situ* pH, temperature, dissolved oxygen, stream width, stream depth, and stream velocity. Benthic macroinvertebrate sampling and identification will be conducted by Marion McClary, Jr., Ph.D., Associate Professor of Biological Sciences and Associate Director of Biological Sciences at Fairleigh Dickinson University, in accordance with the Rapid Bioassessment Protocol (RBP) procedure used by the NJDEP Bureau of Freshwater and Biological Monitoring, which is based on USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (EPA 841-B-99-002 Nov. 1999). The RCE WRP will make stream width, stream depth, and stream velocity determinations in accordance with the procedures specified in Attachment C. *In situ* measurements of pH, temperature, and dissolved oxygen will be conducted by the Rutgers EcoComplex Laboratory (NJDEP Certified Laboratory #03019). Total dissolved solids will be measured by Hampton Clarke Veritech (NJDEP Certified Laboratory #14622) via the Bergen County Utilities Authority.

E. Parameter Table

Measurements of the sampled parameters will be performed in accordance with Table 1A – List of Approved Biological Methods and Table 1B – List of Approved Inorganic Test Procedures (40 CFR Part 136.3) of Attachment D. Sample containers, preservation techniques, and holding times will be in accordance with Table II (40 CFR Part 136.3) of Attachment E. The Bergen County Utilities Authority, Hampton Clarke Veritech, and Garden State Laboratories will provide appropriate containers for all analyses. Any deviations from the test procedures and/or preservation methods and holding times will be reported to the NJDEP Office of Quality Assurance and will be noted in the final report from the laboratory.

8. Schedule:[*]

Task	Date
Submit QAPP	January 2007
Conduct biweekly surface water sampling	May – October 2007
Conduct additional bacteriology sampling	June, July, August 2007
Conduct wet weather surface water sampling	May - October 2007
Conduct biological sampling	Early Summer or Late Summer 2007
Submit data and summary report to NJDEP	January 2008

[*] All scheduling is subject to the natural occurrence of appropriate stream flow conditions (i.e., non-flooding conditions).

9. Project Organization and Responsibility:

Laboratory Operations:	(Bergen CUA)	John Dinice
	(Hampton Clarke V.)	Stanley E. Gilewicz
	(Garden State L.)	Harvey Klein
	(Rutgers EcoComplex)	Lisa Galloway Evrard
	(Fairleigh Dickinson U.)	Marion McClary, Jr.
	(NJDEP Representative)	Marc Ferko
Sampling Operations:	(QA Officer)	Lisa Galloway Evrard
	(NJDEP Representative)	Marc Ferko
Data Processing/ Data Quality Review:	(QA Officer)	Lisa Galloway Evrard
	(NJDEP Representative)	Beth Torpey
		Michele Bakacs
Overall QA:	(QA Officer)	Lisa Galloway Evrard
Overall Coordination:	(Project Officer)	Christopher C. Obropta

10. Organizational Chart:

Overall Coordination: Christopher C. Obropta (RCE WRP) Overall QA: Lisa Galloway Evrard (RCE WRP)
Data Quality Review/Data Processing: Lisa Galloway Evrard (RCE WRP) Beth Torpey (NJDEP) Michele Bakacs (NJDEP)
Sampling QC/Sampling Operations: Lisa Galloway Evrard (RCE WRP) Marc Ferko (NJDEP)
Laboratory Operations: John Dinice (Bergen County Utilities Authority) Stanley E. Gilewicz (Hampton Clarke Veritech) Harvey Klein (Garden State Laboratories) Lisa Galloway Evrard (Rutgers EcoComplex) Marion McClary, Jr. (Fairleigh Dickinson University) Marc Ferko (NJDEP)

11. Sampling Procedures:

All sampling procedures will be in conformance with the NJDEP 2005 Field Sampling Procedures Manual, any applicable USEPA guidance, or with prior written approval.

- Bacteriology samples will be collected in accordance with the methods outlined in section 6.8.2.2.7 of the Field Sampling Procedures Manual (See Chapter 6D - page 67 of 188).
- Manual composite sampling for wider portions of the streams will be conducted in accordance with the methods outlined in section 6.8.2.2.2 of the Field Sampling Procedures Manual (See Chapter 6D – page 64 of 188).

- Grab sampling where the natural stream conditions make compositing unnecessary will be conducted in accordance with the methods outlined in section 6.8.2.2.3 of the Field Sampling Procedures Manual (See Chapter 6D – page 66 of 188).

  In addition, instrumentation used for the collection of field data will be properly calibrated, in conformance with the manufacturer's instructions, laboratory SOPs and QA Manuals, and the NJDEP Field Sampling Procedures Manual.

12. Chain of Custody Procedures:

Chain of Custody procedures will be followed for all samples collected for this monitoring program. A sample chain of custody form is provided in Attachment F. A sample is in someone's "custody" if 1) it is in one's actual physical possession, 2) it is in one's view, after being in one's physical possession, 3) it is in one's physical possession and then locked up so that no one can tamper with it, and 4) it is kept in a secured area, restricted to authorized personnel only.

13. Calibration Procedures and Preventative Maintenance:

Calibration and preventative maintenance of laboratory and field equipment will be in accordance with the manufacturer's instructions, NJDEP Field Sampling Procedures Manual, NJAC 7:18 and 40 CFR Part 136.

14. Documentation, Data Reduction, and Reporting:

The QA Officer, for a minimum of five years, will keep all data on file, and all applicable data will be included in the summary report to NJDEP. An electronic version of all reports and data will be provided on a CD for the Department's use.

15. Quality Assurance and Quality Control:

NJAC 7:18 and 40 CFR Part 136 will be followed for all quality assurance and quality control (QA/QC) practices, including detection limits, quantitation limits, precision, and accuracy. Tables of parameter detection limits, quantitation limits, accuracy, and precision applicable to this study are provided in Attachment G. Bergen County Utilities Authority, Hampton Clarke Veritech, Garden State Laboratories, and Rutgers Cooperative Extension will perform data validation.

Lisa Galloway Evrard of the Rutgers Cooperative Extension Water Resources Program will verify the reference/voucher collection prepared by Marion McClary, Jr., Ph.D. (Associate Professor of Biological Sciences and Associate Director of Biological Sciences at Fairleigh Dickinson University).

16. Performance and Systems Audits:

All NJDEP certified laboratories participate ***annually in a NJDEP mandated Performance Testing program.*** The NJDEP Office of Quality Assurance conducts a performance audit of each laboratory that is certified. The NJDEP Office of Quality Assurance also periodically conducts on-site technical systems audits of each certified laboratory. The findings of these audits, together with the ***NJDEP mandated Performance Testing program***, are used to update each laboratory's certification status.

The NJDEP Office of Quality Assurance periodically conducts field audits of project sampling operations. The Office of Quality Assurance will be contacted during the project to schedule a possible field audit.

17. Corrective Action:

All NJDEP certified laboratories must have a written corrective action procedure which they adhere to in the event that calibration standards, performance evaluation results, blanks, duplicates, spikes, etc. are out of the acceptable range or control limits. If the acceptable results cannot be obtained for the above-mentioned QA/QC samples during any given day, sample analysis must be repeated for that day with the acceptable QA/QC results. NJDEP will be notified if there are any deviations from the approved work plan.

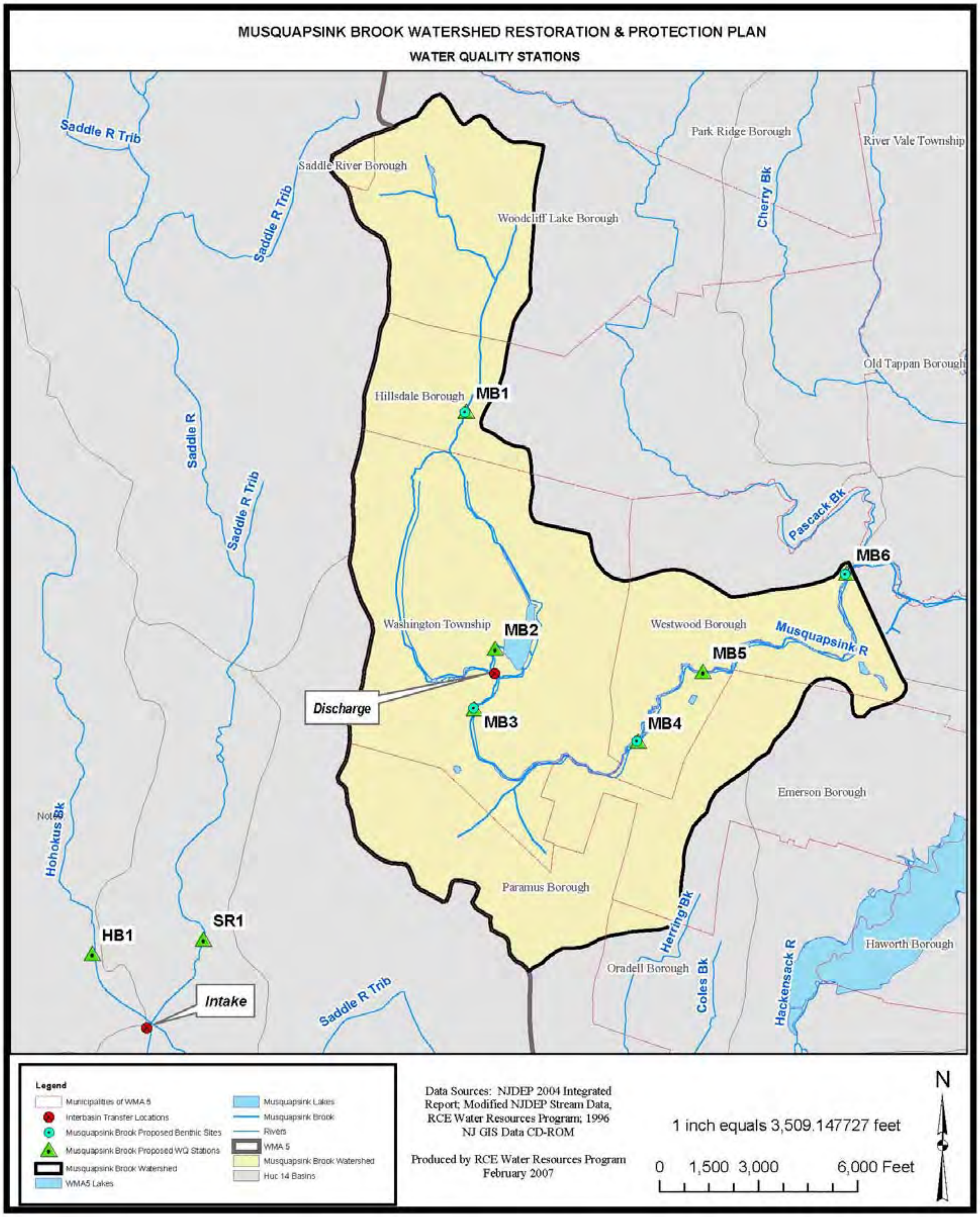
All signatories of this QAPP will be notified when deviations to the QAPP are made prior to their implementation.

18. Reports:

The summary report will include at a minimum an Introduction, Purpose and Scope, Results and Discussion, Conclusions and Recommendations, and an appendix with data tables. An electronic version of all reports and data will be provided on a CD for the Department’s use.

ATTACHMENT A

Sampling Locations
Musquapsink Brook Watershed


MUSQUAPSINK BROOK WATERSHED RESTORATION & PROTECTION PLAN
WATER QUALITY STATIONS
Saddle R Trib
Saddle River Borough
Saddle R Trib
Woodcliff Lake Borough
Park Ridge Borough
Cherry Bk
River Vale Township
Old Tappan Borough
Hillsdale Borough
MB1
Saddle R
Saddle R Trib
Pascack Bk
MB6
Washington Township
MB2
Westwood Borough
Musquapsink R
MB5
Discharge
MB3
MB4
Emerson Borough
Hohokus Bk
Paramus Borough
Herring Bk
HB1
SR1
Haworth Borough
Oradell Borough
Coles Bk
Hackensack R
Intake
Saddle R Trib
Legend
Municipalities of WMA 5
Interbasin Transfer Locations
Musquapsink Brook Proposed Benthic Sites
Musquapsink Brook Proposed WQ Stations
Musquapsink Brook Watershed
WMA5 Lakes
Musquapsink Lakes
Musquapsink Brook
Rivers
WMA 5
Musquapsink Brook Watershed
Huc 14 Basins
Data Sources: NJDEP 2004 Integrated Report; Modified NJDEP Stream Data, RCE Water Resources Program; 1996 NJ GIS Data CD-ROM
Produced by RCE Water Resources Program February 2007
1 inch equals 3,509.147727 feet
0 1,500 3,000 6,000 Feet
N

ATTACHMENT B

Biological Sampling Procedures and Analysis

Biological Sampling Procedures and Analysis

These sampling and data analysis procedures are in accordance with the Rapid Bioassessment Protocol procedures used by the NJDEP Bureau of Freshwater and Biological Monitoring, which is based on USEPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (EPA 841-B-99-02 Nov. 1999).

Sampling Procedures:

Samples will be collected using a multi-habitat sampling approach, concentrating on the most productive habitat of the stream (i.e., the riffle/run areas), plus coarse particulate organic matter (CPOM) or leaf litter. This sampling method minimizes habitat or substrate variation between sampling sites, and includes all likely functional feeding groups of macroinvertebrates in the stream. Three grab type samples will be collected at each sampling site. These samples will be sorted in the field, composited (i.e., the contents from the three grab samples from each site will be combined into a single container), and preserved in 80% ethanol for later subsampling, identification and enumeration.

A composite collection of a variety of CPOM forms (e.g., leaves, needles, twigs, bark, or fragments of these) will be collected. It is difficult to quantify the amount of CPOM to be collected in terms of weight or volume, given the variability of its composition. Collection of several handfuls of material is usually adequate, and the material is typically found in depositional areas, such as in pools and along snags and undercut banks. The CPOM sample will be processed using a U.S. Standard No. 30 sieve, and added to the composite of the grab samples for each site.

A 100-organism subsample of the benthic macroinvertebrate composite sample from each sampling site will be taken in the laboratory according to the methods outlined in the Rapid Bioassessment Protocol used by the NJDEP Bureau of Freshwater and Biological Monitoring. With the exception of chironomids and oligochaetes, benthic macroinvertebrates will be identified to genus. Chironomids will be identified to subfamily as a minimum, and oligochaetes will be identified to family as a minimum.

A habitat assessment will be conducted concurrent with the benthic macroinvertebrate sampling in accordance with the methods used by the NJDEP Bureau of Freshwater and Biological Monitoring. The measurement of physicochemical parameters will also be conducted concurrent with the benthic macroinvertebrate sampling. Surface water sampling for the measurement of pH, temperature, and dissolved oxygen will be conducted on a representative cross section of the steam. At least four subsurface grab samples will be collected across an established transect. These grab samples will be composited, and an appropriate volume will be transferred to sample bottles for *in situ* measurements of pH, temperature, and dissolved oxygen. Stream width, stream depth, and stream velocity will be measured in accordance with the methods outlined in Attachment C. Total dissolved solids (TDS) will also be measured as part of the biological sampling.

Biological Sampling Procedures and Analysis (continued)

Data Analysis:
The NJDEP Bureau of Freshwater and Biological Monitoring uses several community measures of biometrics adapted from the Rapid Bioassessment Protocols to evaluate the biological condition of sampling sites within the Ambient Biomonitoring Network in New Jersey. These community measures include taxa richness, EPT index, %EPT, %CDF, and Modified Family Biotic Index. This analysis integrates several community parameters into one easily comprehended evaluation of biological integrity referred to as the New Jersey Impairment Score (NJIS). The NJIS has been established for three categories of water quality bioassessment for New Jersey streams: non-impaired, moderately impaired, and severely impaired, and is based on comparisons with reference streams and a historical database consisting of 200 benthic macroinvertebrate samples collected from New Jersey streams.

If the above metrics are not utilized, or if different metrics or indices are used, these changes will be discussed with NJDEP for approval. For example, to determine the similarity among the sampling sites with respect to species composition, the Percentage Similarity Index may be calculated for all pair wise comparisons of the sampling sites. Also, the benthic macroinvertebrates may be separated into the four broad functional feeding groups to evaluate community structure. In addition, the Shannon diversity index may be calculated to evaluate community structure. In addition, the findings from the habitat assessment will be used to interpret survey results and identify obvious constraints on the attainable biological potential of the site.

The final report will include a characterization of the aquatic biota, in particular the benthic macroinvertebrate community.

ATTACHMENT C

Stream Flow Measurement Procedure

Stream Flow Measurement Procedure

Stream width, depth, velocity, and flow determinations will be made in conformance with the following procedures:

1. A measuring tape is extended across the stream, from bank to bank, perpendicular to flow. Meter calibration is checked.

2. Using a Marsh-McBirney, Inc. Model 2000 Flo-Mate Portable Water Flow meter, velocity and depth measurements are made at points along the tape. Normally depth is measured using a rod calibrated in tenths of a foot. In shallow streams, a yardstick may be used to measure depth. Velocities are measured at approximately 0.6 depth (from the surface) where depths are less than 2.5 feet and at 0.2 and 0.8 depth (from the surface) in areas where the depth exceeds 2.5 feet.

3. The stream cross section is divided into segments with depth and velocity measurements made at equal intervals along the cross section. The number of measurements will vary with site conditions and uniformity of stream cross section. Each cross section is divided into equal parts depending upon the total width and uniformity of the section. At a minimum, velocities are taken at quarter points for very narrow sections. In general, velocity and depth measurements are taken every one to five feet. A minimum of ten velocity locations is used whenever possible. The velocity is determined by direct readout from the Marsh-McBirney meter set for 5 second velocity averaging.

4. Using the field data collected, total flow, average velocity, and average depth can be computed. Individual partial cross-sectional areas are computed for each depth and velocity measurement. The mean velocity of flow in each partial area is computed and multiplied by the partial cross-sectional area to produce an incremental flow. Incremental flows are summed to calculate the total flow. The average velocity for the stream can be computed by dividing the total flow by the sum of the partial cross-sectional areas. The average depth for the stream can be computed by dividing the sum of the partial cross-sectional areas by the total width of the stream. The accuracy of this method depends upon a number of factors, which include the uniformity of the steam bottom, total width, and the uniformity of the velocity profile.

   - Flow measurements will be collected for all sampling events. However, in accordance with the Field Sampling Procedures Manual (See Section 6.8.1.1, Chapter 6D – page 59 of 188), field personnel will not wade into flowing water when the product of depth (in feet) and velocity (in feet per second) equals ten or greater. All scheduling is subject to the natural occurrence of appropriate stream flow conditions (i.e., non-flooding conditions) to ensure the health and safety of all field personnel. If the stream flow conditions preclude entry into the stream, flow will have to be estimated or calculated based on the recorded flow at the closest USGS gaging station and the drainage area.

ATTACHMENT D

Table 1A – List of Approved Biological Methods
&
Table 1B – List of Approved Inorganic Test Procedures
40 CFR Part 136.3
July 1, 2005

TABLE IA—LIST OF APPROVED BIOLOGICAL METHODS

Parameter and units	Method[1]	EPA	Standard methods 18th, 19th, 20th Ed.	ASTM	AOAC	USGS	Other
Bacteria:							
1. Coliform (fecal), number per 100 mL.	Most Probable Number (MPN), 5 tube 3 dilution, or	p. 132[3]	9221C E[4]				
	Membrane filter (MF)[2], single step.	p. 124[3]	9222D[4]			B–0050–85[5]	
2. Coliform (fecal) in presence of chlorine, number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 132[3]	9221C E[4]				
	MF, single step[6]	p. 124[3]	9222D[4]				
3. Coliform (total), number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221B[4]				
	MF[2], single step or two step	p. 108[3]	9222B[4]	......	......	B–0025–85[5]	
4. Coliform (total), in presence of chlorine, number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221B[4]				
	MF[2] with enrichment	p. 111[3]	9222(B+B.5c)[4]				
5. *E. coli*, number per 100 mL[28].	MPN[7,9,15], multiple tube, ...		9221B.1/9221F[4,12,14]				
	multiple tube/multiple well,		9223B[4,13]	......	991.15[11]	......	Colilert®[13,17] Colilert-18®[13,16,17]
	MF[2,6,7,8,9] two step, or	1103.1[20]	9222B/9222G[4,19] 9213D[4]	D5392–93[10]			
	single step	1603[21] 1604[22]					mColiBue 24[18]
6. Fecal streptococci, number per 100 mL.	MPN, 5 tube, 3 dilution,	p. 139[3]	9230B[4], 9230C[4]				
	MF[2], or	p. 136[3]	......	......	B–0055–85[5]		
	Plate count	p. 143[4]					
7. Enterococci, number per 100 mL.	MPN[7,9] multiple tube	......	9230B[4]				
	multiple tube/multiple well	......	......	D6503–99[10]	......	......	Enterolert®[13,23]
	MF[2,6,7,8,9] two step	1106.1[24]	9230C[4]	D5259–92[10]			
	single step, or	1600[25]					
	Plate count	p. 143[3]					
Protozoa:							
8. *Cryptosporidium*[28]	Filtration/IMS/FA	1622[26] 1623[27]					
9. *Giardia*[28]	Filtration/IMS/FA	1623[27]					
Aquatic Toxicity:							
10. Toxicity, acute, fresh water organisms, LC50, percent effluent.	*Ceriodaphnia dubia* acute	2002.0[29]					

	Sea urchin, *Arbacia punctulata*, fertilization	1006.0[31]					

Notes to Table IA:

[1] The method must be specified when results are reported.

[2] A 0.45 μm membrane filter (MF) or other pore size certified by the manufacturer to fully retain organisms to be cultivated and to be free of extractables which could interfere with their growth.

[3] USEPA. 1978. Microbiological Methods for Monitoring the Environment, Water, and Wastes. Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA/600/8–78/017.

[4] APHA. 1998, 1995, 1992. Standard Methods for the Examination of Water and Wastewater. American Public Health Association. 20th, 19th, and 18th Editions. Amer. Publ. Hlth. Assoc., Washington, D.C.

[5] USGS. 1989. U.S. Geological Survey Techniques of Water-Resource Investigations, Book 5, Laboratory Analysis, Chapter A4, Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples, U.S. Geological Survey, U.S. Department of Interior, Reston, Virginia.

[6] Because the MF technique usually yields low and variable recovery from chlorinated wastewaters, the Most Probable Number method will be required to resolve any controversies.

[7] Tests must be conducted to provide organism enumeration (density). Select the appropriate configuration of tubes/filtrations and dilutions/volumes to account for the quality, character, consistency, and anticipated organism density of the water sample.

[8] When the MF method has not been used previously to test ambient waters with high turbidity, large number of noncoliform bacteria, or samples that may contain organisms stressed by chlorine, a parallel test should be conducted with a multiple-tube technique to demonstrate applicability and comparability of results.

[9] To assess the comparability of results obtained with individual methods, it is suggested that side-by-side tests be conducted across seasons of the year with the water samples routinely tested in accordance with the most current Standard Methods for the Examination of Water and Wastewater or EPA alternate test procedure (ATP) guidelines.

[10] ASTM. 2000, 1999, 1996. Annual Book of ASTM Standards—Water and Environmental Technology. Section 11.02. American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken, PA 19428.

[11] AOAC. 1995. Official Methods of Analysis of AOAC International, 16th Edition, Volume I, Chapter 17. Association of Official Analytical Chemists International. 481 North Frederick Avenue, Suite 500, Gaithersburg, Maryland 20877–2417.

[12] The multiple-tube fermentation test is used in 9221B.1. Lactose broth may be used in lieu of lauryl tryptose broth (LTB), if at least 25 parallel tests are conducted between this broth and LTB using the water samples normally tested, and this comparison demonstrates that the false-positive rate and false-negative rate for total coliform using lactose broth is less than 10 percent. No requirement exists to run the completed phase on 10 percent of all total coliform-positive tubes on a seasonal basis.

[13] These tests are collectively known as defined enzyme substrate tests, where, for example, a substrate is used to detect the enzyme β-glucuronidase produced by *E. coli*.

[14] After prior enrichment in a presumptive medium for total coliform using 9221B.1, all presumptive tubes or bottles showing any amount of gas, growth or acidity within 48 h ± 3 h of incubation shall be submitted to 9221F. Commercially available EC-MUG media or EC media supplemented in the laboratory with 50 μg/mL of MUG may be used.

[15] Samples shall be enumerated by the multiple-tube or multiple-well procedure. Using multiple-tube procedures, employ an appropriate tube and dilution configuration of the sample as needed and report the Most Probable Number (MPN). Samples tested with Colilert® may be enumerated with the multiple-well procedures, Quanti-Tray® or Quanti-Tray® 2000, and the MPN calculated from the table provided by the manufacturer.

[16] Colilert-18® is an optimized formulation of the Colilert® for the determination of total coliforms and *E. coli* that provides results within 18 h of incubation at 35 °C rather than the 24 h required for the Colilert® test and is recommended for marine water samples.

[17] Descriptions of the Colilert®, Colilert-18®, Quanti-Tray®, and Quanti-Tray®/2000 may be obtained from IDEXX Laboratories, Inc., One IDEXX Drive, Westbrook, Maine 04092.

[18] A description of the mColiBlue24" test, Total Coliforms and *E. coli*, is available from Hach Company, 100 Dayton Ave., Ames, IA 50010.

[19] Subject total coliform positive samples determined by 9222B or other membrane filter procedure to 9222G using NA-MUG media.

[20] USEPA. 2002. Method 1103.1: *Escherichia coli* (*E. coli*) In Water By Membrane Filtration Using membrane-Thermotolerant *Escherichia coli* Agar (mTEC). U.S. Environmental Protection Agency, Office of Water, Washington D.C. EPA–821–R–02–020.

[21] USEPA. 2002. Method 1603: *Escherichia coli* (*E. coli*) In Water By Membrane Filtration Using Modified membrane-Thermotolerant *Escherichia coli* Agar (modified mTEC). U.S. Environmental Protection Agency, Office of Water, Washington D.C. EPA–821–R–02–023.

[22] Preparation and use of MI agar with a standard membrane filter procedure is set forth in the article, Brenner *et al.* 1993. "New Medium for the Simultaneous Detection of Total Coliform and *Escherichia coli* in Water." Appl. Environ. Microbiol. 59:3534–3544 and in USEPA. 2002. Method 1604: Total Coliforms and *Escherichia coli* (*E. coli*) in Water by Membrane Filtration by Using a Simultaneous Detection Technique (MI Medium). U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA 821–R–02–024.

[23] A description of the Enterolert® test may be obtained from IDEXX Laboratories, Inc., One IDEXX Drive, Westbrook, Maine 04092.

[24] USEPA. 2002. Method 1106.1: Enterococci In Water By Membrane Filtration Using membrane-Enterococcus-Esculin Iron Agar (mE-EIA). U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–02–021.

[25] USEPA. 2002. Method 1600: Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA–821–R–02–022.

[26] Method 1622 uses filtration, concentration, immunomagnetic separation of oocysts from captured material, immunofluorescence assay to determine concentrations, and confirmation through vital dye staining and differential interference contrast microscopy for the detection of *Cryptosporidium*. USEPA. 2001. Method 1622: Cryptosporidium in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–01–026.

[27] Method 1623 uses filtration, concentration, immunomagnetic separation of oocysts and cysts from captured material, immunofluorescence assay to determine concentrations, and confirmation through vital dye staining and differential interference contrast microscopy for the simultaneous detection of *Cryptosporidium* and *Giardia* oocysts and cysts. USEPA. 2001. Method 1623: Cryptosporidium and Giardia in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–01–025.

[28] Recommended for enumeration of target organism in ambient water only.

[29] USEPA. October 2002. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fifth Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/012.

[30] USEPA. October 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Fourth Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/013.

[31] USEPA. October 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms. Third Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/014.

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES

Parameter, units and method	Reference (method number or page)				
	EPA[1,35]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
1. Acidity, as $CaCO_3$, mg/L:					
Electrometric endpoint or phenolphthalein endpoint.	305.1	2310 B(4a) [18th, 19th, 20th].	D1067–92	I–1020–85	
				I–2030–85	
2. Alkalinity, as $CaCO_3$, mg/L:					
Electrometric of Colorimetric titration to pH 4.5, manual or automatic.	310.1	2320 B [18th, 19th, 20th]	D1067–92	I–1030–85	973.43[3]
	310.2.			I–2030–85	
3. Aluminium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	202.1	3111 D [18th, 19th]		I–3051–85	
AA furnace	202.2	3113 B [18th, 19th].			
Inductively Coupled Plasma/Atomic Emission Spectrometry (ICP/AES)[36].	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
Direct Current Plasma (DCP)[36].			D4190–94		Note 34.
Colorimetric (Eriochrome cyanine R).		3500–Al B [20th] and 3500–Al D [18th, 19th].			
4. Ammonia (as N), mg/L:					
Manual, distillation (at pH 9.5)[6] followed by.	350.2	4500–NH_3 B [18th, 19th, 20th].			973.49[3]
Nesslerization	350.2	4500–NH_3 C [18th]	D1426–98(A)	I–3520–85	973.49[3]
Titration	350.2	4500–NH_3 C [19th, 20th] and 4500–NH_3 E [18th].			
Electrode	350.3	4500–NH_3 D or E [19th, 20th] and 4500–NH_3 F or G [18th].	D1426–98(B).		
Automated phenate, or	350.1	4500–NH_3 G [19th, 20th] and 4500–NH_3 H [18th].		I–4523–85	
Automated electrode					Note 7.
5. Antimony-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	204.1	3111 B [18th, 19th]			
AA furnace	204.2	3113 B [18th, 19th]			
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]			
6. Arsenic-Total[4] mg/L:					

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES—Continued

Parameter, units and method	Reference (method number or page)				
	EPA[1,35]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
Titrimetric (EDTA), or Ca plus Mg as their carbonates, by inductively coupled plasma or AA direct aspiration (See Parameters 13 and 33)	130.2	2340 B or C [18th, 19th, 20th]	D1126–86(92)	I–1338–85	973.52B[3]
28. Hydrogen ion (pH), pH units:					
Electrometric measurement, or	150.1	4500–H^+ B [18th, 19th, 20th]	D1293–84 (90)(A or B)	I–1586–85	973.41[3]
Automated electrode				I–2587–85	Note 21.
29. Iridium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration or	235.1	3111 B [18th, 19th]			
AA furnace	235.2				
30. Iron—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	236.1	3111 B or C [18th, 19th]	D1068–96(A or B)	I–3381–85	974.27[3]
AA furnace	236.2	3113 B [18th, 19th]	D1068–96(C)		
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36] or			D4190–94		Note 34.
Colorimetric (Phenanthroline)		3500–Fe B [20th] and 3500–Fe D [18th, 19th].	D1068–96(D)		Note 22.
31. Kjeldahl Nitrogen—Total, (as N), mg/L:					
Digestion and distillation followed by:	351.3	4500–N_{org} B or C and 4500–NH_3 B [18th, 19th, 20th]	D3590–89(A)		
Titration	351.3		D3590–89(A)		973.48[3]
Nesslerization	351.3	4500–NH_3 C [18th]	D3590–89(A)		
Electrode	351.3	4500–NH_3 C [19th, 20th] and 4500–NH_3 E [18th].			
Automated phenate colorimetric	351.1			I–4551–78[8]	
Semi-automated block digestor colorimetric.	351.2		D3590–89(B)	I–4515–91[45]	
Manual or block digestor potentiometric.	351.4		D3590–89(A)		
Block digester, followed by Auto distillation and Titration, or.					Note 39.
Nesslerization, or					Note 40.
Flow injection gas diffusion					Note 41.
32. Lead—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	239.1	3111 B or C [18th, 19th]	D3559–96(A or B)	I–3399–85	974.27[3]

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AA furnace	239.2	3113 B [18th, 19th]	D3559–96(D)	I–4403–89[51]	
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36]			D4190–94		Note 34.
Voltametry[11] or			D3559–96(C)		
Colorimetric (Dithizone)		3500–Pb B [20th] and 3500–Pb D [18th, 19th].			
33. Magnesium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	242.1	3111 B [18th, 19th]	D511–93(B)	I–3447–85	974.27[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP or					Note 34.
Gravimetric		3500–Mg D [18th, 19th]			
34. Manganese-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	243.1	3111 B [18th, 19th]	D858–95(A or B)	I–3454–85	974.27[3]
AA furnace	243.2	3113 B [18th, 19th]	D858–95(C)		
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36], or			D4190–94		Note 34.
Colorimetric (Persulfate), or		3500–Mn B [20th] and 3500–Mn D [18th, 19th].			920.203[3]
(Periodate)					Note 23.
35. Mercury—Total,[4] mg/L:					
Cold vapor, manual or	245.1	3112 B [18th, 19th]	D3223–91	I–3462–85	977.22[3]
Automated	245.2				
Oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry (ng/L).	1631E[43]				
36. Molybdenum—Total[4], mg/L; Digestion[4] followed by:					
AA direct aspiration	246.1	3111 D [18th, 19th]		I–3490–85	
AA furnace	246.2	3113 B [18th, 19th]		I–3492–96[47]	
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP					Note 34.
37. Nickel—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	249.1	3111 B or C [18th, 19th]	D1886–90(A or B)	I–3499–85.	
AA furnace	249.2	3113 B [18th, 19th]	D1886–90(C)	I–4503–89[51].	
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP[36], or			D4190–94		Note 34.
Colorimetric (heptoxime)		3500–Ni D [17th].			
38. Nitrate (as N), mg/L:					
Colorimetric (Brucine sulfate), or Nitrate-nitrite N minus Nitrite N (See parameters 39 and 40).	352.1				973.50,[3] 419D,[17] p. 28[9]
39. Nitrate-nitrite (as N), mg/L:					
Cadmium reduction, Manual or.	353.3	4500–NO_3^-E [18th, 19th, 20th].	D3867–99(B).		

Nitrate: EPA 300.0;
Ion Chromatography

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TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES—Continued

Parameter, units and method	Reference (method number or page)				
	EPA[1,35]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
Automated, or	353.2	$4500–NO_3^-$ F [18th, 19th, 20th]	D3867–99(A)	I–4545–85.	
Automated hydrazine	353.1	$4500–NO_3^-$ H [18th, 19th, 20th].			
40. Nitrite (as N), mg/L Spectrophotometric:					
Manual or	354.1	$4500–NO_2^-$ B [18th, 19th, 20th].			Note 25.
Automated (Diazotization)				I–4540–85.	
41. Oil and grease—Total recoverable, mg/L:					
Gravimetric (extraction)	413.1	5520B [18th, 19th, 20th][38].			
Oil and grease and non-polar material, mg/L: Hexane extractable material (HEM): n-Hexane extraction and gravimetry.	1664A[42]	5520B [18th, 19th, 20th][38].			
Silica gel treated HEM (SGT-HEM): Silica gel treatment and gravimetry.	1664A[42].				
42. Organic carbon—Total (TOC), mg/L:					
Combustion or oxidation	415.1	5310 B, C, or D [18th, 19th, 20th].	D2579–93 (A or B)		973.47,[3] p. 14[24]
43. Organic nitrogen (as N), mg/L:					
Total Kjeldahl N (Parameter 31) minus ammonia N (Parameter 4)					
44. Orthophosphate (as P), mg/L Ascorbic acid method:					
Automated or	365.1	4500–P F [18th, 19th, 20th]		I–4601–85	973.56[3]
Manual single reagent	365.2	4500–P E [18th, 19th, 20th]	D515–88(A)		973.55[3]
Manual two reagent	365.3.				
45. Osmium—Total[4], mg/L; Digestion[4] followed by:					
AA direct aspiration, or	252.1	3111 D [18th, 19th].			
AA furnace	252.2.				
46. Oxygen, dissolved, mg/L:					
Winkler (Azide modification), or	360.2	4500–O C [18th, 19th, 20th]	D888–92(A)	I–1575–78[8]	973.45B[3]
Electrode	360.1	4500–O G [18th, 19th, 20th].	D888–92(B)	I–1576–78[8].	

Nitrite: EPA 300.0,
Ion Chromatography

47. Palladium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	253.1	3111 B [18th, 19th]			p. S27[10]
AA furnace	253.2				p. S28[10]
DCP					Note 34.
48. Phenols, mg/L:					
Manual distillation[26]	420.1				Note 27.
Followed by:					
Colorimetric (4AAP) manual, or	420.1				Note 27.
Automated[19]	420.2.				
49. Phosphorus (elemental), mg/L:					
Gas-liquid chromatography					Note 28.
50. Phosphorus—Total, mg/L:					
Persulfate digestion followed by.	365.2	4500–P B, 5 [18th, 19th, 20th]			973.55[3]
Manual or	365.2 or 365.3	4500–P E [18th, 19th, 20th]	D515–88(A)		
Automated ascorbic acid reduction.	365.1	4500–P F [18th, 19th, 20th]		I–4600–85	973.56[3]
Semi-automated block digestor.	365.4		D515–88(B)	I–4610–91[48].	
51. Platinum—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	255.1	3111 B [18th, 19th].			
AA furnace	255.2.				
DCP					Note 34
52. Potassium—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	258.1	3111 B [18th, 19th]		I–3630–85	973.53[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
Flame photometric, or		3500–K B [20th] and 3500–K D [18th, 19th].			
Colorimetric					317 B[17]
53. Residue—Total, mg/L:					
Gravimetric, 103–105°	160.3	2540 B [18th, 19th, 20th]		I–3750–85.	
54. Residue—filterable, mg/L:					
Gravimetric, 180°	160.1	2540 C [18th, 19th, 20th]		I–1750–85.	
55. Residue—nonfilterable (TSS), mg/L:					
Gravimetric, 103–105° post washing of residue.	160.2	2540 D [18th, 19th, 20th]		I–3765–85.	
56. Residue—settleable, mg/L:					
Volumetric, (Imhoff cone), or gravimetric.	160.5	2540 F [18th, 19th, 20th].			
57. Residue—Volatile, mg/L:					
Gravimetric, 550°	160.4			I–3753–85.	
58. Rhodium-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	265.1	3111 B [18th, 19th].			

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Colorimetric (methylene blue).	376.2	4500–S^{-2}D [18th, 19th, 20th].			
67. Sulfite (as SO_3), mg/L:					
Titrimetric (iodine-iodate)	377.1	4500–$SO_3$$^{-2}$B [18th, 19th, 20th].			
68. Surfactants, mg/L:					
Colorimetric (methylene blue).	425.1	5540 C [18th, 19th, 20th]	D2330–88.		
69. Temperature, °C:					
Thermometric	170.1	2550 B [18th, 19th, 20th]			Note 32.
70. Thallium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	279.1	3111 B [18th, 19th].			
AA furnace	279.2.				
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
71. Tin—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	282.1	3111 B [18th, 19th]		I–3850–78[8].	
AA furnace, or	282.2	3113 B [18th, 19th].			
ICP/AES	200.7[5].				
72. Titanium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	283.1	3111 D [18th, 19th].			
AA furnace	283.2.				
DCP					Note 34.
73. Turbidity, NTU:					
Nephelometric	180.1	2130 B [18th, 19th, 20th]	D1889–94(A)	I–3860–85.	
74. Vanadium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	286.1	3111 D [18th, 19th].			
AA furnace	286.2		D3373–93.		
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP, or			D4190–94		Note 34.
Colorimetric (Gallic Acid)		3500–V B [20th] and 3500–V D [18th, 19th].			
75. Zinc—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	289.1	3111 B or C [18th, 19th]	D1691–95(A or B)	I–3900–85	974.27,[3] p. 37[9]
AA furnace	289.2.				
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP,[36] or			D4190–94		Note 34.
Colorimetric (Dithizone) or		3500–Zn E [18th, 19th].			
(Zincon)		3500–Zn B [20th] and 3500–Zn F [18th, 19th].			Note 33.

Table 1B Notes:

[1] "Methods for Chemical Analysis of Water and Wastes," Environmental Protection Agency, Environmental Monitoring Systems Laboratory—Cincinnati (EMSL-CI), EPA–600/4–79–020, Revised March 1983 and 1979 where applicable.

[2] Fishman, M.J., *et al.* "Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments," U.S. Department of the Interior, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Denver, CO, Revised 1989, unless otherwise stated.

[3] "Official Methods of Analysis of the Association of Official Analytical Chemists," methods manual, 15th ed. (1990).

[4] For the determination of total metals the sample is not filtered before processing. A digestion procedure is required to solubilize suspended material and to destroy possible organic-metal complexes. Two digestion procedures are given in "Methods for Chemical Analysis of Water and Wastes, 1979 and 1983". One (Section 4.1.3), is a vigorous digestion using nitric acid. A less vigorous digestion using nitric and hydrochloric acids (Section 4.1.4) is preferred; however, the analyst should be cautioned that this mild digestion may not suffice for all samples types. Particularly, if a colorimetric procedure is to be employed, it is necessary to ensure that all organo-metallic bonds be broken so that the metal is in a reactive state. In those situations, the vigorous digestion is to be preferred making certain that at no time does the sample go to dryness. Samples containing large amounts of organic materials may also benefit by this vigorous digestion, however, vigorous digestion with concentrated nitric acid will convert antimony and tin to insoluble oxides and render them unavailable for analysis. Use of ICP/AES as well as determinations for certain elements such as antimony, arsenic, the noble metals, mercury, selenium, silver, tin, and titanium require a modified sample digestion procedure and in all cases the method write-up should be consulted for specific instructions and/or cautions.

NOTE TO TABLE 1B NOTE 4: If the digestion procedure for direct aspiration AA included in one of the other approved references is different than the above, the EPA procedure must be used. Dissolved metals are defined as those constituents which will pass through a 0.45 micron membrane filter. Following filtration of the sample, the referenced procedure for total metals must be followed. Sample digestion of the filtrate for dissolved metals (or digestion of the original sample solution for total metals) may be omitted for AA (direct aspiration or graphite furnace) and ICP analyses, provided the sample solution to be analyzed meets the following criteria:

a. has a low COD (<20)

b. is visibly transparent with a turbidity measurement of 1 NTU or less

c. is colorless with no perceptible odor, and

d. is of one liquid phase and free of particulate or suspended matter following acidification.

[5] The full text of Method 200.7, "Inductively Coupled Plasma Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes," is given at Appendix C of this Part 136.

[6] Manual distillation is not required if comparability data on representative effluent samples are on company file to show that this preliminary distillation step is not necessary; however, manual distillation will be required to resolve any controversies.

[7] Ammonia, Automated Electrode Method, Industrial Method Number 379–75 WE, dated February 19, 1976, Bran & Luebbe (Technicon) Auto Analyzer II, Bran & Luebbe Analyzing Technologies, Inc., Elmsford, NY 10523.

[8] The approved method is that cited in "Methods for Determination of Inorganic Substances in Water and Fluvial Sediments", USGS TWRI, Book 5, Chapter A1 (1979).

[9] American National Standard on Photographic Processing Effluents, Apr. 2, 1975. Available from ANSI, 25 West 43rd Street, New York, NY 10036.

[10] "Selected Analytical Methods Approved and Cited by the United States Environmental Protection Agency", Supplement to the Fifteenth Edition of Standard Methods for the Examination of Water and Wastewater (1981).

[11] The use of normal and differential pulse voltage ramps to increase sensitivity and resolution is acceptable.

[12] Carbonaceous biochemical oxygen demand ($CBOD_5$) must not be confused with the traditional BOD_5 test method which measures "total BOD". The addition of the nitrification inhibitor is not a procedural option, but must be included to report the $CBOD_5$ parameter. A discharger whose permit requires reporting the traditional BOD_5 may not use a nitrification inhibitor in the procedure for reporting the results. Only when a discharger's permit specifically states $CBOD_5$ is required can the permittee report data using a nitrification inhibitor.

[13] OIC Chemical Oxygen Demand Method, Oceanography International Corporation, 1978, 512 West Loop, PO Box 2980, College Station, TX 77840.

[14] Chemical Oxygen Demand, Method 8000, Hach Handbook of Water Analysis, 1979, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[15] The back titration method will be used to resolve controversy.

[16] Orion Research Instruction Manual, Residual Chlorine Electrode Model 97–70, 1977, Orion Research Incorporated, 840 Memorial Drive, Cambridge, MA 02138. The calibration graph for the Orion residual chlorine method must be derived using a reagent blank and three standard solutions, containing 0.2, 1.0, and 5.0 mL 0.00281 N potassium iodate/100 mL solution, respectively.

[17] The approved method is that cited in Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1976.

[18] National Council of the Paper Industry for Air and Stream Improvement, Inc. Technical Bulletin 253, December 1971.

[19] Copper, Biocinchoinate Method, Method 8506, Hach Handbook of Water Analysis, 1979, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[20] After the manual distillation is completed, the autoanalyzer manifolds in EPA Methods 335.3 (cyanide) or 420.2 (phenols) are simplified by connecting the re-sample line directly to the sampler. When using the manifold setup shown in Method 335.3, the buffer 6.2 should be replaced with the buffer 7.6 found in Method 335.2.

[21] Hydrogen ion (pH) Automated Electrode Method, Industrial Method Number 378–75WA, October 1976, Bran & Luebbe (Technicon) Autoanalyzer II. Bran & Luebbe Analyzing Technologies, Inc., Elmsford, NY 10523.

[22] Iron, 1,10-Phenanthroline Method, Method 8008, 1980, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[23] Manganese, Periodate Oxidation Method, Method 8034, Hach Handbook of Wastewater Analysis, 1979, pages 2–113 and 2–117, Hach Chemical Company, Loveland, CO 80537.

[24] Wershaw, R.L., *et al*, "Methods for Analysis of Organic Substances in Water," Techniques of Water-Resources Investigation of the U.S. Geological Survey, Book 5, Chapter A3, (1972 Revised 1987) p. 14.

[25] Nitrogen, Nitrite, Method 8507, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[26] Just prior to distillation, adjust the sulfuric-acid-preserved sample to pH 4 with 1 + 9 NaOH.

[27] The approved method is cited in Standard Methods for the Examination of Water and Wastewater, 14th Edition. The colorimetric reaction is conducted at a pH of 10.0±0.2. The approved methods are given on pp 576–81 of the 14th Edition: Method 510A for distillation, Method 510B for the manual colorimetric procedure, or Method 510C for the manual spectrometric procedure.

[28] R.F. Addison and R.G. Ackman, "Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography," Journal of Chromatography, Vol. 47, No. 3, pp. 421–426, 1970.

[29] Approved methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/L and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to pH of 12. Therefore, for levels of silver above 1 mg/L, 20 mL of sample should be diluted to 100 mL by adding 40 mL each of 2 M $Na_2S_2O_3$ and NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/L the approved method is satisfactory.

[30] The approved method is that cited in Standard Methods for the Examination of Water and Wastewater, 15th Edition.

[31] EPA Methods 335.2 and 335.3 require the NaOH absorber solution final concentration to be adjusted to 0.25 N before colorimetric determination of total cyanide.

[32] Stevens, H.H., Ficke, J.F., and Smoot, G.F., "Water Temperature—Influential Factors, Field Measurement and Data Presentation," Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 1, Chapter D1, 1975.

[33] Zinc, Zincon Method, Method 8009, Hach Handbook of Water Analysis, 1979, pages 2–231 and 2–333, Hach Chemical Company, Loveland, CO 80537.

[34] "Direct Current Plasma (DCP) Optical Emission Spectrometric Method for Trace Elemental Analysis of Water and Wastes, Method AES0029," 1986—Revised 1991, Thermo Jarrell Ash Corporation, 27 Forge Parkway, Franklin, MA 02038.

[35] Precision and recovery statements for the atomic absorption direct aspiration and graphite furnace methods, and for the spectrophotometric SDDC method for arsenic are provided in Appendix D of this part titled, "Precision and Recovery Statements for Methods for Measuring Metals".

[36] "Closed Vessel Microwave Digestion of Wastewater Samples for Determination of Metals", CEM Corporation, PO Box 200, Matthews, NC 28106–0200, April 16, 1992. Available from the CEM Corporation.

[37] When determining boron and silica, only plastic, PTFE, or quartz laboratory ware may be used from start until completion of analysis.

[38] Only use Trichlorotrifluorethane (1,1,2-trichloro-1,2,2-trifluoroethane; CFC–113) extraction solvent when determining Total Recoverable Oil and Grease (analogous to EPA Method 413.1). Only use *n*-hexane extraction solvent when determining Hexane Extractable Material (analogous to EPA Method 1664A). Use of other extraction solvents is strictly prohibited.

[39] Nitrogen, Total Kjeldahl, Method PAI-DK01 (Block Digestion, Steam Distillation, Titrimetric Detection), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.

[40] Nitrogen, Total Kjeldahl, Method PAI-DK02 (Block Digestion, Steam Distillation, Colorimetric Detection), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.

[41] Nitrogen, Total Kjeldahl, Method PAI-DK03 (Block Digestion, Automated FIA Gas Diffusion), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.

[42] Method 1664, Revision A "n-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated n-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry" EPA–821–R–98–002, February 1999. Available at NTIS, PB–121949, U.S. Department of Commerce, 5285 Port Royal, Springfield, Virginia 22161.

[43] USEPA. 2002. Method 1631, Revision E, "Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry," September 2002, Office of Water, U.S. Environmental Protection Agency (EPA–821–R–02–019). The application of clean techniques described in EPA's draft Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels (EPA–821–R–96–011) are recommended to preclude contamination at low-level, trace metal determinations.

[44] Available Cyanide, Method OIA–1677 (Available Cyanide by Flow Injection, Ligand Exchange, and Amperometry), ALPKEM, A Division of OI Analytical, PO Box 9010, College Station, TX 77842–9010.

[45] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Ammonia Plus Organic Nitrogen by a Kjeldahl Digestion Method", Open File Report (OFR) 00–170.

[46] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Chromium in Water by Graphite Furnace Atomic Absorption Spectrophotometry", Open File Report (OFR) 93–449.

[47] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Molybdenum by Graphite Furnace Atomic Absorption Spectrophotometry", Open File Report (OFR) 97–198.

[48] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Total Phosphorus by Kjeldahl Digestion Method and an Automated Colorimetric Finish That Includes Dialysis" Open File Report (OFR) 92–146.

[49] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Arsenic and Selenium in Water and Sediment by Graphite Furnace-Atomic Absorption Spectrometry" Open File Report (OFR) 98–639.

[50] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Elements in Whole-water Digests Using Inductively Coupled Plasma-Optical Emission Spectrometry and Inductively Coupled Plasma-Mass Spectrometry", Open File Report (OFR) 98–165.

[51] "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Inorganic and Organic Constituents in Water and Fluvial Sediment", Open File Report (OFR) 93–125.

TABLE IC—LIST OF APPROVED TEST PROCEDURES FOR NON-PESTICIDE ORGANIC COMPOUNDS

Parameter [1]	EPA method number [2,7]			Other approved methods		
	GC	GC/MS	HPLC	*Standard Methods* [Edition(s)]	ASTM	Other
1. Acenaphthene	610	625, 1625B	610	6440 B [18th, 19th 20th]	D4657–92	Note 9, p. 27.
2. Acenaphthylene	610	625, 1625B	610	6440 B, 6410 B [18th, 19th, 20th]	D4657–92	Note 9, p. 27.
3. Acrolein	603	624[4], 1624B				
4. Acrylonitrile	603	624[4], 1624B				
5. Anthracene	610	625, 1625B	610	6410 B, 6440 B [18th, 19th, 20th]	D4657–92	Note 9, p. 27.

ATTACHMENT E

Table II - Required Containers, Preservation Techniques, and Holding Times
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July 1, 2005

3544. Available from the American Society for Microbiology, 1752 N Street NW., Washington, DC 20036. Table IA, Note 22.

(58) USEPA. 2002. Method 1604: Total Coliforms and *Escherichia coli (E. coli)* in Water by Membrane Filtration using a Simultaneous Detection Technique (MI Medium). U.S. Environmental Protection Agency, Office of Water, Washington D.C. September 2002, EPA 821–R–02–024. Available from NTIS, PB2003–100129. Table IA, Note 22.

(59) USEPA. 2002. Method 1600: Enterococci in Water by Membrane Filtration using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). U.S. Environmental Protection Agency, Office of Water, Washington D.C. September 2002, EPA–821–R–02–022. Available from NTIS, PB2003–100127. Table IA, Note 25.

(60) USEPA. 2001. Method 1622: *Cryptosporidium* in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington, DC April 2001, EPA–821–R–01–026.

Available from NTIS, PB2002–108709. Table IA, Note 26.

(61) USEPA. 2001. Method 1623: *Cryptosporidium* and *Giardia* in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington, DC April 2001, EPA–821–R–01–025. Available from NTIS, PB2002–108710. Table IA, Note 27.

(62) AOAC. 1995. Official Methods of Analysis of AOAC International, 16th Edition, Volume I, Chapter 17. AOAC International. 481 North Frederick Avenue, Suite 500, Gaithersburg, Maryland 20877–2417. Table IA, Note 11.

(c) Under certain circumstances the Regional Administrator or the Director in the Region or State where the discharge will occur may determine for a particular discharge that additional parameters or pollutants must be reported. Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator, or the Director upon the recommendation of the Director of the Environmental Monitoring Systems Laboratory—Cincinnati.

(d) Under certain circumstances, the Administrator may approve, upon recommendation by the Director, Environmental Monitoring Systems Laboratory—Cincinnati, additional alternate test procedures for nationwide use.

(e) Sample preservation procedures, container materials, and maximum allowable holding times for parameters cited in Tables IA, IB, IC, ID, and IE are prescribed in Table II. Any person may apply for a variance from the prescribed preservation techniques, container materials, and maximum holding times applicable to samples taken from a specific discharge. Applications for variances may be made by letters to the Regional Administrator in the Region in which the discharge will occur. Sufficient data should be provided to assure such variance does not adversely affect the integrity of the sample. Such data will be forwarded, by the Regional Administrator, to the Director of the Environmental Monitoring Systems Laboratory—Cincinnati, Ohio for technical review and recommendations for action on the variance application. Upon receipt of the recommendations from the Director of the Environmental Monitoring Systems Laboratory, the Regional Administrator may grant a variance applicable to the specific charge to the applicant. A decision to approve or deny a variance will be made within 90 days of receipt of the application by the Regional Administrator.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Table IA—Bacteria Tests:			
1–5 Coliform, total, fecal, and *E. coli*	PP, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5].	6 hours.
6 Fecal *streptococci*	PP, G	Cool, <10° 0.0008% $Na_2S_2O_3$[5]	6 hours.
7 *Enterococci*	PP, G	Cool, <10° 0.0008% $Na_2S_2O_3$[5]	6 hours.
Table IA—Protozoa Tests:			
8 *Cryptosporidium*	LDPE	0–8 °C	96 hours.[17]
9 *Giardia*	LDPE	0–8 °C	96 hours.[17]
Table IA—Aquatic Toxicity Tests:			
6–10 Toxicity, acute and chronic	P,G	Cool, 4 °C[16]	36 hours.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Table IB—Inorganic Tests:			
1. Acidity	P, G	Cool, 4°C	14 days.
2. Alkalinity	P, G	......do	Do.
4. Ammonia	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
9. Biochemical oxygen demand	P, G	Cool, 4°C	48 hours.
10. Boron	P, PFTE, or Quartz.	HNO_3 TO pH<2	6 months.
11. Bromide	P, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous	P, G	Cool, 4°C	48 hours.
15. Chemical oxygen demand	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
16. Chloride	P, G	None required	Do.
17. Chlorine, total residual	P, G	......do	Analyze immediately.
21. Color	P, G	Cool, 4°C	48 hours.
23–24. Cyanide, total and amenable to chlorination.	P, G	Cool, 4°C, NaOH to pH>12, 0.6g ascorbic acid [5].	14 days.[6]
25. Fluoride	P	None required	28 days.
27. Hardness	P, G	HNO_3 to pH<2, H_2SO_4 to pH<2	6 months.
28. Hydrogen ion (pH)	P, G	None required	Analyze immediately.
31, 43. Kjeldahl and organic nitrogen	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
Metals:[7]			
18. Chromium VI[7]	P, G	Cool, 4 °C	24 hours.
35. Mercury[17]	P, G	HNO_3 to pH<2	28 days.
3, 5–8, 12,13, 19, 20, 22, 26, 29, 30, 32–34, 36, 37, 45, 47, 51, 52, 58–60, 62, 63, 70–72, 74, 75. Metals except boron, chromium VI and mercury[7].	P, G	do	6 months.
38. Nitrate	P, G	Cool, 4°C	48 hours.
39. Nitrate-nitrite	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
40. Nitrite	P, G	Cool, 4°C	48 hours.
41. Oil and grease	G	Cool to 4°C, HCl or H_2SO_4 to pH<2.	28 days.
42. Organic Carbon	P, G	Cool to 4 °C HC1 or H2SO4 or H3PO4, to pH<2.	28 days.
44. Orthophosphate	P, G	Filter immediately, Cool, 4°C	48 hours.
46. Oxygen, Dissolved Probe	G Bottle and top.	None required	Analyze immediately.
47. Winkler	......do	Fix on site and store in dark	8 hours.
48. Phenols	G only	Cool, 4°C, H_2SO_4 to pH<2	28 days.
49. Phosphorus (elemental)	G	Cool, 4°C	48 hours.
50. Phosphorus, total	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
53. Residue, total	P, G	Cool, 4°C	7 days.
54. Residue, Filterable	P, G	......do	7 days.
55. Residue, Nonfilterable (TSS)	P, G	......do	7 days.
56. Residue, Settleable	P, G	......do	48 hours.
57. Residue, volatile	P, G	......do	7 days.
61. Silica	P, PFTE, or Quartz.	Cool, 4 °C	28 days.
64. Specific conductance	P, G	......do	Do.
65. Sulfate	P, G	......do	Do.
66. Sulfide	P, G	Cool, 4°C add zinc acetate plus sodium hydroxide to pH>9.	7 days.
67. Sulfite	P, G	None required	Analyze immediately.
68. Surfactants	P ,G	Cool, 4°C	48 hours.
69. Temperature	P, G	None required	Analyze.
73. Turbidity	P, G	Cool, 4°C	48 hours.
Table IC—Organic Tests[8]			
13, 18–20, 22, 24–28, 34–37, 39–43, 45–47, 56, 76, 104, 105, 108–111, 113. Purgeable Halocarbons.	G, Teflon-lined septum.	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5].	14 days.
6, 57, 106. Purgeable aromatic hydrocarbons	......do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] HCl to pH2[9].	Do.
3, 4. Acrolein and acrylonitrile	......do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] adjust pH to 4–5[10].	Do.
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols[11].	G, Teflon-lined cap..	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction.
7, 38. Benzidines[11]	......do	......do	7 days until extraction.[13]
14, 17, 48, 50–52. Phthalate esters[11]	......do	Cool, 4 °C	7 days until extraction; 40 days after extraction.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
82–84. Nitrosamines[11,14]	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark	Do.
88–94. PCBs[11]	do	Cool, 4 °C	Do.
54, 55, 75, 79. Nitroaromatics and isophorone[11]	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark	Do.
1, 2, 5, 8–12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons[11]	do	do	Do.
15, 16, 21, 31, 87. Haloethers[11]	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5]	Do.
29, 35–37, 63–65, 73, 107. Chlorinated hydrocarbons[11]	do	Cool, 4 °C	Do.
60–62, 66–72, 85, 86, 95–97, 102, 103. CDDs/CDFs[11]			
aqueous: field and lab preservation	G	Cool, 0–4 °C, pH≤9, 0.008% $Na_2S_2O_3$[5]	1 year.
Solids, mixed phase, and tissue: field preservation	do	Cool, <4 °C	7 days.
Solids, mixed phase, and tissue: lab preservation	do	Freeze, ≤ −10 °C	1 year.
Table IC—Pesticides Tests:			
1–70. Pesticides[11]	do	Cool, 4°C, pH 5–9[15]	Do.
Table IE—Radiological Tests:			
1–5. Alpha, beta and radium	P, G	HNO_3 to pH<2	6 months.

Table II Notes

[1] Polyethylene (P) or glass (G). For microbiology, plastic sample containers must be made of sterilizable materials (polypropylene or other autoclavable plastic).

[2] Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4°C until compositing and sample splitting is completed.

[3] When any sample is to be shipped by common carrier or sent through the United States Mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under § 136.3(e). Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See § 136.3(e) for details. The term "analyze immediately" usually means within 15 minutes or less of sample collection.

[5] Should only be used in the presence of residual chlorine.

[6] Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

[7] Samples should be filtered immediately on-site before adding preservative for dissolved metals.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] Sample receiving no pH adjustment must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4°C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re the requirement for thiosulfate reduction of residual chlorine), and footnotes 12, 13 (re the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4 ûû0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16] Sufficient ice should be placed with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the 4C temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature can not be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature.

[17] Samples collected for the determination of trace level mercury (100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. Samples collected for dissolved trace level mercury should be filtered in the laboratory. However, if circumstances prevent overnight shipment, samples should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. Samples that have been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

ATTACHMENT F

Sample Chain of Custody Form

Bergen County Utilities Authority
PO Box 9
Little Ferry NJ 07643

ORDER ID:

CHAIN OF CUSTODY RECORD

	Permit / Site Number	Sampler's Initials	Received Date/Time

I/we certify that the samples below have not been out of our custody until relinquished. **RELINQUISHER(S) SIGNATURE:**	**Work Order Comments:**

Bottle Type	Preservation	pH	pH Check

Sample ID	Sample Type	Analysis	BCUA Bottle Type	Received by: (Initial)	Date	Time

Start Collect Date/Time:	**End Collect Date/Time:**

Sample Comments:

Page 1 of 1

ATTACHMENT G

Tables of Parameter Detection Limits, Accuracy, and Precision

Parameter Detection Limits, Quantitation Limits, Accuracy, and Precision

Parameter:	(Dissolved) Ortho-Phosphate (as P)	Total Phosphorous (as P)	Ammonia-Nitrogen	Nitrate-Nitrogen†	Nitrite - Nitrogen†	Total Kjeldahl Nitrogen	Total Suspended Solids	Total Dissolved Solids†
Referenced Methodology –(NJDEP Certified Methodology)	EPA 365.2	EPA 365.2	EPA 350.2	EPA 300.0	EPA 300.0	EPA 351.3	EPA 160.2	EPA 160.1
Technique Description	Ascorbic Acid, Manual Single Reagent	Persulfate Digestion + Manual	Distillation, Titration	Ion Chroma-tography	Ion Chroma-tography	Digestion, Distillation, Titration	Gravi-metric, 103-105˚C, Post Washing	Gravi-metric, 180˚C
Method Detection Limit (ppm) – Calculated	0.005	0.01	0.164	0.027	0.08	0.579	4	8.9
Instrument Detection Limit (ppm)	NA	NA	NA	NA	NA	NA	NA	NA
Project Detection Limit (ppm)	***0.015***	***0.03***	***0.5***	***0.27***	***0.8***	***1.8***	***12***	***10***
Quantitation Limit (ppm)	***0.015***	***0.03***	***0.5***	***0.27***	***0.8***	***1.8***	***12***	***10***
Accuracy (mean % recovery	98.2	99.6	103.4	90-110	90-110	101.6	NA	NA
Precision -% (mean – RPD	2.23	1.6	2.7	20	20	2.8	9.4	20
Accuracy Protocol (% recovery for LCL/UCL)	75.00 / 123.20	75.00 / 123.20	86.636 / 103.981	---	---	80.8 / 116.8	NA	---
Precision Protocol - % (maximum RPD)	4.7	4.9	4.6	---	---	5.13	28.6	---

RPD- Relative % Difference; NA-Not Applicable

Laboratory: Bergen County Utilities Authority – (NJDEP #02268)

†Laboratory: Hampton Clarke Veritech – (NJDEP #14622)

Parameter:	**pH (SU)**	**Temperature (°C)**	**Dissolved Oxygen (mg/L)**	**†Fecal Coliform**	**‡*Eschericia coli* (*E. coli*)**
Referenced Methodology – (NJDEP Certified Methodology)	Standard Methods 4500-H^+ B	Standard Methods 2550 B	Standard Methods 4500-O G	Standard Methods 9222D	EPA 1603
Technique Description	Electrometric	Thermometric	Electrode	Membrane Filter (MF), Single Step	Membrane Filter (modified mTEC)
Method Detection Limit (ppm)	NA	NA	NA	2 (col/ 100 ml)	<10 organisms per 100 ml
Instrument Detection Limit (ppm)	0.00-14.00 S.U.	0.0 to 100.0 °C	0 – 20 mg/L	NA	NA
Project Detection Limit (ppm)	0.00-14.00 S.U.	0.0 to 100.0 °C	0 - 20 mg/L	2 (col/ 100 ml)	<10 organisms per 100 ml
Quantitation Limit (ppm)	NA	NA	NA	2 (col/ 100 ml)	60,000 organisms per 100 ml
Accuracy (mean % recovery)	NA	NA	NA	NA	NA
Precision (mean – RPD)	± 0.01 S.U.	± 0.3 °C	± 0.3 mg/l	5.7	NA
Accuracy Protocol (% recovery for LCL/UCL)	NA	NA	NA	NA	Detect – 144%
Precision Protocol (maximum RPD)	± 0.01 S.U.	± 0.3 °C	± 0.3 mg/l	20.55	61%

RPD – Relative % Difference; NA – Not Applicable

Laboratory: Rutgers EcoComplex Laboratory (NJDEP #03019)

†Laboratory: Bergen County Utilities Authority (NJDEP #02268)

‡Laboratory: Garden State Laboratories, Inc. (NJDEP #20044)

LISA GALLOWAY EVRARD
Program Associate • Rutgers Cooperative Extension
14 College Farm Road • New Brunswick, NJ 08901-8551 • USA
Phone: 732/932-9800 x 6130 • Fax: 732/932-8644
evrard@rci.rutgers.edu

June 29, 2007

VIA E-MAIL
Michele Bakacs
Watershed Management Area 5 Manager
Division of Watershed Management
New Jersey Department of Environmental Protection
401 East State Street
P.O. Box 418
Trenton, NJ 08625

Re: Addendum to Quality Assurance Project Plans (QAPPs)
RP07-001 Tenakill Brook Watershed Restoration Plan
RP07-002 Musquapsink Brook Watershed Restoration Plan

Michele:

For both the Tenakill Brook and Musquapsink Brook Watershed Restoration Plans, the Bergen County Utilities Authority (BCUA) has requested that surface water samples be delivered to the BCUA laboratory (NJDEP Certified Laboratory #02268) by noon for analysis. To date, this has not been a problem for the biweekly surface water sampling and additional bacteriology sampling. However, it will be extremely difficult, if not impossible, to meet this sample drop-off requirement for the wet weather surface water sampling portion of these studies.

We would like to amend the QAPPs to reflect that for the wet weather surface water sampling portion of these studies Garden State Laboratories (NJDEP Certified Laboratory #20044) will be conducting the necessary water quality analyses. Garden State Laboratories is currently conducting the *E. coli* analyses for these studies, and they have more reasonable sample drop-off requirements, which will be suitable for the wet weather surface water sampling portion of these studies.

I have attached the following for you to review and for you to forward to the Office of Quality Assurance:

- Wet Weather Surface Water Sampling - Parameter Detection Limits, Quantitation Limits, Accuracy, and Precision
- Wet Weather Surface Water Sampling – Table 1A: List of Approved Biological Methods & Table 1B: List of Approved Inorganic Test Procedures, 40 CRF Part 136.3, July 1, 2005
- Wet Weather Surface Water Sampling – Table II: Required Containers, Preservation Techniques, and Holding Times, 40 CFR Part 136.3, July 1, 2005.

If you have any questions, please do not hesitate to contact me at evrard@rci.rutgers.edu or call me at 732-932-9800 x 6130. If for some reason we are not allowed to use Garden State Laboratories for the wet weather surface water sampling portion of the Musquapsink and Tenakill studies, please contact me, Katie Buckley at kbuckley@envsci.rutgers.edu, or Rob Miskewitz at rmiskewitz@aesop.rutgers.edu as soon as possible.

Thank you for your attention to this matter.

Sincerely,

Lisa Galloway Evrard
QAPP QA Officer

C: P. Rector
C. Obropta
K. Buckley
R. Miskewitz

Wet Weather Surface Water Sampling

Parameter Detection Limits, Quantitation Limits, Accuracy, and Precision

RP07-002 MUSQUAPSINK BROOK WATERSHED RESTORATION PLAN
&
RP07-001 TENAKILL BROOK WATERSHED RESTORATION PLAN

Wet Weather Surface Water Sampling
Parameter Detection Limits, Quantitation Limits, Accuracy, and Precision

Parameter:	(Dissolved) Ortho-Phosphate (as P)	Total Phosphorous (as P)	Ammonia-Nitrogen	Nitrate-Nitrogen	Nitrite - Nitrogen	Total Kjeldahl Nitrogen	Total Suspended Solids
Referenced Methodology –(NJDEP Certified Methodology)	Standard Methods 4500-P E	Standard Methods 4500-P E	Standard Methods 4500-NH_3 D	EPA 353.2	Standard Methods 4500-NO_2 B	LACHAT 10-107-06-2-D	Standard Methods 2540 D
Technique Description	Colorimetric	Persulfate Digestion + Manual	Electrode	Automated Cadmium Reduction	Spectro-photometric	Digestion, Distillation, Semiautomated Digestor	Gravi-metric, 103-105˚C, Post Washing
Method Detection Limit (ppm) – Calculated	0.008	0.010	0.018	0.010	0.0002	0.059	NA
Instrument Detection Limit (ppm)	0.01	0.01	0.05	0.20	0.005	0.50	NA
Project Detection Limit (ppm)	0.015	0.03	0.5	0.27	0.8	1.8	12
Quantitation Limit (ppm)	0.015	0.03	0.5	0.27	0.8	1.8	12
Accuracy (mean % recovery	100.8	93.7	99.2	103.9	98.6	89.9	NA
Precision -% (mean – RPD	1.20	0.56	1.75	0.72	1.32	1.50	3.85
Accuracy Protocol (% recovery for LCL/UCL)	90 / 110	90 / 110	90 / 110	90 / 110	90 / 110	90 / 110	90 / 110
Precision Protocol - % (maximum RPD)	10%	10%	10%	10%	10%	10%	10%

RPD- Relative % Difference; NA-Not Applicable

Laboratory: Garden State Laboratories, Inc. (NJDEP #20044)

Parameter:	†pH (SU)	†Temperature (°C)	†Dissolved Oxygen (mg/L)	Fecal Coliform	*Eschericia coli* (*E. coli*)
Referenced Methodology – (NJDEP Certified Methodology)	Standard Methods 4500-H^+ B	Standard Methods 2550 B	Standard Methods 4500-O G	Standard Methods 9222D	EPA 1603
Technique Description	Electrometric	Thermometric	Electrode	Membrane Filter (MF), Single Step	Membrane Filter (modified mTEC)
Method Detection Limit (ppm)	NA	NA	NA	<10 organisms per 100 ml	<10 organisms per 100 ml
Instrument Detection Limit (ppm)	0.00-14.00 S.U.	0.0 to 100.0 °C	0 – 20 mg/L	NA	NA
Project Detection Limit (ppm)	0.00-14.00 S.U.	0.0 to 100.0 °C	0 - 20 mg/L	--	<10 organisms per 100 ml
Quantitation Limit (ppm)	NA	NA	NA	--	60,000 organisms per 100 ml
Accuracy (mean % recovery)	NA	NA	NA	NA	NA
Precision (mean – RPD)	± 0.01 S.U.	± 0.3 °C	± 0.3 mg/l	NA	NA
Accuracy Protocol (% recovery for LCL/UCL)	NA	NA	NA	NA	Detect – 144%
Precision Protocol (maximum RPD)	± 0.01 S.U.	± 0.3 °C	± 0.3 mg/l	NA	61%

RPD – Relative % Difference; NA – Not Applicable

Laboratory: Garden State Laboratories, Inc. (NJDEP #20044)

†Laboratory: Rutgers EcoComplex Laboratory (NJDEP #03019)

Wet Weather Surface Water Sampling

Table 1A – List of Approved Biological Methods
&
Table 1B – List of Approved Inorganic Test Procedures
40 CFR Part 136.3
July 1, 2005

RP07-002 MUSQUAPSINK BROOK WATERSHED RESTORATION PLAN
&
RP07-001 TENAKILL BROOK WATERSHED RESTORATION PLAN

TABLE IA—LIST OF APPROVED BIOLOGICAL METHODS

Parameter and units	Method[1]	EPA	Standard methods 18th, 19th, 20th Ed.	ASTM	AOAC	USGS	Other
Bacteria:							
1. Coliform (fecal), number per 100 mL.	Most Probable Number (MPN), 5 tube 3 dilution, or	p. 132[3]	9221C E[4]				
	Membrane filter (MF)[2], single step	p. 124[3]	9222D[4]			B–0050–85[5]	
2. Coliform (fecal) in presence of chlorine, number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 132[3]	9221C E[4]				
	MF, single step[6]	p. 124[3]	9222D[4]				
3. Coliform (total), number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221B[4]				
	MF[2], single step or two step	p. 108[3]	9222B[4]			B–0025–85[5]	
4. Coliform (total), in presence of chlorine, number per 100 mL.	MPN, 5 tube, 3 dilution, or	p. 114[3]	9221B[4]				
	MF[2] with enrichment	p. 111[3]	9222(B+B.5c)[4]				
5. *E. coli*, number per 100 mL[28].	MPN[7,9,15], multiple tube,		9221B.1/9221F[4,12,14]				
	multiple tube/multiple well,		9223B[4,13]		991.15[11]		Colilert®[13,17] Colilert-18®[13,16,17]
	MF[2,6,7,8,9] two step, or	1103.1[20]	9222B/9222G[4,19] 9213D[4]	D5392–93[10]			
	single step	1603[21] 1604[22]					mColiBue 24[18]
6. Fecal streptococci, number per 100 mL.	MPN, 5 tube, 3 dilution,	p. 139[3]	9230B[4], 9230C[4]				
	MF[2], or	p. 136[3]			B–0055–85[5]		
	Plate count	p. 143[4]					
7. Enterococci, number per 100 mL.	MPN[7,9] multiple tube		9230B[4]				
	multiple tube/multiple well			D6503–99[10]			Enterolert®[13,23]
	MF[2,6,7,8,9] two step	1106.1[24]	9230C[4]	D5259–92[10]			
	single step, or	1600[25]					
	Plate count	p. 143[3]					
Protozoa:							
8. *Cryptosporidium*[28]	Filtration/IMS/FA	1622[26] 1623[27]					
9. *Giardia*[28]	Filtration/IMS/FA	1623[27]					
Aquatic Toxicity:							
10. Toxicity, acute, fresh water organisms, LC50, percent effluent.	*Ceriodaphnia dubia* acute	2002.0[29]					

	Sea urchin, *Arbacia punctulata*, fertilization	1008.0[31]				

Notes to Table IA

[1] The method must be specified when results are reported.

[2] A 0.45 µm membrane filter (MF) or other pore size certified by the manufacturer to fully retain organisms to be cultivated and to be free of extractables which could interfere with their growth.

[3] USEPA. 1978. Microbiological Methods for Monitoring the Environment, Water, and Wastes. Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio. EPA/600/8–78/017.

[4] APHA. 1998, 1995, 1992. Standard Methods for the Examination of Water and Wastewater. American Public Health Association. 20th, 19th, and 18th Editions. Amer. Publ. Hlth. Assoc., Washington, D.C.

[5] USGS. 1989. U.S. Geological Survey Techniques of Water-Resource Investigations, Book 5, Laboratory Analysis, Chapter A4, Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples, U.S. Geological Survey, U.S. Department of Interior, Reston, Virginia.

[6] Because the MF technique usually yields low and variable recovery from chlorinated wastewaters, the Most Probable Number method will be required to resolve any controversies.

[7] Tests must be conducted to provide organism enumeration (density). Select the appropriate configuration of tubes/filtrations and dilutions/volumes to account for the quality, character, consistency, and anticipated organism density of the water sample.

[8] When the MF method has not been used previously to test ambient waters with high turbidity, large number of noncoliform bacteria, or samples that may contain organisms stressed by chlorine, a parallel test should be conducted with a multiple-tube technique to demonstrate applicability and comparability of results.

[9] To assess the comparability of results obtained with individual methods, it is suggested that side-by-side tests be conducted across seasons of the year with the water samples routinely tested in accordance with the most current Standard Methods for the Examination of Water and Wastewater or EPA alternate test procedure (ATP) guidelines.

[10] ASTM. 2000, 1999, 1996. Annual Book of ASTM Standards—Water and Environmental Technology. Section 11.02. American Society for Testing and Materials. 100 Barr Harbor Drive, West Conshohocken, PA 19426.

[11] AOAC. 1995. Official Methods of Analysis of AOAC International, 16th Edition, Volume I, Chapter 17. Association of Official Analytical Chemists International. 481 North Frederick Avenue, Suite 500, Gaithersburg, Maryland 20877–2417.

[12] The multiple-tube fermentation test is used in 9221B.1. Lactose broth may be used in lieu of lauryl tryptose broth (LTB), if at least 25 parallel tests are conducted between this broth and LTB using the water samples normally tested, and this comparison demonstrates that the false-positive rate and false-negative rate for total coliform using lactose broth is less than 10 percent. No requirement exists to run the completed phase on 10 percent of all total coliform-positive tubes on a seasonal basis.

[13] These tests are collectively known as defined enzyme substrate tests, where, for example, a substrate is used to detect the enzyme β-glucuronidase produced by *E. coli*.

[14] After prior enrichment in a presumptive medium for total coliform using 9221B.1, all presumptive tubes or bottles showing any amount of gas, growth or acidity within 48 h ± 3 h of incubation shall be submitted to 9221F. Commercially available EC-MUG media or EC media supplemented in the laboratory with 50 µg/mL of MUG may be used.

[15] Samples shall be enumerated by the multiple-tube or multiple-well procedure. Using multiple-tube procedures, employ an appropriate tube and dilution configuration of the sample as needed and report the Most Probable Number (MPN). Samples tested with Colilert® may be enumerated with the multiple-well procedures, Quanti-Tray® or Quanti-Tray® 2000, and the MPN calculated from the table provided by the manufacturer.

[16] Colilert-18® is an optimized formulation of the Colilert® for the determination of total coliforms and *E. coli* that provides results within 18 h of incubation at 35 °C rather than the 24 h required for the Colilert® test and is recommended for marine water samples.

[17] Descriptions of the Colilert®, Colilert-18®, Quanti-Tray®, and Quanti-Tray®/2000 may be obtained from IDEXX Laboratories, Inc., One IDEXX Drive, Westbrook, Maine 04092.

[18] A description of the mColiBlue24" test, Total Coliforms and *E. coli*, is available from Hach Company, 100 Dayton Ave., Ames, IA 50010.

[19] Subject total coliform positive samples determined by 9222B or other membrane filter procedure to 9222G using NA-MUG media.

[20] USEPA. 2002. Method 1103.1: *Escherichia coli* (*E. coli*) in Water By Membrane Filtration Using membrane-Thermotolerant *Escherichia coli* Agar (mTEC). U.S. Environmental Protection Agency, Office of Water, Washington D.C. EPA–821–R–02–020.

[21] USEPA. 2002. Method 1603: *Escherichia coli* (*E. coli*) In Water By Membrane Filtration Using Modified membrane-Thermotolerant *Escherichia coli* Agar (modified mTEC). U.S. Environmental Protection Agency, Office of Water, Washington D.C. EPA–821–R–02–023.

[22] Preparation and use of MI agar with a standard membrane filter procedure is set forth in the article, Brenner *et al.* 1993. "New Medium for the Simultaneous Detection of Total Coliform and *Escherichia coli* in Water." Appl. Environ. Microbiol. 59:3534–3544 and in USEPA. 2002. Method 1604: Total Coliforms and *Escherichia coli* (*E. coli*) in Water by Membrane Filtration by Using a Simultaneous Detection Technique (MI Medium). U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA 821–R–02–024.

[23] A description of the Enterolert® test may be obtained from IDEXX Laboratories, Inc., One IDEXX Drive, Westbrook, Maine 04092.

[24] USEPA. 2002. Method 1106.1: Enterococci In Water By Membrane Filtration Using membrane-Enterococcus-Esculin Iron Agar (mE-EIA). U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–02–021.

[25] USEPA. 2002. Method 1600: Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA–821–R–02–022.

[26] Method 1622 uses filtration, concentration, immunomagnetic separation of oocysts from captured material, immunofluorescence assay to determine concentrations, and confirmation through vital dye staining and differential interference contrast microscopy for the detection of *Cryptosporidium*. USEPA. 2001. Method 1622: Cryptosporidium in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–01–026.

[27] Method 1623 uses filtration, concentration, immunomagnetic separation of oocysts and cysts from captured material, immunofluorescence assay to determine concentrations, and confirmation through vital dye staining and differential interference contrast microscopy for the simultaneous detection of *Cryptosporidium* and *Giardia* oocysts and cysts. USEPA. 2001. Method 1623: Cryptosporidium and Giardia in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA–821–R–01–025.

[28] Recommended for enumeration of target organism in ambient water only.

[29] USEPA. October 2002. Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms. Fifth Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/012.

[30] USEPA. October 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Fourth Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/013.

[31] USEPA. October 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms. Third Edition. U.S. Environmental Protection Agency, Office of Water, Washington DC. EPA/821/R–02/014.

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES

Parameter, units and method	Reference (method number or page)				
	EPA[1, 35]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
1. Acidity, as $CaCO_3$, mg/L:					
Electrometric endpoint or phenolphthalein endpoint.	305.1	2310 B(4a) [18th, 19th, 20th].	D1067–92	I–1020–85	
				I–2030–85	
2. Alkalinity, as $CaCO_3$, mg/L:					
Electrometric or Colorimetric titration to pH 4.5, manual	310.1	2320 B [18th, 19th, 20th]	D1067–92	I–1030–85	973.43[3]
or automatic.	310.2.			I–2030–85	
3. Aluminum—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	202.1	3111 D [18th, 19th]		I–3051–85	
AA furnace	202.2	3113 B [18th, 19th].			
Inductively Coupled Plasma/Atomic Emission Spectrometry (ICP/AES)[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
Direct Current Plasma (DCP)[36].			D4190–94		Note 34.
Colorimetric (Eriochrome cyanine R).		3500–Al B [20th] and 3500–Al D [18th, 19th].			
4. Ammonia (as N), mg/L:					
Manual, distillation (at pH 9.5)[6] followed by.	350.2	4500–NH_3 B [18th, 19th, 20th].			973.49[3]
Nesslerization	350.2	4500–NH_3 C [18th]	D1426–98(A)	I–3520–85	973.49[3]
Titration	350.2	4500–NH_3 C [19th, 20th] and 4500–NH_3 E [18th].			
Electrode	350.3	4500–NH_3 D or E [19th, 20th] and 4500–NH_3 F or G [18th].	D1426–98(B).		
Automated phenate, or	350.1	4500–NH_3 G [19th, 20th] and 4500–NH_3 H [18th].		I–4523–85	
Automated electrode					Note 7.
5. Antimony-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	204.1	3111 B [18th, 19th]			
AA furnace	204.2	3113 B [18th, 19th]			
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]			
6. Arsenic-Total[4] mg/L:					

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES—Continued

Parameter, units and method	Reference (method number or page)				
	EPA[1,35]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
Titrimetric (EDTA), or Ca plus Mg as their carbonates, by inductively coupled plasma or AA direct aspiration (See Parameters 13 and 33)	130.2	2340 B or C [18th, 19th, 20th].	D1126–86(92)	I–1338–85	973.52B[3]
28. Hydrogen ion (pH), pH units:					
Electrometric measurement, or	150.1	4500–H+ B [18th, 19th, 20th].	D1293–84 (90)(A or B)	I–1586–85	973.41[3]
Automated electrode				I–2587–85	Note 21.
29. Iridium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration or	235.1	3111 B [18th, 19th]			
AA furnace	235.2				
30. Iron—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	236.1	3111 B or C [18th, 19th]	D1068–96(A or B)	I–3381–85	974.27[3]
AA furnace	236.2	3113 B [18th, 19th]	D1068–96(C)		
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36] or			D4190–94		Note 34.
Colorimetric (Phenanthroline).		3500–Fe B [20th] and 3500–Fe D [18th, 19th].	D1068–96(D)		Note 22.
31. Kjeldahl Nitrogen—Total, (as N), mg/L:					
Digestion and distillation followed by:	351.3	4500–N_{org} B or C and 4500–NH_3 B [18th, 19th, 20th].	D3590–89(A)		
Titration	351.3		D3590–89(A)		973.48[3]
Nesslerization	351.3	4500–NH_3 C [18th]	D3590–89(A)		
Electrode	351.3	4500–NH_3 C [19th, 20th] and 4500–NH_3 E [18th].			
~~Automated phenate colorimetric~~	351.1			I–4551–78[8]	
Semi-automated block digestor colorimetric.	351.2		D3590–89(B)	I–4515–91[45].	
Manual or ~~block digestor~~ potentiometric.	351.4		D3590–89(A)		
Block digester, followed by Auto distillation and Titration, or					Note 39.
Nesslerization, or					Note 40.
Flow injection gas diffusion					Note 41.
32. Lead—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	239.1	3111 B or C [18th, 19th]	D3559–96(A or B)	I–3399–85	974.27[3]

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TKN: Lachat 10-107--06-2-D; Digestion, Distillation, Semiautomatic Digestor

AA furnace	239.2	3113 B [18th, 19th]	D3559–96(D)	I–4403–89[51]	
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36]			D4190–94		Note 34.
Voltametry[11] or			D3559–96(C)		
Colorimetric (Dithizone)		3500–Pb B [20th] and 3500–Pb D [18th, 19th].			
33. Magnesium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	242.1	3111 B [18th, 19th]	D511–93(B)	I–3447–85	974.27[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP or					Note 34.
Gravimetric		3500–Mg D [18th, 19th]			
34. Manganese-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	243.1	3111 B [18th, 19th]	D858–95(A or B)	I–3454–85	974.27[3]
AA furnace	243.2	3113 B [18th, 19th]	D858–95(C)		
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP[36], or			D4190–94		Note 34
Colorimetric (Persulfate), or		3500–Mn B [20th] and 3500–Mn D [18th, 19th].			920.203[3]
(Periodate)					Note 23.
35. Mercury—Total,[4] mg/L:					
Cold vapor, manual or	245.1	3112 B [18th, 19th]	D3223–91	I–3462–85	977.22[3]
Automated	245.2				
Oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry (ng/L).	1631E[43]				
36. Molybdenum—Total[4], mg/L; Digestion[4] followed by:					
AA direct aspiration	246.1	3111 D [18th, 19th]		I–3490–85	
AA furnace	246.2	3113 B [18th, 19th]		I–3492–96[47]	
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50]	
DCP					Note 34.
37. Nickel—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	249.1	3111 B or C [18th, 19th]	D1886–90(A or B)	I–3499–85.	
AA furnace	249.2	3113 B [18th, 19th]	D1886–90(C)	I–4503–89[51].	
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP[36], or			D4190–94		Note 34.
Colorimetric (heptoxime)		3500–Ni D [17th].			
38. Nitrate (as N), mg/L:					
Colorimetric (Brucine sulfate), or Nitrate-nitrite N minus Nitrite N (See parameters 39 and 40).	352.1				973.50,[3] 419D,[17] p. 28[9]
39. Nitrate-nitrite (as N), mg/L:					
Cadmium reduction, Manual or.	353.3	4500–NO_3^-E [18th, 19th, 20th].	D3867–99(B).		

Nitrate (as N), EPA 353.2; Automated Cadmium Reduction

TABLE IB—LIST OF APPROVED INORGANIC TEST PROCEDURES—Continued

Parameter, units and method	Reference (method number or page)				
	EPA[1,35]	*Standard Methods* [Edition(s)]	ASTM	USGS[2]	Other
Automated, or	353.2	4500–NO_3^-F [18th, 19th, 20th].	D3867–99(A)	I–4545–85.	
Automated hydrazine	353.1	4500–NO_3^-H [18th, 19th, 20th].			
40. Nitrite (as N), mg/L; Spectrophotometric:					
Manual or	354.1	4500–NO_2^-B [18th, 19th, 20th].			Note 25.
Automated (Diazotization)				I–4540–85.	
41. Oil and grease—Total recoverable, mg/L:					
Gravimetric (extraction)	413.1	5520B [18th, 19th, 20th][38].			
Oil and grease and non-polar material, mg/L: Hexane extractable material (HEM): n-Hexane extraction and gravimetry.	1664A[42]	5520B [18th, 19th, 20th][38].			
Silica gel treated HEM (SGT-HEM): Silica gel treatment and gravimetry.	1664A[42].				
42. Organic carbon—Total (TOC), mg/L:					
Combustion or oxidation	415.1	5310 B, C, or D [18th, 19th, 20th].	D2579–93 (A or B)		973.47,[3] p. 14[24]
43. Organic nitrogen (as N), mg/L: Total Kjeldahl N (Parameter 31) minus ammonia N (Parameter 4).					
44. Orthophosphate (as P), mg/L; Ascorbic acid method:					
Automated or	365.1	4500–P F [18th, 19th, 20th]		I–4601–85	973.56[3]
Manual single reagent	365.2	4500–P E [18th, 19th, 20th]	D515–88(A)		973.55[3]
Manual two reagent	365.3.				
45. Osmium—Total[4], mg/L; Digestion[4] followed by:					
AA direct aspiration, or	252.1	3111 D [18th, 19th].			
AA furnace	252.2.				
46. Oxygen, dissolved, mg/L:					
Winkler (Azide modification), or	360.2	4500–O C [18th, 19th, 20th]	D888–92(A)	I–1575–78[8]	973.45B[3]
Electrode	360.1	4500–O G [18th, 19th, 20th].	D888–92(B)	I–1576–78[8].	

47. Palladium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	253.1	3111 B [18th, 19th]			p. S27[10]
AA furnace	253.2				p. S28[10]
DCP					Note 34.
48. Phenols, mg/L:					
Manual distillation[26]	420.1				Note 27.
Followed by:					
Colorimetric (4AAP) manual, or	420.1				Note 27.
Automated[19]	420.2.				
49. Phosphorus (elemental), mg/L:					
Gas-liquid chromatography					Note 28.
50. Phosphorus—Total, mg/L:					
Persulfate digestion followed by:	365.2	4500–P B, 5 [18th, 19th, 20th]			973.55[3]
Manual or	365.2 or 365.3	4500–P E [18th, 19th, 20th]	D515–88(A)		
Automated ascorbic acid reduction.	365.1	4500–P F [18th, 19th, 20th]		I–4600–85	973.56[3]
Semi-automated block digestor.	365.4		D515–88(B)	I–4610–91[48].	
51. Platinum—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	255.1	3111 B [18th, 19th].			
AA furnace	255.2.				
DCP					Note 34
52. Potassium—Total,[4] mg/L: Digestion[4] followed by:					
AA direct aspiration	258.1	3111 B [18th, 19th]		I–3630–85	973.53[3]
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
Flame photometric, or		3500–K B [20th] and 3500–K D [18th, 19th].			
Colorimetric					317 B[17]
53. Residue—Total, mg/L:					
Gravimetric, 103–105°	160.3	2540 B [18th, 19th, 20th]		I–3750–85.	
54. Residue—filterable, mg/L:					
Gravimetric, 180°	160.1	2540 C [18th, 19th, 20th]		I–1750–85.	
55. Residue—nonfilterable (TSS), mg/L:					
Gravimetric, 103–105° post washing of residue.	160.2	2540 D [18th, 19th, 20th]		I–3765–85.	
56. Residue—settleable, mg/L:					
Volumetric, (Imhoff cone), or gravimetric.	160.5	2540 F [18th, 19th, 20th].			
57. Residue—Volatile, mg/L:					
Gravimetric, 550°	160.4			I–3753–85.	
58. Rhodium-Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration, or	265.1	3111 B [18th, 19th].			

Colorimetric (methylene blue).	376.2	4500–S−2D [18th, 19th, 20th].			
67. Sulfite (as SO_3), mg/L:					
Titrimetric (iodine-iodate)	377.1	4500–SO_3−2B [18th, 19th, 20th].			
68. Surfactants, mg/L:					
Colorimetric (methylene blue)	425.1	5540 C [18th, 19th, 20th]	D2330–88.		
69. Temperature, °C:					
Thermometric	170.1	2550 B [18th, 19th, 20th]			Note 32.
70. Thallium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	279.1	3111 B [18th, 19th].			
AA furnace	279.2.				
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th].			
71. Tin—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	282.1	3111 B [18th, 19th]		I–3850–78[8].	
AA furnace, or	282.2	3113 B [18th, 19th].			
ICP/AES	200.7[5].				
72. Titanium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	283.1	3111 D [18th, 19th].			
AA furnace	283.2.				
DCP					Note 34.
73. Turbidity, NTU:					
Nephelometric	180.1	2130 B [18th, 19th, 20th]	D1889–94(A)	I–3860–85.	
74. Vanadium—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration	286.1	3111 D [18th, 19th].			
AA furnace	286.2		D3373–93.		
ICP/AES	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP, or			D4190–94		Note 34.
Colorimetric (Gallic Acid)		3500–V B [20th] and 3500–V D [18th, 19th].			
75. Zinc—Total,[4] mg/L; Digestion[4] followed by:					
AA direct aspiration[36]	289.1	3111 B or C [18th, 19th]	D1691–95(A or B)	I–3900–85	974.27,[3] p. 37[9]
AA furnace	289.2.				
ICP/AES[36]	200.7[5]	3120 B [18th, 19th, 20th]		I–4471–97[50].	
DCP,[36] or			D4190–94		Note 34.
Colorimetric (Dithizone) or		3500–Zn E [18th, 19th].			
(Zincon)		3500–Zn B [20th] and 3500–Zn F [18th, 19th].			Note 33.

Table 1B Notes:

[1] "Methods for Chemical Analysis of Water and Wastes," Environmental Protection Agency, Environmental Monitoring Systems Laboratory—Cincinnati (EMSL-CI), EPA–600/4–79–020, Revised March 1983 and 1979 where applicable.

[2] Fishman, M.J., *et al.* "Methods for Analysis of Inorganic Substances in Water and Fluvial Sediments," U.S. Department of the Interior, Techniques of Water-Resource Investigations of the U.S. Geological Survey, Denver, CO, Revised 1989, unless otherwise stated.

[3] "Official Methods of Analysis of the Association of Official Analytical Chemists," methods manual, 15th ed. (1990).

[4] For the determination of total metals the sample is not filtered before processing. A digestion procedure is required to solubilize suspended material and to destroy possible organic-metal complexes. Two digestion procedures are given in "Methods for Chemical Analysis of Water and Wastes, 1979 and 1983". One (Section 4.1.3), is a vigorous digestion using nitric acid. A less vigorous digestion using nitric and hydrochloric acids (Section 4.1.4) is preferred; however, the analyst should be cautioned that this mild digestion may not suffice for all samples types. Particularly, if a colorimetric procedure is to be employed, it is necessary to ensure that all organo-metallic bonds be broken so that the metal is in a reactive state. In those situations, the vigorous digestion is to be preferred making certain that at no time does the sample go to dryness. Samples containing large amounts of organic materials may also benefit by this vigorous digestion, however, vigorous digestion with concentrated nitric acid will convert antimony and tin to insoluble oxides and render them unavailable for analysis. Use of ICP/AES as well as determinations for certain elements such as antimony, arsenic, the noble metals, mercury, selenium, silver, tin, and titanium require a modified sample digestion procedure and in all cases the method write-up should be consulted for specific instructions and/or cautions.

NOTE TO TABLE IB NOTE 4: If the digestion procedure for direct aspiration AA included in one of the other approved references is different than the above, the EPA procedure must be used. Dissolved metals are defined as those constituents which will pass through a 0.45 micron membrane filter. Following filtration of the sample, the referenced procedure for total metals must be followed. Sample digestion of the filtrate for dissolved metals (or digestion of the original sample solution for total metals) may be omitted for AA (direct aspiration or graphite furnace) and ICP analyses, provided the sample solution to be analyzed meets the following criteria:

a. has a low COD (<20)

b. is visibly transparent with a turbidity measurement of 1 NTU or less

c. is colorless with no perceptible odor, and

d. is of one liquid phase and free of particulate or suspended matter following acidification.

[5] The full text of Method 200.7, "Inductively Coupled Plasma Atomic Emission Spectrometric Method for Trace Element Analysis of Water and Wastes," is given at Appendix C of this Part 136.

[6] Manual distillation is not required if comparability data on representative effluent samples are on company file to show that this preliminary distillation step is not necessary, however, manual distillation will be required to resolve any controversies.

[7] Ammonia, Automated Electrode Method, Industrial Method Number 379–75 WE, dated February 19, 1976, Bran & Luebbe (Technicon) Auto Analyzer II. Bran & Luebbe Analyzing Technologies, Inc., Elmsford, NY 10523.

[8] The approved method is that cited in "Methods for Determination of Inorganic Substances in Water and Fluvial Sediments", USGS TWRI, Book 5, Chapter A1 (1979).

[9] American National Standard on Photographic Processing Effluents, Apr. 2, 1975. Available from ANSI, 25 West 43rd Street, New York, NY 10036.

[10] "Selected Analytical Methods Approved and Cited by the United States Environmental Protection Agency", Supplement to the Fifteenth Edition of Standard Methods for the Examination of Water and Wastewater (1981).

[11] The use of normal and differential pulse voltage ramps to increase sensitivity and resolution is acceptable.

[12] Carbonaceous biochemical oxygen demand ($CBOD_5$) must not be confused with the traditional BOD_5 test method which measures "total BOD". The addition of the nitrification inhibitor is not a procedural option, but must be included to report the $CBOD_5$ parameter. A discharger whose permit requires reporting the traditional BOD_5 may not use a nitrification inhibitor in the procedure for reporting the results. Only when a discharger's permit specifically states $CBOD_5$ is required can the permittee report data using a nitrification inhibitor.

[13] OIC Chemical Oxygen Demand Method, Oceanography International Corporation, 1978, 512 West Loop, PO Box 2980, College Station, TX 77840.

[14] Chemical Oxygen Demand, Method 8000, Hach Handbook of Water Analysis, 1979, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[15] The back titration method will be used to resolve controversy.

[16] Orion Research Instruction Manual, Residual Chlorine Electrode Model 97–70, 1977, Orion Research Incorporated, 840 Memorial Drive, Cambridge, MA 02138. The calibration graph for the Orion residual chlorine method must be derived using a reagent blank and three standard solutions, containing 0.2, 1.0, and 5.0 mL 0.00281 N potassium iodate/100 mL solution, respectively.

[17] The approved method is that cited in Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1976.

[18] National Council of the Paper Industry for Air and Stream Improvement, Inc. Technical Bulletin 253, December 1971.

[19] Copper, Biocinchoinate Method, Method 8506, Hach Handbook of Water Analysis, 1979, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[20] After the manual distillation is completed, the autoanalyzer manifolds in EPA Methods 335.3 (cyanide) or 420.2 (phenols) are simplified by connecting the re-sample line directly to the sampler. When using the manifold setup shown in Method 335.3, the buffer 6.2 should be replaced with the buffer 7.6 found in Method 335.2.

[21] Hydrogen ion (pH) Automated Electrode Method, Industrial Method Number 378–75WA, October 1976, Bran & Luebbe (Technicon) Autoanalyzer II. Bran & Luebbe Analyzing Technologies, Inc., Elmsford, NY 10523.

[22] Iron, 1,10-Phenanthroline Method, Method 8008, 1980, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[23] Manganese, Periodate Oxidation Method, Method 8034, Hach Handbook of Wastewater Analysis, 1979, pages 2–113 and 2–117, Hach Chemical Company, Loveland, CO 80537.

[24] Wershaw, R.L., *et al*, "Methods for Analysis of Organic Substances in Water," Techniques of Water-Resources Investigation of the U.S. Geological Survey, Book 5, Chapter A3, (1972 Revised 1987) p. 14.

[25] Nitrogen, Nitrite, Method 8507, Hach Chemical Company, PO Box 389, Loveland, CO 80537.

[26] Just prior to distillation, adjust the sulfuric-acid-preserved sample to pH 4 with 1 + 9 NaOH.

[27] The approved method is cited in Standard Methods for the Examination of Water and Wastewater, 14th Edition. The colorimetric reaction is conducted at a pH of 10.0±0.2. The approved methods are given on pp 576–81 of the 14th Edition: Method 510A for distillation, Method 510B for the manual colorimetric procedure, or Method 510C for the manual spectrometric procedure.

[28] R.F. Addison and R.G. Ackman, "Direct Determination of Elemental Phosphorus by Gas-Liquid Chromatography," Journal of Chromatography, Vol. 47, No. 3, pp. 421–426, 1970.

[29] Approved methods for the analysis of silver in industrial wastewaters at concentrations of 1 mg/L and above are inadequate where silver exists as an inorganic halide. Silver halides such as the bromide and chloride are relatively insoluble in reagents such as nitric acid but are readily soluble in an aqueous buffer of sodium thiosulfate and sodium hydroxide to pH of 12. Therefore, for levels of silver above 1 mg/L, 20 mL of sample should be diluted to 100 mL by adding 40 mL each of 2 M $Na_2S_2O_3$ and NaOH. Standards should be prepared in the same manner. For levels of silver below 1 mg/L the approved method is satisfactory.

[30] The approved method is that cited in Standard Methods for the Examination of Water and Wastewater, 15th Edition.

31 EPA Methods 335.2 and 335.3 require the NaOH absorber solution final concentration to be adjusted to 0.25 N before colorimetric determination of total cyanide.

32 Stevens, H.H., Ficke, J.F., and Smoot, G.F., "Water Temperature—Influential Factors, Field Measurement and Data Presentation," Techniques of Water-Resources Investigations of the U.S. Geological Survey, Book 1, Chapter D1, 1975.

33 Zinc, Zincon Method, Method 8009, Hach Handbook of Water Analysis, 1979, pages 2–231 and 2–333, Hach Chemical Company, Loveland, CO 80537.

34 "Direct Current Plasma (DCP) Optical Emission Spectrometric Method for Trace Elemental Analysis of Water and Wastes, Method AES0029," 1986—Revised 1991, Thermo Jarrell Ash Corporation, 27 Forge Parkway, Franklin, MA 02038.

35 Precision and recovery statements for the atomic absorption direct aspiration and graphite furnace methods, and for the spectrophotometric SDDC method for arsenic are provided in Appendix D of this part titled, "Precision and Recovery Statements for Methods for Measuring Metals".

36 "Closed Vessel Microwave Digestion of Wastewater Samples for Determination of Metals", CEM Corporation, PO Box 200, Matthews, NC 28106–0200, April 16, 1992. Available from the CEM Corporation.

37 When determining boron and silica, only plastic, PTFE, or quartz laboratory ware may be used from start until completion of analysis.

38 Only use Trichlorotrifluorethane (1,1,2-trichloro-1,2,2-trifluoroethane; CFC–113) extraction solvent when determining Total Recoverable Oil and Grease (analogous to EPA Method 413.1). Only use n-hexane extraction solvent when determining Hexane Extractable Material (analogous to EPA Method 1664A). Use of other extraction solvents is strictly prohibited.

39 Nitrogen, Total Kjeldahl, Method PAI-DK01 (Block Digestion, Steam Distillation, Titrimetric Detection), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.

40 Nitrogen, Total Kjeldahl, Method PAI-DK02 (Block Digestion, Steam Distillation, Colorimetric Detection), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.

41 Nitrogen, Total Kjeldahl, Method PAI-DK03 (Block Digestion, Automated FIA Gas Diffusion), revised 12/22/94, OI Analytical/ALPKEM, PO Box 9010, College Station, TX 77842.

42 Method 1664, Revision A "n-Hexane Extractable Material (HEM; Oil and Grease) and Silica Gel Treated n-Hexane Extractable Material (SGT-HEM; Non-polar Material) by Extraction and Gravimetry" EPA–821–R–98–002, February 1999. Available at NTIS, PB–121949, U.S. Department of Commerce, 5285 Port Royal, Springfield, Virginia 22161.

43 USEPA. 2002. Method 1631, Revision E, "Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry," September 2002. Office of Water, U.S. Environmental Protection Agency (EPA–821–R–02–019). The application of clean techniques described in EPA's draft Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels (EPA–821–R–96–011) are recommended to preclude contamination at low-level, trace metal determinations.

44 Available Cyanide, Method OIA–1677 (Available Cyanide by Flow Injection, Ligand Exchange, and Amperometry), ALPKEM, A Division of OI Analytical, PO Box 9010, College Station, TX 77842–9010.

45 "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Ammonia Plus Organic Nitrogen by a Kjeldahl Digestion Method", Open File Report (OFR) 00–170.

46 "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Chromium in Water by Graphite Furnace Atomic Absorption Spectrophotometry", Open File Report (OFR) 93–449.

47 "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Molybdenum by Graphite Furnace Atomic Absorption Spectrophotometry", Open File Report (OFR) 97–198.

48 "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Total Phosphorus by Kjeldahl Digestion Method and an Automated Colorimetric Finish That Includes Dialysis" Open File Report (OFR) 92–146.

49 "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Arsenic and Selenium in Water and Sediment by Graphite Furnace-Atomic Absorption Spectrometry" Open File Report (OFR) 98–639.

50 "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Elements in Whole-water Digests Using Inductively Coupled Plasma-Optical Emission Spectrometry and Inductively Coupled Plasma-Mass Spectrometry", Open File Report (OFR) 98–165.

51 "Methods of Analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of Inorganic and Organic Constituents in Water and Fluvial Sediment", Open File Report (OFR) 93–125.

TABLE IC—LIST OF APPROVED TEST PROCEDURES FOR NON-PESTICIDE ORGANIC COMPOUNDS

Parameter[1]	EPA method number[2,7]			Other approved methods		
	GC	GC/MS	HPLC	*Standard Methods* [Edition(s)]	ASTM	Other
1. Acenaphthene	610	625, 1625B	610	6440 B [18th, 19th, 20th]	D4657–92	Note 9, p.27
2. Acenaphthylene	610	625, 1625B	610	6440 B, 6410 B [18th, 19th, 20th]	D4657–92	Note 9, p.27
3. Acrolein	603	624[4], 1624B				
4. Acrylonitrile	603	624[4], 1624B				
5. Anthracene	610	625, 1625B	610	6410 B, 6440 B [18th, 19th, 20th]	D4657–92	Note 9, p. 27

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Wet Weather Surface Water Sampling

Table II - Required Containers, Preservation Techniques, and Holding Times
40 CFR Part 136.3
July 1, 2005

RP07-002 MUSQUAPSINK BROOK WATERSHED RESTORATION PLAN
&
RP07-001 TENAKILL BROOK WATERSHED RESTORATION PLAN

3544. Available from the American Society for Microbiology, 1752 N Street NW., Washington, DC 20036. Table IA, Note 22.

(58) USEPA. 2002. Method 1604: Total Coliforms and *Escherichia coli (E. coli)* in Water by Membrane Filtration using a Simultaneous Detection Technique (MI Medium). U.S. Environmental Protection Agency, Office of Water, Washington D.C. September 2002, EPA 821–R–02–024. Available from NTIS, PB2003–100129. Table IA, Note 22.

(59) USEPA. 2002. Method 1600: Enterococci in Water by Membrane Filtration using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). U.S. Environmental Protection Agency, Office of Water, Washington D.C. September 2002, EPA–821–R–02–022. Available from NTIS, PB2003–100127. Table IA, Note 25.

(60) USEPA. 2001. Method 1622: *Cryptosporidium* in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington, DC April 2001, EPA–821–R–01–026.

Available from NTIS, PB2002–108709. Table IA, Note 26.

(61) USEPA. 2001. Method 1623: *Cryptosporidium* and *Giardia* in Water by Filtration/IMS/FA. U.S. Environmental Protection Agency, Office of Water, Washington, DC April 2001, EPA–821–R–01–025. Available from NTIS, PB2002–108710. Table IA, Note 27.

(62) AOAC. 1995. Official Methods of Analysis of AOAC International, 16th Edition, Volume I, Chapter 17. AOAC International. 481 North Frederick Avenue, Suite 500, Gaithersburg, Maryland 20877–2417. Table IA, Note 11.

(c) Under certain circumstances the Regional Administrator or the Director in the Region or State where the discharge will occur may determine for a particular discharge that additional parameters or pollutants must be reported. Under such circumstances, additional test procedures for analysis of pollutants may be specified by the Regional Administrator, or the Director upon the recommendation of the Director of the Environmental Monitoring Systems Laboratory—Cincinnati.

(d) Under certain circumstances, the Administrator may approve, upon recommendation by the Director, Environmental Monitoring Systems Laboratory—Cincinnati, additional alternate test procedures for nationwide use.

(e) Sample preservation procedures, container materials, and maximum allowable holding times for parameters cited in Tables IA, IB, IC, ID, and IE are prescribed in Table II. Any person may apply for a variance from the prescribed preservation techniques, container materials, and maximum holding times applicable to samples taken from a specific discharge. Applications for variances may be made by letters to the Regional Administrator in the Region in which the discharge will occur. Sufficient data should be provided to assure such variance does not adversely affect the integrity of the sample. Such data will be forwarded, by the Regional Administrator, to the Director of the Environmental Monitoring Systems Laboratory—Cincinnati, Ohio for technical review and recommendations for action on the variance application. Upon receipt of the recommendations from the Director of the Environmental Monitoring Systems Laboratory, the Regional Administrator may grant a variance applicable to the specific charge to the applicant. A decision to approve or deny a variance will be made within 90 days of receipt of the application by the Regional Administrator.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Table IA—Bacteria Tests:			
1–5 Coliform, total, fecal, and *E. coli*	PP, G	Cool, <10 °C, 0.0008% $Na_2S_2O_3$[5].	6 hours.
6 Fecal *streptococci*	PP, G	Cool, <10° 0.0008% $Na_2S_2O_3$[5]	6 hours.
7 *Enterococci*	PP, G	Cool, <10° 0.0008% $Na_2S_2O_3$[5]	6 hours.
Table IA—Protozoa Tests:			
8 *Cryptosporidium*	LDPE	0–8 °C	96 hours.[17]
9 *Giardia*	LDPE	0–8 °C	96 hours.[17]
Table IA—Aquatic Toxicity Tests:			
6–10 Toxicity, acute and chronic	P,G	Cool, 4 °C[16]	36 hours.

TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
Table IB—Inorganic Tests:			
1. Acidity	P, G	Cool, 4°C	14 days.
2. Alkalinity	P, G	do	Do.
4. Ammonia	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
9. Biochemical oxygen demand	P, G	Cool, 4°C	48 hours.
10. Boron	P, PFTE, or Quartz.	HNO_3 TO pH<2	6 months.
11. Bromide	P, G	None required	28 days.
14. Biochemical oxygen demand, carbonaceous	P, G	Cool, 4°C	48 hours.
15. Chemical oxygen demand	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
16. Chloride	P, G	None required	Do.
17. Chlorine, total residual	P, G	do	Analyze immediately.
21. Color	P, G	Cool, 4°C	48 hours.
23–24. Cyanide, total and amenable to chlorination.	P, G	Cool, 4°C, NaOH to pH>12, 0.6g ascorbic acid[5].	14 days.[6]
25. Fluoride	P	None required	28 days.
27. Hardness	P, G	HNO_3 to pH<2, H_2SO_4 to pH<2	6 months.
28. Hydrogen ion (pH)	P, G	None required	Analyze immediately.
31, 43. Kjeldahl and organic nitrogen	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
Metals:[7]			
18. Chromium VI[7]	P, G	Cool, 4 °C	24 hours.
35. Mercury[17]	P, G	HNO_3 to pH<2	28 days.
3, 5–8, 12,13, 19, 20, 22, 26, 29, 30, 32–34, 36, 37, 45, 47, 51, 52, 58–60, 62, 63, 70–72, 74, 75. Metals except boron, chromium VI and mercury[7].	P, G	do	6 months.
38. Nitrate	P, G	Cool, 4°C	48 hours.
39. Nitrate-nitrite	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
40. Nitrite	P, G	Cool, 4°C	48 hours.
41. Oil and grease	G	Cool to 4°C, HCl or H_2SO_4 to pH<2.	28 days.
42. Organic Carbon	P, G	Cool to 4 °C HC1 or H2SO4 or H3PO4, to pH<2.	28 days.
44. Orthophosphate	P, G	Filter immediately, Cool, 4°C	48 hours.
46. Oxygen, Dissolved Probe	G Bottle and top.	None required	Analyze immediately.
47. Winkler	do	Fix on site and store in dark	8 hours.
48. Phenols	G only	Cool, 4°C, H_2SO_4 to pH<2	28 days.
49. Phosphorus (elemental)	G	Cool, 4°C	48 hours.
50. Phosphorus, total	P, G	Cool, 4°C, H_2SO_4 to pH<2	28 days.
53. Residue, total	P, G	Cool, 4°C	7 days.
54. Residue, Filterable	P, G	do	7 days.
55. Residue, Nonfilterable (TSS)	P, G	do	7 days.
56. Residue, Settleable	P, G	do	48 hours.
57. Residue, volatile	P, G	do	7 days.
61. Silica	P, PFTE, or Quartz.	Cool, 4 °C	28 days.
64. Specific conductance	P, G	do	Do.
65. Sulfate	P, G	do	Do.
66. Sulfide	P, G	Cool, 4°C add zinc acetate plus sodium hydroxide to pH>9.	7 days.
67. Sulfite	P, G	None required	Analyze immediately.
68. Surfactants	P ,G	Cool, 4°C	48 hours.
69. Temperature	P, G	None required	Analyze.
73. Turbidity	P, G	Cool, 4°C	48 hours.
Table IC—Organic Tests[8]			
13, 18–20, 22, 24–28, 34–37, 39–43, 45–47, 56, 76, 104, 105, 108–111, 113. Purgeable Halocarbons.	G, Teflon-lined septum.	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5].	14 days.
6, 57, 106. Purgeable aromatic hydrocarbons	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] HCl to pH2[9].	Do.
3, 4. Acrolein and acrylonitrile	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] adjust pH to 4–5[10].	Do.
23, 30, 44, 49, 53, 77, 80, 81, 98, 100, 112. Phenols[11].	G, Teflon-lined cap.	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5]	7 days until extraction; 40 days after extraction.
7, 38. Benzidines[11]	do	do	7 days until extraction.[13]
14, 17, 48, 50–52. Phthalate esters[11]	do	Cool, 4 °C	7 days until extraction; 40 days after extraction.

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TABLE II—REQUIRED CONTAINERS, PRESERVATION TECHNIQUES, AND HOLDING TIMES—Continued

Parameter No./name	Container[1]	Preservation[2,3]	Maximum holding time[4]
82–84. Nitrosamines[11,14]	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark	Do.
88–94. PCBs[11]	do	Cool, 4 °C	Do.
54, 55, 75, 79. Nitroaromatics and isophorone[11]	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$,[5] store in dark	Do.
1, 2, 5, 8–12, 32, 33, 58, 59, 74, 78, 99, 101. Polynuclear aromatic hydrocarbons[11]	do	do	Do.
15, 16, 21, 31, 87. Haloethers[11]	do	Cool, 4 °C, 0.008% $Na_2S_2O_3$[5]	Do.
29, 35–37, 63–65, 73, 107. Chlorinated hydrocarbons[11]	do	Cool, 4 °C	Do.
60–62, 66–72, 85, 88, 95–97, 102, 103. CDDs/CDFs[11]			
aqueous: field and lab preservation	G	Cool, 0–4 °C, pH<9, 0.008% $Na_2S_2O_3$[5]	1 year.
Solids, mixed phase, and tissue: field preservation	do	Cool, <4 °C	7 days.
Solids, mixed phase, and tissue: lab preservation	do	Freeze, < −10 °C	1 year.
Table ID—Pesticides Tests:			
1–70. Pesticides[11]	do	Cool, 4°C, pH 5–9[15]	Do.
Table IE—Radiological Tests:			
1–5. Alpha, beta and radium	P, G	HNO_3 to pH<2	6 months.

Table II Notes

[1] Polyethylene (P) or glass (G). For microbiology, plastic sample containers must be made of sterilizable materials (polypropylene or other autoclavable plastic).

[2] Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler makes it impossible to preserve each aliquot, then chemical samples may be preserved by maintaining at 4 °C until compositing and sample splitting is completed.

[3] When any sample is to be shipped by common carrier or sent through the United States Mails, it must comply with the Department of Transportation Hazardous Materials Regulations (49 CFR part 172). The person offering such material for transportation is responsible for ensuring such compliance. For the preservation requirements of Table II, the Office of Hazardous Materials, Materials Transportation Bureau, Department of Transportation has determined that the Hazardous Materials Regulations do not apply to the following materials: Hydrochloric acid (HCl) in water solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater); Nitric acid (HNO_3) in water solutions at concentrations of 0.15% by weight or less (pH about 1.62 or greater); Sulfuric acid (H_2SO_4) in water solutions at concentrations of 0.35% by weight or less (pH about 1.15 or greater); and Sodium hydroxide (NaOH) in water solutions at concentrations of 0.080% by weight or less (pH about 12.30 or less).

[4] Samples should be analyzed as soon as possible after collection. The times listed are the maximum times that samples may be held before analysis and still be considered valid. Samples may be held for longer periods only if the permittee, or monitoring laboratory, has data on file to show that for the specific types of samples under study, the analytes are stable for the longer time, and has received a variance from the Regional Administrator under § 136.3(e). Some samples may not be stable for the maximum time period given in the table. A permittee, or monitoring laboratory, is obligated to hold the sample for a shorter time if knowledge exists to show that this is necessary to maintain sample stability. See § 136.3(e) for details. The term "analyze immediately" usually means within 15 minutes or less of sample collection.

[5] Should only be used in the presence of residual chlorine.

[6] Maximum holding time is 24 hours when sulfide is present. Optionally all samples may be tested with lead acetate paper before pH adjustments in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then NaOH is added to pH 12.

[7] Samples should be filtered immediately on-site before adding preservative for dissolved metals.

[8] Guidance applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.

[9] Sample receiving no pH adjustment must be analyzed within seven days of sampling.

[10] The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment must be analyzed within 3 days of sampling.

[11] When the extractable analytes of concern fall within a single chemical category, the specified preservative and maximum holding times should be observed for optimum safeguard of sample integrity. When the analytes of concern fall within two or more chemical categories, the sample may be preserved by cooling to 4 °C, reducing residual chlorine with 0.008% sodium thiosulfate, storing in the dark, and adjusting the pH to 6–9; samples preserved in this manner may be held for seven days before extraction and for forty days after extraction. Exceptions to this optional preservation and holding time procedure are noted in footnote 5 (re the requirement for thiosulfate reduction of residual chlorine), and footnotes 12, 13 (re the analysis of benzidine).

[12] If 1,2-diphenylhydrazine is likely to be present, adjust the pH of the sample to 4.0±0.2 to prevent rearrangement to benzidine.

[13] Extracts may be stored up to 7 days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.

[14] For the analysis of diphenylnitrosamine, add 0.008% $Na_2S_2O_3$ and adjust pH to 7–10 with NaOH within 24 hours of sampling.

[15] The pH adjustment may be performed upon receipt at the laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $Na_2S_2O_3$.

[16] Sufficient ice should be placed with the samples in the shipping container to ensure that ice is still present when the samples arrive at the laboratory. However, even if ice is present when the samples arrive, it is necessary to immediately measure the temperature of the samples and confirm that the 4C temperature maximum has not been exceeded. In the isolated cases where it can be documented that this holding temperature can not be met, the permittee can be given the option of on-site testing or can request a variance. The request for a variance should include supportive data which show that the toxicity of the effluent samples is not reduced because of the increased holding temperature.

[17] Samples collected for the determination of trace level mercury (100 ng/L) using EPA Method 1631 must be collected in tightly-capped fluoropolymer or glass bottles and preserved with BrCl or HCl solution within 48 hours of sample collection. The time to preservation may be extended to 28 days if a sample is oxidized in the sample bottle. Samples collected for dissolved trace level mercury should be filtered in the laboratory. However, if circumstances prevent overnight shipment, samples should be filtered in a designated clean area in the field in accordance with procedures given in Method 1669. Samples that have been collected for determination of total or dissolved trace level mercury must be analyzed within 90 days of sample collection.

Appendix D: Tabulated Water Quality Monitoring Data

		Flow Rate	pH	DO	Temperature	Fecal Coliform	*E. coli*	TKN		NH_3 - N		NO_2- N		NO_3- N		PO_4^{3-} Dissolved		TP		TSS	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	MB6	10.7	6.62	6.09	16.80	615	360	0.50	ND	0.50	ND	0.005	ND	1.300		0.03		0.06		19.00	
5/31/2007	MB6	3.9	7.04	6.60	18.70	2600	660	0.50	ND	0.50	ND	0.005	ND	1.100		0.03		0.05		9.00	
6/7/2007	MB6	7.6	7.20	6.30	16.40	720	570	1.10		0.50	ND	0.005	ND	1.000		0.06		0.15		2.00	ND
6/14/2007	MB6	9.3	7.35	NS	16.70	760	1200	Bacteria Sampling Only													
6/19/2007	MB6	7.8	7.02	6.57	20.40	1040	580														
6/21/2007	MB6	7.7	7.10	6.20	18.40	3900	610	0.50	ND	0.50	ND	0.005	ND	1.400		0.07		0.04		2.00	ND
6/28/2007	MB6	31.4	7.00	6.80	22.30	650	38000	Bacteria Sampling Only													
7/5/2007	MB6	33.4	7.11	8.14	19.00	4300	3700	0.50	ND	0.50	ND	0.005	ND	1.400		0.05		0.11		18.00	
7/12/2007	MB6	25.8	6.90	NS	23.10	60000	10000	Bacteria Sampling Only													
7/19/2007	MB6	27.4	4.77	7.24	22.30	11000	5300														
7/24/2007	MB6	20.3	6.76	7.57	19.60	11000	2600														
7/26/2007	MB6	20.8	7.10	7.68	21.00	627	380														
8/2/2007	MB6	19.1	7.27	7.61	21.30	587	410	0.50	ND	0.50	ND	0.005	ND	2.000		0.08		0.10		2.00	ND
8/9/2007	MB6	25.1	7.20	7.20	24.10	900	480	Bacteria Sampling Only													
8/16/2007	MB6	14.1	7.39	7.41	20.70	2500	760	0.50	ND	0.50	ND	0.005	ND	2.300		0.15		0.19		6.00	
8/23/2007	MB6	19.5	7.11	8.10	18.10	4300	560	Bacteria Sampling Only													
8/30/2007	MB6	4.3	6.75	7.77	19.50	660	380														
9/13/2007	MB6	17.1	6.90	6.09	18.20	720	490														
9/27/2007	MB6	4.4	6.85	5.70	20.10	500	210														
10/10/2007	MB6	17.4	6.49	5.66	17.70	31000	20000	0.82		0.21		0.027		1.350		0.09		0.16		11.00	
10/10/2007	MB6	5.9	7.01	7.56	17.30	27000	28000	0.99		0.21		0.024		1.350		0.09		0.16		5.00	
10/11/2007	MB6	5.9	6.36	6.35	17.90	3200	3400	0.71		0.11		0.005	ND	0.005	ND	0.06		0.01	ND	1.00	
10/25/2007	MB6	6.1	6.79	6.32	15.00	70000	1000	2.00		0.50	ND	0.005	ND	0.62		0.22		0.29		NS	
n		23	23	21	23	23	23	11		11		11		11		11		11		10	
min		3.9	4.77	5.66	15.00	500	210	0.50		0.11		0.01		0.01		0.03		0.01		1.00	
mean*		15.0	6.87	6.90	19.33	10373	5202	0.78		0.41		0.01		1.26		0.08		0.12		7.50	
max		33.4	7.39	8.14	24.10	70000	38000	2.00		0.50		0.03		2.30		0.22		0.29		19.00	
std. dev.		9.3	0.5	0.78	2.32	19115	9935	0.46		0.15		0.01		0.614		0.06		0.082		6.65	

ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

		Flow Rate	pH	DO	Temperature	Fecal Coliform	*E. coli*	TKN		NH_3-N		NO_2-N		NO_3-N		PO_4^{3-} Dissolved		TP		TSS	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	MB5	11.9	7.04	4.98	16.70	880	400	0.50	ND	0.50	ND	0.005	ND	1.200		0.03		0.07		5.00	
5/31/2007	MB5	3.5	6.48	2.86	17.80	580	570	0.50	ND	0.50	ND	0.005	ND	1.000		0.03		0.06		2.00	ND
6/7/2007	MB5	4.7	6.70	4.30	15.80	220	550	0.50	ND	0.50	ND	0.005	ND	0.900		0.04		0.12		2.00	ND
6/14/2007	MB5	6.1	6.97	NS	16.20	800	1900	Bacteria Sampling Only													
6/19/2007	MB5	8.5	6.96	3.34	19.50	980	680														
6/21/2007	MB5	5.2	6.90	4.30	18.40	5900	2600	0.50	ND	0.50	ND	0.005	ND	1.100		0.05		0.01	ND	5.00	
6/28/2007	MB5	20.5	6.80	4.90	23.10	680	33000	Bacteria Sampling Only													
7/5/2007	MB5	29.6	6.74	4.88	20.30	5100	6000	1.00		0.50	ND	0.005	ND	0.005	ND	0.04		0.10		16.00	
7/12/2007	MB5	16.9	6.90	NS	23.10	58000	20000														
7/19/2007	MB5	16.9	6.30	5.13	21.10	3900	5700	Bacteria Sampling Only													
7/24/2007	MB5	20.2	6.35	6.13	20.00	3900	2900														
7/26/2007	MB5	20.0	6.71	6.07	21.60	1060	540														
8/2/2007	MB5	19.4	7.12	5.91	22.40	600	420	0.50	ND	0.50	ND	0.005	ND	0.005	ND	0.29		0.35		2.00	ND
8/9/2007	MB5	22.2	7.00	7.00	23.00	1680	120	Bacteria Sampling Only													
8/16/2007	MB5	15.8	7.32	6.02	20.90	740	590	0.50	ND	0.50	ND	0.005	ND	2.800		0.27		0.30		2.00	ND
8/23/2007	MB5	16.8	6.92	6.86	17.05	1220	760														
8/30/2007	MB5	2.4	6.67	5.36	19.90	124	460	Bacteria Sampling Only													
9/13/2007	MB5	16.7	6.77	5.05	17.50	660	1300														
9/27/2007	MB5	3.4	6.40	4.00	18.70	106	780														
10/10/2007	MB5	12.6	7.03	3.25	18.50	33000	33000	0.99		0.15		0.020		0.700		0.05		0.12		3.00	
10/10/2007	MB5	5.2	6.85	3.86	18.30	26000	21000	1.16		0.21		0.018		0.630		NS		0.14		NS	
10/11/2007	MB5	2.0	6.88	4.64	17.30	5200	5100	0.71		0.10		0.005	ND	1.110		0.05		0.01	ND	6.00	
10/25/2007	MB5	5.4	6.63	3.21	14.80	1100	1700	0.50	ND	0.50	ND	0.005	ND	0.01	ND	0.01		0.10		2.00	ND
n		23	23	21	23	23	23	11		11		11		11		10		11		10	
min		2.0	6.30	2.86	14.80	106	120	0.50		0.10		0.01		0.01		0.01		0.01		2.00	
mean*		12.4	6.80	4.86	19.22	6627	6090	0.67		0.41		0.01		0.86		0.09		0.12		4.50	
max		29.6	7.32	7.00	23.10	58000	33000	1.16		0.50		0.02		2.80		0.29		0.35		16.00	
std. dev.		7.8	0.25	1.19	2.44	13896	10197	0.26		0.16		0.01		0.793		0.10		0.11		4.33	

ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

		Flow Rate	**pH**	**DO**	**Temperature**	**Fecal Coliform**	***E. coli***	**TKN**		**NH_3-N**		**NO_2-N**		**NO_3-N**		**PO_4^{3-} Dissolved**		**TP**		**TSS**	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	MB4	8.7	7.17	5.63	16.90	1060	410	1.01		0.50	ND	0.005	ND	1.300		0.03		0.07		8.00	
5/31/2007	MB4	2.6	6.64	3.20	18.10	620	560	0.50	ND	0.50	ND	0.005	ND	1.200		0.03		0.06		6.00	
6/7/2007	MB4	5.5	7.20	4.30	15.80	3200	760	0.50	ND	0.50	ND	0.005	ND	1.100		0.04		0.11		5.00	
6/14/2007	MB4	5.7	7.15	NS	16.10	640	890	Bacteria Sampling Only													
6/19/2007	MB4	5.8	7.03	4.80	19.60	660	630														
6/21/2007	MB4	7.8	7.20	4.50	17.80	4000	2500	0.50	ND	0.50	ND	0.005	ND	1.300		0.01		0.07		2.00	ND
6/28/2007	MB4	16.5	6.90	5.30	23.10	580	11000	Bacteria Sampling Only													
7/5/2007	MB4	24.9	6.87	6.50	20.70	3800	3800	0.50	ND	0.50	ND	0.005	ND	0.660		0.03		0.11		22.00	
7/12/2007	MB4	12.1	6.90	NS	23.20	49000	24000	Bacteria Sampling Only													
7/19/2007	MB4	12.1	6.28	6.01	22.20	3400	8000														
7/24/2007	MB4	18.5	6.93	6.15	20.10	3400	2800														
7/26/2007	MB4	18.9	6.85	6.50	21.00	1160	610														
8/2/2007	MB4	17.4	7.26	6.36	22.60	780	460	0.50	ND	0.50	ND	0.005	ND	0.660		0.29		0.35		2.00	ND
8/9/2007	MB4	22.6	7.20	5.60	23.40	1670	160	Bacteria Sampling Only													
8/16/2007	MB4	15.8	7.38	6.35	21.00	420	460	0.50	ND	0.50	ND	0.005	ND	2.900		0.26		0.03		4.00	
8/23/2007	MB4	17.8	6.91	6.96	17.40	900	680	Bacteria Sampling Only													
8/30/2007	MB4	5.6	6.58	5.12	18.60	720	310														
9/13/2007	MB4	15.3	6.92	5.30	17.90	4400	2100														
9/27/2007	MB4	2.7	6.67	4.74	18.50	410	270														
10/10/2007	MB4	9.8	5.84	4.62	18.70	20000	25000	0.87		0.14		0.019		0.800		0.05		0.11		3.00	
10/10/2007	MB4	3.4	6.98	6.35	18.60	21000	19000	0.95		0.17		0.017		0.790		0.08		0.11		19.00	
10/11/2007	MB4	1.8	6.72	4.25	17.30	4200	4000	0.76		0.11		0.005	ND	1.350		0.05		0.01	ND	11.00	
10/25/2007	MB4	5.2	6.61	3.01	14.30	1160	2200	0.50	ND	0.50	ND	0.005	ND	0.52		0.01		0.08		2.00	ND
n		23	23	21	23	23	23	11		11		11		11		11		11		11	
min		1.8	5.84	3.01	14.30	410	160	0.50		0.11		0.01		0.52		0.01		0.01		2.00	
mean*		11.1	6.88	5.31	19.26	5530	4809	0.64		0.40		0.01		1.14		0.08		0.10		7.64	
max		24.9	7.38	6.96	23.40	49000	25000	1.01		0.50		0.02		2.90		0.29		0.35		22.00	
std. dev.		6.9	0.35	1.09	2.55	10975	7606	0.21		0.17		0.01		0.654		0.10		0.09		6.98	

ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

		Flow Rate	pH	DO	Temperature	Fecal Coliform	*E. coli*	TKN		NH_3 - N		NO_2- N		NO_3- N		PO_4^{3-} Dissolved		TP		TSS	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	MB3	4.4	7.36	7.30	19.20	433	260	0.50	ND	0.50	ND	0.005	ND	1.100		0.03		0.05		2.00	
5/31/2007	MB3	1.2	7.06	4.85	21.10	840	530	0.50	ND	0.50	ND	0.005	ND	0.960		0.02		0.04		7.00	
6/7/2007	MB3	3.3	7.20	4.20	17.40	1000	540	0.50	ND	0.50	ND	0.005	ND	0.910		0.04		0.09		4.00	
6/14/2007	MB3	3.8	7.48	NS	17.40	580	740	Bacteria Sampling Only													
6/19/2007	MB3	2.3	7.28	6.70	22.30	700	660														
6/21/2007	MB3	2.5	7.50	6.40	19.40	3400	930	0.50	ND	0.50	ND	0.005	ND	0.730		0.03		0.09		13.00	
6/28/2007	MB3	7.2	7.60	7.00	25.20	120	5400	Bacteria Sampling Only													
7/5/2007	MB3	8.9	7.44	7.71	22.40	3600	4600	0.50	ND	0.50	ND	0.005	ND	0.005	ND	0.02		0.07		13.00	
7/12/2007	MB3	4.8	7.40	NS	23.20	44000	5100														
7/19/2007	MB3	4.8	6.52	6.54	23.90	2000	2000	Bacteria Sampling Only													
7/24/2007	MB3	6.5	7.21	7.71	20.80	2000	2200														
7/26/2007	MB3	1.9	6.99	6.75	22.40	760	340														
8/2/2007	MB3	1.5	7.45	6.64	23.30	310	160	0.50	ND	0.50	ND	0.005	ND	2.900		0.04		0.08		4.00	
8/9/2007	MB3	3.7	7.50	7.00	24.60	706	460	Bacteria Sampling Only													
8/16/2007	MB3	1.2	7.48	6.43	21.80	260	270	0.50	ND	0.50	ND	0.005	ND	0.560		0.01	ND	0.03		22.00	
8/23/2007	MB3	2.3	7.13	6.91	18.80	1300	860														
8/30/2007	MB3	1.3	6.80	7.87	20.30	627	580	Bacteria Sampling Only													
9/13/2007	MB3	1.9	6.87	4.63	17.50	4100	2000														
9/27/2007	MB3	0.8	6.72	4.98	19.50	420	260														
10/10/2007	MB3	3.2	6.94	5.72	20.00	7700	6600	0.74		0.09		0.008		0.260		0.01		0.06		3.00	
10/10/2007	MB3	1.3	6.99	5.22	19.90	9400	7800	0.75		0.11		0.008		0.270		0.01		0.05		2.00	
10/11/2007	MB3	0.4	6.52	6.09	17.90	870	790	0.54		0.08		0.005	ND	0.560		0.02		0.01	ND	1.00	
10/25/2007	MB3	2.2	6.67	6.32	14.40	120	560	0.50	ND	0.50	ND	0.005	ND	0.94		0.05		0.13		2.00	ND
n		23	23	21	23	23	23	11		11		11		11		11		11		11	
min		0.4	6.52	4.20	14.40	120	160	0.50		0.08		0.01		0.01		0.01		0.01		1.00	
mean*		3.1	7.14	6.33	20.55	3706	1897	0.55		0.39		0.01		0.84		0.03		0.06		6.64	
max		8.9	7.60	7.87	25.20	44000	7800	0.75		0.50		0.01		2.90		0.05		0.13		22.00	
std. dev.		2.2	0.336	1.05	2.68	9106	2294	0.10		0.19		0.00		0.766		0.01		0.034		6.64	

ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

		Flow Rate	pH	DO	Temperature	Fecal Coliform	*E. coli*	TKN		NH_3 - N		NO_2- N		NO_3- N		PO_4^{3-} Dissolved		TP		TSS	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	MB2	1.5	7.28	6.95	20.50	280	170	0.50	ND	0.50	ND	0.005	ND	1.100		0.03		0.06		7.00	
5/31/2007	MB2	0.8	7.42	4.90	23.50	2000	680	0.50	ND	0.50	ND	0.005	ND	1.000		0.02		0.05		16.00	
6/7/2007	MB2	0.9	6.60	6.30	19.60	2100	190	0.50	ND	0.50	ND	0.005	ND	0.800		0.03		0.11		11.00	
6/14/2007	MB2	3.0	8.20	NS	19.50	4400	460	Bacteria Sampling Only													
6/19/2007	MB2	1.6	7.89	7.43	24.60	480	620														
6/21/2007	MB2	1.0	7.90	6.80	6.80	1600	730	0.50	ND	0.50	ND	0.005	ND	0.480		0.04		0.07		9.00	
6/28/2007	MB2	1.9	7.80	7.90	25.20	60	1300	Bacteria Sampling Only													
7/5/2007	MB2	4.5	7.75	8.12	23.30	230	280	2.50		0.50	ND	0.005	ND	0.005	ND	0.01		0.06		11.00	
7/12/2007	MB2	2.3	7.80	NS	24.90	12000	2200	Bacteria Sampling Only													
7/19/2007	MB2	2.3	6.15	6.04	25.20	493	230														
7/24/2007	MB2	2.5	7.58	8.11	21.80	493	390														
7/26/2007	MB2	0.8	8.13	8.15	24.90	156	60														
8/2/2007	MB2	0.8	7.56	5.90	26.50	106	120	0.50	ND	0.50	ND	0.005	ND	2.800		0.04		0.09		9.00	
8/9/2007	MB2	1.4	7.90	7.30	26.20	538	420	Bacteria Sampling Only													
8/16/2007	MB2	0.4	8.44	6.93	24.50	800	370	0.50	ND	0.50	ND	0.005	ND	0.005	ND	0.01		0.05		10.00	
8/23/2007	MB2	1.1	6.89	6.60	20.00	230	190	Bacteria Sampling Only													
8/30/2007	MB2	0.3	8.11	7.78	23.50	680	140														
9/13/2007	MB2	0.6	7.05	4.79	20.60	3200	540														
9/27/2007	MB2	0.3	6.98	4.63	21.70	1600	150														
10/10/2007	MB2	2.2	7.90	0.21	21.20	420	470	0.81		0.09		0.005	ND	0.005	ND	0.01		0.05		4.00	
10/10/2007	MB2	2.0	7.90	0.19	21.20	340	350	0.82		0.09		0.005	ND	0.005	ND	0.02		0.05		4.00	
10/11/2007	MB2	0.1	8.19	0.24	19.70	350	370	0.92		0.08		0.006		0.270		0.02		0.08		15.00	
10/25/2007	MB2	2.1	6.82	6.11	16.30	1500	600	0.50	ND	0.50	ND	0.005	ND	1.10		0.06		0.13		2.00	ND
n		23	23	21	23	23	23	11		11		11		11		11		11		11	
min		0.1	6.15	0.19	6.80	60	60	0.50		0.08		0.01		0.01		0.01		0.05		2.00	
mean*		1.5	7.58	5.78	21.79	1481	480	0.78		0.39		0.01		0.69		0.03		0.07		8.91	
max		4.5	8.44	8.15	26.50	12000	2200	2.50		0.50		0.01		2.80		0.06		0.13		16.00	
std. dev.		1.0	0.58	2.56	4.18	2538	463	0.59		0.19		0.00		0.836		0.02		0.027		4.44	

ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

		Flow Rate	pH	DO	Temperature	Fecal Coliform	*E. coli*	TKN		NH_3 – N		NO_2- N		NO_3- N		PO_4^{3-} Dissolved		TP		TSS	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	MB1	1.1	7.44	7.60	16.3	250	180	0.50	ND	0.50	ND	0.005	ND	1.800		0.04		0.05		2.00	
5/31/2007	MB1	0.3	7.08	7.85	17.9	200	170	0.50	ND	0.50	ND	0.005	ND	1.700		0.05		0.05		2.00	ND
6/7/2007	MB1	0.5	9.00	7.20	14.8	660	490	0.50	ND	0.50	ND	0.005	ND	1.800		0.05		0.14		2.00	ND
6/14/2007	MB1	0.2	8.20	NS	19.5	5400	560	Bacteria Sampling Only													
6/19/2007	MB1	0.8	7.69	8.88	18.3	980	460														
6/21/2007	MB1	0.4	7.90	9.30	15.6	460	360	0.50	ND	0.50	ND	0.005	ND	2.000		0.04		0.01	ND	2.00	ND
6/28/2007	MB1	0.6	7.40	7.90	21.2	210	4800	Bacteria Sampling Only													
7/5/2007	MB1	1.4	6.78	7.94	19.8	4200	4000	0.50	ND	0.50	ND	0.005	ND	1.000	ND	0.06		0.12		17.00	
7/12/2007	MB1	1.0	7.60	NS	19.5	28000	5300	Bacteria Sampling Only													
7/19/2007	MB1	27.4	5.74	8.79	20.7	3500	3300														
7/24/2007	MB1	0.9	7.74	9.55	17.6	3500	1600														
7/26/2007	MB1	0.4	7.62	9.09	19.6	860	570														
8/2/2007	MB1	0.3	7.87	9.47	19.5	1040	480	0.50	ND	0.50	ND	0.005	ND	1.700		0.06		0.07		2.00	ND
8/9/2007	MB1	0.6	7.80	8.80	21.4	763	410	Bacteria Sampling Only													
8/16/2007	MB1	0.2	7.88	8.43	19.8	780	440	0.50	ND	0.50	ND	0.005	ND	1.900	ND	0.05		0.06		2.00	ND
8/23/2007	MB1	0.4	7.55	8.78	16.9	1060	480	Bacteria Sampling Only													
8/30/2007	MB1	0.1	7.09	9.37	18.4	1270	560														
9/13/2007	MB1	0.1	7.23	7.01	15.6	720	610														
9/27/2007	MB1	0.0	7.34	6.24	19.4	370	16000														
10/10/2007	MB1	0.6	8.05	0.28	17.1	16000	11000	0.96		0.05		0.011		1.410		0.12		0.16		5.00	
10/10/2007	MB1	0.6	7.88	0.26	16.7	7000	780	0.67		0.06		0.012		1.420		0.12		0.15		3.00	
10/11/2007	MB1	0.0	8.43	1.35	16.7	1100	7800	0.50	ND	0.50	ND	0.005		1.530		0.08		0.09		1.00	
10/25/2007	MB1	0.1	6.70	6.30	12.9	1700	490	0.50	ND	0.50	ND	0.005	ND	1.00		0.06		0.12		2.00	ND
n		23	23	21	23	23	23	11		11		11		11		11		11		11	
min		0.0	5.74	0.26	12.90	200	170	0.50		0.05		0.01		1.00		0.04		0.01		1.00	
mean*		1.7	7.57	7.16	18.05	3479	2645	0.56		0.42		0.01		1.57		0.07		0.09		3.64	
max		27.4	9.00	9.55	21.40	28000	16000	0.96		0.50		0.01		2.00		0.12		0.16		17.00	
std. dev.		5.6	0.65	2.91	2.17	6375	4052	0.14		0.18		0.00		0.337		0.03		0.049		4.54	

ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

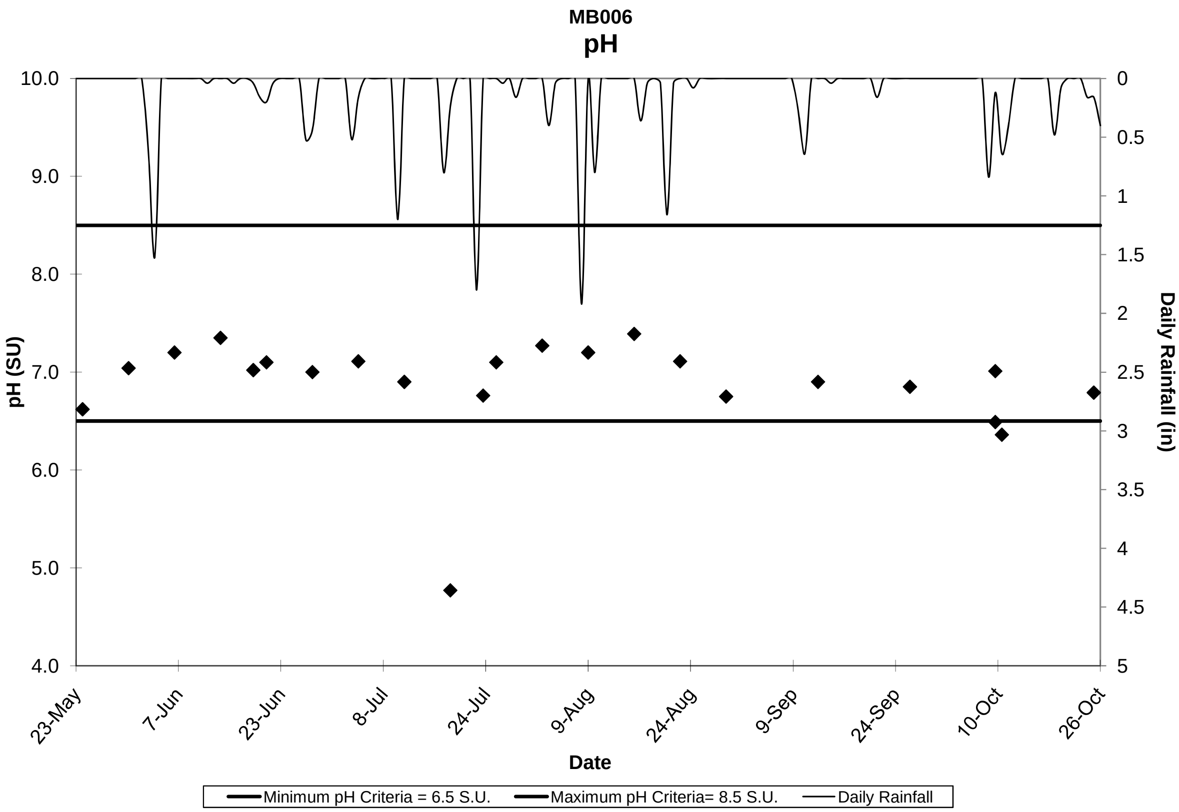
		Flow Rate	pH	DO	Temperature	Fecal Coliform	*E. coli*	TKN		NH_3 – N		NO_2- N		NO_3- N		PO_4^{3-} Dissolved		TP		TSS	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	HB1	45.3	7.22	7.60	19.10	3300	2600	0.50	ND	0.50	ND	0.005	ND	7.200		1.20		1.34		6.00	
5/31/2007	HB1	10.6	7.08	6.49	20.60	2100	780	2.20		1.40		0.005	ND	8.200		1.81		1.85		8.00	
6/7/2007	HB1	30.9	6.60	6.40	17.40	2200	660	2.30		0.50	ND	0.005	ND	9.400		1.70		2.10		2.00	ND
6/14/2007	HB1	54.4	7.62	NS	16.10	900	1800	Bacteria Sampling Only													
6/19/2007	HB1	29.0	NS	NS	NS	5900	1400														
6/21/2007	HB1	22.7	7.30	5.80	19.30	780	820	0.50	ND	0.50	ND	0.005	ND	13.000		2.00		2.20		2.00	ND
6/28/2007	HB1	45.7	7.60	7.20	23.20	200	5200	Bacteria Sampling Only													
7/5/2007	HB1	43.2	7.01	8.79	21.70	1160	2700	0.50	ND	0.50	ND	0.005	ND	0.005	ND	0.80		0.91		10.00	
7/12/2007	HB1	75.8	7.30	NS	22.10	41000	NS	Bacteria Sampling Only													
7/19/2007	HB1	75.2	6.74	6.37	22.50	5900	3700														
7/24/2007	HB1	69.3	7.38	9.08	20.00	5900	2800														
7/26/2007	HB1	28.9	7.24	7.77	22.20	1200	1700														
8/2/2007	HB1	22.5	7.22	7.54	23.30	800	430	1.20		0.50	ND	0.005	ND	12.000		2.10		1.80		2.00	ND
8/9/2007	HB1	43.0	7.50	7.50	24.00	1420	430	Bacteria Sampling Only													
8/16/2007	HB1	19.7	7.55	7.25	22.60	860	410	0.50	ND	0.50	ND	0.005	ND	11.000	ND	1.90		2.20		10.00	
8/23/2007	HB1	19.7	7.16	7.74	19.60	880	640	Bacteria Sampling Only													
8/30/2007	HB1	20.0	7.00	6.96	21.80	1030	1800														
9/13/2007	HB1	22.3	6.98	6.23	19.40	2700	840														
9/27/2007	HB1	15.9	7.29	4.91	22.10	880	560														
10/10/2007	HB1	NS	7.61	0.23	19.10	26000	22000	1.30		0.13		0.061		5.410		0.94		1.05		5.00	
10/10/2007	HB1	NS	7.56	0.23	19.00	21000	16000	0.93		0.13		0.064		5.640		0.98		1.03		4.00	
10/11/2007	HB1	NS	8.38	2.10	19.20	1100	1600	NS		NS		NS		NS		NS		NS		NS	
10/25/2007	HB1	19.5	7.11	6.67	16.70	40000	440	1.40		0.50	ND	0.005	ND	14.00		2.20		1.80		2.00	ND
n		20	22	20	22	23	22	10		10		10		10		10		10		10	
min		10.6	6.60	0.23	16.10	200	410	0.50		0.13		0.01		0.01		0.80		0.91		2.00	
mean*		35.7	7.29	6.14	20.50	7270	3150	1.13		0.52		0.02		8.59		1.56		1.63		5.10	
max		75.8	8.38	9.08	24.00	41000	22000	2.30		1.40		0.06		14.00		2.20		2.20		10.00	
std. dev.		20.0	0.37	2.49	2.20	12295	5354	0.69		0.35		0.02		4.235		0.53		0.5029		3.28	

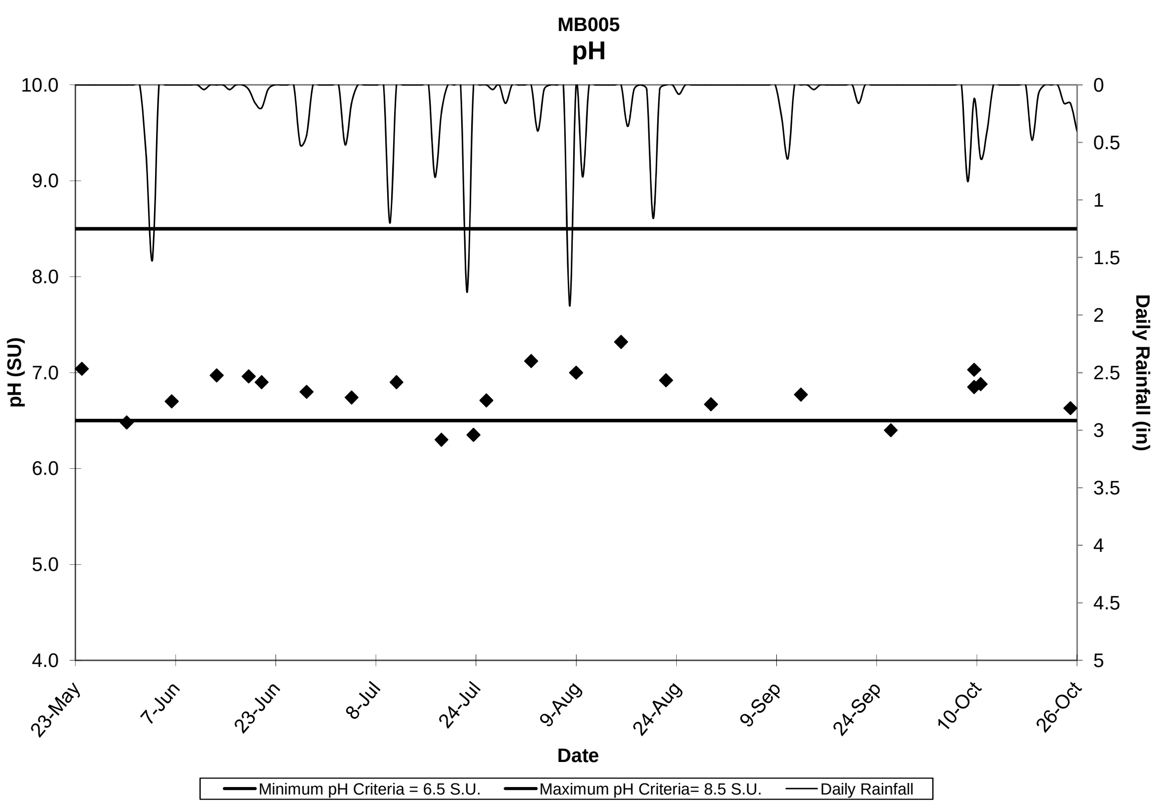
ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

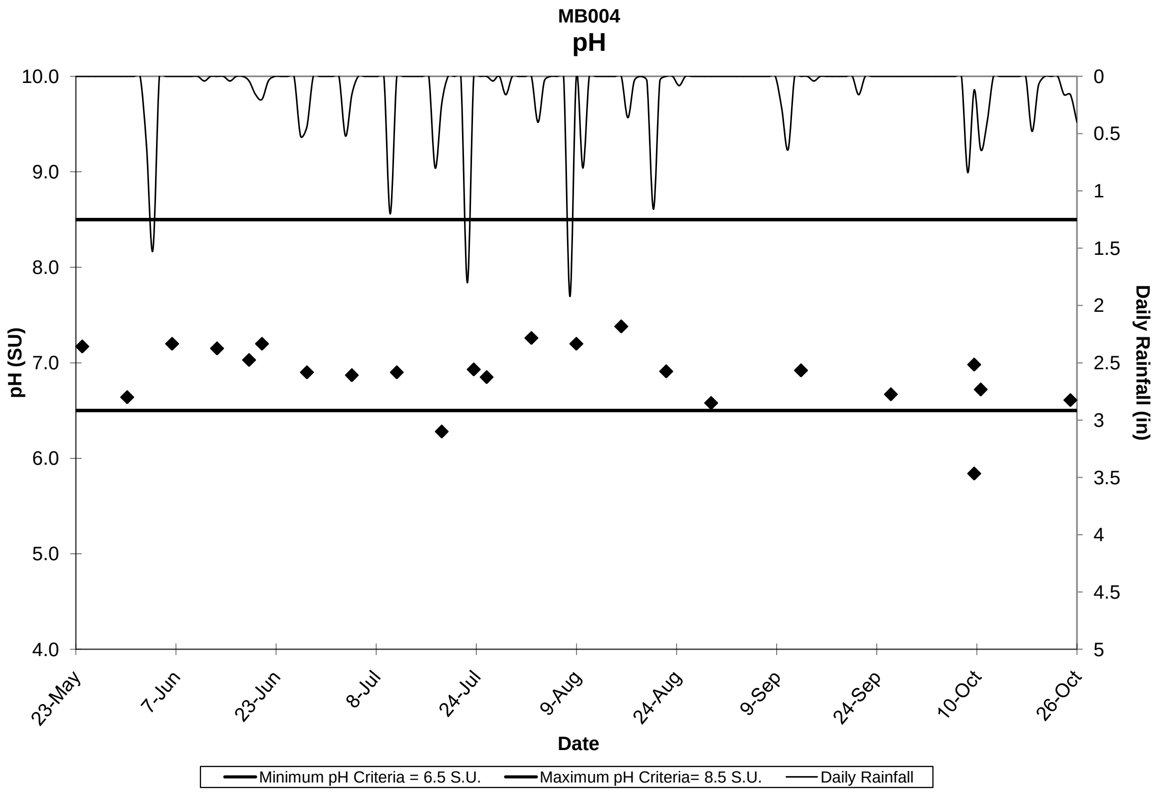
		Flow Rate	pH	DO	Temperature	Fecal Coliform	*E. coli*	TKN		NH_3 - N		NO_2- N		NO_3- N		PO_4^{3-} Dissolved		TP		TSS	
Date	*Station ID*	*cfs*	*S.U.*	*(mg/L)*	*deg C*	*col/100 ml*	*col/100 ml*	*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*		*(mg/L)*	
5/24/2007	SR1	25.1	7.49	8.34	17.90	820	440	0.50	ND	0.50	ND	0.005	ND	1.800		0.02		0.03		4.00	
5/31/2007	SR1	5.8	6.98	7.21	18.70	700	380	0.50	ND	0.50	ND	0.005	ND	1.800		0.03		0.04		2.00	ND
6/7/2007	SR1	12.0	6.20	7.90	16.00	2200	590	0.50	ND	0.50	ND	0.005	ND	1.600		0.03		0.11		2.00	ND
6/14/2007	SR1	17.0	7.35	NS	17.60	1060	1100	Bacteria Sampling Only													
6/19/2007	SR1	12.8	7.45	7.40	22.80	4900	1800														
6/21/2007	SR1	13.1	7.50	7.00	17.80	3900	790	0.50	ND	0.50	ND	0.005	ND	1.800		0.03		0.04		2.00	ND
6/28/2007	SR1	27.2	7.50	7.70	21.80	170	6100	Bacteria Sampling Only													
7/5/2007	SR1	34.2	7.55	8.50	19.30	3700	3700	0.50	ND	0.50	ND	0.005	ND	1.400		0.03		0.07		7.00	
7/12/2007	SR1	41.0	7.20	NS	21.40	39000	NS	Bacteria Sampling Only													
7/19/2007	SR1	41.0	6.38	8.42	21.80	5800	4100														
7/24/2007	SR1	43.6	7.27	8.76	18.50	5800	3500														
7/26/2007	SR1	12.2	7.09	8.04	20.60	1020	520														
8/2/2007	SR1	11.5	7.50	8.52	21.90	110	390	0.50	ND	0.50	ND	0.005	ND	1.400		0.01	ND	0.01		2.00	ND
8/9/2007	SR1	23.5	7.40	7.40	22.70	1270	390	Bacteria Sampling Only													
8/16/2007	SR1	9.3	7.52	8.29	20.40	553	430	0.50	ND	0.50	ND	0.005	ND	1.600		0.02		0.06		2.00	ND
8/23/2007	SR1	9.3	6.85	8.64	17.10	900	460	Bacteria Sampling Only													
8/30/2007	SR1	6.8	6.75	8.11	19.20	420	430														
9/13/2007	SR1	8.5	7.02	4.99	16.90	2000	630														
9/27/2007	SR1	4.6	6.90	6.02	19.20	820	480														
10/10/2007	SR1	NS	8.11	0.28	17.50	33000	23000	0.91		0.09		0.018		1.490		0.07		0.12		10.00	
10/10/2007	SR1	NS	7.41	0.26	17.10	12000	9400	0.94		0.13		0.018		1.500		0.08		0.13		10.00	
10/11/2007	SR1	NS	8.41	2.15	16.90	3000	2600	0.52		0.07		0.008		1.560		0.04		0.07		2.00	
10/25/2007	SR1	7.6	6.88	6.54	13.80	4500	1700	0.50	ND	0.50	ND	0.005	ND	1.30		0.02		0.08		2.00	ND
n		20	23	21	23	23	22	11		11		11		11		11		11		11	
min		4.6	6.20	0.26	13.80	110	380	0.50		0.07		0.01		1.30		0.01		0.01		2.00	
mean*		18.3	7.25	6.69	19.00	5550	2860	0.58		0.39		0.01		1.57		0.03		0.07		4.09	
max		43.6	8.41	8.76	22.80	39000	23000	0.94		0.50		0.02		1.80		0.08		0.13		10.00	
std. dev.		12.8	0.49	2.62	2.35	10025	5045	0.17		0.19		0.01		0.174		0.02		0.0386		3.30	

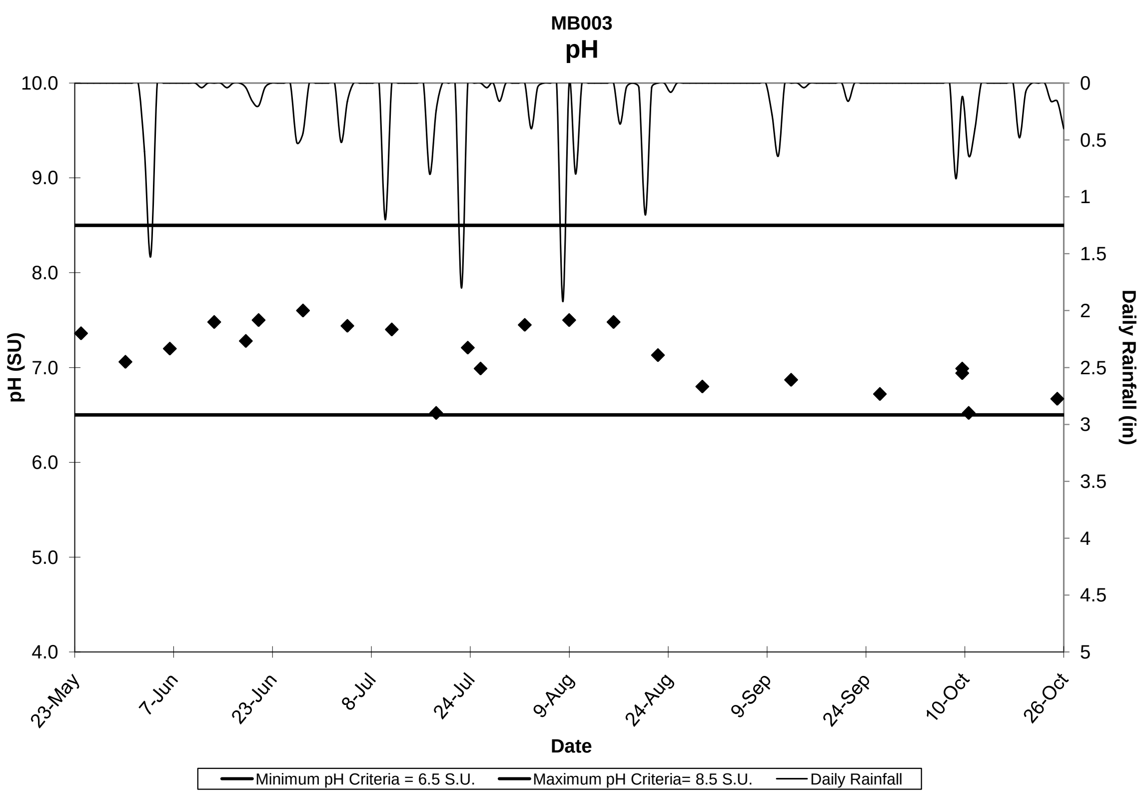
ND indicates value is one half of the detection limit
*For fecal coliform and *E. coli*, geometric means were calculated

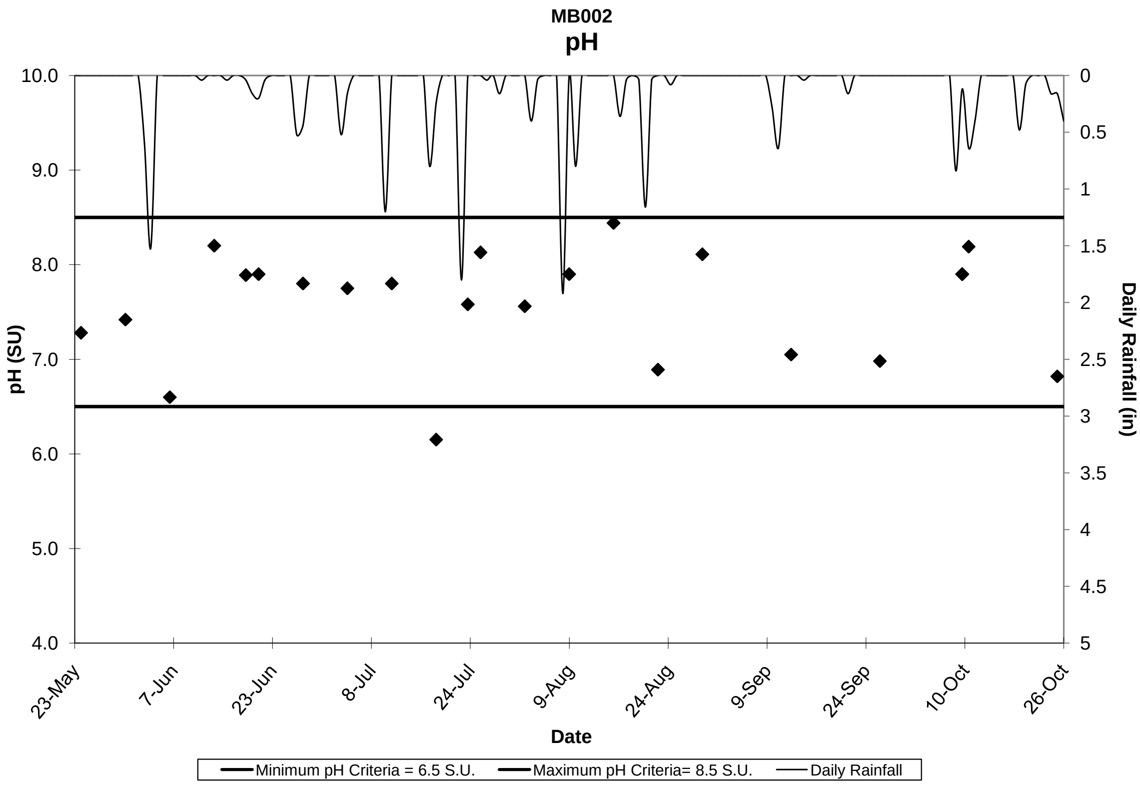
Appendix E: Presentation of Graphed Instream Water Quality Data


MB006
pH
pH (SU)
Daily Rainfall (in)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall

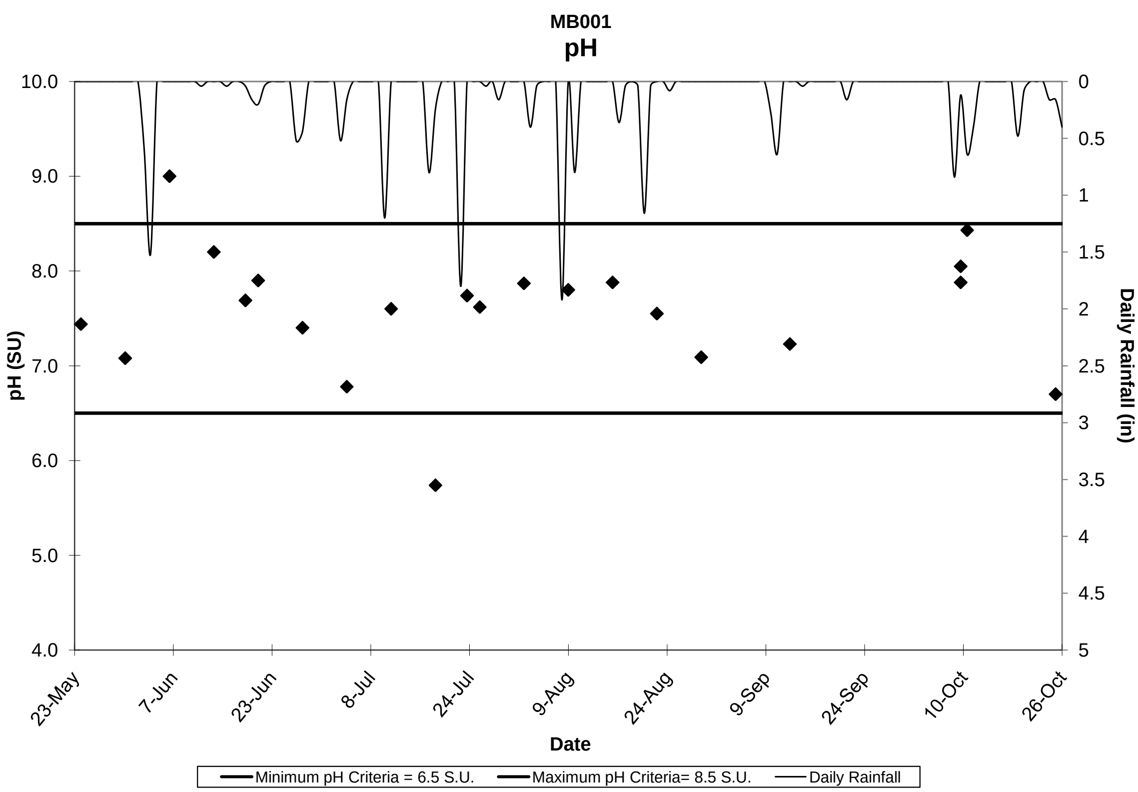

MB005
pH
pH (SU)
Daily Rainfall (in)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall


MB004
pH
pH (SU)
Daily Rainfall (in)
Date
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall

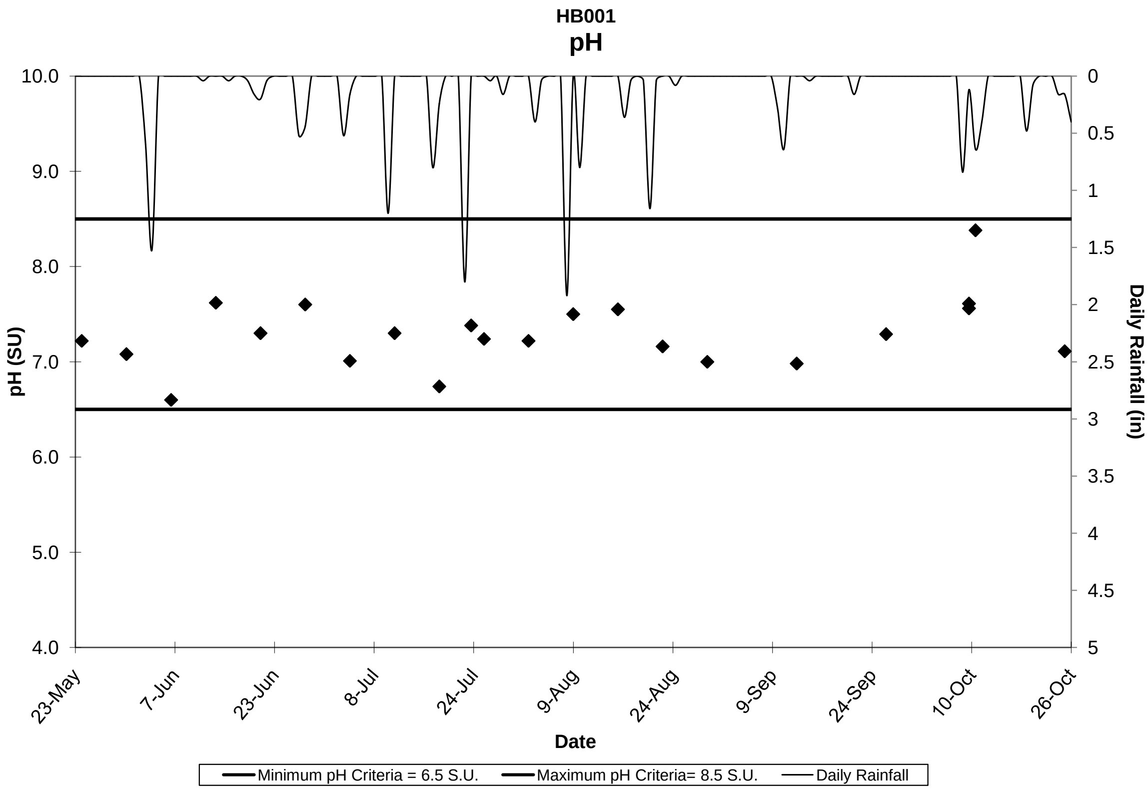

MB003
pH
pH (SU)
Daily Rainfall (in)
Date
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall



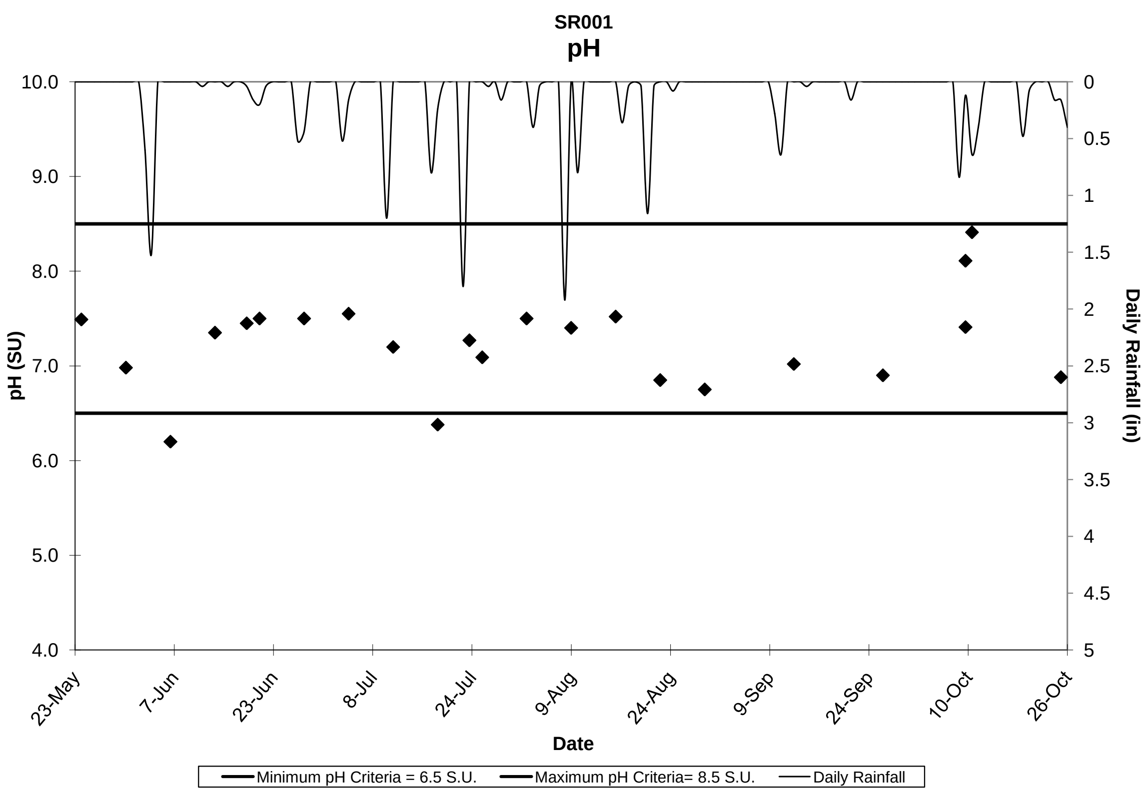
MB002
pH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
pH (SU)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall



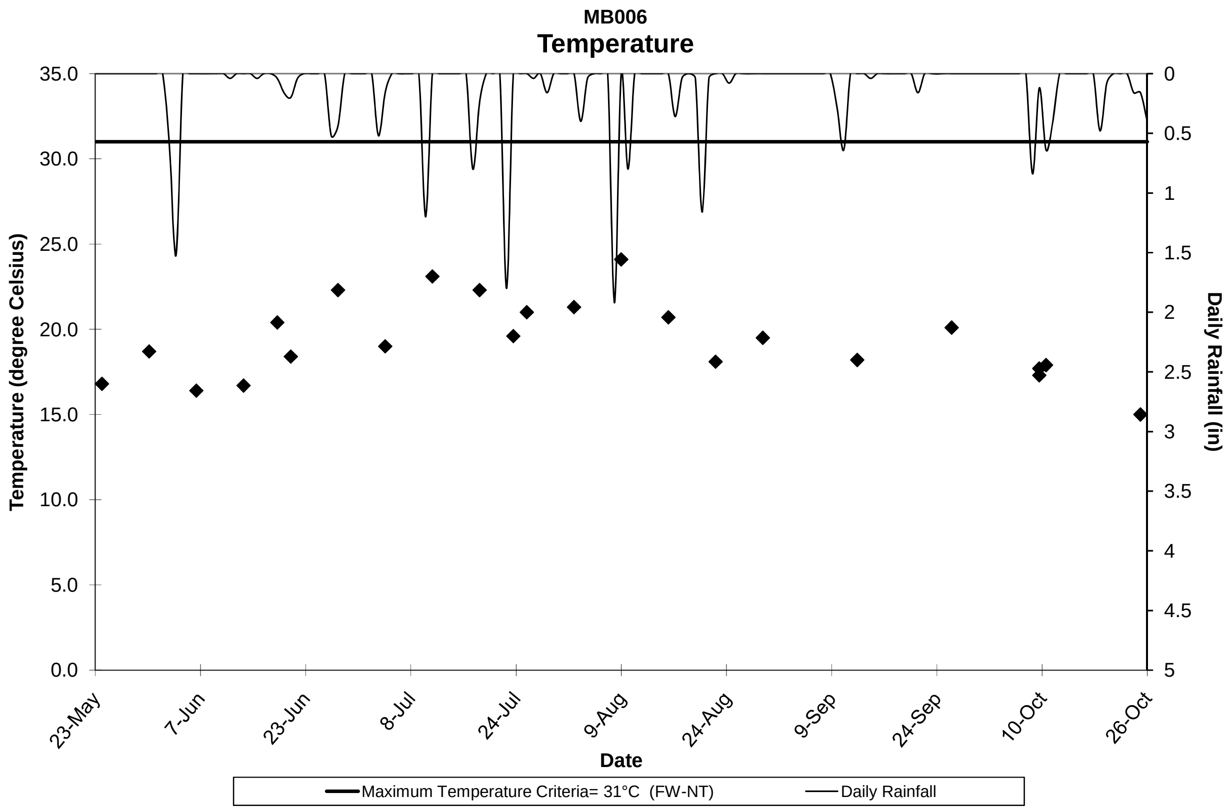
MB001
pH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
pH (SU)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall

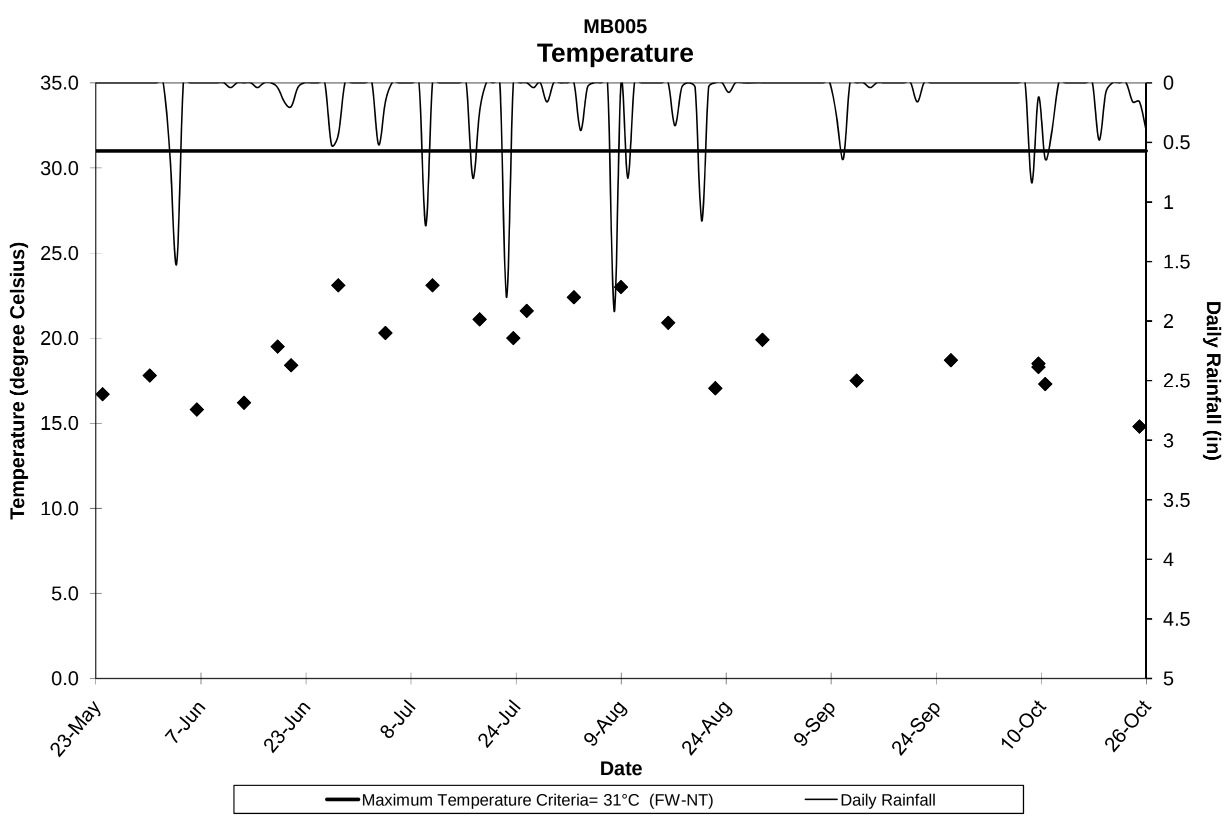


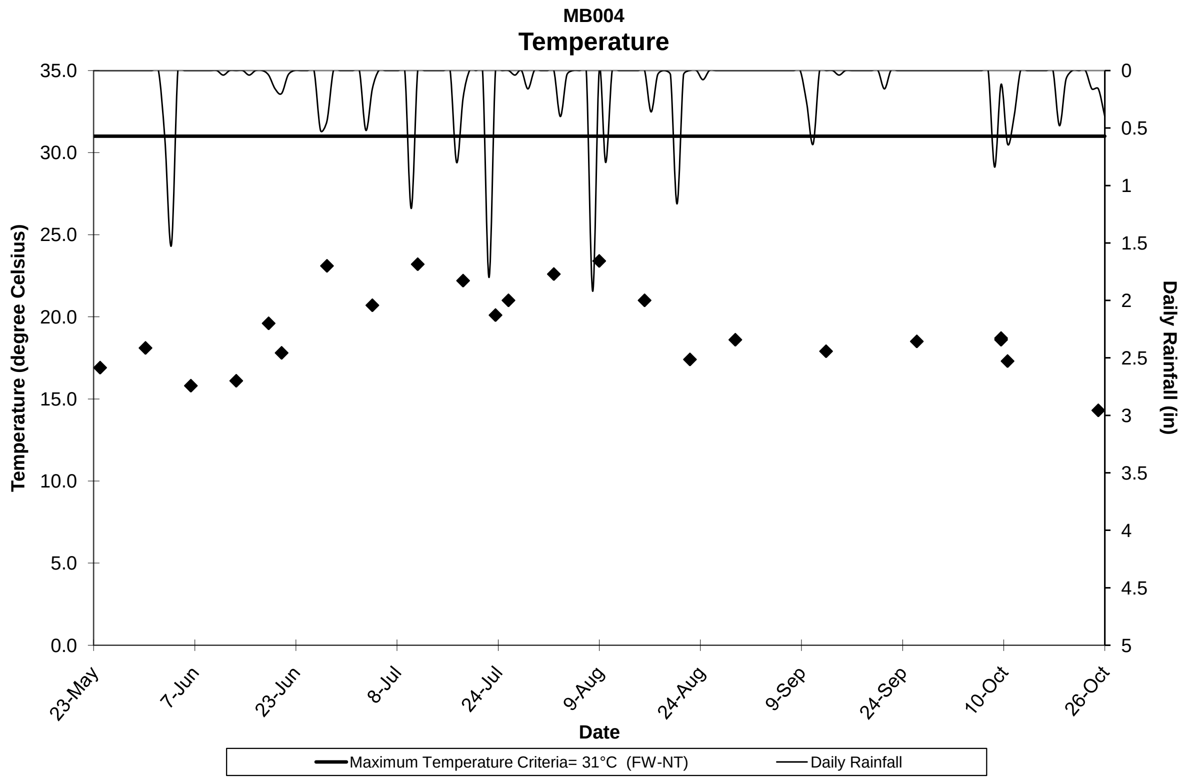
HB001
pH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
pH (SU)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall



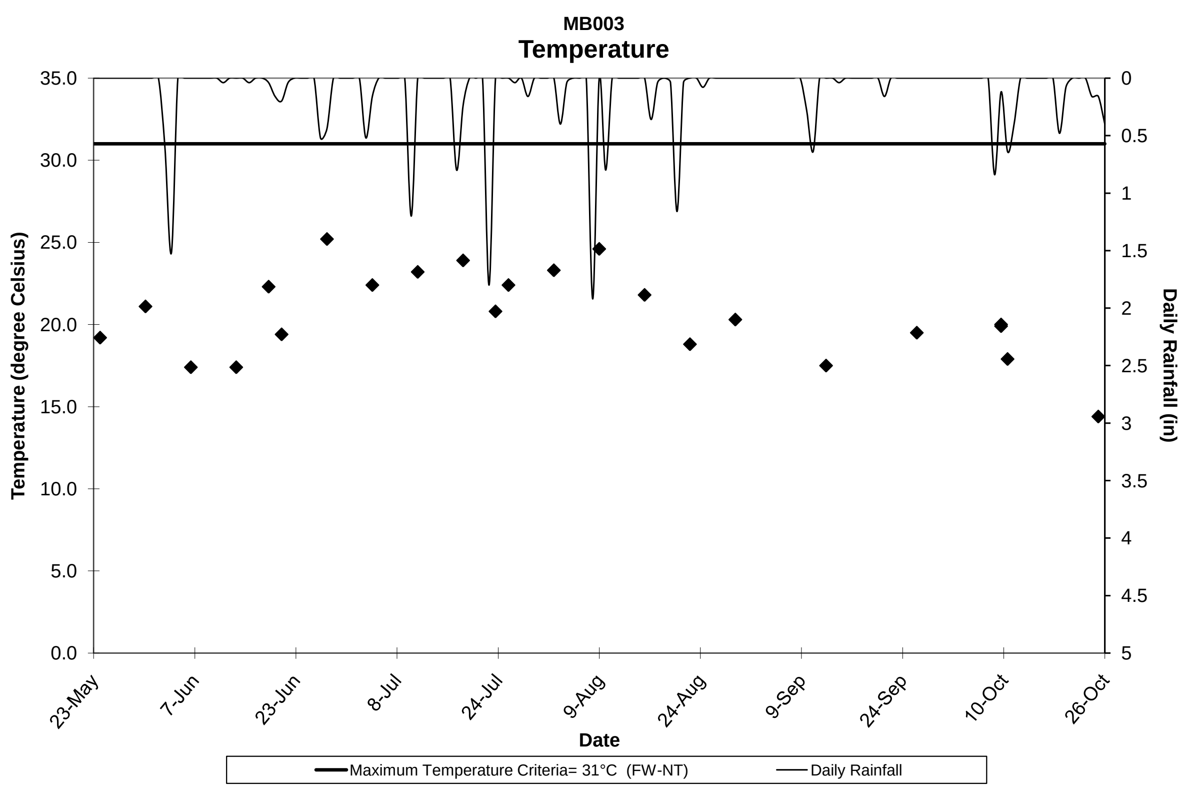
SR001
pH
10.0
9.0
8.0
7.0
6.0
5.0
4.0
pH (SU)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Minimum pH Criteria = 6.5 S.U.
Maximum pH Criteria= 8.5 S.U.
Daily Rainfall


MB006
Temperature
Temperature (degree Celsius)
Daily Rainfall (in)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

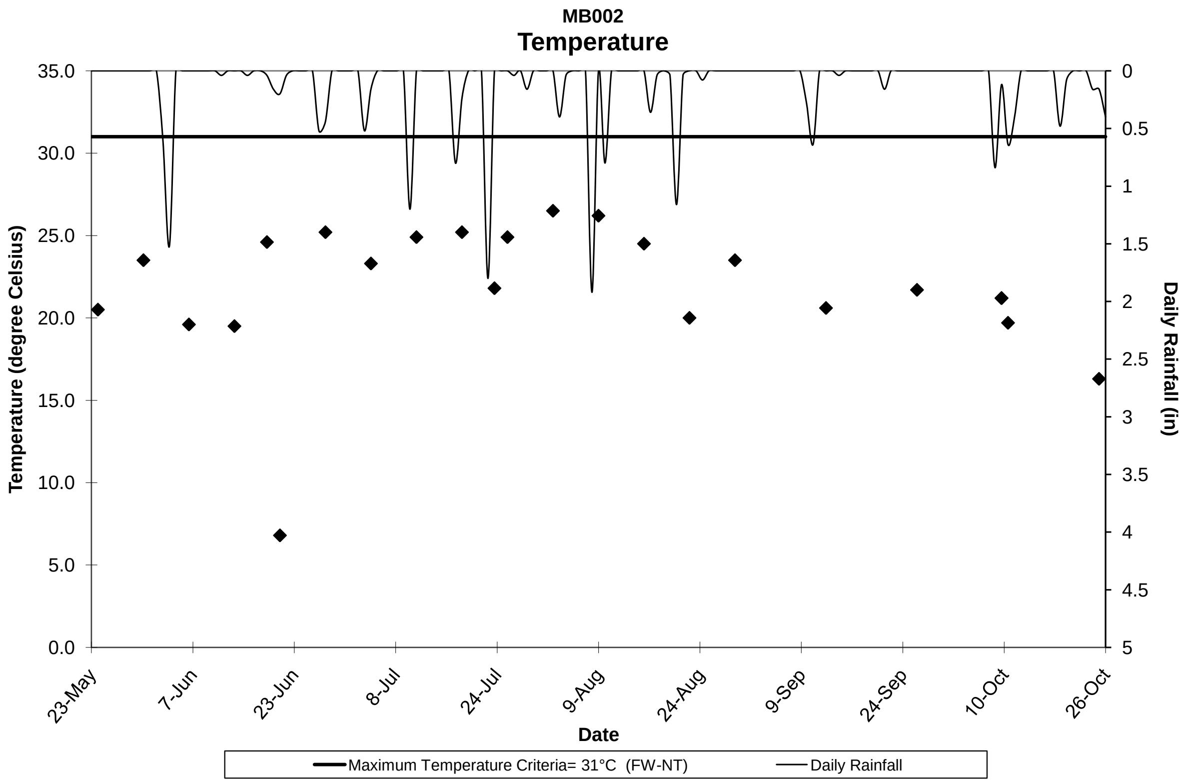

MB005
Temperature
Temperature (degree Celsius)
Daily Rainfall (in)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

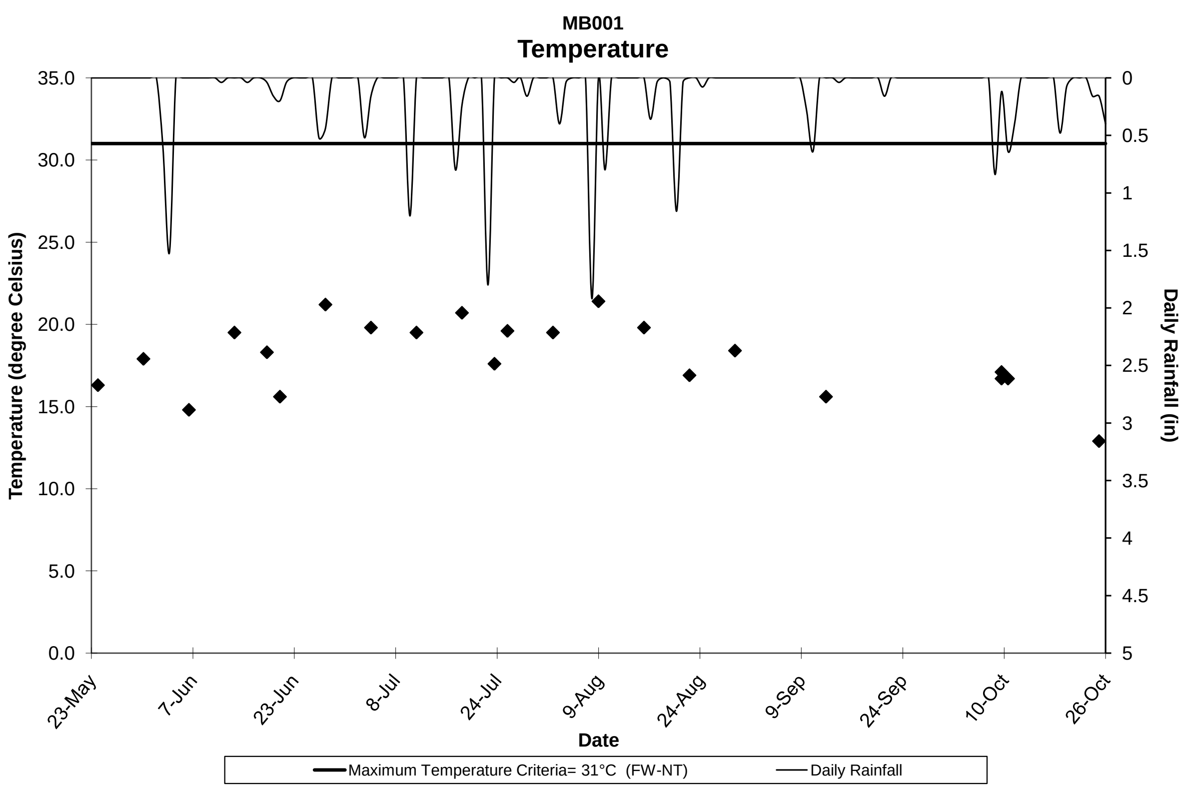


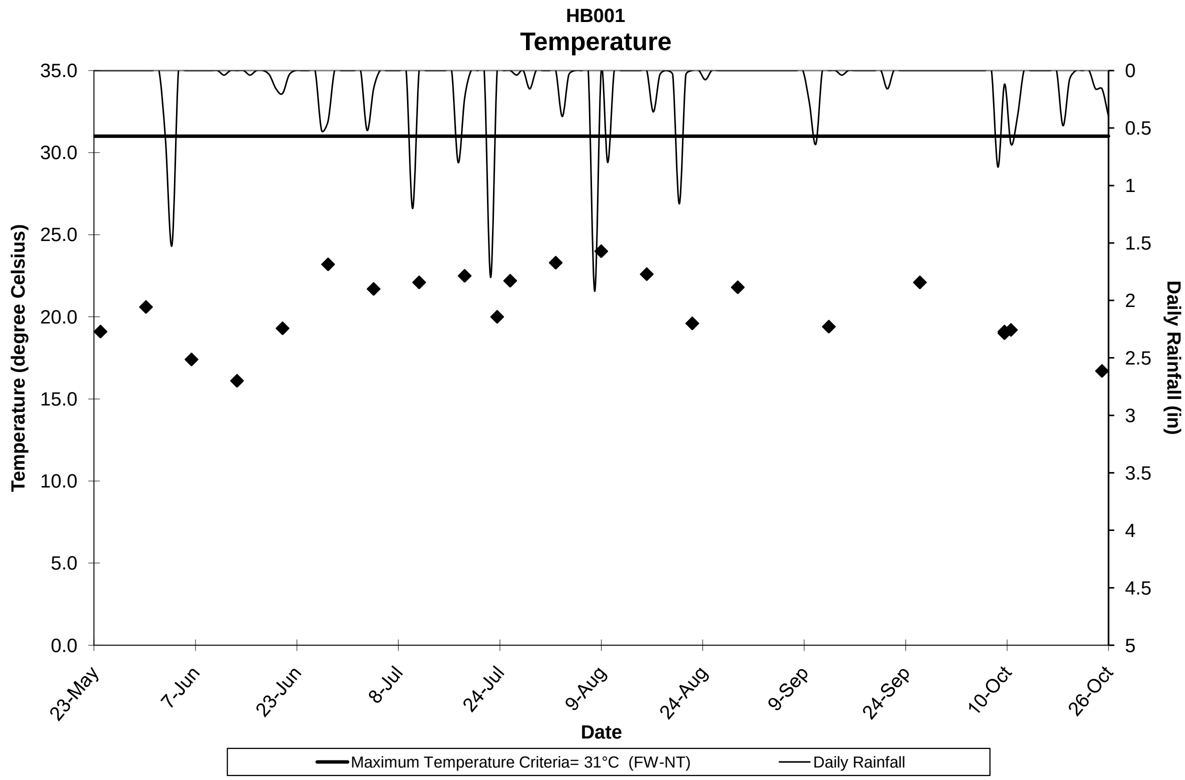
MB004
Temperature
Temperature (degree Celsius)
Daily Rainfall (in)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

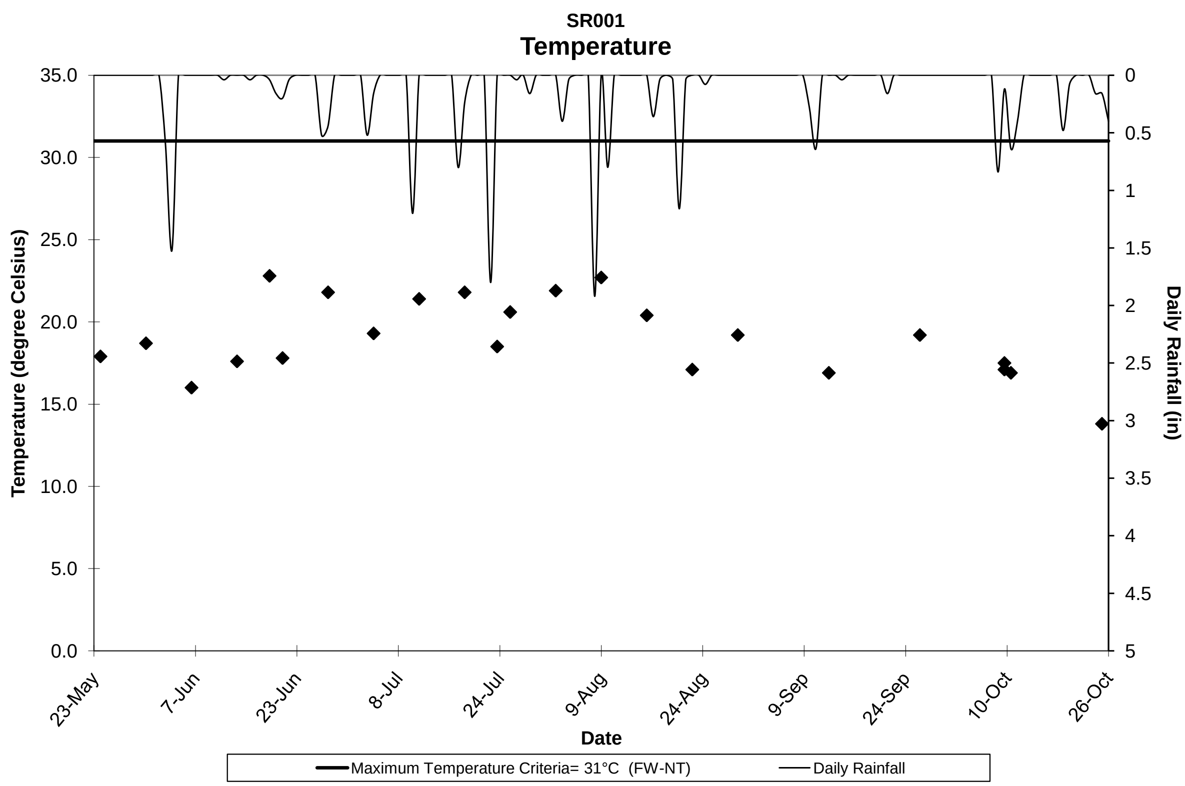


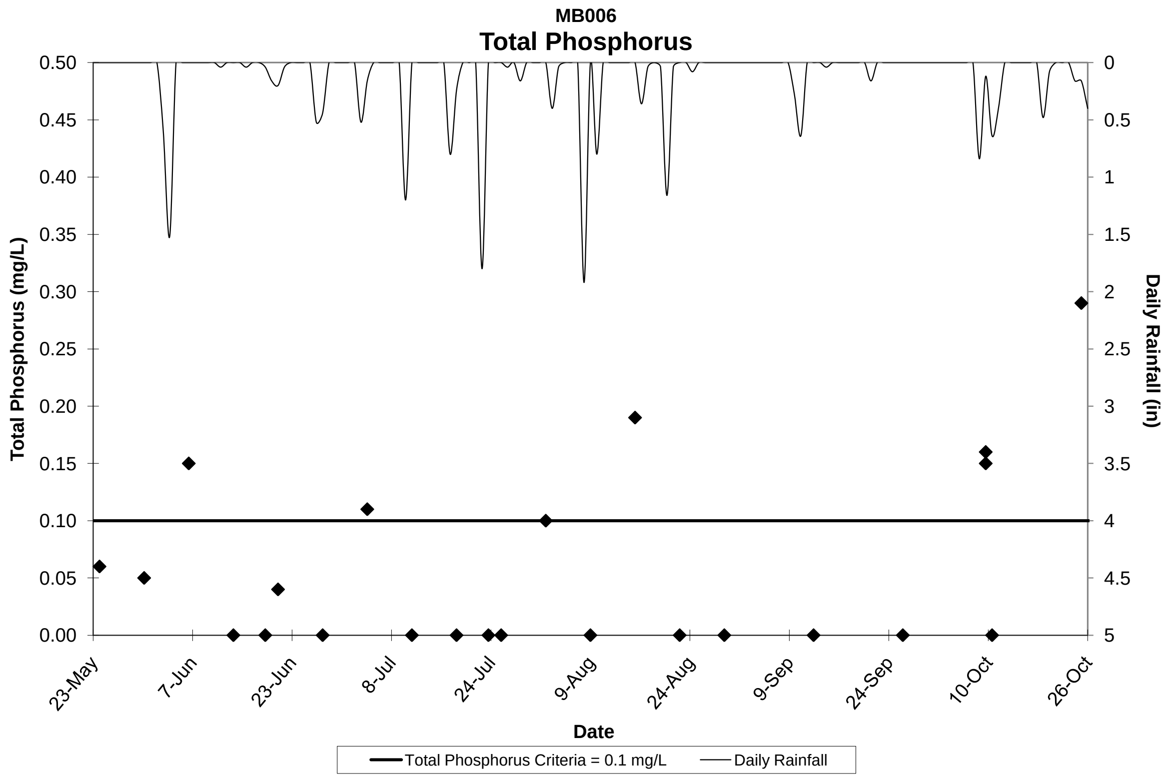
MB003
Temperature
Temperature (degree Celsius)
Daily Rainfall (in)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

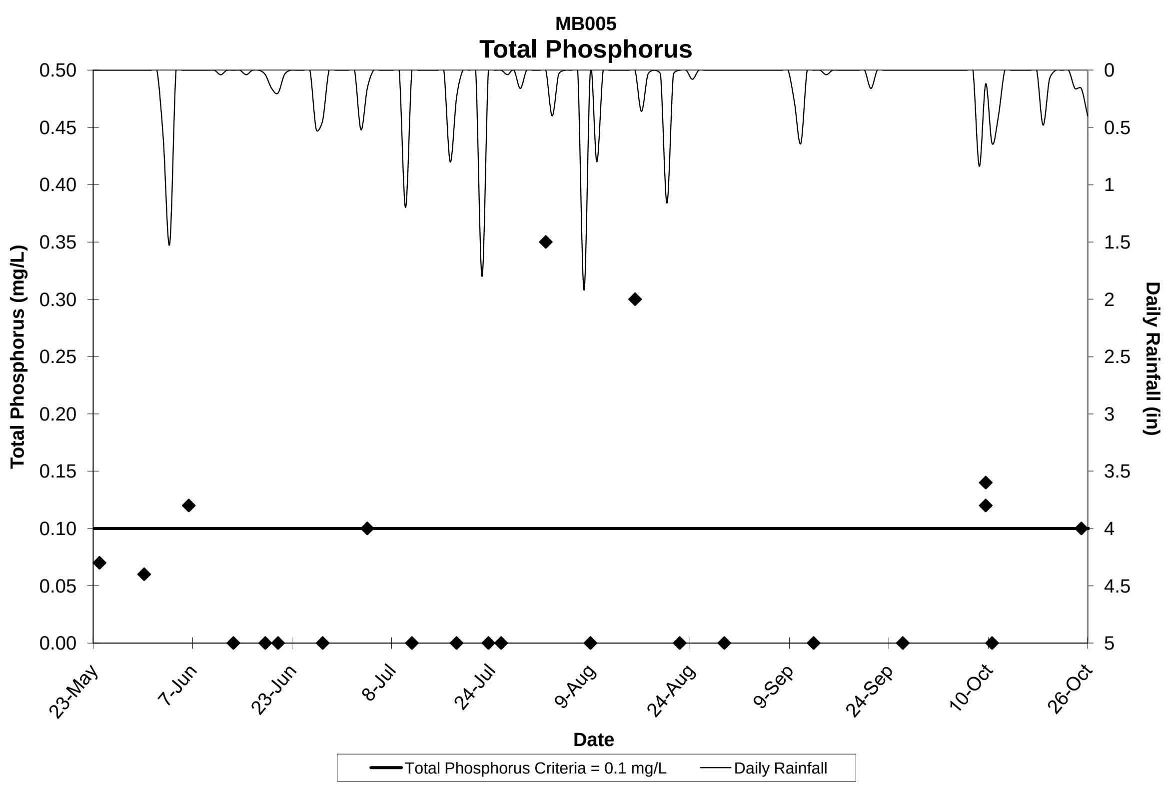

MB002
Temperature
Temperature (degree Celsius)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Daily Rainfall (in)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

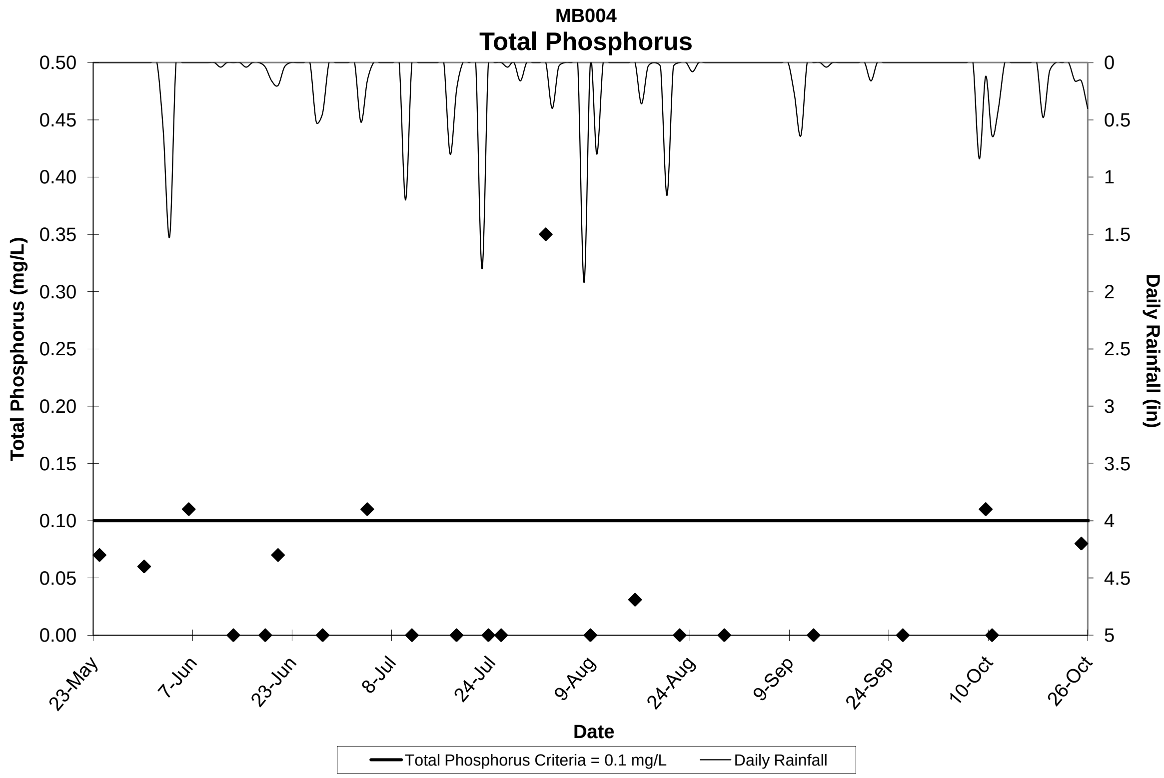

MB001
Temperature
Temperature (degree Celsius)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Daily Rainfall (in)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

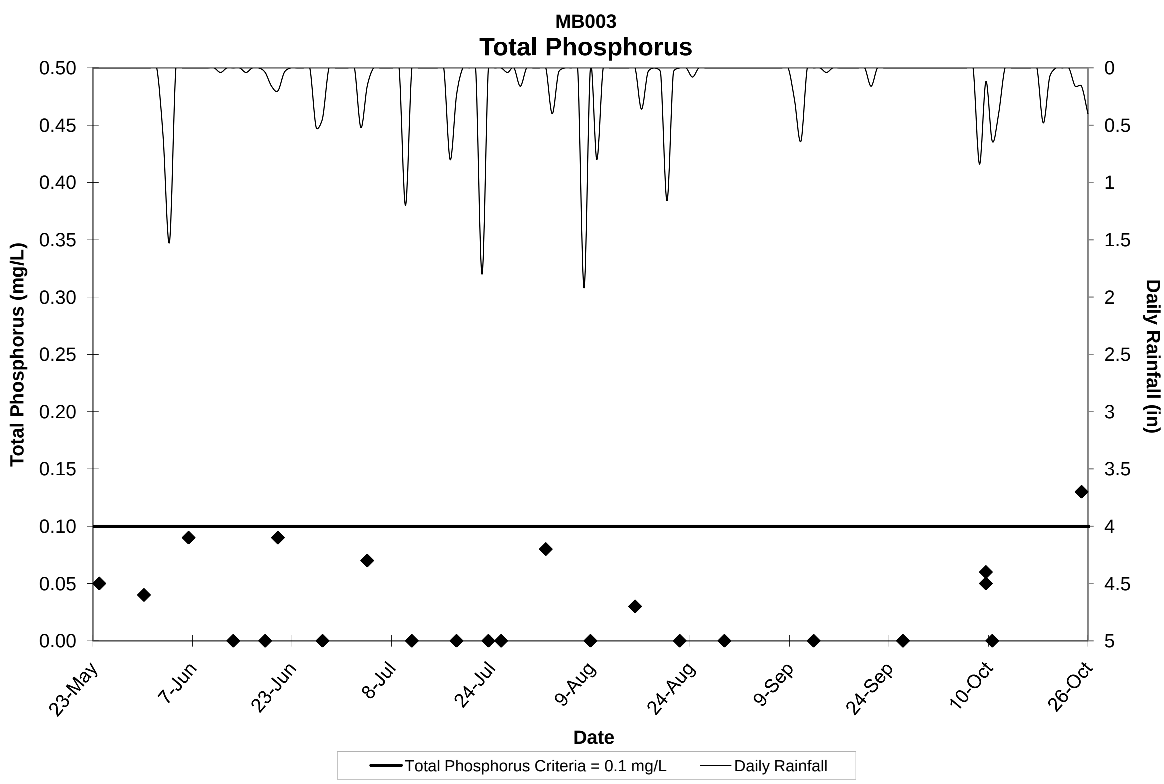

HB001
Temperature
Temperature (degree Celsius)
Daily Rainfall (in)
Date
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

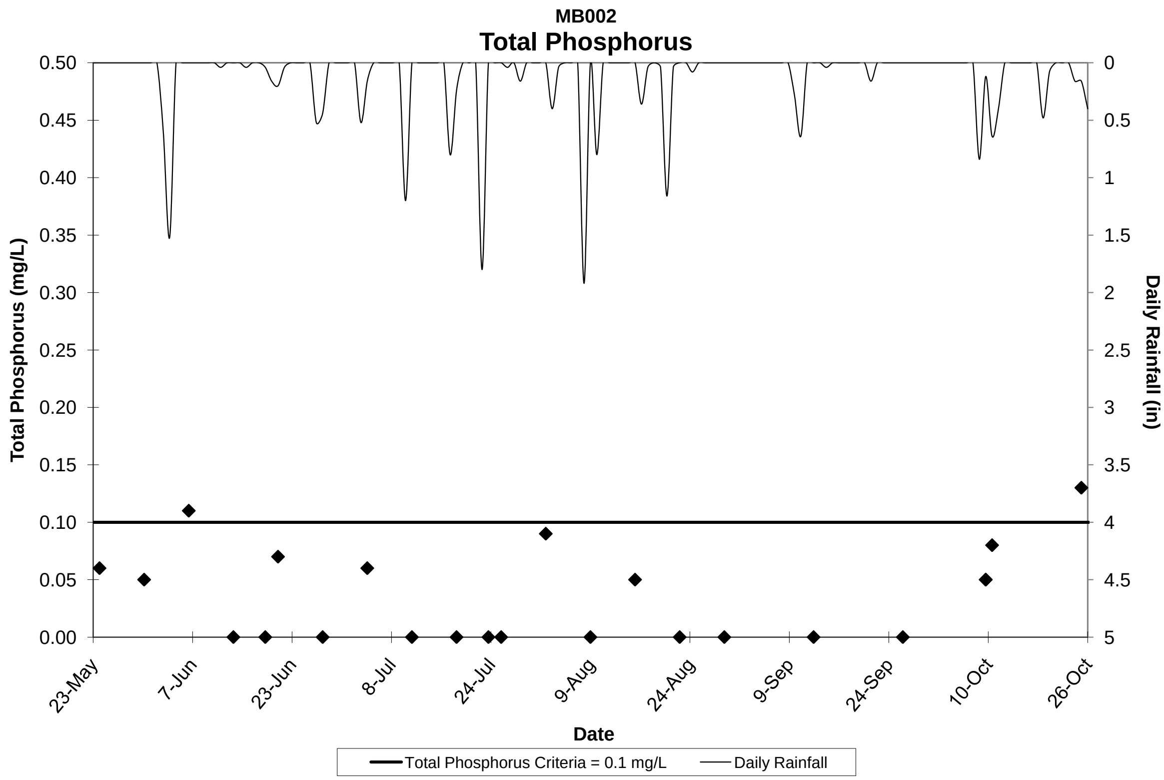

SR001
Temperature
Temperature (degree Celsius)
Daily Rainfall (in)
Date
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Maximum Temperature Criteria= 31°C (FW-NT)
Daily Rainfall

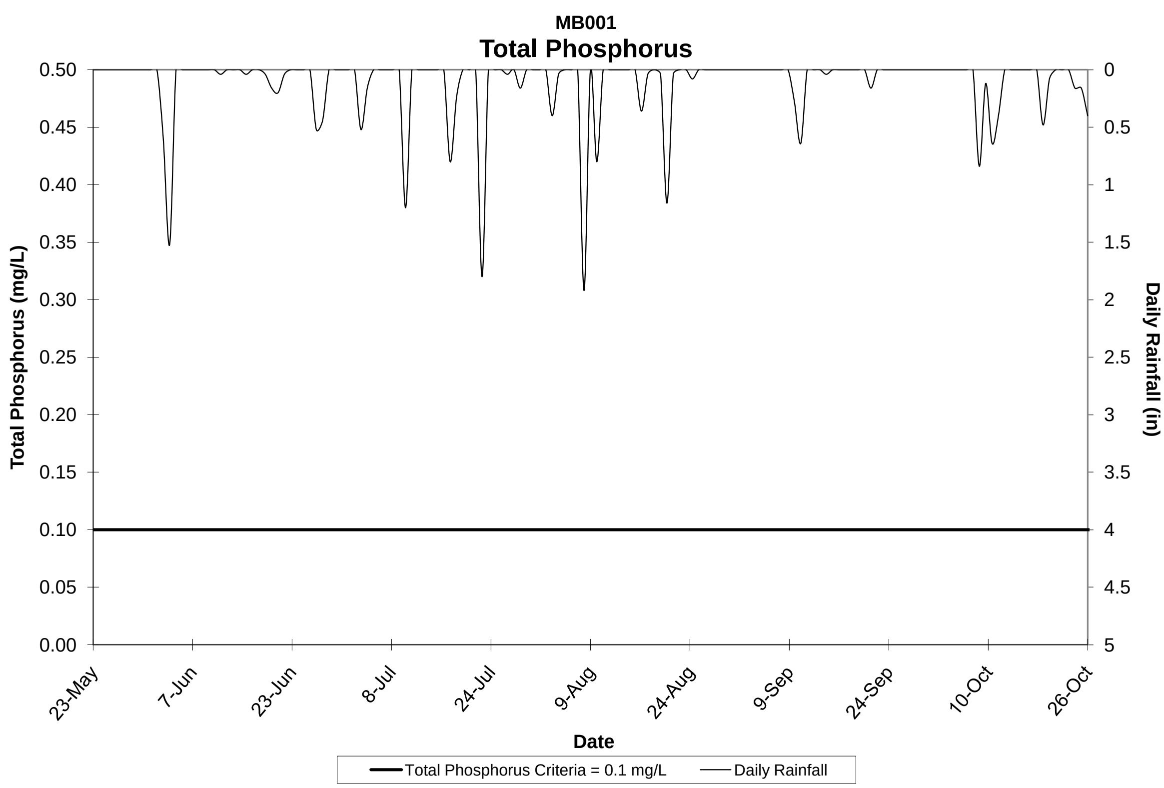

MB006
Total Phosphorus
Total Phosphorus (mg/L)
Daily Rainfall (in)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

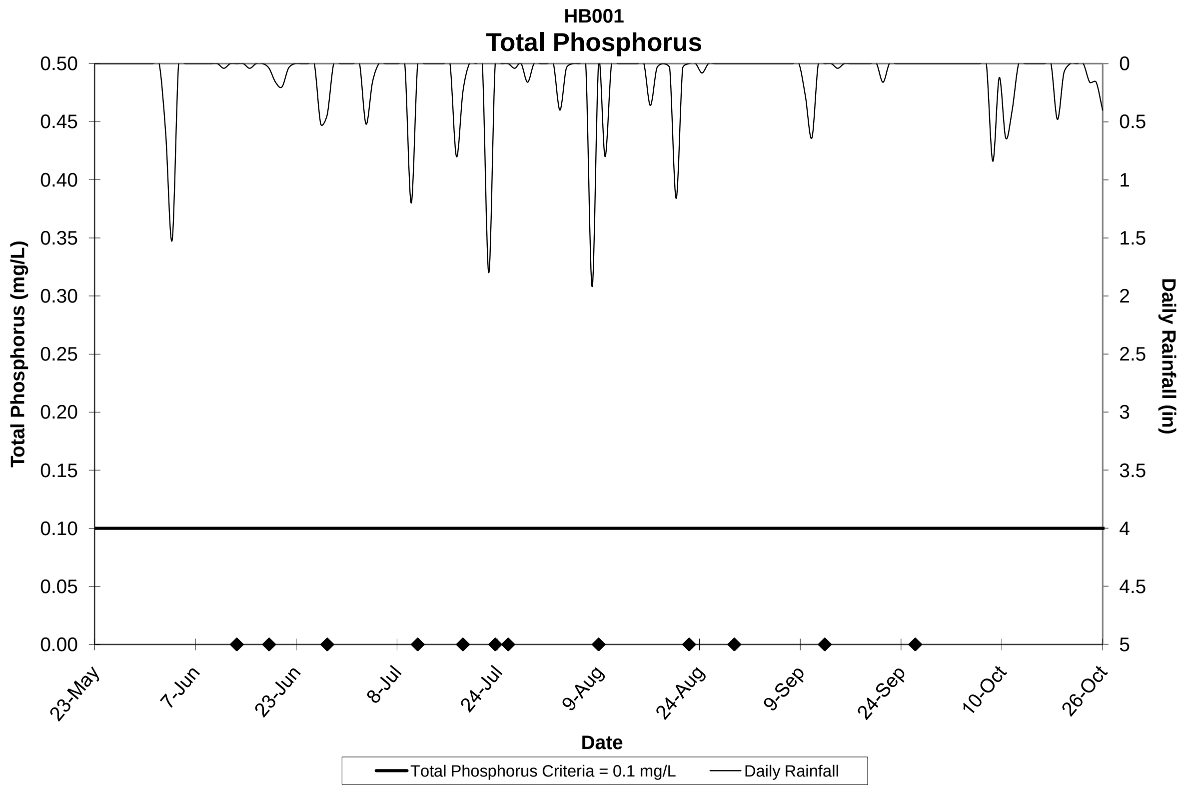

MB005
Total Phosphorus
Total Phosphorus (mg/L)
Daily Rainfall (in)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

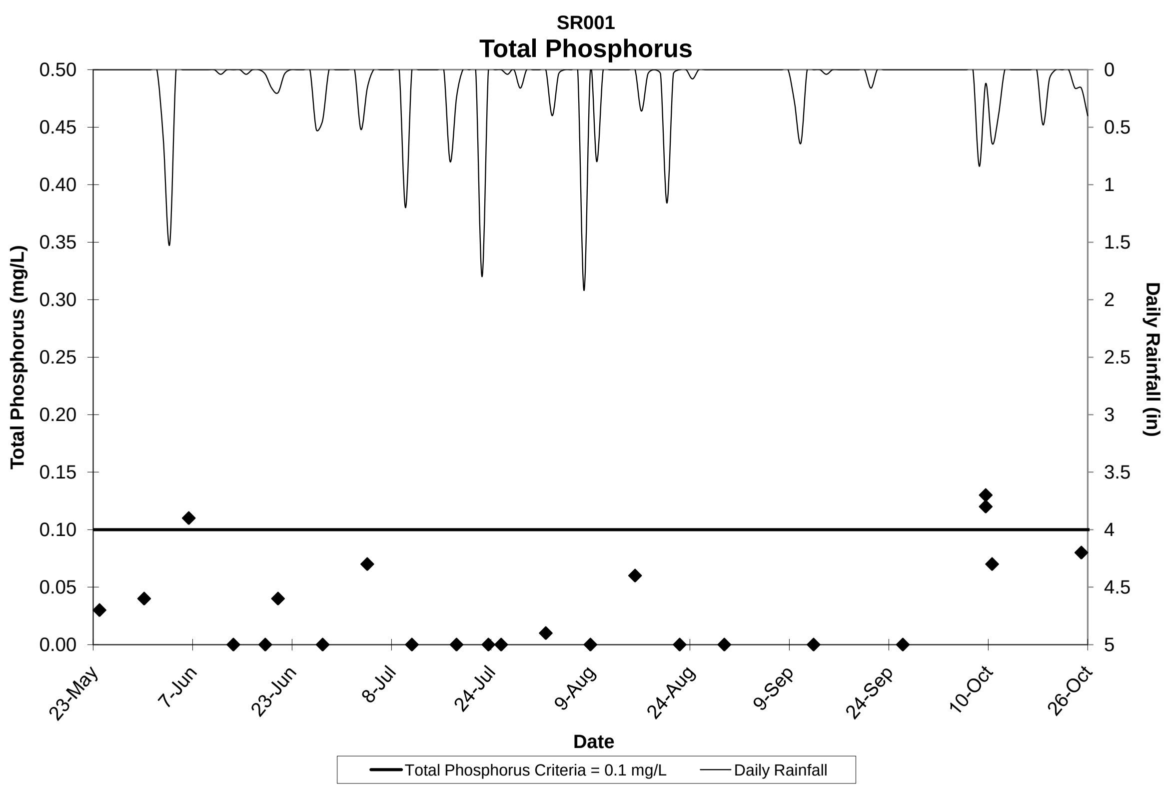

MB004
Total Phosphorus
Total Phosphorus (mg/L)
Daily Rainfall (in)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

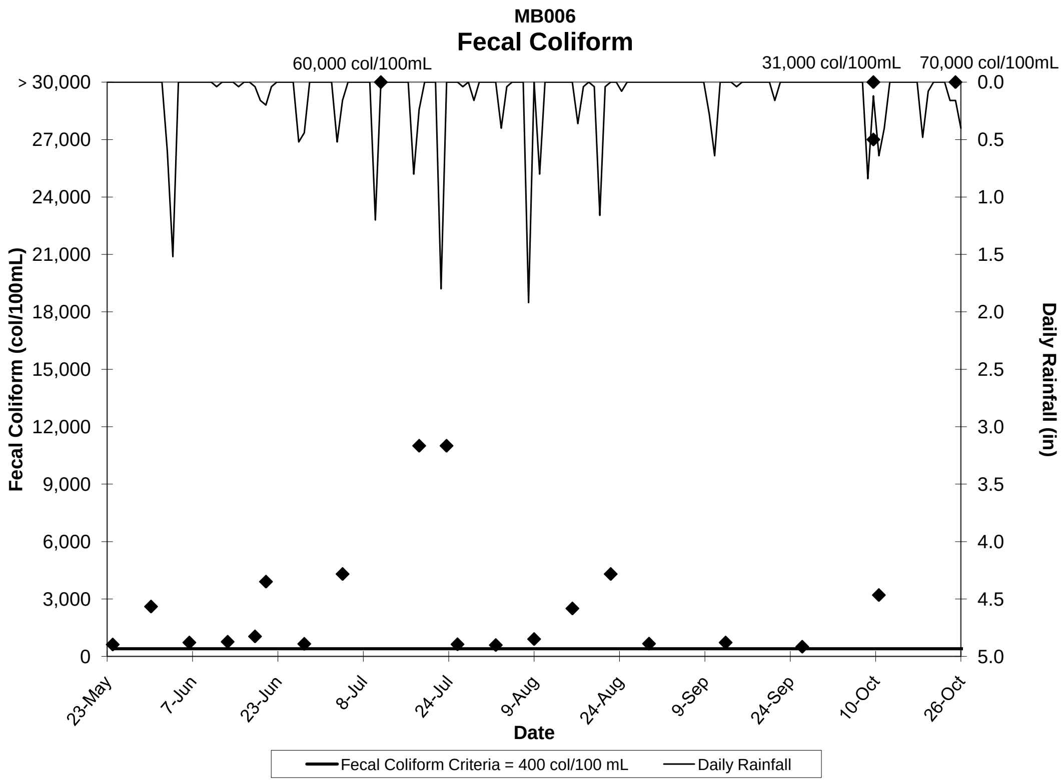

MB003
Total Phosphorus
Total Phosphorus (mg/L)
Daily Rainfall (in)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

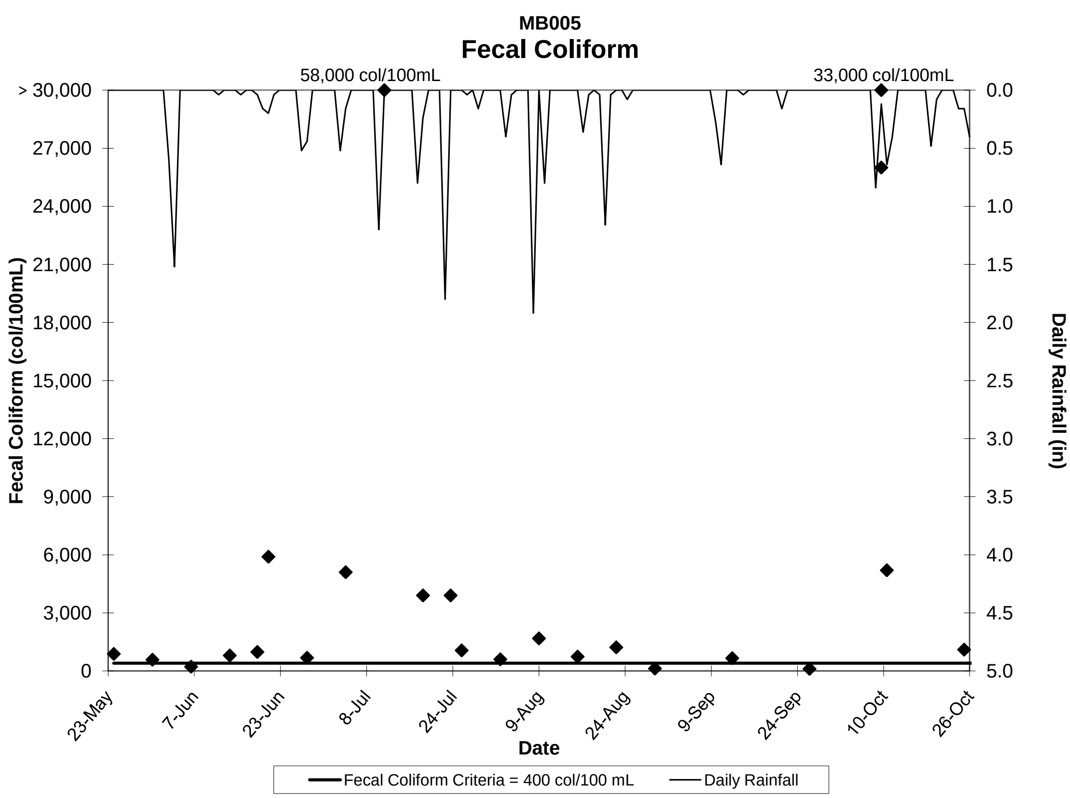

MB002
Total Phosphorus
Total Phosphorus (mg/L)
Daily Rainfall (in)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

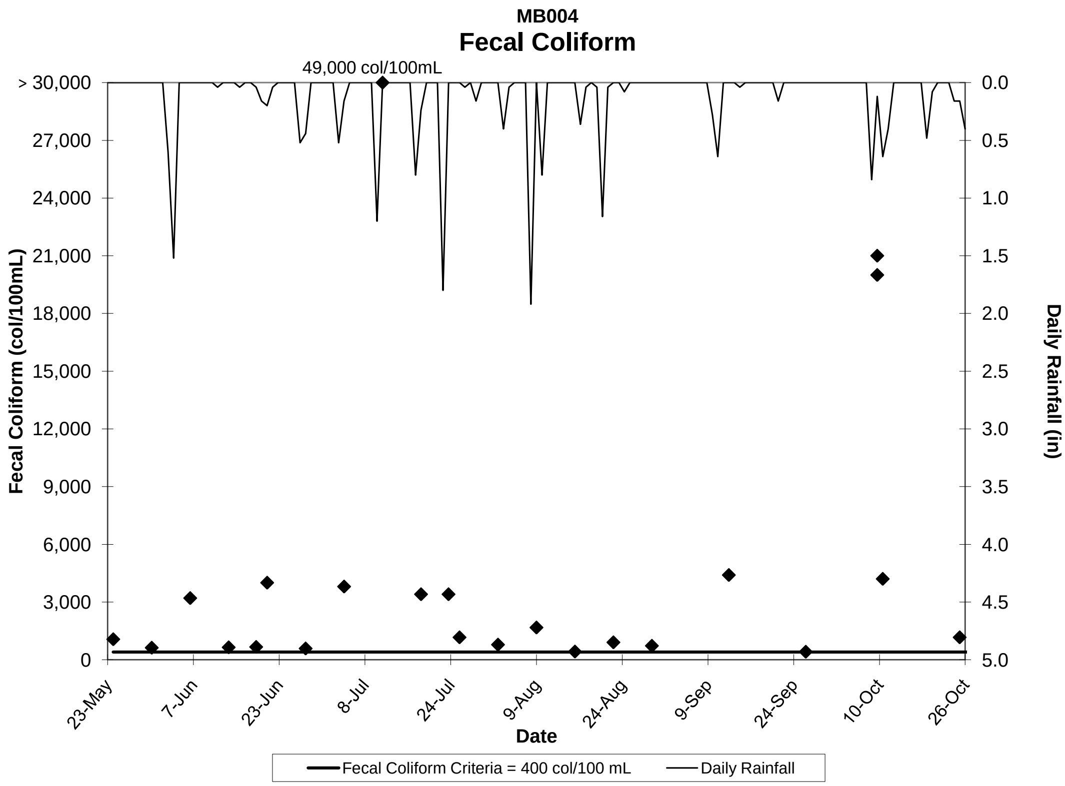

MB001
Total Phosphorus
Total Phosphorus (mg/L)
Daily Rainfall (in)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

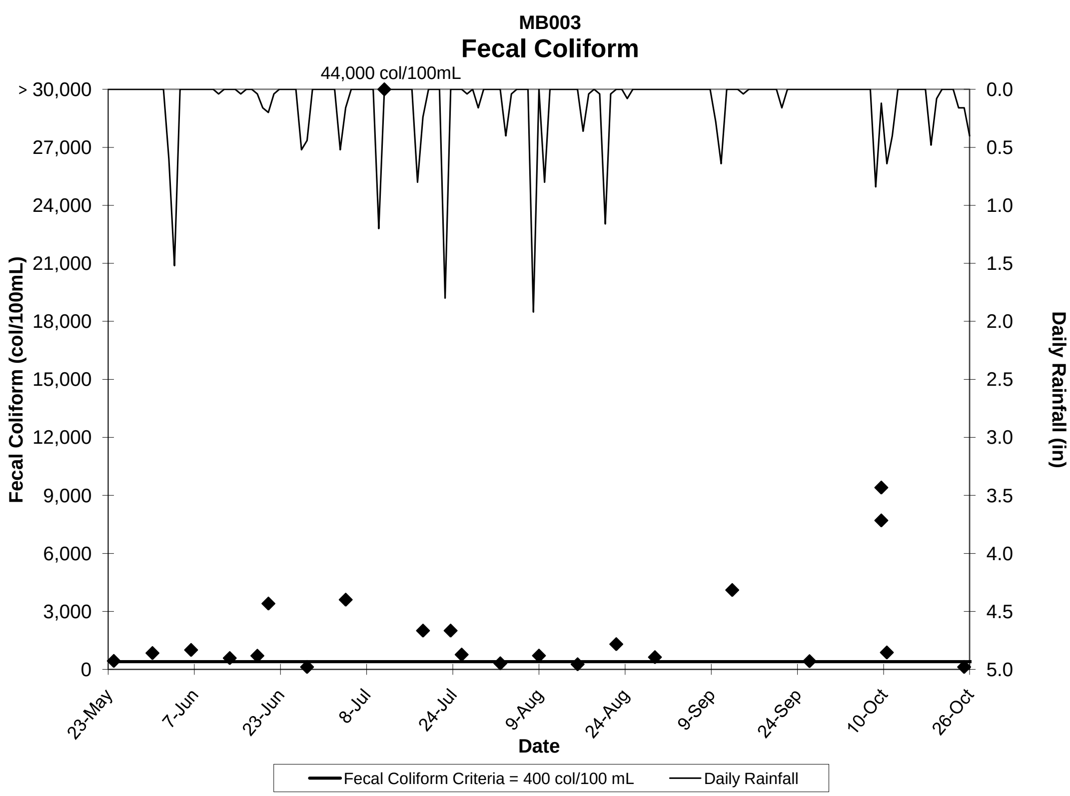

HB001
Total Phosphorus
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Daily Rainfall (in)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

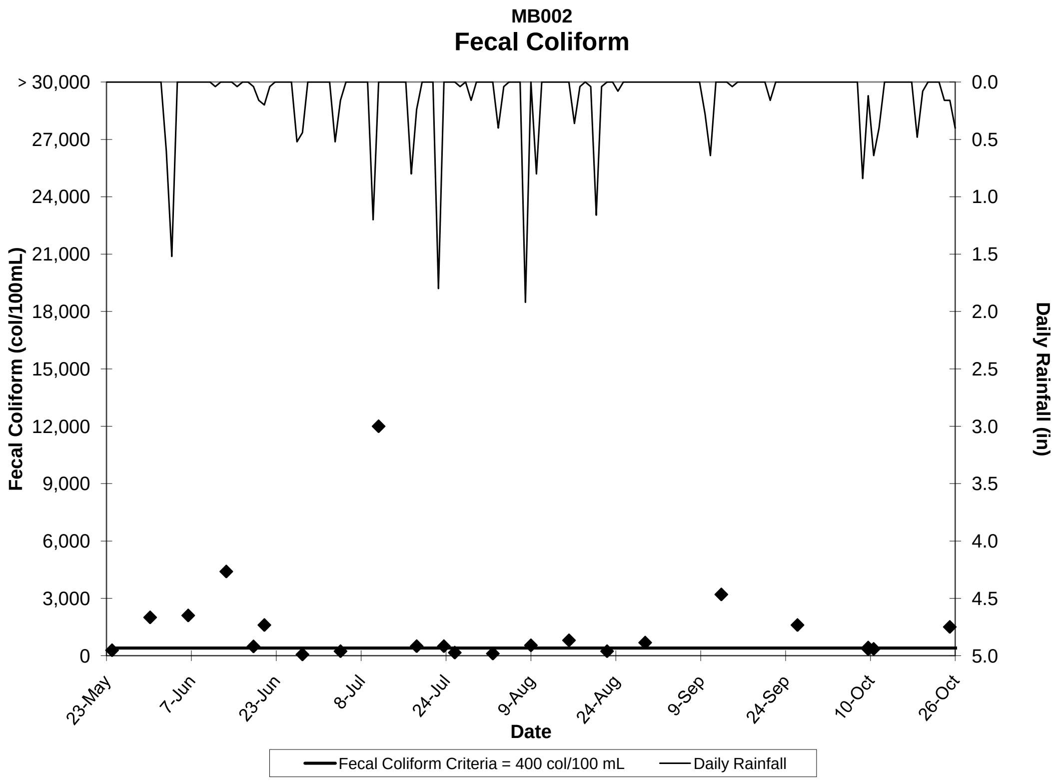

SR001
Total Phosphorus
Total Phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Daily Rainfall (in)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Total Phosphorus Criteria = 0.1 mg/L
Daily Rainfall

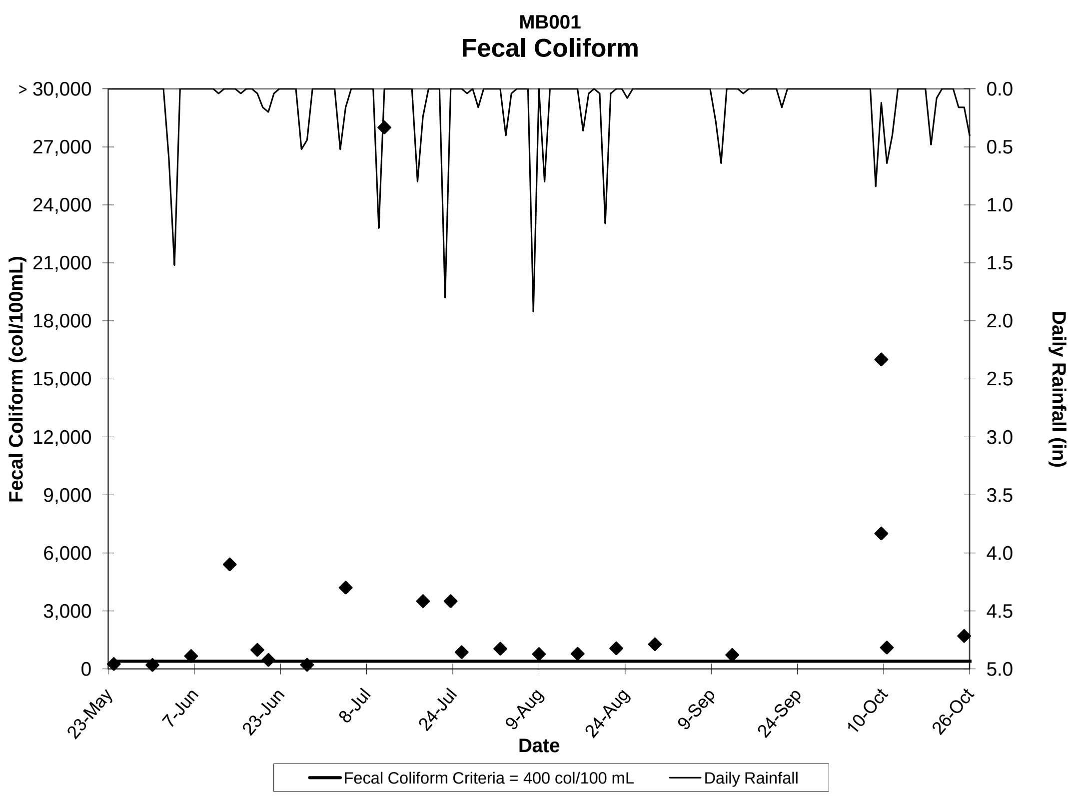

MB006
Fecal Coliform
60,000 col/100mL
31,000 col/100mL
70,000 col/100mL
Fecal Coliform (col/100mL)
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Daily Rainfall (in)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall

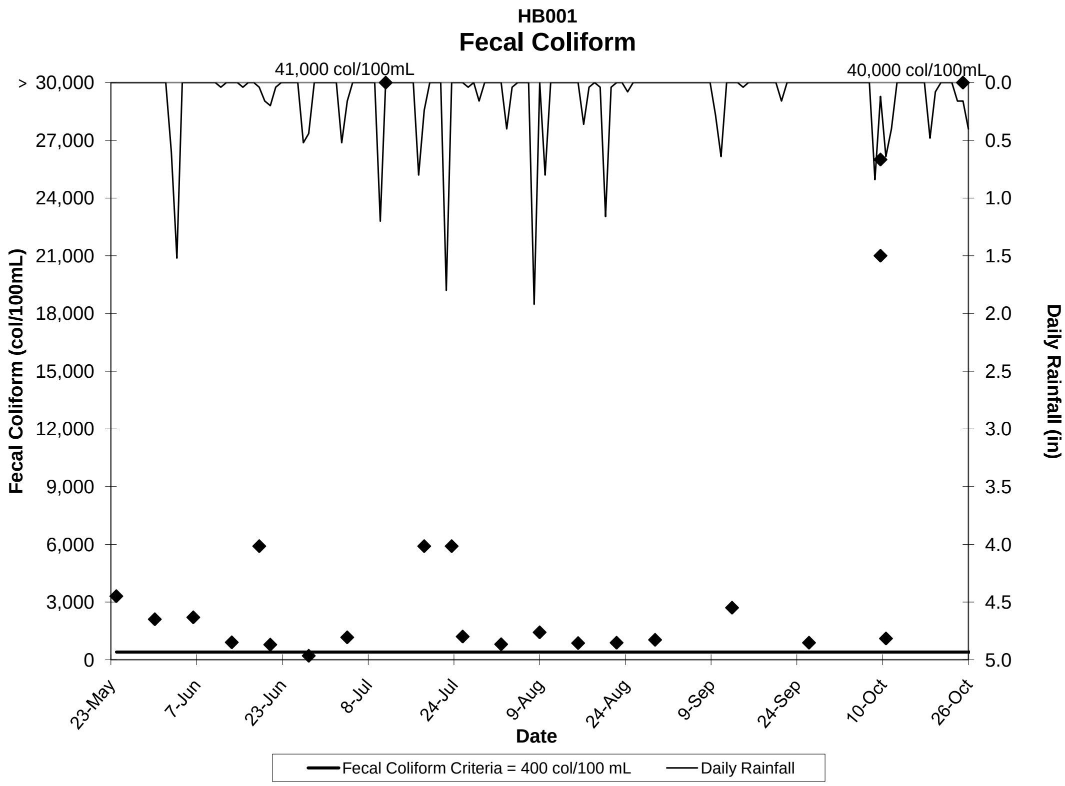

MB005
Fecal Coliform
58,000 col/100mL
33,000 col/100mL
Fecal Coliform (col/100mL)
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Daily Rainfall (in)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall

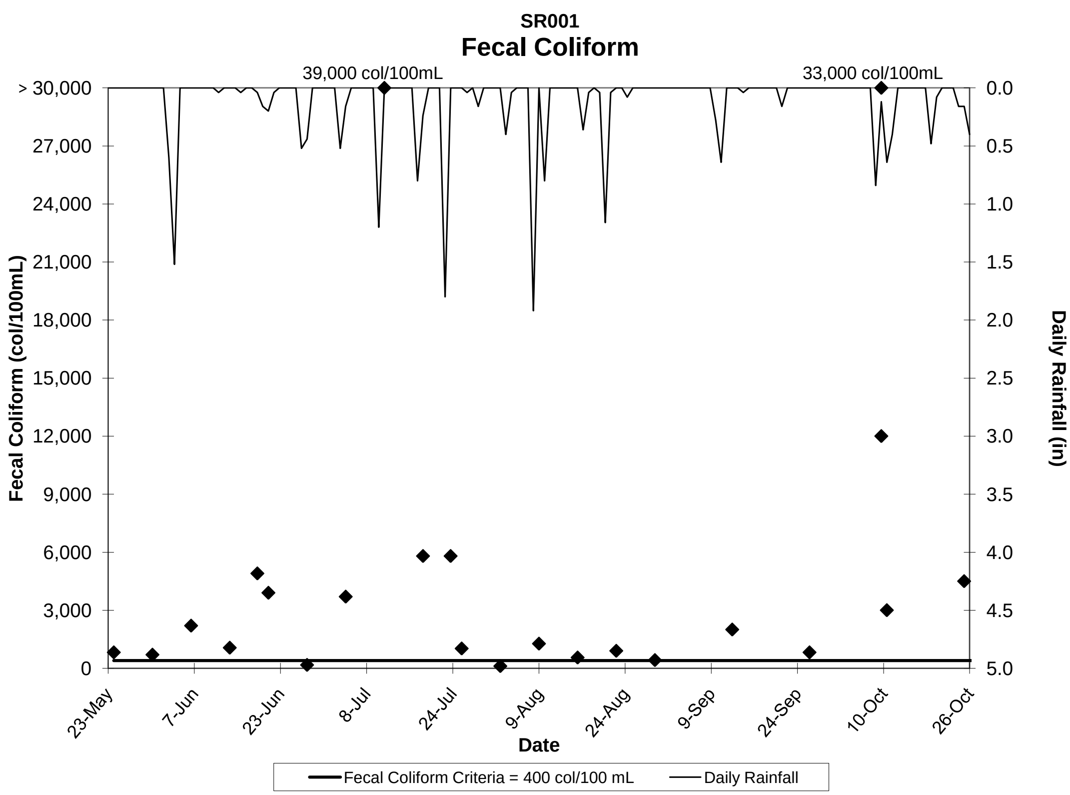

MB004
Fecal Coliform
49,000 col/100mL
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Fecal Coliform (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall

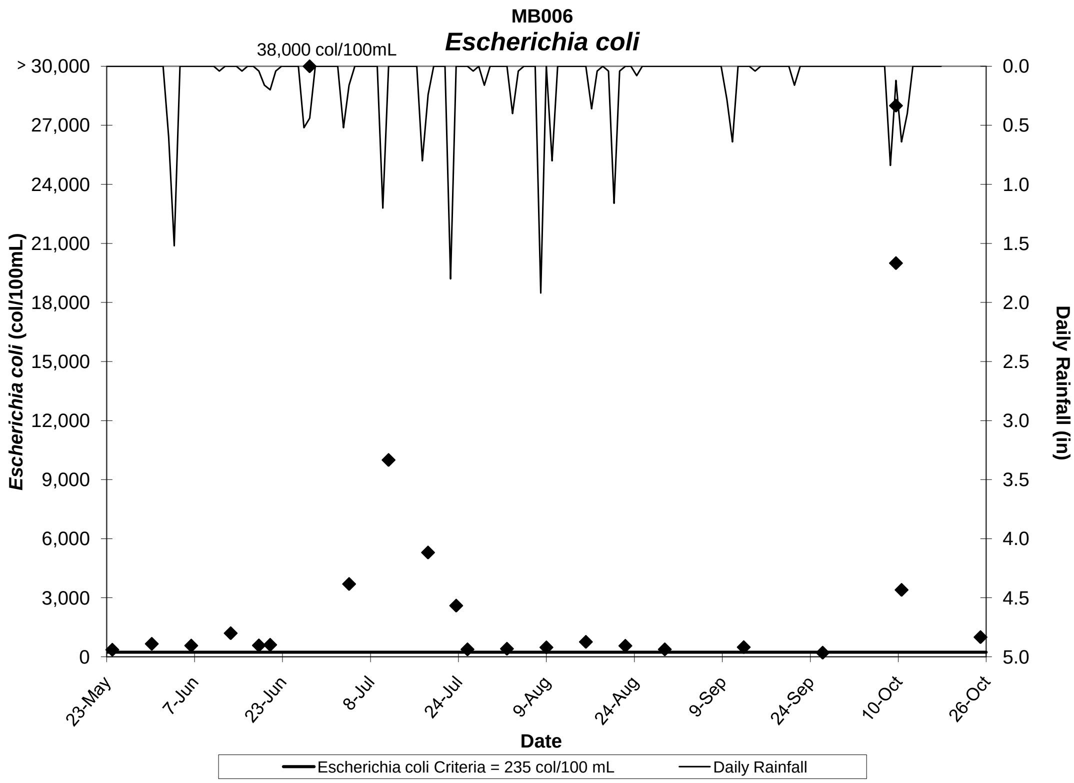

MB003
Fecal Coliform
44,000 col/100mL
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Fecal Coliform (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall


MB002
Fecal Coliform
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Fecal Coliform (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall

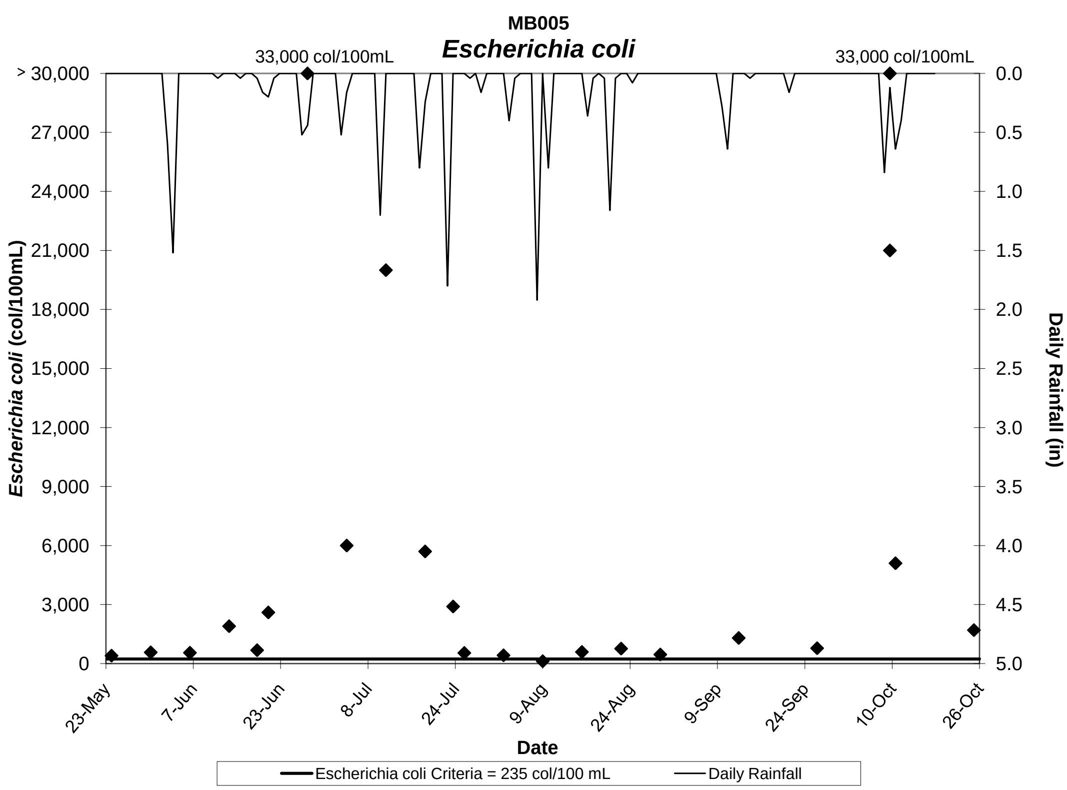

MB001
Fecal Coliform
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Fecal Coliform (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall


HB001
Fecal Coliform
41,000 col/100mL
40,000 col/100mL
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Fecal Coliform (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall

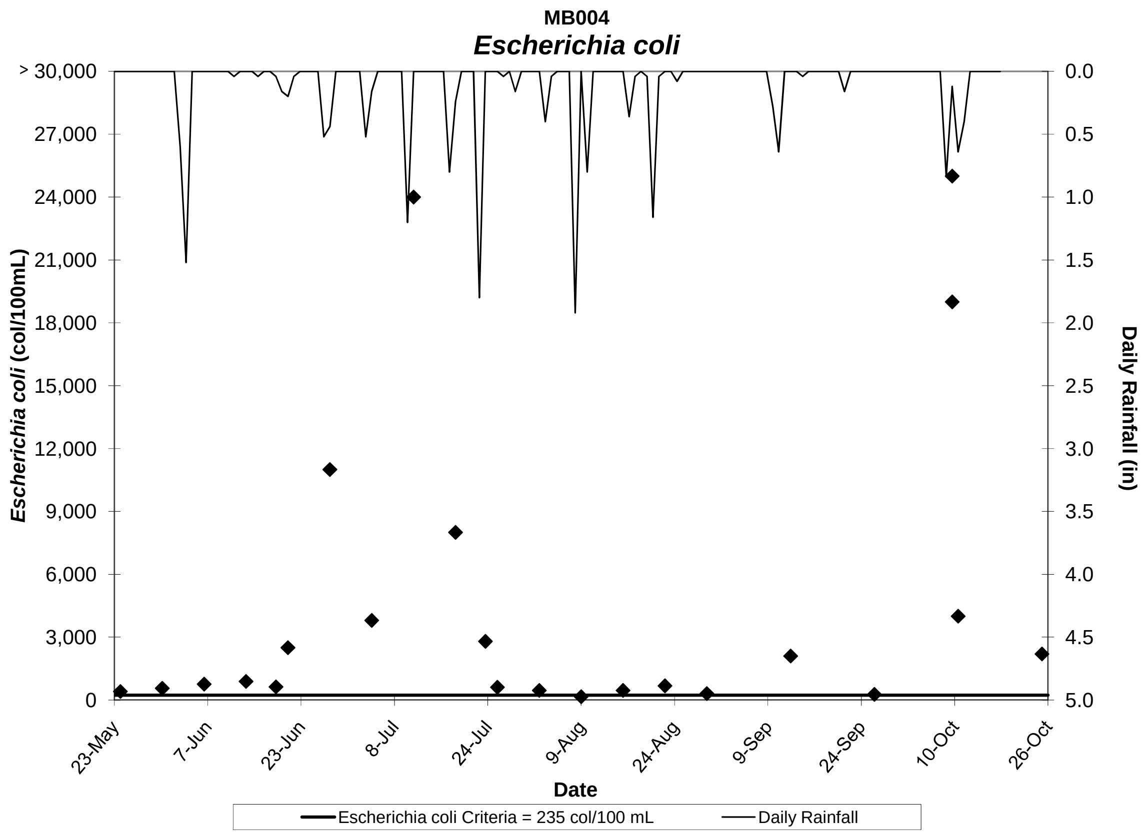

SR001
Fecal Coliform
39,000 col/100mL
33,000 col/100mL
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Fecal Coliform (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Fecal Coliform Criteria = 400 col/100 mL
Daily Rainfall



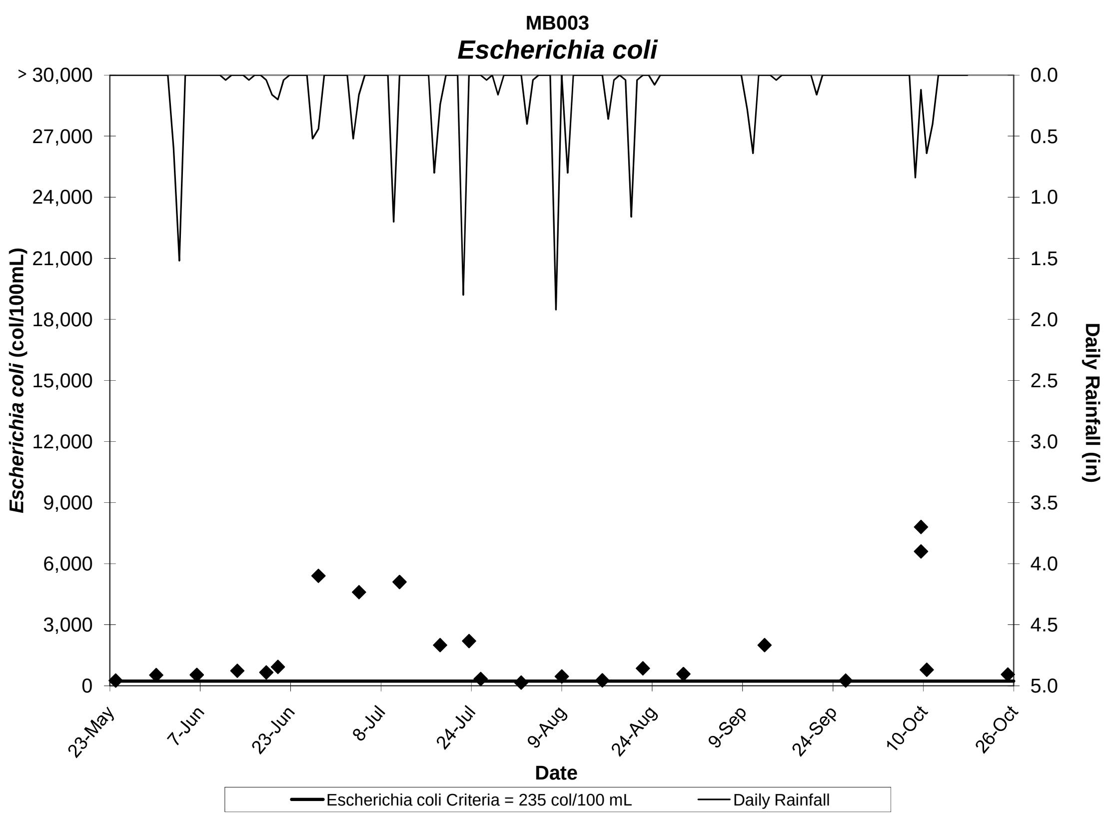
MB006
Escherichia coli
38,000 col/100mL
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Escherichia coli (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall



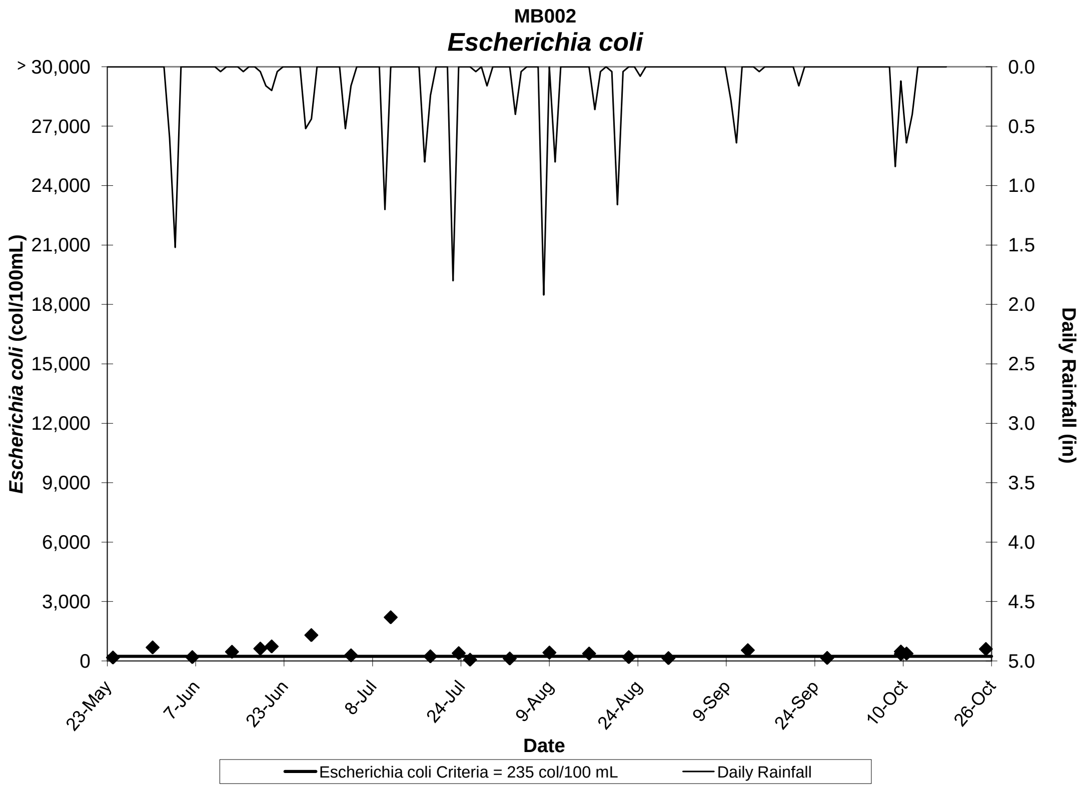
MB005
Escherichia coli
33,000 col/100mL
33,000 col/100mL
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Escherichia coli (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall

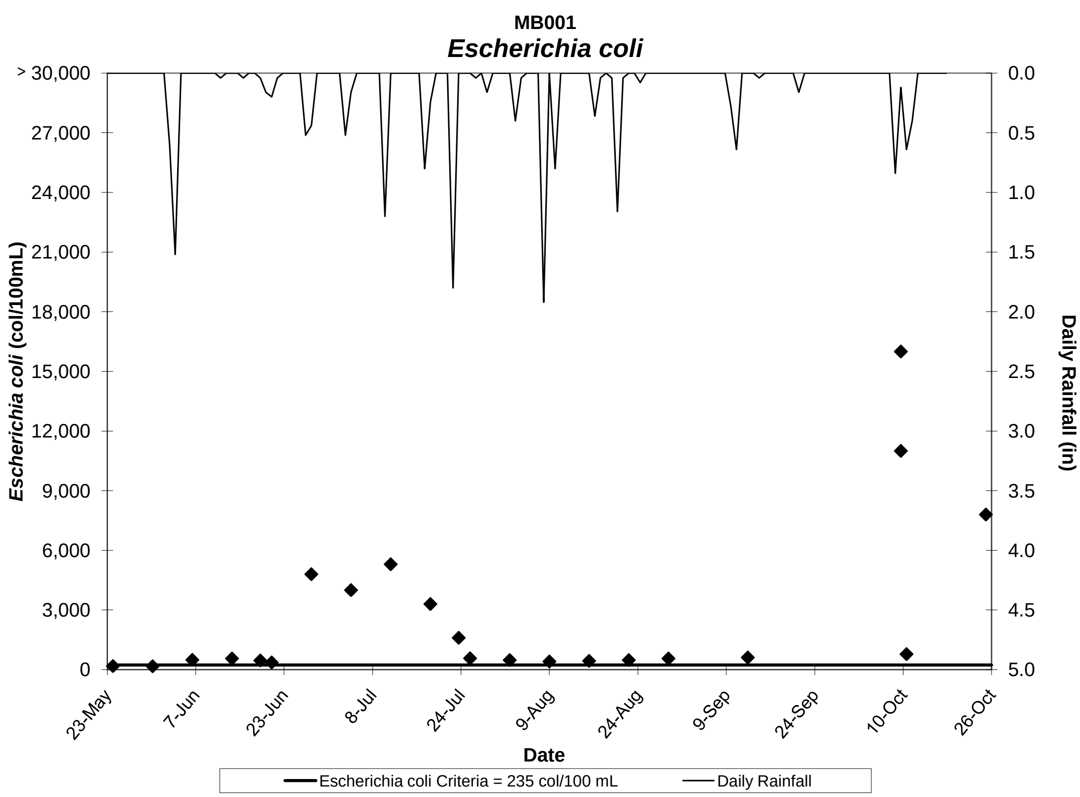


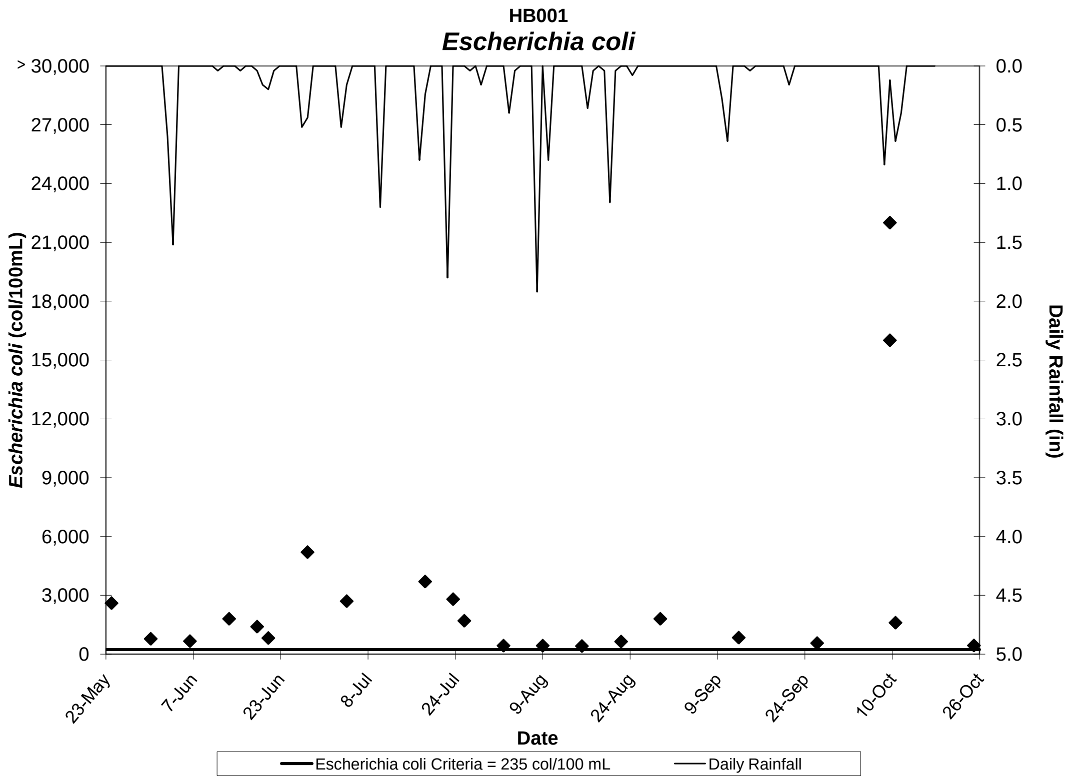
MB004
Escherichia coli
Escherichia coli (col/100mL)
Daily Rainfall (in)
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall



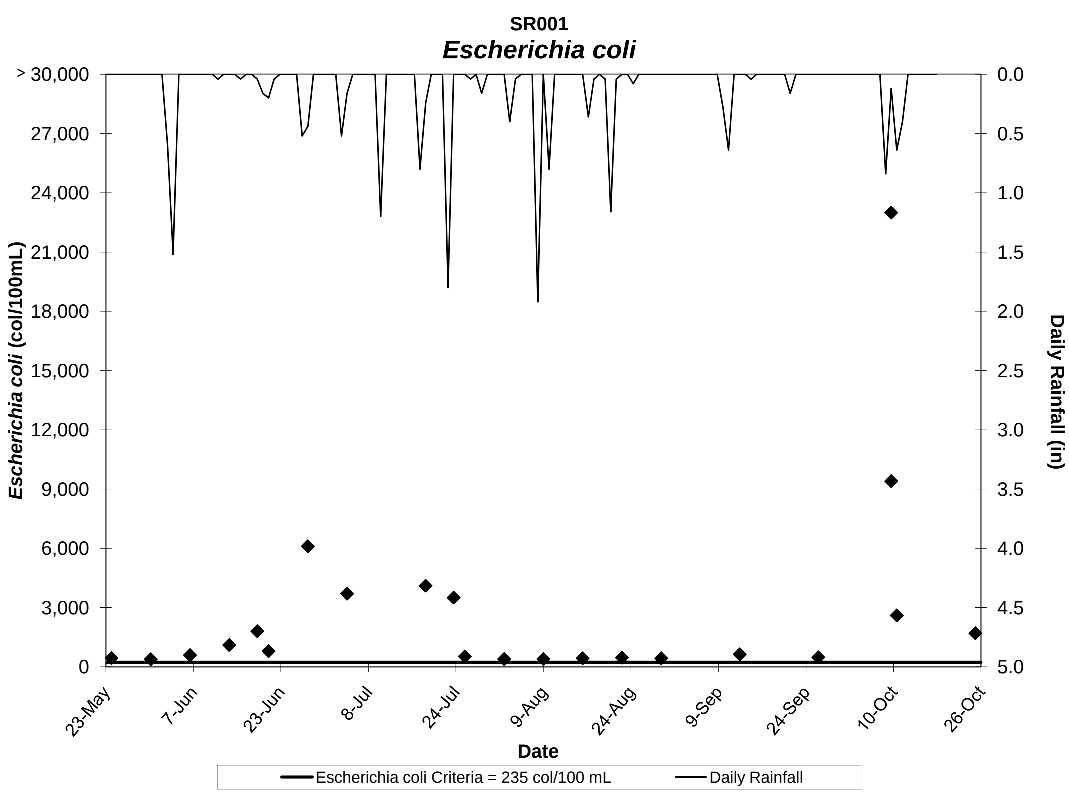
MB003
Escherichia coli
Escherichia coli (col/100mL)
Daily Rainfall (in)
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall


MB002
Escherichia coli
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Escherichia coli (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall


MB001
Escherichia coli
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Escherichia coli (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall



HB001
Escherichia coli
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Escherichia coli (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall



SR001
Escherichia coli
> 30,000
27,000
24,000
21,000
18,000
15,000
12,000
9,000
6,000
3,000
0
Escherichia coli (col/100mL)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Daily Rainfall (in)
23-May
7-Jun
23-Jun
8-Jul
24-Jul
9-Aug
24-Aug
9-Sep
24-Sep
10-Oct
26-Oct
Date
Escherichia coli Criteria = 235 col/100 mL
Daily Rainfall

APPENDIX B

Optical Brightener Sampling Report

RUTGERS
New Jersey Agricultural
Experiment Station

Musquapsink Brook Watershed Restoration and Protection Plan
Optical Brightener Sampling Report

Developed by the Rutgers Cooperative Extension Water Resources Program

Funded by the New Jersey Department of Environmental Protection
RP 07–002

May 2011

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Figures

Background

Sources of pathogenic enteric bacteria in waterways include human, farm animal and/or wildlife excrement. Methods for detecting fecal coliform bacteria and identifying pathways from their sources are important in addressing point and nonpoint source pollution in watersheds (Tavares et al., 2008). Bacterial Source Tracking (BST) involves a series of microbiological and chemical analyses to determine sources of fecal bacteria in environmental water samples. One such source tracking method to identify *human* bacterial contamination in surface water is the fluorometric detection of optical brighteners. Optical brighteners are compounds added to laundry detergents and soaps, and have no natural sources. Because household plumbing systems combine effluent from washing machines and toilets, optical brighteners are associated with human sewage in sewer lines, septic systems and wastewater treatment plants (Hartel et al., 2007). Their presence in surface water, therefore, can be an indicator of an illicit connection, leaking pipes, or contamination from wastewater.

Data results obtained from surface water quality sampling in the Musquapsink Brook watershed show both wet and dry weather sources of *E. coli* and fecal coliform contamination. Microbial Source Tracking (MST) sampling using qPCR analysis has indicated the presence of human sources of bacterial loadings to the watershed. Potential human sources include leaking sewer lines and illicit connections. The project partners are required to identify and quantify sources of pollution in the watershed, as outlined by the tasks presented in the Quality Assurance Project Plan (QAPP) submitted for this project in January 2007 and as outlined by the objectives described in the original proposal for the Musquapsink Brook Watershed Restoration Plan, submitted in May 2006. These objectives and tasks were developed so that appropriate management practices are implemented and resources are allocated efficiently and economically throughout the watershed. Investigation beyond MST sampling is required to track down areas of detected human sources of pathogenic contamination so that point sources within the watershed can be adequately identified and addressed in the final Watershed Restoration and Protection Plan. Rutgers Cooperative Extension (RCE) Water Resources Program proposes to accomplish this using fluorometric analysis to detect the presence of optical brighteners in the stream.

Methods

Two rounds of optical brightener sampling and fluorometric analysis were completed between May and August 2010 during dry conditions (no recorded precipitation within 48 hours of sampling event). Initially, there were 16 sites sampled. Two additional sites were added for the August sampling event. See Figure 1 below for locations of sampling sites. Site M03 was sampled in May 2010 but data is not included since the site location lies just outside of the watershed boundary.

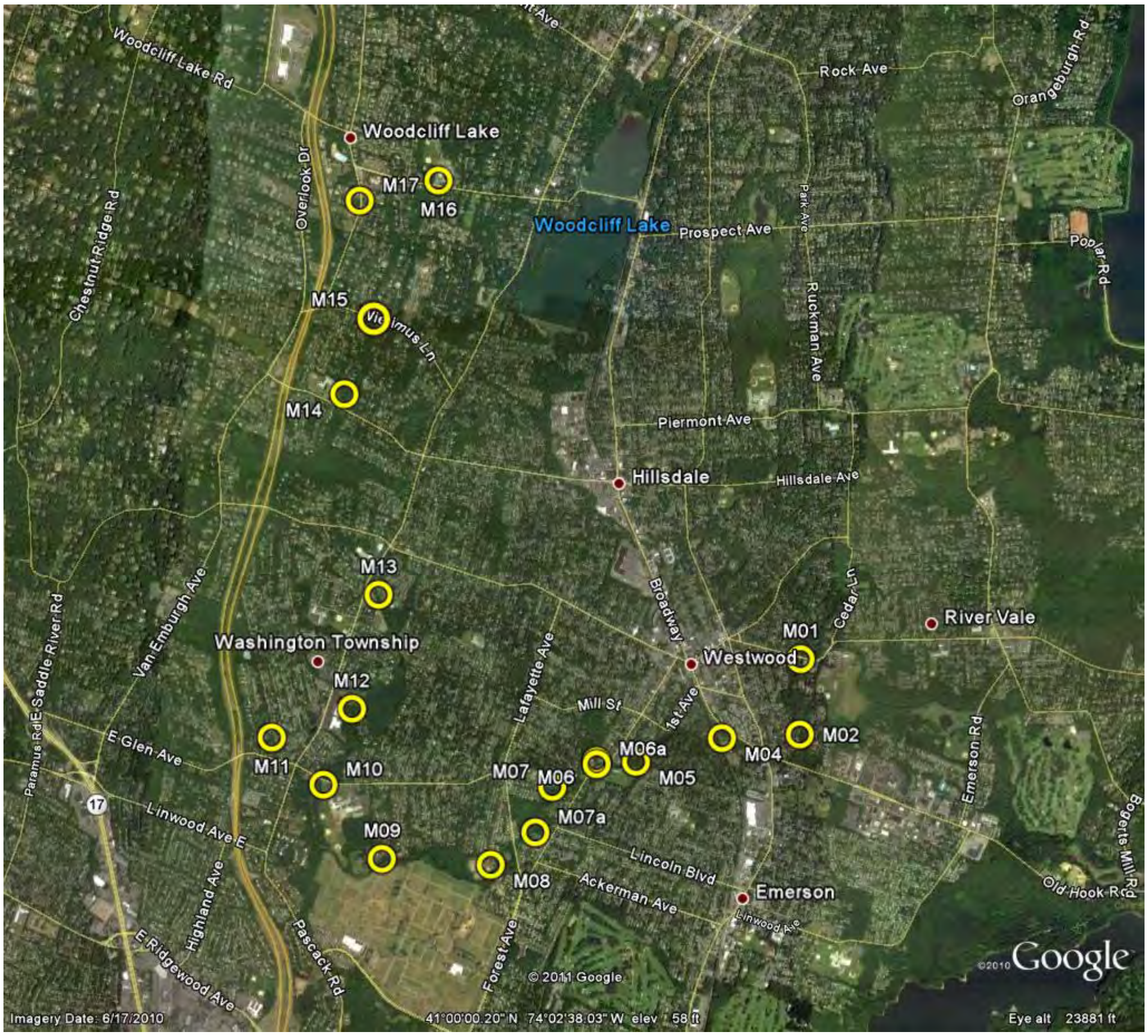


Figure 1 Optical Brightener Sampling Locations in the Musquapsink Brook Watershed

Data Summary

Fluorescence measurements were recorded from fluorometric analysis of the samples collected. The relative concentration of optical brighteners was measured in comparison to a blank solution with a known concentration of optical brighteners used in calibration. This data, as well as *in-situ* measurements of pH, dissolved oxygen (DO), and surface water temperature recorded during sampling, is provided in Appendix A. The average fluormetric reading for each sampling site is shown in Figure 2 below.

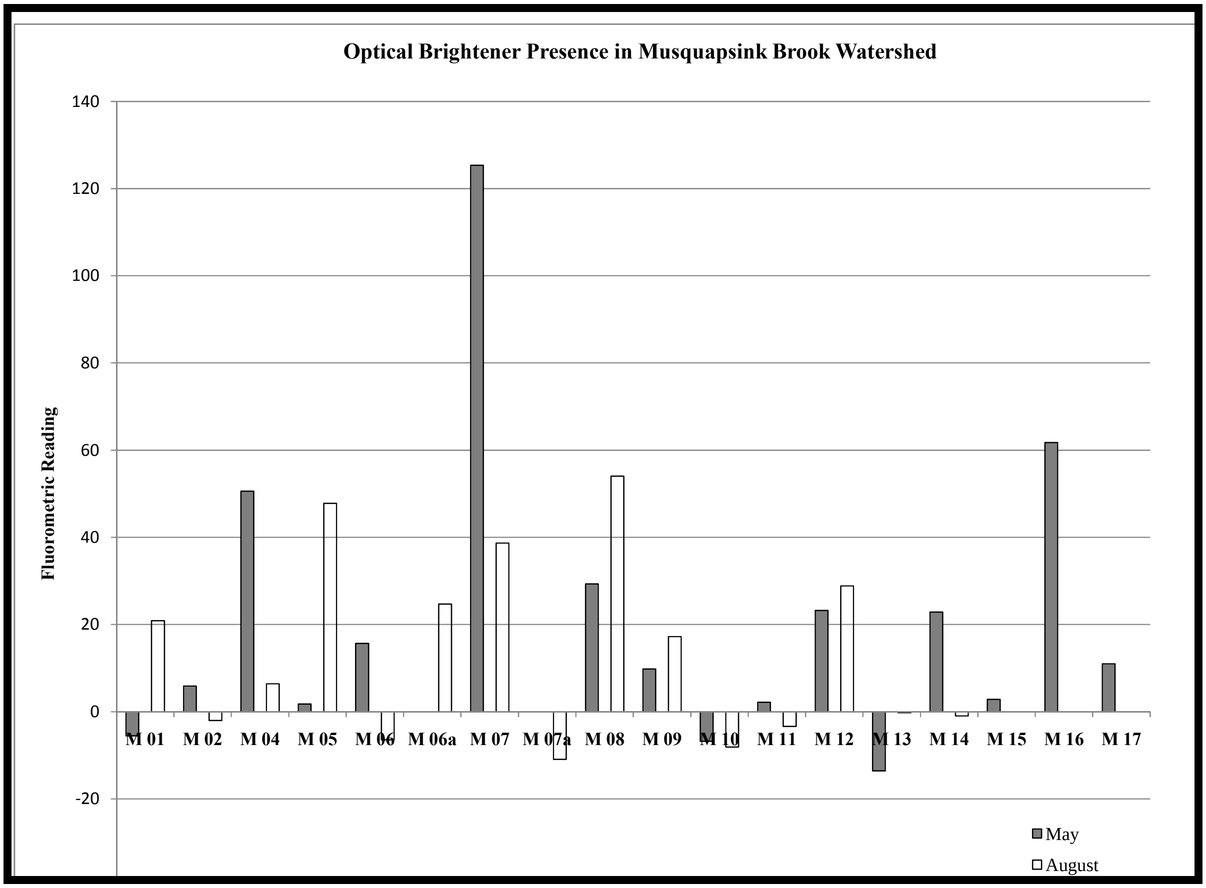


Figure 2 Average Fluorometric Readings for Samples Collected in May and August, 2010

The magnitude of the fluorescence reading indicates the relative strength of optical brightener in the sample. The highest fluorescence readings recorded were for samples collected from sites M04, M07, and M16. To further refine the trackdown of bacteria sources, fluorometric analysis results from the first round of sampling were used to adjust the location of sampling sites in the second round. Due to limited stream access and low-flow conditions, additional sampling locations could not be included in the regions of M04 and M16. M06a and M07a are located downstream and upstream, respectively, of site M07. Values at or below zero indicate little to no presence of optical brightener in the sample.

Source tracking investigations completed by other research groups have reported positive correlations between fecal bacteria numbers and optical brightener levels, linking high levels of both indicators to human contamination. The RCE Water Resources Program study attempted to link physical surface water parameters (pH, DO, temperature) to optical brightener levels. The Pearson Product Moment is the ratio of covariance between the variables to the product of their standard deviations. The numerical value of the Pearson Product Moment ranges from -1.0 to +1.0. The closer the calculated coefficients are to +1.0 or –1.0, the greater the strength of the linear relationship between two independent variables. Correlations between *in-situ* physical surface water parameters and optical brightener levels were found to be, in general, weak and therefore no overlying conclusions could be drawn from this set of data. Further experimental design and laboratory research may provide further insight into the relationship between pH, DO, temperature and optical brightener presence in surface water.

APPENDICES

APPENDIX A
Tabulated Data

May 2010

Location ID	pH	DO	Temperature	Flourometric Units[1]		
		(mg/L)	(degree Celsius)	Reading 1	Reading 2	Reading 3
M01	7.11	5.93	20.4	-12	-8.9	4.22
M02	7.12	6.45	20.4	-13	16.1	14.5
M04	7.02	6.54	20.45	43.8	53.3	54.6
M05	6.79	3.81	19.5	-56	41.9	13
M05b*	6.79	3.81	19.5	22.1	-32	21.6
M06	6.74	3.56	19.15	36.3	12.4	-1.7
M07	6.84	4.19	19.45	122	118	136
M08	6.82	4.26	19.7	25.3	28	34.6
M09	6.83	3.83	20.15	-6.1	19.1	16.4
M10	7.08	6.41	21.4	2.82	-22	-1.1
M11	7.38	8.63	16.15	10.8	-5.8	1.5
M12	7.25	6.9	22.95	48	22	47.3
M12b*	7.25	6.9	22.95	4.3	22.1	-4.4
M13	7.42	8.84	17.55	-30	-1.8	-9
M14	7.47	8.6	18.55	24.9	27.1	16.5
M15	7.36	8.44	18.75	-22	-11	16.8
M15b*	7.36	8.44	18.75	29.1	3.4	0.56
M16	7.12	7.3	17.85	74.5	54.9	55.8
M17	7.28	8.11	19.1	12.2	9.6	11.1

*Duplicate samples were collected at this location
[1]Based on a scale of 0 to 100, with 100 indicating strong presence of optical brighteners in surface water sample

August 2010

Location ID	pH	DO	Temperature	Flourometric Units[1]		
		(mg/L)	(degree Celsius)	Reading 1	Reading 2	Reading 3
M 01	7.64	6.33	23.1	12.2	36.1	14.3
M 02	7.64	6.67	23.2	-3.1	10.2	-13.1
M 04	7.25	6.8	23.6	54	9.8	5.4
M04*	7.25	6.8	23.6	-32	-11	12.3
M 05	7	3.52	22.8	89.2	53.9	0.23
M 06a	7.22	4.21	23.1	24.1	37.8	12.2
M 06	7.23	3.35	22.2	5.4	-9.5	-15.3
M 07	7.32	5.11	22.6	45.2	54.2	16.7
M 07a	7.28	5.3	22.3	-5.6	1.2	-22.3
M07a*	7.28	5.3	22.3	5.4	-19.7	-24.7
M 08	7.18	5.29	22.6	15.3	67.9	78.9
M 09	7.18	5.49	23.2	34.2	15.4	2.1
M 10	6.87	5.64	21.6	-22	8.7	-11
M 11	7.94	8.74	23	3.9	-5	-14
M11*	7.94	8.74	23	-12	5.6	1.3
M 12	6.66	4.49	24.6	35.6	24.1	26.9
M 13	7.76	10.7	22.2	-23	10.1	12.3
M 14	7.6	7.54	24.4	17.3	-2.4	-17.8
M 15[2]	N/A	N/A	N/A	-	-	-
M 16[2]	N/A	N/A	N/A	-	-	-
M 17[2]	N/A	N/A	N/A	-	-	-

*Duplicate samples were collected at this location
[1]Based on a scale of 0 to 100, with 100 indicating strong presence of optical brighteners in surface water sample

[2]Sites with little to no flow. No samples collected.

APPENDIX B
Optical Brightener Standard Operational Procedure

RUTGERS
School of Environmental and Biological Sciences

STANDARD OPERATING PROCEDURE
OPTICAL BRIGHTENER ANALYSIS BY FLUOROMETRY

Authors: Jillian Thompson and Robert Miskewitz
Developed: January 2010

I. Background

Optical brighteners are compounds added to nearly all modern laundry detergents, which adhere to fabric and absorb and emit light, countering the yellowing appearance of whites and making other colors appear brighter. These compounds are excited by light in the near UV range (360-365nm) and emit light in the blue range (400-440 nm). After light absorption, fluorescence is given off during the second exited state and can be measured by a fluorometer (Tavares et al. 2008).

Because household plumbing systems combine effluent from washing machines and toilets, optical brighteners are associated with human sewage in septic systems, sanitary sewer systems, and wastewater treatment plants (Hartel et al., 2007). Their presence in surface water, therefore, indicates contamination from wastewater.

II. Materials

A. Fluorometer (Model 10-AU-000, Turner Designs, Sunnyvale, California).
B. Optical Brightener Optical Kit (Turner Designs, part number10-302R): lamp (10-049) emitting near UV light at 310-390nm; a filter (10-069R) for the 300-400 nm light range; a 436 nm filter to greater decrease background fluorescence
C. Tide® Powder Original Scent (no bleach)
D. Deionized water
E. Timer
F. Nalgene 250 mL opaque collection bottles
G. Transfer bottle
H. Refrigerator
I. Glass Cuvettes
J. Cooler
K. Scale (1.0 mg readability)

III. Sample Collection and Storage

A. Collect samples from the targeted waterbody in Nalgene 250 mL sampling bottles that have been acid cleaned and stored with 1% HCl (~5mL).
B. Transfer bottle is rinsed three (3) times with sample water before filling.
C. Sample water is collected with the transfer bottle placed 10cm below water surface facing upstream. Water is poured from the transfer bottle into a sample bottle.
D. Sample bottles are labeled and kept on ice and in a dark cooler after collection.
E. Upon arrival to the lab samples may be read after reaching room temperature or refrigerated at 4°C for up to five (5) days.

IV. Flourometric Calibration and Standard Curves

A. An optical brightener optical kit is installed in the fluorometer before any samples are read. This kit includes a lamp (10-049) emitting near UV light at 310-390 nm, a filter (10-069R) for the 300-400nm light range, and finally a 436 nm filter to greater decrease background fluorescence.
B. Make two-fold serial dilutions from a solution of 100mg powdered Tide in one liter deionized water (100 ppm).
   a. Mix 500 mL of the 100 ppm Tide solution with 500 mL deionized water to create the first dilution (50 ppm).
   b. Mix 500 mL of the 50 ppm solution with 500 mL deionized water to create the second dilution (25 ppm).
   c. Mix 500 mL of the 25 ppm solution with 500 mL deionized water to create the third dilution (12.5 ppm).
C. Create a standard curve using the serial dilutions from 100mg of Tide in one liter of deionized water (100 ppm).
   a. Adjust the fluorometer to a 80% sensitivity scale.
   b. The fluorometric value of 0 should be set equal to pure deionized water.
   c. The fluorometric value of 100 should be set equal to 100ppm of Tide in 1 liter of deionized water. This sets the equipment calibration.
   d. Record fluorometric readings of the solutions created from the serial dilution procedure.
   e. All results should be graphed (Fluormetric Reading vs. Concentration) to obtain a linear standard curve
D. Create a second standard curve using two-fold serial dilutions of 100mg Tide in one liter of ambient water. A standard curve created with ambient water will indicate the influence of background organic matter on fluorescence readings.
   a. Adjust the fluorometer to a 80% sensitivity scale.
   b. The fluorometric value of 0 should be set equal to deionized water.
   c. The fluorometric value of 100 should be set equal to 100ppm of Tide in 1 liter of deionized water. This sets the equipment calibration.

d. Once the two-point equipment calibration is established, create serial dilutions of Tide in ambient water.
e. Record fluorometric readings of the serial dilutions (100ppm, 50ppm, 25ppm, 12.5ppm)
f. All results will be graphed (Fluormetric Reading vs. Concentration) to obtain a second linear standard curve.

E. Compare the two standard curves. If organic matter in the ambient water is contributing to fluorescence readings, the ambient water solution readings will be higher than the deionized water solution readings.
a. The average difference between ambient water and deionized water fluorescence readings are calculated. This average represents a fluorescence reading due to background organic matter.
b. Any sample providing a reading at or below this calculated average will be considered to have only background sources of fluorescence.

V. Sample Analysis

A. Allow fluorometer and samples to warm up for 30 minutes
B. Shake each sample well before analysis.
C. Pour 9 mL sample water into cuvette (approximately 1/3 full). Place in fluorometer and start 10 second countdown.
D. Record reading.
E. Dispose of 9mL sample water and rinse cuvette with deionized water.
F. Repeat steps C through E three times for each sample.
G. Rinse the cuvette three times with deionized water before analyzing the next sample.

Sample analysis will provide qualitative results. Any fluorescence reading above the average difference between ambient water and deionized water fluorescence readings from the standard curves provide insight into the presence of optical brighteners in the sampled waterway. The magnitude of the fluorescence reading indicates the relative strength of optical brightener through multiple result and multiple site comparisons.

VI. Statistical Analysis

The three fluorometric readings recorded for each sample will be averaged and presented with the standard deviation. All data (both field and fluorometric) will be compiled to determine if significant relationships exist between optical brightener readings and other parameters. Data will be statistically analyzed using Microsoft Excel. A correlation analysis of the entire set of data will be completed to determine the relationship between optical brightener values and pH, dissolved oxygen, and water temperature measurements, respectively. The Pearson’s Product Moment analysis will be used to determine correlation coefficients. Coefficients will be presented with p-values to demonstrate statistical significance.

VII. References

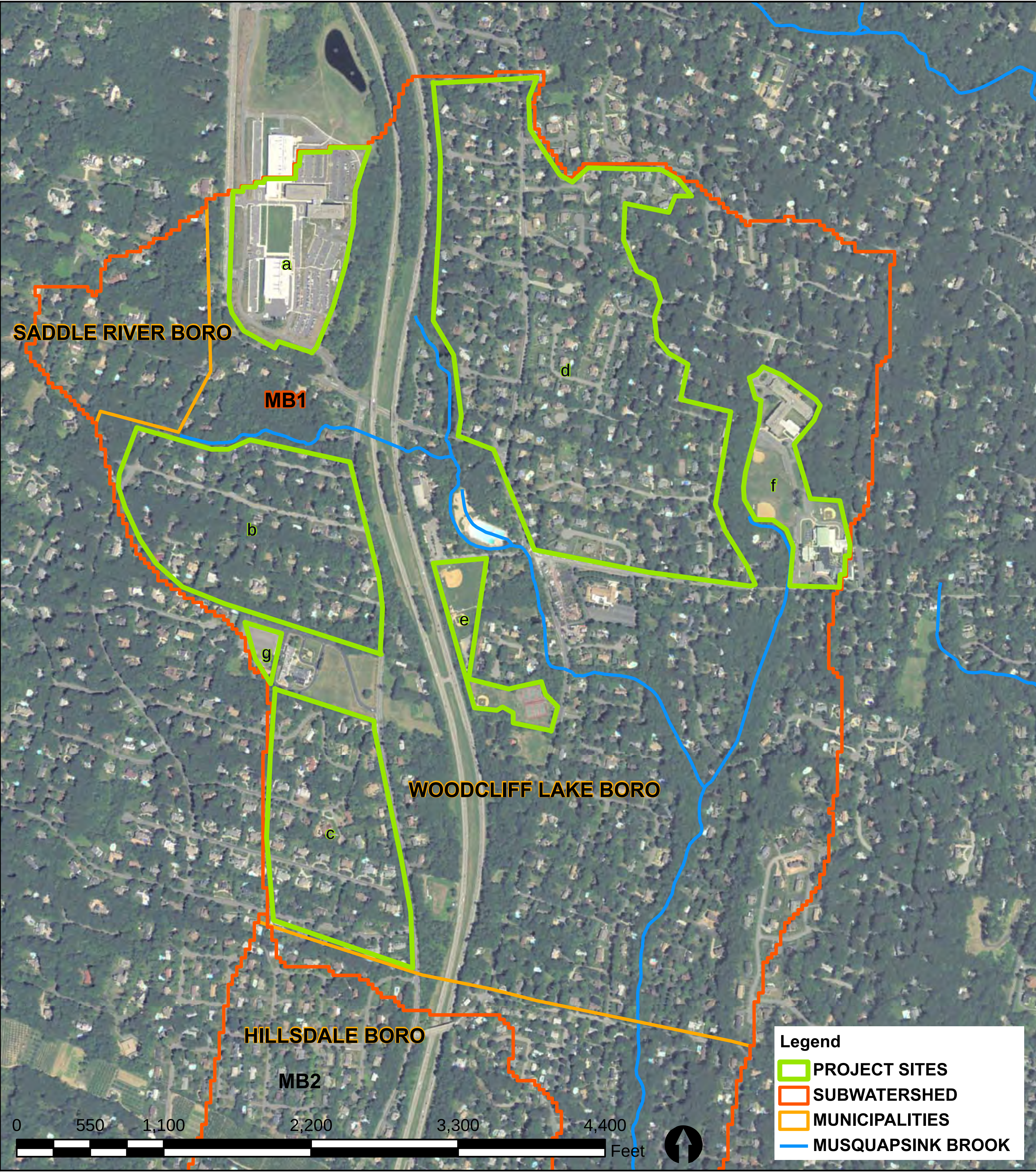
1. Hartel, Peter G., Jennifer McDonald, Lisa Gentit, Sarah Hemmings, Karen Rodgers, Katy Smith, Carolyn Belcher, Robin Kuntz, Yaritza Rivera-Torres, Ernesto Otero, and Eduardo Schroder. "Improving Fluorometry as a Source Tracking Method to Detect Human Fecal Contamination." Estuaries and Coasts 30 (2007): 551-61.

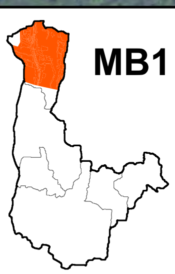
2. Tavares, Mary E., I. H. Spivey, Matthew McIver, and Michael A. Mallin. "Testing For Optical Brighteners and Fecal Bacteria To Detect Sewage Leaks in Tidal Creeks." University of North Carolina Wilmington Center for Marine Sciences (2008). http://people.uncw.edu/hillj/classes/EVS595/Optical%20brightener%20paper%20for%20NCAS.pdf

3. Leeds Point Chemistry Laboratory Standard Operating Procedures: Optical Brighteners. New Jersey Department of Environmental Protection. December 2006.

APPENDIX C

Site Specific Restoration Projects





MB1 Borough of Woodcliff Lake

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

Rutgers New Jersey Agricultural Experiment Station
Water Resources Program

Subwatershed MB1

Borough of Woodcliff Lake

<table>
<tr><th colspan="2"><u>Project Identifier</u></th><th colspan="2"><u>Geographic Coordinates</u></th></tr>
<tr><td>MB1_WL</td><td>a</td><td>N41°01'37.9"</td><td>W074°04'18.0"</td></tr>
<tr><td colspan="4"><u>Site Description and BMP Implementation Opportunities</u>: The site is approximately 25 acres in area and is occupied by a car dealership. The parking lot contains several islands that could be retrofitted with curb cuts, rain gardens or vegetated swales. Parking areas could be re-paved with pervious concrete. Flow-through planter boxes (e.g., Filterra®) could be installed at the existing catch basins to capture and treat bacteria in runoff.</td></tr>
</table>

<u>Site Photos</u>:

<table>
<tr><th colspan="2"><u>Project Identifier</u></th><th colspan="2"><u>Geographic Coordinates</u></th></tr>
<tr><td>MB1_WL</td><td>b</td><td>N41°01'19.1"</td><td>W074°04'33.5"</td></tr>
<tr><td colspan="4"><u>Site Description and BMP Implementation Opportunities</u>: The site is a large residential area with several opportunities for roadway disconnection. A demonstration rain garden could be sited on Mill Road Extension, where runoff could be directed towards the two storm drains situated directly across from one another. The rain gardens would capture stormwater runoff from the roadway and filter out sediment, nutrients, and bacteria that accumulate on the street (see photos below) and enters the basins draining to the stream.</td></tr>
</table>

<u>Site Photos</u>:

Project Identifier		Geographic Coordinates	
MB1_WL	c	N41°00'54.7"	W074°04'30.7"

Site Description and BMP Implementation Opportunities: The site is an alleyway located off Blueberry Drive. Demonstration rain gardens downgradient of the street could be used to educate the community about issues surrounding stormwater runoff. Rain barrels could be placed on downspouts of houses. Pervious pavement could replace existing concrete basketball court, increasing groundwater recharge and decreasing stormwater volumes entering waterways.

Site Photos:



Project Identifier		Geographic Coordinates	
MB1_WL	d	N41°01'22.9"	W074°03'55.7"

Site Description and BMP Implementation Opportunities: The site is a series of residential roadways, most of which are off of Werimus Road, about 14 streets and 110 acres in total. The majority of roads in this community contain no curbs or sidewalks. Roadside vegetated swales and rain gardens could be implemented adjacent to the streets. In addition to downspout disconnection, swales along the road would greatly reduce stormwater volumes and pollutant loads to waterways.

Site Photos:



Project Identifier		**Geographic Coordinates**	
MB1_WL	e	N41°01'17.8"	W074°04'02.1"

Site Description and BMP Implementation Opportunities: The site is Woodcliff Lake Historic Park and is currently under construction. Opportunities for rain garden installations and pervious pavement retrofits exist. A rain garden can be incorporated into the landscape alterations near the historic building, collecting roof runoff and increasing infiltration on site. Pervious asphalt or pavers in the parking spots, approximately 27 spots, near the swimming pool would decrease runoff volumes and pollutant loads. Public access to the site offers opportunities for educational workshops.

Site Photos:



Project Identifier		**Geographic Coordinates**	
MB1_WL	f	N41°01'29.6"	W074°03'35.7"

Site Description and BMP Implementation Opportunities: Dorchester Elementary School is located off Dorchester Road and has recently been repaved. However, a rain garden opportunity exists with the aid of a curb cut in the island of the lot. The island is of substantial size and would provide adequate space for a rain garden. The rain garden would capture pollutants from the parking lot, while reducing runoff volumes. Stormwater education with the rain garden installation as the focus could be implemented at the school.

Site Photos:



Project Identifier		Geographic Coordinates	
MB1_WL	g	N41°01'11.1"	W074°04'23.6"

Site Description and BMP Implementation Opportunities: The site is a large parking lot at Temple Emmanuel, approximately 3,800 square feet. Pervious pavement in the upper portion of the parking lot would limit stormwater runoff and allow for a route for recharge.

Site Photos:



MB2 Hillsdale Borough

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

Rutgers
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB2

Borough of Hillsdale

Project Identifier		**Geographic Coordinates**	
MB2_H	a	N41°00'31.1"	W074°04'13.4"

Site Description and BMP Implementation Opportunities: The site is a parking lot located on Werimus Road. The parking lot is a combination of grassed area and gravel. Strategic tree/shrub selection and planting location would infiltrate runoff and provide shade to the lot.

Site Photos:

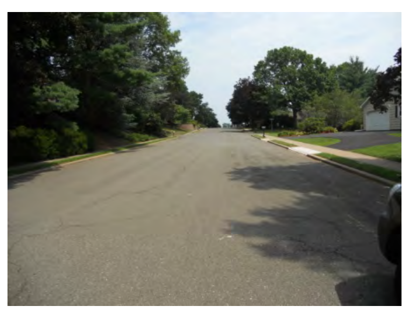


Project Identifier		**Geographic Coordinates**	
MB2_H	b	N41°00'30.3"	W074°04'34.1"

Site Description and BMP Implementation Opportunities: The site a large residential community located near the intersection of Craig and Glen Hook roadways. BMPs such as residential rain gardens and rain barrels for downspout disconnections would decrease stormwater runoff volumes and pollutant loads.

Site Photos:





Project Identifier		**Geographic Coordinates**	
MB2_H	c	N41°00'42.5"	W074°04'26.1"

Site Description and BMP Implementation Opportunities: The site is a neighborhood of medium density residential housing. An applicable BMP would be the implementation of Green Streets to the community on some blocks. Due to the above-average width of the streets, more stormwater runoff is directed to storm sewers. The volume may be limited by creating curb cuts in some locations along the street, allowing for runoff to flow to adjacent rain gardens or stormwater planters. In addition, narrowing the streets with curb extensions in certain areas would lessen the volume created while still providing adequate space for traffic flow.

Site Photos:

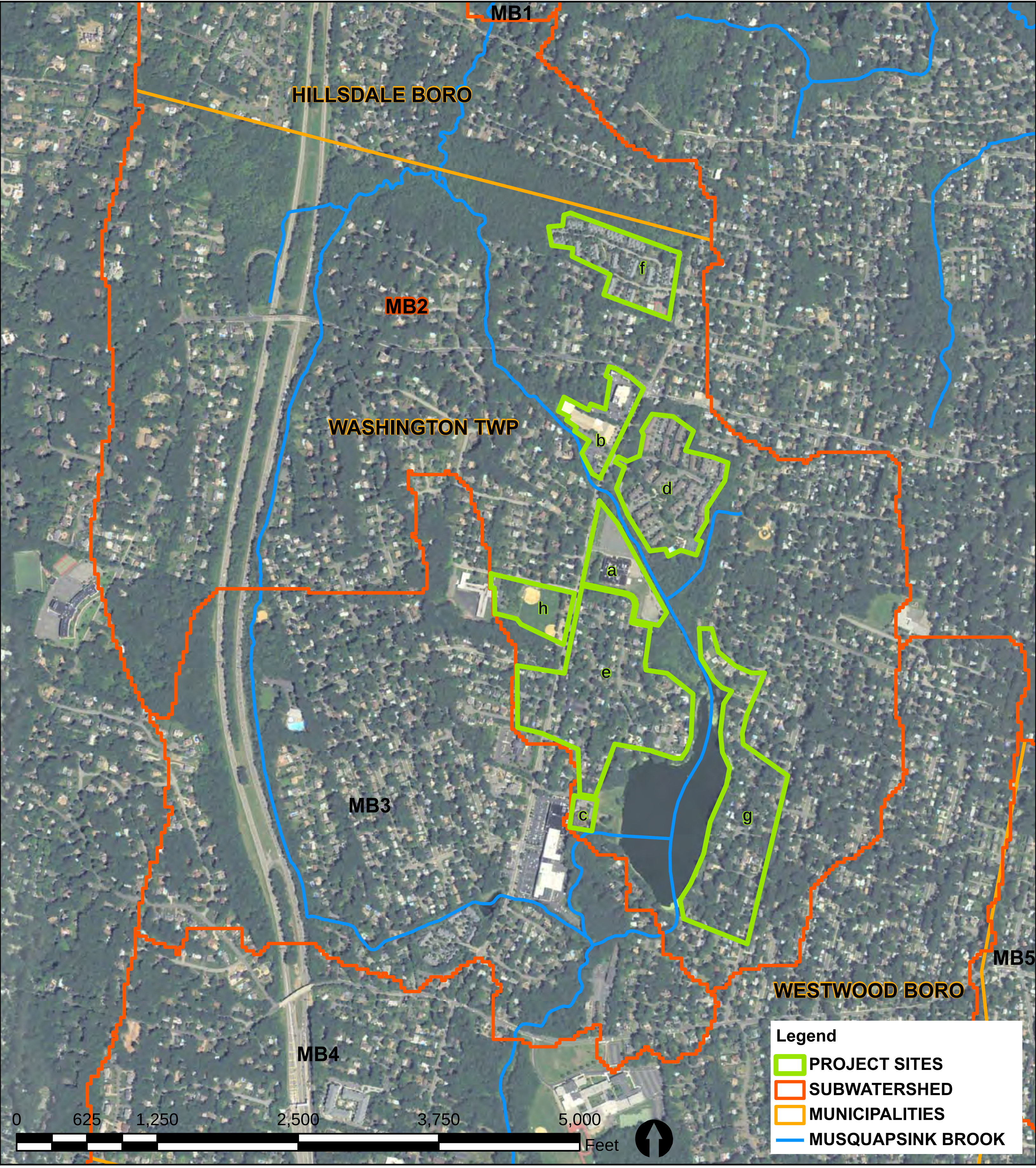


Project Identifier		**Geographic Coordinates**	
MB2_H	d	N41°00'22.9"	W074°04'1.3"

Site Description and BMP Implementation Opportunities: The site is the Ann Blanche Smith Elementary School located on Hillsdale Avenue. The school is an ideal location to provide educational outreach about stormwater issues and BMPs. BMPs would include rain barrels, a rain garden on the island of the parking lot, and vegetated swales adjacent to the roadways.

Site Photos:





MB2 Washington Township

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB2

Washington Township

<table>
<tr><th colspan="2"><u>Project Identifier</u></th><th colspan="2"><u>Geographic Coordinates</u></th></tr>
<tr><td>MB2_Wa</td><td>a</td><td>N40°59'38.7"</td><td>W074°03'37.4"</td></tr>
<tr><td colspan="4"><u>Site Description and BMP Implementation Opportunities</u>: The Bergen County Jewish Community Center near Berkley Court is located at this site. Recommended BMPs for implementation at this site include a naturalized detention basin and vegetated swales. Rain gardens can be installed on the parking lot islands. Invasive species, such as the Japanese knot weed, would have to be removed before BMPs are installed.</td></tr>
</table>

Site Photos:



<table>
<tr><th colspan="2"><u>Project Identifier</u></th><th colspan="2"><u>Geographic Coordinates</u></th></tr>
<tr><td>MB2_Wa</td><td>b</td><td>N40°59'43.4"</td><td>W074°03'39.4"</td></tr>
<tr><td colspan="4"><u>Site Description and BMP Implementation Opportunities</u>: The site is located at the Washington Township Fitness and Tennis Club. The parking lot, approximately 1,115 ft^2, could be replaced with permeable pavement.</td></tr>
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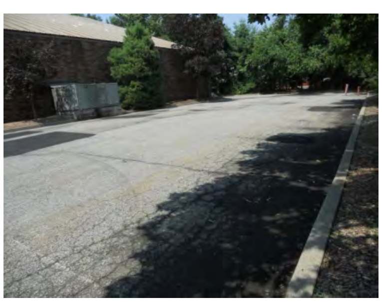
Site Photos:



Project Identifier		Geographic Coordinates	
MB2_Wa	c	N40°59′03.1″	W074°03′44.3″

Site Description and BMP Implementation Opportunities: This site is occupied by a shopping center. The parking lot of the shopping center is in close proximity to the Musquapsink Brook; they are separated by just a small grassed area. There is evidence of streambank erosion, and the site would benefit from streambank stabilization measures. A rain garden or swale can be installed to capture the pollutants in runoff from the nearby parking lot. In addition, the parking lot can be retrofitted with permeable pavement.

Site Photos:



Project Identifier		Geographic Coordinates	
MB2_Wa	d	N40°59'03.1"	W074°03'44.3"

Site Description and BMP Implementation Opportunities: This site includes an alleyway, approximately 1,600 ft^2 in area, located between two apartment buildings. The apartment buildings contain a directly-connected impervious cover. The downspouts of the buildings should be disconnected with rain barrels or cisterns. A green alleyway can be installed in the area between the two apartment buildings to further collect stormwater runoff.

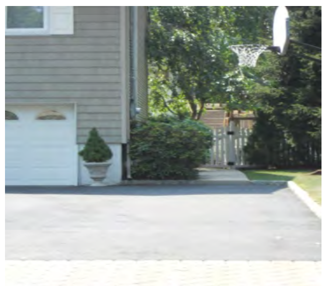
Site Photos:

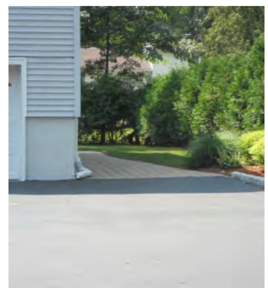


Project Identifier		Geographic Coordinates	
MB2_Wa	e	N40°59'18.4"	W074°03'44.1"

Site Description and BMP Implementation Opportunities: This site is a residential neighborhood with approximately 50 homes on approximately ¼ acre lots. About 55% of the properties are directly connected to impervious cover. The downspouts of these homes should be disconnected with rain gardens or rain barrels. The driveways should incorporate permeable pavement. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:





Project Identifier		Geographic Coordinates	
MB2_Wa	f	N41°00'0.8"	W074°03'35.0"

Site Description and BMP Implementation Opportunities: This site is a residential neighborhood with approximately 11 condominium buildings on ¼ acre lots. Almost all of the downspouts are directly connected to roadway catch basins. The downspouts should be disconnected with rain gardens and rain barrels. In addition, the existing detention basin and swale near the condos can be naturalized using native plants and shrubs.

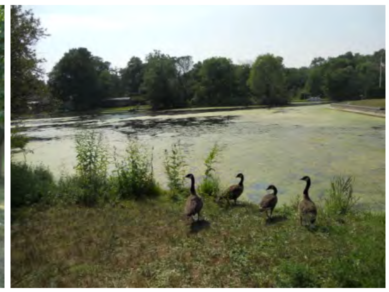
Site Photos:

Project Identifier		Geographic Coordinates	
MB2_Wa	g	N40°59'21.1"	W074°03'23.2"

Site Description and BMP Implementation Opportunities: This site is a park in a residential neighborhood. A rain garden can be installed to collect runoff from the parking lot. In addition, shoreline stabilization methods should be implemented to deter geese from entering the nearby Schlegel Lake. Geese fecal matter has been linked to the spread of diseases and bacterial contamination of water. To prevent this fecal matter from entering the water, high-growing native plants should be installed along the perimeter of the lake.

Site Photos:





Project Identifier		Geographic Coordinates	
MB2_Wa	h	N40°59'31.8"	W074°03'52.4"

Site Description and BMP Implementation Opportunities: The Washington Township Elementary School is located at this site. A rain garden can be installed near the right wing of the school to collect runoff from the 760 ft^2 parking lot. Also, the parking lot can be retrofitted with permeable pavement. Students would benefit from the educational opportunities offered by the Water Resources Program through the *Stormwater Management in Your School Yard* curriculum.

Site Photos:



MB3 Washington Township

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB3

Washington Township

Project Identifier		**Geographic Coordinates**	
MB3_Wa	a	N40°59'5.856"	W074° 3' 45.1866"

Site Description and BMP Implementation Opportunities: The site is Washington Township Shopping Center located on Pascack Road, near Finnerty Place. In the rear parking lot of the site, the creek is in view and is accessible. Runoff from the site enters the waterway directly. A vegetated buffer should be installed. A vegetated swale placed along a fence that separates the brook from the parking lot would serve the purpose of filtering stormwater runoff and conveying it away from the stream. Pervious pavement should be installed where possible to limit the runoff from the parking lot. Rain gardens should also be installed to limit pollutant (sediment and hydrocarbon) load into the creek.

Site Photos:



Project Identifier		**Geographic Coordinates**	
MB3_Wa	b	N40° 58' 53.6082"	W074° 3' 41.5182"

Site Description and BMP Implementation Opportunities: The site is Our Lady of Good Counsel Church, which is located off Ridgewood Road. The location consists of a large parking lot. There is an opportunity for downspout disconnection and rain gardens near the main entrance.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB3_Wa	c	N40° 59' 0.5784"	W074° 3' 59.8428"

Site Description and BMP Implementation Opportunities: Pine Lake Estates, a townhouse complex, is located at this site. All driveways and downspouts are directly connected to roadways or catch basins in nearby lawns. Disconnection by means of rain barrels and rain gardens would be ideal for this community.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB3_Wa	d	N40° 59' 24.8058"	W074° 3' 53.136"

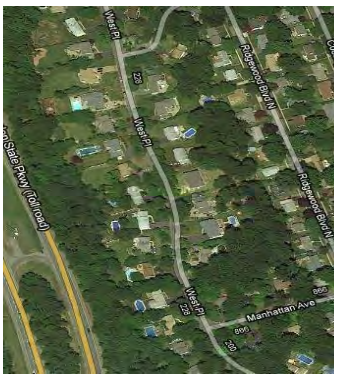
Site Description and BMP Implementation Opportunities: The site is a residential neighborhood consisting of about 60 homes on ¼ acre lots. 69% of the homes are directly connected to impervious cover. Some streets (Crest Place & Viola Terrace) do not have sidewalks. Therefore, rain gardens or vegetated swales along the streets with curb cuts to capture, treat, infiltrate runoff from roadways would be ideal BMPs. The disconnection of impervious cover by rain barrels or rain gardens is also appropriate for this site. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB3_Wa	e	N40° 59' 7.4286"	W074° 4' 10.326"

Site Description and BMP Implementation Opportunities: The site is a residential neighborhood on West Place. The streets have no sidewalk, and the development contains about 25 homes on ¼ acre lots. 77% of the homes are directly connected to impervious cover. The creek is located behind homes on the west side of West Place. Rooftops should be disconnected with rain barrels or rain gardens on the residents' property. Also, roadside vegetated swales or gardens would limit stormwater volume entering waterways while filtering out pollutants. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

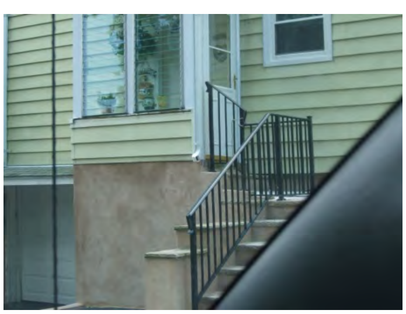
Site Photos:

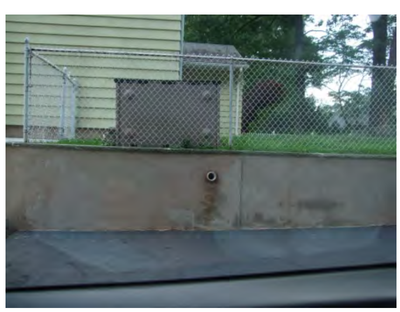


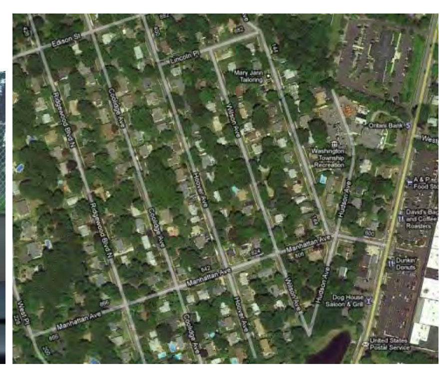
Project Identifier		**Geographic Coordinates**	
MB3_Wa	f	N40° 59' 17.5194"	W074° 4' 5.7288"

Site Description and BMP Implementation Opportunities: This site is a residential neighborhood consisting of about 170 houses on ¼ acre lots. Almost 70% of the homes are directly connected to impervious cover. Rooftops should be disconnected by means of rain barrels or rain gardens. Roadways could be converted to Green Streets and retrofitted with vegetated swales, curb extensions, and/or planter boxes. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:



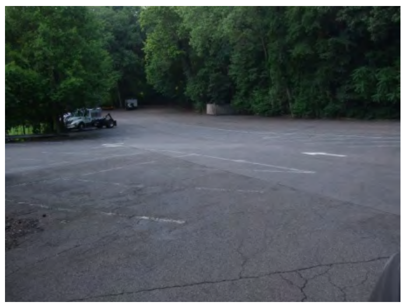




Project Identifier		**Geographic Coordinates**	
MB3_Wa	g	N40° 59' 22.8264"	W074° 4' 17.3136"

Site Description and BMP Implementation Opportunities: The site is Washington Township Recreation Park on Ridgewood Boulevard East. The location consists of an office building, an athletic field, and a ¾ acre parking lot in poor condition. The site is adjacent to a stream and has little buffer to protect waterway from polluted runoff. The buffer should be increased to adequately filter pollutants and slow stormwater flow.

Site Photos:

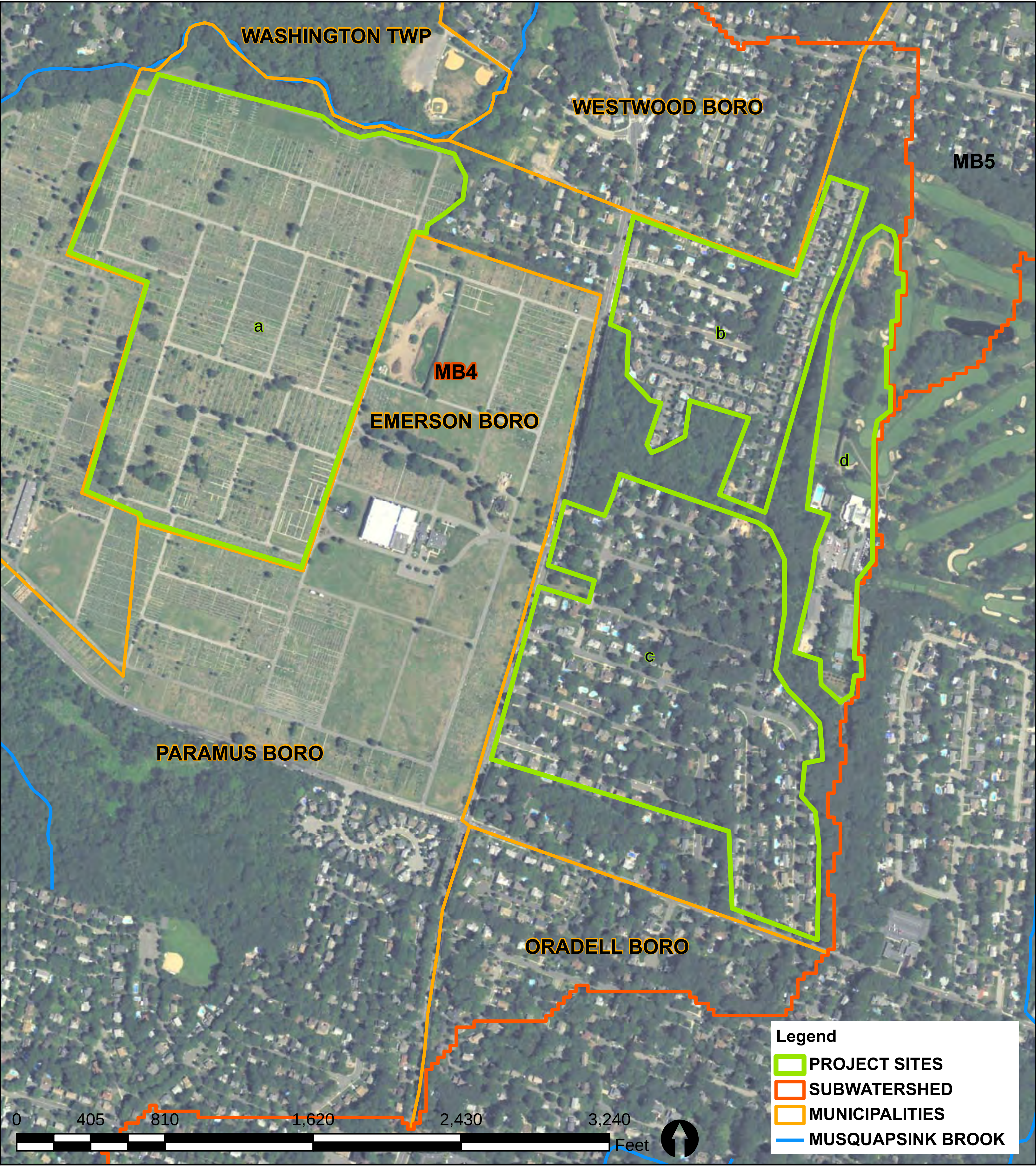




Project Identifier		**Geographic Coordinates**	
MB3_Wa	h	N40° 59' 31.164"	W074° 3' 55.3746"

Site Description and BMP Implementation Opportunities: The site is Washington Elementary School at 600 School Street. The site has a 3,000 square-foot parking lot, ranging from average to poor conditions. There are cement channels for stormwater conveyance. Recommendations include replacement of cement channels with vegetated swales, installation of rain gardens to capture, treat, and infiltrate stormwater before it reaches storm drains, and implementation of *Stormwater Management In Your School Yard* curriculum in the school.

Site Photos:





MB4 Borough of Emerson

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB4

Borough of Emerson

Project Identifier		**Geographic Coordinates**	
MB4_E	a		
Site Description and BMP Implementation Opportunities: Approximately 82 acres of the Beth El and Cedar Park Cemetery is located on this site. The cemetery property extends to the stream edge, with approximately 20 feet of existing riparian buffer. Storm drains located along the roadways appear to be clogged with sediment. Geese populations are abundant. Flow-though planter boxes could be installed near storm drains on the property.			

Project Identifier		**Geographic Coordinates**	
MB4_E	b	N40° 58' 24.276"	W074° 2' 34.3428"
Site Description and BMP Implementation Opportunities: The site is a residential neighborhood consisting of about 90 homes. 87% of the rooftops are directly connected to impervious surfaces. Rooftops should be disconnected with residential rain gardens or rain barrels. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.			

Site Photos:

Project Identifier		Geographic Coordinates	
MB4_E	c	N40° 58' 6.6606"	W074° 2' 40.1382"
Site Description and BMP Implementation Opportunities: The site is a residential neighborhood which consists of about 160 homes on ¼ acre lots. 61% of the rooftops are directly connected to impervious surfaces. Rooftops should be disconnected with residential rain gardens or rain barrels. Some streets in the neighborhood have no curbs. Vegetated swales or roadside rain gardens could be utilized to capture, treat and infiltrate roadway runoff. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.			

Site Photos:

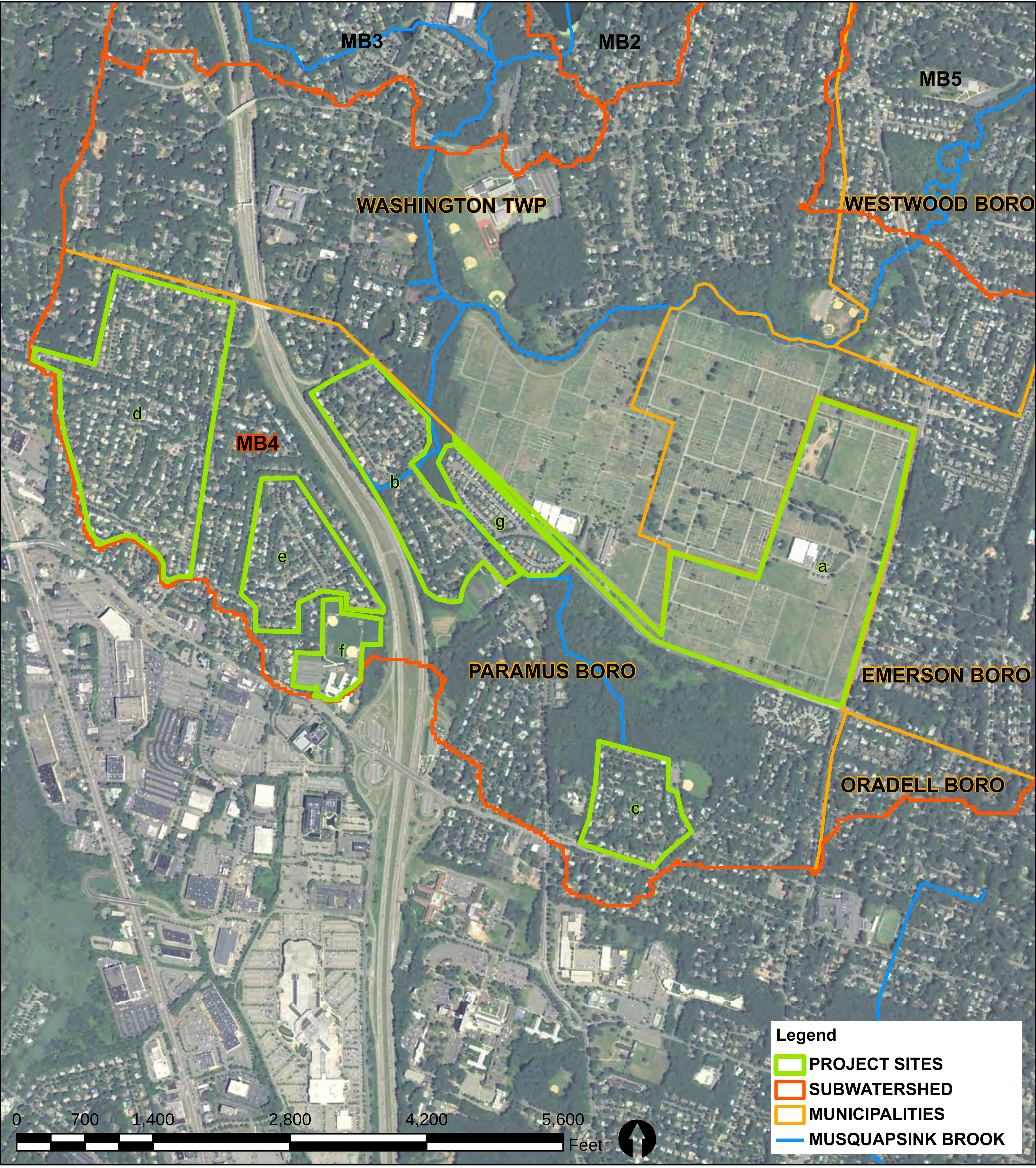
Project Identifier		Geographic Coordinates	
MB4_E	d	N40° 58' 7.842"	W074° 2' 48.6918"
Site Description and BMP Implementation Opportunities: The site is a community park located within a residential neighborhood. There is an opportunity for roadway disconnection via vegetated swales or rain gardens installed on the park property. This would provide stormwater capture and filtering, as well as improved aesthetic and wildlife habitat.			

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB4_E	e	N40° 58' 9.7248"	W074° 2' 28.935"

Site Description and BMP Implementation Opportunities: The site is a private golf club located on Golf Club Road, near Soldier Hill Road. The site has large portions of impervious cover, including the parking lot and club building. Pervious asphalt or permeable pavers would aid in groundwater recharge and would protect nearby waterways.

Site Photos:



MB4 Borough of Paramus

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB4

Borough of Paramus

Project Identifier		**Geographic Coordinates**	
MB4_P	a		

Site Description and BMP Implementation Opportunities: This site contains 100 acres of the Beth El and Cedar Park cemetery. Storm drains located along the roadways are clogged with sediment. Geese populations are abundant. Flow-though planter boxes could be installed near storm drains on the property to capture and treat bacteria from geese fecal matter and nutrients from fertilizer applications.

Project Identifier		**Geographic Coordinates**	
MB4_P	b	N40°58.337’	W074°03.789’

Site Description and BMP Implementation Opportunities: The site is a residential neighborhood with the Musquapsink Brook passing through near Bluebell Court and Cottonwood Court. The neighborhood consists of about 40 homes on ¼ acre lots. 74% of the rooftops are directly connected to impervious surfaces. Rooftops should be disconnected with residential rain gardens or rain barrels. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:

Project Identifier		Geographic Coordinates	
MB4_P	c		

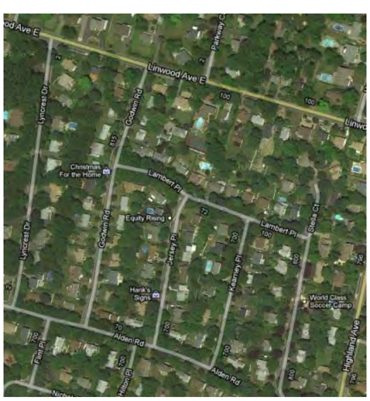
Site Description and BMP Implementation Opportunities: The site is a residential neighborhood; the Musquapsink Brook is accessible at the end of Drexel Road. The neighborhood consists of about 40 homes on ¼ acre lots. 77% of the rooftops are directly connected to impervious surfaces. Rooftops should be disconnected with residential rain gardens or rain barrels. Homeowners should be offered educational workshops on the importance of management and BMP implementation. An adequate buffer should be in place to provide the stream with protection.

Site Photos:

Project Identifier		Geographic Coordinates	
MB4_P	d		

Site Description and BMP Implementation Opportunities: The site is a residential neighborhood consisting of about 90 homes on ¼ acre lots. 67% of the rooftops are directly connected to impervious surfaces. Rooftops should be disconnected with residential rain gardens or rain barrels. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:



Project Identifier		**Geographic Coordinates**	
MB4_P	e		

Site Description and BMP Implementation Opportunities: The site is a residential neighborhood which consists of about 100 homes on ¼ acre lots. 75% of the rooftops are directly connected to impervious surfaces. Rooftops should be disconnected with residential rain gardens or rain barrels. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation. .

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB4_P	f	N40°57.987'	W074°04.117'

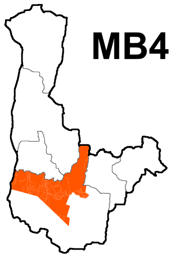
Site Description and BMP Implementation Opportunities: The site is Parkway School, approximately 10 acres in area. Approximately five acres is occupied by athletic fields and 1.5 by parking lot. Rain gardens could be implemented on the islands in the parking lot or near the school. Educational workshops or implementation of *Stormwater Management in Your School Yard* curriculum would increase the knowledge of the importance of stormwater management and BMP implementation.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB4_P	g	N40°58.337'	W074°03.789'

Site Description and BMP Implementation Opportunities: The site is a residential neighborhood with the Musquapsink Brook passing through behind Manchester Way. The neighborhood consists of about 45 homes on ¼ acre lots. 30% of the rooftops are directly connected to impervious surfaces. The rooftops, therefore, should be disconnected with residential rain gardens or rain barrels. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:



MB4 Washington Township

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB4

Washington Township

Project Identifier		**Geographic Coordinates**	
MB4_Wa	a	N040°58.4'	W074°03.8'

Site Description and BMP Implementation Opportunities: Approximately 90 acres of the Beth El and Cedar Park Cemetery is located on this site. The cemetery property extends to the stream edge, with approximately 20 feet of existing riparian buffer. Storm drains located along the roadways appear to be clogged with sediment. Geese populations are abundant. Flow-though planter boxes could be installed near storm drains on the property. There is an opportunity to increase the riparian buffer width along the northern edge of the property.

Project Identifier		**Geographic Coordinates**	
MB4_Wa	b	40° 58' 42.4128"	W074° 3' 57.3834"

Site Description and BMP Implementation Opportunities: The site contains a large parking lot, approximately ½ an acre, in both the front and the back of the building. The front parking lot does not offer any possibility for BMPs. The back parking lot drains to a field through multiple curb cuts and accounts for approximately 35% of the total impervious area on the site. Rain gardens and permeable pavement are viable implementation options.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB4_Wa	c	N040°58.7'	W074°04.1'

Site Description and BMP Implementation Opportunities: The site is the Valley Bible Chapel, off of Pascack Road. The majority of the chapel's downspouts are disconnected. There is a possible location behind the building, near the garbage, for a rain garden, which can serve to capture, treat, and infiltrate stormwater at the source.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB4_Wa	d	N040°58.6'	W074°04.3'

Site Description and BMP Implementation Opportunities: This site belongs to a business with a large parking lot. The parking lot covers approximately one acre of the property with impervious surface. Permeable pavement is the only BMP option for this site.

Project Identifier		Geographic Coordinates	
MB4_Wa	e	N040°58.4'	W074°03.9'

Site Description and BMP Implementation Opportunities: The site is Washington Pond, which is a series of streets surrounding a central pond in a residential area. Divided into Pond Court, Pond Drive, and Pond Terrace, several opportunities for BMP implementation exist. Pond Court contains approximately five townhouse buildings on approximately ¼ acre lots. All but one downspout are directly connected. Pond terrace contains approximately six townhouse buildings, also on approximately ¼ acre lots, where only some side downspouts are disconnected. Pond Drive contains approximately four townhouse buildings, also on ¼ acre lots, with the majority being directly connected. Downspouts should all be disconnected with rain barrels to reduce the stormwater runoff from the roofs of the development. There is potential for a community rain garden to infiltrate and reduce the stormwater flow. The upper half of the development drains to the pond, where no buffer currently exists. A vegetated buffer should be installed to reduce both stormwater flow and pollutant loading. The lower half of the development drains to Musquapsink Brook.

Site Photos:



Project Identifier		Geographic Coordinates	
MB4_Wa	f	N040°58.685'	W074°04.013'

Site Description and BMP Implementation Opportunities: This site is a small residential community, with less than 50 townhouse units. There are two main drainage channels to the Musquapsink Brook, all from impervious surfaces. One section drains to a riprap swale, which is in poor condition. Most of the impervious surfaces in this development drain to this. The rest drain to a 28″ reinforced concrete pipe, which discharges into the Brook as well. The roof leaders are all directly connected to these conveyance channels. The riprap swale is eroding because of the large stormwater volumes. The channel also lacks a buffer and a significant amount of sediment has accumulated. Rain gardens and rain barrels are recommended for disconnection of impervious surfaces on this site. Vegetated buffers around the riprap channel would help to filter out pollutants and sediment while also reducing erosion from stormwater flows.

Site Photos:



Project Identifier		Geographic Coordinates	
MB4_Wa	g	N40°58.7'	W074°03.1'

Site Description and BMP Implementation Opportunities: This site is a residential area centered about the Pershing Avenue, with approximately 120 homes on ¼ acre lots. 55% of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain barrels or rain gardens. Also, the driveways could be retrofitted with pervious pavement. The homeowners should be offered an educational program stressing the importance of stormwater management and BMP implementation.

Site Photos:

Project Identifier		Geographic Coordinates	
MB4_Wa	h	N040°58'34.22"	W074°02'57.6"

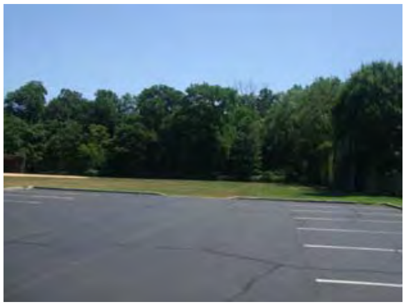
Site Description and BMP Implementation Opportunities: This site contains 3 baseball fields and a gravel parking lot located on the side. There is a stream along the backside of the field that lacks a buffer, therefore a vegetated buffer should be installed to help control erosion, stabilize stream channels, reduce flooding, and filter pollutants.

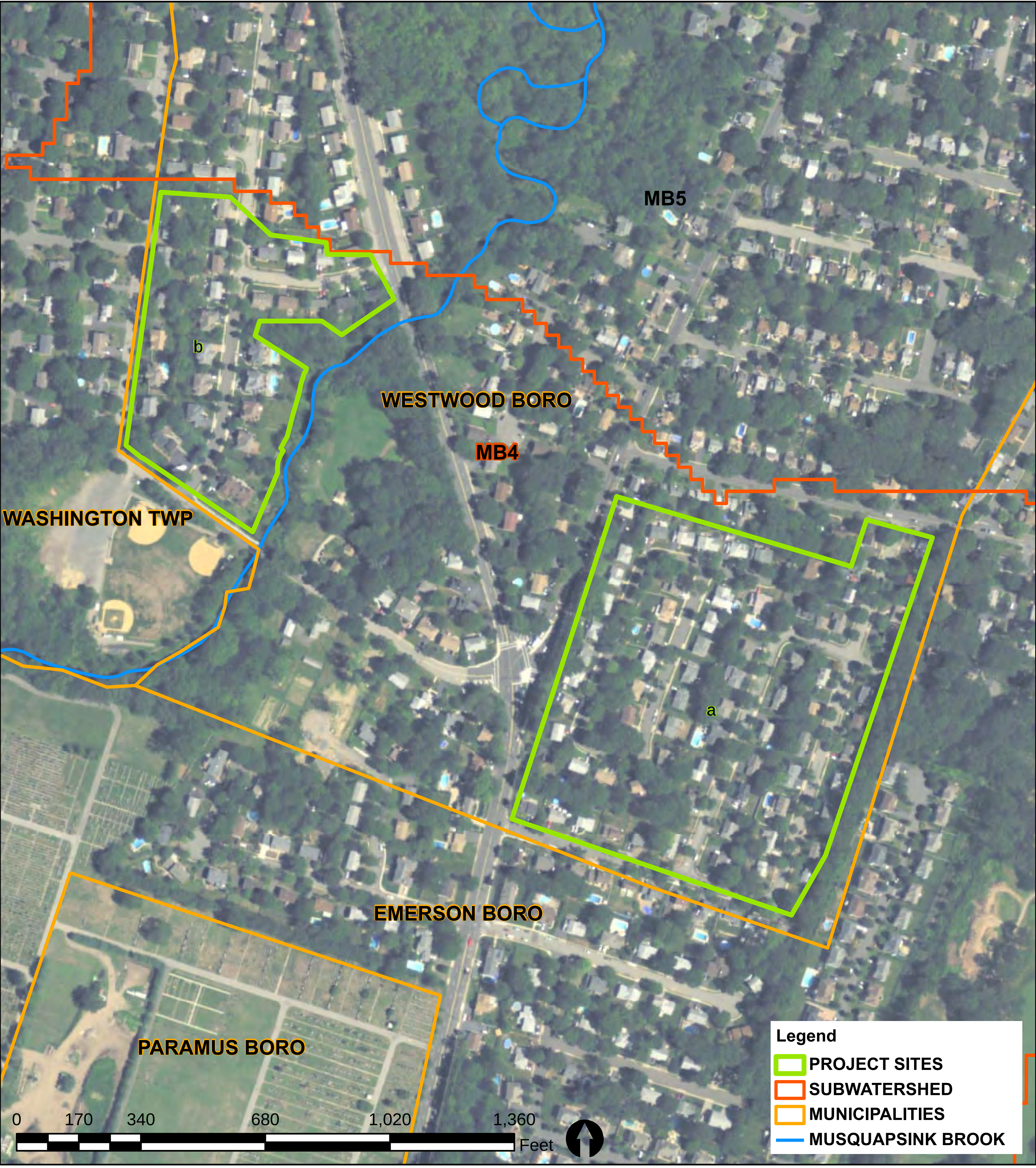
Site Photos:

Project Identifier		**Geographic Coordinates**	
MB4_Wa	i	N040°58.820'	W074°03.741'

Site Description and BMP Implementation Opportunities: This site is the Westwood High School property, and has a possible rain garden location in the back of the school, near the tennis courts. This rain garden would serve to collect, treat, and infiltrate runoff from the parking lot. There is also another rain garden implementation opportunity near the tennis court parking lot, which covers approximately 0.5 acres.

Site Photos:





MB4 Borough of Westwood

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB4

Borough of Westwood

Project Identifier		**Geographic Coordinates**	
MB4_We	a	N40° 58' 31.4034"	W074° 2' 37.3596"
Site Description and BMP Implementation Opportunities: The site is a residential neighborhood of about 7 streets and 100 houses on ¼ acre lots. 62% of the homes are directly connected to impervious cover. Rooftops should be disconnected via residential rain gardens or rain barrels. Driveways can be converted to permeable pavement. In addition, roadways can be converted to Green Streets with curb cuts and roadside rain gardens or with curb extensions. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.			

Site Photos:

Project Identifier		Geographic Coordinates	
MB4_We	b	N40° 58' 40.8396"	W074° 2' 52.0728"

Site Description and BMP Implementation Opportunities: The site is a residential neighborhood of about 4 streets and 70 houses on ¼ acre lots. 54% of the homes are directly connected to impervious cover. Rooftops should be disconnected by residential rain gardens or rain barrels. Driveways can be converted to permeable pavement. In addition, roadways can be converted to Green Streets with curb cuts and roadside rain gardens or with curb bump outs. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:

MB5 Borough of Emerson

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

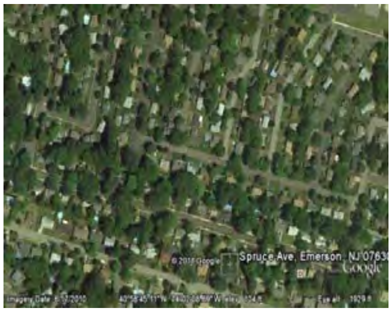
Water Resources Program

Subwatershed MB5

Borough of Emerson

Project Identifier		**Geographic Coordinates**	
MB5_E	a	N040°58'40.3"	W074°02'06.1"
Site Description and BMP Implementation Opportunities: This site is a residential area with approximately 80 homes on ¼ acre lots. 53% of the properties in this area contain directly connected downspouts to impervious surface. Rooftops should be disconnected with rain gardens or rain barrels. Driveways should be retrofitted with permeable pavement. Homeowners should also be offered an educational workshop on the importance of stormwater management and BMP implementation.			

Site Photos:



Project Identifier		**Geographic Coordinates**	
MB5_E	b	N040°58'36.37"	W074°02'22.13"
Site Description and BMP Implementation Opportunities: The site consists of residential streets, totaling approximately 40 homes with about 44% containing directly connected downspouts. Ackerman Park is located in this neighborhood. The park is small, and the area is limited, but there is a potential to install a community rain garden. Public access to the park provides educational opportunities centered around the rain garden installation.			

Site Photos:

MB5 Borough of Westwood

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

Subwatershed MB5

Borough of Westwood

Project Identifier		**Geographic Coordinates**	
MB5_We	a	N40° 58' 46.26"	W074° 2' 38.76"

Site Description and BMP Implementation Opportunities: This site includes residential neighborhoods along Carl Place and Langner Place. Gabion baskets and riprap have been placed along portions of Carl Place for stabilization and flood control. Homeowners have also included riprap in their landscaping to mitigate flooding on their property. These two streets contain approximately 30 houses on ¼ acre lots. 87% of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain gardens or rain barrels. Driveways should be retrofitted with permeable pavement. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB5_We	b	N40°58.730′	W074°02.799′

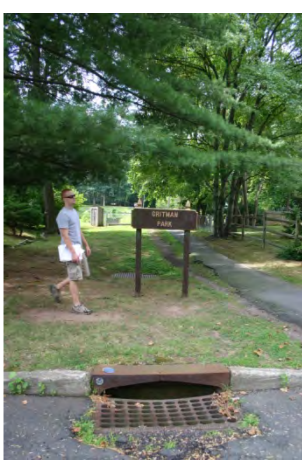
Site Description and BMP Implementation Opportunities: This site is a residential neighborhood, located along Forest Avenue, with approximately 15 houses on ¼ acre lots. 30% of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain gardens or rain barrels. Driveways should be retrofitted with permeable pavement. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Project Identifier		Geographic Coordinates	
MB5_We	c	N40° 58' 42.38"	W074° 2' 33.5724"
Site Description and BMP Implementation Opportunities: This site is a residential neighborhood located along Ward Avenue and Taco Avenue with approximately 25 houses on ¼ acre lots. 72% of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain gardens or rain barrels. Driveways should be retrofitted permeable pavement. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.			

Project Identifier		Geographic Coordinates	
MB5_We	d	N40°58.908′	W074°02.796′
Site Description and BMP Implementation Opportunities: This site is a residential neighborhood located along Ruckner Avenue with approximately 20 houses on ¼ acre lots. 71% of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain gardens or rain barrels. Driveways should be retrofitted permeable pavement. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.			

Project Identifier		Geographic Coordinates	
MB5_We	e	N40° 58' 54.48"	W074° 2' 24.55"
Site Description and BMP Implementation Opportunities: This site is occupied by Gritman Park and the surrounding residential neighborhood. The park contains a man-made pond with four stormwater inlets that drain the adjacent properties and roadways. The pond has no riparian buffer and evidence of geese presence was documented on the park property. The pond ultimately discharges to the Musquapsink Brook.			

Site Photos:



Project Identifier		**Geographic Coordinates**	
MB5_We	f	N 40° 59' 8.44"	W074° 2' 21.75"

Site Description and BMP Implementation Opportunities: This site is a residential neighborhood located along 4th Avenue with approximately 15 houses on ¼ acre lots. Several of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain gardens or rain barrels. Driveways should be retrofitted with permeable pavement. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Project Identifier		**Geographic Coordinates**	
MB5_We	g	N 40° 59' 7.69"	W0 74° 2' 46.64"

Site Description and BMP Implementation Opportunities: This site is a residential neighborhood located between Lafayette Avenue and Clairmont Avenue with approximately 150 houses on ¼ acre lots. Approximately 60% of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain gardens or rain barrels. Driveways should be retrofitted with permeable pavement. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:

Project Identifier		Geographic Coordinates	
MB5_We	h	N40° 59' 2.28"	W074° 2' 23.35"

Site Description and BMP Implementation Opportunities: This site is characterized by an open tract of land situated adjacent to the Musquapsink Brook and served as a sampling point (MB005) for the surface water quality monitoring. The site is located along 3rd Avenue and across from athletic fields. It contains no riparian buffer, and geese presence has been documented on several occasions.

Site Photos:

Project Identifier		Geographic Coordinates	
MB5_We	i	N40°58.956′	W074°02.610′

Site Description and BMP Implementation Opportunities: This site is occupied by Brookside Elementary School and contains directly connected sidewalks, a roof, and a parking lot. The site offers an opportunity for a 400 square-foot rain garden installation at the main entrance. Students and teachers would benefit from both an in-class lesson and hands-on learning experience related to nonpoint source pollution and stormwater management.

Site Photos:

MB6 Borough of Emerson

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB6

Borough of Emerson

Project Identifier		**Geographic Coordinates**	
MB6_E	a	N40°58.957′	W074°02.014′

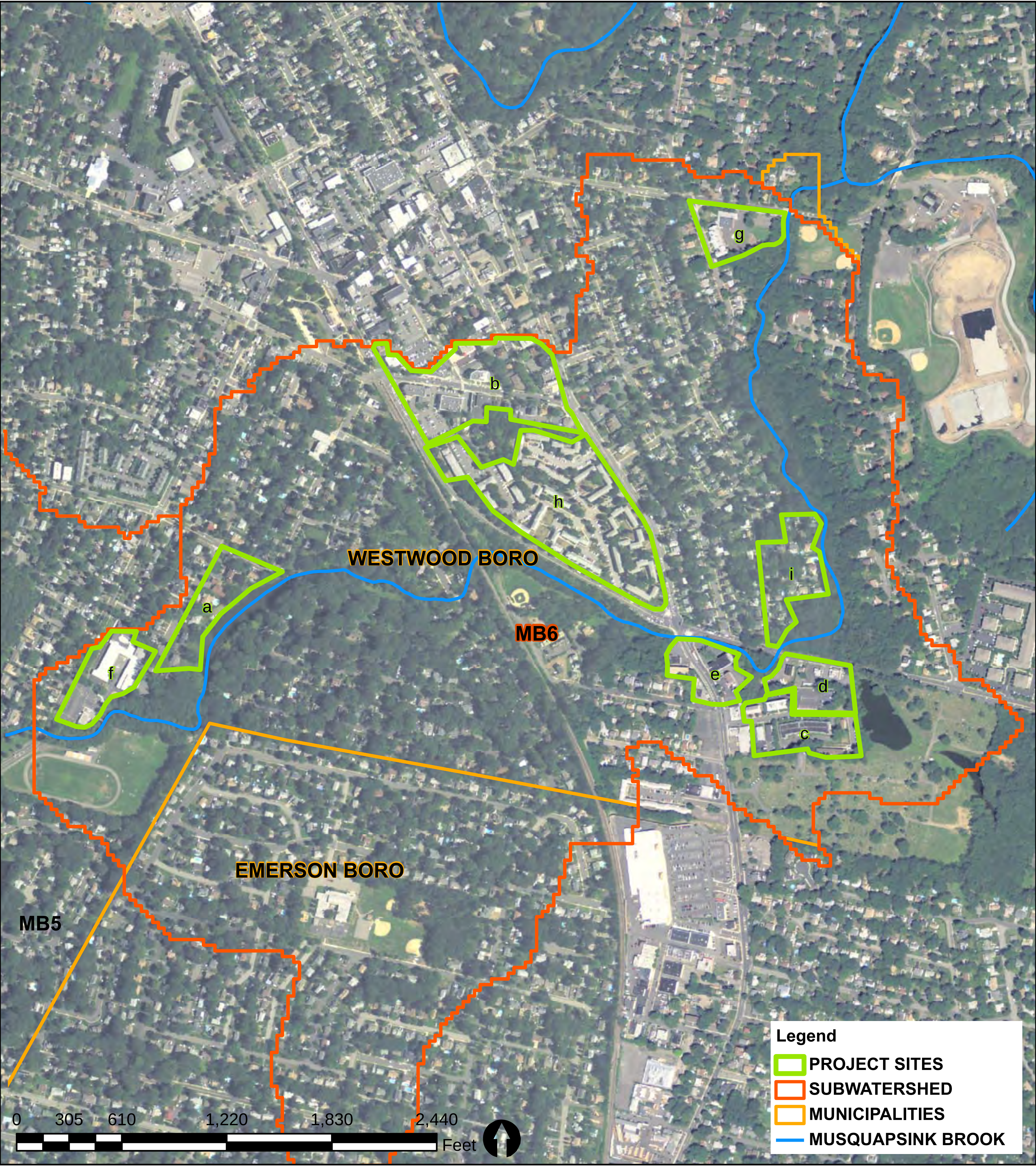
Site Description and BMP Implementation Opportunities: This site is a residential neighborhood with approximately 85 homes on ¼ acre lots. 76% of the properties contain directly connected impervious cover. Rooftops should be disconnected with rain barrels or rain gardens. Roadways should be converted to Green Streets. Homeowners should be offered educational workshops on the importance of stormwater management and BMP implementation.

Site Photos:

<table>
<tr><th colspan="2"><u>Project Identifier</u></th><th colspan="2"><u>Geographic Coordinates</u></th></tr>
<tr><td>MB6_E</td><td>b</td><td>N40°58.908′</td><td>W074°01.993′</td></tr>
<tr><td colspan="4"><u>Site Description and BMP Implementation Opportunities</u>: This site is the Emerson Memorial Elementary School property. The site is approximately six acres of which about 2.5 acres is impervious cover. The current stormwater conveyance system is in poor condition and sediment has built up in many of the cement channels on the property. Implementing vegetated swales in place of the cement channels would help infiltrate some of the rain water instead of simply directing it to storm drains. Rain gardens in the parking lot islands and near the school entrance would provide more opportunity for pollutant removal and groundwater recharge.</td></tr>
</table>

<u>Site Photos</u>:





MB6 Borough of Westwood

Map of Proposed Areas of Disconnection
Musquapsink Brook Watershed
Restoration and Protection Plan

RUTGERS
New Jersey Agricultural Experiment Station

Water Resources Program

Subwatershed MB6

Borough of Westwood

Project Identifier		**Geographic Coordinates**	
MB6_We	a	N40°59.203'	W074°02.099'

Site Description and BMP Implementation Opportunities: The site is a large mill pond receiving runoff from various sources – both grass runoff and storm sewer lines. The pond is located behind homes on 2nd Avenue and has no buffer. There is a stone reinforcement on the narrow side of pond. A buffer should be implemented to lower pollutant loads to the pond and slow stormwater flows.

Site Photos:



Project Identifier		**Geographic Coordinates**	
MB6_We	b	N40° 59' 34.1232"	W074° 1' 55.527"

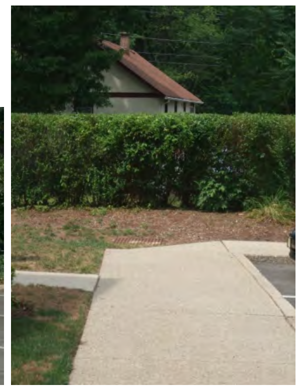
Site Description and BMP Implementation Opportunities: The site is a commercial property, including The Learning Express and the Hanami Japanese and Chinese restaurant. The parking lot at this site should be retrofitted with pervious asphalt or pavers.

Site Photos:

Project Identifier		Geographic Coordinates	
MB6_We	c	N40° 59' 2.49"	W074° 1' 19.0662"

Site Description and BMP Implementation Opportunities: This site is a 2.5 acre apartment housing complex located on Crest Street. The Westwood Manor Complex is directly adjacent to a large pond which receives runoff from the back portion of the parking lot. The complex contains much impervious cover; downspouts should be disconnected via rain barrels or rain gardens. Limiting the volume of stormwater reaching the pond will limit the chance of contamination.

Site Photos:



Project Identifier		Geographic Coordinates	
MB6_We	d		

Site Description and BMP Implementation Opportunities: This site is occupied by a car leasing business on Old Hook Road. The parking lot is pitched toward the stream with little riparian buffer to protect the waterway. The parking lot should be replaced with permeable pavement to capture polluted runoff.

Project Identifier		**Geographic Coordinates**	
MB6_We	e	N40° 59' 7.386"	W074° 1' 28.8582"

Site Description and BMP Implementation Opportunities: The site, Bedrogian Reality Agency, is a commercial property adjacent to the stream. The site has an elevated parking lot, which drains to the lower lot and then to the Musquapsink Brook. Pervious pavement should be utilized to limit the amount of impervious cover, thereby reducing the amount of stormwater and pollutants entering the waterway.

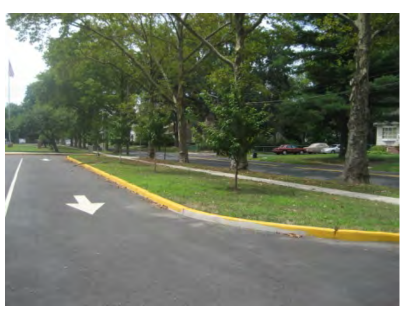
Site Photos:



Project Identifier		**Geographic Coordinates**	
MB6_We	f	N40° 59' 4.8366"	W074° 2' 16.5006"

Site Description and BMP Implementation Opportunities: The site is Ketler Elementary School, located on 3rd Avenue. The Musquapsink Brook is accessible from some portions of the site, which includes a large parking lot, asphalt playground, and numerous impervious surfaces. Implementation of rain gardens near the school and off the parking lot would reduce pollutant loadings to the stream.

Site Photos:


Project Identifier		**Geographic Coordinates**	
MB6_We	g	N40° 59' 30.5514"	W074° 1' 27.5226"

Site Description and BMP Implementation Opportunities: The site is Berkeley Elementary School, located on the corner of Harrington and Berkeley Avenues in Westwood, New Jersey. The Musquapsink Brook is located adjacent to the parking lot for the school property. Runoff from the lot and the grassed area reaches the stream directly. Downspouts on the school should be disconnected with rain gardens. A green roof could be installed on a portion of the school building. The parking lot could be retrofitted with permeable pavement.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB6_We	h	N40° 59' 13.6998"	W074° 1' 38.0676"

Site Description and BMP Implementation Opportunities: The site is occupied by the Westwood Hills Apartment Complex and covers approximately 14 acres. The roofs of the buildings have external downspouts which should be disconnected with the implementation of rain barrels and cluster rain gardens.

Site Photos:

Project Identifier		**Geographic Coordinates**	
MB6_We	i	N40° 59' 12.2418"	W074° 1' 27.6018"

Site Description and BMP Implementation Opportunities: The site is a residential neighborhood, including Fern Street, Lexington Avenue, Brook Place, and Roosevelt Avenue with homes on ¼ acre lots. The Musquapsink Brook is accessible at the end of both Fern Street and Brook Place. An adequate buffer should be installed to ensure protection of the stream from common pollutants transported by road runoff. 58% of the properties contain directly connected impervious cover. Rooftops should be disconnected via rain barrels and/or rain gardens. Two cul-de-sac streets could take extra measures and push for street cleaning to prevent the entrance of pollutants and sediments into the storm drains.

APPENDIX D

Select BMP Concept Designs

<table>
<tr><td colspan="2">Project ID: MB5_We_h</td></tr>
<tr><td rowspan="2">Location:
Segment of stream along 3rd Avenue</td><td>Municipality: Borough of Westwood</td></tr>
<tr><td>Subwatershed: MB5</td></tr>
<tr><td>BMP Description:
Riparian Buffer Restoration
Streambank Stabilization</td><td>Targeted Pollutants:
Fecal contamination from geese
total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) in surface runoff</td></tr>
<tr><td colspan="2">Existing Conditions and Issues:
This location served as a sampling site for the surface water quality monitoring conducted in the Summer of 2007. Currently, there is no vegetative buffer separating the Musquapsink Brook from the adjacent land. Geese inhabit this site and have been documented both in the stream and on the land. Because geese are prevalent in the Musquapsink Brook Watershed, they have been identified as significant contributors to fecal pollution. This portion of the stream also receives overland flow, which may carry excess nitrogen or phosphorus from fertilizer applications to nearby lawns or athletic fields. Evidence of downcutting is apparent along the streambank.</td></tr>
<tr><td colspan="2">Proposed Solution(s):
A 30-foot wide buffer should be installed along the 150-foot section of stream that currently has no vegetation along the banks. This will prohibit geese from entering the Brook and will also function to filter out pollutants from overland flow. The streambank should be stabilized with live stakes and coir logs to prevent further erosion and downcutting.</td></tr>
<tr><td colspan="2">Anticipated Benefits:
A 30-foot riparian buffer, similar to a vegetated filter strip, could be estimated to achieve a 30% removal rate for TN and TP, as reported in the NJDEP BMP Manual. TSS loadings may be reduced by up to 80%. Pathogens and Bacteria such as E. coli and Fecal Coliform will be reduced by up to 90% as well. A riparian buffer would also provide ancillary benefits, such as enhanced wildlife habitat and aesthetic appeal to surrounding property owners. The biostabilization of the streambank would reduce sediment loadings. Ketler Elementary School is located across from the proposed site. Rutgers Cooperative Extension Water Resources Program could present the Stormwater Management in Your School Yard curriculum to students and then include them in the riparian buffer planting efforts as an augmentation to the in-class lessons. It can also be used as a demo project to launch educational programming for DPW and Parks Staff.</td></tr>
<tr><td colspan="2">Possible Funding Sources:
319(h) grants from the New Jersey Department of Environmental Protection
Bergen County Soil Conservation District
Borough of Westwood
United Water New Jersey</td></tr>
<tr><td colspan="2">Partners/Stakeholders:
Borough of Westwood
Ketler Elementary School
Bergen SWAN or other watershed groups</td></tr>
</table>

Estimated Cost:

Task	Task Description			Estimated Cost
1	Complete topographic survey and soils test			$500
2	Prepare final design			$1,000
3	Activities for BMP installation	Unit Cost	Quantity	
	Plant materials	$5.00	1,125	$5,625
	Soil amendments, if necessary (lime, fertilizer)	-	-	$300
	Installation (assume volunteer-based effort)	$25.22/hr*	15 people 8 hr/person	$3,027
	Supervision of volunteers	$1,000	1	$1,000
	Educational Programs (Schools and DPW)	$2,000		$2,000
	Contingency (20%)	-	-	$2,390
	Total BMP Installation Cost			**$14,342**
Total Estimated Project Cost				**$15,842**

*Based on New Jersey State Value for Volunteer Time as reported by the Corporation for National and Community Service

Project ID: MB4_Wa_f	
Location: Washington Green Townhomes, Hampton Court	Municipality: Washington Township Subwatershed: MB4
BMP Description: Cluster rain gardens	Targeted Pollutants: total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) Pathogens (*E. Coli* and fecal coliform)
Existing Conditions and Issues: This site is a small residential community, with less than 50 townhouse units. There are two main drainage channels from the property to the Musquapsink Brook. Most of the impervious surfaces in this development drain to a riprap swale, in poor condition. A small portion of the property drains to a 28" reinforced concrete pipe. The roof leaders are all directly connected to these conveyance channels. The section of the Brook receiving stormwater from this site is eroding because of the heavy water volumes.	
Proposed Solution(s): Cluster rain gardens are recommended for disconnection of impervious surfaces on this site. Approximately ten (10) bioretention systems, 200 square feet each, could be installed in this community.	
Anticipated Benefits: The rain gardens would each disconnect 1,000 square feet of impervious cover, reducing stormwater volumes by 250,000 gallons and reducing E.coli, Fecal Coliform, TN, TP, and TSS loads by 90%. The rain gardens would provide enhanced wildlife habitats and improved aesthetics.	
Possible Funding Sources: 319(h) grants from the New Jersey Department of Environmental Protection New Jersey Department of Transportation Bergen County Soil Conservation District Washington Township United Water New Jersey	
Partners/Stakeholders: Washington Township Bergen SWAN or other watershed groups Residents of Washington Green Townhomes	

Estimated Cost:

Task	Task Description	Unit Cost	Quantity	Estimated Cost
1	Complete topographic survey and soil tests			$500
2	Prepare final design			$1,500
3	Activities for BMP installation	Unit Cost	Quantity	
	Rain garden installation (assume contractor effort)*			$10,000
	Plant materials*	$10/unit	400	$4,000
	Contingency (20%)			$2,800
	Total BMP Installation Cost			**$16,800**
	Total Estimated Project Cost			**$18,800**

*Based on cluster rain garden installations at Tivoli Gardens in Parsippany-Troy Hills, NJ

Project ID: MB5_We_e	
Location: Gritman Park and surrounding neighborhood	Municipality: Borough of Westwood Subwatershed: MB5
BMP Description: Vegetated buffer around pond Streamside Living extension program for residents	Targeted Pollutants: total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) in surface runoff *E. coli* and Fecal Coliform (geese contributions)
Existing Conditions and Issues: Gritman Park contains a man-made pond with four stormwater inlets that drain adjacent properties and roadways. There is one outlet from the pond that ultimately discharges to the Musquapsink Brook. The pond has no riparian buffer and geese fecal matter was documented on the park property. The pond is approximately one acre in area while the surrounding neighbhorhood covers nine. There are approximately 60 residential properties within the vicinity.	
Proposed Solution(s): A 30-foot vegetative buffer around the perimeter of the pond (approximately 600 feet) would deter geese from entering the water. The buffer would also intercept and filter overland flow, decreasing *E. coli* (fecal coliform) and sediment loadings to the stream. A Streamside Living extension program for residents in the surrounding neighborhood would help to address the polluted runoff entering the pond via the stormwater inlets. The Streamside Living program would be modeled after the workshops offered in New Hampshire (Landscaping at the Water's Edge) and would engage homeowners in environmental stewardship. The program would offer information on the findings of this Watershed Restoration and Protection Plan, landscaping practices, local ordinance and land use regulations, and also on ideal BMPs for implantation on individual properties to achieve load reductions in TN, TP, TSS, and *E. coli* (fecal coliform). Workshop attendees could apply for "mini-grants" offered through the Streamside Living extension program. Selected applicants with approved designs would receive monetary support for installation of BMPs on their properties. This will reduce stormwater runoff at the source.	
Anticipated Benefits: A 30-foot vegetative buffer, similar to a filter strip, could be estimated to achieve a 30% removal rate for TN and TP, as reported in the NJDEP BMP Manual. TSS loadings may be reduced by up to 80%. A buffer would also provide ancillary benefits, such as enhanced habitat for desirable wildlife and aesthetic appeal to surrounding property owners. Up to 90% reduction of Fecal coliform and E. coli is to be expected.	
Possible Funding Sources: 319(h) grants from the New Jersey Department of Environmental Protection New Jersey Department of Transportation Bergen County Soil Conservation District Borough of Westwood United Water New Jersey	

Partners/Stakeholders:
Borough of Westwood
Bergen SWAN or other watershed groups

Estimated Cost:

Task	Task Description			Estimated Cost
1	Complete topographic survey			$500
2	Prepare final design			$1,500
3	Activities for BMP installation	Unit Cost	Quantity	
	Plant materials	$5/unit	4,500	$22,500
	Installation (assume volunteer-based effort)	$25.22/hr*	30 people/ 8 hours	$6,053
	Supervision of volunteers	$1,000	2	$2,000
	Contingency (20%)			$6,111
	Streamside Living extension program			$4,500
	Mini-grants for homeowners to install BMPs	$500/grant	30	$15,000
	Total BMP Installation Cost			**$56,164**
	Total Estimated Project Cost			**$58,164**

*Based on New Jersey State Value for Volunteer Time as reported by the Corporation for National and Community Service

Project ID: MB6_E_a	
Location: Roadways in residential neighborhood; Intersection of Pascack Avenue and Haines Street	Municipality: Borough of Emerson Subwatershed: MB6
BMP Description: Curb extensions, flow-through planter boxes and rain gardens as part of a Green Street program.	Targeted Pollutants: total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS) and fecal coliform in roadway surface runoff
Existing Conditions and Issues: This medium-density residential neighborhood contains approximately 85 homes on ¼ acre lots, with 76% of the properties containing directly connected impervious cover. Roadways account for approximately 2.5 acres (15%) of impervious cover in this area. Stormwater runoff from these roads contains sediment, salt, fuel hydrocarbons and/or nutrients that accumulate as a result of urban activities.	
Proposed Solution(s): Green Streets reduce the negative impacts of stormwater runoff by mimicking natural conditions. Soil and native vegetation are used to manage runoff on the surface, at the source. Curb extensions, flow-through planter boxes, and rain gardens will be installed as part of a comprehensive Green Street program for this neighborhood. A curb extension is an angled narrowing of a roadway with a concurrent widening of the sidewalk space. Rain gardens can be incorporated into these extensions to capture stormwater flow from streets. Flow-through planter boxes are long, narrow landscaped areas with vertical walls and flat bottoms open to the underlying soil. They allow for increased stormwater storage volume in minimal space.	
Anticipated Benefits: Green Streets have been shown to reduce peak stormwater flows by 80%. Fecal coliform, TN, TP and TSS will be removed through the filtering and adsorption capabilities of both the vegetation and soil. Flow-through planter boxes are estimated to achieve 25-50% TP removal and 40-60% TN removal.	
Possible Funding Sources: 319(h) grants from the New Jersey Department of Environmental Protection New Jersey Department of Transportation Bergen County Soil Conservation District Borough of Emerson United Water New Jersey	
Partners/Stakeholders: Borough of Emerson Bergen SWAN or other watershed groups	

Estimated Cost:

Task	Task Description			Estimated Cost
1	Complete topographic survey and soils test			$500
2	Prepare final design			$1,500
3	Activities for BMP installation	Unit Cost	Quantity	
	Curb extensions	$44/sqft	550 sqft	$24,200
	Flow-through planter boxes	$35/sqft	600 sqft	$21,000
	Rain gardens	$2/sqft	4,000 sqft	$8,000
	Contingency (20%)			$10,640
	Total BMP Installation Cost			**$63,840**
Total Estimated Project Cost				**$65,840**

*Based on New Jersey State Value for Volunteer Time as reported by the Corporation for National and Community Service

<table>
<tr><td colspan="2">Project ID: MB6_We_g</td></tr>
<tr><td rowspan="2">Location:
Berkeley Elementary School</td><td>Municipality: Borough of Westwood</td></tr>
<tr><td>Subwatershed: MB6</td></tr>
<tr><td>BMP Description:
Green Roof
Rain Garden
Permeable Pavement
Stormwater Management in Your School Yard Curriculum</td><td>Targeted Pollutants:
total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS) in surface runoff</td></tr>
<tr><td colspan="2">Existing Conditions and Issues:
This school located just upstream of the confluence of the Musquapsink Brook and Pascack Brook, near sampling point MB6 and at the corner of Berkeley Avenue and Harrington Avenue. The Musquapsink Brook flows adjacent to the school property and receives direct runoff from the 0.5-acre parking lot situated next to it. The entire school property contains approximately 2.5 acres of directly connected impervious cover.</td></tr>
<tr><td colspan="2">Proposed Solution(s):
An extensive green roof is proposed for part of the school facility located along Harrington Avenue. An extensive green roof is 6 inches or shallower and is designed to be virtually self-sustaining and with minimal maintenance requirements.
Two (2) 200 square feet rain gardens are proposed for downspout disconnection on the main school building located along Berkeley Avenue.
Replacing the existing asphalt with permeable pavement on the easternmost parking lot is also recommended for this site.
Introduce Stormwater Management in your School Yard curriculum to engage students in how stormwater can have a negative impact on local bodies of water and how the students can have a positive impact in their own local surroundings.</td></tr>
<tr><td colspan="2">Anticipated Benefits:
The green roof would replace and disconnect approximately 4,000 square feet of rooftop. Green roofs are estimated to reduce runoff volumes by 50% on a yearly basis. This equates to 55,000 gallons of stormwater runoff that no longer reaches the Musquapsink Brook. Green roofs also offer benefits such as the mitigation of urban heat-island effects, conserving energy, creating wildlife habitat, and improving the aesthetics of a building (EPA, 2009).

The two (2) rain gardens would disconnect approximately 2,000 square feet of rooftop, capturing approximately 50,000 gallons of stormwater and removing 90% of TN, TP, and TSS loadings. The rain gardens can also reduce 90% of E. Coli and Fecal Coliform loads in stormwater runoff by capturing runoff at the source before it can pick up non point source pollutants.

The permeable pavement would replace 8,000 square feet of parking lot, capturing approximately 165,000 gallons of stormwater and reducing TN, TP, and TSS loads by nearly 60% (Virginia DCR Spec No. 7, 2011).</td></tr>
<tr><td colspan="2">Possible Funding Sources:
319(h) grants from the New Jersey Department of Environmental Protection
New Jersey Department of Transportation
Bergen County Soil Conservation District
Borough of Westwood
United Water New Jersey</td></tr>
</table>

Partners/Stakeholders:
Borough of Westwood
Bergen SWAN or other watershed groups

Estimated Cost:

Task	Task Description			Estimated Cost
1	Soil tests, Site delineation, permitting fees			$1,000
2	Prepare final design			$2,000
3	Activities for BMP installation	Unit Cost	Quantity	
	Green roof installation and maintenance[1]	$20/sqft	4,000 sqft	$80,000
	Rain garden installation	$2/sqft	400 sqft	$800
	Permeable pavement[2]	$10/sqft	8,000 sqft	$80,000
	Contingency (20%)			$32,160
	Implementation of school curriculum			$1,000
	Total BMP Installation Cost			**$193,960**
Total Estimated Project Cost				**$196,960**

[1]Green Roofs for Stormwater Runoff Control, EPA, 2009
[2]Virginia DCR Stormwater Design Specification No. 7, 2011

MUSQUAPSINK BROOK WATERSHED RESTORATION & PROTECTION PLAN

Third Avenue Concept Design

Project ID: MB5_We_h
Municipality: Borough of Westwood
Subwatershed: MB5
Location: Segment of stream along 3rd Avenue

SITE PHOTOS

PROJECT LOCATION

RIPARIAN/FORESTED BUFFER (1)

A riparian or forested buffer is an area along a shoreline, wetland, or stream where development is restricted or prohibited. The primary function of aquatic buffers is to physically protect and separate a stream, lake, or wetland from future disturbance or encroachment. If properly designed, a buffer can provide stormwater management, and can act as a right-of-way during floods, sustaining the integrity of stream ecosystems and habitats. As conservation areas, aquatic buffers are part aquatic ecosystem and part urban forest.

www.epa.gov

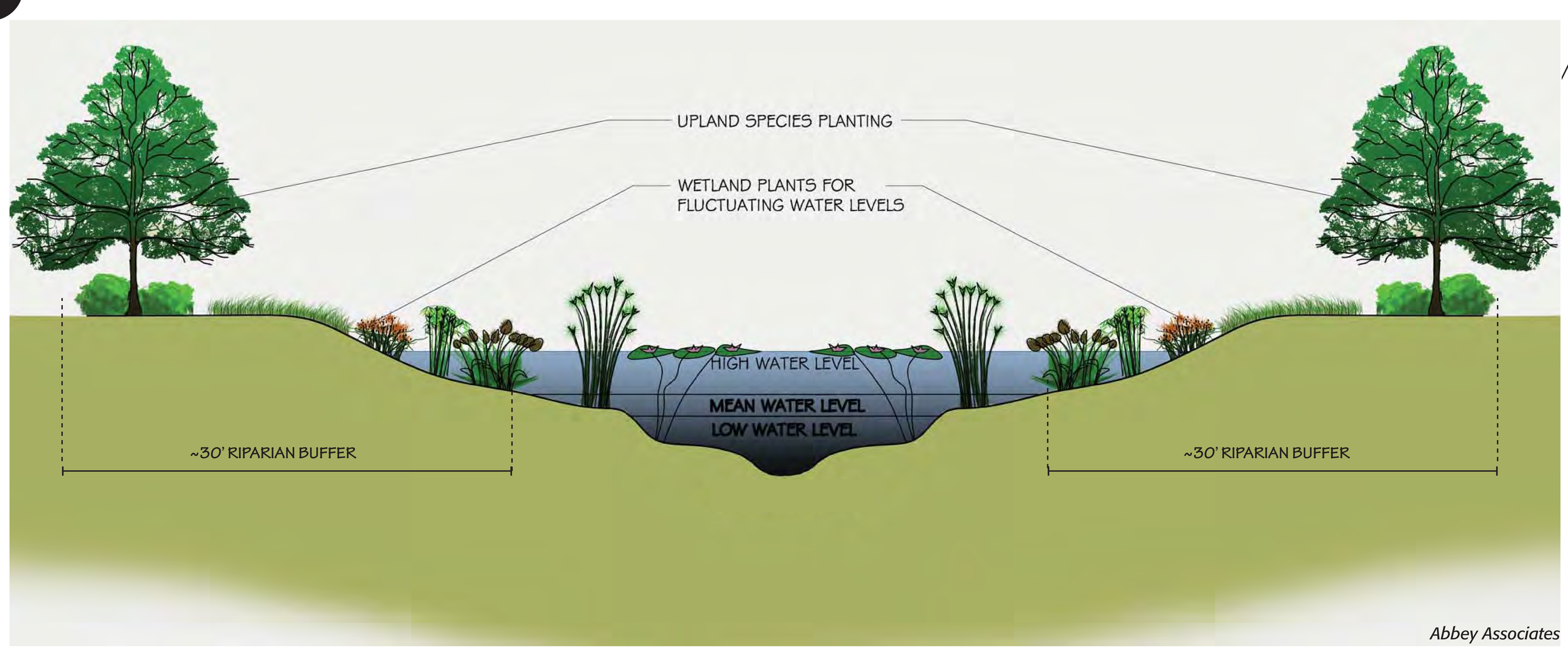
STREAMBANK STABILIZATION (2)

Streambank stabilization consists of using vegetation or structural materials to stabilize and protect banks of streams, brooks, rivers, or excavated channels against scour and erosion from flowing water. Streambank vegetation that is sufficiently developed contributes large woody material to streams, creates critical structural elements of habitats for many different species. Still streambanks stabilized with shrub and tree vegetation provides excellent habitat for fish and wildlife species.

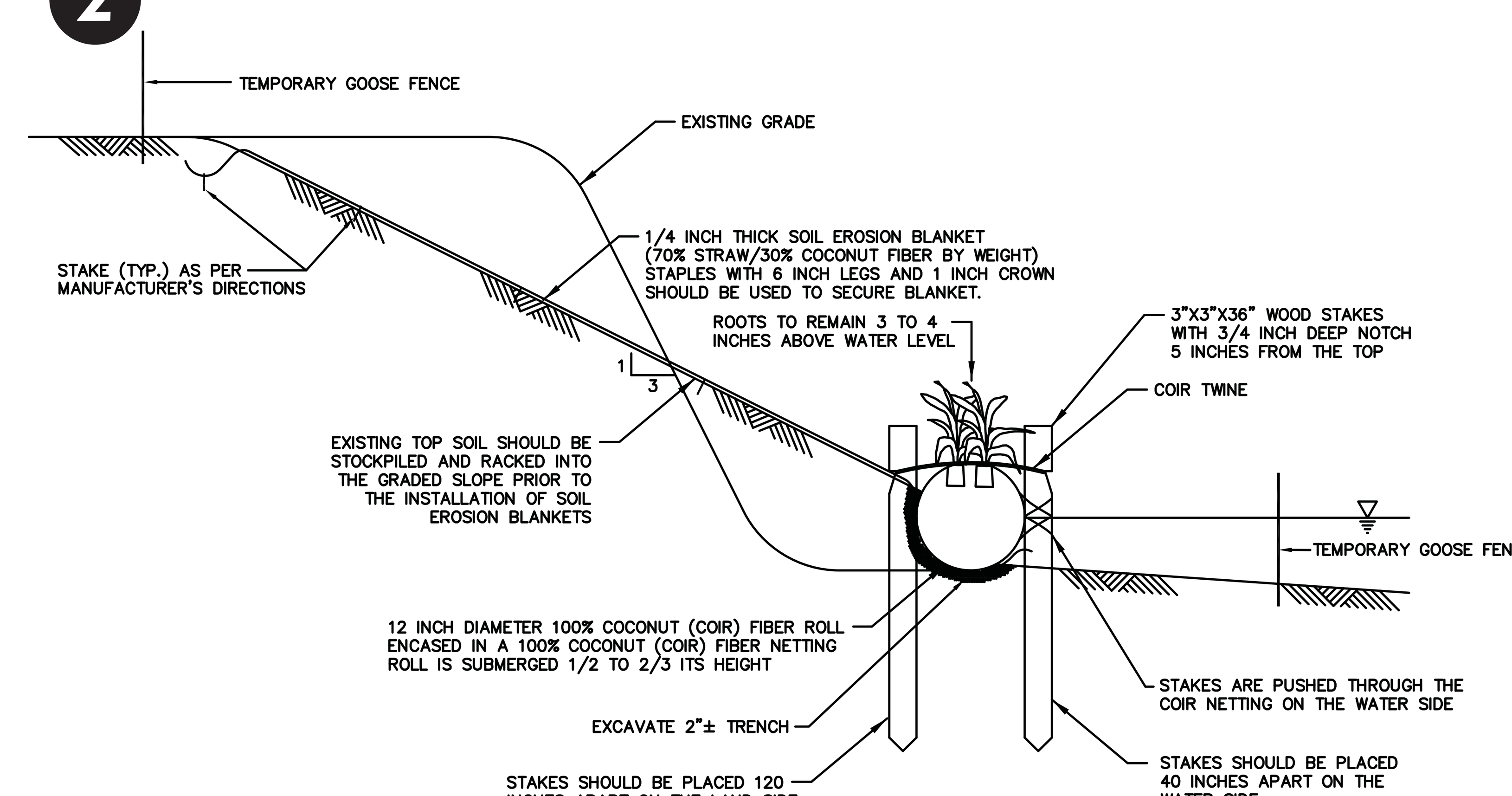
www.maine.gov

SITE PLAN

1 RIPARIAN BUFFER RESTORATION



2 STREAMBANK STABILIZATION



SHORELINE WITH COCONUT FIBER ROLL AND ECO-NET STABILIZATION

MUSQUAPSINK BROOK WATERSHED RESTORATION & PROTECTION PLAN

Berkeley Elementary School Concept Design

Project ID: MB6_We_g
Municipality: Borough of Westwood
Subwatershed: MB6
Location: Berkeley Elementary School

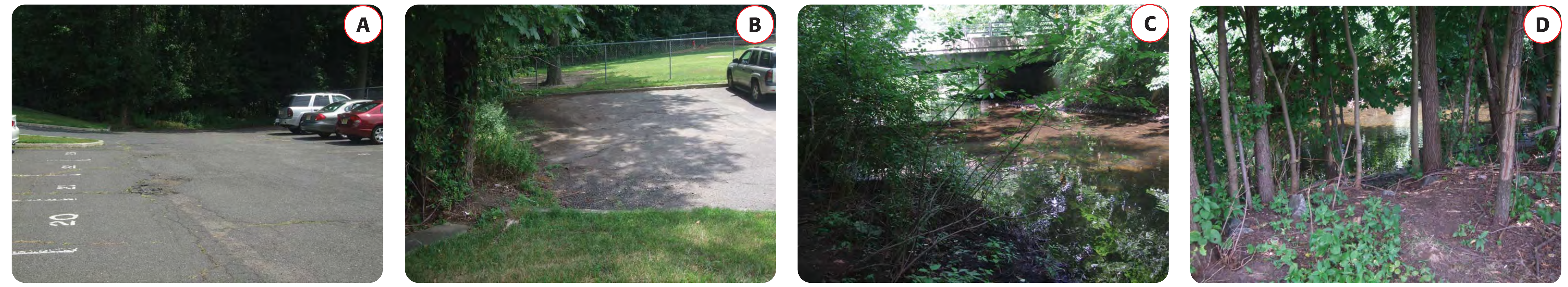
PROJECT LOCATION

RAIN GARDEN (1)
A rain garden is a landscaped, shallow depression that captures, filters, and infiltrates stormwater runoff. The rain garden removes nonpoint source pollutants from stormwater runoff while recharging groundwater.

GREEN ROOF (2)
A green roof, or rooftop garden, is a vegetative layer grown on a rooftop. Green roofs provide shade and remove heat from the air through evapotranspiration, reducing temperatures of the roof surface and the surrounding air. On hot summer days, the surface temperature of a green roof can be cooler than the air temperature, whereas the surface of a conventional rooftop can be up to 90°F (50°C) warmer.

STORMWATER MANAGEMENT IN YOUR SCHOOL YARD (3)
The Stormwater Management in Your School Yard educational program is designed to provide fourth and/or fifth grade students with an opportunity to apply their science, math, and communication skills to real-world environmental problems through the building of a rain garden on the school's campus. The main focus of the Stormwater Management in Your School Yard program curriculum is rain gardens. However, topics such as water, soil, and plant ecology are presented, and connections between these topics and rain gardens are introduced and discussed with the students.

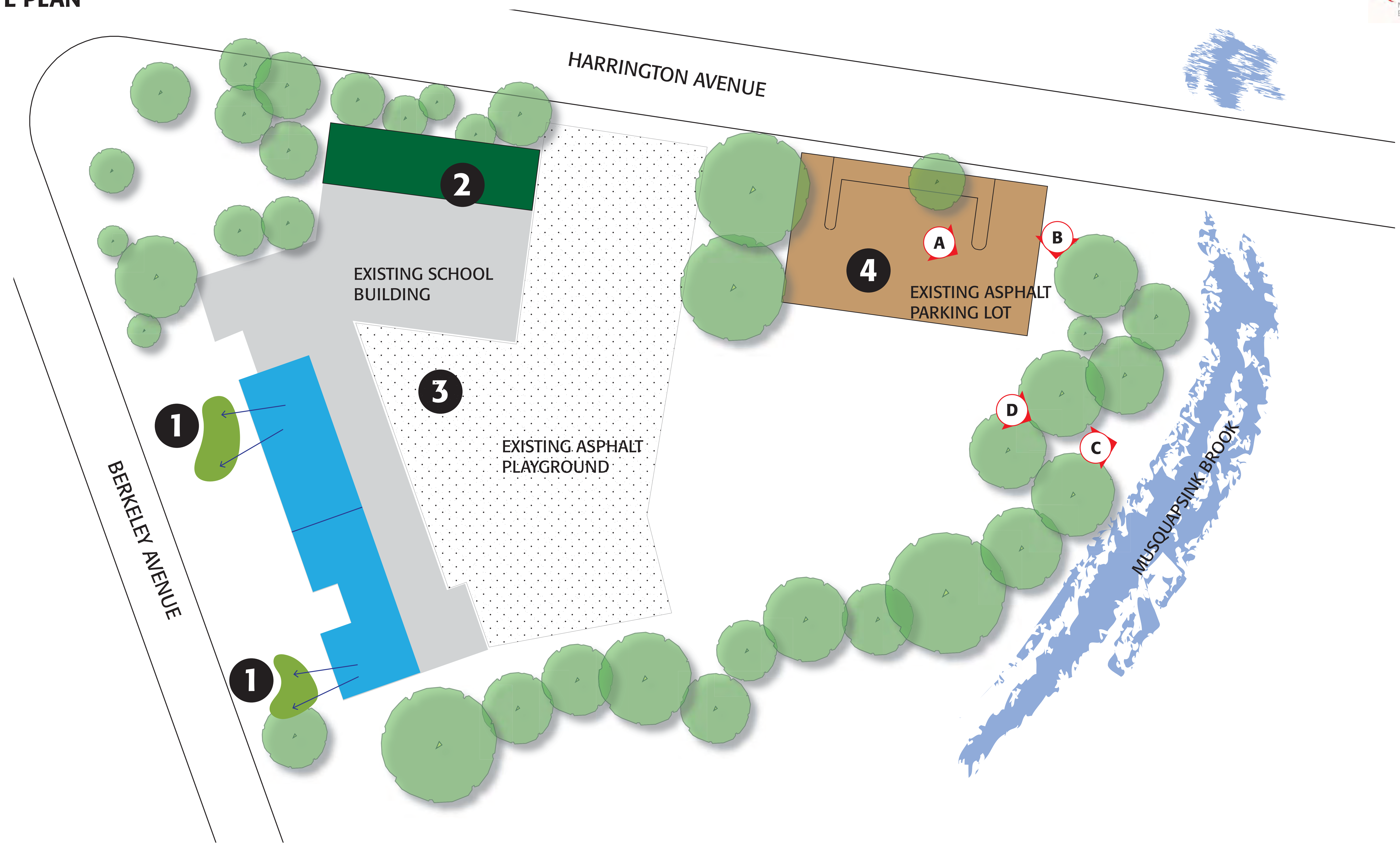
PERVIOUS PAVEMENT (4)
Permeable pavement is an alternative to asphalt or concrete surfaces that allows stormwater to drain through the porous surface to a stone reservoir underneath. The reservoir temporarily stores surface runoff before infiltrating it into the subsoil. The appearance of the alternative surface is often similar to asphalt or concrete, but it is manufactured without fine materials and instead incorporates void spaces that allow for storage and infiltration. *(www.epa.gov)*



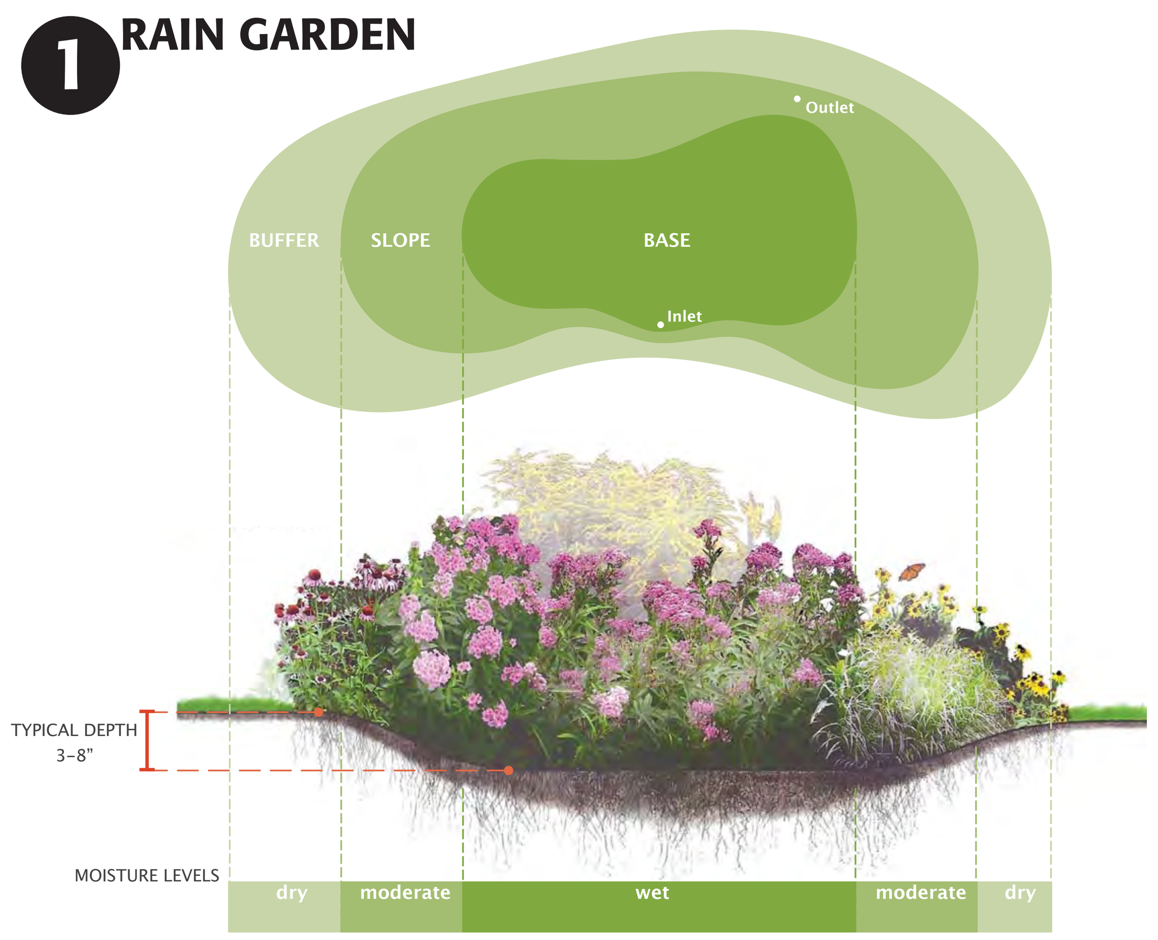
SITE PHOTOS

Rutgers New Jersey Agricultural Experiment Station
Water Resources Program

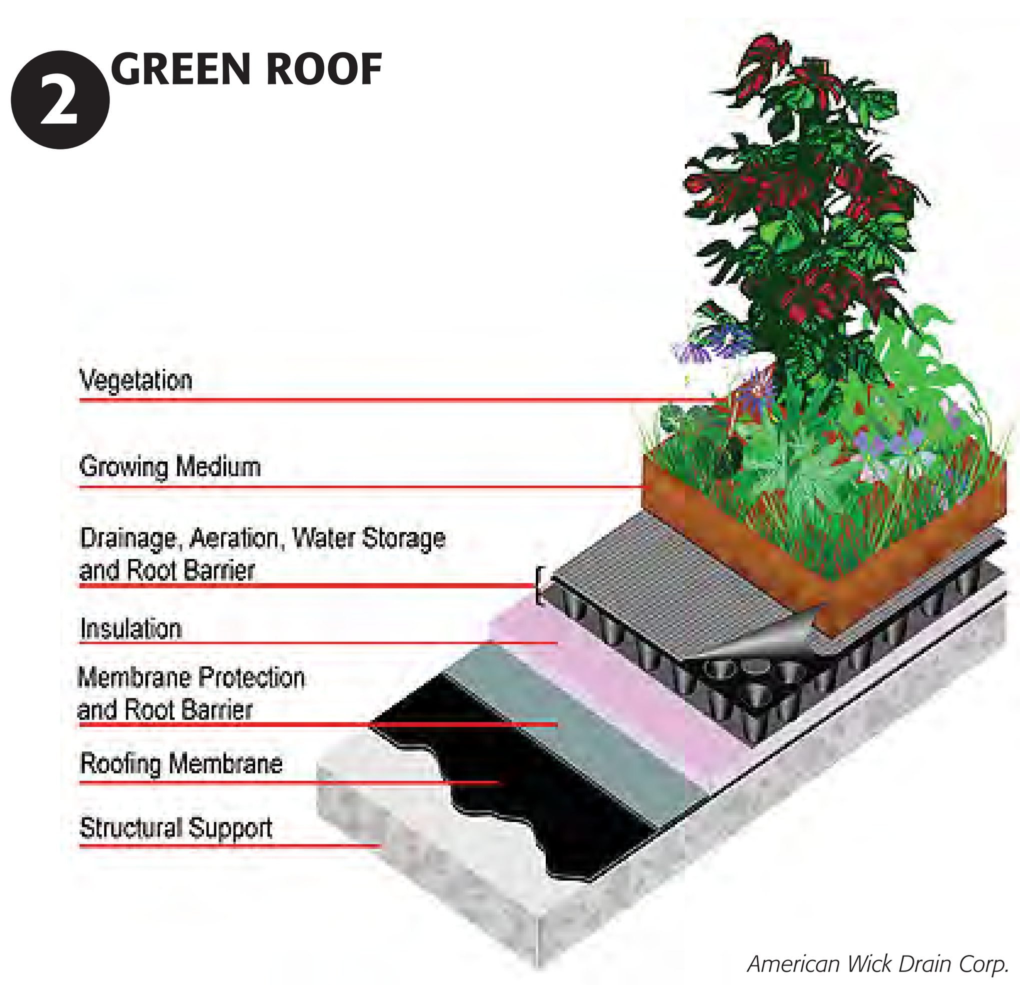
SITE PLAN



1 RAIN GARDEN



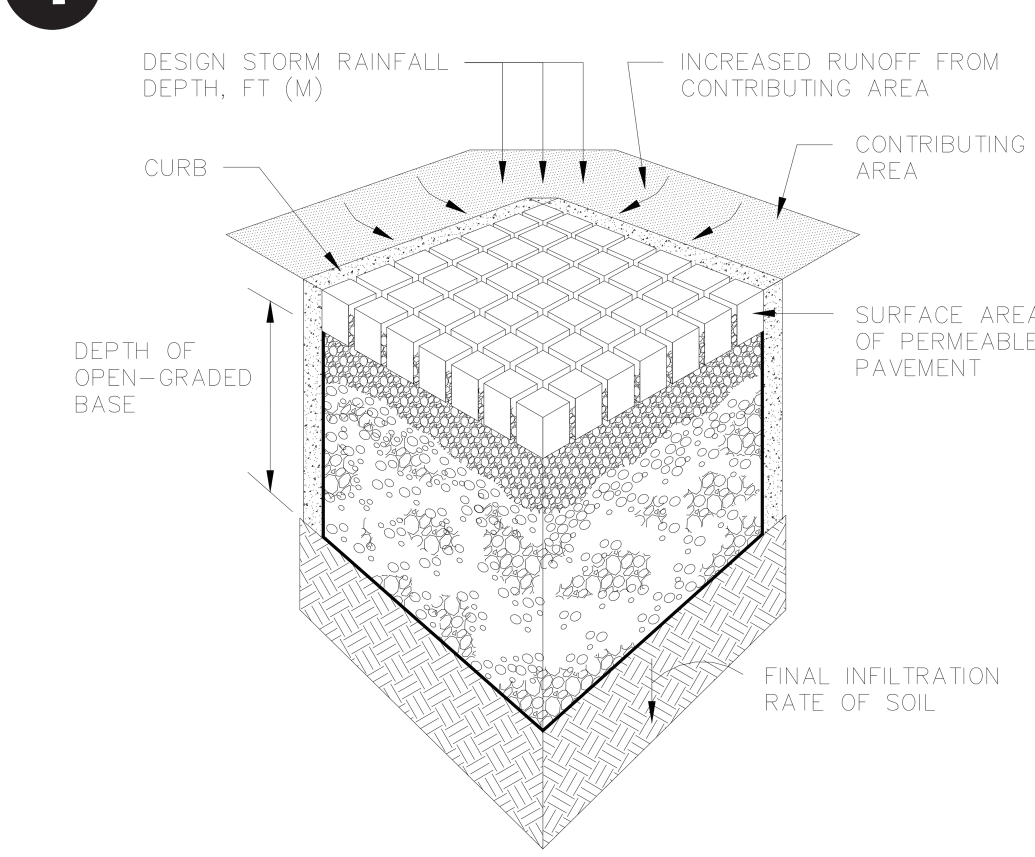
2 GREEN ROOF



American Wick Drain Corp.

3 STORMWATER MANAGEMENT IN YOUR SCHOOL YARD

4 PERVIOUS PAVEMENT



MUSQUAPSINK BROOK WATERSHED RESTORATION & PROTECTION PLAN

Gritman Park Concept Design

Project ID: MB5_We_e
Municipality: Borough of Westwood
Subwatershed: MB5
Location: Gritman Park and surrounding neighborhood

SITE PHOTOS

RUTGERS
New Jersey Agricultural Experiment Station
Water Resources Program

PROJECT LOCATION

RIPARIAN/FORESTED BUFFER (1)
A riparian or forested buffer is an area along a shoreline, wetland, or stream where development is restricted or prohibited. The primary function of aquatic buffers is to physically protect and separate a stream, lake, or wetland from future disturbance or encroachment. If properly designed, a buffer can provide stormwater management, and can act as a right-of-way during floods, sustaining the integrity of stream ecosystems and habitats. As conservation areas, aquatic buffers are part aquatic ecosystem and part urban forest.

www.epa.gov

STREAMSIDE LIVING (2)
Streams, rivers and lakes are part of a dynamic system that changes over time. While many changes are natural, people have the greatest impact on the system.

- Polluting the water with pesticides, fertilizers and chemicals.
- Diverting water from the stream.
- Altering the banks or bed of a stream or the natural flow of water.

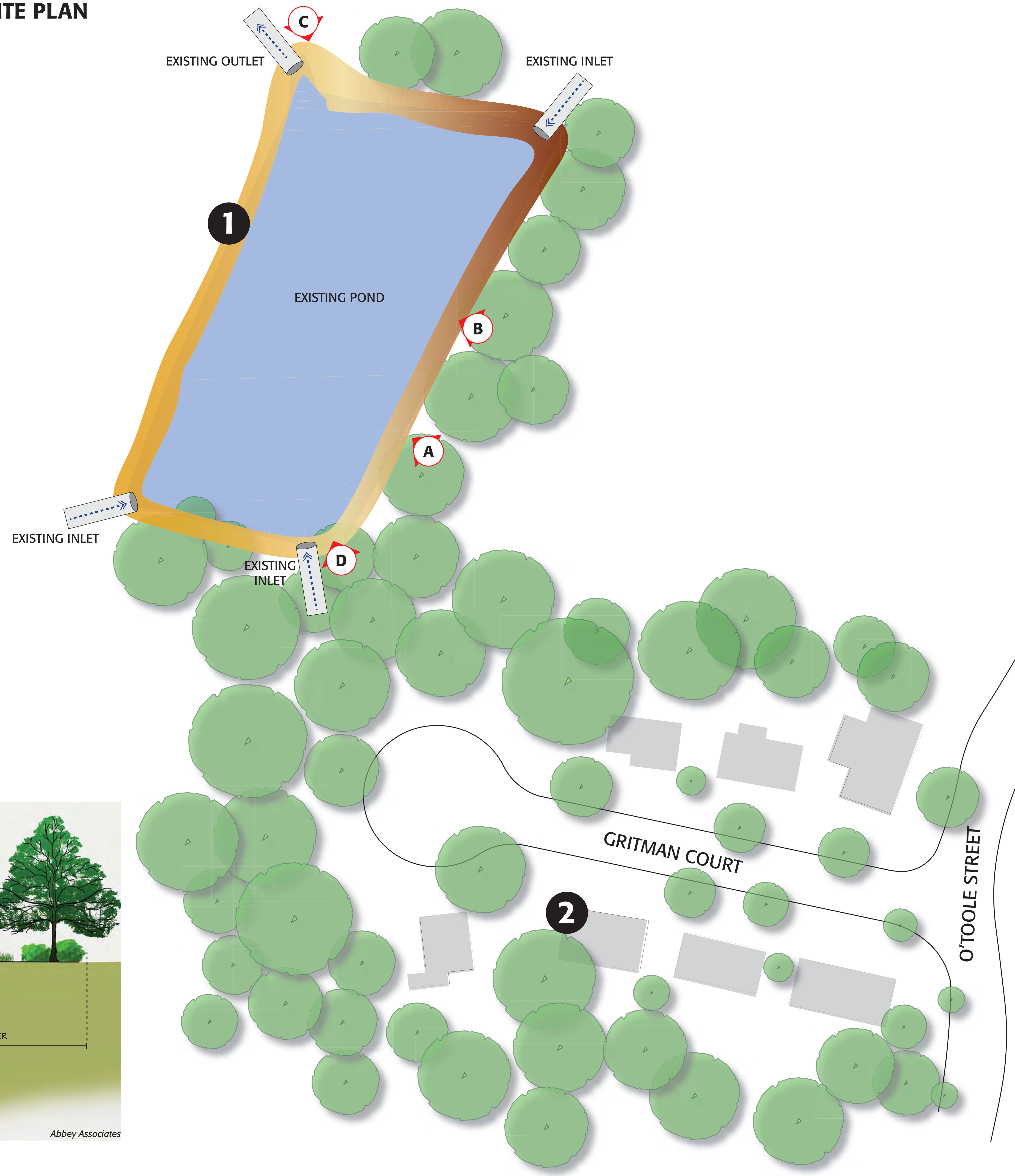
Each of these activities affects the health of the water and the streamside habitat. One change might not seem like a lot, but the everyday activities of landowners all add up to an enormous impact.

Healthy streamsides have stable soils that support a variety of plant life, from grasses to shrubs and trees. Streamside riparian areas provide:

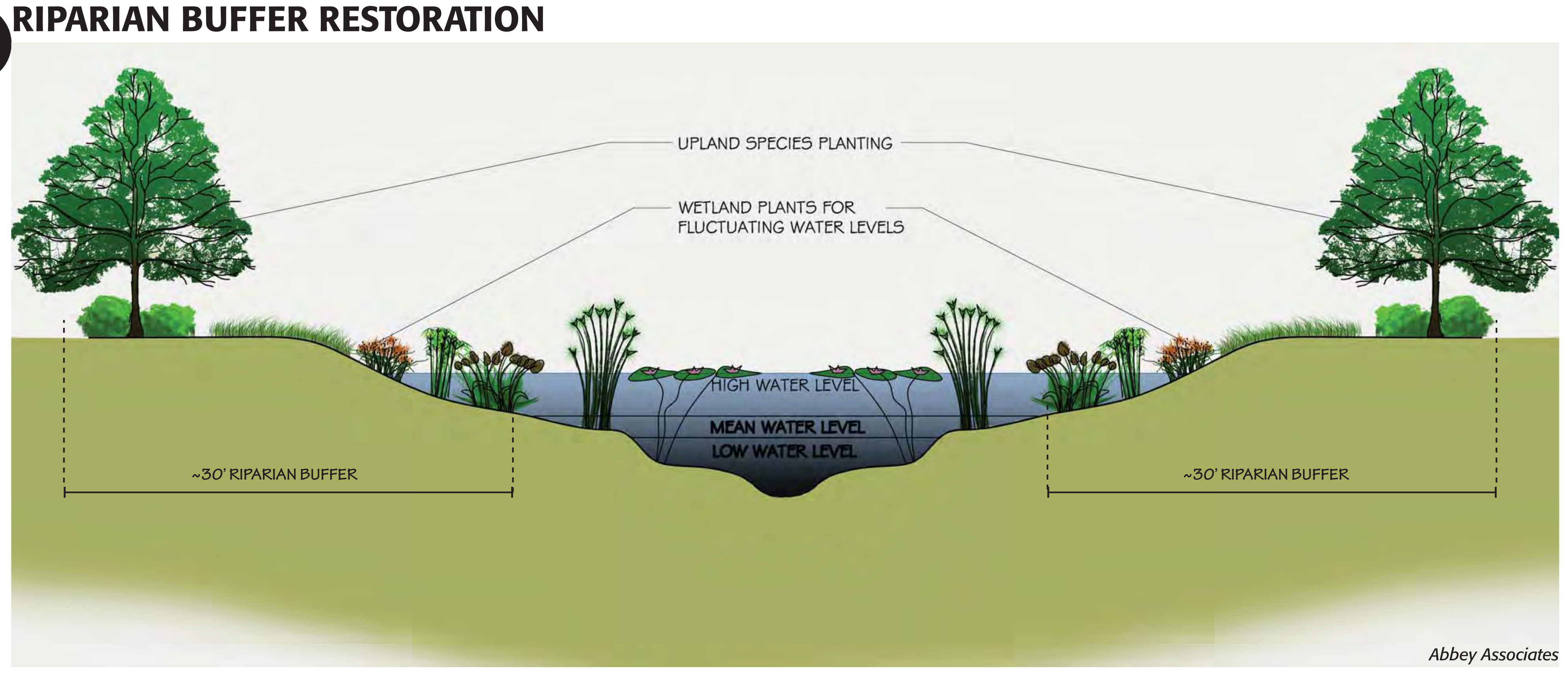
- Protection of property from flood damage and erosion by holding soil in place with plant roots.
- Clean water by preventing fertilizers, pesticides, animal wastes, sediment, and pollutants from entering streams.
- Habitat for fish and wildlife as plants provide shelter and food for wildlife and shade the water to create cooler temperatures needed by fish.
- Enhanced water supplies and stream flows by storing the rain water that soaks into the soil. The riparian area then slowly releases the water during the dry season.

www.sccd.org

SITE PLAN



1 RIPARIAN BUFFER RESTORATION



2 STREAMSIDE LIVING - RAIN BARRELS + EDUCATION

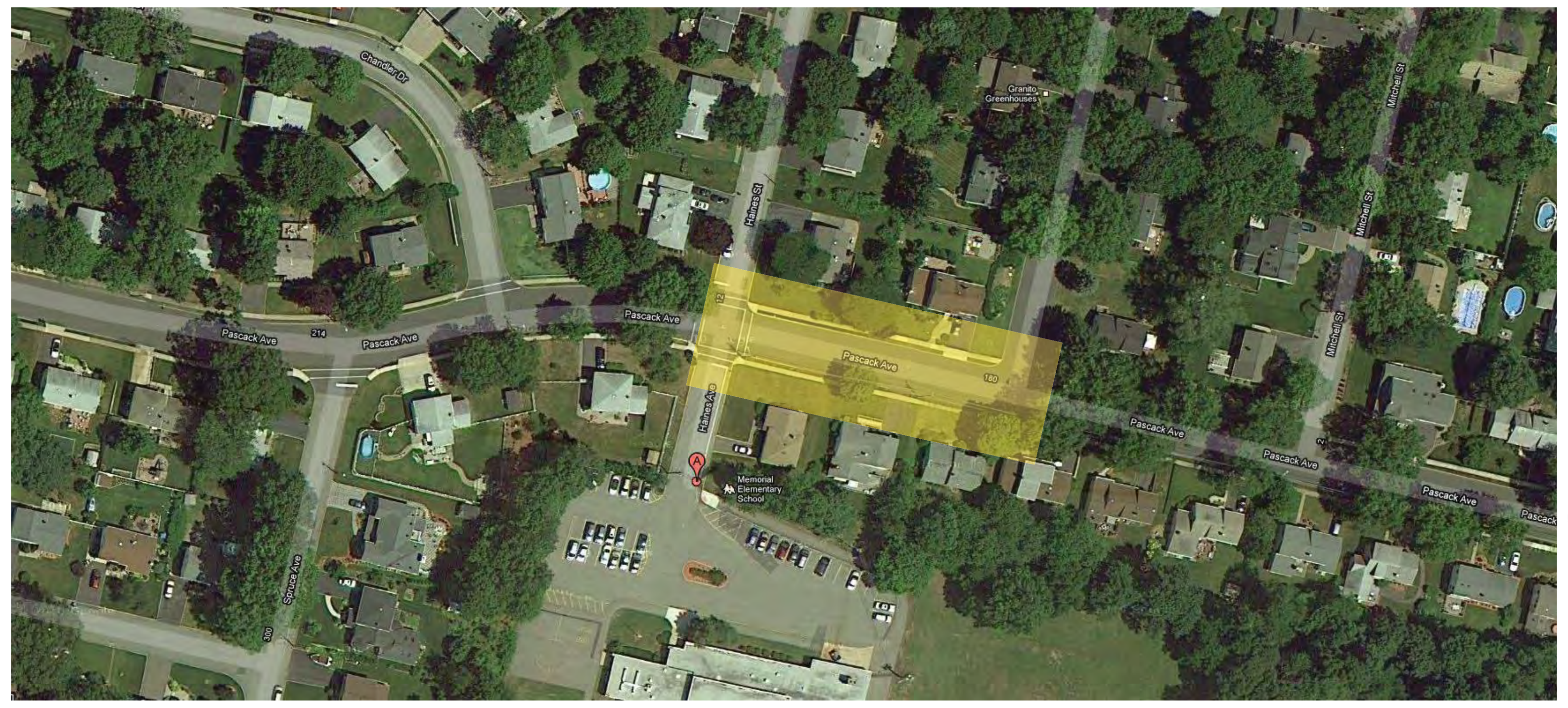
MUSQUAPSINK BROOK WATERSHED RESTORATION & PROTECTION PLAN

Green Street Concept Design

RUTGERS New Jersey Agricultural Experiment Station

Water Resources Program

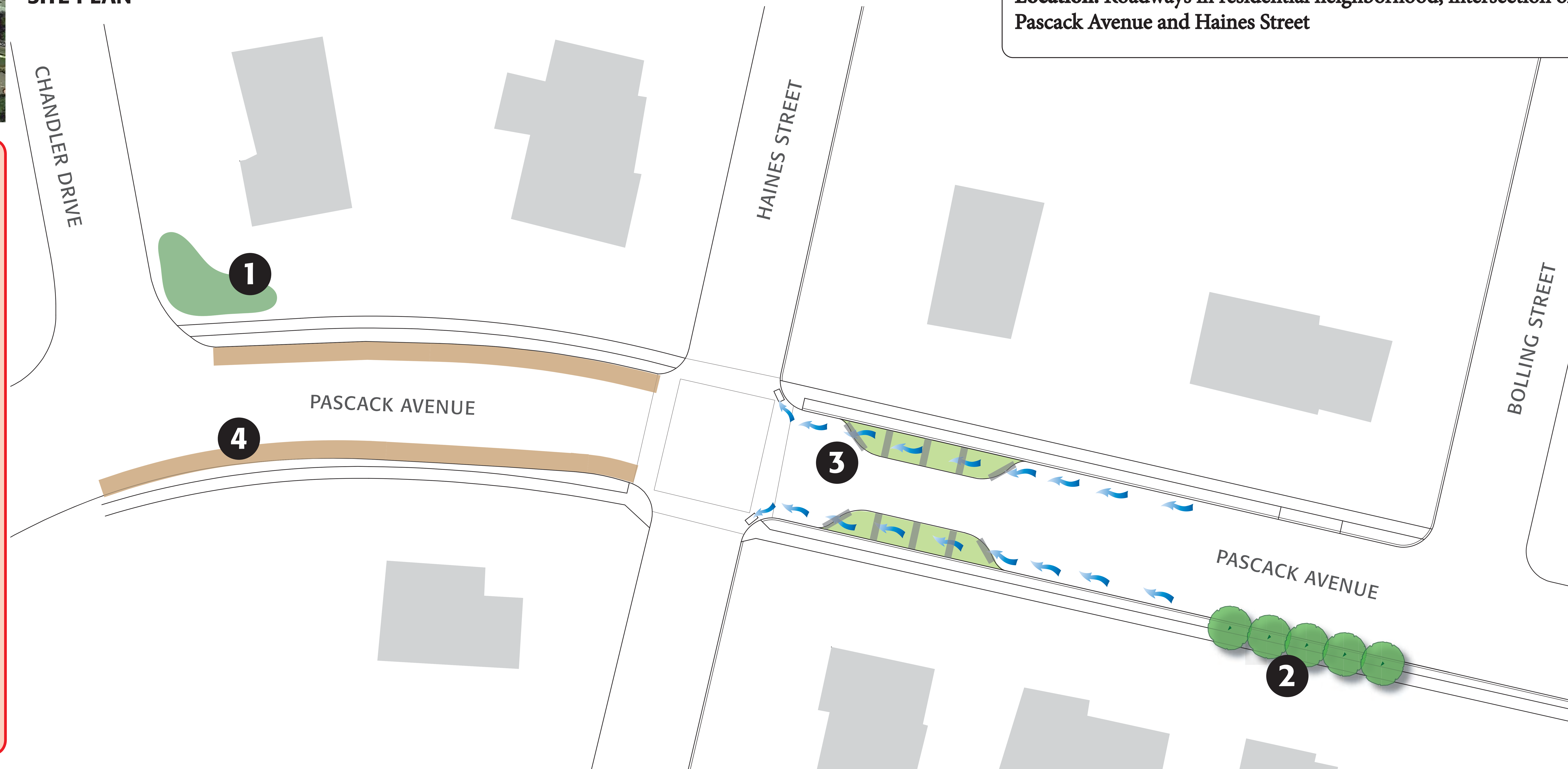
PROJECT LOCATION



SITE PHOTOS

Project ID: MB6_E_a
Municipality: Borough of Emerson
Subwatershed: MB6
Location: Roadways in residential neighborhood; intersection of Pascack Avenue and Haines Street

SITE PLAN



What is a Green Street?
Green streets are an innovative design concept that can transform our streets into appealing landscaoed areas while managing stormwater runoff. Designed to be attractive as well as functional, green streets use vegetation and soil to capture, slow, filter, and infiltrate stormwater runoff. They manage stormwater, provide environmental benefits, beautify our streetscapes, add greenery to urban areas, enhance pedestrian and bicycle safety, and provide habitat.

RAIN GARDEN (1)
A rain garden is a landscaped, shallow depression that captures, filters, and infiltrates stormwater runoff. The rain garden removes nonpoint source pollutants from stormwater runoff while recharging groundwater.

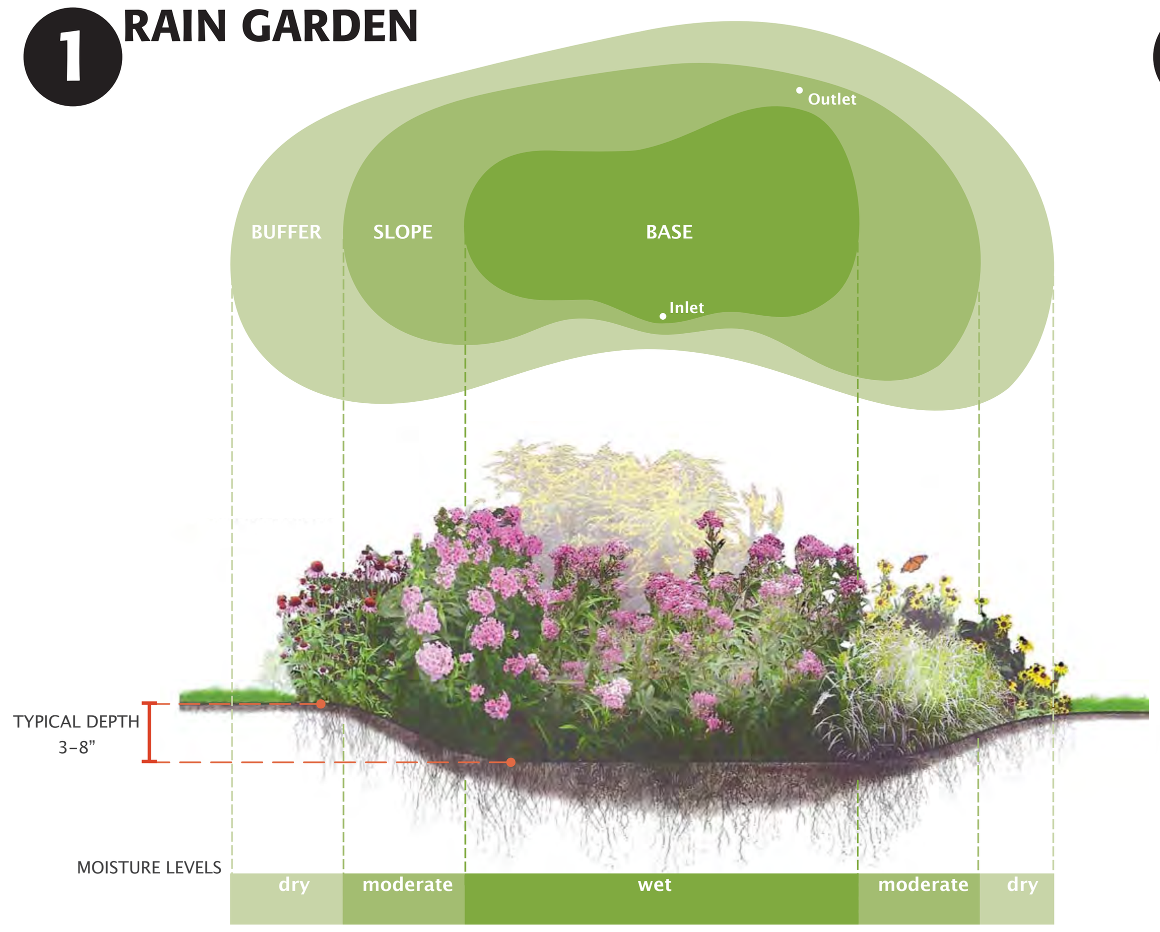
TREE BOX FILTER (2)
Tree box filters are in-ground containers used to control runoff water quality and provide some detention capacity. Often premanufactured, tree box filters contain street trees, vegetation, and soil that help filter runoff before it enters a catch basin or is released from the site. Tree box filters can help meet a variety of stormwater management goals, satisfy regulatory requirements for new development, protect and restore streams, control combined sewer overflows (CSOs), retrofit existing urban areas, and protect reservoir watersheds.

STORMWATER CURB EXTENSION (3)
A curb extension or bump out is typically a paved area that extends into the street and is used to help calm traffic and increase pedestrian safety. By altering this design with curb openings that allow runoff to enter and adding a special soil mix and appropriate vegetation, a curb extension can function as an attractive stormwater facility while still providing traffic calming benefits.

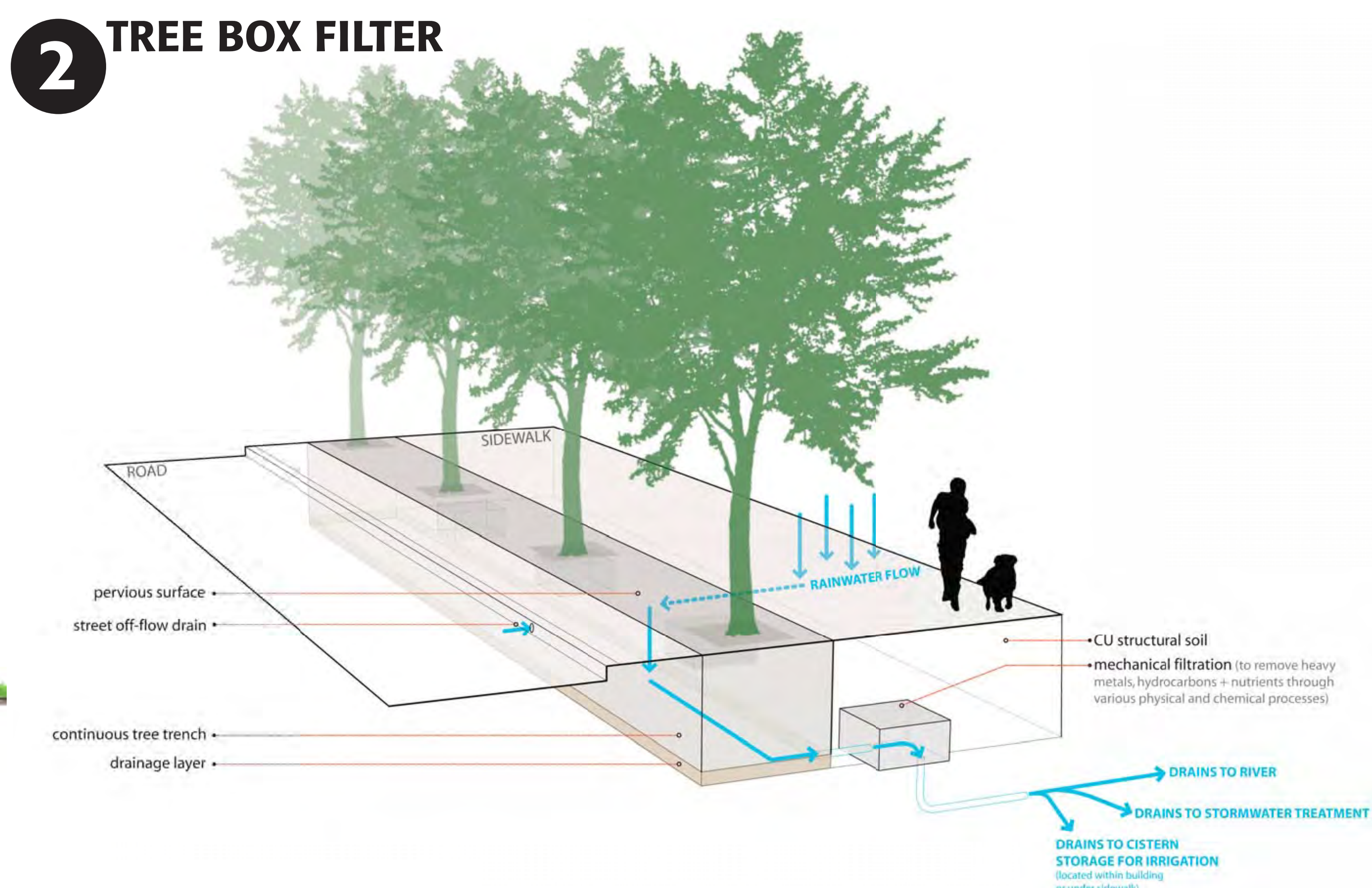
PERVIOUS PAVEMENT (4)
Permeable pavement is an alternative to asphalt or concrete surfaces that allows stormwater to drain through the porous surface to a stone reservoir underneath. The reservoir temporarily stores surface runoff before infiltrating it into the subsoil. The appearance of the alternative surface is often similar to asphalt or concrete, but it is manufactured without fine materials and instead incorporates void spaces that allow for storage and infiltration.

www.epa.gov

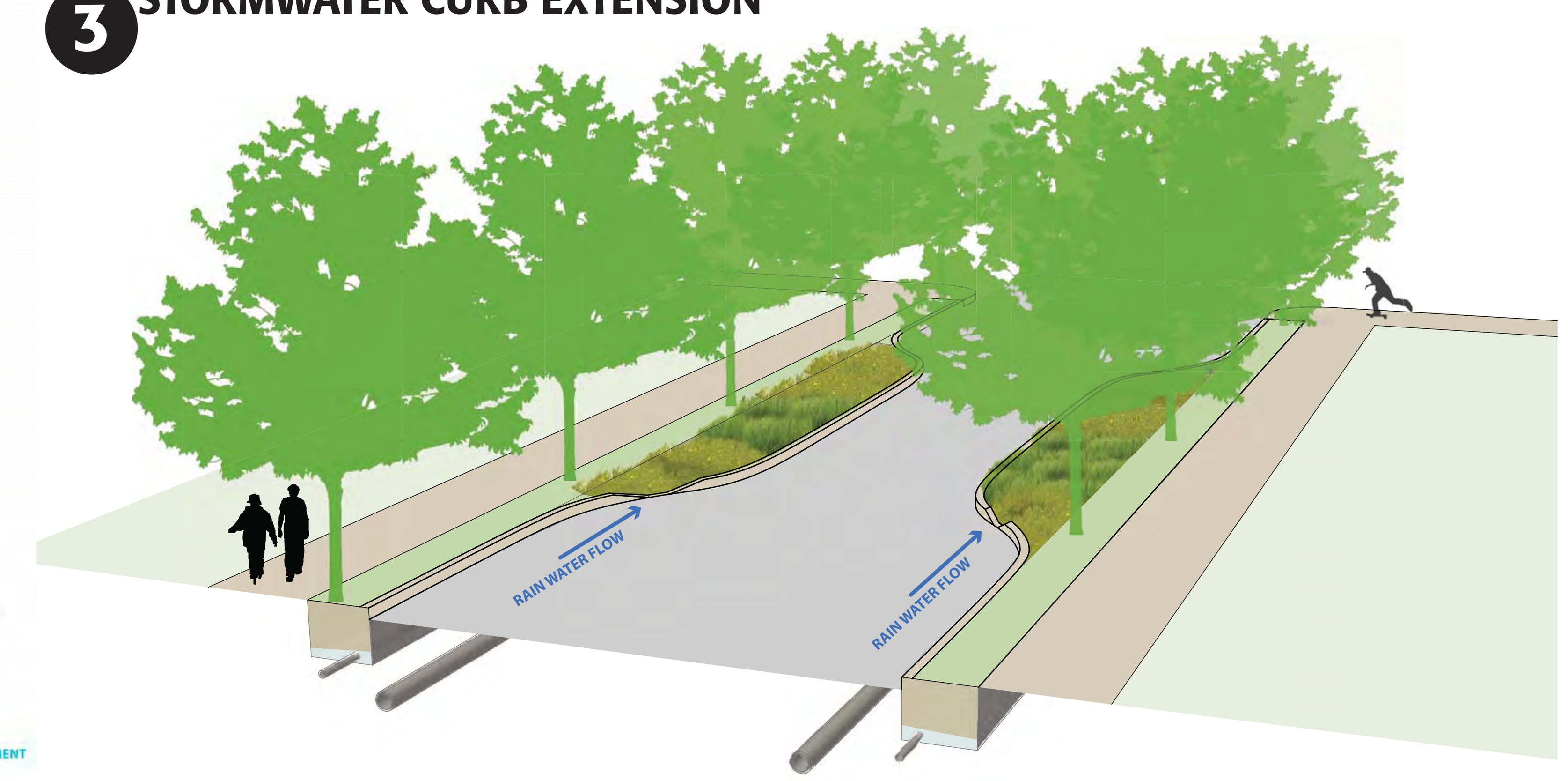
1 RAIN GARDEN



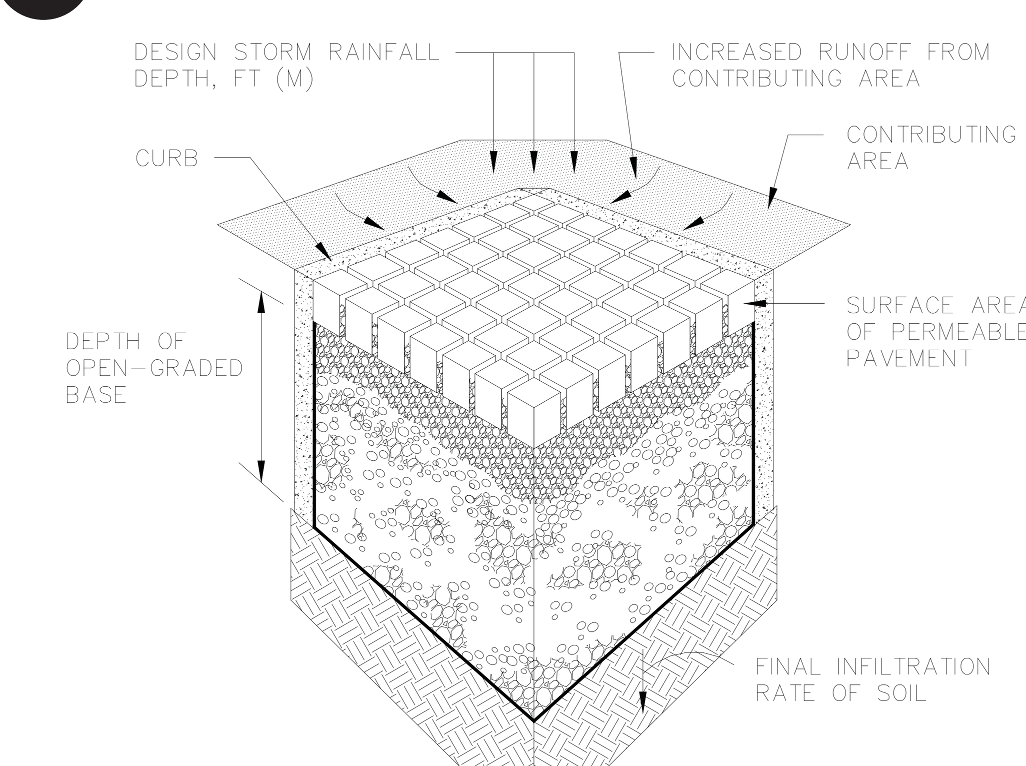
2 TREE BOX FILTER



3 STORMWATER CURB EXTENSION



4 PERVIOUS PAVEMENT



Hatch Mott MacDonald

MUSQUAPSINK BROOK WATERSHED RESTORATION & PROTECTION PLAN

Washington Green Townhomes Concept Design

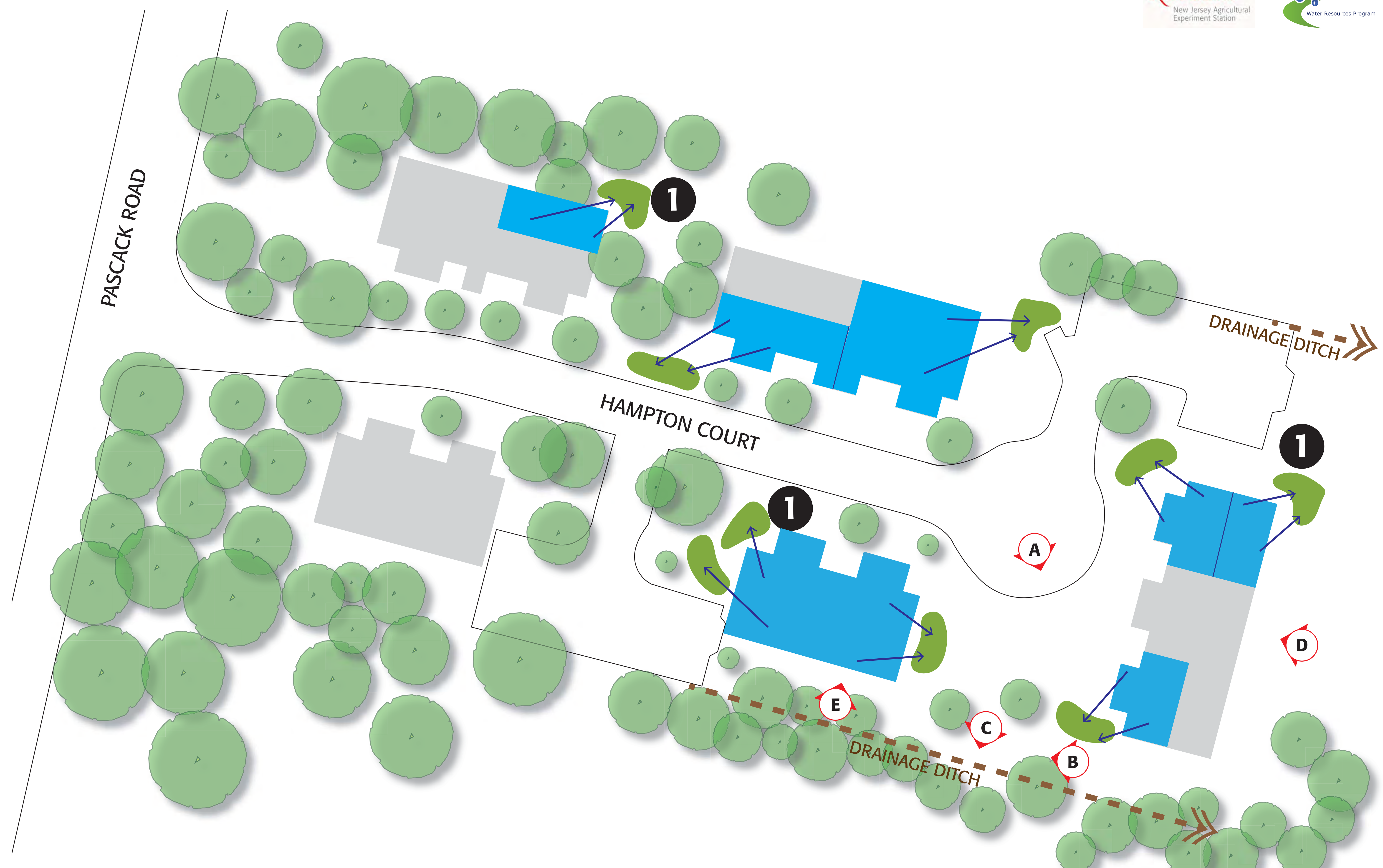
Project ID: MB4_Wa_f
Municipality: Washington Township
Subwatershed: MB4
Location: Washington Green Townhomes, Hampton Court

PROJECT LOCATION

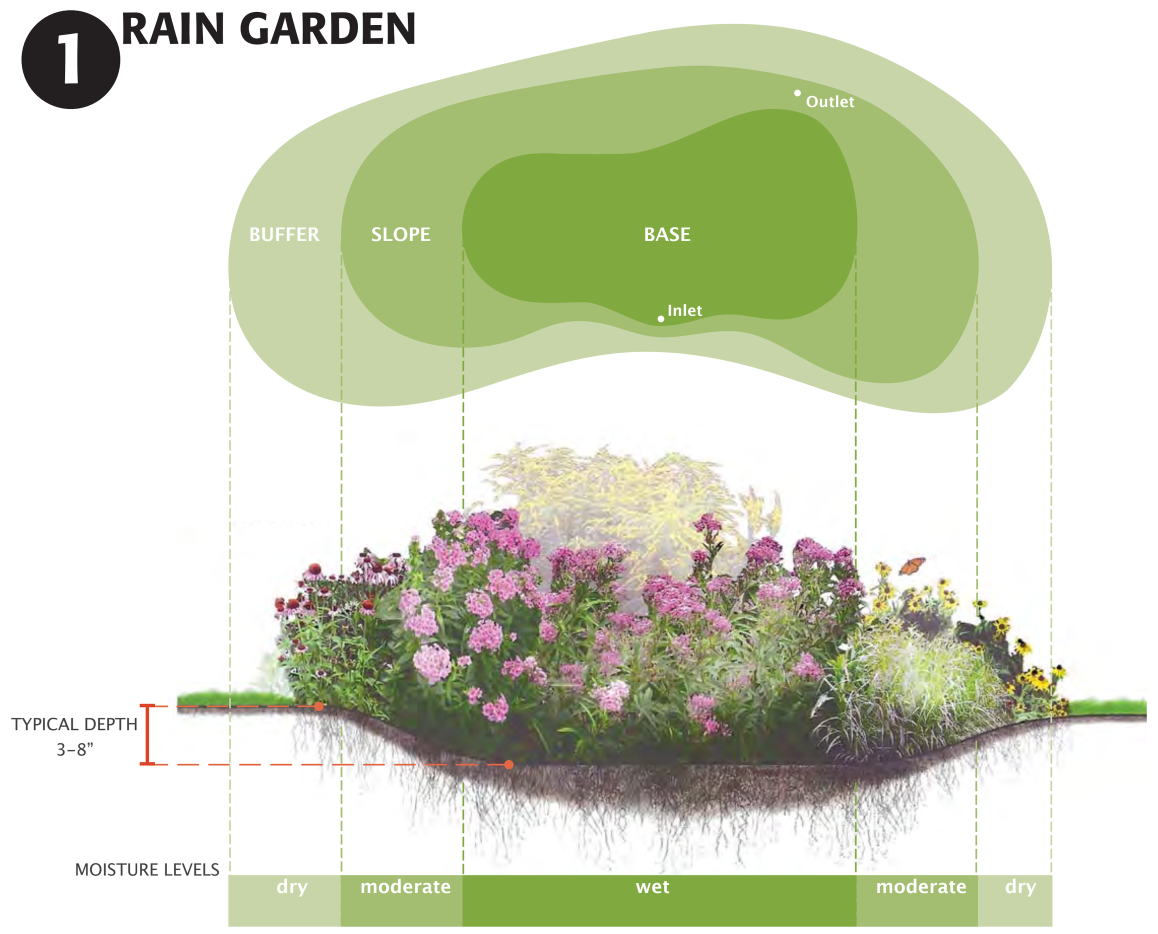
SITE PHOTOS

WHAT IS A RAIN GARDEN?
A rain garden is a landscaped, shallow depression that captures, filters, and infiltrates stormwater runoff. The rain garden removes nonpoint source pollutants from stormwater runoff while recharging groundwater. A rain garden has two main goals. The first goal is to serve as a functional system to capture, filter, and infiltrate stormwater runoff at the source, and the second goal is to be an aesthetically pleasing garden. Rain gardens are an important tool for communities and neighborhoods to create diverse, attractive landscapes while protecting the health of the natural environment.

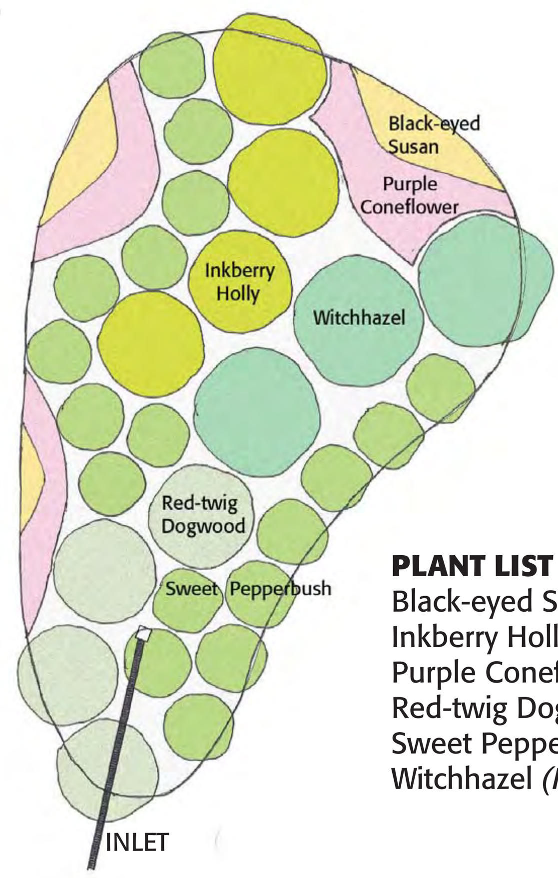
SITE PLAN



1 RAIN GARDEN

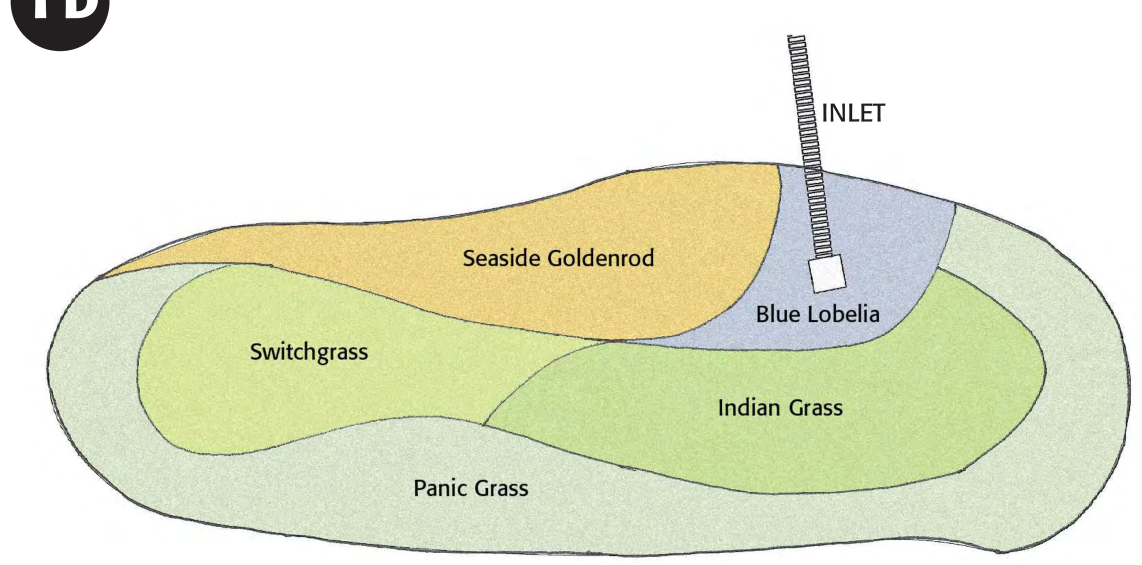


1a PLANTING PLAN - SHRUB RAIN GARDEN



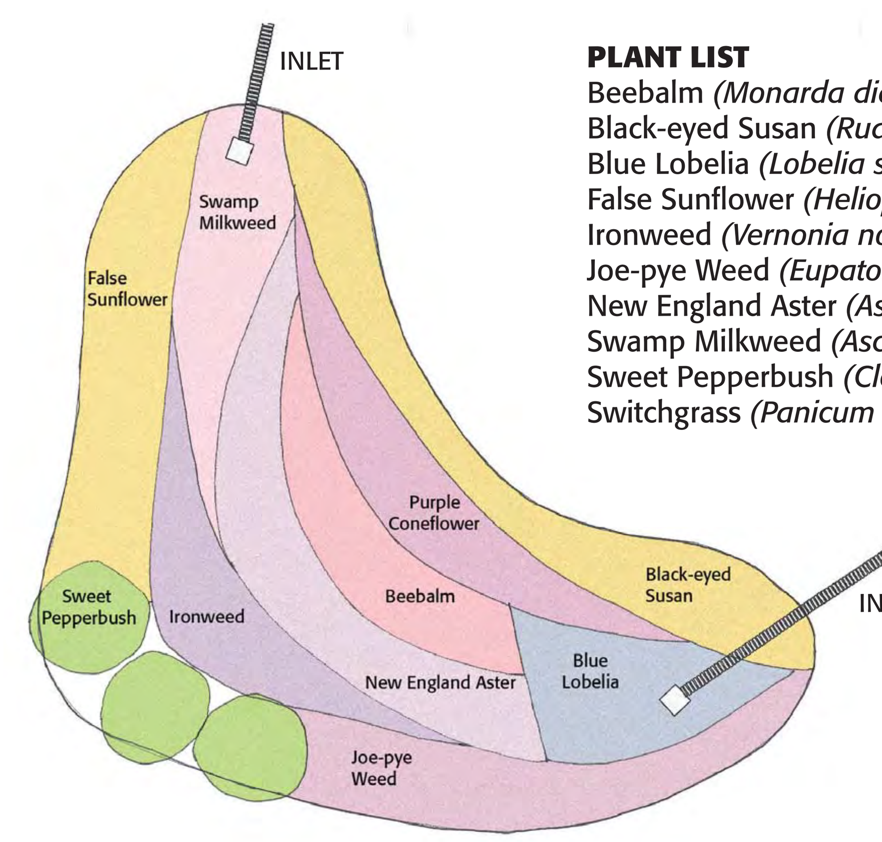
PLANT LIST
Black-eyed Susan *(Rudbeckia laciniata)*
Inkberry Holly *(Ilex glabra)*
Purple Coneflower *(Echinacea purpurea)*
Red-twig Dogwood *(Cornus sericea)*
Sweet Pepperbush *(Clethera alnifolia)*
Witchhazel *(Hamamelis virginiana)*

1b PLANTING PLAN - GRASSES RAIN GARDEN



PLANT LIST
Blue Lobelia *(Lobelia siphilitica)*
Indiangrass *(Sorghastrum nutans)*
Panic Grass *(Panicum virgatum)*
Seaside Goldenrod *(Solidago sempivrens)*
Switchgrass *(Panicum virgatum)*

1c PLANTING PLAN - WILDFLOWER RAIN GARDEN



PLANT LIST
Beebalm *(Monarda didyma)*
Black-eyed Susan *(Rudbeckia laciniata)*
Blue Lobelia *(Lobelia siphilitica)*
False Sunflower *(Heliopsis helianthoides)*
Ironweed *(Vernonia noveboracensis)*
Joe-pye Weed *(Eupatorium spp.)*
New England Aster *(Aster novae-angliae)*
Swamp Milkweed *(Asclepias incarnata)*
Sweet Pepperbush *(Clethera alnifolia)*
Switchgrass *(Panicum virgatum)*